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TABLE OF CONTENTS
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Original scientific paper

CONCEPT DESIGN AND ENGINEERING ANALYSES OF MODULAR INTERIOR OF DOUBLE-DECKER PASSENGER TRAIN

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A b s t r a c t: In this paper an attempt to find the most appropriate solution concept for designing the interior of a double-decker passenger train from ready-to-use modules is presented. The guiding idea is to apply the most appropriate form of modules that will provide their easy and efficient coupling, multiplication, flexibility in spatial displacement, possibility of recombination, etc. The presented idea is developed in the form of several types of flexible systems of coupling modules for the first and second class seats and a module for persons with disabilities. By applying algorithmic design, an algorithm is designed that forms the arrangement of modules in a double-decker coach. The testing phase is finished with the application of modern engineering methods examining the ergonomics of the new concept and the natural and artificial lighting in the coach.

Key words: modular design; futuristic design; algorithm design; nesting design; accessibility; eco design

КОНЦЕПТ ЗА ДИЗАЈН И ИНЖЕНЕРСКИ АНАЛИЗИ НА МОДУЛАРЕН ЕНТЕРИЕР НА ДВОКАТЕН ПАТНИЧКИ ВОЗ

А п с т р а к т: Во рамките на овој труд е презентиран обид за изнаоѓање најсоодветно решение, концепт, за формирање на ентериер од готови модули за изградба на двокатен патнички воз. Водечка идеја беше изнаоѓање најсоодветна форма на модулите, која ќе обезбеди нивно лесно и ефикасно спојување, мултиплицирање, флексибилност во просторното разместување, можност за рекомбинација итн. Презентираната идеја е разработена во вид на неколку типови флексибилни системи за спојување на модули на седишта за I и II класа и модули за лица со инвалидитет. Со примена на алгоритамскиот дизајн се дизајнира алгоритам кој го формира распоредот на модулите во еден двокатен вагон. Направено е испитување со помош на современи инженерски методи за ергономијата на новиот дизајн и за природното и вештачко осветлување во вагонот.

Клучни зборови: модуларен дизајн; дизајнирање со помош на алгоритам; дизајн со помош на вмрежување; пристапност; еколошки дизајн

INTRODUCTION

Societies around the world are looking for alternatives to their transportation needs. The need for making passenger rail vehicles for public transport is very important for economic, environmental and industrial aspects. Today about 80% of employees are traveling to work individually with their own transport vehicle that is designed for 5 persons so that is unprofitable and the intention is to reduce the rate and increase the percentage of use of public transport. Modern vehicles for passenger transport should be carefully designed to offer a fun, comfortable and convenient travel and thus to encourage more people to use [6, 7, 8].

Lately worldwide rail vehicles become topical because of the economy, speed and comfort. Most modern double-decker trains are fast. The bi-level passenger train has two levels of travel accommodation, which increases the capacity of passengers in some cases up to 57% per car. The use of double-decker coaches can solve the problem by increasing the capacity of the train, excluding other options for changing the infrastructure by building longer trains, with an increased number of trains per hour or building new tracks next to the existing ones. The purpose of this research is to determine the performance and technical capabilities for a new generation of interior double-decker passenger train through the creation of a new method of modular design. The new modular interior is designed using all modern rules of design, safety, accessibility, lighting, ergonomics and standards used in the use of materials and colors in production [1].

INSPIRATION FOR DEFINING THE SHAPE AND CONNECTION OF THE MODULES

With the help of bionics, i.e. the analysis of the form, color and function of the vertebrae in the giraffe derived the idea of connecting the modules. The giraffe neck is composed of a series of similar shaped bones called vertebrae (Fig. 1).

Fig. 1. Vertebrae in the giraffe

Like other mammals, the giraffe has seven neck vertebrae of similar size. The modules are connected in a linear array that provides a solid structure and necessary balance. Like the vertebrae, the modules in the train are completing their function only when coupled in series, while independently as a separate entity have no function [10].

A CONCEPT OF THE BASIC FORM OF THE THREE-DIMENSIONAL MODULE

Because the interior is of a modular character, the basic shape of the three components (for classes I, II and class for the disabled) is the same for easy and efficient mounting, dismounting, flexibility in spatial displacing, the possibility of recombination etc. The module has fixed dimensions – width and height, where only the length can vary. The body of the vehicle can be modulated in the longitudinal direction.

The concept is based on the application of three-dimensional rectangular modules that will form the structure of the interior. The Fig. 2 shows 2D layout of connected modules with rectangular base.

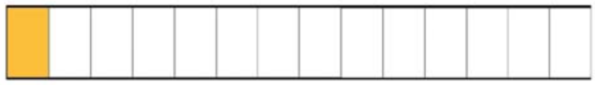

Fig. 2. 2D layout of connected modules with rectangular base

Rectangular prisms represent the simplest geometric form that allows easy and efficient coupling, multiplier flexibility in spatial displacement and the possibility of recombination. It also allows a spacious comfort. Three types of modular capsules were designed: Modules for class I and class II and a module for the disabled.

A CONCEPT OF MODULAR INTERIOR DESIGN FOR CLASS I

The module for class I is designed to accommodate six passengers (Fig. 3). The major task for the design of the module for the first class is to provide greater comfort. It is designed also to form a semi-enclosed capsule enclosed by glass area (electronic glass). The seats in the module are larger than in the other two modules, so they allow the greatest comfort.

Fig. 3. Three-dimensional view of the first class module

Technical drawing for the first class module is shown on Fig. 4.

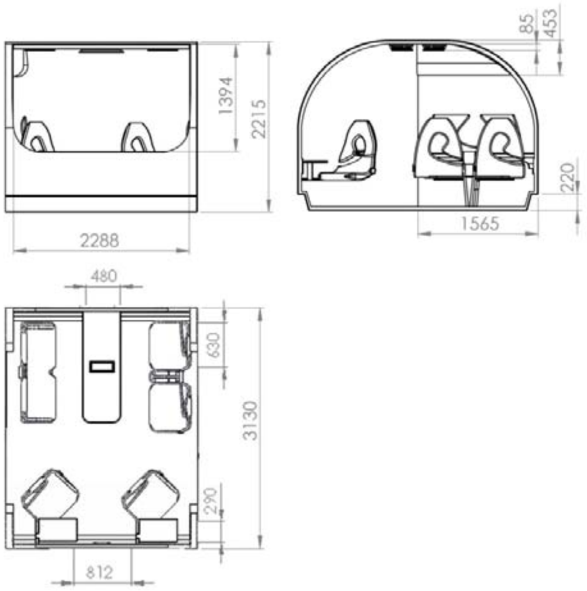

Fig. 4 Dimensions of the first class module

The 3D appearance of connected multiple modules of class I in the double-decker passenger train is shown on Fig. 5.

Fig. 5. Joined modules of class I in longitudinal direction

A CONCEPT OF THREE-DIMENSIONAL MODULE FOR CLASS II

The module for class II is designed for eight passengers with 2 + 2 seats. Both seats are placed next to each other on the console that aims to keep the seats fixed at a certain height from the floor. The arm rest is designed to be used at the same time by two passengers. That is provided with two different heights for setting the hands to rest. In each seat headphones are fitted and each passenger can choose specifically what to hear. The side windows have tilted rectangular shape which gives a sense of dynamism and speed.

The difference between the three types of the module for class II is that different seating is combined with table or storage. The first type is generally a 2 × 2 seats facing back to back. Storage area is located in the upper right corner and below the ceiling (Fig. 6).

Technical drawings for the second class module for class II are shown on the Fig. 7.

Fig. 6. 3D view of the module for class II type 1

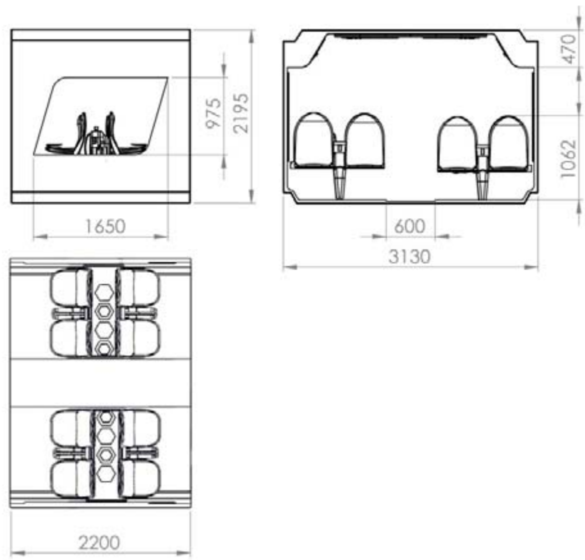

Fig. 7. Dimensions of the module for class II

The type 2 is similar to type 1, only the storage for luggage is placed between the seats (Fig. 8).

2 × 2 seats are facing each other, and there is a fixed table between them. The storage for luggage is set between the four seats. The table has strict geometric lines, reduced to minimalism (Fig. 9).

Fig. 8. 3D view of the module for class II, type 2

Fig. 9. 3D view of the module for class II, type 3

The space for lighting and ventilation has clean, geometric shapes and simple lines that arouse futuristic vision versus everyday unfashionable spaces in today's buses and trains (Fig. 10).

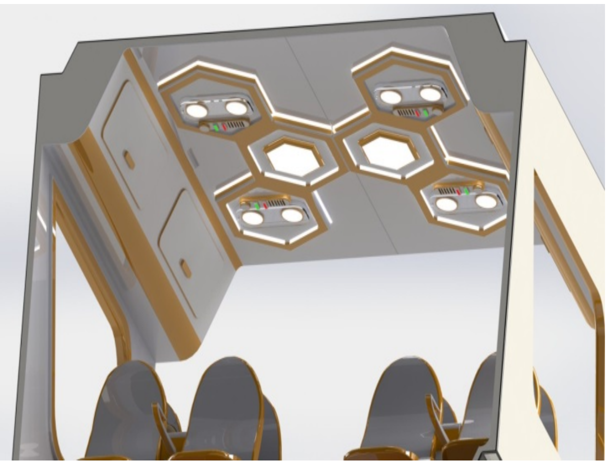

Fig. 10. Honeycomb shaped space for lighting and ventilation

A CONCEPT OF THREE-DIMENSIONAL MODULE FOR PERSONS WITH DISABILITIES

The layout and the arrangement of the module for people with disabilities depend on accessibility, so it is placed next to the doors for easier entry and exit and easier and faster accommodation for the passengers in wheelchairs. The fixed seating on trains are designed according to international standards. Human factors and ergonomics are critical for providing adequate space in the area for a wheelchair. Although it is recommended that travelers use the seats of the train, they usually remain in the wheelchair who is facing forward or backward, but never on this side (Fig. 11). Technical drawings for the module for class II are shown on the Fig. 12 [2, 3, 9]

Fig. 11. 3D view of the module for the persons with disabilities

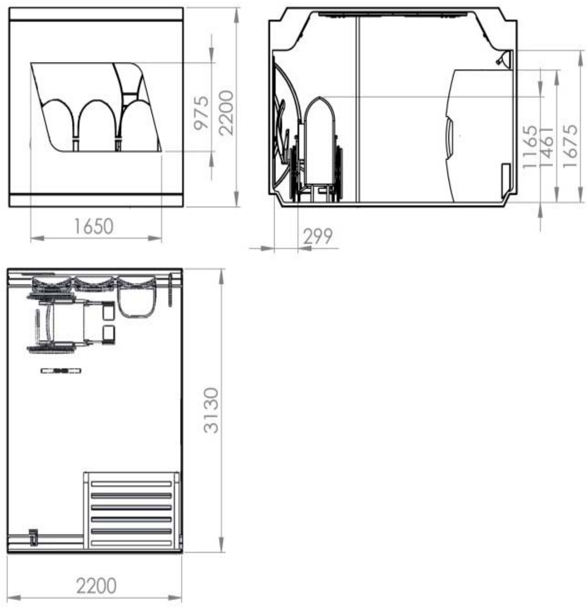

Fig. 12. Dimensions of the module for the persons with disabilities

CROSS-SECTION OF A COACH

The intersection of combined modules for classes I and II in the double-decker train is shown on Fig. 13.

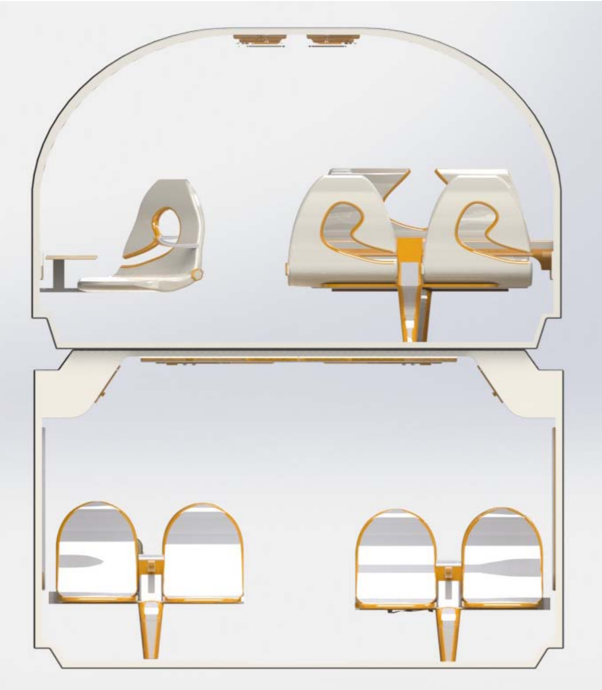

Fig. 13. The cross-section of the double-decker train (Module for clses I and II)

By applying algorithmic design an algorithm it is developed which defines the layout of the modules in a coach. The main parameters that are entered are the length and width of the car, and the dimensions of the modules [7].

The selected layout and combination of modules (Fig. 14), shows that one wagon has a capacity of 104 seats for passengers that:

– 36 in class I, 56 in class II, 12 for disabled and infirm persons.

– Ability to store 4 bikes.

– Two toilets.

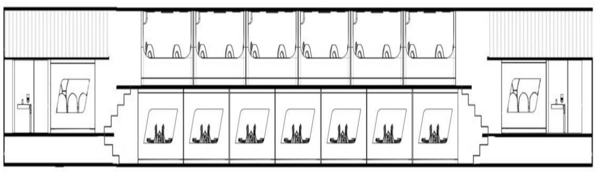

Fig. 14. Intersection of a wagon

ERGONOMIC ANALYSIS MADE WITH JACK PLM HUMAN MODELING

Jack PLM Human Modeling is computer software of the company *Siemens* specialized in 2D and 3D products. With the help of Jack several ergonomic analyses are made that are crucial for the design of the interior of the passenger train. Most important of all is the early detection of possible defects before actual performance of the product and their correction in the design process. The preparation of the analysis began selecting anthropometric data (gender, nationality and percentile). Analyses were made by German human model of 5th female percentile and 95th men percentile [4, 5].

The created model can change its position depending on the need of research. In this project, the most important are:

– seating comfort;
– holding the handles;
– easy movement and passing on the train;
– easy and fast storage of luggage.

In an analysis the tool *Comfort Assessment* determine that the human model is positioned in a comfortable position in Jack. Based on various studies for comfort seating, Tool Comfort Assessment:

• allows a choice from a list of six different studies of comfort, five based on a common point, and a study which analyzed comfort based on the whole body posture (Porter and Gyi, Krist, Grandjean, Rebiffe, Dreyfuss 2D and 3D*)* (Fig. 15).

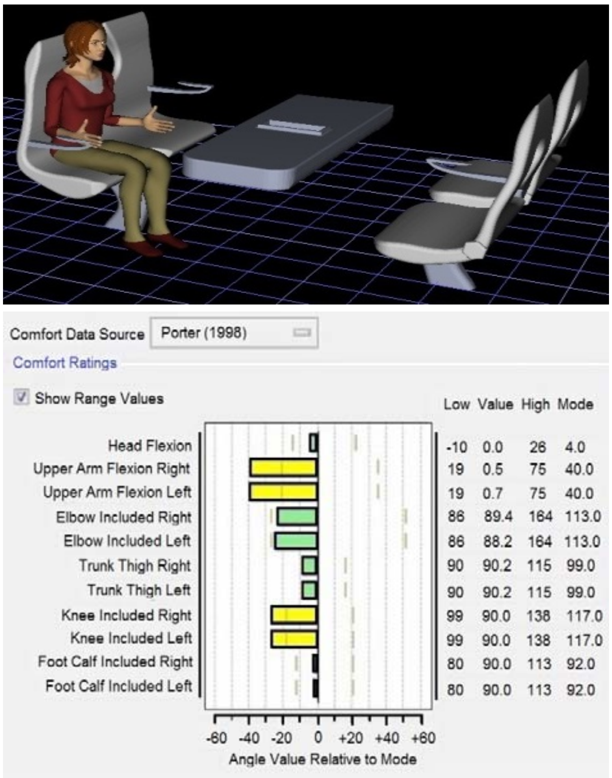

Fig. 15. Comfort analysis in Jack (Porter)

The analysis is performed by moving the human model to another position. The TSB analysis predicts the road required for the human model to achieve his goal. The road is represented using the red footprints in Jack scene (Fig. 16).

Ergonomic Report – TSB outcome of the simulation is the ability to automatically perform ergonomic analysis in real time. The results of the analysis to store luggage in class II, show the time in seconds required to perform the function and use of force by the body's muscles (Fig. 17).

Analses were made on the ergonomics of the holders, the use of the toilet and moving in the middle space in the module for second class. The results are displayed on Figs. 18 and 19. On the images can be seen that it is not necessary to change the measures in the design because it used anthropometric data and dimensions of space satisfying ergonomics.

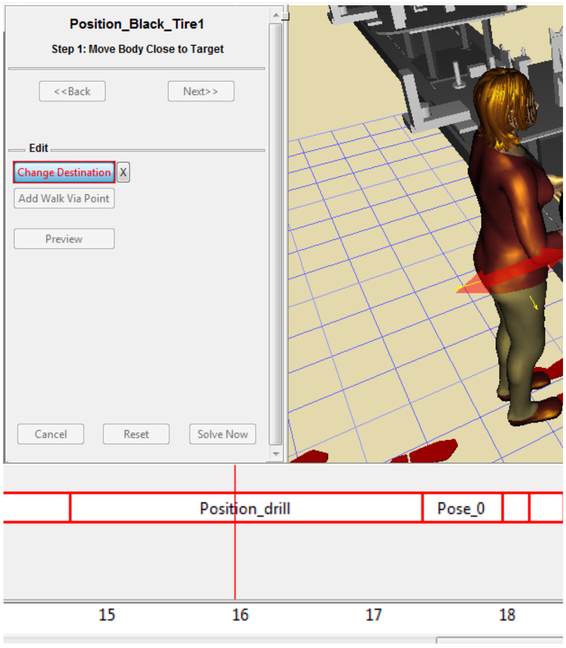

Fig. 16. Moving analysis from position A to position B in Jack

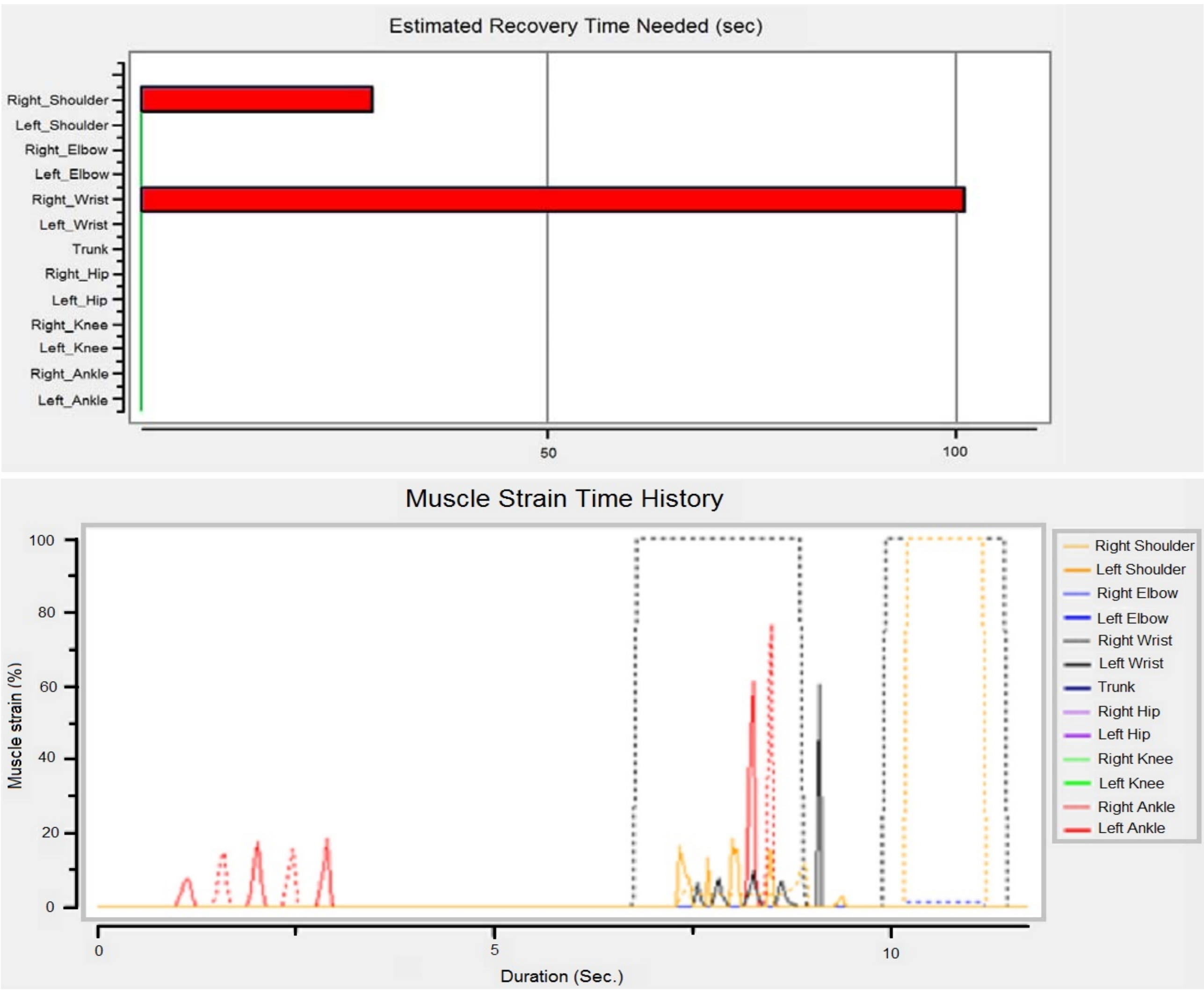

Fig. 17. Results of the analysis to store luggage in the module for class II in Jack

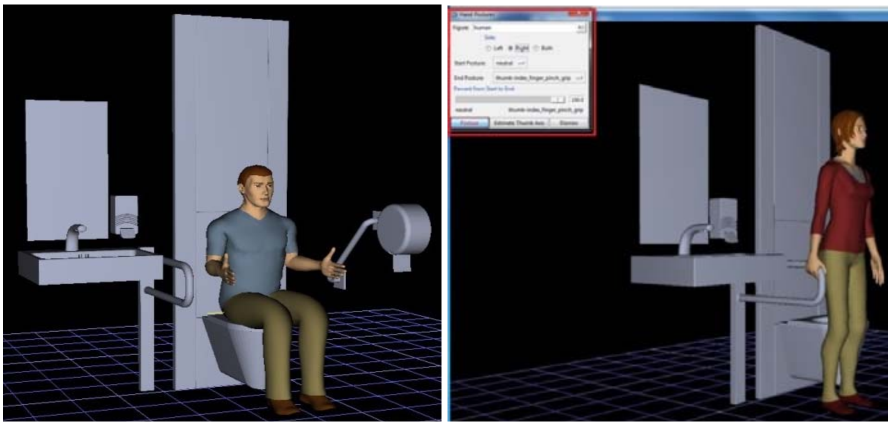

Fig. 18. Analysis on the ergonomics of using the toilet in Jack

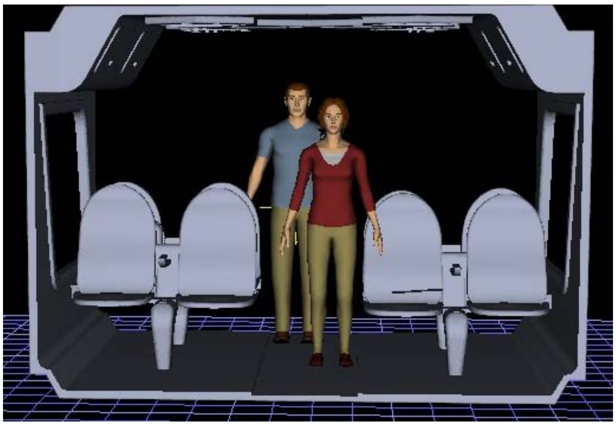

Fig. 19. Analysis for easy moving in the middle space in the module for the second class in Jack

ANALYSIS OF NATURAL AND ARTIFICIAL LIGHTING IN THE DOUBLE-DECKER COACH

Radiosity (3ds Max) is rendering technology that realistically simulates the way light works in the environment. Light levels in confined spaces – buildings, vehicles etc, are selected using the recommended level of brightness for different workspaces (Table 1).

Table 1

Recommended level of brightness for different workspaces

Activity	Lighting (lux, lumen/m^2)
Public areas in dark environment	20 – 50
Spaces for brief visits	50 – 100
Areas of work where only occasionally perform visual tasks	100 – 150
Warehouses, homes, theaters, archives	150
Easy office work	250
Normal office work, computer work, libraries, exhibition halls , laboratories	500
Supermarkets, mechanical workshops, offices	750
Drawing, detailed mechanical workshops, working in theaters	1,000
Detailed drawing, very detailed mechanical workshops	1500 – 2000
Perform visual tasks with low contrast and very small size of the longer period	2000 – 5000
Making a very long and precise visual tasks	5000 – 10000
Making a very special visual tasks with extremely low contrast and small size	10000 – 20000

For lighting the double-decker train is provided natural and artificial light or extra range 200–300 lux to perform normal activities – reading, simple computer work and activities related to entertainment and recreation, or watch movies, games and so on. The analysis of the brightness on the first floor of the double-decker train, designed to travel in the first class is shown on Fig. 20.

The analysis of lighting is made as a result of the impact of natural light or solar radiation in summer time in 12 hours. It may be noted that due to lighting curved windows in the end zone satisfy the range of 300–400 lux.

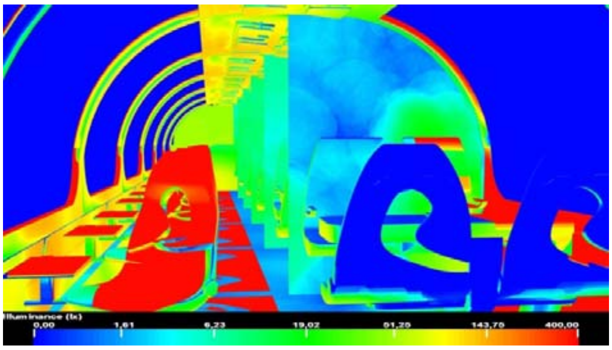

Fig. 20. Lighting analysis in the double decker train – class I with normal lighting in summer time in 12 pm

The analysis of lighting caused by artificial light (for each module 4 LED lamps measuring 25 W) shows that the tables are lit with 200–300 lux and hallway is lit with 300-400 lux due to the central placement of the lights because the rounded windows (Fig. 21).

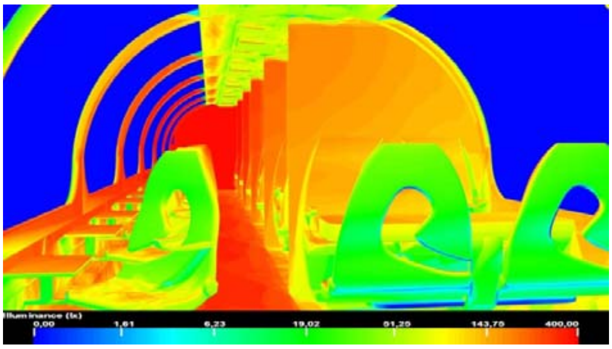

Fig. 21. Lighting analysis in the double decker train – class I with artificial lighting

An lighting analysis on the ground floor of the double-decker train, designed to travel in the second class, the impact of natural light or solar radiation in summer time in 12 pm is shown on Fig. 22. It can be noticed that the lighting in the area of the windows (where the sun's rays penetrate) satisfies the range of 300–400 lux, and in the opposite area to windows 50–100 lux. The orientation of the train is changing because its movement allows you to change these features. The analysis shows that the central part – the corridor should have more artificial lighting, although in certain times of day what can satisfyes the function for which it is intended.

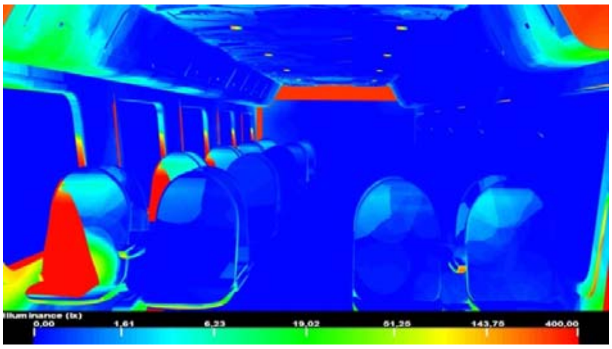

Fig. 22. Lighting analysis in the double decker train – class II with normal lighting in summer time in 12 pm

The analysis of lighting caused by artificial light (for each module 4 LED lamps measuring 25 W) shows that the sitting area is lit by 150–250 lux and hallway is lit by 250 lux. Seats which gravitate toward the hallway are well lit due to the positioning of the lights which are approximately over them (Fig. 23).

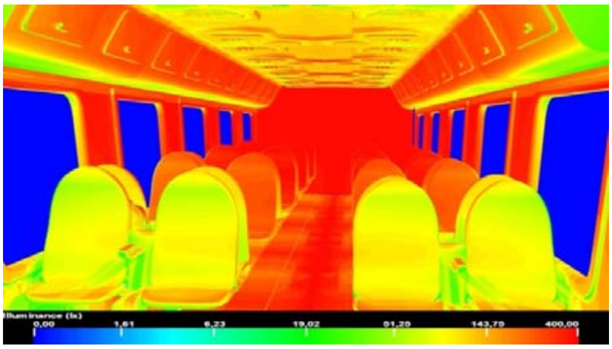

Fig. 23. Lighting analysis in the double decker train – class II with artificial lighting

CONCLUSIONS

This paper presents the concept of forming the interior with modules to build a double-decker passenger train. The shapes of the modules provide them easy and efficient coupling, multiplier flexibility in spatial displacement and possibility of recombination.

An ergonomic analysis is made with Jack PLM Human Modeling for comfort in sitting, holding the handles, movement and storage of luggage. The results showed that the problem with ergonomics is solved and the new design offers comfort for the passengers. Analysis of natural and artificial lighting in the area is done in Radiosity (3ds Max), which actually simulated the way light works in the environment.

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Original scientific paper

NUMERICAL ANALYSIS OF STEEL STRUCTURES FOR AIRCRAFT MAINTENANCE HANGAR

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A b s t r a c t: The focus of this research paper is to present the numerical analyses of tubular steel structures for aircraft maintenance hangars. Mainly these structures are complex with a large span roof so the structural analysis has been performed using SAP2000 and Eurocodes as bases to the loads and the stability analysis. Attention was given future investigation of the wind loads as a major load as well as the earthquake loads. Since these structures are challenging because of their fire protection requirement, performance code case study is done in order to better understand the pool fire and his effect on to the surround structure. During the analysis, there will be examined individual elements with nonlinear material properties. Combined loading analysis will be done with FEM on the individual elements for better understanding of structural behavior under the fire. This document will highlight the major findings during investigation.

Key words: steel structure; tubular sections; eurocode; performance based code; fire analysis

НУМЕРИЧКА АНАЛИЗА НА НОСЕЧКИТЕ ЧЕЛИЧНИ КОНСТРУКЦИИ КАЈ АВИОНСКИ ХАНГАРИ

А п с т р а к т: Фокусот на ова истражување е да се презентира нумеричка анализа на цевчестите носечки челични конструкции кај авионски ханагри. Многу од овие конструкции се доста сложените со големи распони, и поради тоа анализата е извршена со користење на софтверот САП2000 и еврокодови како основа за аплицираните дејства и проверката на стабилитет (анализа). Посебно внимание е посветено на влијанијата од ветер, како и на новите начини на испитувањата на оптоварувањата од ветер и на земјотресните оптоварувања. Најголем предизвик кај овие конструкции е нивната противпожарна заштита. Поради тоа е направена студија на случај со код базиран на однесување, со цел подобро да се разбере пожар од дамка („pool fire“) и негов ефект (термичко оптоварување) врз носечките челични конструкции. Во анализата се истражувани индивидуални елементи од конструкцијата со нелинеарни механички карактеристики на материјалот. Анализа на комбинирани дејства е направена за подобро разбирање на структурното однесување на носечките елементи за време на пожар. Овој труд ги прикажува главните делови од истражувањето кое е направено.

Клучни зборови: носечка челична конструкција; цевчести профили; еврокод; код базиран на однесување; анализа на пожар

INTRODUCTION

During the last ten years, IATA (International Air Transport Association) stated that the demands for further development of aviation transport increased considerably. Directly with these requirements, the development of larger aircraft like jumbo Airbus A380 and Boing 747 with a capacity of 800 is being applied. Since the aircraft maintenance is one of the most important activity facilities such as aircraft hangars been influenced by these changes. Aircraft hangar is a structure designed for storage and maintenance of the aircrafts. The complexity of these buildings is in the large roof structures without any intermediate supports that could resist heavy dead loads, earthquake loads, imposed loads from suspended equipment "cranes" as well as the uplift forces or pressures generated when the hangar doors are completely open. In order to achieve these structural requirements, it is necessary to design a structure with excellent stiffness and in the same time, a structure that is able to comply with the external loads and optimal weight. In this research the numerical analysis is performed using the Abaqus V6.12 as well as the universal FEM software SAP2000 for static, earthquake analyses and fire analysis. The relevant design checks, loads and load combinations have been carried out with Eurocodes in order to fulfil the building regulations. In order to achieve these structural requirements, it is necessary to design a structure with excellent stiffness and in the same time, a structure that is able to comply with the external loads and optimal weight. One of the ways to achieve stiff and optimized weight structure is to use structural steel tubular sections. The tubular sections are very widely used because of their effective cross section properties to resist axial and torsion. Besides these features, the tubular sections have also great importance in application in exposed structures.

By nature the aircraft maintenance hangars have unique challenges for their fire protection. They are large open floors with large obstructions like access platforms for maintenance of the aircraft. Sense is not practical and economical the fuel to be removed from the tank of the aircraft before maintenance, large amount of fuel is present in the aircraft and the maintenance of the aircraft can cause a variety of potential ignition sources were both of them can cause large pool fires. There are two goals for the protection of the aircraft hangar: a) protection of the aircraft, b) preventing collapse, damages of the main columns and unprotected low level roof structure. The main purpose of this thesis is to investigate if these large pool fires will cause misbehavior of the individual steel columns under normal loadings (circumstances). The investigation was done through the fire protection, performance case study where the most dangerous cases have been identified and analyzed. This study was done by a physical model of the hangar and numerical analysis using FEM software SAP2000 V.16 and Eurocode for applying load as well as the stresses check. In order to achieve more realistic temperatures, physical model was created using FDS (Fire Dynamic Simulator). The "measured" adiabatic temperatures have been used in the next step of the analysis, which is building a thermal response model. In order to find the stresses on the structures caused by the static and thermal loadings Abaqus V12 FEM software being used for investigating complex stress analyses induced by the static load and the thermal load coming from the pool fire [1].

Numerical structural analysis with SAP2000

Aircraft maintenance hangar (Fig. 1) has been designed to accommodate aircraft Airbus A380 and Boing 747 for maintenance purposes. The necessary equipment's which are required for the full maintenance are also considered during the designing of this massive structure.

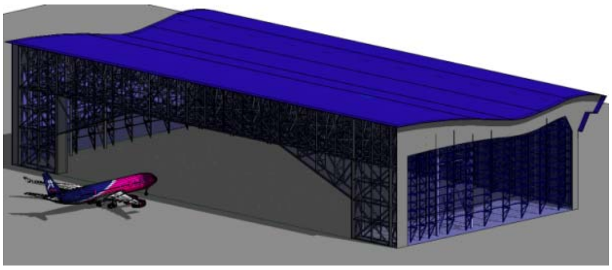

Fig. 1. 3D model aircraft maintenance hangar

The dimensions of this large structure (Fig. 2) are with length 200 m, width 110 m and height 45 m. The main steel structure of the aircraft hangar is built from the following main elements: portal frame, main steel space trusses, columns, façade trusses, vertical bracings and roof system (secondary steel, purlins and bracings).

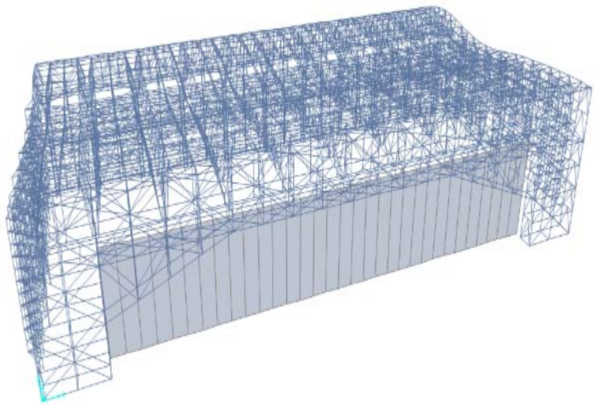

Fig . 2. Structural model SAP2000

The main vertical loads coming from the several loadings from the purlins will be received by secondary steel trusses and then to the main space trusses. The space trusses will be mounted on every 20 m with a clear span of 91 m.

These loadings will flow from the space trusses on to the portal frame and the rear columns, then the columns will transfer the loadings on the foundation. Joints between the steel portal frame / columns and the concrete foundation will be anticipated as a pinned connections.

The lateral loads (x and y) direction coming from the earthquake and wind loads will be received by the façade which is located on the left, right and back side of the building, and then will be restrained from the vertical bracings and the horizontal bracing installed on the roof. The horizontal and vertical bracings will be designed to receive compression and tension.

Designing the most appropriate roof, structural system is driven by the number of factors such as span, type of suspended loadings and geometry of the roof. Additional major loadings which this roof is exposed on is the excessive deflection from the self-weight and wind loads, especially when the hangar doors are completely open.

The selected material for all the elements of the structure is low carbon mild steel S355 with the following properties Yield Strength 355 N/mm^2 and Tensile Strength 490 N/mm^2 which is already existing on the SAP2000. The elastic analysis will be performed on all of the sections for checking the frame deflection under service and ultimate load.

The loads caused by the self-weight of the building and load from the different services will be applied to the model. The loadings from the purlin and the permanent loadings from the MEP will be applied as linearly distributed loads along the line of the main and secondary steel trusses. The analysis of the hangar doors will not going to be calculated and therefore the hangar doors will be modeled as shell elements (Fig. 2).

The main portal frame, main space trusses and the façade trusses will be analyzed as pin jointed frames release on the (moment My and torsion T) while the bottom and top chords of the trusses will be designed as continues members.

Wind loads and CFD analyses

In the analysis of the hangars the wild loads are considered to be the major loading and it is very difficult to predict them since they are complex behavior of the wind state and they are not constant. During the calculation of the wind loads as per the Eurocode 1991-1-4 it has been planned that the hangar door will be completely open in occurrence of maximum wind speed of 100 km/h. The maximum forces are originated from the uplift pressure, which approximately 6 kN/m^2 is applied in the first 10 m starting on the beginning roof. The Eurocodes are giving an option for two ways of calculating the wind loads quasi-static load and dynamic and aero-elastic. On this research the wind loads have been calculated primarily for quasi-static loads taken from the code and as well as for the presentation the CFD simulation was done as per the figures (Figs. 3 and 4) shown below

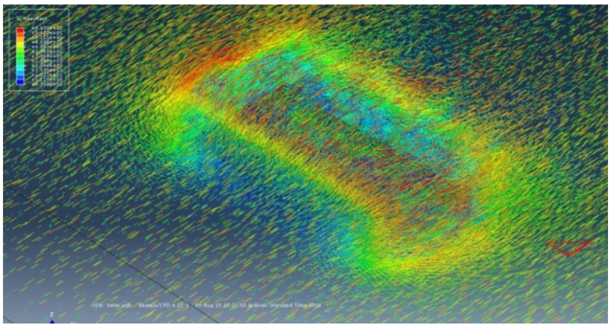

Fig. 3. Wind speed

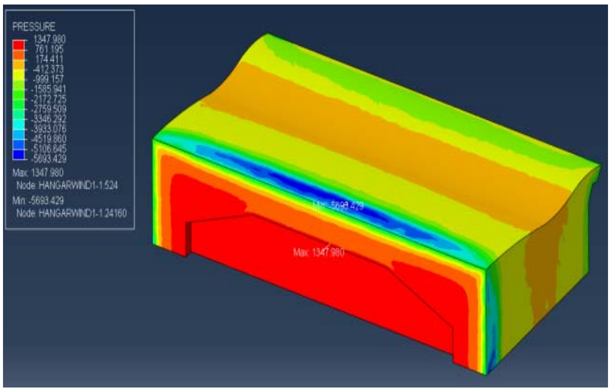

Fig. 4. Wind pressure

Earthquake design

The earthquake forces are one of the greatest natural forces and they are not predictable and occur suddenly. One of the main part which needs to be considered during the design the aircraft hangars is also to design to resist the earthquake loads. The seismic loads have also been applied as per the earthquake zone in the Arabian Peninsula Region Zone 2A as per the UBC1997 which is equal to surface wave magnitude Ms = 5.5 with ground acceleration of $a_g = 0.15$ g and the ground type A as design response spectra has been defined in accordance with BS EN 1998. The analysis in the SAP2000 was done with static seismic lateral force analysis where forces are applied to the structure representing the effect of ground acceleration, the base shear force calculated in the software was also matched with the analytical calculation. By implementing all the rules given by the Eurocode in the Figure 5 are shown the graphs for the elastic and design response period.

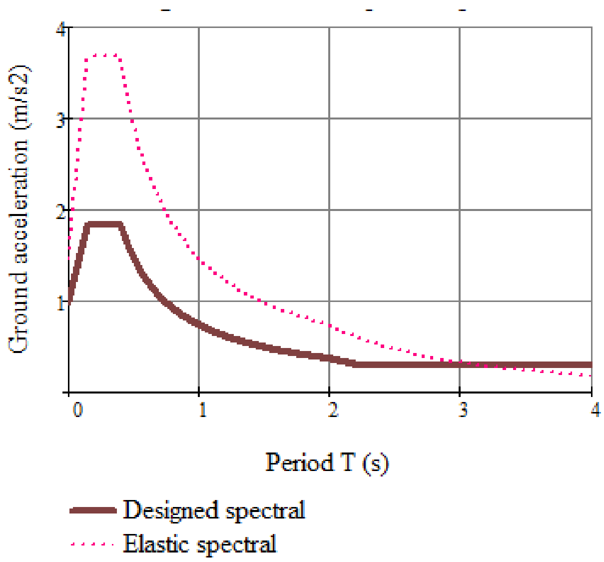

Fig. 5. Designed/elastic response period

Another challenging aspect when the maintenance hangars are designed is the importance of the roof suspended equipment's. When the structure is analyzed apart of the self-weight of the cranes and their loads the effect of the acceleration and deceleration needs to be considered. The loadings applied to this structure was calculated as per EN 1991-3:2006 since the action of the cranes has not been provided by the particular crane supplier. The roof tolerances imposed by these cranes are very strict and needs to be followed, especially for the situation under service load.

When the structure as analyzed the worst cases was implemented and different loads were combined as per the Eurocode requirements.

RESULTS FROM THE STRUCTURAL CALCULATION

From the analyzed model the major difficulty was to deal with the maximum deflection occurred on the roof from the self-weight to the structure. Many solutions were analyzed previously until the most optimized truss configuration was achieved. After the performed simulation of the structural model under service loads it has been observed that the maximum deflections in the middle of the structure are 260 mm < L/350 = 91000/250 = 364 mm which is acceptable as per the code for the roof structure. Since we have designed that there will be suspended underslung cranes, for the deflection tolerances will be enforced the one of these cranes which is L/600. One way to accommodate these tolerances is to provide pre-cambering on the trusses during the fabrication or installation. From the Figures 6 and 7 displayed it can be seen that with pre-chambering of trusses the deflection after loading with service permanent loads will be on acceptable level following the crane deflection requirements.

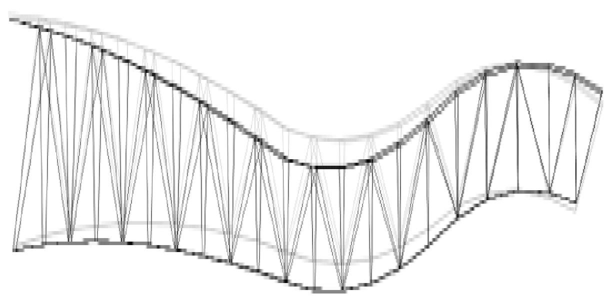

Fig . 6. Main space truss-deflection

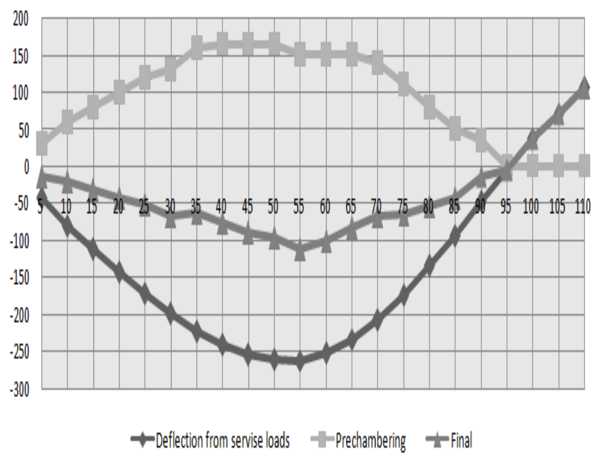

Fig . 7. Pre-cambering of trusses

Modal analysis

On the Figures 3 and 4 is shown the performed modal analysis of the structure using the Eigen method.

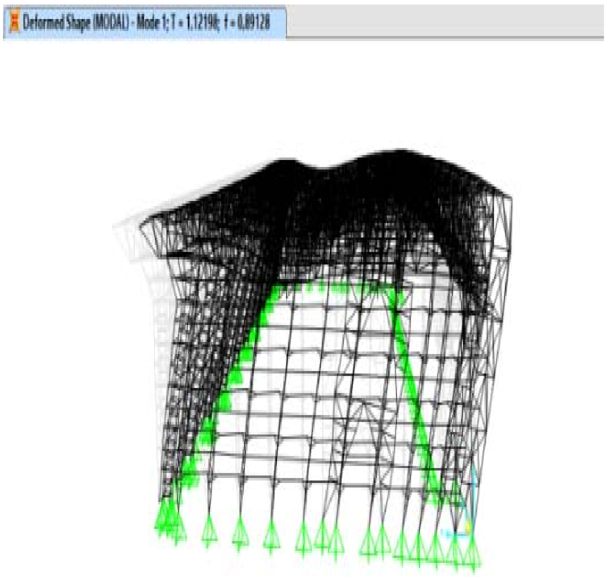

Fig. 8. UX T = 1.12 s *f* = 0.89

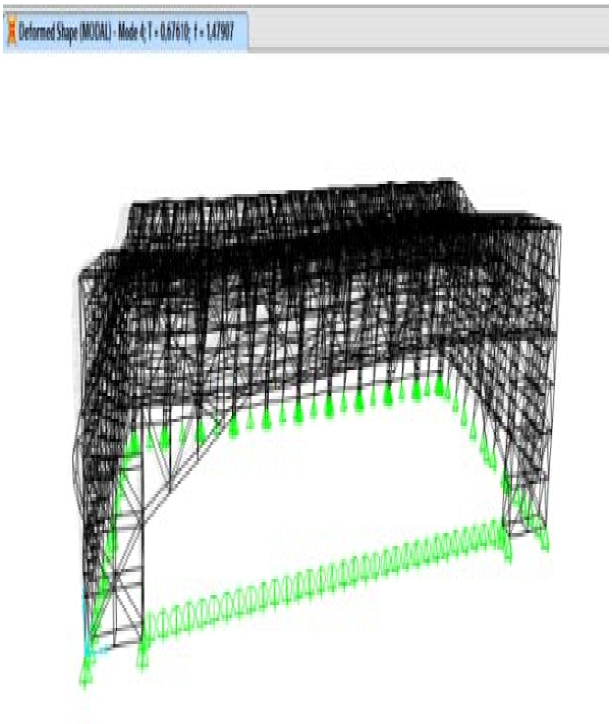

Fig. 9. UY T = 0.67 s *f* = 1.47

The main stability of the structure has been checked (Fig. 10) with SAP2000 software in compliance with EN 1993-1-1. The detail analysis, such as stability, stiffness, strength of the structure was done with the use of Eurocodes especially, with EN 1993-1-1, EN 1993-1-8. The results for the maximal axial loads during the ULS and SLS were used in the further analysis of the individual members analytically using Mathcad V15.

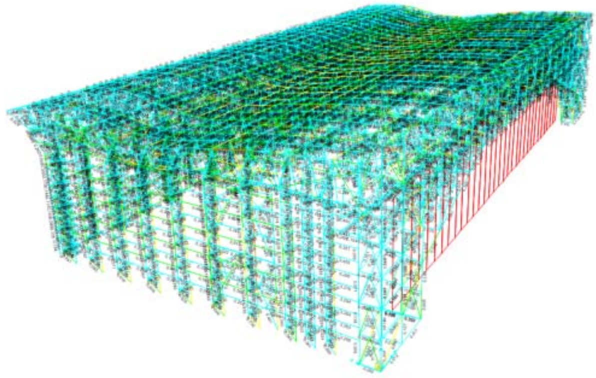

Fig. 10. Stress check - BS EN 1993-1-1

Pool fire

Fire in general, it could appear in many forms and in all the forms he involves a chemical reaction between the combustion material and oxygen from the air. Pool fires are occurring in many industrial areas specifically in aircraft hangars where high possibilities of oil or fuel leak on the floor. After ignition of these pool fires there will be released large amount of heat during their combustion. Specifically for the pool fire is that the burning will happen only in the area where there is an oil or fuel leak. Many processes of heat release will appear in the combustion, but the most critical one will be from the radiation. As per SFPE Handbook [2] the heat release rate from a pool fire can be calculated as per the:

$$Q = \dot{m}''\cdot\Delta \mathrm{H}_{c,eff}\cdot(1-e^{-k\beta D})\cdot A_{dik\theta}$$

where is:

Q – pool fire, heat release rate,

$\dot{m}''$ – mass burning rate of fuel per unit surface area,

$\Delta H_{c,eff}$ – effective heat of combustion of fuel

$A_{dik\theta}$ – surface area of pool fire,

kβ – empirical constant,

D – diameter of the pool fire.

Adiabatic temperature

The heat transferred from fire of hot gases to the surface is transferred by radiation and convection. Both of these temperatures are creating the total heat flux,

$$\dot{q}''_{tot} = \dot{q}''_{rad} + \dot{q}''_{con}$$

where is:

$\dot{q}''_{tot}$ – total heat flux,

$\dot{q}''_{rad}$ – heat flux from radiation,

$\dot{q}''_{con}$ – heat flux from convection.

During the experiments or real test is very difficult to measure them as separate items. The new approach has been implemented "adiabatic temperature". The adiabatic temperature is the temperature that results from the combustion process without any heat transfer or loss from the changes of the kinetic energy.

Fire analysis using the performance based code and FDS software – a case study

By nature the aircraft maintenance hangars have unique challenges for their fire protection. They are large open floors with large obstructions like docking systems for access during the maintenance of the aircraft. During the maintenance, large amount of fuel is present in the aircrafts and the maintenance of the aircraft can cause a variety of potential ignition sources were both of them can cause large pool fires. There are no specific local building codes for the aircraft hangars and they are acknowledged as a single-story building. NFPA 409 provides guidance for these types of structures in particular the active and passive fire protection systems. One of the recommendations of the structures carrying vertical load is to be protected with 2 hours fire protection systems.

This research is developed as per the performance based code and is new alternative design in comparison with the standard based. The design based on performance is an alternative design in comparison with the standard based design and it has been developed and improved in the last years for different engineering disciplines.

The Eurocode BS EN 1991-1-2 and BS EN 1993-1-2 recognizes and identifies the alternative approach for usage of fire performance based code. Where is possible to undertake a procedure for determining adequate performance, which incorporates some or all of the parameters and by demonstrating that the structure or individual components will give adequate performance in real building fire [2]. This type of design approach completely changes the purpose for achieving satisfied resolution and it is predetermined at the beginning of the project. The performance based code is based on the following main requirements:

- Already determined fire protection goals.
- Identify and analyze the probable scenarios of fire.
- Quantitative examination and alternative design to the already required goals for fire protection, safety by implementing a different engineering tools, methodologies and acceptance criteria.

The difference between the standard based design, the performance based design is the following:

- Performance based design is based in specification on quantitative and physical performance criteria used for evaluation of the achievement of the purpose of the fire protection.
- Performance based design is based on the dynamic analysis of the selected scenarios.
- Performance based design is based on quantitative assessment on the predicted scenarios with accepted engineering tools.

The goal of the performance based design analysis is to demonstrate with appropriate engineering analysis that an acceptable level of fire protection will be achieved through the comprehensive detail of the conditions for its use. The process for performance based design is:

- Define the project scope.
- Identifying the fire safety goals.
- Client on the project and designing and developing the behavior criteria.
- Development of fire scenarios.
- Development and evaluation of design based testing.
- Documentation.

In this research since the concern is the fire protection of the steel structures (passive fire protection system) specifically will be considered in developing of fire scenarios, evaluation of the designed based testing and the final evaluation of the testing results.

In order more detailed design evaluation to be provided (CFD) computational fluid dynamics was used in comparison with the correlation included in the Eurocode and the referenced standards. For the assumptions of the fuel (kerosene) properties like heat of combustion and the carbon monoxide yield was incorporated in the analysis. Large number of computer programs with different features are available in the market. CFD modeling was done for this research by Fire Dynamic Simulator (FDS, version 6.1.0) developed and maintained at the National Institute of Standards and Technology (NIST). It is a computational fluid dynamics (CFD) model designed for low speed and thermal driven flow, with an emphasis on the numerical simulation of the heat transfer. More information on the model verification and validation can be found in the FDS Verification Guide and FDS Validation Guide that can be downloaded from the NIST website (http://www.fire.nist.gov/verificationvalidation.html).

Methodology for fire modeling

Geometry. The aircraft hangar has been built according to the size and dimension used in the SAP2000 model. The size of the model is 204 × 294 × 42 m (Fig. 11). The elements which are included in this model are portal frame designed as solid section material steel with dimension 200 × 5 × 45 m, solid steel columns on the rear side of the building. Aircraft has also been drawn on the model for presentation reasons. The height of the opening of the portal frame (Fig. 12) will represent that during the fire the hangar will be completely open. The fire source is designed as rectangular with area 176 m^2, and it should represent the pool fire. This model is created to conduct computation, modeling to develop an understanding of the pool fire and potential impact on to the elements of the steel structure.

Item	Dimensions
Model	204 × 294 × 42 m
Portal frame	200 m × 5 m × 45 m
Columns	5 × 5 × 45
Aircraft A380	72 m × 78 × 24.5 m
Heat source	176 m^2

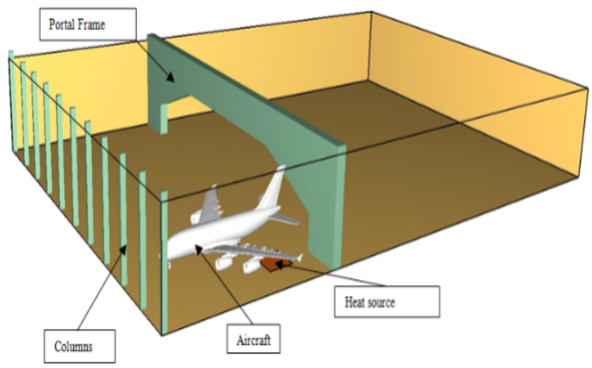

Fig. 11. 3D model in pirosim / FDS

Since the dimension of the columns can vary (different sections) they haven't been implemented in the model. Instead, thermocouples are used to measure the adiabatic temperature on the surface of the portal frame. The location of these thermocouples is representing the arrangement of the steel elements.

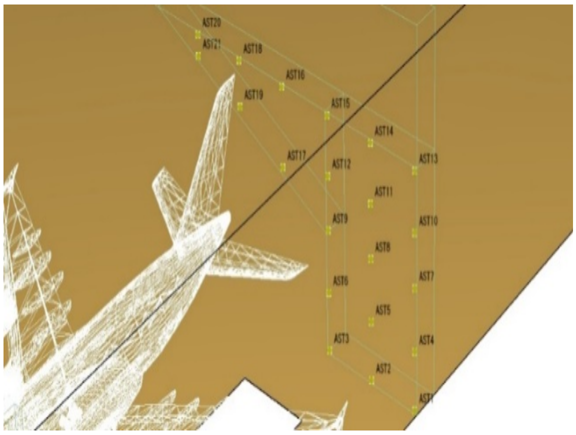

Fig. 12. Location of the thermocouples

Mesh. In FDS is required that the model is splited in cells. From the size of the cells the result may vary, i.e. the smaller size of the cells will give higher accuracy of the results and analysis.

Design scenario. The fire source in the simulation was represented by burning of liquid pool fire with a total surface area of 176 m^2 located 15 m away from the steel columns. The maximum heat release rate is calculated as per the equation shown above and it is 391 MW or 2219 kW/m^2. The size of the pool fire is determined from the location of the floor drainage which is positioned on every 15 m. The total duration of the simulation is 3640 s or 64 min which depends from the total burning time of the amount stored inside the aircraft. Knowing that the aircraft is using the fuel, kerosene type Jet-A1 the following properties will inserted:

```
&REAC ID='Kerosene',
 FUEL='REAC_FUEL',
 FORMULA='C15H32',
 CO_YIELD=0.012,
 SOOT_YIELD=0.042,
 HEAT_OF_COMBUSTION=4.32E4/
```

From the simulation the visual results are presented on Figure13 from the x and y slide and it is observed that the maximum temperature of the plume is 930 ^{o}C.

The exposure conditions of steel structures are generally characterized by thermocouple surface adiabatic temperature measurements. From the applied thermocouples the “measured” adiabatic temperatures are displayed in the Figure 14 in particular the temp. for thermocouple AST3 AST4 and AST 6 are presented.

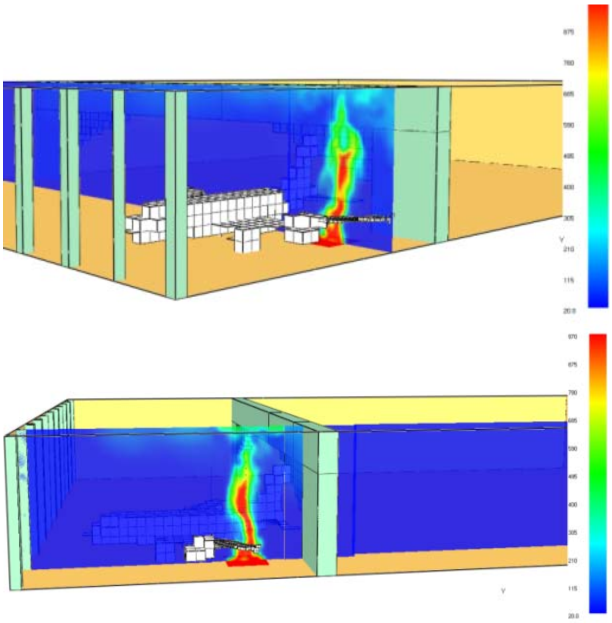

Fig. 13. Visuals of the temperature slice in × & y

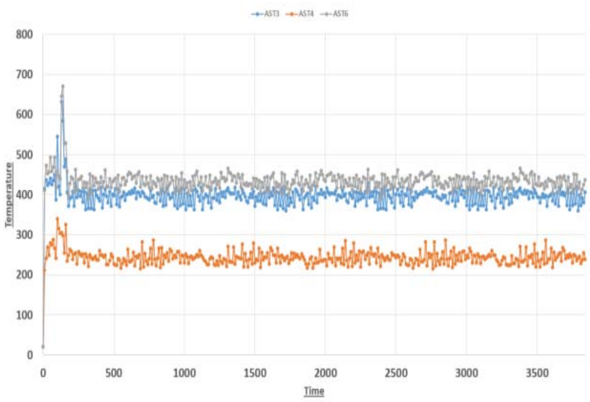

Fig. 14. Adiabatic temp

Detail analysis of the steel structure

For further investigation of the structural behavior on the elements affected by the pool fire, FEM software “ABAQUS / CAE 6.12" was used. This type of analysis gives the opportunity for a wide range of studies, as well as the elimination of some limitations coming from the experimental trial.

The analysis of the entire structure is often not economical and requires time and resources. For this analysis individual elements will be investigated as shown in Figures 15 and 16.

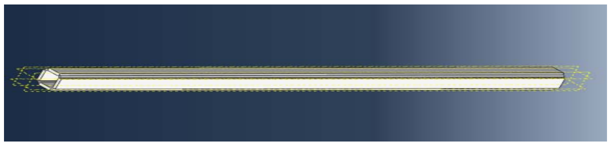

Fig. 15. 3D Element

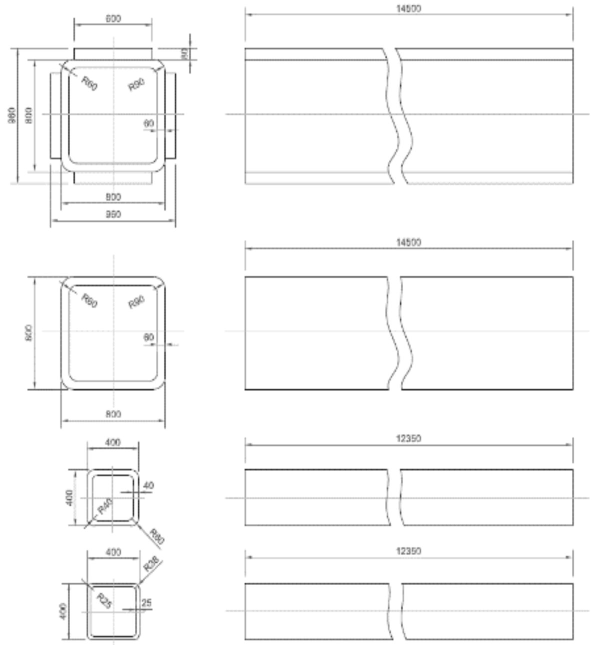

Fig. 16. Section profiles

The analysis will be done in four modules were in the first module will be done only heat transfer analysis. The result of this analysis will then be used for the remaining modules where complex thermo mechanical stress analysis will be performed.

The individual elements will be modeled as shown in the Figures 15 and 16 with the original dimensions.

Loads. On the Table 1 are presented the forces which will be used for the analysis these loads are extracted from the previous mode done in SAP2000. The selected forces are taken from a service limit state where there is high possibility of occurring during the incident time.

Table 1

Section	Axial force (kN)
SHS400 × 400 × 25	2123.591
SHS400 × 400 × 40	–6221.635
SHS800 × 800 × 60	–4091.780
SHS800 × 800 × 140	–14553.301

MATERIAL PROPERTIES

The behavior of the mechanical properties of the steel under elevated temperatures needs to be known in order to understand the behavior of the steel structure at fire. The selected material for these elements will be low carbon steel S355 with the following mechanical and thermal properties under elevated temperatures.

The mechanical properties for the S355 are taken from BS EN 1993 (Figs. 17 and 18).

Elastic Young's modulus

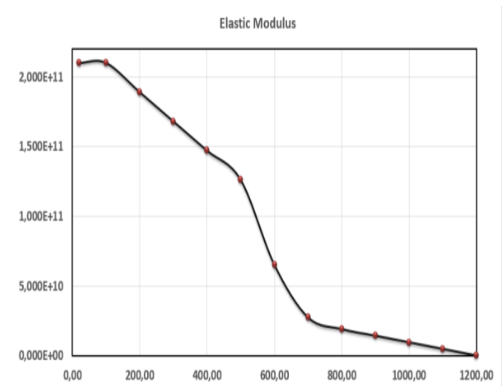

Fig. 17. Elastic modulus of carbon steel

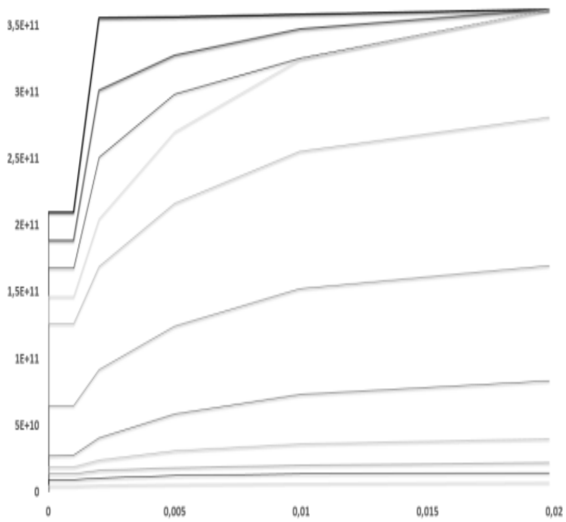

Fig. 18. Stress – Strain relationship at elevated temperatures carbon steel

Thermal properties. Thermal properties of steel S355 under elevated temperatures are also presented in Figures 19 and 20.

The properties of the material will be inserted in Abaqus in tabular form.

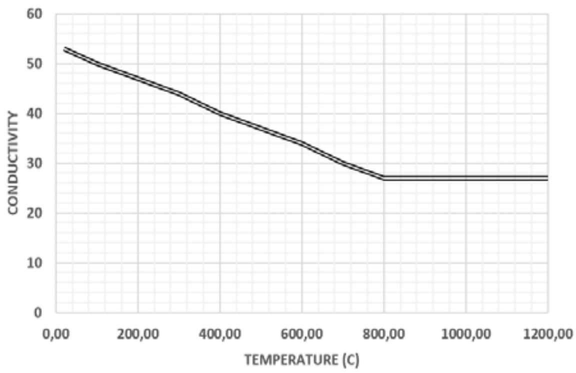

Fig. 19. Specific heat of carbon steel

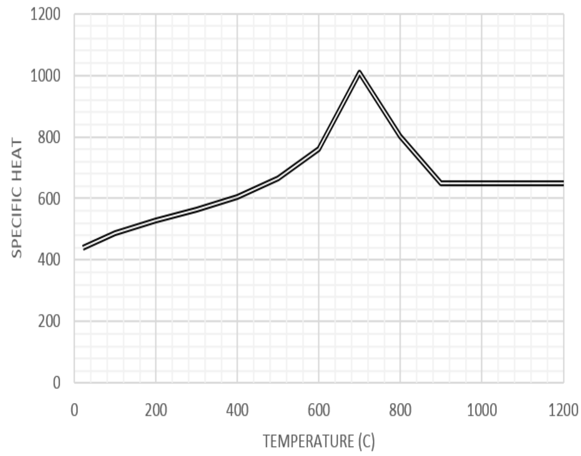

Fig. 20. Conductivity of carbon steel

RESULTS

Heat transfer analysis

To predict the development of the temperatures in the structural member's heat transfer analysis needs to be performed. The applied temperatures are the one measured in the FDS software (Fig. 14). The heat transfer of the members is governed by the following Fourier differential equations given below

$$\frac{\partial(\rho c\theta)}{\partial t}+\frac{\partial\left(\lambda\frac{\partial\theta}{\partial x}\right)}{\partial x}+\frac{\partial\left(\lambda\frac{\partial\theta}{\partial y}\right)}{\partial y}+\frac{\partial\left(\lambda\frac{\partial\theta}{\partial z}\right)}{\partial z}=0$$

where is:

x, y, z – coordinates in m,
θ – is temperature in x, y, z in ^{o}C,
ρ – density in kg/m^3,
c – specific heat J/kg
λ – thermal conductivity in W/m K.

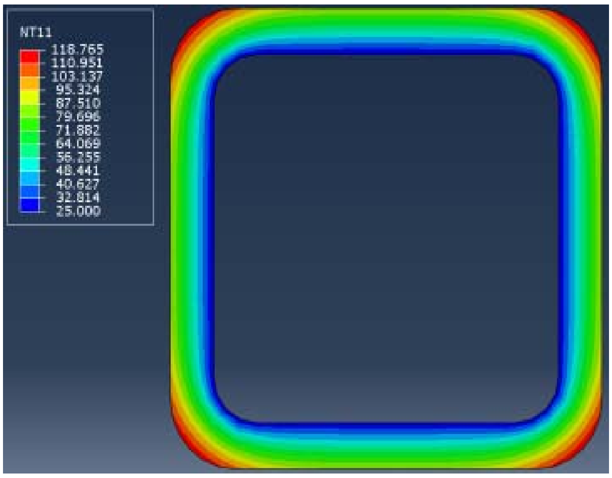

Fig. 21

The results after the analysis are presented in the Figure 22. The distribution of the temperature across the depth of the wall is shown visually and it can be seen that the maximum temperature after 64 minutes of exposure on all external sides is 118 ^{o}C.

On the same figure it can also be seen the graphs which are representing the maximum steel temperature vs time of the exposure. The peak of the applied temperature is 631 ^{o}C on the first 300 sec and then it is with stay constant with value of 450 ^{o}C The temperature of the steel elements on the other hand increases on the first 300 sec and then is with constant value of 118 ^{o}C.

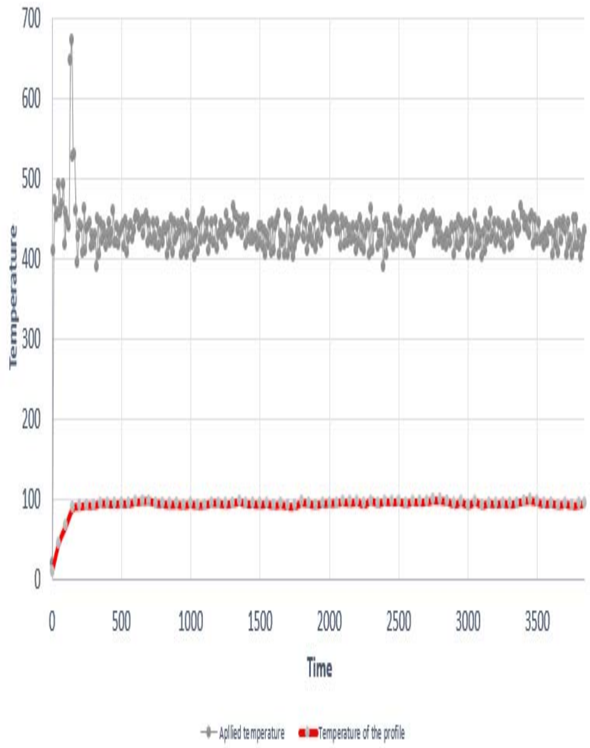

Fig. 22. RHS 400×400×40 heat transfer analysis

Thermal analysis

The second module examines the mechanical behavior of the steel element from the applied temperatures. From the figure below it can be seen that due to the heating the element elongates in a positive direction. In ideal case if the temperature distribution is equal to the entire section the stresses occurred in the element will be equal trought the entire wall thickens.

These unequal temperature distributions across the wall thickens will cause additional stresses due to the unequal elongation (Fig. 23).

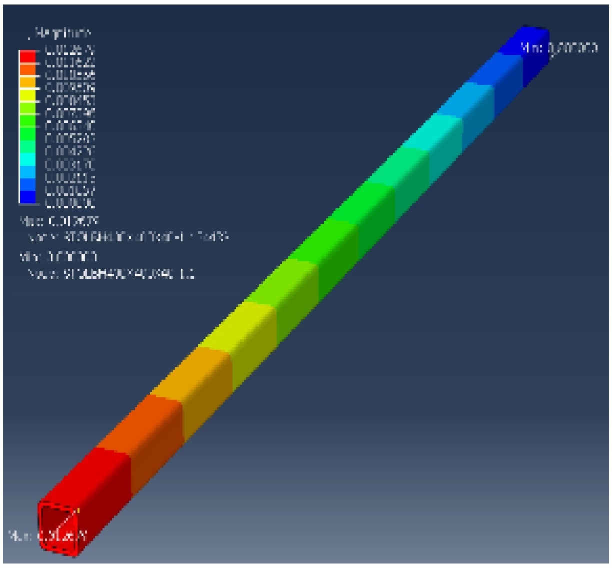

Fig. 23. Elongation of the element

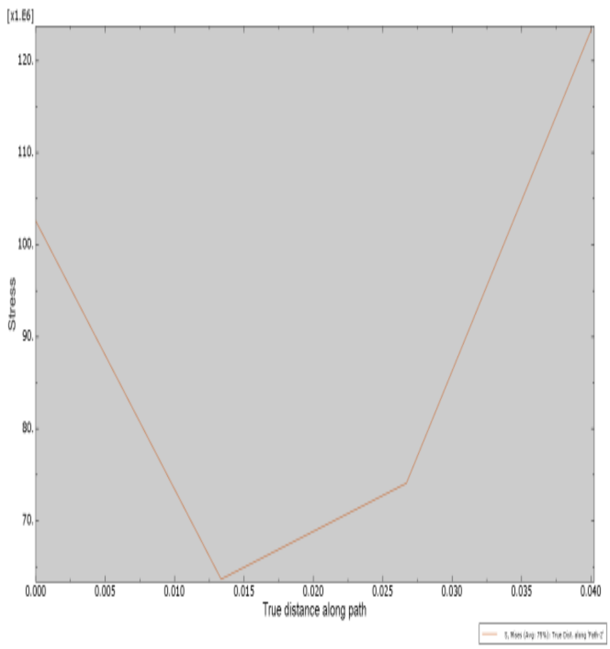

Fig. 24. Stress along wall thickness

Combined thermo-mechanical analysis

This analysis has been done for better understanding the behavior of the structure under the combined loading. The analysis will be done in two main steps. The location where the stresses will be monitored is identified in (Fig. 25).

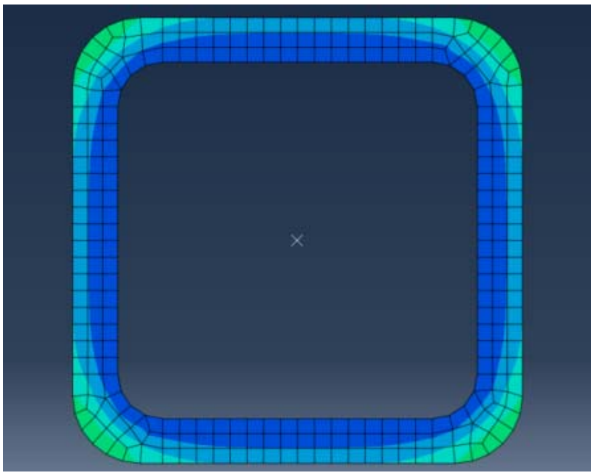

Fig . 25. Location of the monitored stresses

In the fist step (Fig. 26) it will be shown the elastic behavior of the element with applied axial load. The axial load has been applied continuously through the entire simulation time. As presented in the graphs, the stresses are increasing linearly with the growing of the load. After 3840 sec or 64 min the temperature loads are applied and the static loading will be continues through the remaining simulation time. It can be observed that there is an immediate stress grown with the external elements. These stresses are due to the stress caused by the thermal loading. From the result is shown that the maximum stresses occurred from this analysis are around 170 N/mm^2 where is much less than the yield strength of the S355 where is 355 N/mm^2. From the above investigation, we may conclude that with the thermal load induced by the combustion of pool fire the element will still behave linearly and the stresses will be much less than the limit. Therefore, this analysis has shown the fire protection of these elements is not required as stated in NFPA 409 of 2 hour fire rating.

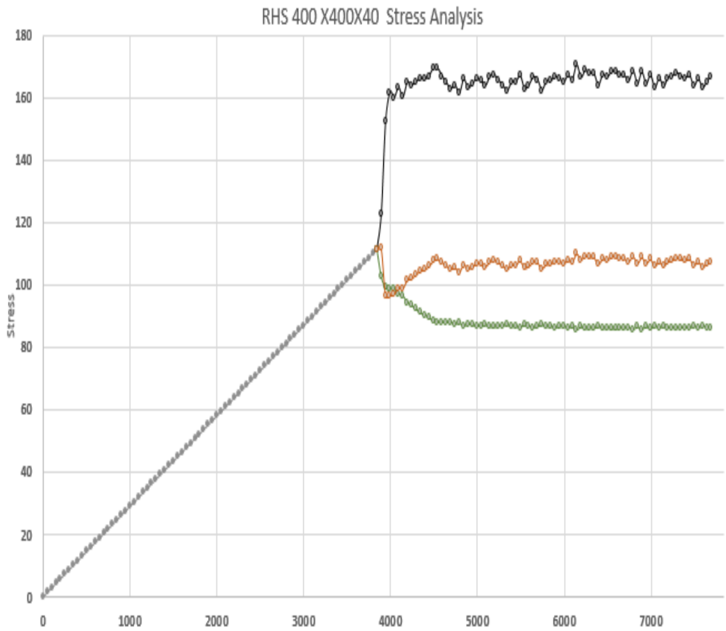

Fig. 26. History results from the combined loading

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Original scientific paper

STATE OF THE ART IN RESEARCH OF REINFORCED STRUCTURAL GLASS ELEMENTS

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A b s t r a c t: Glass is used in structures mainly because of its transparency which allows for visual dematerialisation of the structure. Since architectural trends tend to fully transparent structures, new forms of bearing elements are in need. Thus research is started in using glass not only as infill but also as bearing element in the structure. But the brittleness of the glass does not guarantee integrity of the element once the glass is broken. This is a reason for setting the focus on ways for achieving residual strength for glass. Laminating with polymer interlayer is one way of getting this result, but not satisfactory in some environmental conditions since the post breakage behaviour of such structures are influenced by interlayer properties which on the other hand depend on time and temperature. Another way of gaining residual strength for glass is reinforcing using different kind of construction materials. Research done in this area is summarised and presented in this paper.

Key words: Structural glass; reinforcement; state of the art; hybrid beams; hybrid plates

ПРЕГЛЕД НА ПОСТОЕЧКИ ТРЕНДОВИ ВО ИСПИТУВАЊАТА НА ЗАЈАКНАТИ КОНСТРУКТИВНИЕЛЕМЕНТИ ОД СТАКЛО

А п с т р а к т: Конструктивното стакло се користи во конструкциите главно поради неговата трансапрентност која овозможува визуелно дематеријализирање на коснтрукцијата. Откако трендот во архитектурата вклучува целосно транспарентни коснтрукции, се јавува потреба од нови форми на носечки елементи. На овој налин заполнуваат истражувањата на можностите стаклото да се користи за изработка на носечки елемент во конструкцијата. Меѓутоа, неговата кртост не овозможува гаранција за интегритетот на елементот во моментот кога ќе се јави лом. Ова е причина за истражување на начини за обезбедување на носивост на стаклото и по појавата на лом. Ламинирањето како процес, претставува еден начин на постигвување на оваа цел, меѓутоа не е доволна за одредени улсови на експлоатација поради фактот што капацитетот на преостаната носивост кај ламинираните структури директно зависи од видот на материјалот кој се користи при ламинирањето чиишто карактеристики од друга страна зависат од времето и температурата. Друг начин да се постигне капацитет на носивост по појава на лом е со употреба на различни видови на мтеријали за зајакнување на стаклото. Истраѓувањата направени во оваа област се сумирани и претставени во овој труд кој претставува преглед на постоечките трендови во областа на зајакнати елементи од стакло.

Клучни зборови: Конструктивно стакло; зајакнување; преглед на постоечки трендови; хибридни носачи; хибридни плочи

INTRODUCTION

The appearance and the behaviour of a structure depend on the geometry and mechanical characteristics of the elements it consists from. In order to get structural integrity, three main structural characteristics are important: constructive elements geometry, their function in the structure and the types of connections between them. The good compressive strength of the glass allows for including connection elements with greater strength and hardness, like steel. Steel connection elements are used for point support and bolted connections in connecting glass elements, cases where stress concentrations may occur. Additionally, steel is used when adhesive connections are included in the structure for more even stress distribution. On the other hand, glass is known for its brittleness and low tensile strength which results in zero residual strength.

One of the used solutions regarding this problem is using reinforcement of the glass which in most cases includes steel. Now, using different types of connection, hybrid glass composites are gained. When different materials work together as opposed to separately a composite action achieved which is directly influenced by the connection characteristics [1]. This influence becomes great challenge for structural engineers and is being researched in different hybrid element forms including, beams, columns, sandwich plates, laminated structures etc.

REINFORCED BEAM ELEMENTS

Special interest for elements involving glass is shown when it is used as load bearing structural element being a vital part of one structure – beams. Glass beams are used as single bearing elements or combined in multipart beams by multiplying in piles for reinforced profile (Fig. 1)[2].

Fig. 1. Glass beams [2]

A lot of research is done on the bearing capacity of such linear glass elements because of their sensitivity in bending. Since glass has no residual strength, these elements are mostly used in hybrid forms whose post breakage capacity is achieved by means of additional materials in the structure of the element: steel, timber, concrete, FRP etc. added in tension zone.

Cruz and Paqueno have researched timber-glass elements where flanges made of timber are connected through adhesive connection to the glass rib. Different beam cross sections and sizes are tested through experimental setups for defining the mechanical properties of the hybrid element. Tested in bending, the post breakage behaviour of the element is analyzsed when cracking of the glass occurs and glass can no longer transmit load especially in tension (Fig. 2) [3].

Fig. 2. Timber-glass beams [3]

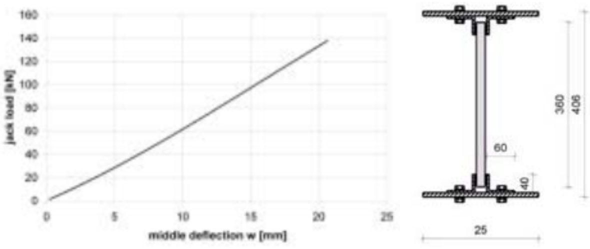
On the other hand, Freytag investigates glass beams reinforced with two concrete flanges (Fig. 3). The connection between the glass rib and the flanges is done by inserting glass in wet concrete [4] . The beams 7.8 m long are tested for their residual capacity but their long term capacity is again researched by Veer who suggest possible corrosion of glass due to high alkalinity of concrete [5].

Fig. 3. Glass-concrete beams [5]

Palumbo analysis the behaviour of glass beams reinforced with CFRP added in the tension zone of the glass beam (Fig. 4). The beam is constructed by laminating several piles of annealed glass and reinforcing the profile with a profile of carbon fibre reinforced polymer adhesively bonded to the tensile edge [6]. Similarly, Agnetti does a research of beams reinforced by steel fibers. The elements are formed by float glass sheet glued between them and with the reinforcement using common structural resins and by PVB laminated annealed glass with the reinforcement bonded at the intrados with resin. The aim is to increase tensile resistance and solve the problem of the brittleness of the glass and the great dispersion of the tensile strength values [7].

Fig. 4. CFRP reifnorced glass beams [6]

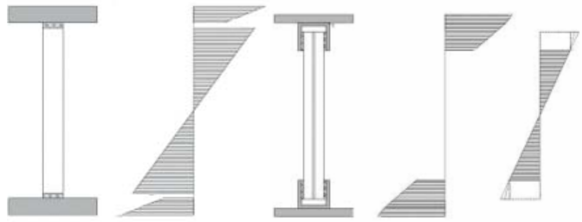
Most prominent research done in the area of reinforced glass beams are for steel-glass hybrid beams. Wellersh off studies steel to glass beams analyzing their behaviour under bending. Experimentally he gains the mechanical behaviour of the beams with I profile made of steel flanges attached to glass rib through four point bending testing where as a result a load deflection curve of the element is defined (Fig. 5) [8].



a) b)

Fig. 5. Steel-glass beams [8]

Netušil and Eliášova analyze similar steel-glass beam whose profile is achieved by different types of adhesive connections [9]. They main goal is accurately predict the behaviour of the beam, describe the stress distribution along the cross section and safely and economically design such a kind of structure with semi-rigid shear connection, performed by polymer adhesive (Fig. 6).



a) b)

Fig. 6 Normal stress distribution along the cross- section of the beam with direct connection between flanges and web (a) and U-profile connection (b)

In 2010, Weller has done research on steel glass beam elements made of laminated glass plies reinforced in tension by steel different steel profiles [10]. The steel elements, which are linearly connected to the glass using a transparent acrylate adhesive, increase the residual strength of the hybrid glass beams after breakage of all glass beams (Fig. 7).

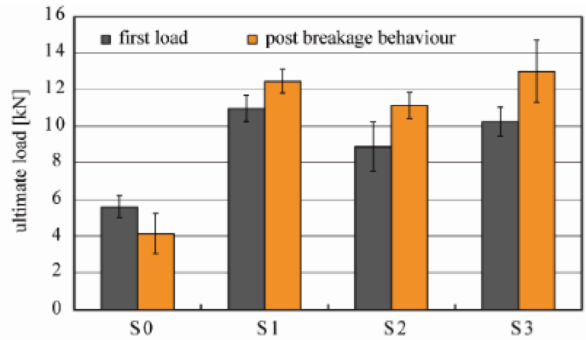
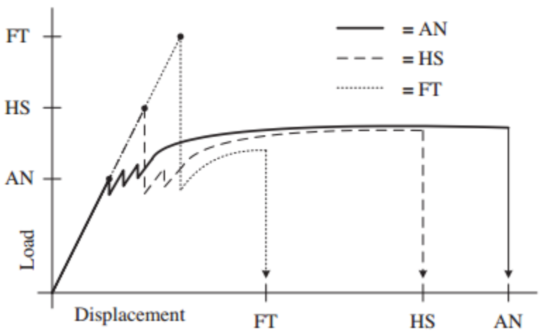


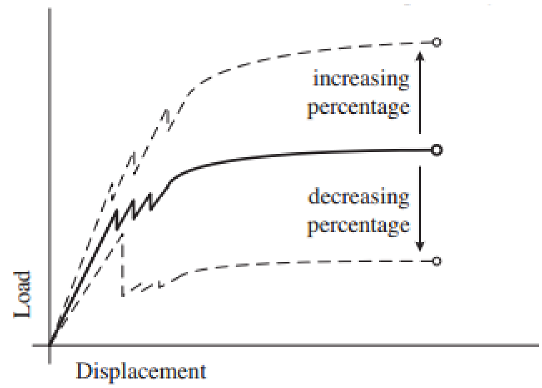
Fig. 7. Post breakage behaviour of steel–glass beams [10]

Louter in 2012 tests Sentry Glass laminated reinforced glass beams with different reinforcement capacity of added steel elements under four point bending. The beams are of a different size (1.5 and 3.2 m) and are made of different glass type (annealed AN, heat-strengthened HS and fully tempered FT). From the results it is concluded that the applied glass type has a significant effect on both the initial failure strength – due to a difference in apparent strength of the glass types – and the post-breakage behaviour – due to a difference in fracture pattern of the glass types of the reinforced glass beams (Fig. 8).

Additionally, the reinforcement percentage has a significant effect on the structural performance of the reinforced glass beams, as it influences the initial height of the compression zone and the post-breakage strength and stiffness of the beams [11] .



*Qualitative effects of glass type



*Qualitative effects of reinforcement percentage

Fig. 8. Post-breakage behaviour of steel –glass beams [11]

REINFORCED PLATE ELEMENTS

Using the glass in buildings at first was only wtih a function of infill element, where glass plates were used as windows. As years past, glass facades come in focus with glass plates used within a steel structure system forming a transparent facade. But as fully transparent pavilions are made, glass plates become load bearing elements forming shear walls as fully transparent structures. At this point, lot of research is done in order to investigate the possibility of providing residual strength for a plate used as bearing element. Lamination is not enough as the residual strength capacity is directly influenced by the interlayer properties which on the other hand are heavily dependent of temperature and time. Thus, researchers are investigating different forms of reinforcing glass plates by presenting different composite concepts. Steel is usually used as reinforcing element in forms of profiles, thin stripes or plates. Additionally, GFRP or aluminium profiles may be used.

Wellershoff and Sedlacek present concepts of GFRP profiles reinforced glass plates which are tested under bending. This sandwich structures are experimentally analyzed for their overall stiffness which is influenced by the stiffness of reinforcing profile, its size, the adhesive layer thickness and the location of the reinforcement (Fig. 9) [8].

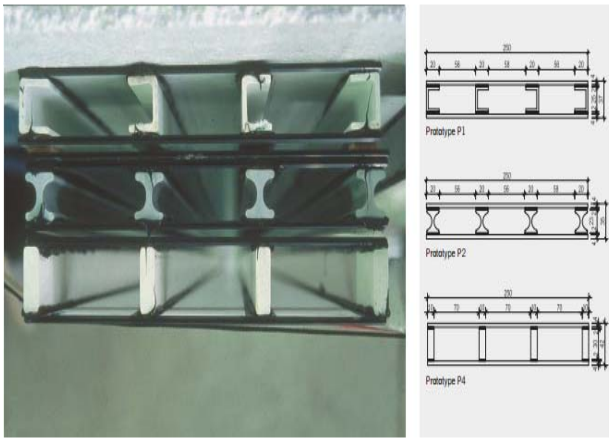


Fig. 9. GFRP reinforced glass plates [8]

Weller on the other hand, investigates glass-polycarbonate hybrid plates as overhead glazing elements (Fig. 10). He concludes that the structural behaviour of glass-polycarbonate sandwich structures depends on its bending stiffness. The bending stiffness of the composite section results from the concurrence of the material stiffness (elasticity modulus) and the section stiffness (geometrical moment of inertia 2nd order) of the single components as well as of the existing transfer of shear forces applied. The post-breakage behaviour of the glass-polycarbonate sandwich plates depends essentially on thickness of polycarbonate sheets. A significant dependency of post-breakage behaviour on the formed fracture pattern and therefore the used type of glass is not identified during his experiments [12].

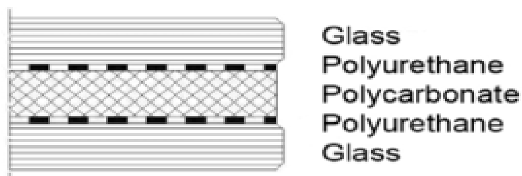


Fig. 10. GFRP reinforced glass plates [12]

Reinforcing glass plates with steel profiles is done by Nhamoinesu [1] and Silvestru [13]. Glass plates are reinforced with steel profilces adhesively bonded along the edges of the plate and tested under bending. Different residual strength are gained using analyzing different types of adhesives and different structure formes: single glass pane or two glass pane used in the reinforced element structure (Fig. 11).

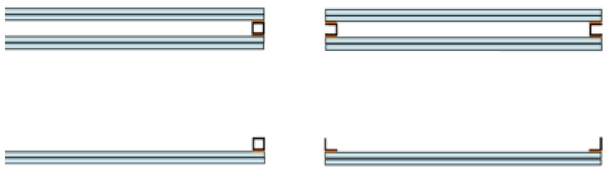


Fig. 11. Different concepts of the steel reinforced glass plates [1]

Using laminated structure as base for its concepts, Feirabend presents laminated hybrid glass plate structure where steel perforated plate is used as reinforcement embedded between interlayer during lamination process. In this way, he tries to compromise for the disadvantages of the polymer interlayer when standard laminated glass plates are used by activating the elasto-plastic properties of the steel layer included. The residual strength is guaranteed even after breakage of both glass plies which increases the safety and the integrity of the element. The residual strength is tested for different interlayer types: PVB and SG, and for different temperatures (Fig. 12) [14].

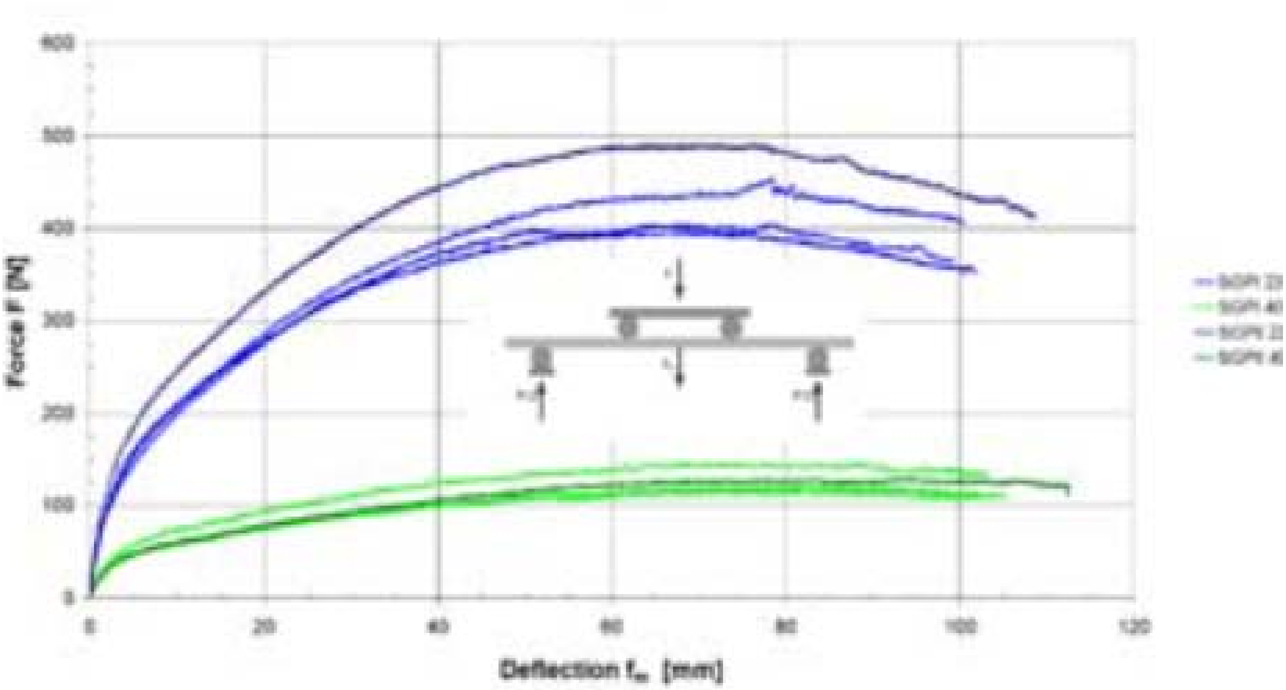


Fig. 12. Residual strength of the steel-glass plates [14]

CONCLUSIONS

The current state in research of reinforced glass elements shows active interest in development of new concepts that will improve the safety and load bearing capacity of glass elements by influencing the residual strength of the glass. Different forms and materials of reinforcement are researched and still a lot of possibilities stay open in contributing in this area. The biggest challenge for engineers remains choosing right form of connecting the elements in glass composites in order to achieving greater composite action thus greater reinforcement capacity and at the same time not compromising the transparency of the glass as its main cause for use in structures.

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Original scientific paper

DEVELOPMENT OF HYBRID GLASS-STEEL STRUCTURAL ELEMENT SHAPE USING PARAMETRIC ANALYSIS

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A b s t r a c t: In this paper a new concept of hybrid structural elements which include single glass panel connected to thin perforated metal layer through adhesive connection is presented. This metal layer at the same time gives the residual strength to the brittle glass while conserving its transparency. The perforation is gained through parametrical analysis and has a function of influencing the mechanical behaviour of the glass element. The results give different forms of perforation based on the type of panel support, which allow different reinforcement capacity.

Key words: hybrid structural element; reinforcement; parametric analysis; structural glass; metal layer

РАЗВОЈ НА КОНСТРУКТИВЕН ХИБРИДЕН ЕЛЕМЕНТ ОД СТАКЛО И ЧЕЛИК СО ПОМОШ НА ПАРАМЕТРИЧКА АНАЛИЗА

А п с т р а к т:: Во овој труд е претставен нов концепт на хибридни конструктивни елементи кои се составени од единичен панел од стакло и тенок перфориран метален лим поврзани помеѓу себе преку врска изведена со лепење. Металниот елемент има функција да обезбеди капацитет на преостаната носивост на елементот по појава на прв лом, а во исто време да ја задржи транспарентноста на стаклото. Формата на перфорацијата на елементот се добива преку параметриска анализа и има за цел да влијае на механичките каратеристики на елементот од стакло. Како резултат од анализата се добиваат различни форми на перфорација во зависност од начинот на потпирање на панелот, со што се постигнува различен капацитет на зајакнување.

Клучни зборови: хибриден конструктивен елемент; зајакнување; параметриска анализа; конструктивно стакло; метален елемент

INTRODUCTION

Structural glass is a brittle isotropic material whose transparency has been main reason for its use in buildings. However, today glass is known to be vital part of structures even as a bearing element. This comes as result of revolutionary changes in the processes of production, including glass product dimensions and forms as well as larger use of strengthening processes and laminated structures of glass panels. All of these transformations are made with one cause of changing the mechanical behaviour of the glass and make it more suitable for a structural element that can accept and transmit loads without compromising its integrity.

Glass, under normal temperatures of service behaves as a linear elastic material that will break when tensile stresses exceed a critical value. But the most prominent characteristic of glass as a structural element is its brittleness causing the glass elements to collapse suddenly, without any residual post-failure strength due to the brittle way of fracturing and its propagation through the whole element [1]. Thus, the main concept of enhancement of glass structural capacity, especially when it comes to the glass planar elements, is to reinforce the overall structural capacity by adding a supporting layer or lamination. This is usually done by combination of two materials developing a structural composite: individual or doubled glass plate and reinforcement layer. The reinforcing layer could be used to enhance the load bearing capacity of the planar element or to introduce more plasticity in the structural behaviour of the glass element and to enhance the post-breakage behaviour of laminated glass [2]. The metal layer is added to the glass element usually perforated in order to provide certain level of transparency of the structural element. However, the use of standard perforated metal sheets although are adding to the load bearing capacity of the glass element, it is also reducing glass transparency and due to its standard formats of perforation it is limiting the architectural expression of the glass metal reinforced elements [3].

CONCEPT OF THE HYBRID ELEMENTS

Proposed concept of the hybrid elements in this paper hold two main characteristics of providing residual strength for the glass panel and allowing capacity of shading. The concept consists of single glass panel made of tempered glass that has metal layer applied in its tension zone. This metal layer presents thin perforated stainless steel plate which is adhesively bonded over glass panel`s surface.

Having in mind the form of the concept, a lot of advantages of the excising structural glass concepts are included. Namely, the laminated structure of the element combines the characteristics of the three different materials included and acts as composite which by itself changes the mechanical behaviour of the single glass panel. Compared to laminated glass, in this way, the overall weight of the panel is decreased since only one ply of glass is used. On the other hand the interlayer properties which influence the mechanical behaviour and post breakage capacity of the element are successfully replaced by the adhesive used in the concept.

What is new in the proposed concepts is the possibility of redistributing and decreasing the principle stresses in the glass panel by the specific perforation of the metal layer. Taking in consideration the dimensions of the glass panel, boundary conditions and loading, a unique perforation can be formed which depends on the stress state of the panel under the defined conditions. In order to do this, a parametric study was made and different perforations types were formed.

PARAMETRIC ANALYSIS

The parametric analysis is done by using software algorithm that produces geometrical forms through mathematical functions. This algorithm uses inputs defined by the glass panel stress state under applied loading, the types of support and its dimensions. Another important input is the material model of the metal layer since the geometry of its perforation is the end result.

The inputs concerning glass panel are gained through another analysis using finite element method. The glass panel is subjected to pure bending, under out of plane load (Fig. 1 and Fig. 2). In pure bending the load bearing capacity of the glass panel mostly depends on the strain and stresses that occur in the tensioned zone. For that matter, the metal layer is adhesively bonded directly to the glass surface that experiences tension under the subjected load.

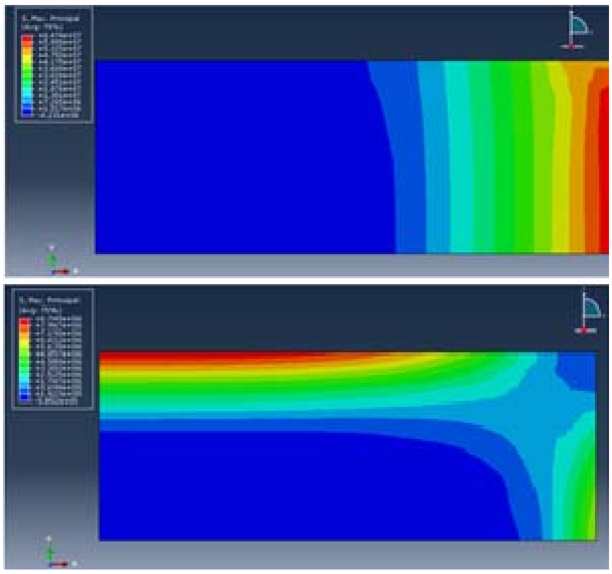

Fig. 1. Stress distribution in glass panel (2 edges support and 4 edges support)

The models of the glass panel as well as the hybrid glass-metal elements were defined and analyzed using ABAQUS. In the first state glass panels 3000×1500 mm with thickness of 10 mm were modeled under out of plane surface pressure load of 1200 N/m^2 and a different support conditions, simple support in four end nodes and ideal linear support on two shorter edges and four edges. Three different material models were used during analysis, all defined with elastic mechanical properties: glass with Young`s modulus of 70 GPa, adhesive with 603.5 MPa and steel with 210 GPa, and a Poisson's ratio 0,22; 0,43 and 0,3 accordingly. For the finite element mesh, 20-nodes brick elements were used for every model with a finer mesh near the supports and the middle of the panel where highest stresses were expected.

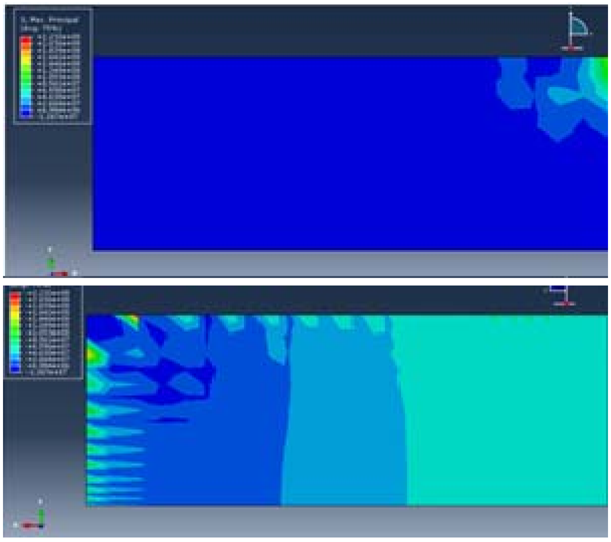

Fig. 2. Stress distribution in glass panel
(4 nodes support front side and 4 nodes support back side)

After conducting the analysis of the glass panel, stress state including principal stresses distribution and magnitude was gained as results. These results were then used for defining the parametric algorithm for forming the perforation of the reinforcement layer.

The parametric analysis was done using Grasshopper as software capable of graphic algorithm, software used in architecture. This tool uses geometric objects and mathematical functions as inputs and outputs for adjustments of parts which then affect the whole model. Grasshopper does not work on the real geometries, rather on the logic behind the geometries. Once logic has been set up, one can change parameters such as starting and ending angles, the shape of the object by supplying different profile curves as well as rotation axis. For modelling the perforation of the reinforcement metal sheet, the load conditions and resultant forces are used as inputs. In order to combine the parameterized geometric models and finite element calculation an additional plug-in is used called Karamba. This plug-in generates a structural analysis model based on the generated Grasshopper geometries [3].

The code starts with the constant parameters which define the dimension of the model set to 1.2 / 3.2 m envisioning the glass element as a facade element. By setting the nodes and defining the surface, through sets of numerical and mathematical expressions, the model goes for analysis performed by Karamba tools. The main variable inputs which define the perforation forms, dimensions and location are the boundary conditions, including support type and load, the material properties of steel and the stress state from the finite element analysis. All of the steps mentioned of forming the algorithm are given in Fig. 3 where the end result is an unique perforation of steel element.

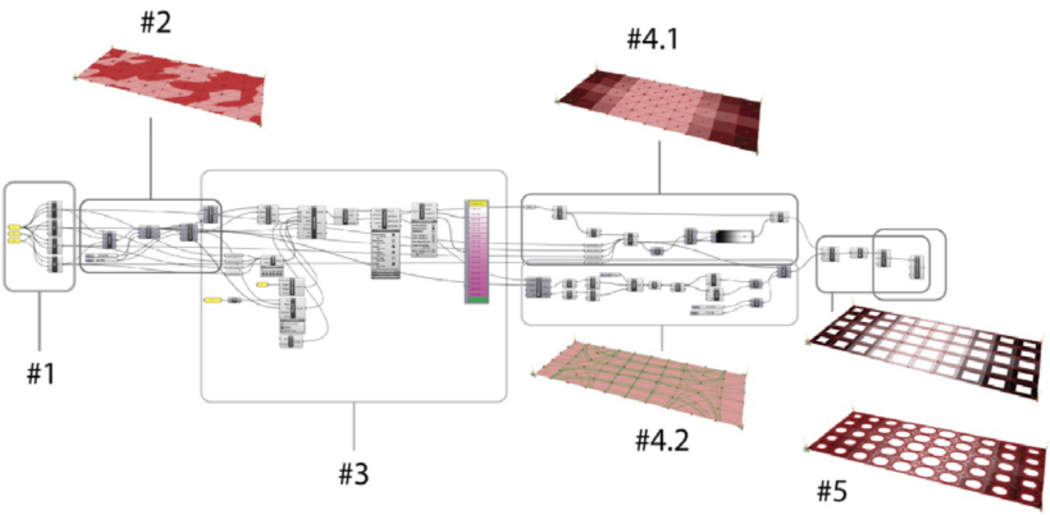

Fig. 3. Stress distribution in glass panel

In the first step (#1) the dimension of the panel is set. This value can be change once the whole algorithm is formed, thus the algorithm can e used for different panel dimensions. The panel is split in small finite elements forming a mesh in the second phase (#2). The boundary conditions are set at third step (#3) where the type of the support, load, stress state and the material properties are defined. In phase four (#4) through mathematical functions and links, the location of the perforation holes are defined governed by the stress distribution in the panel and the type of the support. The fifth phase (#5) is the phase where we can set the type of the form of perforation, circle, ellipse, square etc. The end results are different perforation type influenced by the parameters included in the algorithm (Fig. 4).

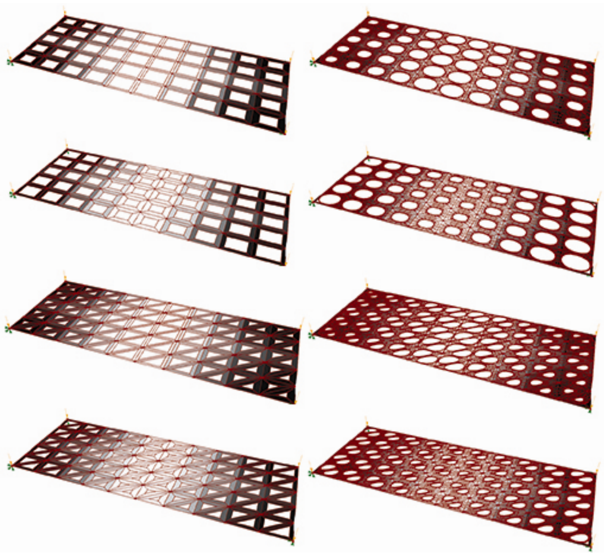

Fig. 4. Different metal layer perforation

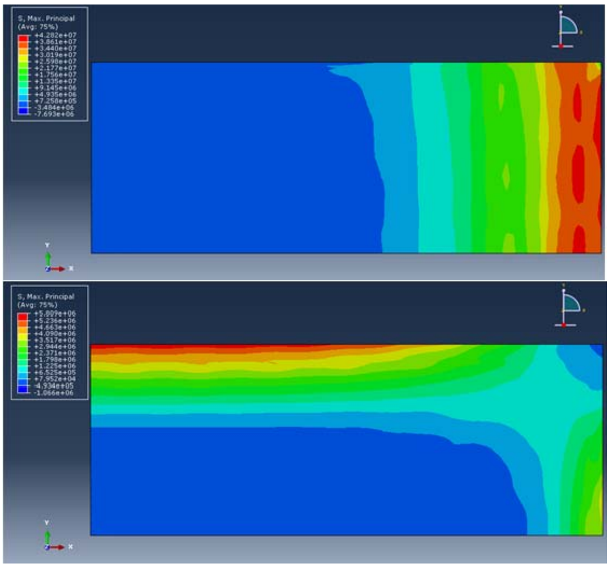

Fig. 5. Stress distribution in glass panel (2 edges support and 4 edges support)

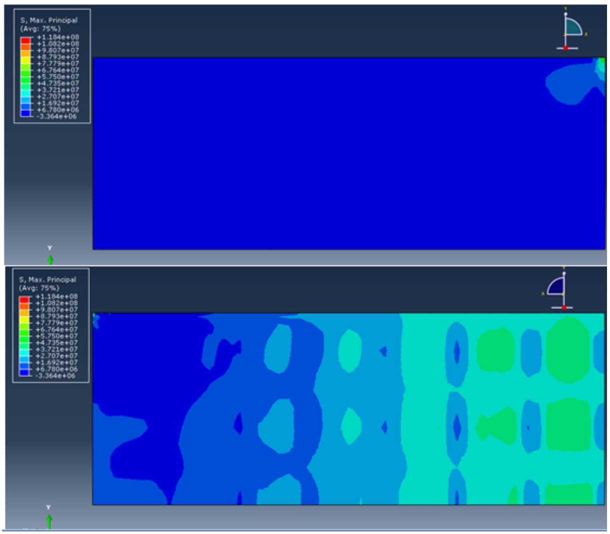

Fig. 6. Stress distribution in glass panel (4 nodes support front side and 4 nodes support back side)

EVALUATION OF THE NEW PERFORATION GEOMETRIES

The parametrical study results in different perforations of the reinforcement layer depending on the stress distribution in the glass panel. The perforations were than analyzed again in ABAQUS as part of the metal-glass composite. The contact between the different materials was defined as tie constrains, master to slave surface. What was obvious from the results (Fig. 5 and Fig. 6) was the decrease of the magnitude and change in distribution of the stresses in the glass panel, which was the main objective at this phase of the research regarding the mechanical characteristics of the new hybrid element.

This change is observed through the graphical view of the stress distribution which shows differentiable magnitude fields which we recognize by the legend of colours. Big difference can be seen in the first analyzed case where two side supports are included. What the perforated metal sheet has influenced is change in distribution of the stresses near the supported edge.

A changed in maximal stress continuity has occurred and as legend shows, also decrease in stress magnitude is introduced. Additionally, the concentration of stress is reduced as we can notice that stress fields have widened. This also relates to the case of four edges support, and is the main change in the four nodes support where the stress concentration near the supports is the biggest problem. As we can see from the results, these concentrations cannot be seen in the tensioned zone of the composite because the distribution of the stresses is more uniform.

CONCLUSION

Different types of perforated reinforcement layer were analyzed and elaborated. The investigated examples of parametrically gained geometry are showing influence in the mechanical characteristics of the modelled metal-glass composite. The stress distribution is changed due to specific pattern of perforations of the metal layer which was directly depending on the stress state of a single glass panel. So far, transparency defined as valuable factor design in the proposed concept is satisfied, and is planed as part of the future parametrical investigation of the perforated geometry as a changing variable in combination with static resultants of the element. The possibilities of finite element analysis and designing software are extensive and constantly increasing. Related to this, a convergence study is to be done regarding element type and mesh size which can additionally influence the accuracy of the finite element analysis. Thus this solution has lots of potential for further development including concept verification by following experimental testing.

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Original scientific paper

METOLOGY FOR SELECTION AND ANALISYS OF COGENERA-TIVE THERMAL POWER PLANT, USING NATURAL GAS FOR CLINIC CENTRE

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A b s t r a c t: Industrial cogeneration as high efficiency technology for production electricity and heat from natural gas in R.Macedonia will perform high impact on stabilization of the power system and reducing electricity imports. The implementation of industrial cogeneration power plants will provide independence of the consumers from the national power system, improving the energy efficiency and range of environmental benefits. This paper represents analysis and comparison of the obtained values from the simulation of the technical parameters in the software RETScreen and the real parameters of the current situation at the Clinic center – Skopje power plant.

Key words: Cogeneration; electricity and heat; clinic center; energy efficiency

МЕТОДОЛОГИЈА ЗА ИЗБОР И АНАЛИЗА НА КОГЕНЕРАТИВНА ТЕРМОЕНЕРГЕТСКА ПОСТРОЈКА СО КОРИСТЕЊЕ НА ПРИРОДЕН ГАС ЗА ПОТРЕБИТЕ НА КЛИНИЧКИ ЦЕНТАР

А п с т р а к т: Индустриската когенерацијата како високо ефикасна технологија за производство на електрична и топлинска енергија со природен гас во иднина ќе изврши големо влијание врз стабилизацијата на електроенергетскиот систем и намалувањето на увозот на електрична енергија во Р. Македонија. Со имплементацијата на когенеративните постројки во индустрискиот сектор ќе се обезбеди независност на потрошувачите од електроенергетскиот систем, подобрување на енергетската ефикасност и низа дополнителни еколошки придобивки. Во овој труд е извршена анализа и споредба на добиените вредности од симулацијата на техничките параметри во софтверскиот пакет RETScreen и реалните параметри од тековната состојба на енергетскиот капацитет при Клинички центар – Скопје.

Клучни зборови: когенерација; електрична и топлинска енергија; клинички центар; енергетска ефикасност

INTRODUCTION

The promotion and development of high efficiency electricity and heat generated by cogeneration which is based on economically justified needs of heat for heating and cooling with purpose saving of the primary energy and reducing the emission of carbon dioxide is a priority of EU and subject of the Euro-parliament and Council of Europe directive 2004/8/EC and 2009/28/EC.

The application of cogeneration in the EU Member States varies from state to state. The share of the production of electricity from cogeneration plants in total electricity generation is represented in the diagram in Fig. 1 Before the adoption of these directives, and after their adoption and application by members lately result in increased electricity produced from cogeneration plants in all EU Member States.

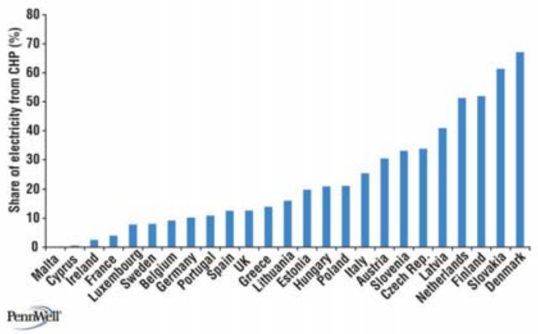


Fig. 1. Usage of electricity produced by cogeneration in Europe

Cogeneration as a high efficiency technology have big potential for using in the clinic centers, which are consumers with wide range of energy types (electricity, hot water, cold water, steam, etc.). In this paper are analyzed the opportunities of implementation the cogeneration technology in clinic center.

TECHNICAL DESCRIPTION OF THE CURRENT POWER PLANT

Clinic centre – Skopje for technological needs, hot water and heating uses superheated steam from own boilers and electricity purchased from the public electric grid. Below are the specific indicators related to energy consumption and production of electrical and thermal energy:

– year-round exploitation 8760 h/a;

– electricity consumption ≈9900 MWh/a;

– heavy oil consumption (3000÷4500) t/a;

– usual annual energy consumption for heating, steam and hot water is 34600 MWh/a;

The values of the consumed energy are shown on Fig. 2 that follows.

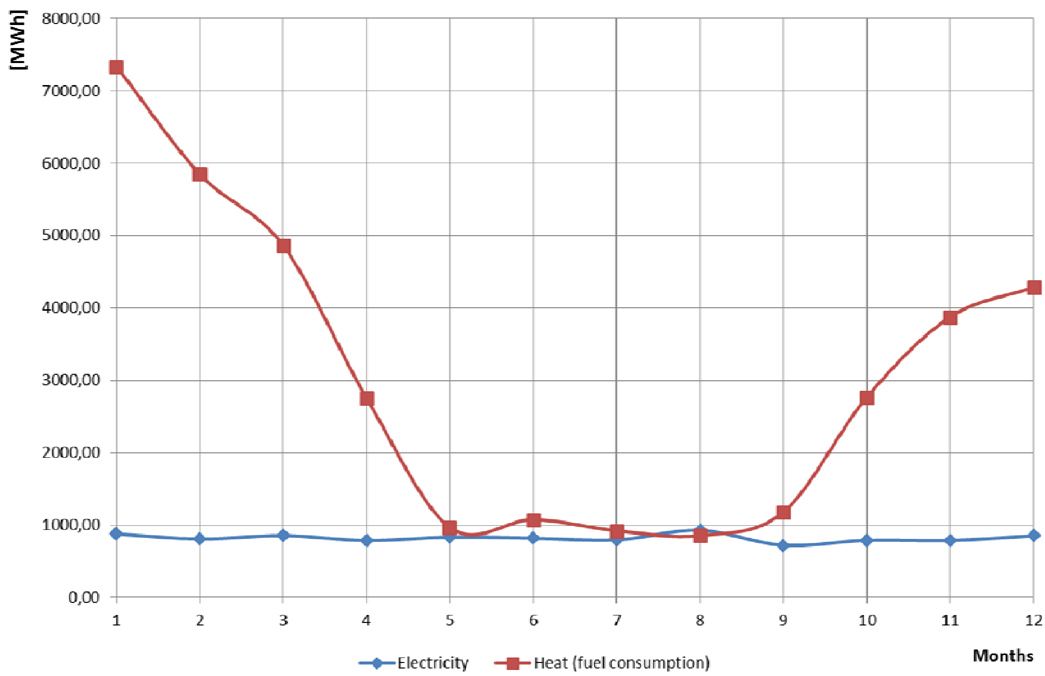


Fig 2. Annual energy consumption for Clinic center – Skopje

The usual consumption is uniform, without significant variation. It can vary (10% ÷ 15%) depending on the outside temperature in summer due to the fact that the cooling and air conditioning is performed with chillers and split systems that use electricity.

In a preliminary analysis examine various capacities and configurations of CHP plant when changing the main technical parameters in the range of values that roughly correspond to the investigated location. In the application of technical and economic optimal solution, examine various configurations and scenarios that drive the investor in the CHP plant will ensure maximal and sure income in specific conditions that define the legislation.

SIMULATON OF DIFERENT CONFIGURATION AND SCENARIOS

Preliminary analysis and simulation of different configurations and scenarios will be performed in the software RETScreen that allows energy, economic and environmental assessment of a given technology and configuration for electricity and heat.

The software has a complete database of climatic conditions of the location, technical characteristics of various HVAC and thermal power plants, fuel, and there is a possibility to perform a wide range of analyzes for different configurations and different capacities.

In this paper using RETScreen are made three scenarios of different configuration and capacities.

The base case system characteristics of the power plant located are shown in Fig. 3.

Base case heating system		Single building - space & process heating
Heated floor area for building	m²	110.000
Fuel type		Natural gas - m³
Seasonal efficiency	%	80%
Heating load calculation		
Heating load for building	W/m²	120,0
Domestic hot water heating base demand	%	5%
Peak process heating load	kW	1.300,0
Process heating load characteristics		Standard
Equivalent full load hours - process heating	h	7.000
Space heating	MWh	21.084
Process heating	MWh	9.100
Total heating	MWh	30.184
Total peak heating load	kW	14.500,0
Fuel consumption - annual	m³	3.623.144
Fuel rate	€/m³	0,470
Fuel cost	€	1.702.878
Proposed case energy efficiency measures		
End-use energy efficiency measures	%	0%
Net peak heating load	kW	14.500,0
Net heating	MWh	30.184

Fig. 3. Base case heating sistem specification

The first scenario is based on configuration which will cover whole electricity load and the base heating load. The capacity consist of gas engine with power 1 × 1265 kW. The load duration curves for scenario 1 are shown on Fig. 4.

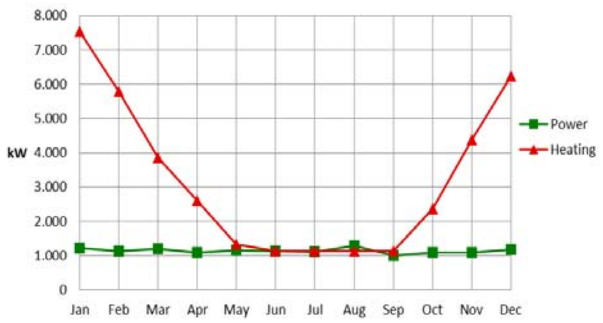


Fig. 4, Load duration curves scenario 1

The second scenario is based on configuration which will cover 7% of the heating load, technological needs and apsorption cooling. The capacity consists of two gas engines units "GE J320 GS" with power 2 × 633 kW and absorption chillers 1 × 872 kW and 1 × 628 kW. The load duration curves for scenario 2 are shown on Fig. 6. At Fig. 5 are shown base case load duration curves.

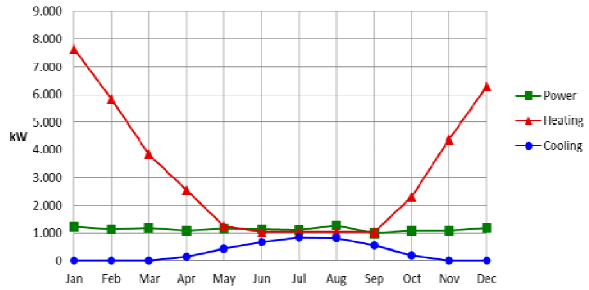


Fig. 5. Load duration curves base case

The third scenario is based on configuration which will cover 15% of the thermal load for heating, full coverage of the heat technological needs and full coverage of the cooling load. The configuration consist of gas engines 4 × 633 = 2532 kW and absorption chillers 1 × 872 kW and 1 × 700 kW. The load duration curves for scenario 3 and the functional scheme are shown in Fig. 6 and Fig. 7.

The simulaton of each scenarios and configuration using RETSceen are shown below in Figs. 8 –13.

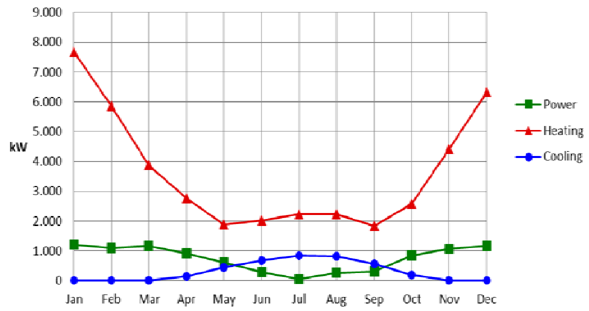


Fig. 6. Load duration curves scenario 2,3

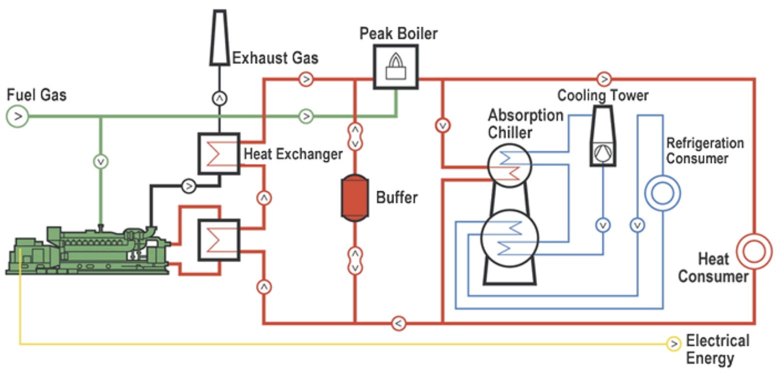
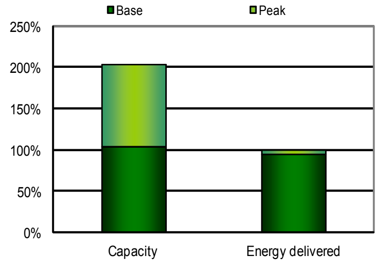


Fig. 7. Functional scheme of scenario 3

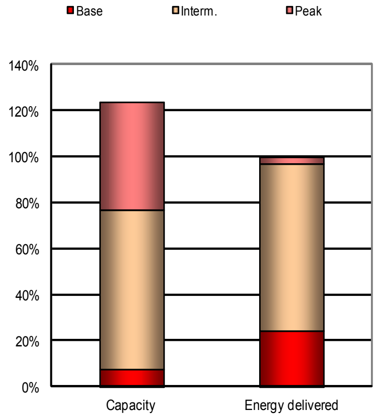
Operating strategy - base load power system				
Fuel rate - base case heating system	€/MWh	56,42	€/kWh	0,056
Electricity rate - base case	€/MWh	100,80	€/kWh	0,101
Fuel rate - proposed case power system	€/MWh	45,13	€/kWh	0,045
Electricity export rate	€/MWh	37,40	€/kWh	0,037
Electricity rate - proposed case	€/MWh	97,64	€/kWh	0,098

Operating strategy	Electricity delivered to load MWh	Electricity exported to grid MWh	Remaining electricity required MWh	Heat recovered MWh	Remaining heat required MWh	Power system fuel MWh	Operating profit (loss) €	Efficiency %
Full power capacity output	8.588	1.939	452	9.007	21.177	23.394	391.915	83,5%
Power load following	**8.588**	**0**	**452**	**7.348**	**22.836**	**19.085**	**420.283**	**83,5%**
Heating load following	8.588	1.939	452	9.007	21.177	23.394	391.915	83,5%

Power				
Base load power system				
Technology		Reciprocating engine		
Operating strategy		Power load following		
Capacity	kW	1.265	103,8%	
Electricity delivered to load	MWh	8.588	95,0%	
Electricity exported to grid	MWh	0		
Peak load power system				
Technology		Grid electricity		
Suggested capacity	kW	1.218,1		
Capacity	kW	1.219	100,1%	€ -
Electricity delivered to load	MWh	452	5,0%	
Back-up power system (optional)				
Technology		Električna energija mreže		
Capacity	kW	300		€ -



Heating				
Base load heating system				
Technology		Reciprocating engine		
Capacity	kW	1.082,3	7,5%	
Heating delivered	MWh	7.348	24,3%	
Intermediate load heating system				
Technology		Boiler		
Fuel type		Natural gas - m³		
Fuel rate	€/m³	0,440		
Capacity	kW	10.084	69,5%	
Heating delivered	MWh	21.967	72,8%	
Manufacturer		Ajax Boiler	See PDB	
Model		WF_21000	2 unit(s)	
Seasonal efficiency	%	80%		
Peak load heating system				
Technology		Boiler		
Fuel type		Natural gas - m³		
Fuel rate	€/m³	0,470		
Suggested capacity	kW	4.416,0		
Capacity	kW	6.786	46,8%	
Heating delivered	MWh	869,2	2,9%	
Manufacturer		Smith Cast Iron Boilers	See PDB	
Model		4500A-22	3 unit(s)	
Seasonal efficiency	%	80%		
Back-up heating system (optional)				
Technology		Котелска постројка		
Capacity	kW	500,0		



Proposed case system summary	Fuel type	Fuel consumption - unit	Fuel consumption	Capacity (kW)	Energy delivered (MWh)
Power					
Base load	Natural gas	m³	1.832.699	1.265	8.588
Peak load	Electricity	MWh	452	1.219	452
			Total	**2.484**	**9.040**
Heating					
Base load	Recovered heat			1.082	7.348
Intermediate load	Natural gas	m³	2.636.825	10.084	21.967
Peak load	Natural gas	m³	104.333	6.786	869
			Total	**17.952**	**30.184**

Fig. 8. RETScreen simulation of scenario 1

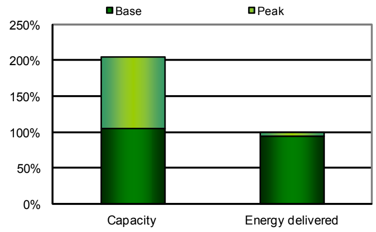
Base case cooling system	Single building - space cooling	
Cooled floor area for building	m²	30.000
Fuel type		Electricity
Coefficient of performance - seasonal		0,80
Cooling load calculation		
Cooling load for building	W/m²	50,0
Non-weather dependant cooling	%	5%
Total cooling	MWh	2.941
Total peak cooling load	kW	1.500,0
Fuel consumption - annual	MWh	3.676
Fuel rate	€/kWh	0,098
Fuel cost		€ 359.136
Proposed case energy efficiency measures		
End-use energy efficiency measures	%	0%
Net peak cooling load	kW	1.500,0
Net cooling	MWh	2.941

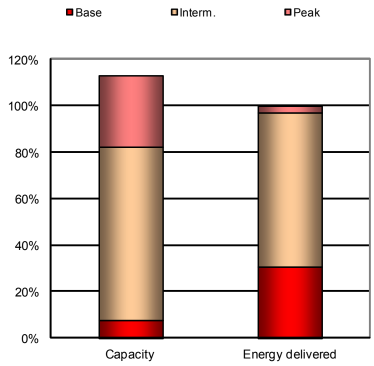
Fig. 9. Basic cooling data for the facility

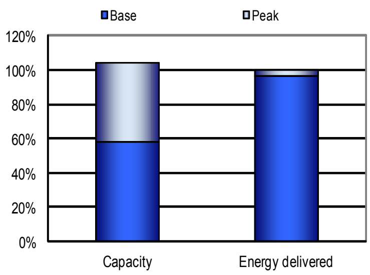
Technology		Absorption		
Fuel source		Heating system		
Capacity	kW	872,0	58,1%	
Coefficient of performance - seasonal		0,70		
Manufacturer		Broad		
Model		BZ75		1 unit(s)
Cooling delivered	MWh	2.851	96,9%	
Peak load cooling system				
Technology		Absorption		
Fuel source		Heating system		
Suggested capacity	kW	628,0		
Capacity	kW	700,0	46,7%	
Coefficient of performance - seasonal		0,80		
Manufacturer		Carrier		
Model		16JB-200		1 unit(s)
Cooling delivered	MWh	90	3,1%	

Fig. 10. Proposed cooling system

Power					
Base load power system					
Technology		Reciprocating engine			
Operating strategy		Heating load following			
Capacity	kW	1.266	105,3%		
Electricity delivered to load	MWh	6.121	95,0%		
Electricity exported to grid	MWh	4.414			
Peak load power system					
Technology		Grid electricity			
Suggested capacity	kW	1.202,2			
Capacity	kW	1.204	100,1%		€ -
Electricity delivered to load	MWh	322	5,0%		
Back-up power system (optional)					
Technology		Električna energija mreže			
Capacity	kW				€ -
Heating					
Base load heating system					
Technology		Reciprocating engine			
Capacity	kW	1.237,9	7,5%		
Heating delivered	MWh	10.302	30,6%		
Intermediate load heating system					
Technology		Boiler			
Fuel type		Natural gas - m³			
Fuel rate	€/m³	0,440			
Capacity	kW	12.288	74,8%		
Heating delivered	MWh	22.410	66,6%		
Manufacturer		Smith Cast Iron Boilers	See PDB		
Model		6500A-25	3 unit(s)		
Seasonal efficiency	%	80%			
Peak load heating system					
Technology		Boiler			
Fuel type		Natural gas - m³			
Fuel rate	€/m³	0,470			
Suggested capacity	kW	4.142,7			
Capacity	kW	5.042	30,7%		
Heating delivered	MWh	957,6	2,8%		
Manufacturer		Ajax Boiler	See PDB		
Model		WF_21000	1 unit(s)		
Seasonal efficiency	%	80%			
Back-up heating system (optional)					
Technology		Котелска постројка			
Capacity	kW	300,0			
Cooling					
Base load cooling system					
Technology		Absorption			
Fuel source		Heating system			
Capacity	kW	872	58,1%		
Cooling delivered	MWh	2.851	96,9%		
Peak load cooling system					
Technology		Absorption			
Fuel source		Heating system			
Capacity	kW	700	46,7%		
Cooling delivered	MWh	90	3,1%		
Back-up cooling system (optional)					
Technology		Електрични чилери			
Capacity	kW	300			







Proposed case system summary	Fuel type	Fuel consumption - unit	Fuel consumption	Capacity (kW)	Energy delivered (MWh)
Power					
Base load	Natural gas	m³	2.248.283	1.266	6.121
Peak load	Electricity	MWh	322	1.204	322
Electricity exported to grid					4.414
			Total	2.470	10.858
Heating					
Base load	Recovered heat			1.238	10.302
Intermediate load	Natural gas	m³	2.689.970	12.288	22.410
Peak load	Natural gas	m³	114.944	5.042	958
			Total	18.568	33.669
Cooling					
Base load	Heating system			872	2.851
Peak load	Heating system			700	90
			Total	1.572	2.941

Fig. 11. RETScreen simulation of scenario 2

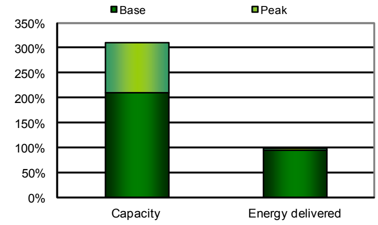
System selection		Base load system		
Base load power system				
Technology		Reciprocating engine		
Availability	%	95,0%		8.322 h
Fuel selection method		Single fuel		
Fuel type		Natural gas - m³		
Fuel rate	€/m³	0,470		
Reciprocating engine				
Power capacity	kW	2.532	210,6%	
Minimum capacity	%	25,0%		
Electricity delivered to load	MWh	6.121	95,0%	
Electricity exported to grid	MWh	13.439		
Manufacturer		GE		
Model		JMS 312 GS-B.L - 633kW		4 unit(s)
Heat rate	kJ/kWh	8.000		
Heat recovery efficiency	%	80,0%		
Fuel required	GJ/h	20,3		
Heating capacity	kW	2.475,7	15,1%	

Fig. 12. Proposed CHP system

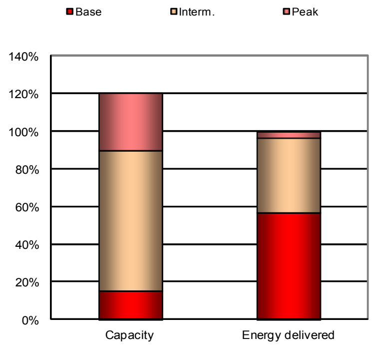
Operating strategy - base load power system		
Fuel rate - base case heating system	€/MWh	56,42
Electricity rate - base case	€/MWh	100,80
Fuel rate - proposed case power system	€/MWh	45,13
Electricity export rate	€/MWh	37,40
Electricity rate - proposed case	€/MWh	97,64

Operating strategy	Electricity delivered to load MWh	Electricity exported to grid MWh	Remaining electricity required MWh	Heat recovered MWh	Remaining heat required MWh	Power system fuel MWh	Operating profit (loss) €	Efficiency %
Full power capacity output	6.121	14.950	322	19.126	14.543	46.825	142.779	85,8%
Power load following	5.089	0	1.355	4.975	28.693	11.308	287.544	89,0%
Heating load following	**6.121**	**13.439**	**322**	**19.126**	**14.543**	**43.468**	**237.800**	**89,0%**

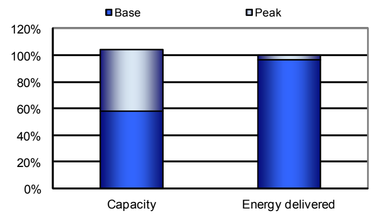
Power				
Base load power system				
Technology		Reciprocating engine		
Operating strategy		Heating load following		
Capacity	kW	2.532	210,6%	
Electricity delivered to load	MWh	6.121	95,0%	
Electricity exported to grid	MWh	13.439		
Peak load power system				
Technology		Grid electricity		
Suggested capacity	kW	1.202,2		
Capacity	kW	1.204	100,1%	€ -
Electricity delivered to load	MWh	322	5,0%	
Back-up power system (optional)				
Technology		Električna energija mreže		
Capacity	kW			€ -



Heating				
Base load heating system				
Technology		Reciprocating engine		
Capacity	kW	2.475,7	15,1%	
Heating delivered	MWh	19.126	56,8%	
Intermediate load heating system				
Technology		Boiler		
Fuel type		Natural gas - m³		
Fuel rate	€/m³	0,440		
Capacity	kW	12.288	74,8%	
Heating delivered	MWh	13.298	39,5%	
Manufacturer		Smith Cast Iron Boilers	See PDB	
Model		6500A-25	3 unit(s)	
Seasonal efficiency	%	80%		
Peak load heating system				
Technology		Boiler		
Fuel type		Natural gas - m³		
Fuel rate	€/m³	0,470		
Suggested capacity	kW	4.142,7		
Capacity	kW	5.042	30,7%	
Heating delivered	MWh	1.245,0	3,7%	
Manufacturer		Ajax Boiler	See PDB	
Model		WF_21000	1 unit(s)	
Seasonal efficiency	%	80%		
Back-up heating system (optional)				
Technology		Котелска постројка		
Capacity	kW	300,0		



Cooling			
Base load cooling system			
Technology		Absorption	
Fuel source		Heating system	
Capacity	kW	872	58,1%
Cooling delivered	MWh	2.851	96,9%
Peak load cooling system			
Technology		Absorption	
Fuel source		Heating system	
Capacity	kW	700	46,7%
Cooling delivered	MWh	90	3,1%
Back-up cooling system (optional)			
Technology		Електрични чилери	
Capacity	kW	300	



Proposed case system summary	Fuel type	Fuel consumption - unit	Fuel consumption	Capacity (kW)	Energy delivered (MWh)
Power					
Base load	Natural gas	m³	4.174.186	2.532	6.121
Peak load	Electricity	MWh	322	1.204	322
Electricity exported to grid					13.439
			Total	**3.736**	**19.883**
Heating					
Base load	Recovered heat			2.476	19.126
Intermediate load	Natural gas	m³	1.596.222	12.288	13.298
Peak load	Natural gas	m³	149.446	5.042	1.245
			Total	**19.806**	**33.669**
Cooling					
Base load	Heating system			872	2.851
Peak load	Heating system			700	90
			Total	**1.572**	**2.941**

Fig. 13. RETScreen simulation of scenario 3

CONCLUSION

By the performed technical analysis of different configurations and scenarios can be easily seen that except the first scenario, the second and third configuration produce a large amount of surplus electricity. With this method of interpolation, ie consideration of various scenarios can get to optimal system both technically and economic aspect.

From a technical point the most optimal plant of the considered scenarios currently is the plant in scenario 2, for wide range of base heat load which covers that do not produce surplus heat and electricity whose sale is economically unprofitable action. The load duration curves foe scenario 2 are shown in Fig. 14.

If to the consumption of electricity and thermal energy join and additional items the required power will increase and the load curves will be changed as shown in Fig. 15.

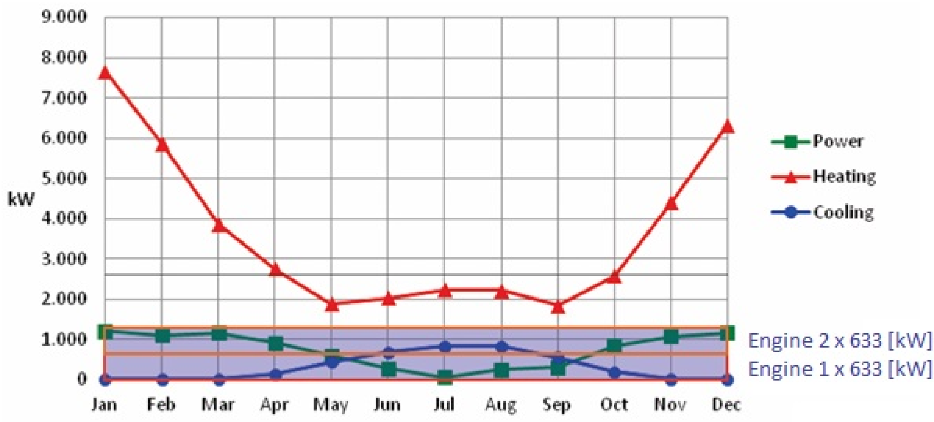


Fig. 14. Load duration curves for scenario 2

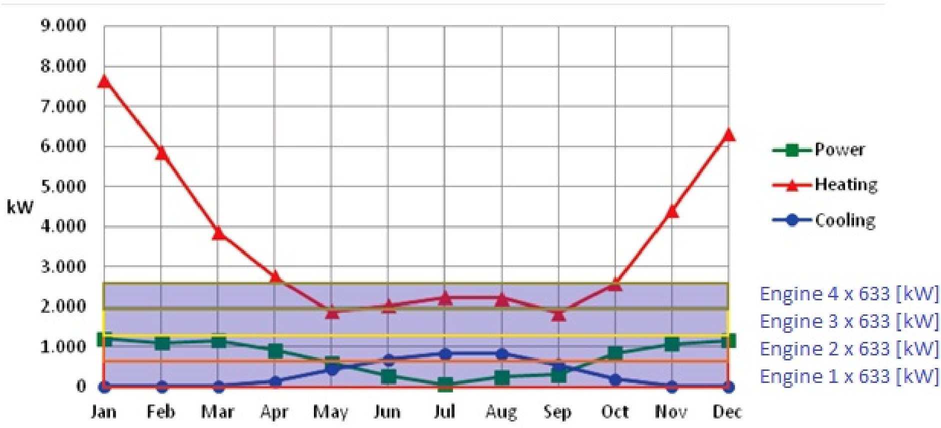


Fig. 15. Load duration curves for scenario 3

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Original scientific paper

PREDICTION OF HYDRAULIC FORCE AND MOMENTUM ON PELTON TURBINE JET DEFLECTOR BASED ON CFD SIMULATION

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A b s t r a c t: The numerical simulation of three-dimensional turbulent flow through the jet-distributor, free-stream jet and deflector of Pelton Turbine is presented in this work. The calculations are performed using the CFD package Ansys CFX (Navie-Stokes equations and the k-omega SST turbulent model). A traditional definition for calculation of hydraulic forces and momentum on the jet deflector and a method for experimental evaluation are described. The steps for flow modelling, mesh (grid) generation, as well as the results obtained from the numerical simulation of the flow and stress deformation calculations of the jet-deflector are presented. This work corresponds with the actual approach of methods development for flow simulation and calculations of Pelton Turbines. The kinematic and dynamic parameters are calculated based on CFD simulations. The results of the calculations represents reliable tool in the procedure of development and construction of Pelton Turbines.

Key words: Pelton turbine; jet deflector; flow simulation; CFD

ОПРЕДЕЛУВАЊЕ НА ХИДРАУЛИЧНАТА СИЛА И МОМЕНТ ВРЗ ДЕФЛЕКТОРОТ НА МЛАЗОТ НА ПЕЛТОНОВА ТУРБИНА СО *CFD* СИМУЛАЦИИ

А п с т р а к т: Во трудот е обработена нумеричка симулацијата на тридимензионално турбулентно струење низ струјниот простор во млазникот, слободниот млаз и скренувачот на Пелтон турбина. Пресметките се извршени со помош на пресметкованиот пакет Ansys CFX (Navie- Стоксови равенки и k-omega SST модел на турбуленција). Во трудот е даден приказ на основните кинематски односи кај Пелтон турбините. Прикажан е начинот на традиционалното дефинирање и определување на хидрауличката сила и момент на дефлекторот. Презентирани се чекорите на моделирање на струењето, креирање на структурирана мрежа, прикажани се добиените резултати од нумеричката симулација на струењето и јакостна пресметка на дефлекторот. Трудот се совпаѓа со тенденциите на новиот пристап во современиот развој на методите за симулација на струењето и пресметките на Пелтон турбини. Со помош на ЦФД симулации, пресметани се кинематичките и динамичките параметри на дефекторот на млазот. Резултатите од пресметките даваат сигурни показатели за применливост при развојот и конструирањето на Пелтон турбини.

Клучни зборови: Пелтон турбина; дефлектор на млазот; нумеричка симулација на струењето; CFD

INTRODUCTION

The purpose of this study is to find an accurate numerical procedure that would be capable of accurate predicting stress analysis for various positions of Pelton turbine deflector. To obtain acceptable stress analysis results of Pelton turbine deflector, first numerical flow analysis should be done with high accuracy for a different operational conditions. An investigation of deflector design at high-head turbine shall be presented in this paper.

Two phase flow (water, air) in Pelton turbines is always turbulent and unsteady, but we would like to obtain reasonable results by steady state analysis. The free surface flow analysis cannot be avoided and has to be modelled by a multiphase model. Numerical analysis of flow in a Pelton turbine is therefore quite complex and time consuming.

In the last ten years a lot of papers about numerical and experimental analysis of flow in Pelton turbines have been published [2], [3]. It was also proven that CFD can reproduce free surface flow in Pelton turbines with reasonable accuracy. On the basis of numerical and experimental results mentioned above, a mass of new knowledge about dynamic process in Pelton turbine was obtained, but there is no any paper about deflector stress analysis.

FREE SURFACE FLOW ANALYSIS

Free surface flows refer to a multiphase situation where the fluids are separated by a distinct resolvable interface. They can be modelled via a homogeneous or inhomogeneous model. For Pelton turbines the homogeneous model is usually used; in this paper homogeneous model was used. It is therefore sufficient to solve bulk transport equations for shared fields instead of solving individual transport equations.

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{U}) = \sum_{\beta=1}^{N_p} \Gamma_{\alpha\beta} \quad (1)$$

$$\frac{\partial}{\partial t}(\rho \vec{U}) + \nabla \cdot (\rho \vec{U} \otimes \vec{U} - \mu(\nabla \vec{U} + (\nabla \vec{U})^T)) = \\ = S_M - \nabla p \quad (2)$$

$\Gamma_{\alpha\beta}$ in equation 1 is the mass flow rate per unit of volume from phase β to phase α. Density and viscosity are calculated from density and viscosity of all phases in the fluid:

$$\rho = \sum_{\alpha=1}^{N_p} r_\alpha \rho_\alpha; \quad \mu = \sum_{\alpha=1}^{N_p} r_\alpha \mu_\alpha . \quad (3)$$

A detailed description of multiphase models and modelling of free surface flows can be found in [1].

HYDRAULIC FORCES AND MOMENTUM

The hydraulic force of the flow on the jet deflector can be defined as follows:

$$\vec{F} = \frac{d\vec{I}}{dt} = Q(\vec{c}_2 - \vec{c}_1)$$

Due to the incidence of the flow, the outlet velocity have different outlet angle than the plate geometry angle as it is shown in Fig. 1, and lower intensity:

$$\vec{c}_2 = \psi' c_1 \cos\varphi'$$

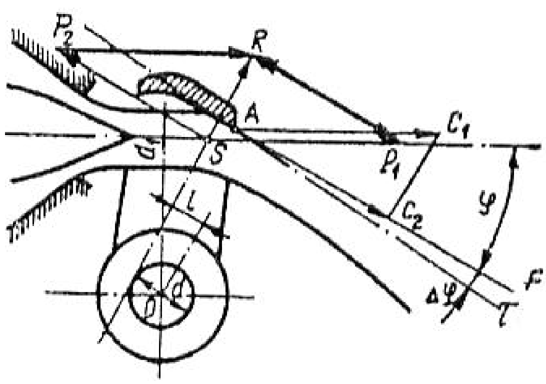

Fig. 1. Velocities and forces on the deflector

So, finally the forces P1 and P2 have the values:

$$\vec{F}_1 = \rho' Q(0 - \vec{c}_1) = -\frac{\pi d_1^2}{4} c_1 \vec{c}_1$$

$$\vec{F}_2 = \rho Q(\vec{c}_2 - 0) = 2\left(\frac{\pi d_1^2}{4} \rho g H\right) \psi \cos\varphi$$

The hydraulc momentum on the shaft is equal $Mh = R\,l$, where R is the resulting hydraulic force and l is the distance from the center of rotation (see Fig. 1).

NUMERICAL ANALYSIS

The geometry and computational domain of the test case analyzed in the paper is presented in Fig. 2. The size of free surface area computational domain has been defined in connection with reflected water jet from the deflector. Computational analysis has been done for four different positions of deflector [4]. Only the results for closing angle 18^0 (full closing) are presented in this paper.

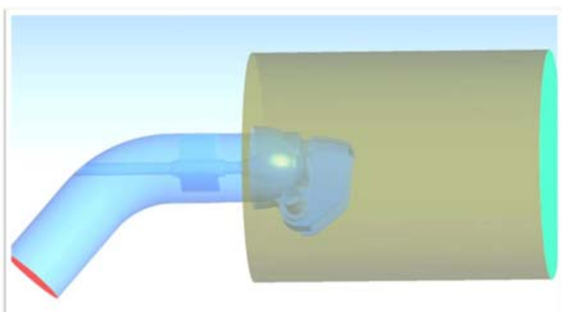

Fig.2. Deflector geometry and computational domain

The quality of computational grid is an important condition for accurate numerical flow analysis results, particularly in case of free surface flow analysis. Automatic grid refinement method is used to accurate predict the water jet from the nozzle. The grid refinement is clearly shown in Fig. 3. Grid refinement is also very important near the point where the jet is exiting the nozzle.

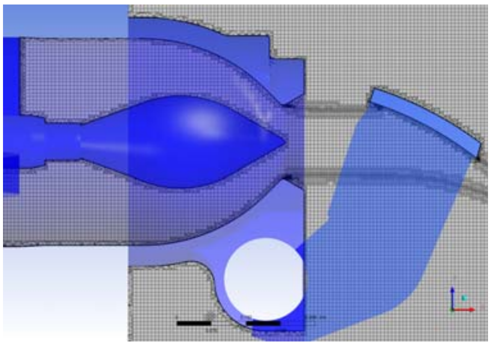

Fig. 2. Computational grid at angle positions 18^0

Numerical analysis of the flow in Pelton turbine deflector has been carried out only by steady state numerical methods using turbulent model *k-ω* SST. Although we are aware that the real flow is unsteady the steady state results should be accurate enough for our second step activity, where the stress analysis of the deflector has been done.

CFD RESULTS

The velocity vector distributions in water jet for deflector angle position of 18^0 are shown in Fig. 3. For the angle position of 18^0 we have full acceptance of the jet without spieling of the flow over the upper edge of the deflector. As we can see from the velocity vectors distribution for deflector position of 18^0 the flow values near the wall drop to 25m/sec. This leads to forming of pressurized zone as can be seen in details from the figures for pressure distribution over the deflector.

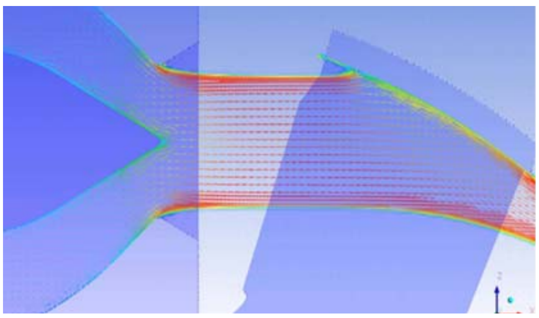

Fig. 3. Velocity vector distributions for angle of 18^0

The pressure distribution over the surface of the upper plate of the deflector is very important for design of the deflector itself and control mechanism. There for, a special attention was dedicated to grid generation in the zone of the top plate surface. After several modifications of the grid, the pressure distribution results are accepted as it is shown in Fig. 4. The pressure value on the side plates is low to app. 0.8 MPa. For angle position of 18^0 the area of maximal pressure is large and the flow over the side plates is more intensive with the maximal pressure up to 3 MPa.

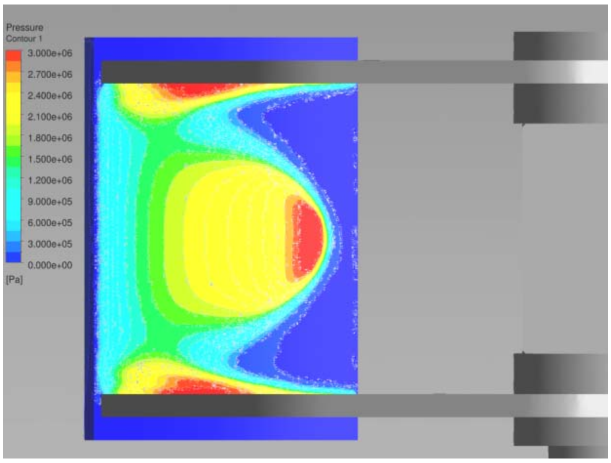

Fig. 4. Pressure distributions at angle 18^0

Based on the flow simulation results a calculation of the hydraulic forces and hydraulic momentum of the jet deflector is performed. The maximal values for angle position of 18^0 are as follows:

$$F_{xh} = 42.19 \text{ kN} \quad F_{zh} = 74.69 \text{ kN} \quad F_{yh} = 6.45 \text{ N}$$

$$F_{Rh} = 85.78 \text{ kN} \quad M_h = 12.45 \text{ kNm}$$

It should be notice that the symmetry of the jet flow is very good, so the value of the hydraulic force in Y-direction is very small. These calculated values were used for stress analysis of the jet deflector.

STRESS AND DEFORMATION ANALYSIS

The deflector stress analysis, which is a focus of this research, deals with complex stress conditions where forces are pointing in many directions corresponding to the 3D curvature of its surface and position. The maximal deformation work hypothesis is the basis for contemporary plasticity theories and used in practically all finite elements (FE) program packages. Based on the previous experiance [5], the following simplified Von Mises equation can be used for 3D stress condition:

$$\sigma_{ek}=\sqrt{\sigma_1^2+\sigma_2^2+\sigma_3^2-\sigma_1\sigma_2-\sigma_2\sigma_3-\sigma_1\sigma_3}\leq\sigma_d.$$

FE analysis has been used to perform the mathematical modelling of the nozzle and deflector. Ansys Workbench software package is employed for the calculations and it enables detailed picture of the stress and deformation changes with the possibility to follow the local trends in specific locations.

The nozzle design is developed for 9 MPa of maximal pressure, inlet diameter of 450 mm and outlet diameter of 162 mm. The jet deflector is designed with 20 mm thick side plates and 25 mm thick top plate. Fig. 5 shows the basic deflector design and the mesh created covering the whole computational domain. The total number of elements forming the computational mesh extends to over 292 thousand, depending to calculation for different analyzed cases.

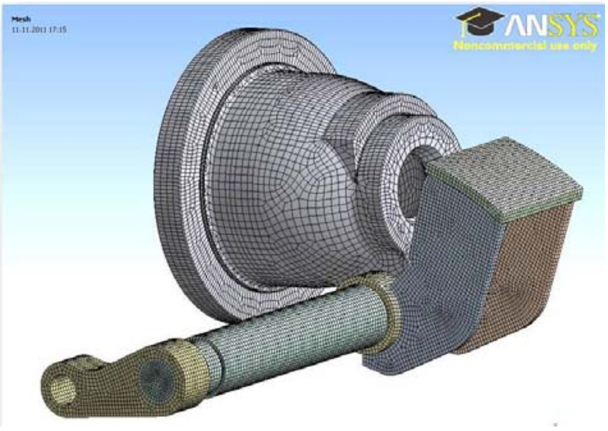

Fig. 5. Deflector design and computational grid

Due to the unacceptable values of equivalent stress and deformatin of the original jet deflector design (named OD-110), several modificatins were performed and corresponding results analyzed. The final deflector design (marked as FD-140) has modified parts as: shaft diameter of 140 mm, drive connection lever, nozzle head and 27 mm upper plate tickness.

The equivalent stresses on the shaft and deflector plate are shown in Fig. 6 with shaft stresses lower than 130 MPa (safety factor of almost 2). The stresses on the deflector upper plate are lower than 200 MPa. The maximum stress concentration occurs at the end of the edge connections (significantly lower values in comparison with OD), as shown in Fig. 6.

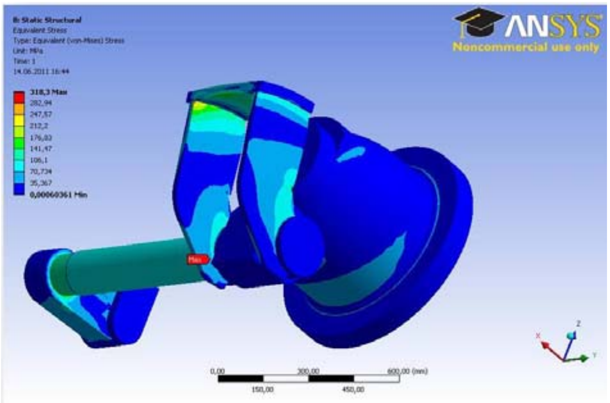

Fig. 6. Equivalent stresses in FD-140

The absolute value of deformations in X-direction (vertical) and Y-direction (axial) are lower in comparison with original design for more than twice as it is shown in the Fig. 7. Also, the deformations in Z-direction are lower (see Figure 8), i.e. the maximum value for FD-140 is 1.04 mm against 2.01 mm for OD-110.

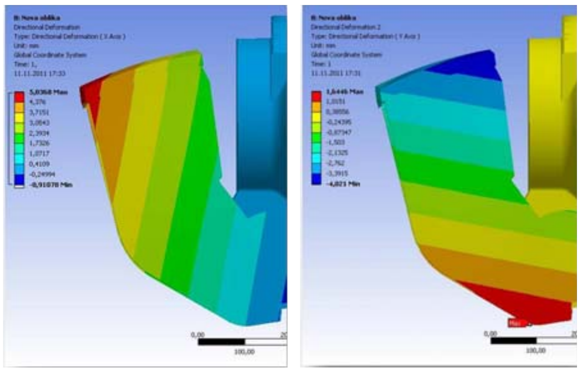

Fig. 7. Deformation in X and Y axis of FD

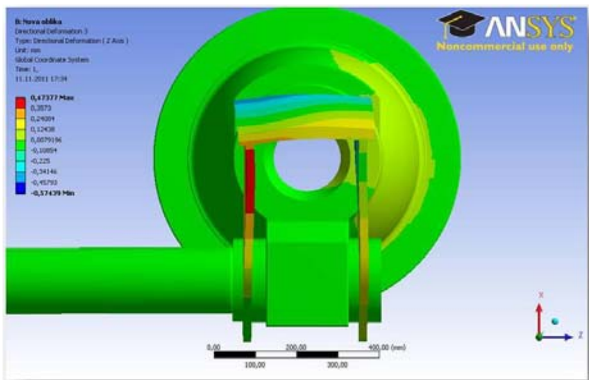

Fig. 8. Deformation in Z axis of FD-140

Fig. 9 shows the total deformations' disposition, where the maximal value of 5.6 millimeters ensures stable deflector operation from a hydraulic point of view, turbine geometry and doesn't affect the hydraulic and kinematic characteristics. The drive mechanism deformations are lower than 0.6 mm, which also ensures its safe operation. Presented stress and deformation analysis of the improved FD-140 design shows that the modifications and optimization performed on the basic design insures safe deflector operation.

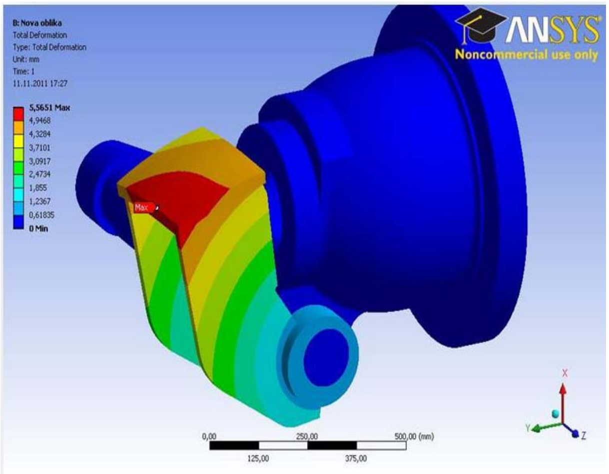

Fig. 9. Total deformation of FD-140

CALCULATION OF THE DIMENSIONLESS DYNAMIC PARAMETERS

The calculation of the kinematic and dynamic parameters presented above are performed for turbine net head of 520 m and nominal discharge 1,5 m^3/sec. Based on the calculated values of the hydraulic force and momentum on the jet deflector, the corresponding specific values are calculated as follows:

$$F_{h11} - \frac{F}{H \cdot d_m^2}, \qquad M_{h11} - \frac{M}{H \cdot d_m^3}$$

The values specific force and momentum, calculated for different angle position of the deflector are shown in Fig. 10.

If we assume usual value of bucket width *B* as 2,5 of nozzle outlet diameter d_m , the values of hydraulic force and momentum as a function of net head *H* and bucket width *B* are calculated as follows: F_h = 1,006 H B^2 and M_h = 0,36 H B^3. The results for hydraulic force and for hydraulic momentum are shown in Fig. 11 and Fig. 12, respectively.

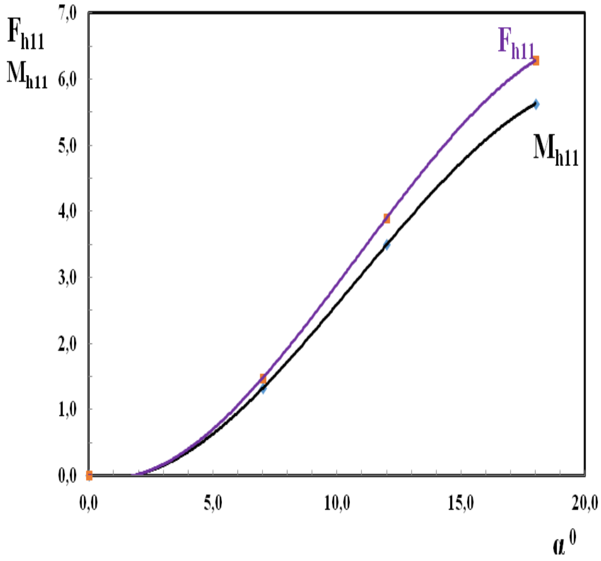

Fig. 10. Specific force and momentum of the deflector

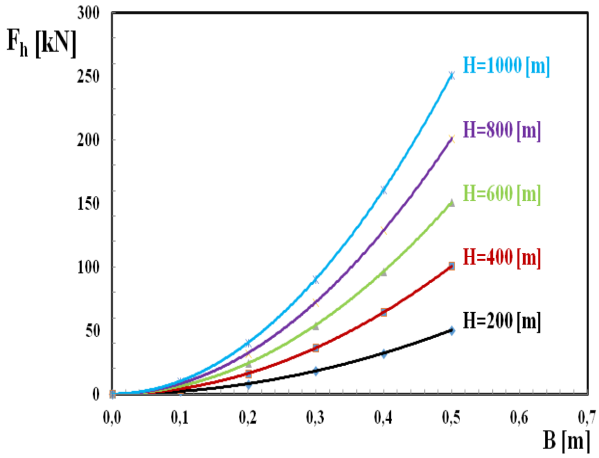

Fig. 11. Hydraulic force of the jet deflector

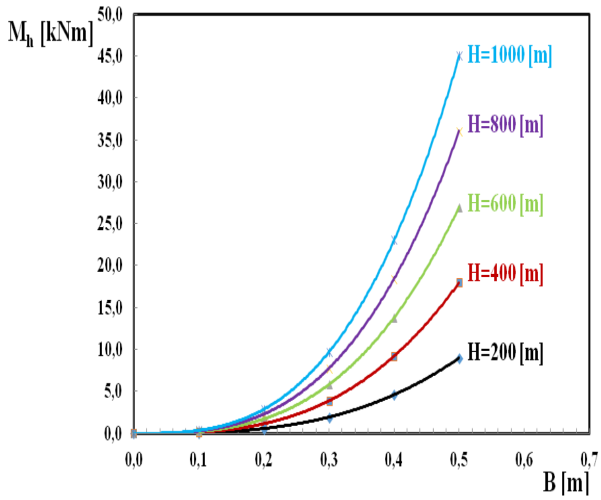

Fig. 12.. Hydraulic momentum of the jet deflector

CONCLUSION

The numerical flow and stress analysis of the Pelton turbine deflector was performed for several deflector positions. On the basis of the results it can be concluded that accurate calculation of jet is very important for prediction of Pelton turbine operation. Grid quality is greatly influences the results and is one of the most important reasons for discrepancies between numerical and experimental results. Numerical results are sufficiently accurate to be used for stress analysis of some parts of Pelton turbine.

Although some simplification is used the numerical analysis of a Pelton turbine still demands large computing capacities and usage of excessive CPU time.

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Original scientific paper

PREDICTION OF OVERALL LEVEL OF FEED-IN TARIFFS FOR SMALL HYDROPOWER PLANTS – STUDY CASE FOR R. MACEDONIA

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A b s t r a c t: An investigation of methods for prediction of feed-in tariffs level based on energy production costs is a main goal of this investigation. Also, the condition for positive financial effects and profit should be satisfied. An overview of development of renewable energy sources (RES) in respect of the methods for estimation of feed-in tariffs for energy production from Small Hydropower Plants (SHPP) is given. The examination based on model for evaluation of the energy production is performed. As an example, the analysis for a package of SHPP over different sizes in outputs is presented. The specific investment costs and economical parameters of SHPP and the shape of energy production cost curve for selected package of twelve SHPP are determined. The objective of this work is to present the influence of the structure and level of the feed-in tariffs on the economic performances of selected package of SHPP for development. The data for green field investment on a basic design level, for different SHPP across a range of sizes were used for the analysis. Using the site hydrology data, the energy production was evaluated through the actual energy production cost and compared with the existing feed-in tariffs in R. Macedonia. As a conclusion, several recommendations for influence of the site parameters and SHPP capacity on the level and structure of the feed-in tariffs are proposed.

Key words: small hydropower plant; feed-in tariffs; renewable energy

ОПРЕДЕЛУВАЊЕ НА НИВОТО НА ПОВЛАСТЕНИТЕ ТАРИФИ ЗА МАЛИ ХИДРОЕЛЕКТРАНИ (ПРИМЕР ЗА РЕПУБЛИКА МАКЕДОНИЈА)

А п с т р а к т: Главна цел на истражувањето во овој труд е да се изврши проучување на моделите за определување на висината на повластените тарифи од аспект на цената на чинење на произведената енергија и задоволување на условот за постигнување позитивни техно-економски ефекти и профит од реализираната инвестиција. Во првиот дел од трудот е даден преглед на искуствата од примената на обновливите извори на енергија (ОИЕ) во земјите во ЕУ и во регионот, како и стимулативните модели кои се користат за поттикнување на развојот на користењето на ОИЕ. Презентирана е методологија за определување на повластени тарифи (feed-in tariffs) за произведената електрична енергија од мали хидроелектрани (МХЕ). Истражувањата се спроведени според моделите за вреднување на производството од малите хидроелектрани. Притоа како пример за спроведената анализа се земени определен број МХЕ предвидени за изградба во Република Македонија, со различна големина на инсталираната моќност и топографски параметри на локацијата. Определени се инвестициските и економските параметри на МХЕ и анализиран е трендот на промена на производната цена на енергијата за селектираниот пакет од дванаесет МХЕ.

Клучни зборови: мали хидроелектрани; повластени тарифи; обновливи извори на енергија

INTRODUCTION

Many countries now place a high priority on the encouragement of renewable generation sources generally, and on hydrogeneration in particular. In many cases this has led to the development of policies to achieve target levels for renewable generation. Precise details of these policies vary quite widely from country to country, but almost all of them can be classified into two main types of measures:

Renewable energy minimum obligations: under these arrangements (which are often combined with a system of tradable green certificates) the network operators, suppliers, or consumers are typically given minimum obligations for the proportion of their energy purchases that must come from renewable sources. This sets the quantity and allows the price to be set by market forces. Those to whom the obligations apply can find ways to meet it at least cost (for example by tendering for new plants), an enhanced efficiency can be achieved with a green certificate system which allows trade between participants. This can be a very efficient system for achieving the policy targets at least costs, but the arrangements can be complex and administratively burdensome, and can present a higher degree of risk for investors. Examples of EU Member States using this approach are the UK, Sweden, Italy, and Poland.

Feed-in tariffs for renewables: under these schemes a set price is specified at which any quantity of renewable energy will be purchased by the network operator or retailer. The price is generally set for a period of several years, and the extra costs are recovered from consumers through a supplement on the retail electricity price. The quantity purchased is determined by the available supply at the specified price, and care is needed in setting and resetting the feed-in tariff to ensure that over funding is avoided. This type of scheme is particularly well suited to purchases from small renewable schemes, where individual tendering would be disproportionately burdensome and expensive. A significant number of countries now use schemes of this sort.

There have been periodic debates about whether feed-in tariffs, obligations, or other schemes represent the most efficient approach to encouraging renewable generation. We do not attempt to review that debate here, but it is important to emphasize that the feed-in tariff approach does have advantages in terms of its policy and administrative simplicity. One of the EU reports [1] reviewed the approaches that Member States adopted to support renewable electricity, and found that feed-in tariffs played a major role in many countries.

In the remainder of this report we will focus on feed-in tariffs arrangements, and in the following sub-section we present the results of our own review of policies applied. But first, it is worthwhile to mention other findings on support for SHPPs that were presented recently in the EU Commission report mentioned above.

In terms of costs, the report noted that technology is of particular relevance for some of the new Member States, and terrain is also of importance. The report's findings emphasized the wide range of costs that exists: on an LRMC basis, with an assumed pay back of 15 years, the cost for SHPPs was estimated to vary from around €40 per MWh to around €180 per MWh. Generally, the report found that existing feed-in tariffs are relatively well matched with the costs of generation, with the Austrian and the Portuguese tariffs at the lower end of the cost spectrum. On the other hand, it noted that the Finnish tax incentive scheme is unable to cover the costs needed to stimulate investment in new generation capacity. The results show that particularly good financial conditions for SHPPs exist in France and in Slovenia, though the down side of this is that overfunding may exist to some degree.

REVIEW OF FEED-IN TARIFFS ARRANGEMENTS FOR SHPP

However, within Europe, there are a number of countries that both possess significant hydroresources and that have adopted the feed-in tariff approach. These include Austria, Germany, France, Spain, and Slovenia, and we can conclude from a review of those tariffs schemes their relative success.

Though difficult to draw overall conclusions on the basis of this limited review, it does appear that these arrangements have been broadly successful in developing hydroexploitation, reinforcing the message from the EU study mentioned earlier. However, is not appropriate to attribute the success solely to the existence of a single policy instrument, as other policy measures, such as simplified approval procedures, are also important. On the other hand, the design of the instrument is clearly important, as experience with feed-in tariffs in some countries demonstrates – renewable electricity has had limited development there, due to inadequate levels of feed-in tariffs.

We will consider these options under the following four main headings:

- The scope of the tariff, in terms of both the size category of plants to which it applies and whether it applies only to new plants or to other types of plants.
- The overall level of the feed-in tariff, that is setting it at a level that not only reflects the likely costs of energy from this source, but also the willingness to pay for this type of renewable electricity.
- The desirable structure of the tariff, in terms of how it can be designed to provide appropriate incentives to the developers; and.
- Other terms and conditions that are necessary if the scheme is going to be effective in incentivizing the necessary investment.

These issues are discussed in sub-sections, and we highlight the options that will need to be considered in the context of design of a feed-in tariff for SHPPs in Macedonia.

The hydrology data-base in R. of Macedonia estimates that approximately 1100 GWh of electric energy can be produced by small hydropower plants (SHPP), which would represent significant part of technical hydropotential of the country. In the future, this would improve the balance of the renewable at the expense of non-renewable energy resources. Having in a mind the growth of the importing electricity in R. of Macedonia in the last decade, each new energy source is precious for the energy balance, as well as the country budgeting. In order to stimulate construction of SHPP, the Government of R. Macedonia eight years ago established feed-in tariffs for energy production from renewable energy sources, including SHPP up to 10 MW. Also, in six consecutive years public announcements for water concession were performed by the Government of R. Macedonia and over seventy contracts granted. Unfortunately, only small number of SHPP is under construction and few new SHPP are completed?!

OVERALL LEVEL OF THE FEED-IN TARIFF

In a well designed feed-in tariff arrangement, the tariff needs to be set so that it reflects the likely costs of developers, whether that is for new plants or for refurbishment of existing plants. If the feed-in tariff arrangement is to operate successfully it clearly needs to be set at a level at which it will cover the costs of developers, including a reasonable profit. In considering costs, the measure normally discussed is the cost per MWh, as this reflects the total costs of a plant, both capital costs and operating costs. Comparisons on this basis need to be made with care, however, as the calculation of per MWh cost requires assumptions about the life of the plant and about the discount rate (or rate of return) to be used in the calculation.

On the basis of an agreed life and discount rate, it is possible to estimate the typical cost of hydroplants, using data from potential sites. To assist in the design of a suitable feed-in tariff it is desirable that further research is carried out to identify likely costs more accurately. This would help to identify the "supply curve" of plants, with some being relatively cheap to exploit and others more expensive, as is illustrated in Figure 1.

Some of this cost variation may be accounted for by differences in size, but much of the variation is to be accounted by differences in site conditions, including access, and hydrological conditions. The existence of this supply curve has two main implications for the design of a feed-in tariff. First, is the question of setting the tariff at a level that brings forward the required amount of capacity?

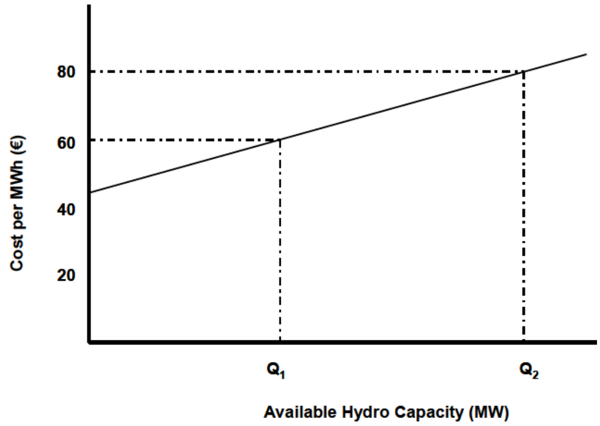

Fig. 1. The supply curve for SHPP

The second implication of the supply curve is that a fixed feed-in tariff is likely to result in some degree of excess profit for the developers of those plants with the lowest costs. Thus, for example, in the situation illustrated in Figure 1, if the feed-in price is set at €80 per MWH, then Q2 of capacity is likely to be offered, and compared to the costs of developing the plants there will be a substantial element of excess profit, as shown by the shaded area in Figure 2.

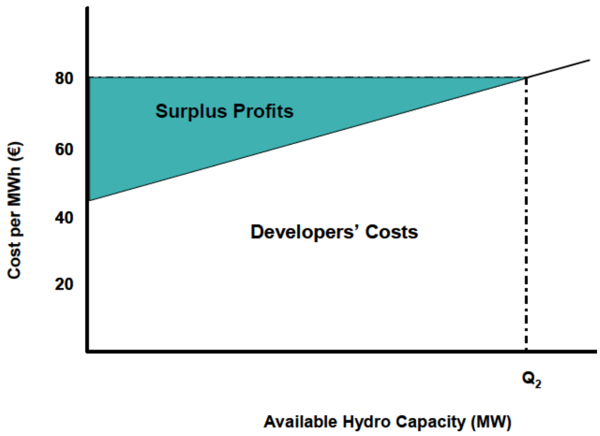

Fig.2. The supply curve and surplus profits

There are two possible ways to address this issue. First, the feed-in tariff arrangements could be developed in stages, over a number of years. For example, it would be possible to start the feed-in tariff program with a relatively low tariff, say €60, so that the lowest cost plants would be developed during this first stage. Then in a second stage, when most or all of the lower cost plants were developed, the tariff could be reviewed and raised to a higher level if thought appropriate at that time.

Though developers would still earn some degree of surplus profits, its total quantity would be substantially reduced. Figure 3 shows that in ideal circumstances this surplus profit could be limited to the two smaller shaded areas, compared to the large shaded area in Figure 2.

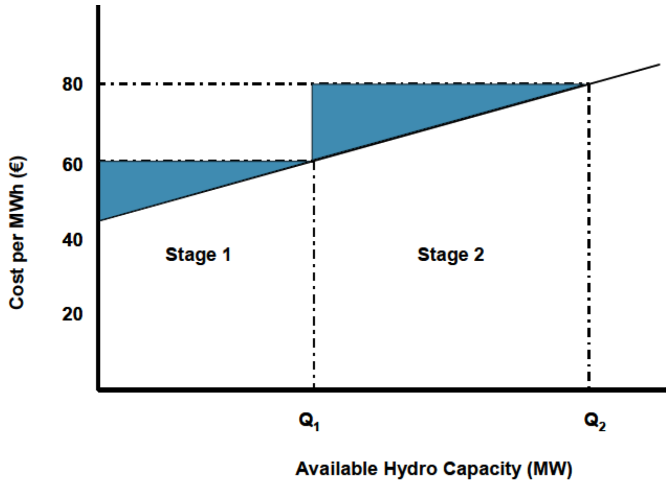

Fig. 3. Reducing surplus profits

The previous sub-section dealt with the question of the general level of the tariff that would need to be offered to provide incentives for developers of SHPPs, but it is also important to consider the options for the structure of the tariff that would be offered. In this section we consider two specific issues related to tariff structure:

- Differentiation of tariff by plant size or location.
- A one-part tariff or a two-part tariff with capacity and energy components.

As noted earlier, little reliable data is available on the estimated cost of developing SHPPs in Macedonia, but the data that is available suggests that the MWh cost for larger plants may be lower than that for smaller plants. If that were the case, then it may be desirable for the feed-in tariff to have some degree of differentiation by size, as that would allow costs to be reflected more accurately and help to minimize the surplus profit that developers would earn.

An important feature of any hydroplant is that a large proportion of the costs are fixed once the plant is commissioned, and so the costs of production per unit of output can vary widely depending on the level of output. This is illustrated in Figure 4, which illustrates the fixed costs of the plant, and the total costs taking account of the operating costs such as labor, etc.

The downward sloping curved line shows the unit costs of the plant (in cost per MWh), and it is clear that these will reduce very significantly as the output of the plant varies. If the output of the plant were fully under the control of the operator this cost structure would not be such an important issue, but output of hydroplants will always be subject to some extent to the hydrological conditions from year to year.

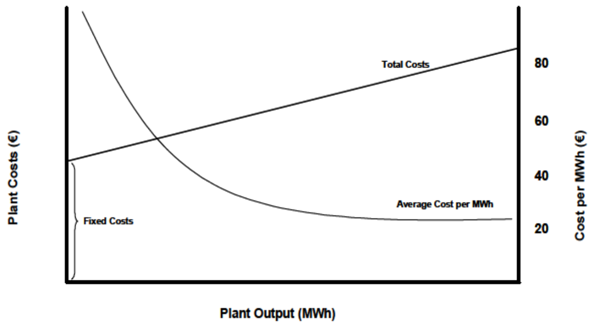

Fig. 4. Costs and level of output

This combination of uncertain hydrology and large fixed costs inevitably imposes risks on the plant operator, if the tariff is on the basis only of MWh produced, and one way of mitigating this risk is to have a two-part tariff structure consisting of:

- an annual capacity payment according to the size of the plant, and dependent on physical availability of the plant, regardless of the hydrology; and
- an energy payment that is dependent directly on the MWh produced.

Such a two-part tariff inevitably complicates the operation of the feed-in tariff, and, for example, requires a regime for the checking of availability. We have found in our review of feed-in tariff arrangements in selected other countries that only in one EU country is there a separate capacity component on the feed-in tariff. Nevertheless, this is an option that should be considered in the context of the design of a new feed-in tariff.

An example of application of the methodology described above in the analysis of RES pilot project consists of 250 different locations where 64 of them are SHPP are the results shown in Fig. 5 [2]. The characteristic values in the chart show that construction of 37 MW total capacities is feasible without external costs included; 317 MW with the local external costs included; and 390 MW with global external costs included. This correspond to 0,9%, 5,6% and 10,3% of RES production is economically feasible in total energy production. Developing of this type of analysis give us clear picture of possible production from RES, depending of the willing to pay (or to set) particular level of the feed-in tariff.

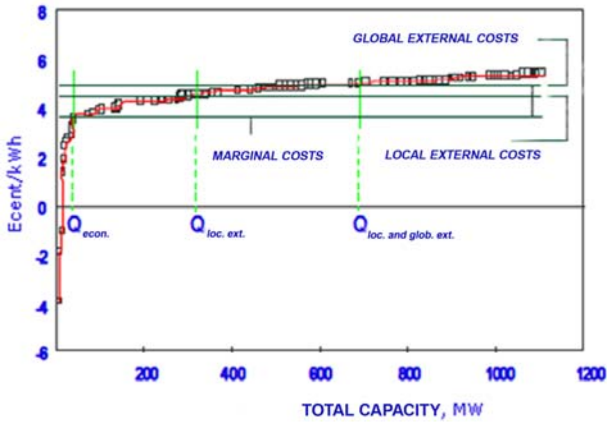

Fig. 5. Diagram of energy supply cost from RES

DETERMINATION OF THE FEED-IN TARIFFS LEVEL – STUDY CASE FOR MACEDONIA

In principle, the tariff could be set initially just on the basis of costs of other sources of generation, and what is considered to be a reasonable cost for hydro generation. However, it is recommended that the level of the tariff be set in a way that also takes account of the estimated construction and operating costs of typical plants, using an agreed life and discount rate.

Based on an assumed plant with a capacity in range of 250 to 1.000 kW and an expected 20 year project life, it is possible to derive estimates of:

- the total investment cost;
- the annual energy production;
- the annual operating costs.

On the basis of these estimates and an assumption about the output price, the cash flows for the project can be calculated.

According to a pre-feasibility study for investigation of possible sites for mini HPP in Macedonia carried out some years ago [3], over 400 possible sites suitable for SHPP development are thought to exist in Macedonia. The task set in the study [4] is to select a sample of about 10 to 15 sites, based on a number of criteria. In order to be relevant to a potential SHPP program, it was decided that the selected sites should be:

- New facilities, not renovations.
- Those about which most is known regarding site conditions and hydrology.
- The most straightforward to develop.
- Only sites with generating capacities between 250 kW and 1000 kW.
- Relatively easy to connect to the distribution system.

Twelve SHPP sites were selected for further investigation and comparison of the energy production costs with the existing Feed-in Tariffs in R. Macedonia. The basic design parameters were calculated for this group of SHPP. The detailed technical parameters are described in [4], and these were then converted into estimates of the necessary investment costs. These include all relevant costs, including project management and the costs of connection to the system.

The total cost of each HPP is calculated as a sum value of the civil works cost C_{cv} and the cost for mechanical and electrical equipment C_{eq}, as well the cost of the grid connection C_{gr} and the infrastructure facilities C_{rd}. In this total value, the cost for the preparatory works C_{ms} (preparation of investment documentation, measurements, area survey etc.) is also included. The total investment value of each HPP is calculated as a sum of these costs:

$$C_{in} = C_{cv} + C_{eq} + C_{rd} + C_{gr} + C_{ms}$$

The expected energy production is calculated taking into account:

- The duration of the discharge (inflow) as monthly average value.
- The HPP operational time.

The operational time is calculated taking into account the following:

- Planned yearly maintenance lasting 10 days.
- Accident shut-off in total duration of 96 hours.

This value has been taken into consideration for calculation of the energy production for each HPP, as a monthly average value.

The price of the produced electricity is defined taking into account the annual operational costs, which consists of installments (payments), maintenance and operation. It is usual that these costs are expressed as a percentage p of total investment costs. According to this, the price of the produced electric energy is:

$$C_{ep} = pC_{ei} \text{ EUR/kWh.}$$

The value of the annual cost factor p is calculated taking into account as follows:

- project life time — 20 years;
- loan repayment period — 10 + 3 years grace period;
- interest rate — 6 percent.

The annual costs are calculated for operation of the SHPP without personnel (only management staff is assumed). Based on these conditions, the calculated average energy cost Cep for the project lifetime for each HPP is plotted in Fig. 6. The margin of ± 2 eurocents is plotted in dash-lines.

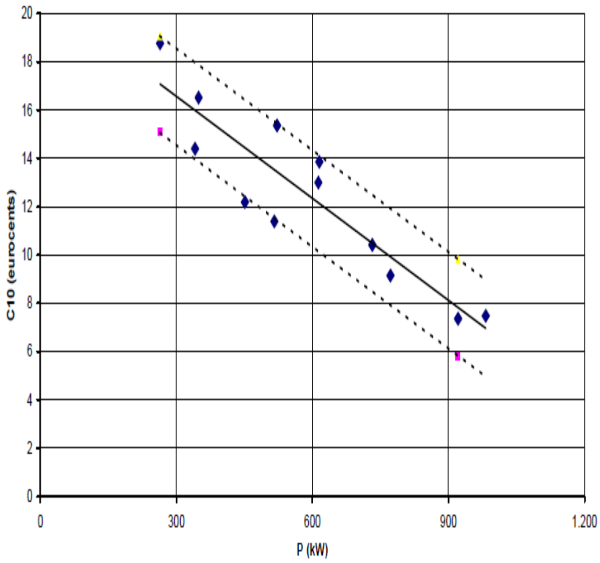

Fig. 6. Average energy cost for selected SHPP

The drawn line of the change in trend of the production price during the economic lifetime of the project (Fig. 6), shows linear dependence of the rated power from min 7,5 eurocent/kWh up to approx. 18,5 eurocent/kWh. The line drawn with a 2,0 eurocent/kWh margin actually embeds all calculated values. The chart shows that, besides the rated power, big influence is expected from the on-site conditions (topography, infrastructure etc). The calculated values show that for same rated power, the difference in the production price can be up to 35 percent! In reality, this difference can be even larger if more plants are compared.

5. EVALUATION THE ENERGY PRODUCTION IN RESPECT OF FEED-IN TARIFFS

As noted above, it is clear from the Energy Law that the Government of R. Macedonia has the power to set SHPP tariffs, and to regulate the other entities in the power sector. However, the power to issue water concessions, and hold associated tenders for construction and operation of hydrofacilities rests with the Government.

The chart representing the production curve for the selected SHPP package (Fig. 7), shows that the average production price influences the total production. This chart shows feasibility of the SHPP package, i.e. how much electricity can be produced by the SHPPs depending on the feed-in tariffs level. For example, the set average level of 12 eurocent/kWh enables economic lifetime production of approx. 18 GWh from the selected package, i.e. feasibility according the loan annual payback criterion.

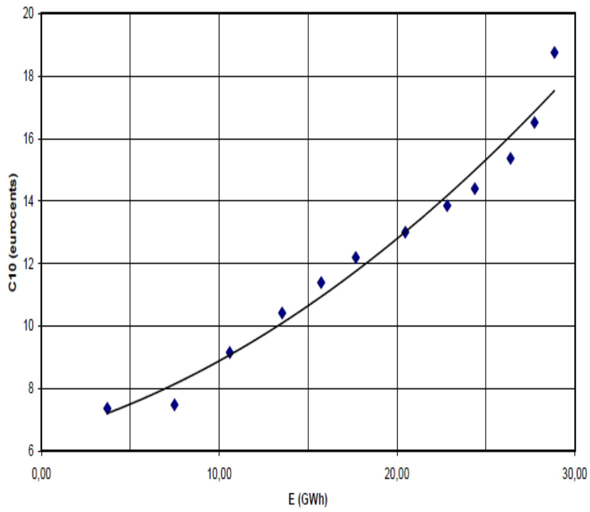

Fig. 7. Energy production curve for SHPP package

The chart given in Fig. 8 shows the change in the production price depending on the annual SHPP production. Full horizontal lines represent the values of the feed-in tariffs for particular amounts of delivered electricity from SHPPs per year according the existing tariffs in R. Macedonia. The comparison of these values with the production price of individual SHPPs from the selected package show that there is a significant difference of 2 to 10 eurocent/kWh in the entire range, i.e. the production price is higher than the feed-in tariff, excluding the larger plants with annual production of more than 4,0 GWh. This clearly shows that the existing feed-in tariffs aren't quite adequate for most of the selected SHPPs, i.e. they don't follow in adequate manner the energy production costs (taking into account the assumptions specified above).

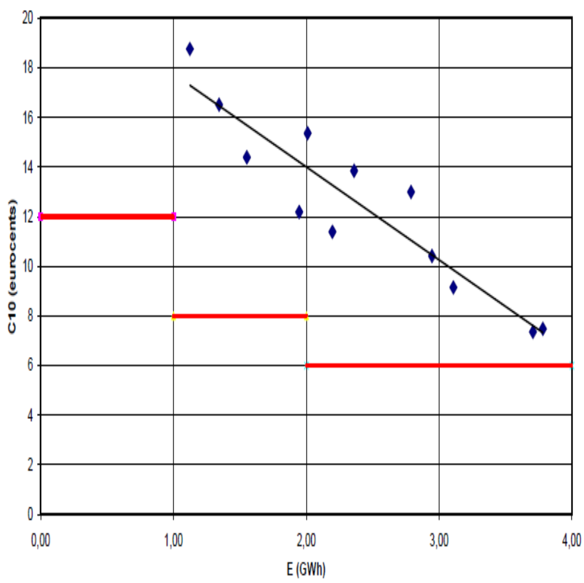

Fig. 8. Comparisons of production cost and the feed-in tariff

7. CONCLUSIONS

Based on our analysis of calculated actual costs of energy production from SHPP in the range of 250 kW up to 1.000 kW, in comparison with the regulatory framework following the policy of the existing Feed-in Tariffs, the following conclusions can be specified:

1) Assuming usual investment conditions and operational and maintenance costs, the actual energy price for each SHPP is calculated. The values are plotted in separate chart for the selected package of twelve SHPP in range of 250 kW up to 1.000 kW. The average energy cost for SHPPs in this range is approximately 12,0 eurocents.

2) The influence of the site conditions on the average energy cost is in the range of ± 3 eurocents for HPPs up-to 1,000 kW rated output. So it can be concluded that the site conditions can vary the energy production cost in the range of ± 30%.

3) The charts show the influence of the rated output of SHPP on the average energy cost. In the range from 250 kW to 1,000 kW, the average energy cost is over twice the value.

4) The model of progressive feed-in tariff much better follows the trend of the actual cost of energy production from SHPP (especially for facilities up to 1,000 kW) in comparison with the flat level of the price. This type of feed-in tariffs also generally fulfils the requirement of reducing surplus profits as it is noticed in para. 3.

5) Once set level of feed-in tariffs needs to be updated in order to follow the actual investment costs and make feasible the construction of particular group of SHPP. The necessary tool for planning of development of selected projects and corresponding total annual energy production is construction of energy production curve for the group of SHPP.

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Original scientific paper

INFLUENCE OF BALANCING VALVES IN ENERGY EFFICIENCY IN AIR CONDITIONING SYSTEM

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A b s t r a c t: The aim of this paper is to determine the the positive effects of balancing of the heating, ventilation and air conditioning systems. Explore changes to the flow of working medium through control valve with and without using the differential pressure controller through practical measurements. All measurements are made on test device that is composed of different types of balancing valves, consumers and circulation pump.

Key words: balancing; control valve; differential pressure controller; test device

ВЛИЈАНИЕ НА РЕГУЛАЦИОНИТЕ ВЕНТИЛИ ВРЗ ЕНЕРГЕТСКАТА ЕФИКАСНОСТ ВО СИСТЕМИТЕ КАЈ КЛИМАТИЗАЦИЈА

А п с т р а к т: Целта на овој труд е да се утврдат позитивните ефекти од балансирање на системите за греење, вентилација и климатизација. Истражувана е промената на протокот на работен медиум низ регулационот вентил со и без користење на регулатор на диференцијален притисок преку практични мерења. Сите мерења се направени на испитен уред кој е составен од различни видови регулациони вентили, потрошувачи и циркулациона пумпа.

Клучни зборови: балансирање; регулационен венти; регулатор на диференцијален притисок

INTRODUCTION

All HVAC installations should try to reach two fundamental objectives. First, they should deliver the specified comfort level. Second, they should reach the first objective using a minimum amount of energy, thereby maximizing efficiency and minimizing costs. In theory, current building-management-system technology can help achieve these objectives, but, in practice, even the most sophisticated control system can have problems that lead to reduced comfort and higher operating costs. In many cases, these problems are found in hydronic systems in space. Full integration of control and hydraulics in one system is achieved with balancing. In systems that are properly designed or dimensioned, but they are unbalanced constantly arise problems during the work with actuators and control valves, uneven distribution of energy for heating and cooling to consumers, some rooms are very hot, other very cold, increased costs for energy consumption and etc [1, 2, 3].

COMPONENTS OF TEST DEVICE

The test device-substation which make measurements and analysis consists of four manual balancing valves (STAD DN15/14), two pressure independent and control valves (TBV-CMP DN15NF), two pressure independent balancing valves (TBV-CM DN15LF – with the possibility to connect with an actuator), a differential pressure controller (STAP 10-60-DN20 combined with STAD DN20), a partner valve (STAD DN20) and a circulating pump ALPHA2 25-60 130 fig.1. All measurements and analyses are made by the TA CBI instrument and all balancing on test device are made with TA method.

Fig. 1. Test device-substation

CONTROL AND OPERATING MODE OF CIRCULATING PUMP

In ALPHA2, control is effected by difference in pressure which is measure on the entry and exit from the pump. This differential pressure is compared with the default value of the differential pressure in controller of pump. Pressure difference Δp is a difference between upper p_g and lower limits of pressure p_d, (Fig. 2.) Speed of the pump is reduced by increasing of Δp and leads to the defined operating limit at low speed. The pump works with the same speed until changes Δp. The increase speed of the pump occurs if the working pressure drops below the lower limit. Changing speed of the pump results in a change of power the pump, so that at low speed reduces power consumption of the pump [4].

The pump has the following control modes [5]:

a) Proportional – pressure control adjusts the pump performance to the actual heat demand in the system, but the pump performance follows the selected performance curve, PP1 or PP2 (Fig. 3.) The head of the pump proportionally changes with the change of flow.

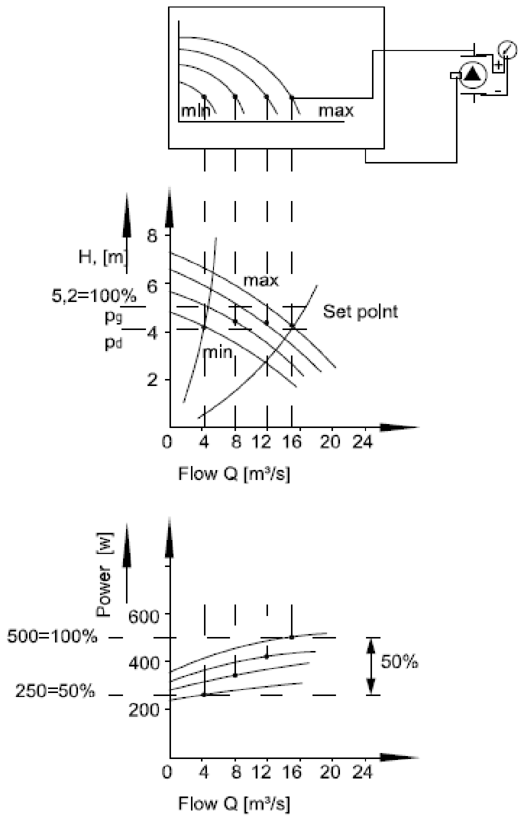

Fig. 2. Pressure difference control of the pump

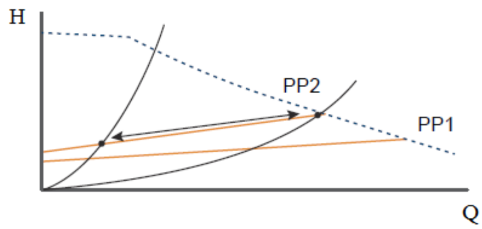

Fig. 3. Proportional – pressure control

b) Constant – pressure control – in this mode of control the operating point of the pump lies on curves CP1 and CP2 (Fig. 4). The head of the pump remains constant independent from change of the flow through the pump. The mode of proportional and constant control is continuous control of the speed that can be achieved in two ways: with voltage and frequency control.

c) Constant – curve control – the pump work at a constant speed, I, II or III, independent of the thermal load of the system (Fig. 5). The pump performance follows the selected performance curve, I, II or III.

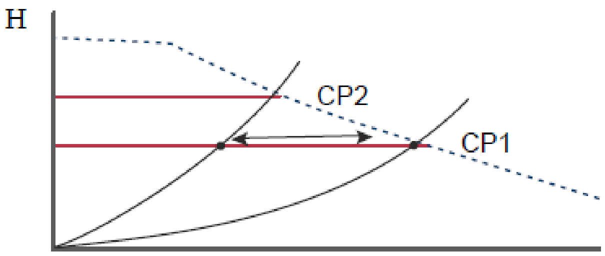

Fig. 4. Constant – pressure control

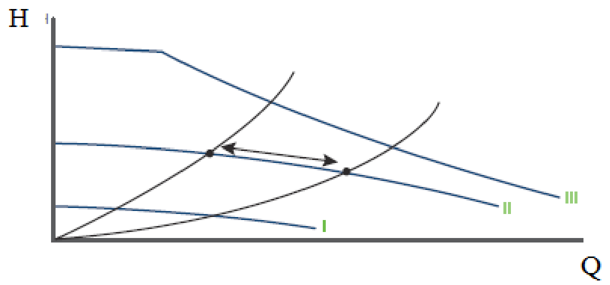

Fig. 5. Constant – curve control

ANALYSIS ON GET RESULTS OF THE MEASUREMENTS

Balancing valves are control elements which control the flow of water through the pipe installation and provide equal distribution of heat for heating and cooling for all consumers or for any part of the building. Table 1 defines the required flow through each balance valve from test device which should provide circulating pump in control mode PP2. It requires values for a system that we want to provide through each branch of the test substation. For unbalanced system is measured flow through each balance valve in control mode of the pump PP2. The measured flows for unbalanced system are shown in Table 2. Table 2 shows that the balance valves or heating/cooling units that are closer to the source have a larger flow or heat capacity related to of thermal units that are further. These values relative to predefined substantially different. Thus, to provide the required flow in the most unfavourable balance valve, or to provide the necessary heat capacity for this thermal unit, it is necessary to increase the total flow of the system. The total flow from ≈550 l/h to provide the required flow at the last balance valve from 180 l/h increases to ≈780 l/h or about 42%. Increasing the flow of the system pulls and increases the power of pump. To provide the required total flow of ≈550 l/h in control mode PP2, the pump has electric power of ≈21 W, while for the flow of ≈780 l.h the pump works in a new control mode, that it is the mode CP2 and in this mode of operation has power of ≈36 W, (Table 3.) The power consumption of the pump in operation CP2 increases by approximately 72% compared to the PP2 mode. Increasing the total flow in the system contributes to the heat capacity of the heating / cooling units that are closer to the source.

Table 1

Required flow through each valve to be provided by the pump in control mode PP2
(Power of the pump 20–22 W)

Type of valve	Position	Required flow (l/h)
1. STAD DN15/14	2,00	120
2. STAD DN15/14	2,00	150
3. STAD DN15/14	2,00	100
4. STAD DN15/14	2,00	180
1. TBV-CMP DN15	off	0
2. TBV-CMP DN15	off	0
1. TBV-CM DN15	off	0
2. TBV-CM DN15	off	0
1. Partner – STAD DN20	4,00	550

Table 2

Measured flows at unbalanced system – the pump works in control mode PP2
(Power of the pump 20–22 W; *Kv* value* = 0.57)

Type of valve	Position	Measured	
		Differential pressure (kPa)	Flow (l/h)
1. STAD DN15/14	2,00	5,98	139,6
2. STAD DN15/14	2,00	6,38	143,8
3. STAD DN15/14	2,00	5,83	136,8
4. STAD DN15/14	2,00	5,19	129,5
1. Partner - STAD DN20	4,00	0,94	551,4

**Kv* value is a value that shows hydraulic characteristics, that is, the hydraulic losses in the valve (calculated by the formula $Kv = 10\ V/\mathrm{sqrt}(dP)$, where V is the volume flow through the valve, and dP - pressure drop across the valve)
Kv.

Table 3

Measured flows at unbalanced system – the pump work in control mode CP2
(Power of the pump 20–22 W; Kv value = 0.57)

Type of valve	Position	Measured	
		Differential pressure (kPa)	Flow (l/h)
1. STAD DN15/14	2,00	12,47	200,3
2. STAD DN15/14	2,00	12,59	202,4
3. STAD DN15/14	2,00	11,47	192,7
4. STAD DN15/14	2,00	10,28	181,8
1. Partner -STAD DN20	4,00	2,1	780,2

Table 4 shows the measured values after the balancing of the substation. As a method of balancing is used TA Balance method. By use of this method calculated the exact position of each balance valve so as to through the valve to allow the same predefined required flow, and the index branch – branch who is the most unfavourable. For a concrete example of how most unfavourable balance valve that occurs in the system is the third balance valve. From Table 4 we realize that the measured values do not deviate too much relative to the defined. In this case the pump works in a defined mode PP2 with the same energy consumption, regarding it works with the electric power of 21 W.

Table 4

Measured flows at balanced system – the pump works in control mode PP2
(Power of the pump 21 W)

Type of valve	Position	Measured differential pressure (kPa) at given position	Measured differential pressure (kPa) with closed valve	Kv value	Measured flow (l/h)
1. STAD DN15/14	1,95	5,1	10,1	0.51	121,7
2. STAD DN15/14	2,28	4,84	9,38	0,62	148,3
3. STAD DN15/14	1,87	4,39	9,25	0,57	102,7
4. STAD DN15/14	2,68	3,02	8,76	1,04	179,5
1. Partner -STAD DN20	4,00	1,01	22,27	5,7	552,2

The task of the differential pressure controller is to control the pressure difference in the distribution and the return line [6, 7]. The desired value of the differential pressure in measurement is adjusted by Allen key through the center of the hand wheel of STAP valve which is combined with STAD valve with dimension DN20. On test device is made measurement for the system as shown in Fig. 6. By changing the position of the control valve comes to a change of the available pressure drop. The reduction of the flow in the system will result in an increase of the available pressure drop for consumers, it is analogous to the change the set point of the characteristic the pump in the area of higher pressure, which at lower flow achieved higher head. Stabilization of pressure difference which occurs by changing the position of the control valve for system can be achieved by the differential pressure controller STAP-STAD. When closing the TBV-CMP valves come to increasing the total flow through STAD DN20 valve, and it appears appropriate to increase the flow through other valves STAD DN15/14. The STAP valve starts to open when the pressure drop which occurs on closure of TBV-CMP valve to exceed the adjust pressure drop, and the additional flow of water passing through the capillary tube of the STAP valve.

Table 5 shows the measured values of a balanced system where the differential pressure controller is not put into operation and the TBV-CMP valves are open. In case of closing TBV-CMP valves the flow through other valves are changes. New measured values with closed TBV-CMP valves and without differential pressure controller are shown in Table 6. The measured flow through each balance valve after closing two valves are differ from previously measured flow.

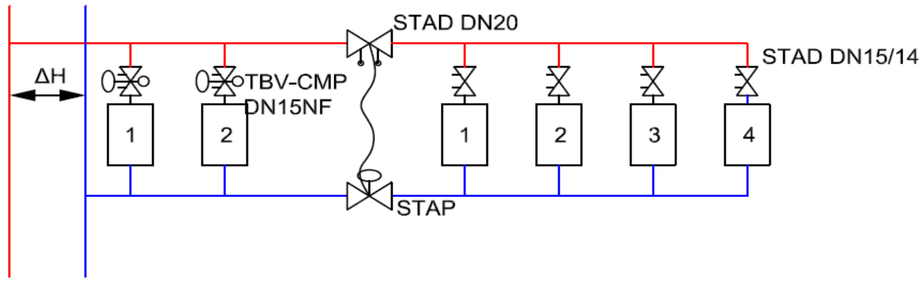

Fig. 6. Hydraulic scheme of system with differential pressure controller

Table 5

Measured flow through each valve with open TBV-CMP valves and without differential pressure controller

Type of valve	Position	Measured differential pressure (kPa)	Kv value	Measured flow (l/h)
1. STAD DN15/14	1,77	5,01	0,44	99,19
2. STAD DN15/14	2,20	4,68	0,68	147,5
3. STAD DN15/14	2,01	3,23	0,57	103,1
4. STAD DN15/14	2,79	2,91	1,15	196,9
1. TBV-CMP DN15NF	3,00	11,9	0,38	137,9
2. TBV-CMP DN15NF	5,00	10,85	0,52	178,8

Table 6

Measured flow through each valve with closed TBV-CMP valves and without differential pressure controller

Type of valve	Position	Measured differential pressure (kPa)	Kv value	Measured flow (l/h)
1. STAD DN15/14	1,77	7,62	0,44	123,6
2. STAD DN15/14	2,20	6,63	0,68	176,2
3. STAD DN15/14	2,01	4,96	0,57	128,8
4. STAD DN15/14	2,79	3,42	1,15	213,3
1. TBV-CMP DN15NF	off	/	/	/
2. TBV-CMP DN15NF	off	/	/	/

If the differential pressure controller is put into operation and TVB-CMP valves are closing, we will notice that the measured flow through each balance valve using differential pressure controller differs from the flow which is measured when the differential pressure controller is not put into operation. The measured flow through each valve with differential pressure controller is shown in Table 7.

The differential pressure controller has an important role in improving the authority of control valves if installed along with them. He works together with the balance valve to a set pressure drop. If the flow falls below the nominal flow, differential pressure controller progressive closes, allowing part goes through balancing valve to remain constant.

Table 7

Measured flow through each valve with closed TBV-CMP valves and with differential pressure controller

Type of valve	Position	Measured differential pressure (kPa)	Kv value	Measured flow (l/h)
1. STAD DN15/14	1,77	5,82	0,44	108,2
2. STAD DN15/14	2,20	5,17	0,68	156,4
3. STAD DN15/14	2,01	3,43	0,57	106,6
4. STAD DN15/14	2,79	3,06	1,15	202,3
1. TBV-CMP DN15NF	off	/	/	/
2. TBV-CMP DN15NF	off	/	/	/

CONCLUSIONS

The results of practical measurements performed on a test device that is composed of different types of balancing valves are presented. Analysis of balanced and unbalanced system results in lower power consumption, high quality internal climate, providing accurate design value of the flow of hot and cold water, reduces noise in circulation pump, etc. Properly balanced system is a prerequisite for the proper functioning of the control system. Application of the differential pressure controller provides stabilization of the pressure difference which occurs by changing the position of the control valve. Moreover, he provides correct, efficient and well – balanced modulating control, and less noise from control valves.

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Short communication

OVERVIEW OF THE DEVELOPMENT PLANNING THEORY

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A b s t r a c t: The level of importance of the development planning is differently perceived by the national governments in the world, and by the different theoreticians of the issue, but nobody argues that it can be neglected nor avoided in the contemporary societies. After some 20 to 25 years from the introduction of the first academic planning concepts (called traditional), the theory has gone through a serious crisis and has stagnated for about a decade after which it emerged again by producing several modern concepts of planning. Both approaches, the traditional and the modern one, are stil very live and present, but used in different form and in different combinations. The aim of this paper is to introduce the most essential aspects of the most important (and used) planning schools in order to contribute towa possess all the “ingredients” for an effective development planning process.

Key words: cevelopment planning; theory of planning; planning schools and approaches

ПРЕГЛЕД НА ТЕОРИЈАТА ЗА РАЗВОЈНОТО ПЛАНИРАЊЕ

А п с т р а к т: Важноста на развојното планирање е перципирана на различен начин од страна на владите на различни земји во светот, како и од различни теоретичари на ова прашање, но никој не тврди дека во современите општества оваа тема може да биде занемарена или избегната. Некаде по 20 до 25 години по воведувањето на првите академски концепти на планирање (наречени традиционални), теоријата на планирањето мина низ сериозни кризи и нејзиниот развој стагнираше околу една цела декада, за повторно да се појави со продуцирање неколку модерни концепти на планирање. Двата пристапа, традиционалниот и модерниот, сè уште се многу живи и присутни, но се користат во различни форми и комбинации. Целта на овој труд е да ги претстави најсуштинските аспекти на најважните (и најупотребувани) школи на планирање заради давање придонес преку нивно вклучување во процесот на ефективно развојно планирање.

Клучни зборови: развојно планирање; теорија на планирањето; школи и пристапи на планирање

INTRODUCTION

What is planning? Why do we plan? How to plan? These are the three essential questions related to planning which do not have easy answers, nor are equally defined in the academic community.

“Planning is an abstraction, and it has not a clear defined meaning” argue Skeoch L. A. and Smith D. C. [1]; however, all authors agree that it is a process oriented towards the future and as Broady M. [2] says a process dedicated to the people. We plan because we want to shape and influence the future and because we want to achieve the best results by using the least resources possible. We plan simple because we want to be effective!

Many authors, based on the theoretical background but much more driven by their experience were trying to develop a universal process, a series of steps to follow, for developing a plan. Their efforts have resulted in dozens and dozens of suggestions on how to plan and what is the most efficient methodology to be applied, but the problem is that they all considerable differ one from another. Thus, over the years driven by the different perceptions of the authors, as well as the different specifics of the environment (Simpson B. J. [3]), different approached have been suggested for the planning process, resulting in a very vivid and dynamic debate on the issue. As example, in the Republic of Macedonia several authors (Jovanovski B. R. et al. [4]) have suggested that the development model of the companies can be utilized for planning purposes as well.

The debate on the planning is far from over. Moreover, it still addresses some of the core questions related to the one, such as: whether the planning should be considered to be a scientific discipline or not. In most of the cases, the key argument of the academics who argue in favour of the scientific nature of the issue is related to the variety of different models and techniques incorporated and applied in the process, while their opponents are not convinced that it is a sufficient argument for such a conclusion. Friedmann J. [4] probably best explains the confusion of this debate by considering the issue of planning as an ideology based on a scientific concept. Anyway, the fact remains that the importance of the issue of planning is growing each day. As the issue grows, its theoretic base also grows, providing answers to some old questions but also raising some new ones, so one may easily conclude that the process of scientific establishment of the issue is still ongoing. In light of this, the goal of this short paper is to introduce the historical background of the issue by presenting the most dominating theoretical concepts of the planning, from its early beginnings until today.

THEORY OF PLANNING

The process of public planning in the modern sense of the term was introduced in few isolated cases in the first decades of the XX century. Namely, the first public development plans were produced by the Belgian government in 1906 (a 15-year public railway and mines investment plan for Belgian Congo) and by the British governor of Ghana in 1919 (a 10-year integrated development plan) (Greenstreet D. K. [5]). Surprisingly, it was not some country of the "western" world, but the Soviet Union that has established a first practice of public development planning in 1929, by introducing the state five-year plans. However, no country in the world has exercised a long-term planning process on continuing bases until the end of World War II (WWII). Indisputably, the global conflict in the mid of the last century as well as its devastating effects forced the world governments to rethink about the use, importance and necessity of the developing planning for stabilizing and rebuilding their societies. The planning process was increasingly used by more and more governments in both hemispheres, so the application of the process gained different characteristics in the "two worlds". Namely, the one implemented in the west was decentralized and consisted of number of public investment projects, while the one in the east was heavily centralized, very detailed and referred to the economic and industrial aspects of the issue. Besides these qualities, the main point of division of the two concepts was the fact that one was engineered to be used in a free-market economy, while the other one was shaped to work in a socialist environment (centrally planned economy). Due to the huge difference in their "working" environments, it is more that understandable why both concepts have evolved in different directions (the "western" one became more detailed and integrated, while the "eastern" one less centralized – Mason E. S. [6]) and were based on different theory. Since all the eastern part of the Europe, including Macedonia, has left the socialist environment back in the history, the only relevant and applicable development planning theory is the one that was developed in the western hemisphere, or more precisely in the USA in the very first years after the end of the WWII – a period that is marked as a period of birth of the planning theory.

The effects of the application of the development planning throughout the countries in the world significantly varied. In some cases, the results were outstanding (like the cases of Malaysia and India), while in some other not that good, which served as a good argument for some governments (like the Japanese and Mexican) for not introducing the concept of development planning in their operations at national level at all (Abraham W. I. [7]). Thus, we may conclude that the process of development planning is not universal and cannot be identically applied everywhere, instead, it should and must be shaped according to the circumstances and needs of the client (the state in question).

The foundations of the academic theory related to development planning were laid down in the 1950-ies, which makes the developing planning to be only a 65 year-old scientific approach. In the early stages of the academic studying of the development planning, its theoreticians and practitioners were completely or mostly concentrated only on the economic aspects of the issue, neglecting all other aspects associated with the topic. As result of this, the development planning in these periods was also referred as economic development, a terminology which may be found with some “very traditional” authors even today. A wider recognition by majority theoreticians of the development planning on the non-economic aspects of the issue began in the end of 1980-ies and the begging of 1990-ies, while a process of clear differentiation of the remaining aspects of the issue took place in the last 15 years (Willis K. [8]; Dale R. [9]; Blakely E. J. and Bradshaw T. K. [10], and many other authors).

In 2007 Grabowski R., Self S. and Shields M.P. [11] tried to go a step further and locate the difference and the point of divergence between the local economic development and the development planning theories, but without any success. The reason for this unsuccessful attempt was that the two concepts evolved side-by-side and together and indisputably had considerable influence one to another. Due to the fact that the aforementioned research of the three authors was delivered recently, there is a high probability that this process of segregation of the two theoretical concepts is still not completed. If this is the case, we may expect that this moment will come in a very near future, maybe even in the next five to ten years, while the moment will be marked when both theoretical concepts will become fully aware and respective of each other, i.e. when the scientific papers and studies will consider and be related only to one, and not to the both theoretical concepts.

During the period of its evolution, two general approaches to the development planning have been developed by the academics – traditional and modern, which will be briefly presented below.

The traditional concept of the development planning incorporates the following five traditional schools of planning:

- (Comprehensive) rational or synoptic planning;
- Incremental planning;
- Transaction planning;
- Advocacy planning, and
- Radical planning.

The rational approach to planning is the most dominant academic planning theory and it is considered as predecessor to the other concepts of planning (Hudson, B. M. [12]). The approach was developed as a respond to the need of developing a generic model of planning for the free market societies, but which besides the economic aspects will incorporate also the sociologic and other scientific themes. The rational planning usually considers the problems from a perspective of a system, applying conceptual or mathematical models in order to establish a functional relation between the objectives and the resources/constrains, i.e. between ends and means, by heavily relying on quantitative analysis. The founder of the rational planning is Banfield E. C. [13] [14] in the mid 1950-ies of the last century and in general the approach integrates the following five elements:

– setting goals,
– designing activities,
– comparative analysis and scenarios evaluation,
– selection of scenario, and
– implementation of the plan,

which a decade later Harris B. [15] described as the five Ds (Desires, Design, Deduction, Decision, and Deeds).

The strongest side of the synoptic approach lays in the excellent methodological elaboration and use of numerous analytical tools, such as: cost-benefit analysis, operational research, optimization and minimization, establishing selection criteria, multiple goals, etc. (Klosterman R. E. [16]; Weimer D. L. and Vining A. R. [17]). On the other hand, a considerable disadvantage of the model lays in its complexity. Anyhow, it is normal that synoptic planning like every other model has its supporters and critics. However, the fact remains that for more than 20 years it was the most widely applied planning theory globally.

Incremental planning

The main advocate of the incremental planning was Lindblom C. E. [18], who has criticized and qualified the synoptic planning model as unreal and centralized, and therefore, argued in favour of applying a more decentralized approach that will reflect the values of the democratic society and the free market economy, by defining goals and policies at the same time (Stiftel B. [19]). According to Lindblom's theory, the nature and extent of action is decided by adding an incremental change in the desired direction to status quo. In other words, the incrementalism is focused not on the optimization but on the level of satisfaction, and it tries to replace the planner's values with a process which involves all the interested parties. Lindblom himself considers the incremental planning to be a "partisan mutual adjustment" or "disjointed incrementalism”.

Therefore, the incremental planning approach was developed on the week aspects and points of the synoptic planning, mostly related to the inadequate use of the organizational and institutional capacities, presumption of the common interest, the artificial separation between the goals and the possibilities, and the centralization of the process. As result of the introduction of this new approach in the first half of 1960-ies, the world have been introduced to the concept of strategic planning, which is a very popular and widely used model in the public planning even today

Transactive planning

The transactive planning is focused on exploiting the people's experience in the process of defining the areas and issues that need to be addressed. The transactive approach, as well as its founder – Friedmann J. [20], argues that the citizens and the authorities and not the planners are the ones that need to have the leading and key role in the process of planning, in order to ensure a greater implementability of the plans in practice. Thus, the concept is executed through face-to-face contact with people that are affected by the plan, while it is implemented through several techniques like field surveys, interpersonal dialogue, public opinion on police and crime rate, etc. In light of this, the approach is not based on the field researches or complex analysis, instead on direct contact and interaction with the people that are most concerned with the planning process, i.e. by the very result of the one – the plan.

Transactive planning is considered as an evolutional step forward in the process of decentralization of the planning because it requires the people, and not the institutions, to play the role of managers of the social processes and to stimulate them to become creators of its own wellbeing. Thus, the approach provides possibility for the planners to learn from the people about the community's needs and ambitions, while in the same time, the people can learn on the planning process. On the negative side of the model, the major criticism is related to the considerable time needed to complete the process, as well as to the fact that the process can be guided by subjective views of the people involved in the one.

Unlike the incremental planning, the transactive approach in not focused on the economic logic but on the effect that the implementation of the plans will have on the people. On the other hand, a common point that it shares with the incremental planning is that both approaches do not consider themselves to be pure scientific techniques but rather than a behavioural styles and tools.

Advocacy planning

The concept of the advocacy planning was developed during the 1960-ies as results of the imperfection of the previous three approaches to planning, but especially because the smaller and the more fragile communities in the society were not able to make the rest of the community willing to address their needs (Alinsky S. D. [21]). Advocacy planning has also contributed to the general trend in planning by moving the one from the point of being neutral on the social problems to a point when the process became more explicit in addressing the social justice issues. Thus, the advocacism abandons the objective and the non-political view of the planning process, and changes the role of the planners into lawyers – to advocate and defend the interests of particular underrepresented group. As result of the practical implementation of the concept on the field, during the 1970-ies a considerable number of non-profit advocacy agencies we established in the USA in order to represent the smaller community and to facilitate the planning process.

In general, the effects from this planning concept were positive, and mostly resulted in raising the voice of the small communities in the society. In addition to this, the process also resulted in increasing the number of planning documents to be adopted, from one (a general plan) to several thematic plans (Davidoff P. [22]). The reason for this lays in the fact that it is much easier to integrate a biggest number of communities' interest in several thematic plans, rather than in one general document. However, the approach has presented considerable weaknesses as well. Namely, it proved to be very difficult to identify adequate representatives that will represent the interest of a small community, and not individual views or interests, as well the enormous time needed for the process to be completed, which has significantly influenced the effectiveness of the one (Peattie L. [23]).

Radical planning

The concept of the radical planning is the youngest among the five major traditional schools of planning since it was established in the first half of 1970-ies. The concept is mostly based on the work of Goodman R. [24], Gordon D. M. [25], Illich I. [26], Hampden-Turner C. [27], and Katz A. and Bender E. [28], and in its core is the rejection of the bureaucracy, as well as of the long and centralized planning processes that are guided by professional planners that dominate the process. Instead the concept argues for a more effective form of planning that may be achieved by establishing a number of non-professional neighbourhood planning committees that will encourage the citizens not only to address but to solve their problems. The expected (idealistic) outcome of such process should be a collective action that will be taken in order to achieve a concrete result in a very near future.

In essence, the concept is consisted of two mainstreams or directions. The first one is based on spontaneous activism, solely relaying on the self-reliance and mutual assistance and it is dominantly an idealistic direction, while the second one is focused on the social processes at macro level and is mainly academic, i.e. theoretic direction. Thus, given the nature of the two main directions, one may easily conclude that the radical planning had the smallest application in practice.

Friedmann J. and Hudson B. M. [29] in 1974, for the first time described the five most important traditional schools and concepts of planning as SITAR (according to the first letters of their titles: Synoptic, Incrimental, Transactive, Advocacy and Radical), an acronym that became widely used since then. Sitar also stands for a type of Indian traditional instrument with 5 strings that can be played by using one or more strings simultaneously, which provides the analogy with the five traditional schools. Namely, until the mid 1970-ies it was more that clear to anyone that none of the five schools is ideal for all countries and societies; instead, based on the country or society's specifics, a combination of two or more approaches should be considered.

After the "invention" of the five traditional schools of planning, during the mid 1970-ies, the planning theory has faced the fact that the mid-term planning did not give the expected results in number of countries Killick T. [30], and as result of it enter into its biggest crises during which a considerable number of theoreticians and practitioners argued for a failure of planning! It took about a decade the planning to overcome its most essential crisis and in the second half of 1980-ies to start producing additional planning concepts and approaches that are referred as modern planning approaches. Certainly one of the globally most known, recognized and implemented concepts of this kind is the sustainable development planning.

Sustainable development planning

The roots of the sustainable development planning can be traced back to end of 1960-ies and begging of 1970-ies, when number of planning authors started to be worried about the devastating effects that the development has on the environment in general and especially on the biodiversity, climate change, forests and water supply.

The critics were so laud and strong that some authors have started to argue for zero-growth policy (Daly H.E. [31]), i.e. for status-quo in development. In such circumstances, in 1983 the United Nations (UN) established a World Committee on environment and development (WCED) aiming to address the raising criticisms to the development process. The Committee that was chaired by Mr. Harlem Bruntland – a Norwegian Prime Minister in that time, in 1987 have produced a report on this issue entitled as "*Our common Future*", which was later also referred as the Bruntland Report, which argues in favour of applying a more environmentally-friendly approach to planning. In the core of the report lies an already proven approach in exploiting forestry and water resources called "maximal sustainable production" (Rogers P. P., Jalal K. F. and Boyd J. A. [32]), which predetermines the quantity of the resources that can be used by not causing decrease in the resource that will be available in the future.

In its early stages, the concept envisioned three priorities to be included in the development policies of each national government: sustaining the ecological processes, sustainable use of the resources, and maintaining the genetic diversity. However, as the time went by, beside the environmental and the economical aspect of the concept, additional aspects were added such as cultural, social, physical and even spiritual, resulting in adding a third general aspect to the concept – societal or socio-cultural. Each of the three aspects, i.e. elements, interacts with the other two, in a common environment.

The UN World Summit held in Johannesburg in 2002, called all national governments to develop and adopt a sustainable development document (strategy) by 2005, a requirement that was fulfilled by some 85 member-countries of UN (Azapagic A., Perdan S. and Clift R. [33]) until the target year. The vast application of this particular planning concept was further reinforced by number of international agencies and organizations, among which the European Union as well, which have adopted the sustainable planning as official planning methodology for planning of their future operations.

EXPERIENCE WITH THE PUBLIC PLANNING IN MACEDONIA

After the end of the World War II, Macedonia as member of the former Yugoslav federation developed and implemented a highly centralized development planning system that was based on the socialist values and in the core of which were the 5-year plans (Horvat B. [34]). The structure of the system has remained more or less unchanged until the independence of the country, since the last 5-year plan was developed for the period 1986–1990 (Assembly of SR Macedonia [35] and Dimitrieva, E. [36]).

The biggest influence on the planning system and the planning processes in the country was made by the change of the social system and the declared independence of the country – two events that took place in the early nineties of the last century. Both events occurred in the same time period, a period in which a huge number of reforms in all areas were initiated and conducted, while the planning system remained mostly unreformed and continued to be shaped more by inertia rather than as an organized attempt for introducing a modern and comprehensive national planning system. In light of this, the 5-year plans were replaced with significantly larger number of variety of strategic and planning documents at all levels of government and in all development areas. As results of this, in the period from the independence of Macedonia (in 1991) until the end of 2013 at least 149 national, 34 regional and 351 local development plans were developed (based on the survey conducted by Igor Kostovski [37]). There is not a single development areas that is was addressed in a strategic document at national level, while at local two topics have dominated – local economic development and environment, by consisting more than 55% of all strategic documents adopted at local level.

From the point of view of the theoretical approach that was used and the methodology applied when developing the strategic documents, two periods can be identified. Namely, the years from the independence until 2001 or 2002, consist the first methodological period which is famous by the analysis performed on mass quantity of data – which is a clear characteristic of the synoptic school of planning, the development of several development scenarios, the lack of vertical logic of the documents (lack of clear hierarchy of goals and activities), as well as by the small number of strategic documents that have been developed and adopted in this period. In most of the cases, the development of the strategies in this period was entrusted to academic institutions or large group of proven domestic experts, so the documents had a form of scientific study rather than of usual development document.

On the other hand, the documents that have been developed in the second period (since 2002 until today), consist more than 95% of all development documents developed and adopted at all levels in independent Macedonia, are characterized with methodological shift towards strategic planning (as the most prominent representative of the incremental planning), decrease in the use of analytical techniques by focusing solely on the SWOT analysis, and with replacement on the academic institutions and the large expert groups from the previous period with planning committees consisted of administration's representatives and citizens. Thus, the planning processes in the second period have became more open and democratic compared to the ones conducted in the period prior to this, but unfortunately, the quality of the strategic documents produced in the second period started increasingly to deteriorate.

Additional significant change in the public planning in the country was detected in the years following Macedonia awarding a status of candidate country for membership in the European Union (EU) in 2005, when a process of harmonization of the national legislation with the one of the EU was initiated and which has influenced the public planning mostly in the terminology used but not significantly in the methodology of approached used. In the same period of time, the Government of Macedonia (GoM), following the conclusions of UN's World Summit held in Johannesburg in 2002, accepted the modern approach to planning – the sustainable planning model, as official approach in public planning in the country (United Nations [38]). However, such decision of GoM was never completely implemented on the field, since only some and not all the legislation shaping the Macedonian public planning system has included the model in question.

On the other hand, the planning process is also directly related to the management style and with possibilities to manage changes that will result with the process of planning. However, some local research (Sutevski D. and Polenakovikj R. [40]) showed that there is no straight relationship between the management style and the reaction of the managers to the organizational change.

In summary, one can conclude that Macedonia is practicing an organized approach to development planning for more than 65 years, during which period of time the model has evolved forced by the social environmental changes and the requirements that have been placed in front of the one. Focusing on the last two and a half decades, since the independence of the country, it can be concluded that two traditional schools of planning are dominating the area of public development planning: the rational (synoptic) and the incremental planning approach. However, given the fact that more than 95% of all development documents have been developed in the last 12 years it is clear that the synoptic planning is increasingly fading, leaving the process of planning in the country to be dominated by the traditional incremental strategic planning approach and the modern school of sustainable planning.

On the other hand, besides the reforms made since the independence of the country, the public planning processes at national level in Macedonia is still highly centralized, since almost none of the existing strategic documents have not included the local or regional views or interests during the process of its development. The same remark goes for the process of implementation of the strategies, which is completely conducted at central level in almost all cases and regardless of the specifics of the activities to be implemented. Furthermore, the system of public development planning practiced in the country today has inherited an approach where the spatial (physical) planning is separated from and dominating the development (non-physical) planning processes, instead of being its spatial representation – which can be considered as one of the weakest links of the current model.

CONCLUSIONS

The development planning is a scientific concept that started to emerge in the second decade of the previous century, but became subject to the academic interest in the years following the end of the World War II. The debate whether the planning is a scientific approach or not is still on-going and far for completed. However, the importance that the issue has for the public planning is indisputable.

In the early stages of its development, the development planning was closely associated with the economic development, a tendency that was motivated by the dominant economic aspect of the development planning in that time. However, as the development planning was further studied, more and more additional (non-economic) aspects of the issue emerged/were discovered, resulting with a conclusion on the development planning as on a multidisciplinary scientific concept that includes theoretical knowledge and methodological tools of number of areas, such as: management, demographics, environment, economics, urbanism (urban and spatial planning), geography, real estate, finance, sociology, political science, anthropology, marketing, etc. It may seem that the place of marketing in the above list of areas is unnecessary and illogical; however, that is not the case. Namely, the significant role that the area of marketing has in the development planning is ensured with the need for maximization of the financial effects produced by the use of the limited primary resources (human capital) that are at disposal, an argument that is also supported by one of the biggest contemporary marketing theoreticians – Michael Porter.

In general, the theory of the development planning consists of two broad schools or trends: traditional and modern, which are represented by several planning concepts each. However, unlike the traditional schools of planning whose aspects can be combined among each other, the modern schools are far more "jealous" and promote the use of a single concept of planning rather than a combination of several concepts.

Today, both schools of planning (traditional and modern) are used and applied in the public planning throughout the world. The best representative of the modern approaches is the sustainable development planning, while the most common one at global level is the representative of the incremental school – the strategic planning method.

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METHODOLOGY FOR ASSESSING THE DONOR PROGRAMS' IMPACT

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A b s t r a c t: Donor programs significantly influence the economic and social development of the recipient countries, but the literature on research methodologies for comprehensive assessment of their contribution is very limited. Also, the assessment of the real success of these programs often is a problem due to subjectivity of the formal administrative procedures. This paper delivers a methodology for objective assessment of international bilateral and multilateral donor programs aimed to support the development and growth of small and medium sized enterprises (SMEs). The proposed approach should be applied for assessment of the donor programs financed by international donors and development of appropriate instruments supported with public funds, which is crucial factor for the efficiency of the interventions.

Key words: international donors; grants; SMEs development instruments; start-up support; SME growth support.

МЕТОДОЛОГИЈА ЗА ОЦЕНА НА ВЛИЈАНИЕТО НА ДОНАТОРСКИТЕ ПРОГРАМИ

А п с т р а к т: Иако донаторските програми значително влијаат врз економскиот и социјалниот развој на земјите корисннчки, литературните извори за методологии за сеопфатно истражување на нивниот придонес се значително ограничени. Покрај тоа, оценaтa на реалниот успех на програмите честопати е недоволно точна поради субјективноста во формалните административни процедури. Овој труд претставува методологија за објективна оцена на меѓународните билатерални и мултилатерални донаторски програми кои имаат за цел да го поддржат развојот и растот на малите и средни претпријатија (МСП). Предложениот пристап треба да биде применет за оцена на донаторските програми финансирани од меѓународни донатори, како и за развој на соодветни инструменти поддржани со јавни средства, кои се клучен фактор за ефикасноста на интервенцијата.

Клучни зборови: меѓународни донатори; грантови; инструменти за развој на МСП; поддршка за започнување и за почетни бизниси; поддршка за раст на МСП

INTRODUCTION

During global economic crisis and limited resources for investment, it is of crucial importance that the official development assistance offered by the donors and the international financial institutions is utilized in a highly coordinated manner and streamlined towards precisely determined priority sectors for fulfilling the strategic development objectives. The importance of the donor programs for the development of the recipient countries, especially in the developing regions is widely acknowledged. There are numerous examples of this type of programs aiming to stimulate local economic activities or to assist local governments in preparing strategic policy documents and plans for the economic development. Previous studies on intergovernmental transfers indicate that an important objective of a donor is to ensure that the recipient provides certain minimal level of public services, with which the donor can be identified easily [1], [2], [3].

External support is still crucial in order to improve the business environment and to encourage internationalization at all levels and among all stakeholders. Having such influence around the region, it requires very complex systems that need to be understood in order to be integrated in the local, national or regional plans, or to be influenced. Evaluations are one of the most essential tools for evidence-based decision-making.

The difference between a program and a project is that a program is a set of financial tools, organizational solutions and human resources mobilized to achieve a clearly stated objective or set of objectives within a given period, while a project is a single intervention directed towards the attainment of operational objectives, with a fixed time schedule, a dedicated budget and placed under the responsibility of an operator [4]. The grants for projects always require specific set of indicators for measuring and describing the project impact on the stakeholders and the level of success in achieving the proposed goals. However, the indicators are set prior to the project implementation which might leave a chance for mismatching the project outcomes. Also, the formal procedures are not followed strictly and objectively because the parties conducting these procedures are actually the project stakeholders (implementers and donors), which might cause the reported results to be subjective and biased. In addition to this, the project sustainability and its long-term effects are of a great interest and are also assessed by the stakeholders themselves. Therefore, the evaluation of the real donor programs' success and the effects on the end beneficiaries is very important to be conducted by an independent party and taken into consideration while planning the further donor programs in order to maximize their effectiveness.

Many researchers and policymakers acknowledge the great significance and contribution of SMEs to the national economic growth [5]–[11]. Most economic structures are mainly consisted of SMEs and despite the presence of large corporations, the greatest part of the employment is concentrated in this group. Polices designed for promotion and facilitation of the SME sector are of particular interest and there has been substantial expansion of these efforts, which is also reflected in many donor programs and initiatives.

In these circumstances, a need for a methodology for objective assessment of donor programs emerges, and its application while planning the new programs significantly increases the chances for their effectiveness. In this paper we will propose a methodology for donor programs assessment that should be applied in the development of future donor programs.

The paper is consisted of the following parts: firstly, a review of relevant literature and the research objective will be presented; then the methodology that was developed for assessment of the donor programs will be described; in the third part the results from the methodology and main findings will be outlined; and finally, the most important concluding lines will be summarized in the last part.

STATE OF THE ART AND RESEARCH OBJECTIVES

Many scholars have tried to develop evaluation standards that aim to contribute to the improved exploitation of the measures set by promoting meaningful evaluation procedures to foster strategic intelligence building and evidence-based decision making in the appropriate areas [4], [12]. Reference [13] provides a review of different evaluation approaches, methods, practices and examples and is designed to be used by policymakers and managers. Among other information, the evaluation standards should address the authorities commissioning the evaluations; evaluators carrying out the evaluation studies; and organizations and stakeholders that are subject to the evaluation, such as implementers and beneficiaries. For successful evaluation, it is important working with representatives of all groups affected by the program [12]. The purpose of these standards is introducing internationally acknowledged terminology and evaluation theory framework. For majority of them, it is common the focus on issues, such as: relevance, efficiency, efficacy, impact and sustainability. According to the time evaluations are carried out in relation to the implementation of a strategy, piece of legislation, program or project, and depending on the evaluation purpose, it could be distinguished six evaluation types [4]:

- Ex-ante evaluation – conducted prior to the implementation;
- Interim evaluation – conducted during the implementation;
- Terminal evaluation – conducted immediately at the end of the implementation;
- Ex-post evaluation – conducted a short time after the end of the implementation;

– Periodical evaluation – conducted regularly throughout the implementation;
– Ad hoc evaluation – the evaluation was not foreseen during the development or implementation, but is conducted to meet a need that emerged later.

Most of the evaluation standards are focused on single project level, providing evaluation schemes for performance-based distribution of the tight public finances [4], [12]. Furthermore, some authors propose using the evaluation mechanisms not only by central decision-makers, but also by everyone in the society willing to understand what programs accomplish and why they fall short on their objectives [14]. On this way the community recognises their own interests and discovers opportunities for action through the participation in the projects. Evaluation is also explained as very important tool for demonstrating the accountability by organizations, improve their performance, increase the abilities for obtaining funds or future planning, and fulfil the organizational objectives [15]. In this context, seven evaluation types are listed: formative, process, summative and outcome evaluation in relation to the project phases, which indicates that the project evaluation process is closely related to the project management process.

The reviewed evaluation methods are very helpful for ensuring the efficiency and efficacy of the activities and fulfilling the project objectives set. However, for donors and policymakers an evaluation framework that will objectively assess the real impact on the society in recipient countries by an independent party is urgently needed for the effective planning of the future donor programs. The goal of this research is to address this gap.

Therefore, the research objective posed in this study is development of evaluation methodology that could be widely applicable regardless of the research topic, aggregation level and targeted period, and could be applied for answering the following questions:

– identifying the impact of donor programs in supporting the economic growth and reforms in the business environment connected to private sector development and competitiveness; and
– recognising good practices to extract the knowledge about the lessons learned through projects' implementation by the donors from one side and the implementers from the other.

METHODOLOGY FOR ASSESSING THE DONOR PROGRAMS SUCCESS

The research is based on a framework analysis approach as an analytical process with set of tools which are used as part of an iterative process to aid structured and systematic data analysis [16]. Data management through framework analysis approach offers aim to order data to facilitate interpretation. For interpretation, this approach involves thematic analysis, typologies and explanatory analysis. The methodology framework that was developed is presented on Figure 1. The chart represents the overall process which is consisted of eight levels of activities (presented with the blue squares).

The data management and collection process can be divided on: primary analysis for reordering and making the data accessible and secondary analysis for reducing the data volume based on prioritizes questions. Theme based and case based approaches as "cutting-up" data tools are used in data management process.

The mass of qualitative data in the research should be summarized by the qualitative data analysis. The methodology contains qualitative and quantitative elements for assessing the effects through data analysis in the research. The literature on the qualitative evaluation of private sector development programs suggests that various evaluation techniques can be used [17], [18], [19].

Primary and secondary data sources have been analyzed. The analysis in this research is based on an examination of the following data: (1) primary sources of data: questionnaires for the project donors, questionnaires for the project implementers, and interviews of key projects' donors, implementers, and beneficiaries; and (2) secondary sources of data such as: publicly available donor assistances, policies, including websites, databases, strategy papers, policy documents, donor commitments and other multilateral forms.

The data collection is organized in the following eight stages (Figure 1):

- Stage 1 – Determining project selection criteria
- Stage 2 – Selecting the relevant projects
- Stage 3 – Analyzing the Economic Development Project (EDP) database
- Stage 4 – Surveying the donors and implementers

- Stage 5 – Interviewing the selected donors and implementers
- Stage 6 – Selecting the beneficiaries' best practices
- Stage 7 – Interviewing the selected beneficiaries
- Stage 8 – Analyzing the outputs from the fifth and seventh stage.

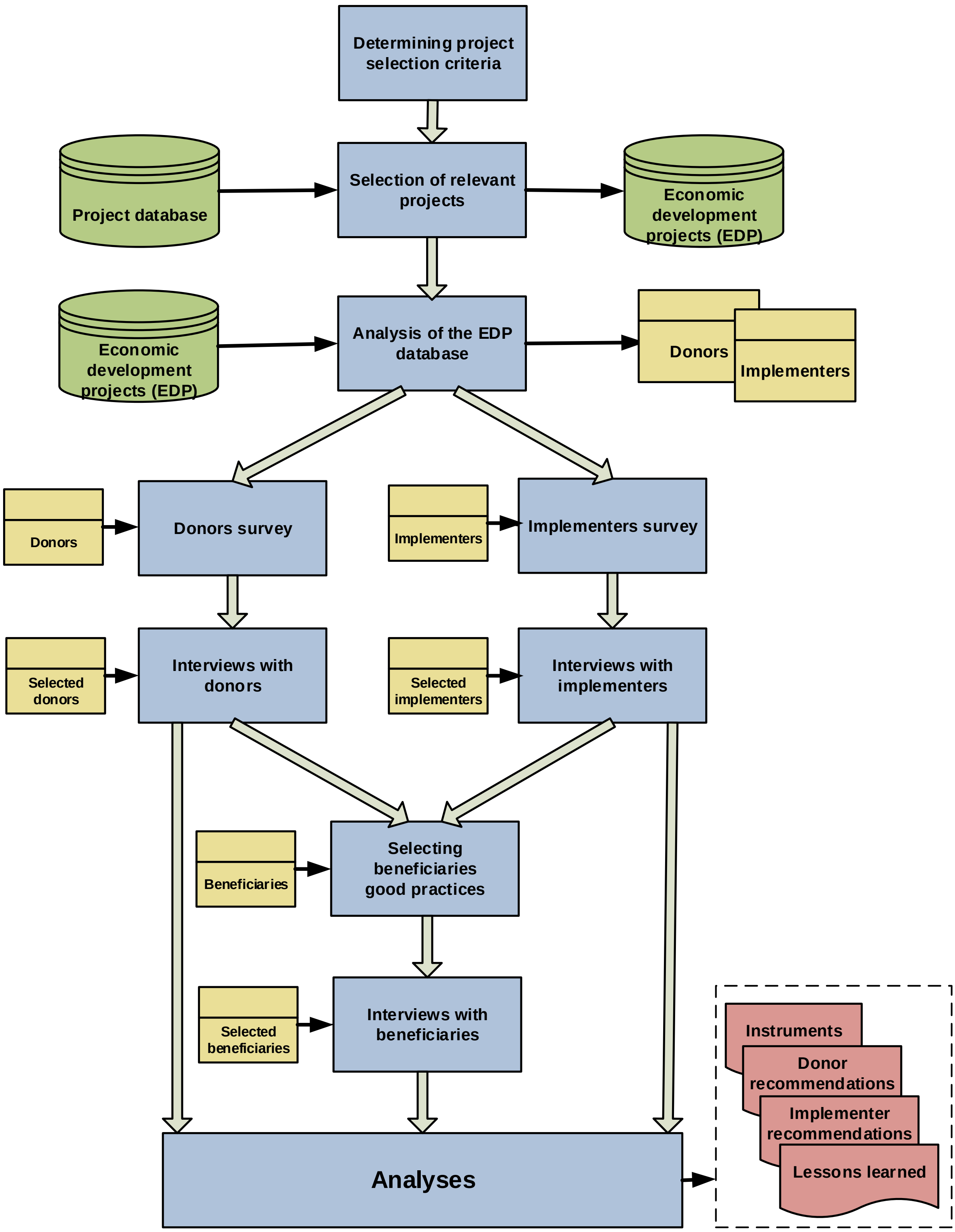

Fig. 1. Methodology framework

The first three stages analyze the project data base and gradually reduce the amount of data, so at the end of the third stage two tables for the most active donors in the analyzed area and adequate project implementers are extracted. These outputs are inputs for the following two stages: applying qualitative and quantitative research methods to the donors and implementers. After conducting the interviews with the selected donors and implementers, the beneficiaries' good practices are determined, which is actually the sixth stage of the overall process. In the next stage, the selected beneficiaries are interviewed, and the produced outcomes, together with the outcomes from the fifth stage are the subject for analyzing in the final stage. The deliverables from this research are: instruments, donor and implementer recommendations and lessons learned. In the following part of the paper, each of the stages will be explained in more details.At the beginning of the process, the researchers have to define the research goals and to set the criteria for selecting the projects. So, the purpose of the first stage of the data collection is to have clear definition of the dataset that should be analyzed as a part of the research. The comprehensiveness may be assured through analysis of central project database, such as the Central Donor Assistance Database (CDAD), which includes extended set of information for each project. It should be determined which project area is of interest, and what is the period that should be observed. For example, if the main aim is assessment of the projects assisting in the economic development of the country, the projects that belong to the policy: "Economic Development and Social Cohesion" should be analyzed with special attention. In addition, the database offers opportunities for filtering the projects by location, donors, implementers, polices, sectors, etc.

The second stage covers the process of application of the determined selection criteria to the full project database. This process results in new Economic Development Project (EDP) database with reduced number of projects that should be subject to further processing in the following stages. One project should be selected and included in the EDP database if the project is categorised in the relevant policy, and the project is implemented (at least partially) in the period which is of interest. In order to avoid the influence of possible mistakes in the classification of the projects, the listed projects should be additionally checked based on the project description, if the sector or the type of assistance is influencing the targeted areas: entrepreneurship, competitiveness, innovation, export promotion, and general SME support. The final EDP database should be an input to the third stage of the overall process.

The next stage of the data collection process serves to transform the reduced project database to separate donors and implementers tables. In this step, the critical evaluation of the researchers is crucial for determining of the key set of donors which are the most active in the analyzed region, achieving significant economic impact. After extracting the key donors, the projects that are donated by them should be further analyzed in order to be investigated which institutions are the implementers of their projects. After qualitative filtering by the researchers, the final implementers table should be delivered. The donors and implementers tables should be reduced, processed and analyzed in the next project stages.

The quantitative research methodologies should be applied in the fourth stage of the methodology. The researchers prepare separate questionnaires for surveying the donors and implementers, relating to all identified factors from the desk research. The proposed form of the questionnaires among other sections should contain: general questions, financial questions, section for gaining an objectivity data and sustainability questions. In addition to this, the questionnaires for the implementers should pay special attention to the specific implementing topics, lessons learned from the implementing process and the areas where beneficiaries often require the most assistance.

After conducting the surveys, a subset of donors and implementers should be selected for the interviews. The purpose of the interviews is more in-depth discussion on the same issues covered in the questionnaires, as well as determining the end beneficiaries that should be a base for case studies development. The donors should be questioned about their current experiences with the implementers, their views on the implementing process and their future plans on providing further instruments for supporting the economic growth. The questions should cover the main identified factors from the desk research. Also, it should be taken into account that there is different approach in the level of particularity between bilateral and multilateral donors. Most of the bilateral donors have reserved funds and projected areas of possible interventions, letting the implementers to propose more specific details. Unlike them, multilateral donors usually have precise strategy and action plans, resulting with foreseen goals, target groups, indicators and instruments. The implementers should be interviewed more on the implementation process itself, their collaboration with donors end beneficiaries, short and long term effects, as well as sustainability of the projects. The questionnaire for the implementers should be adapted for all possible categories of institutions that could participate in donor projects: public institutions, non-profit domestic institutions, foreign and international institutions and private sector. Some examples for the implementers that usually participate in donor projects are: NGOs, governmental institutions, higher education institutions, international organizations and private companies. Nowadays, international donors are increasingly looking to the private sector as a key partner and driving forces for achieving sustainable development results with focus on the economic growth. Private sector actors, private companies and foundations, are seen as a source of innovation, expertise and finance to be harnessed in addressing development challenges [20]. At the same time, private sector actors are playing an increasing role in their own right both as founders of development interventions and as important business partners. Donors coordinate their aid efforts with focus on the economic growth and the private sector as driving forces behind development.

The interviews with donors and especially with implementers should provide detailed information on the wide variety on project beneficiaries, indicating on the most successful cases. This input should assist the researchers in selecting the list of beneficiaries for conducting interviews. The key beneficiaries should be questioned about their experience and satisfaction from the involvement in the projects, projects' effects and impacts on their institutions / companies. The institutions that should be expected to be included in this list are: enterprises, governmental institutions, business development service providers, financial institutions and the national workforce.

The last stage of the delivered model is related to final analysis of the collected data from all sources and preparation of conclusions related to projects' relevance, impact, efficacy, efficiency, and providing the lessons learned, as well as presentation of the research findings. Therefore, the outcomes from the fifth and seventh stages should be reconsidered and taken for further analysis. This means that the main analyses should be performed on the cases prepared with an assistance of the interviews conducted with the donors, implementers and beneficiaries. The main deliverables from this methodological stage, as well as from the overall process are: identified types of instruments, recommendations for donors, recommendations for implementers and lessons learned.

RESULTS AND RECOMMENDATIONS

The methodology framework is based on: 1) cutting edge thinking and experience/lessons learned from donors and implementers, 2) a review of key policy documents related to the introduction of foreign assistance in developing countries, and 3) in-country interviews with the donors, implementers and beneficiaries in the recipient country.

The application of this methodology is expected to result with lessons learned for:

– Describing the experience from the usage of foreign assistances and impacts at economic growth analyzed at strategic level and projects implementation.
– Identifying the success factors and challenges of the process, highlighting the unique features and lessons learned.
– Making key decisions and highlighting the driving forces behind economic growth and development.

Although the evaluation process should be conducted by an independent party, it should include activities for gathering data that are joint work between the evaluators and the stakeholders. In this direction, a number of recommendations for the evaluators arise from this study:

– **Motivating donors to participate** – Donors could be motivated to take part in this type of evaluations by emphasising the importance of the evaluation outcomes for the effectiveness of their future programs. Unlike other evaluation procedures undertaken by the project and program stakeholders (most often donors and implementers), the evaluations conducted by an independent party guarantee an objectivity of the outcomes. Also, the strategic approach taken aims to assess the real long-term impact of the donor programs on the society in the recipient country, rather than evaluating the project specific indicators defined prior to project's implementation, which provides unique and strategic inputs for donors and policymakers while projecting the future donor programs and instruments.

– **Motivating implementers to participate** – Implementers could be encouraged to participate by pointing out the importance of this methodology for the excellence of donor programs and their enhanced impact and benefit for the society. Moreover, the evaluation outcomes should provide general overview of the donors' strategic objectives and goals. On this way, the implementers could recognise their own interests and discover opportunities to take part in the future programs.
– **Motivating beneficiaries to participate** – Identification of the successful cases of beneficiaries is the key step in the development of cases for best practices. Therefore, motivating the chosen beneficiaries to give their input in the evaluation procedure is very important for this evaluation process. It should be emphasised that participating in the evaluation process could increase their visibility for the donors and the implementers, which increases the opportunities for involvement in future project activities, either as beneficiaries or even as implementers.
– **Enhancing the tracking and comparability of private sector funding** – Evaluators need to agree on a common set of sector codes to measure donor contributions to economic growth and private sector development.
– **Setting indicators for measuring the economic, social and environmental sustainability** – Evaluators need to establish qualitative and quantitative indicators for measuring the economic, social and environmental sustainability and monitoring framework for following the positive development impacts that build on best practices among donors, implementers and beneficiaries.

CONCLUSION

Projects financed by international donors play significant role in the development of certain area in the recipient countries. These types of projects are strategically planned and aim to boost the development of the most urgent or most potential areas, such as: improving the competitiveness, inclusive growth and increasing the employability, green growth, etc. These initiatives have significant effect on the regional and economic developments and social conditions in the recipient country. Also, the donor support plays important role in the promotion of governance based on European principles in society and economic standards.

For the success of the donor programs and their effective planning, it is vital an objective system for evaluation and assessment to be provided. Each of the projects contains a set of relevant indicators that are proposed and assessed by the project stakeholders (donors and implementers), which might introduce subjectivity and bias in the results. That's why it is crucial the impact evaluation, which seeks to answer cause-and-effect questions, and the changes in outcomes that are directly attributable to a policy, program or project, to be done by an independent party.

This paper proposes a strategic approach for evaluation of the programs by independent party that should be applied while planning the future donor programs in order to maximize their effectiveness. The data source that is proposed to be base for this research is comprehensive database covering all donor projects in the analyzed region. The research methodology covering eight stages can be presented as three main phases: analysis of the database(s), gathering primary data from the selected stakeholders, and analysis of the outputs.

The approach should be applied for assessment of the international donor projects in the countries. The analysis of the collected data should produce concrete results on the programs' success, as well as lessons learned on the assessment process, identification of the success factors and challenges, and determination of the driving forces behind economic growth and development. The outputs produced should contribute to the understating of the challenges that the main stakeholders – donors, implementers and beneficiaries – are facing. This knowledge is important to support cross-cutting reforms in the business environment, innovation capacities and labour market, as well as facilitating sector-level reforms in order to increase growth, competitiveness and opening the new jobs.

This study is beneficial for the international donors, but also for the practitioners who propose, implement and evaluate internationally financed programs. The proposed approach can be also applied by the policymakers in the projecting of future national strategic programs for the development of the SME sector. Last but not the least, the theoretical contribution of this paper is also important for the scholars researching in the area of project evaluation and assessment.

During this study, several related areas where further research could be beneficial were identified. A need for measuring the engagement of the international donors with the society and their impacts on the development of the private sectors in the recipient countries emerges. Also, the policies implemented by the donors should be assessed ex-post, or after certain period of time after the implementation when their real effect could be evaluated. In the same direction, the impact that is caused by donors' assistance on the ground should be assessed. At the end, it should be paid greater attention to fostering the triangular sustainable development cooperation between donors, implementers and private sector in order to support and increase the economic growth. Therefore, the following areas for further research and investigation are proposed:

– Measurement of the international donors' engagement and impacts in private sector development.

– Assessment of international donors' policies implementation in practice.

– The impact of the assistances on the ground.

– Factors for fostering the triangular sustainable development cooperation between donors, implementers and private sector due to increasing the economic growth.

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MODEL OF SEMI-QUANTITATIVE RISK ASSESSMENT FOR SAFETY AT WORK IN MANUFACTURING INDUSTRY

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A b s t r a c t: The problem of occupational safety and health in the manufacturing industry is very important and significant since this industry has the largest number of injuries. The number of injuries is about 5 times larger than the construction industry which is the second industry with the largest number of injuries. The main hypothesis of this paper is that it is possible to develop occupational safety model for semi-quantitative analysis risk assessment in the manufacturing industry, based on real data for occupational injuries. This model may find its use as a support tool for all stakeholders involved in the implementation of the occupational safety system and risk assessment. The developed database in this model generate a condition that represents the basics for prediction of certain critical points that may be a potential risk for accident occurrence. Thus indicates that this model will increase the objectivity and provides accurate and reliable risk assessment.

Key words: Semi-quantitative analysis; occupational safety and health; risk assessment; manufacturing industry

МОДЕЛ НА СЕМИКВАНТИТАТИВНА АНАЛИЗА ЗА ПРОЦЕНА НА РИЗИК ЗА БЕЗБЕДНА РАБОТА ВО ПРЕРАБОТУВАЧКАТА ИНДУСТРИЈА

А п с т р а к т: Проблемот со безбедност и здравје при работа во преработувачката индустрија е исклучително значаен и актуелен со оглед на фактот што во оваа дејност има најголем број повреди. Бројот на повреди во преработувачката индустрија е 5 пати поголем од втората најризична индустриска гранка, односно градежната индустрија. Основната хипотеза во овој труд е дека може да се формира модел за семиквантитативна процена на ризик за безбедност при работа во преработувачката индустрија, базиран на реални податоци за повредите при работа. Овој модел може да најде своја примена како помошна алатка за сите чинители кои се вклучени во изработката на процената на ризик. Формираната база во моделот генерира одредена состојба којашто претставува добра основа за предвидување на одредени критични точки кои претставуваат потенцијален ризик за појава на одредена несреќа. Тоа подразбира дека вака развиениот модел ја зголемува објективноста и дава прецизна и веродостојна процена на ризик.

Клучни зборови: семиквантитативна анализа; безбедност и здравје при работа; процена на ризик; преработувачка индустрија

INTRODUCTION

Every industry generates occupational risks that very often arise as a result of the workplace, resources and the working environment. The probability of risk occurrence depends on the organization of the work process in order to ensure safe performance of the working activities and also depends on the level of training that employees have in order to perform their activities in a safe manner. By increasing the complexity of a certain working processes, the time and resources are respectively increased in order to organize a safe workplace.

Regardless of the level of complexity in the manufacturing industry, the workflow can be clearly defined with a systematic approach by identifying all elements in the process and their mutual relations. The process of identification of the connections and characteristic relations between the elements of the working processes should be applied precisely in the risk management analysis during the implementation of the occupational safety and health system.

Most of the recorded injuries by number of employees in the Republic of Macedonia belongs to the manufacturing industry [1]. This data is a result of the fact that this industry is the largest employer in the country, with employment of about 19.5% of the total working population [6]. Therefore we can conclude that the manufacturing industry is facing huge losses, primarily in human lives, and further, losses in working hours and financial resources. Therefore, the urgency of managing the risks in the occupational safety is at the highest level. In order to design much safer workplace the employers must think in a proactive way that would implement preventive measures in order to reduce losses.

If a risk is not recognized, it's expected that they will not give it any importance, and thus it will not be considered for any control mechanisms which is a basic prerequisite for the prevention of various dangers and hazards. The fundamentals for the process of risk identification are located in relevant database, members of the management team and all project team members (employees, line managers, and other suppliers), external experts and others. Each stakeholder is a potential source of knowledge and experience in the process of risk identification. But if the knowledge from the project members and their previous experience from the successfully implemented projects are not kept in written or electronic form, it increases the probability that those data will be lost.

In these databases are included all the relevant data that can be obtained through proper analysis of the recorded occupational injuries at the relevant institutions. The information in the database represent the current situation of the number and type of injuries in the manufacturing industry on a national level. The database gives the exact information on the working conditions and circumstances under which the injury occurred.

Therefore, quality databases are representing the most important resource in the process of risk identification and risk control in the area of occupational safety.

SEMI-QUANTITATIVE RISK ASSESSMENT

The semi-quantitative risk assessment is based on a qualitative assessment, in which qualitative determinants, probability level and injuries are expressed by numerical values through their quantification. This enables comparison on different levels of risk. One methodology for effectively determination of the risk level is the probability/impact matrix which is shown in the Table 2 [9], [19]. Despite the numerical determinants, the matrix may also contain descriptive determinants. In this matrix, three levels of risk are defined: high, medium and low, which because of easier classification is advised to be marked with different colors depending on the risk level, red, yellow and green respectively.

In the process of risk assessment with this methodology (probability/impact matrix) it is necessary to define the probability of risk occurrence by selecting a corresponding value in the range from 1 to 4. Each of these values defines probability of risk occurrence according Table 1. The suggested range for the probability of risk occurrence is not constrained and it can be revised according the company needs and their risk management plan [17].

Table 1

Quantification of the probability of risk occurrence

Qualitative determinant for the probability of risk occurrence	Appropriate quantitative determinant
Unlikely (almost impossible)	0,00 – 0,10
Fairly Likely	0,11 – 0,40
Likely	0,41 – 0,80
Very likely (in a certain time interval)	0,81 – 1,00

In this analysis, major significance has the description of the identified risk, which justifies the probability and forms the basis for assessment of the level of consequences that may occur.

The classification of the risk level and the probability of certain risks, for the matrix of probability of occurrence and health consequences, should be adopted in the initial phase of risk management, before the process of risk identification [9]. In order to design more accurate classification, for each consequence an appropriate weight coefficient should be assigned, which is representing the severity of the consequences [18], [9]. With the implementation of the weight coefficient actually the qualitative description is transformed into quantitative (semi-quantification)

These two parameters (probability of occurrence and the level of the influence of consequences) are the basis for assessment of the risk level and are essentials for qualitative assessment. The risk level can be defined by different ratings, depending on the required level of precision and the needs of the company.

Table 2

Matrix of probability of occurrence and consequences

Probability		Level of consequences			
		Very small or without	Small	Medium	High
		0,10	0,25	0,50	1,00
Unlikely	0,10	0,01	0,025	0,05	0,10
Fairly likely	0,40	0,04	0,10	0,20	0,40
Likely	0,80	0,08	0,20	0,40	0,80
Very likely	1,00	0,10	0,25	0,50	1,00

On the represented matrix, the limit values for the level of risk are 0.1 and 0.4, therefore all the risks with value less than 0.1 are characterized as small, risks in the interval from 0.1 to 0.4 are medium risks, while the risk with a value equal to or greater than 0.4 represent high level of risks.

DATABASE STRUCTURE OF OCCUPATIONAL INJURIES

For the purpose of the model a database of occupational injuries occurred in the manufacturing industry has been developed. The database is designed in order to define the potential risk sources and their relations with the specified workplace, used materials, tools, machines and the human resource characteristics. The occupational injuries database also provides important informations for determining the significance of the observed determinants and facilitates the quantification of the risk parameters (probability and consequences).

The data in the database are taken on the basis of the application form ET-8 submitted to the Health Insurance Fund by the doctor specialist who determined the severity of the injury and its consequences. Only the injuries that occurred in the manufacturing industry are conducted for further analysis.

According the Law on Pension and Disability Insurance of Macedonia, occupational injury means injury that has been caused by the immediate and short-term mechanical, physical or chemical effect, and the injury that has been caused by unexpected changes in the human body position, impulsive load on the body or other changes in the physiological condition of the body, if such injury is related to the execution of the job activities. Occupational injury also is injury that has been occurred on a way from residence to work and vice versa, on a business trip, as well as other conditions that are related with the arrival at the work place. But these injuries outside the workplace, will not be considered in the model because from the informations of those injuries we can't identify any indicator of improvement of the working conditions. According the Law as occupational diseases can be considered illness of the employee directly occurred as a result of exceptional accident or force majeure during the performance of work or in correlation with it. Injuries at work and occupational diseases are directly related to the characteristics of the work process and workplace conditions.

The structure of the database of occupational injuries is the most important parameter for measuring the quality of the base. The database must include all informations relevant to the observed injury. Therefore the number of data should be observed to the minimum possible extent and should be structured as simply to allow more efficient use of the database. The database is structured in a way that will provide information for all parameters that are relevant for the risk identification and quantification. The final structure of the database for occupational injuries has the biggest limitation factor, which is that it is predefined by the health insurance fund, which makes the database directly dependent on the data available in the application form (ET-8).

Database of occupational injuries is represented by four groups of data:

1. Group of data for the injured employee.
2. Group of data for the time dimension of the occurred injury.
3. Group of data for the source of the injury, cause of injury and the manner of the injury occurred.
4. Group of data for the injury consequences.

Each data set consists several sub-groups that provide accurate information about the observed parameters of the injury. These data can be used to determine the probability and the level of the consequences of injury. In addition, the group of data for the injured employee for a specific workplace together with the source and cause of the injury can be interrelated numerically with the value of the probability of occurrence of the injury. On the other hand the group of data on the injury consequences determines the parameter of the level of consequences. The parameter for the time dimension of the injury can show the increasing probability of injury occurrence for specific workplace during the year, month, work week or the working day.

The third parameter of the risk level, the frequency of the hazard (risk exposure) directly depends on the selected workplace. Therefore this parameter can determine how often employee's in execution of the working activities for specific workplace will be at risk to be injured. It is important to note that for the purposes of this paper will be used methodology with two parameters for risk assessment upon which the model is based. Which mean that the third parameter of the frequency will not be considered because the methodology with two parameters is described by the probability that the risk will occur and by defining the level of the possible consequences if that risk occurs. The probability of the occurrence of certain risk is defined in percentage values, while the level of the consequences is determined by semi-quantification or by assigning numerical values for each level of consequences according to Table 2.

Group of data for the injured employee

Data for the injured employee, analyzed on the basis of the available information in the application form for occupational injury are of great importance for the identification of risky categories of employee. Group data for the injured employee are:

1. Date of birth.
2. Gender.
3. Workplace (position).
4. Age of the worker at the time of injury occurrence (expressed in whole years).
5. Age of the worker at the time of occurrence of the injury in intervals (intervals are adopted: 18 and 19 yr., 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65 or more) [1].
6. Work experience of the employee expressed in intervals (intervals are adopted: one week, one month, 1–6 months, 6–12 months, 1–5 years, over 5 years)

Group of data for the time dimension of the occurred injury

Data on the time of occurrence of the injury present an overview of the frequency of injuries in terms of year, month, day and hour. Analysis of the data from the time dimension allows the determination of the risks that occurred during the execution of the working activities of a certain workplace in a certain months, days and hours. Group data for the time dimension of the occurred injury are:

1. Year of injury.
2. Month of injury.
3. Date of occurrence of the injury.
4. The week day of occurrence of the injury.
5. Time in which the injury occurred.
6. Hours passed in the workplace (from the start of the workday till the injury occurrence)

Identification of the rate of increase in the number of injuries in certain months, days or working hours allows to employers to develop accurate plans for prevention that will increase surveillance, increase vacation time and other preventive measures in the time intervals where the risk of injury occurrence is increased.

Group of data for the source of the injury, cause of the injury and the manner of the injury occurred

The information in the application form for notification of an accident at work do not give a detailed description of the source of the injury nor the cause of the injury. Therefore the data on the manner of injury occurrence and the sources as a reason for injury occurrence are defining the risk for execution of the working activities for a particular workplace. Certain workplaces are only exposed to a certain number of risks. Thus it is necessary to determine which machines, tools and materials generate what type of a risk, and to determine the most common manners of injury occurrence for that particular workplace. But very often the information on the source of the injury and the manner of the injury occurrence are not enough to perceive the essential reason that the injury is caused, instead they only give us insight into the consequences.

- source of injury,
- cause of injury, and
- the manner of the injury occurrence

Source of injury

Internal and external physical injury of the human body, are consequences from the energy release or direct impact of hazardous materials. The following source of injuries are defined [20]:

- sources of energy (mechanical, electrical, thermal, chemical and radiation), and
- hazardous materials (liquefied gas, gas pressure, corrosive materials, combustible substances, poisons, oxidizing materials and dust)

In order to determine the source of the direct injury, based on the description in the application form, we need to perform certain identification of:

1. Machines that are a source of injury.
2. Tools that are a source of injury.
3. Materials that are a source of injuries.
4. Equipment that is a source of injury.

For every injure occurrence there is a source that is represented in one of the above elements. Data on the source of the injury combined with the job description precisely define the technical cause of injury that enables risk identification and its quantification.

For a detailed analysis of the machines that are a source of injury the machines in the manufacturing industry will be classified based on their type and technical characteristics. The types of machines used in the certain workplace are contained in the job description which is predefined and for this model needs to be standardized. Despite the impact of the machines the impact of the tools, material and equipment are also considered as a source of injury.

The identification of sources of the injury is closely associated with the identification of the way of occurrence of the injury. Even after the establishment of these two parameters we can fully analyze the situation that caused the injury and material or other causes of injury.

Cause of injury

Determining the cause of injury is very important parameter for the process of risk identification and quantification. If we don’t perceive the reason for the injury occurrence, it is impossible to analyze all injury factors.

The reasons causing the injuries are directly related to the implementation of the working activities for the particular workplace and therefore they should be analyzed on two levels:

- Indirect causes of injury (e.g. a way of working of the employee, the tool used, working conditions, etc.).
- Essential causes of injury (e.g. why there is a breakdown of the machine).

The division of the two levels of causes of the injury is accepted on the basis of the guidelines of the Occupational Safety and Health Administration (OSHA) [20]. Detailed division of the reasons causing injury at work is accepted according the analysis of the occurrence of injuries and by a series of authors. [20], [21], [18], [22], [11], [15].

The manner of the injury occurrence

Many authors applied research studies on the possible manners of the injury occurrence and they accepted various divisions. In this paper we analyzed several such divisions that are applicable for the methodology used [22], [15], [11]. Detailed overview of the manner of the injury occurrence is accepted by analyzing these authors. Through these analyzes and the information of the application form for occupational injury basic structure is accepted for the manner of injury occurrence consisted of nine groups:

1. Hitting to the worker by....
2. Hitting the worker to...
3. Captured.
4. Fall.
5. Extreme physical strain on the body and exhaustion.
6. Exposure to harmful substances and harmful environment.
7. The accident occurred in internal traffic or transport.
8. Involvement (by rotating mechanical parts, typical for manufacturing industry).
9. Other.

Group of data for the injury consequences

The volume of data included in the database relating to the consequences of the injury is significantly limited by the volume of the data available in the analyzed application forms for occupational injuries. In addition to the analysis of the application form the following data are required:

- Where and how the accident occurred.
- Findings and doctor opinion (sick-leave, period).
- Injury description.

Based on the above data it is necessary to receive the next group of data for the injury consequences:

- severity of the injury,
- injured body part.

Severity of the injury

OSHA define four degree division of injuries [10] such as: injuries causing absence of the employee less than 4 days, injuries causing absence of the employee from 4 to 14 days, injuries causing absence of the employee from 14 days to 3 months and injuries that cause the absence of the employee more than 3 months or caused permanent loss of working ability.

In R. Macedonia under Article 36 of the Law on Occupational Safety and Health at Work (Official Gazette No 92/2007.) [2], the employer must immediately, or within 48 hours to notify the State Labour Inspectorate for every injury that resulted with death consequences, collective accident and occupational injuries that cause a temporary inability to work longer than 3 working days [5]. Thus the categorization of OSHA [10] can be accepted for the model of semi-quantitative analysis, because such data are analyzed and they are corresponding with the application form for the occupational injury. More detailed classification of the severity of injuries adopted for this model includes six categories:

- Minor injuries (injuries that are not treated or which required first aid or absence from work for up to four days).
- Medium (injuries which required first aid and/or doctor (not hospitalized) or absence from 4 to 13 days).
- Major injuries (injuries which required hospital treatment (hospitalized) or absence from work of at least 14 days).
- Very large (injuries which led to complete loss of working capacity of the employee).
- Death (death occurred immediately or later as a result of the consequences of the occupational injury).
- Collective death (one or more than one employee is involved in the incident with fatal consequences).

Data on the severity of injuries as a result of the incident that occurred, are very important for the process of risk quantification. The quantification is provided by setting a relation between the severity of the injury, the incident which is the cause of the injury occurrence and the risk that is predecessor to the incident.

Injured body part

Data on the injured part of the body give a precise details into the characteristics of the injury, and thus the risk. Which parts of the body will be more exposed to risk depends on the nature of work or working activities for each workplace. The classification of the injured body part has been made through the analysis of more international organizations and individual authors [10], [13], [11].

Based on the analysis of the authors and lacking of specific information in the application form for the occupational injury, the following six group are accepted:

1. Head and face
2. Upper limb
3. Lower limb
4. Torso, organs and neck
5. Multiple injuries (injuries of more body parts)
6. Unknown

MODEL OF SEMI-QUANTITATIVE ANALYSIS RISK ASSESSMENT FOR OCCUPATIONAL SAFETY

The models of semi-quantitative risk assessment are combined of qualitative and quantitative assessment whereby to the qualitative determinants a numerical values are given. The qualitative assessment is usually implemented on the subjective views of one or more experts, thus reduce the objectivity of the methodology. In order to avoid this problem in the determination of the risk level and its parameters, it is necessary the process to be based on existing statistical data. The reduction of the experts and other stakeholder's subjectivity during the risk assessment is a major step forward in standardization and efficiency in the implementation of the occupational safety and health system. This model can assist to the occupational health and safety experts during the implementation of the risk assessment and the process of risk identification.

The database can provide information on the cause for the occurrence of injuries depending on the observed sample and thereby can indicate the most common manner of the injury occurrence, the injured parts of the body and the level of the injuries. By establishing the mutual relations to those data and quantification of their connection, the basis for a model of semi-quantitative risk assessment are designed.

In order to design the model it's essential to analyze the database and to identify the most important parameters for the risk assessment. Also, it's required to quantify their importance or their impact on the level of risk in case of injury.

Analysis of the database must be performed systematically in order to discover the group of data that have the greatest impact on the injury occurrence. Given the fact that the database covers a large number of groups of data, the analysis should include all of them in order to select the most influential data. For this model it is crucial to identify the most influential parameters in each data groups that affect the injury occurrence.

The link between database of occupational injuries, trough the defined groups of data and two parameter methodology for risk assessment is presented on Fig. 1. This figure allows us to determine the significance of the developed groups of data in the implementation of risk assessment. The first group of data for the injured employee together with the time dimension of the injure occurrence and of the group of data for the source of the injury, cause of injury and the manner of the injury occurrence can be linked numerically with the parameter for the probability of the risk occurrence. While the group of data on the consequences of the injury is determined with the parameter consequences, severity of the injury. It is important to note that each group of data from the occupational injuries database has a respective subgroup that increases the accuracy of the risk assessment methodology.

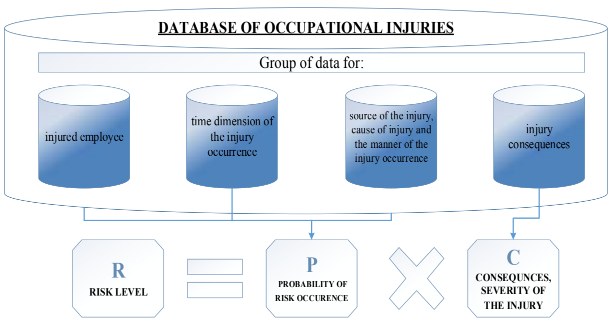

Fig. 1. Link between occupational injuries database and risk assessment methodology

Analyzing the process of risk management, the methodology for risk assessment and the existing models for risk quantification we can confirm that the model of semi-quantitative analysis risk assessment should be based on the occupational injuries database. The model will also include the processes of identification, analysis and risk quantification.

As more detailed informations from the occupational injuries model consist there is a greater chance for more accurate risk identification, analysis and quantification to be made.

In the model the process of risk identification is based on the identification of the dangerous events by analyzing the specific workplace and pre-defined job description. As it was already presented in the paper, every workplace brings different levels of risk depending on various human resources that execute the working activities. Therefore it is very important to be perceived the parameter for the human resource characteristics or their age and experience that directly affect the probability of occurrence of a certain injury due to unsafe operation or employee behavior.

The risk level is already defined on the basis of two parameters, the probability of risk occurrence and the second parameter expressed through the consequences, severity of the injuries. Both parameters can be determined by comparative analysis of the job description of the workplace and the information from the occupational injuries database.

It should be noted that the importance of certain parameters that are included in the model of semi-quantitative analysis for risk assessment is directly dependent on the number of injuries that occurred or the data incorporated in the database. But for some of the parameters the research methodology of primary source of information can be implemented, by conducting questionnaire that will contribute to determining the significance of these parameters.

CONCLUSIONS

The main advantage of the model is that the risk identification is performed by identifying the causes of injuries of a specific workplace through the database of injuries, while the quantification is done by defining the number of injuries and determining the values of corrective factors that increase or reduce the probability of occurrence of a specific injury. The corrective factors associated with the characteristics of the working activities, material and human resources fully depend on the data about the actual injuries from the database.

With the linkage between the identification and quantification of the risk through the database the subjectivism of risk assessment is significantly reduced because it is based on the real data of injuries. On the other hand the accurately within the defined methodology reduces the possibility of potential mistakes and large deviations in the implementation of risk assessment by various experts.

The model is an important tool for employers in order to increase the efficiency of its operations by more accurately determining the preventive measures in implementation of the specific operation of the defined workplace. The data from the database can provide precise information on identification of the potential risks and can directly reduce the number of unforeseen or unidentified risks in the assessment process.

Therefore it is clear that by increasing the volume of data in the database the precision of the model increases, which again enhance the importance of the national qualitative databases and the systematic approach to the problem of gathering the information on the occupational injuries. With further development of the model for semi-quantitative risk assessment on one workplace, it easily can be upgraded for risk assessment of more working places in a factory or entire technological process (e.g. making punching die).

The basic disadvantage of the model is that the precision of the assessment is directly dependable on the validity of the data reported to the authorities or in the report documents. This dependency of the model of the application form for occupational injury can represent a disadvantage due to the fact that the application usually is submitted by the employer, and in very rare cases by the injured worker, therefore the objectivity of the person who is fulfilling the application and the information presented in it sometimes may be not reliable.

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Short communication

BENEFITS OF IMPLEMENTATION OF FLEXIBLE AUTOMATION AND CAD/CAM SYSTEMS IN METAL PROCESSING COMPANIES

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A b s t r a c t: The main goal of the research presented in this paper is to show the benefits that companies from the metal processing industry gain from the implementation of CAD/CAM technology in all segments of the product life cycle, from design to production of final product. Analyzing the production processes in metal processing companies and the global market requirements, in order to stay competitive on the market, the implementation and using of the flexible automation and CAD/CAM technology in the companies in all steps of the product life cycle is necessary. The crucial benefits of using the CAD/CAM technology in the metal processing companies are increased productivity of the engineers-designers, increased production productivity, high and repeatable quality and high production flexibility.

Key words: CAD/CAM technology, Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), metal processing industry, product life cycle, selecting of CAD/CAM systems.

ПРИДОБИВКИ ОД ИМПЛЕМЕНТАЦИЈА НА ФЛЕКСИБИЛНАТА АВТОМАТИЗАЦИЈА И СИСТЕМИТЕ CAD/CAD ВО КОМПАНИИТЕ ОД МЕТАЛОПРЕРАБОТУВАЧКАТА ИНДУСТРИЈА

А п с т р а к т: Главната цел на истражувањето прикажано во овој труд е да ги прикаже придобивките кои компаниите од металопреработувачката индустрија ги имаат со примената на технологијата CAD/CAM во сите сегменти од животниот циклус на еден производ, од дизајн до производство на готов производ. Анализирајќи ги производните процеси во компаниите од металопреработувачката индустрија и барањата на глобалниот пазар, со цел компаниите да останат конкурентни на пазарот, имплементацијата и примената на флексибилната автоматизација и технологијата CAD/CAM во сите чекори од животниот циклус на производот е неопходна. Клучни придобивки од примената на CAD/CAM технологијата во компаниите од меалопреработувачката индустрија се зголемена продуктивност на инженерите дизајнери, зголемена продуктивност на производниот процес, висок квалитет и негова повторливост, како и висока флексибилност на самите производни процеси.

Клучни зборови: технологија CAD/CAM, компјутерски помогнато дизајнирање (CAD), компјутерски помогнато производство (CAM), металопреработувачка индустрија, жи вотен циклус на производ, избор на системи CAD/CAM.

1. INTRODUCTION

The companies of the metal processing industry today are facing with very big challenges, as a result of the tremendous competition on global level. High quality, low price and short delivery times are the elements that the company should realize in order to stay competitive on the market. In one word, the companies have to orientate into the borders of so-called “Iron triangle”, presented on Figure 1 [1].

On other side, the dynamic of product changes and improvements desired by the market, needs high flexibility of the company in all steps in the product life cycle, from design to production of final product.

High product quality and high productivity, the companies can achieve with application of automation in the production process. In order to enable desired changes, flexibility in the designing and production process, the implementation and using of the flexible automation and CAD/CAM technology in all steps of the product life cycle is necessary.

Fig. 1. "Iron triangle" [1]

In practice, the CAD/CAM technology is used for creating technical drawings, making drafts, geometric modeling of parts and assemblies that actually present digital representation of the designed products, geometric model analysis, creating technical documentation, programming CNC (Computer Numerical Controlled) production equipment, production process, quality control, packaging, etc.

Implementation of CAD/CAM technology in metal processing companies includes choosing of the right combination of CAD/CAM system (software, hardware and production equipment), purchasing the system and staff education. Which type of CAD and CAM tools will be used, depends of the product type, prescribed production technology, desired quantities, desired quality level and quality repetition requirements and desired design and production flexibility. The benefits that the metal processing companies gain from the implementation of CAD/CAM technology in the design and production processes, as well as, the approaches in choosing the right CAD/CAM system, are presented in this paper. The presented results are based on practical experience from the metal processing companies.

2. POSITION OF THE CAD/CAM TECHNOLOGY IN THE PRODUCT LIFE CYCLE

The Figure 2 [2, 7] presents the position of the CAD/CAM technology in the typical life cycle of one product from the metal processing industry. The typical product life cycle contains two main processes:

- the design process,
- the manufacturing process.

In general, the typical life cycle starts with idea for development of a new or redesigned existing product, mainly as result of market research (for new products) or market feedback (for existing product). All necessary information about the product (design and functionality requirements, quality level, desired production quantity, very often the price level, etc.) are collected and analyzed in order to define the final concept of the product that will pass through all steps in the designing and manufacturing process.

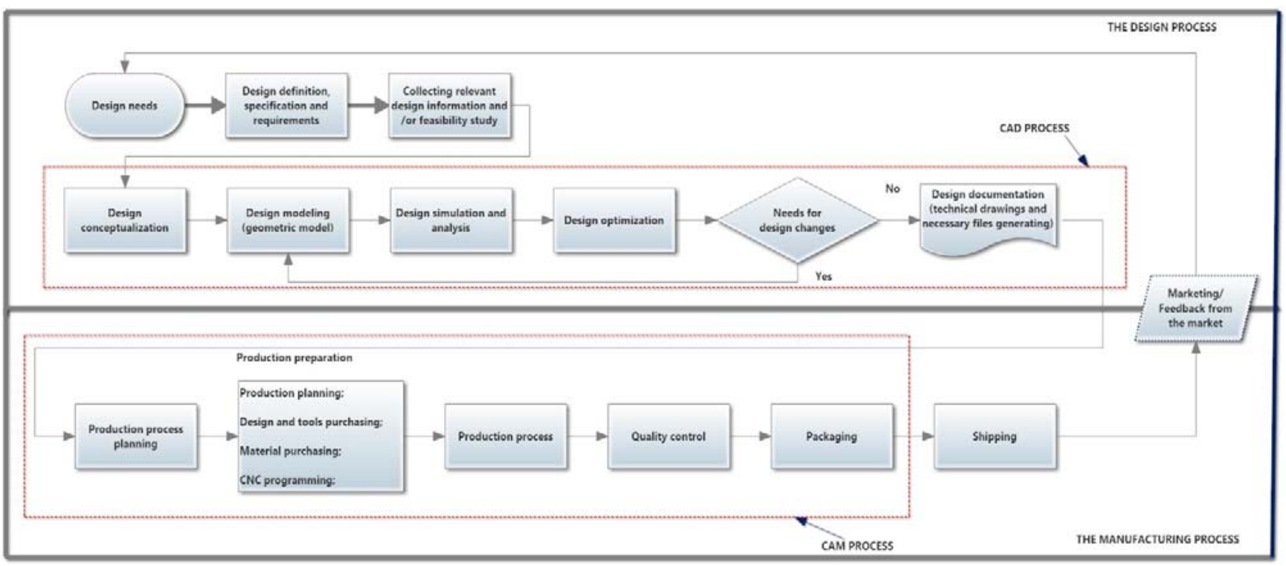

Fig. 2. Typical product life cycle [2]

CAD (Computer Aided Design) is part of the designing process, which is based on creating geometric model of the product that presents a digital representation of the designed product. In this process, except the visualization of the product, the CAD tools are used for additional activities with the geometric model, like different types of strength analyses, simulation of the product functionality and at the end, as output from the designing process, preparation of technical documentation and generating necessary files as DXF, STEP, IGES or other files, that could be used in the process of manufacturing, if is necessary.

CAM (Computer Aided Manufacturing) is a part of the manufacturing process. Input in this process are the technical documentation, the geometric model and the created files in the design process. The largest influence of the CAM technology in the production process is in preparation of the production (mainly in the process of CNC based equipment programming) and in the direct process of production, where CNC based production equipment is used.

3. COMPUTER AIDED DESIGN (CAD) AND BENEFITS FROM IT`S IMPLEMENTATION

CAD (Computer Aided Design) can be defined as a product design by application of hardware (computer) and graphical software, that supports and improve the designing process in all its stages, from conceptualization to final documentation [9, 13]. The base of CAD is creating visual and digital interpretation of the product, represented by geometric model [4].

Today many different companies are present on the world market, that offer CAD applications, which includes different modules for designing and analyzing of the models, manipulation with the models and generating the necessary documentation [11]. From the wide range of applications on the market, the most used in the metal processing industry are CATIA and SolidWorks from Dassault System Company, AutoCad and Inventor from Autodesk, NX Unigraphis and SolidEdge from Siemens, etc.

All this applications include wide range of modules for different activities with the geometric model of the designed product, as modules for strength analysis, motion simulation, thermal and fluid flow simulation and analysis, etc. [9].

Nowadays, it is impossible company from the metal processing industry to be competitive on the market, without using CAD application in the design process. We can mention the general benefits that the companies gain with implementation of CAD system, compared with non using of CAD system. The major benefits are mentioned bellow [13]:

- Increased productivity of the engineers-designers;
- Increased quality of the product design;
- Unification of the design standards;
- Data base creation;
- Determination of the product quality and functionality early in the construction stage;
- Decreasing or completely elimination of the prototyping needs;
- Uniquely designation of the parts names;
- Elimination of the irregularities that can be issued by manual making of the drawings;
- Fast and simple way for model corrections;
- The engineers-designers become free from routine activities. That enables them to be more concentrated on creative activities;
- Design process starts directly with 3D (three dimensional) modeling;
- Easy file exchanges (communication) between different CAD applications using standard files – translators as IGES, STEP, ACIS, DXF, etc.;
- Geometric model can be used for different analysis and CNC programming directly.

For the purposes of this paper, in order to present the influence of using CAD application in the design process on the designer's productivity, two different approaches in designing with CAD application, are compared for the same product. Namely, the design process for one product group from the metal processing industry, fork extensions for fork lift (Fig. 3), that contains 200 different dimensions (variants), cross sections and lengths from the same design, is analyzed. All dimensions that define the cross sections and the lengths of the variants, are closely connected with the dimensions of the parent fork on which the product is mounted, with exactly defined equations according ISO 13284–2003.

For this purpose, the designing process is done by using SolidWorks software, as CAD application.

The both analyzed approaches in the design process, are:

- Designing each variant separately;
- Designing, using parameter modeling with design tables.

Fig. 3. Fork extensions for fork lift – 3D model

In the first approach, all variants (cross sections and lengths) are designed separately with changing of each dimension that defines the product for each variant.

In the second approach, design table is created, in which all relations between the products dimensions and parent fork dimensions are defined, and each variant is designed only with changing of the parent fork dimensions. The only activity that designer should do is to fill the measures for the parent fork (Fig. 4). The dimensions of the fork extension are calculated automatic using the defined equations, and all dimensions are applied on the 3D model.

For the both approaches, the times necessary for design process are measured and estimated per unit of variant. The results are presented in Table 1.

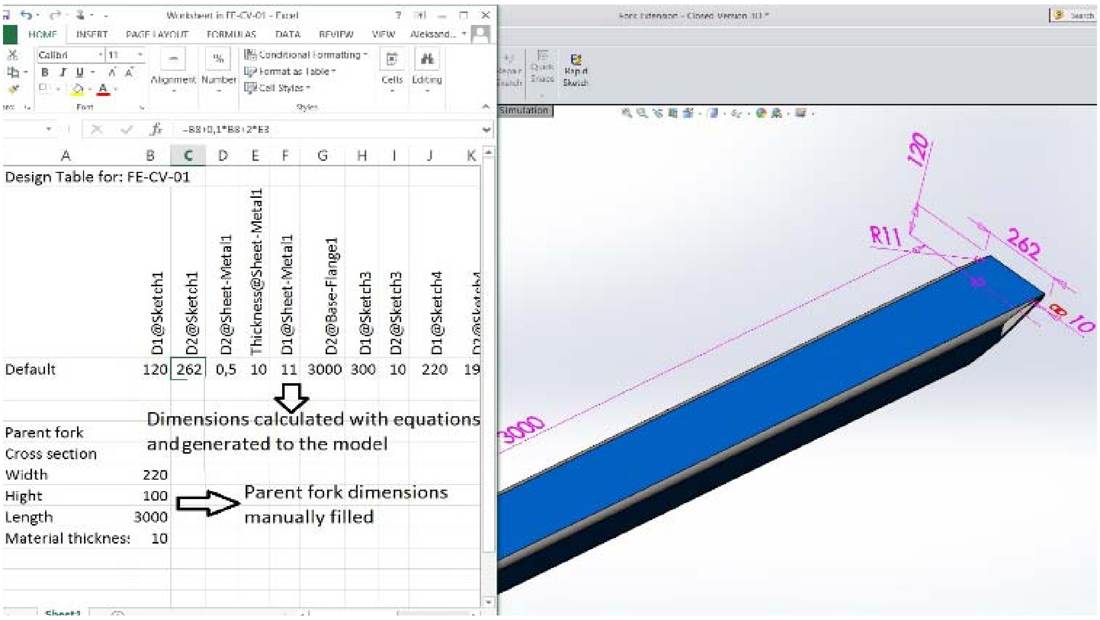

Fig. 4. Modeling with design table

Table 1

Measured times of the both approaches for designing product from Figure 3 [10]

Design steps	Design each variant separately	Design using design table	
	Time per variant (min)	Total time (min)	Time (min)/variant for 200 variants
Creating 3D model	20		
Creating 2D drawing	10		
Creating DXF files	2		2
Creating 3D model and design table		360	1,8
Initial creating 2D drawing		20	0,1
Creating 3D model using design table for each variant			3
Creating 2D drawing using design table for each variant			2
Total time per variant (min)	**32**		**8,9**

Analyzing the results in the table, we can see that the first approach doesn't include any lead time for preparation of the designing of variants, which make it much more productive approach in designing of few variants. But designing of bigger number of variants, according the results in the Table 1, takes much less time using design tables, because the time estimated per unit of variant is few times less than the first approach.

Namely, the productivity of the designers using the second approach is 32/8.9 = 3.56 times bigger.

Saving time of 32–8.9 = 23.1 minutes per variant, for 200 variants is 77 hours in total, which equals to two work weeks of the designers.

Finally, we can summarize that different approaches in designing process, using different tools available in the CAD applications, can increase the designer's productivity several times.

4. COMPUTER-AIDED MANUFACTURING (CAM) AND BENEFITS FROM IT`S IMPLEMENTATION

CAM (Computer Aided Manufacturing) can be defined as application of computer technology in the process of production, using Computer Numerical Controlled machines (CNC machines) and software applications, nearly in all steps in the production process [9].

Implementation of CAM technology in the production process is one of the key factors for the companies from the metal processing industry to stay competitive on the market [4].

Today, almost all technological process that are part of the metal processing industry, are covered by CAM and CNC technology. Milling, cutting, bending, drilling, turning, painting, etc., as basic technological processes in metal processing industry are completely covered with flexible automation, with using CNC machines and adequate software applications (CAM tools) for programming of the machines.

Of course, the conventional approach in above mentioned technological processes using conventional production equipment is still present in metal processing industry. CAM supported and the conventional technological process have their own advantages and disadvantages. The general comparison, between CAM supported and conventional approach in metal processing technological processes are presented in Table 2.

Table 2

CAM supported vs conventional technological processes

Criteria	CAM	Conventional
Flexibility	+	+
Productivity	+	–
Desired operator knowledge for the technological process	+	–
Influence of the operator on the product quality	+	–
Product quality	+	–
Quality repetition	+	–
Programming engineer engagement	–	+
Costs per hour	–	+
Maintenance costs	–	+
Production preparation time	–	+
Scrap (for cutting machines)	+	–

The general benefits that the companies gain from the implementation of CAM technology in the production process, are:

- High productivity;
- High flexibility in the production process;
- High quality and repeatability of the quality;
- Less influence of the operators on the product quality;
- Elimination of technological errors during the programming of the equipment;
- Less scrap (for the cutting technology)

For purposes of this paper, in order to present the influence of the implementation of CAM technology on the productivity of production process in metal processing industry, two major technological process are analyzed, milling and welding. For the both approaches, preparation and production times, for milling same part using CAM technology and conventional milling technology and welding of same product using robot welding station and manual welding, are measured. The results are estimated per unit of product and analyzed.

Milling process

Milling process is analyzed for metal part, shown on Figure 5.

Material of 407 cm^3 is removed from the processed part with simple milling in lines, using the same milling tools on CNC milling center and conventional milling machine and using optimal available milling parameters (number of revolutions, feeds and cutting depts) on the both machines. CNC milling is done on CNC vertical milling center with FANUC 0i–M controller.

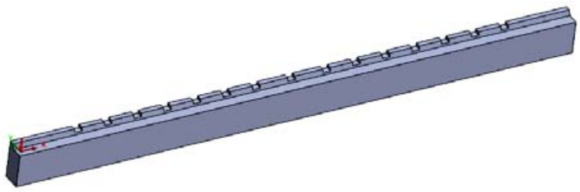

Fig. 5. Milled metal part – 3D model

Fig. 6. Milling process on CNC milling center

Programming is done using CamWorks software application.

The conventional milling is done using conventional vertical milling machine.

The time for production preparation and production time are measured and estimated per piece for the both approaches and they are presented in Table 3.

Table 3

Measured processes time for milling part form Figure 5 using CNC milling centre and conventional milling machine [10]

Approach	For 1 piece			For 10 pieces		For 100 pieces		For 1000 pieces	
	Preparation time (min)	Production time (min)	Total (min)	Preparation time (min)	Total (min)	Preparation time (min)	Total (min)	Preparation time (min)	Total (min)
1 Milling on conventional milling machine	70	360	430	7	367	0,7	361	0,07	360
2 Milling on CNC milling center	165	110	275	16,5	126,5	1,65	112	0,165	110
3 Productivity of CNC milling VS conventional milling			**1,56**		**2,90**		**3,23**		**3,27**

On Fig. 7 is presented diagram of the measured times for the milling process that refers to Table 3.

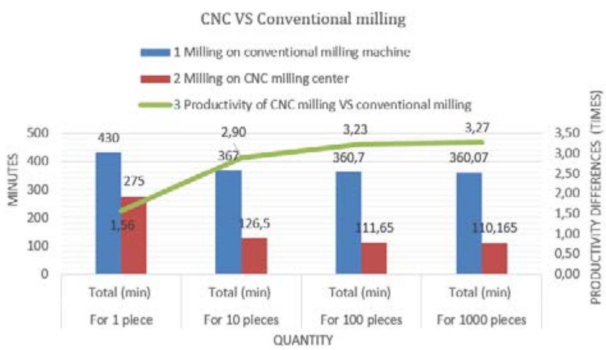

Fig. 7. Diagram presentation of Table 3

Analyzing the measured times, we can see that time for production preparation of the CNC milling center is longer than preparation of the conventional milling machine, but the production time is smaller. For the current case, CNC milling as approach is 1.56 times or 56% more productive approach than the milling on conventional machine.

Increasing of the product quantity, decreases the preparation time per piece, and even for 10 pieces, the CNC technology is almost 3 times more productive approach. Additional increasing of the quantity (up to 100 or 1000 pieces), decrease the preparation time to minimal amount. The influence on the total production time, comparing with the direct production (milling) time, is minor and each quantity increasing, gives smaller and smaller rise of productivity. For example, for 10 pieces, the CNC technology is 2.9 times more productive than conventional milling, and for 1000 pieces, it is 3.27 times more productive, or for increasing the quantity 100 times, the productivity is increased only 12.7%.

Of course, these numbers represent only the current case. This analysis gives results that are different from case to case, but they present real and clear picture, how the implementation of CAM technology in metal processing industry influence on the productivity of the milling technology.

Welding process

Welding process is analyzed for metal assembly, shown on Figure 8.

The welded part has 860 mm weld length in total, and the same welding parameters (current, voltage and welding speed) are used for the manual welding and the welding using the robot welding station. For this purpose, PANASONIC robot welding station is used. For programming the robot welding station on-line method "Point to point" is used [7]. The time for welding preparation and welding process time is measured and estimated per piece for the both approaches. They are presented in Table 4.

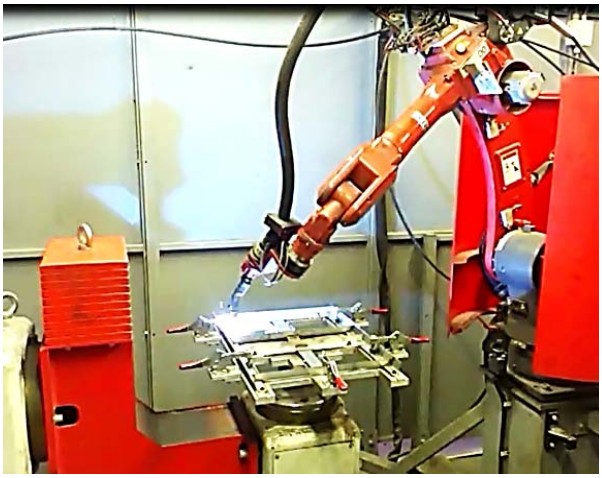

Fig. 8. Welding on robot welding station

Table 4

Measured welding time for assembly from Figure 8 using robot welding station and manual welding [10]

Approach	For 1 piece			For 10 pieces		For 100 pieces		For 1000 pieces	
	Preparation time (min)	Welding time (min)	Total (min)	Preparation time (min)	Total (min)	Preparation time (min)	Total (min)	Preparation time (min)	Total (min)
1 Manual welding	0	11,3	11,3	0	11,3	0	11,3	0	11,3
2 Robot welding	420	3,6	423,6	42	45,6	4,2	7,8	0,42	4,02
3 Productivity of robot welding vs manual welding (times)			**0,03**		**0,25**		**1,45**		**2,81**

On Fig. 9 is presented diagram of the measured times for the welding process that refers to Table 4.

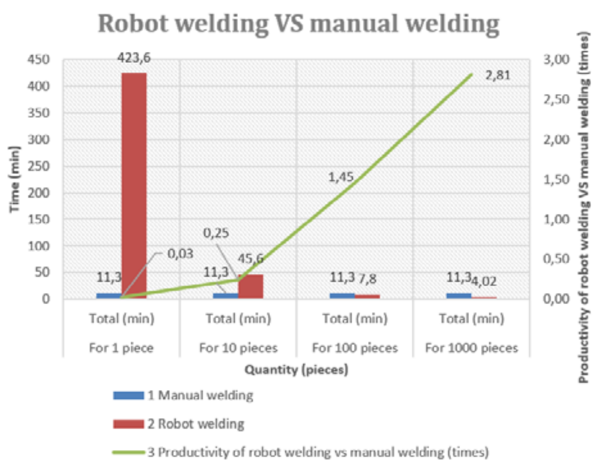

Fig. 9. Diagram presentation of Table 4

Analyzing the measured times from Table 4, we can see that the welding time on the welding station is less than the time necessary for manual welding, but the time necessary for programming of the robot welding station is significantly longer, that makes using of robot welding station for one piece, less productive and wrong choice. Even for 10 pieces, the total time for welding of robot welding station, estimated per piece, is longer than manual welding. According the diagram (Fig. 9), the total time for robot welding approach will be on same level with the manual welding on quantity of around 50–60 pieces.

Keeping in mind the fact that robot welding technology is much more expensive than manual welding, using of robot welding station could be right approach on quantity of more than 100 pieces, where the productivity of the robot welding station is 45% higher than the manual welding.

The additional quantity increasing of up to 1000 pieces, results with 2.8 times higher productivity of the robot welding station, compared with the manual welding.

According the results, we can summarize that if the preparation time for the robot welding process is longer (if the assembly on which is performed welding is more complex, the programming time is longer), the quantity that make this approach more productive is bigger.

Of course, these numbers represent only the current case, and this analysis gives different results from case to case. But nevertheless they present real and clear picture how the implementation of the flexible automation in metal processing industry influence on the productivity of the welding technology.

Influence of the CAM technology in material saving (scrap decreasing)

In general, as a start of direct process of production in metal processing industries, the first action on the raw material is preparation of parts, using different technological processes for plates cutting (plasma cutting, laser cutting, gas or water jet cutting), tubes, bars and profile cutting (conventional or CNC controlled sawing), etc.

This step in the production process is directly connected with the material utilization and influence on the scrap quantity, especially for plates cutting. Using conventional cutting equipment, that is limited to cutting of straight line contours, enable big influence of the operator's skills on the material utilization. Namely, the plan for nesting of the desired parts on the raw material (the plate) is done by the operator, which in case of wide range of different part dimensions, is not always able to make the right nesting of the part, that leads to smaller material utilization (bigger quantity of scrap).

Implementation of CAM technology, mainly in the process of cutting complex contour shapes, supported with the market available nesting software applications, has improved the utilization of the row material, on the way that computer technology and software applications are used for complex calculations that make the nesting of the parts on the plates. The nesting applications have opportunities to generate NC code that is used for the CNC cutting machine as well. So the combination of the software application and CNC machine, forms the CAM system, which improves the productivity and quality of the cutting technology and the material utilization.

For purposes of this paper, in order to present the influence of the CAM technology on the raw material utilization, the case of conventional cutting using conventional shearing machine and the case of using CNC controlled plasma cutting machine for the same part specification, are analyzed.

In the first case, the material nesting is done by the operator, and in the second case, it is used the nesting software ProNest (Fig. 10). For the second case, it is also analyzed the material utilization, using different optimization levels in order to present the influence of the optimization level on the material utilization [10].

In all cases standard dimension of the raw material is used, mild steel plate 6 mm thickness, 1500 × 6000 mm plate dimensions, quality S355J2.

The highest level of optimization requires larger computer capacities, which influences of the time necessary for nesting procedure, but results with higher material utilizations, Lower optimization level, requires lower computer capacities, takes less nesting time, but results with lower utilization. Which optimization level will be used, depends of the utilization criteria, the programmer`s experience and available computer capacities. On Figure 11 is presented the material utilization using ProNest application, with higher optimization level and on Figure 12 is presented the material utilization using ProNest application, with lower optimization level.

The measured average utilization done by the operator for the same part specification is approximately 77%.

The results are presented in Table 5. According the results from Table 5, application of CAM tools can increase the utilization of the material from 7% to 10%, depends of the nested parts shapes and dimensions. Using different optimization levels, results with few percentage better material utilization.

We should mention, that manual cutting on conventional sawing machine, needs additional rework on the parts, which results with additional costs.

For illustration, one mid-size metal processing company that process annual quantity of 500 to 1000 tons raw material, with 10% material saves (50 to 100 tons saves), depends of the current material prices, the investment for CAM system in the process of cutting plates, can be returned in few years.

We can summarize that implementation of CAM technology in the process of material cutting, can save around 10% of the raw material, increases the productivity few times and enables cutting of complex contour shapes.

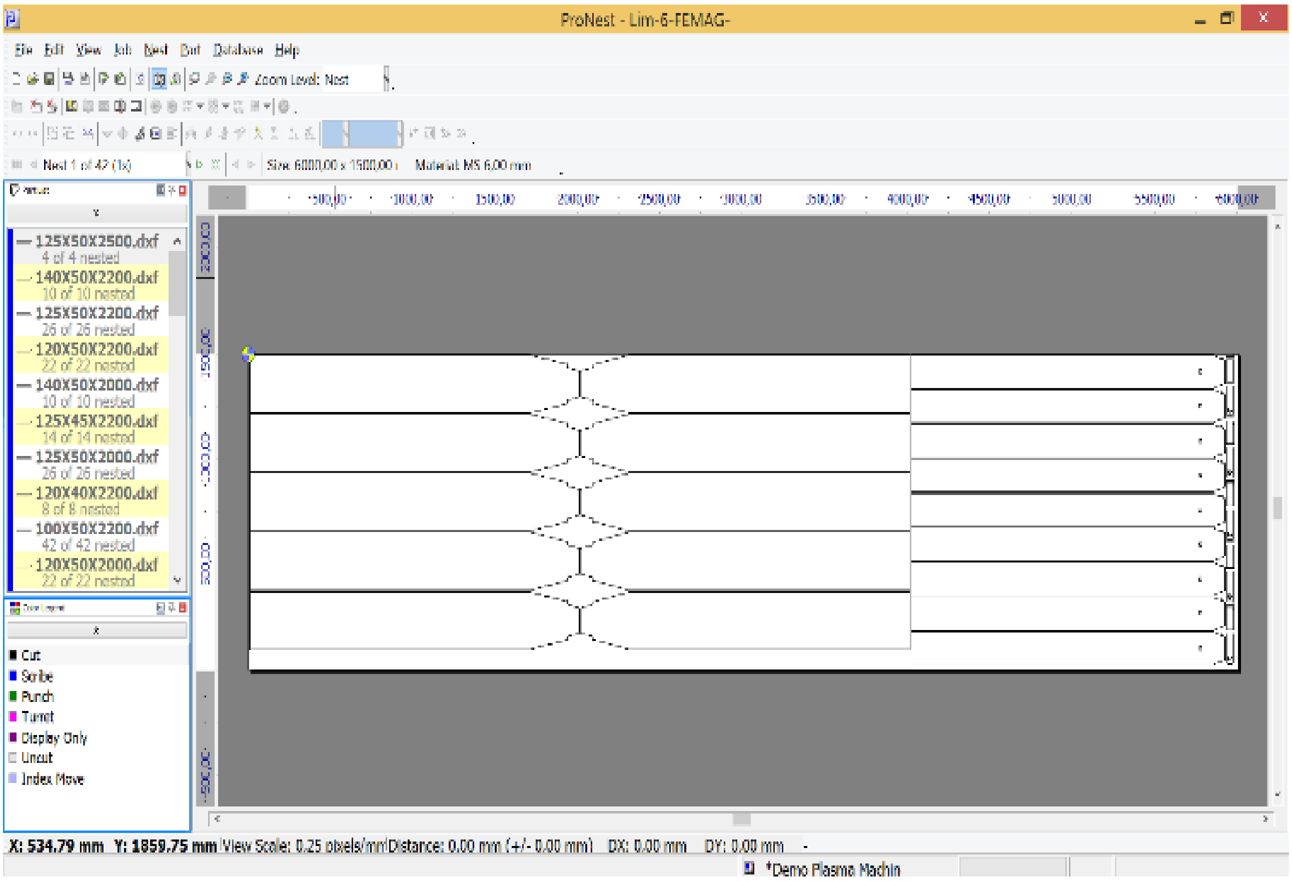

Fig. 10. Nesting with ProNest application

Machine:	Demo Plasma Machine	Cut # of Times:	1
CNC Filename:	Lim-6-FEMAG-STR801.CNC	Number of Parts:	24
Plate Dimension:	6000,00 x 1500,00 mm.	Production Time:	0:32:52
Nest Dimension:	5982,76 x 1482,18 mm.	Processes Used:	Plasma
Material:	MS 6,00 mm.	True Utilization:	88,99 %
Nest #:	1 of 42	Crop Utilization:	88,99 %

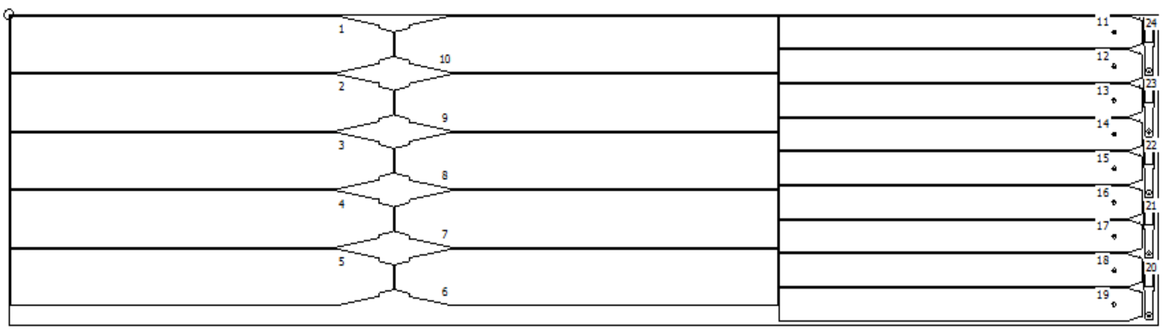

Fig. 11. Material utilization with higher level optimization [10]

Machine:	Demo Plasma Machine	Cut # of Times:	1
CNC Filename:		Number of Parts:	82
Plate Dimension:	6000,00 x 1500,00 mm.	Production Time:	1:04:57
Nest Dimension:	5996,78 x 1499,00 mm.	Processes Used:	Plasma
Material:	MS 6,00 mm.	True Utilization:	84,40 %
Nest #:	1 of 45	Crop Utilization:	84,40 %

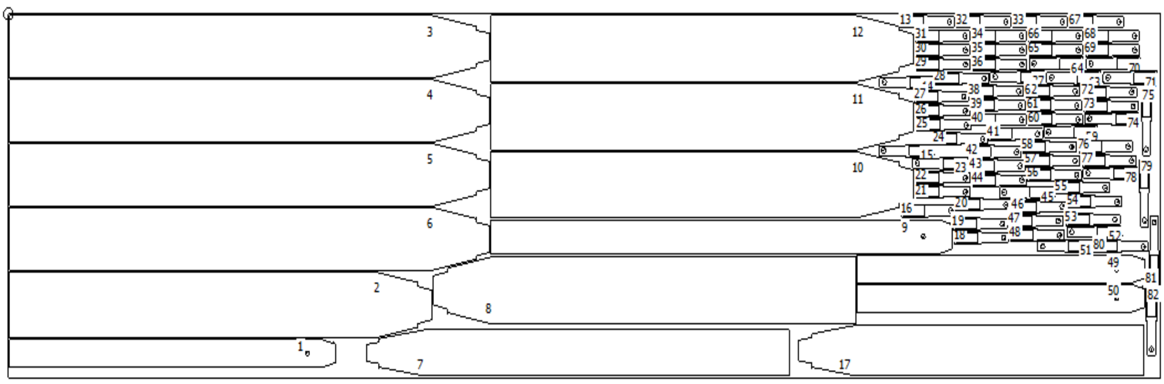

Fig. 12. Material utilization with lower level optimization [10]

Table 5

Material utilization for different nesting approaches

Nesting approach	Utilization (%)
Utilization by operator	77
Nesting with ProNest lower optimization level	84.4
Nesting with ProNest higher optimization level	88.9

SELECTION OF CAD/CAM SYSTEM

Nowadays, on the market exist wide range of CAD/CAM systems and CNC production equipment that can be implemented almost in each technological process from the metal processing industry.

The companies from the metal processing industry sometimes have a doubt to choose CAD/CAM technology or to choose conventional approach in their processes, mainly in the production process because, as it is already mentioned, today the designing process is almost impossible without application of CAD system in the company.

Criteria for selecting CAD/CAM system

Which CAD/CAM system will be chosen by the company, depends on many factors, but in general, the company prescribes some criteria that the system has to fulfil in order to be adopted as best choice for the current needs of the company. There are many criteria, but in general can be classified in two bigger groups [3]:

- exploitation criteria,
- economical-strategic criteria.

The exploitation criteria, refers to the characteristic of the CAD/CAM system, which are directly connected with its usage in the practice. Some more important exploitation criteria are given below:

– Easy for use and learning;

– Compatibility with the existing company equipment;

– Effectiveness and efficiency;

– Available support, service and training;

– Upgrade possibilities;

– Available literature, manuals and handbooks.

As economical-strategic criteria we can mention the following:

– Company needs and strategies;

– Price;

– Total investment costs.

The priority level for each of above mentioned criteria,is defined by the company and it is part of its strategy. The most important during decision making is the right analysis of the company needs and adequate defining of the criteria priority. In practice, the process of analysis and making decision is time consuming, depends from case to case, and can lasts from few months to one year or more.

Productivity and cost effective analysis

Keeping in mind all advantages of the CAD/CAM systems and CNC technology, the decision, CAD/CAM or conventional approach in the production process, mainly depends on the volume of the production series. To determine which approach is better choice, it is necessary to analyze the both approaches from the aspect of productivity and cost effectiveness.

In general, CAM and CNC technology is much more productive, compared with the conventional technology, but the preparation for the production process takes much more time. Therefore, the production time and the preparation time estimated per piece have to be considered in order to make decision, which should be more productive. The total production time for the both approaches has to be compared, so the following equation can be used:

$$\frac{T_{pzc}}{n} + T_{prc} < \frac{T_{pzk}}{n} + T_{prk}\,, \qquad (1)$$

where T_{pzc} is preparation time for the CAM based technological process, T_{prc} is production time of the CAM based technological process, T_{pzk} is preparation time for the conventional technological process, T_{prk} is production time of the conventional technological process and n is number of pieces form the production series. Hence, the minimal quantity of pieces in the production series that makes application of CAM systems and CNC technology more productive than the conventional approach, can be calculated as:

$$n_{\min} > \frac{T_{pzc} - T_{pzk}}{T_{prk} - T_{prc}}\,. \qquad (2)$$

But, in the decision making process, which approach is better choice, the CAD/CAM systems and CNC technology or the conventional production technology, one of the biggest disadvantages of the CAD/CAM technology, the costs for implementation and the running costs, have to be considered. Namely, the CAD/CAM systems and CNC based production equipment has higher costs per working hour, and depending on the analyzed production technology, can be even several times more expensive. Therefore, the productivity analysis is always connected with the costs analysis for the technological process. Each company has internal cost politic and calculated costs per working hour for each production equipment. The calculated costs per working hour for each production equipment include the following: costs for purchasing and implementation of the CAD/CAM system and CNC production equipment, costs for equipment amortization, labour costs, tooling costs, maintenance costs, staff education costs, etc.

Hence, considering the costs per working hour, the minimal quantity of pieces in the production series that makes application of CAM systems and CNC technology cheaper solution than the conventional approach, can be calculated as:

$$n_{\min} > \frac{T_{pzc} \cdot C_{tc} - T_{pzk} \cdot C_{tk}}{T_{prk} \cdot C_{tk} - T_{prc} \cdot C_{tc}}\,, \qquad (3)$$

where C_{tc} is the cost per working hour for the CAD/CAM system and CNC based production equipment, and C_{tk} is the cost per working hour for conventional production process.

The analysis of the productivity and the costs for both approaches in the production process, can help the company to decide – CAD/CAM system or conventional approach. Sometimes, the companies can chose CAD/CAM technology, even the costs are higher, if the productivity is decision criteria number one. At the end, the decision is part of the company strategy politic, which defines what are the priority criteria in decision making (productivity, costs, quality, etc.).

CONCLUSION

Implementation of the CAD/CAM technology in all steps of the product life cycle in the metal processing industry, from design to production, enable the companies to stay competitive and to response on the market requirements.

Analyzing the comparison between using CAD/CAM systems and conventional approach for the production technology processes, we can conclude that CAD/CAM systems have more advantages than the conventional approaches, especially in cases of higher volume of production series. Higher quality and quality repetition, higher flexibility, higher designers productivity, higher design quality, higher production productivity that can be bigger several times, saving material more than 10%, etc., are the key benefits that the companies gain from the implementation of the CAD/CAM technology and CNC based production equipment.

The analysis of the minimal volume of the production series, from aspect of productivity and economical aspects as basic criteria, helps the company to make decision which approach is more effective. Of course, the final decision needs more complex analysis, in which the companies prescribe the criteria list, and select the priority which the CAD/CAM systems have to fulfill.

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Short communication

BENEFITS OF UPGRADING CNC MACHINE FOR ENGRAVING AND CLEANING METAL PARTS

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A b s t r a c t: The main goal of this research is to demonstrate a design solution of upgrading an existing CNC engraving machine for cleaning metal parts. With this improvement the time of finishing metal parts was reduced and higher quality of the finished products was obtained, with improving the safety usage standards. Special CNC engraving machine was designed, which is used for final processing of metal parts. Also improvements in the automatization of the whole process were implemented. The practical aspect was based on the improvements and adaptation of an existing CNC engraving machine with applying innovative measures, which increase the productivity by automating the process and reduction the risk of injuries of the operators.

Key words: CNC machine; engraving; upgrading; cleaning; improvements

ПРИДОБИВКИ ОД НАДГРАДБАТА НА CNC-МАШИНА ЗА ГРАВИРАЊЕ И ЧИСТЕЊЕ МЕТАЛНИ ДЕЛОВИ

А п с т р а к т: Целта на ова истражување е да се покаже конструктивно решение за надградбата на веќе постојна CNC-машина за гравирање во машина за чистење на метални делови. Со ова подобрување се намалува времето на доработка на метални делови и се постигнува поголем квалитет на готовиот производ, со истовремено подобрување на безбедносните стандарди на користење. Конструктивното решение се состои од дизајн на CNC-машина за гравирање е наменета за доработка на металните делови. Исто така се направени подобрувања за автоматизирање на целиот процес. Практичниот аспект се базира на подобрување и адаптација на постојна CNC-машина за гравирање со примена на иновативни мерки кои ја зголемуваат продуктивноста со автоматизирање на процесот и намалување на ризиците од повреда на операторите.

Клучни зборови: CNC машина; гравирање; надградба; чистење; подобрувања

INTRODUCTION

Metal parts in the car industry for production of catalysts are not final products. Usually the customers have additional quality requirements, and for that reason final processing of the products is necessary.

The request is done on written form with an attached sketch. There is a statement regarding which part of the metal product need final processing, surface cleaning from the chemical coating.

The sketch often contains too little information and this is the main reason, why the best quality method of cleaning is applied in order to prevent complaints from customers. The chemical coating that remains on the metal parts after their production is a problem in the welding process, because chemically reacts with the weld seam and changes its physical properties. The chemical coating contains very strong acids and bases, depending on the applied method of welding and reacts differently. In that case it is obviously that an additional welding process will be problematic in case of presence of remains of chemical coating.

Analyses were done in order to investigate how metal parts in similar industries have been cleaned so far. Analyses have shown that two methods are usually applied for cleaning metal parts: using a machine to clean the circular parts or applying a robotic arm. In order to select the most appropriate method an analysis of the advantages and disadvantages of the previous methods was conducted. The advantages and disadvantages of the current cleaning methods are given in Table 1.

Table 1

Advantages and disadvantages of the cleaning methods used so far

Machine for cleaning circular parts		Robot arm for cleaning metal parts	
Advantages	Disadvantages	Advantages	Disadvantages
Costs	Limited shape	Unlimited shape	Complex equipment
Number of cleaned parts	Quality of cleaned parts	Quality of cleaned parts	Costs
Simple equipment			Number of cleaned parts

From Table 1 it can be seen that the both applied methods have quite opposite advantages and disadvantages. Depending on the request from the client, an appropriate method which adequately responds to the client requests is used. To select the most appropriate method additional analysis of the order, has to be conducted. The obtained results are presented in Table 2

Table 2

Analysis of customers' requirements

Planned production on a monthly basis	Cleaning capacity	Possible solutions
Current production of elliptical metal parts is 40.000 pieces	Manual cleaning – 18.000 pieces. Monthly capacity of 2-3 operators	Bringing machine for cleaning with dry ice [11]
Planed aadditional 40.000 elliptical pieces that need to be cleaned in the current year	A cleaning machine with dry ice with a capacity of 60.000 pieces per month (the machine is located outside the country)	Designing a special CNC engraving machine for cleaning metal parts, which will also satisfy the capacity for cleaning the planned number of pieces
30.000 pieces other round parts	Total cleaning capacity of 78.000 pieces per month	Implementing this process in production with the appropriate quality standards [14]
Other forms of parts-8.000 pieces		
Total number of parts which need to be cleaned - almost 120.000 pieces		

From the analysis we can conclude that it is necessary to apply a method which can enable a greater range of geometric shapes of working parts. In this case it is necessary to apply a high precision method, which will be able to clean various types of geometrical shapes (elliptical, circular parts). Cleaning methods applied so far, could not fully respond to the customer requests. In order to respond to the customer demands, a new innovative cleaning method was applied, involving the usage of a CNC engraving machine.

UPGRADING OF CNC MACHINE FOR CLEANING METAL PARTS

The cleaning concept consists of using a CNC engraving machine, as a tool for cleaning metal parts with different shapes [2]. The basis of this idea consists of part A (whose shape and diameter can considerably vary), which needs to be cleaned and to be positioned and a CNC engraving machine where the spindle with a metal brush for cleaning B performs complex movements around the part where the cleaning process is necessary (Figure 1).

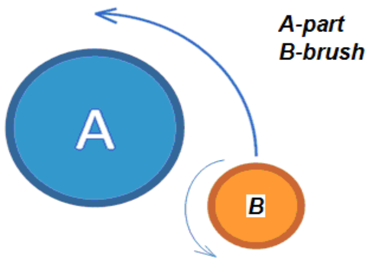

Fig. 1. Movements of the metal brush around the piece [7]

In order to confirm the concept of using an existing CNC [1] engraving machine as initial equipment, firstly the system for holding the parts which need cleaning, was constructed. Since different parts with different shapes [10] have to be cleaned, the biggest challenge was to make an universal system that can grip all forms of processing parts.

Figure 2 shows the concept of design of gripping mechanism for the parts which need cleaning. This system consists of several elements which have specific role in gripping the parts which have to be cleaned and to be placed on the machine desk.

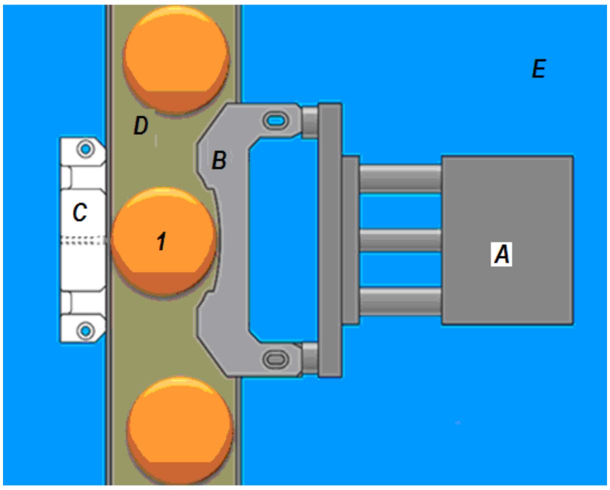

Fig. 2. A conceptual design for gripping parts which need cleaning

A movable arm element B is attached to the air cylinder A. The mobile arm has the shape of the one side of the working part which needs cleaning. The working parts travel on a conveyor belt D, until the moment when the part comes to the center of the static element C. An optical sensor is positioned on that place, which operates using a transmitter-receiver (Figure 3).

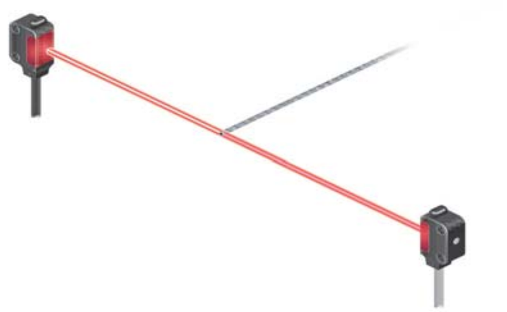

Fig. 3. Optical censor [16]

When the sensor signal is interrupted, an optical sensor detects a piece and the conveyor D stops, while the center section of the part is located just in the middle of the movable element B.. The sensor sends a signal that there is a piece in front of it and it sends the information to the air cylinder A to move. The piece moves to the static element C and it acts on it with constant pressure from the air cylinder A. Figure 4 shows a 3D model of the proposed idea for gripping unit.

Because large amounts of metal parts need cleaning, it was decided this system for cleaning metal parts to be incorporated into the CNC engraving machine with multiple cleaning heads. According the size and needs for cleaning metal parts, the optimal solution was upgrading of a CNC engraving machine with 4 cleaning heads. Figure 5 shows a 3D model of an upgraded CNC engraving machine with 4 cleaning heads.

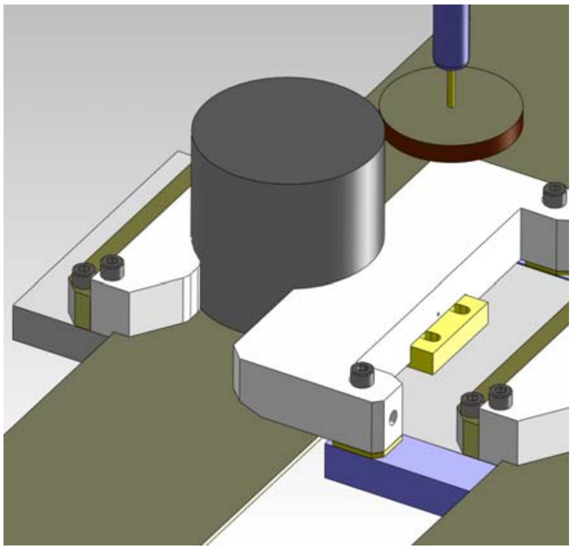

Fig. 4. A 3D model of the proposed idea for gripping unit

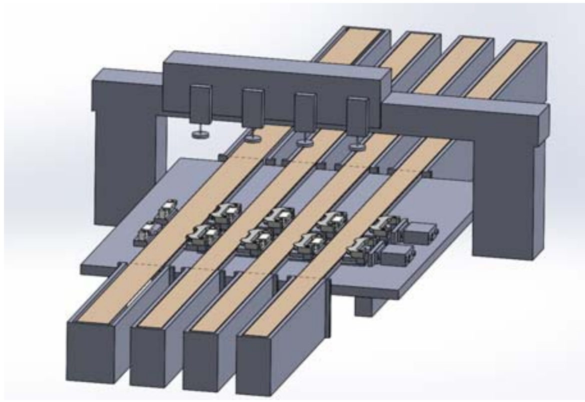

Fig. 5. A 3D model of the implemented system for gripping parts on the engraving machine [6]

All necessary simulations were done on the 3D model in order to check the functionality of the system [3]. All performed tests demonstrated positive results. After that, the next step was implementation of upgraded existing CNC engraving machine. Figure 6 shows a photo of the upgraded CNC engraving machine.

The real model justified the expectations and demonstrated that various forms of working parts can be cleaned at high speed. After the design, the process of complete cleaning with detailed overview of each step [12], was defined. For each step the necessary time was specified, and the total time for cleaning of a particular product was defined.

After the upgrading of CNC engraving machine, a significant step is also the optimization of the overall cleaning process, where all steps are discussed in details and additional improvements are introduced.

Fig. 6. A photo of the upgraded CNC engraving machine [5]

IMPROVEMENT OF THE PROCESS FOR CLEANING METAL PARTS

The metal parts should be cleaned from both sides. After the implementation of CNC engraving machine [13] and its daily use in the cleaning of metal parts, a logical step was a defining standard working procedures for each of the working positions, standard number of operators and jobs, standard time for the working cycle of the machine and finding a technical solution for elimination of the manual work [8].

It was necessary to examine the scope of tasks for each of the operators working on the CNC machine and at the tracks of material flow.

In this analysis the number of pieces that passed through the operators hands were observed. The higher the number of pieces, the greater the opportunities for making errors and omissions. Manipulation and catching the pieces are steps which operators do not notice during the operation. Therefore, the observation was made by another person from distance. The lean tool that was used for this analysis is called Yamazumi-line balancing. The role and involvement of operators who are the most familiar with their work is crucial, so their creativity comes to the fore with this tool. A very important step that should not be forgotten before the start of the observation is the communication with operators which will be involved in the measurement. An important part of this phase of the project was the involvement of operators as the best source of accurate information and experts in the relevant field. Data collection was conducted by two methods of measurement. Firstly, by observing of a video recording and secondly, by direct observation of the work of the operators on the workplace. Dual monitoring was done in order to obtain accurate confirmation of collected data. The calculation of the required number of operators on each of the working positions was done by dividing the total time required to perform all work steps at each working position with the time of one machine cycle (see Table 3).

The required number of operators is rounded to the next integer value.

Table 3

Calculation of the required number of operators for each of the working positions

	Position			
	1	2	3	4
Time of work steps (s)	40	8	8	31,9
Machine cycle (s)	18	18	18	18
Number of needed operators	2,2~3	0,44~1	0,44~ 1	1,77~2

Once the required time for each position was individually defined, the required number of operators for each of these positions, was also established. After the results of the measurements were obtained for each position, an analysis of the data was conducted. Using the collected data, several successive improvements in the cleaning process were made.

- First improvement –- An analysis of the initial balance was conducted. A schedule for operators was made in order to get a more balanced work.
- Second improvement – An extension of the exit conveyors was made and tools for cleaning were defined.
- Third improvement – Analysis and standardization of the machine cycle for parts cleaning.
- Fourth improvement – extension of the conveyors front part in order to get more parts on stock. A Kanban system for inventory control was also introduced.
- Fifth improvement – Adding a second machine for cleaning parts from the both sides and definition of the overall process.

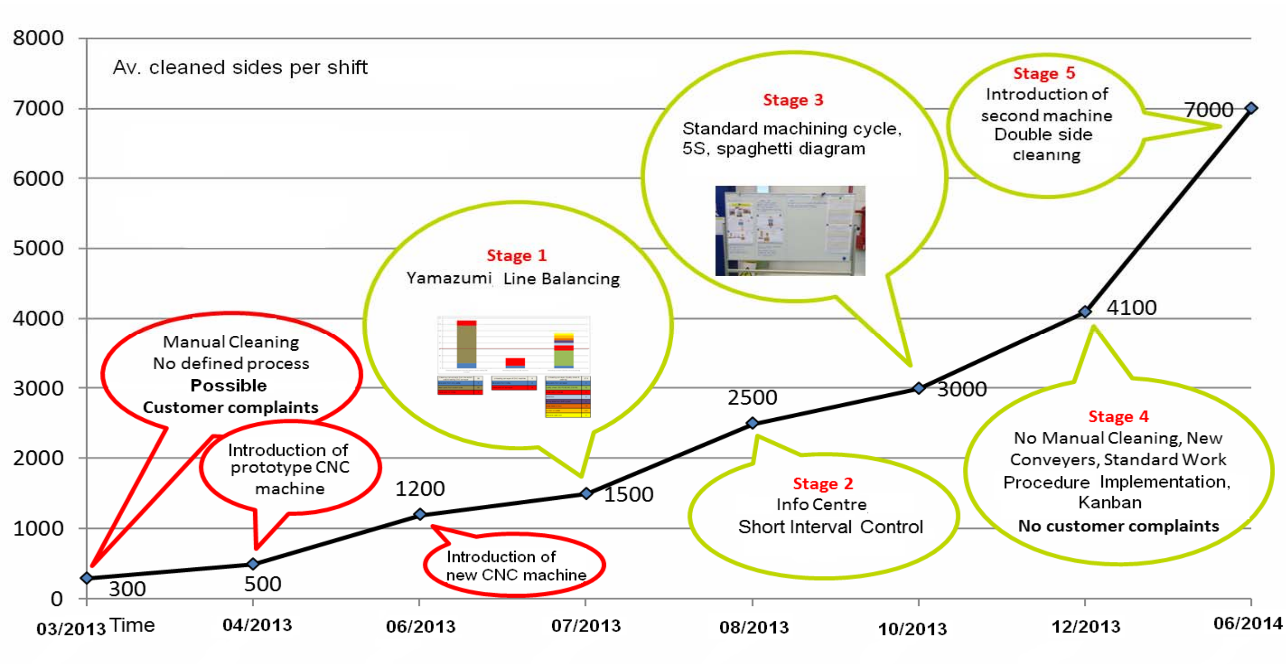

Fig. 7. Influence of improvements on the productivity

All these improvements were made subsequently, one after the other. So, after the each implemented improvement, an additional analysis of the overall cleaning process was made, in order to identify the weak points and to find ways to eliminate them. The relation how the improvements affected on the productivity is presented in Figure 7, where the improvements are presented by stages.

CONCLUSION

This innovation project is an excellent example how a simple CNC engraving machine can be upgraded and used for different purposes. Although the overall project seems very simple, in fact it is a brand new concept for cleaning metal parts, which offers a new direction in the automotive industry. This concept has already been accepted in two factories and it is applied in the same manner. Modern production requires fully functional equipment. The fulfillment of these conditions is only possible if the specialization of the equipment is raised to a high level and the production time of products is drastically reduced, as it is the case with the above mentioned CNC engraving machine.

To achieve this goal, it is necessary to know the specifics of the production process and the applied technical and technological solutions. Different design solutions in practice show different results in terms of quality and time of the finalization of the products under specific conditions of exploitation. But considering cost-effectiveness, it can be said that this design was the best solution. With upgrading the existing CNC engraving machine and optimization of the process of cleaning, the number of the cleaned parts increased from 300 to 7.000 pieces per day.

After this achievement in the process of finishing metal parts, it is expected overall process to be improved with more complex equipment, which can allow finalization of much larger and more complex parts.

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[3] M. Golay, in: *Gas Chromatography*, D. Desty, ed. Butterworths, London, 1958, p. 36.

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