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МАШИНСКО ИНЖЕНЕРСТВО – НАУЧНО СПИСАНИЕ
МАШИНСКИ ФАКУЛТЕТ, СКОПЈЕ, РЕПУБЛИКА МАКЕДОНИЈА

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Original scientific paper

ANALYSIS OF SURFACE ROUGHNESS AND SURFACE HEAT AFFECTED ZONE OF STEEL EN S355J0 AFTER PLASMA ARC CUTTING

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A b s t r a c t: This paper deals with thermal cutting technology of materials with plasma arc. In the first part of this paper the theoretical knowledge of the principles of plasma arc cutting and current use of this technology in industry are presented. The cut of products with this technology is perpendicular and accurate, but the ude of this technology affects micro-structural changes and depth of the heat affected zone (HAZ). This article deals with the experimental evaluation of plasma arc cutting technological process. The influence of technological factors on the roughness parameter *Ra* of the steel surface EN S355J0 has been evaluated by using planned experiments. By using the factor experiment, the significance of the four process factors such as plasma burner feed speed, plasma gas pressure, nozzle diameter, distance between nozzle mouth and material has been analyzed. Regression models obtained by multiple linear regression indicate the quality level of observed factors function. The heat from plasma arc cutting affects the micro-structural changes of the material, too.

Key words: plasma arc cutting; factor experiment; heat affected zone (HAZ)

1. INTRODUCTION

Modern industry depends on processing of metals and alloys. We need metals to build different constructions, tools and transportation devices necessary for modern businesses and modern living. For example, we build cranes, cars, skyscrapers, robots, and suspension bridges with precisely formed metal components. Metals are extremely strong and durable, so they are the logical choice for most constructions that need to be especially big, especially endurable, or both. But, materials strength could be a weakness during their processing [1].

Because the metals are very good in resisting damage, it is very difficult to process them and to form them into specialized pieces. The question is how people precisely cut and process the metals when they need to build something as large and as strong as an airplane wing? In most cases, the answer is plasma cutting. It may sound like something from the science fiction novel, but the plasma cutting is actually a common tool that has been invented in the period around the World War II [2].

Conceptually, the plasma cutting is extremely simple (Fig. 1). Instead of cutting tool we use plasma arc. Plasma is the fourth and the most energized state of matter such as solid, liquid, gas and then plasma. In fact, plasma looks and behaves like a high-temperature gas, but with an important difference, it conducts electricity. The plasma arc results from electrically heating a gas (typically air) to a high temperature. This ionizes gas atoms and enables them to conduct electricity. A fluorescent light is an example of plasma in action. A plasma arc torch spins gas around an electrode. The gas is heated in the chamber between the electrode and the torch tip, ionizing the gas and creating plasma.

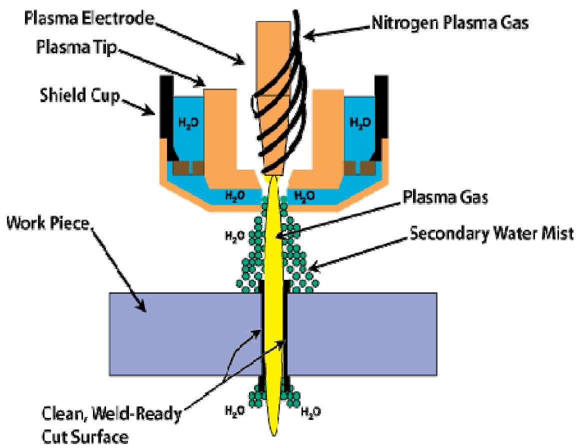

Fig. 1. The principle of plasma cutting [3]

2. THE EXPERIMENTAL EVALUATION OF PLASMA ARC CUTTING TECHNOLOGICAL PROCESS

The influence of technological factors on roughness parameter *Ra* of the steel surface EN S355J0 has been evaluated using planned experiments. By using the factor experiment, the significance of the four process factors such as nozzle diameter, plasma burner feed speed, plasma gas pressure, distance between nozzle mouth and material has been analyzed (Fig 2). This experiment evaluates combinations of all these factors. Constructional steel EN S355J0 with 6 mm thickness was used as an experimental material and the plasma gas was air. We made 16 samples of the constructional material for the experiment.

In the experiment we used four factors [4]. In fact we have the tetra dimensional model. By two levels of different factors, where particular levels are coded as –1 and +1 it presents a full factor experiment of 2^k type. Then with the four factors $2^4 = 16$ different relations will be realized. Such a two-level factor experiment will be used for simple specification of factors, that statistically significantly impact on the variability of the values of the variables y_{Ra}, y_{Rz}, y_{δ}.

The exact test besides main factors also includes interactions of all combinations of factors and levels. After investigation of the impact of all potentially possible combinations of factors and after elimination of statistically not-signified factors it is possible more detailed and more accurate experimental schemes to be developed. To the coded values of –1 and +1 levels, that present the level of observed area of particular factors, real level values of these factors have been assigned (Table 1).

Table 1

Real level values of the experiment factors

N	Marking	Description	Value	Interval of factors –1	+1
1	x_1	nozzle diameter (*d*)	mm	1	1.2
2	x_2	plasma burner feed speed (*v*)	m/min^{-1}	0.6	0.9
3	x_3	plasma gas pressure (*p*)	MPa	0.55	0,68
4	x_4	distance between nozzle mouth and material (*z*)	mm	6.6	7.8

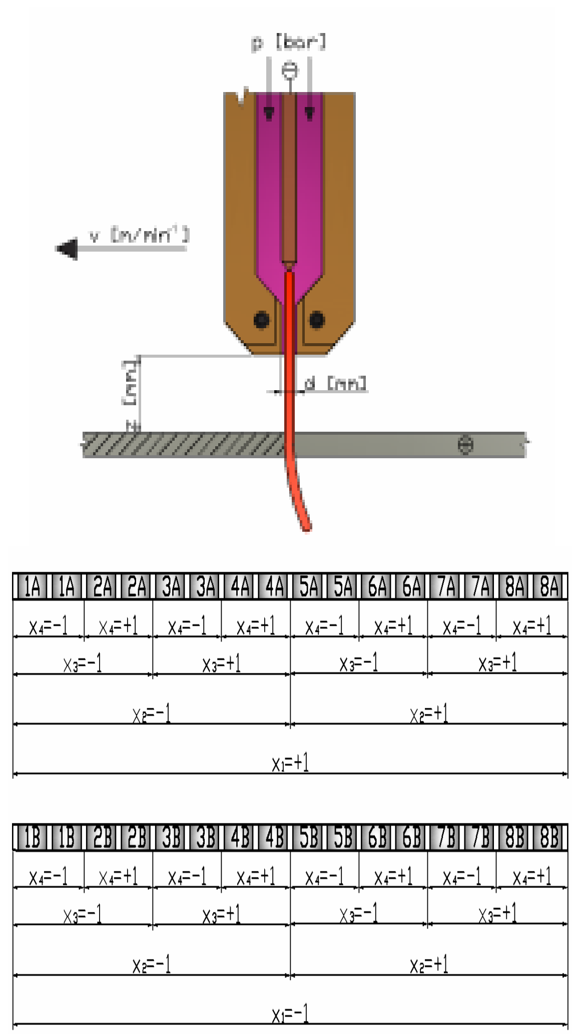

Fig. 2. The process parameters and factor analysis

The roughness was measured in two lines, one and five millimetres from the upper edge. Measurement was realized by the measuring equipment Mitutoyo. Roughness of the surface is created by anomalies of the surface with small separation, which includes anomalies from different technology of manufacturing or other effects. We suppose that these anomalies are within defined limits, for example in the primary length.

Measurement in the first line

The influence of monitored factors to parameter of roughness *Ra on distance on one millimeter* from the upper edge is given in the Paret´s graph (Fig. 3) [5].

The results from the Paret´s graph show that the most influencing factor on the roughness Ra factor is the plasma burner feed speed. From the Paret's graph it is obvious, that the feed factor of plasma torch has the highest impact to the middle arithmetical deviation of surface roughness. The pressure of plasma gas has also significant impact on the quality of machined surface. The nozzle diameter presents lower impact on the quality. The lowest impact is presented by the distance of nozzle mouth from material. After realization of the hypothesis about the importance of particular equations coefficients and elimination of not-signified factors out of linear regression, the final equation was obtained, that expresses the middle arithmetical deviation of the *Ra* profile on relevant measured depth *h* = 1 mm.

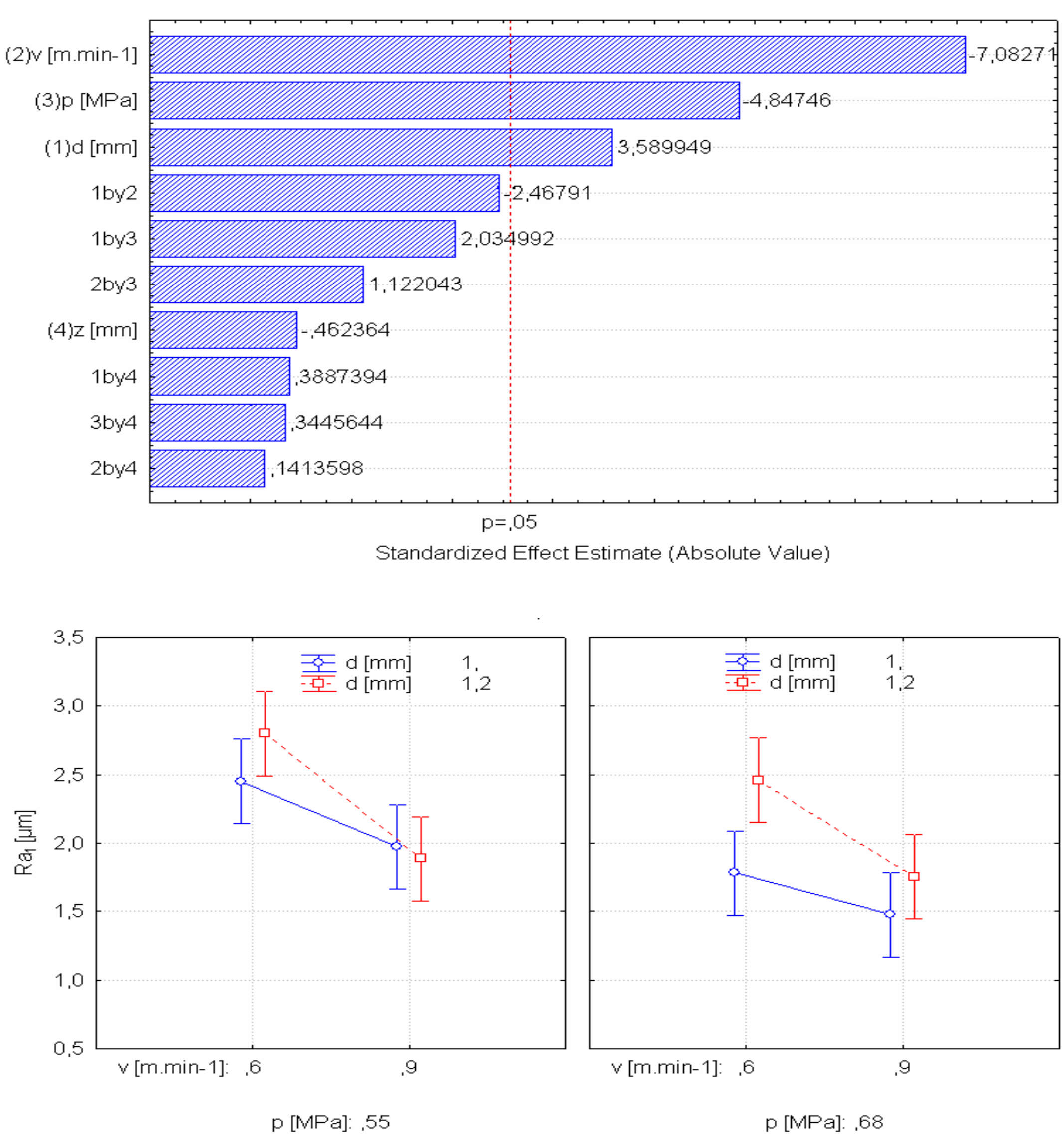

Fig. 3. The Paret´s graph for distance one millimetre from the upper edge

Measurement in the second line

The influence of monitored factors on the to parameter on the roughness *Ra in the distance of five millimeters* from the upper edge is given in the Paret´s graph (Fig. 4).

From the Parent's graph it is obvious, that the feed factor of plasma torch has the highest impact on the middle arithmetical deviation of surface roughness. The pressure of plasma gas has also significant impact. Minimal impact level is presented by the nozzle diameter and the distance between the nozzle mouth and material.

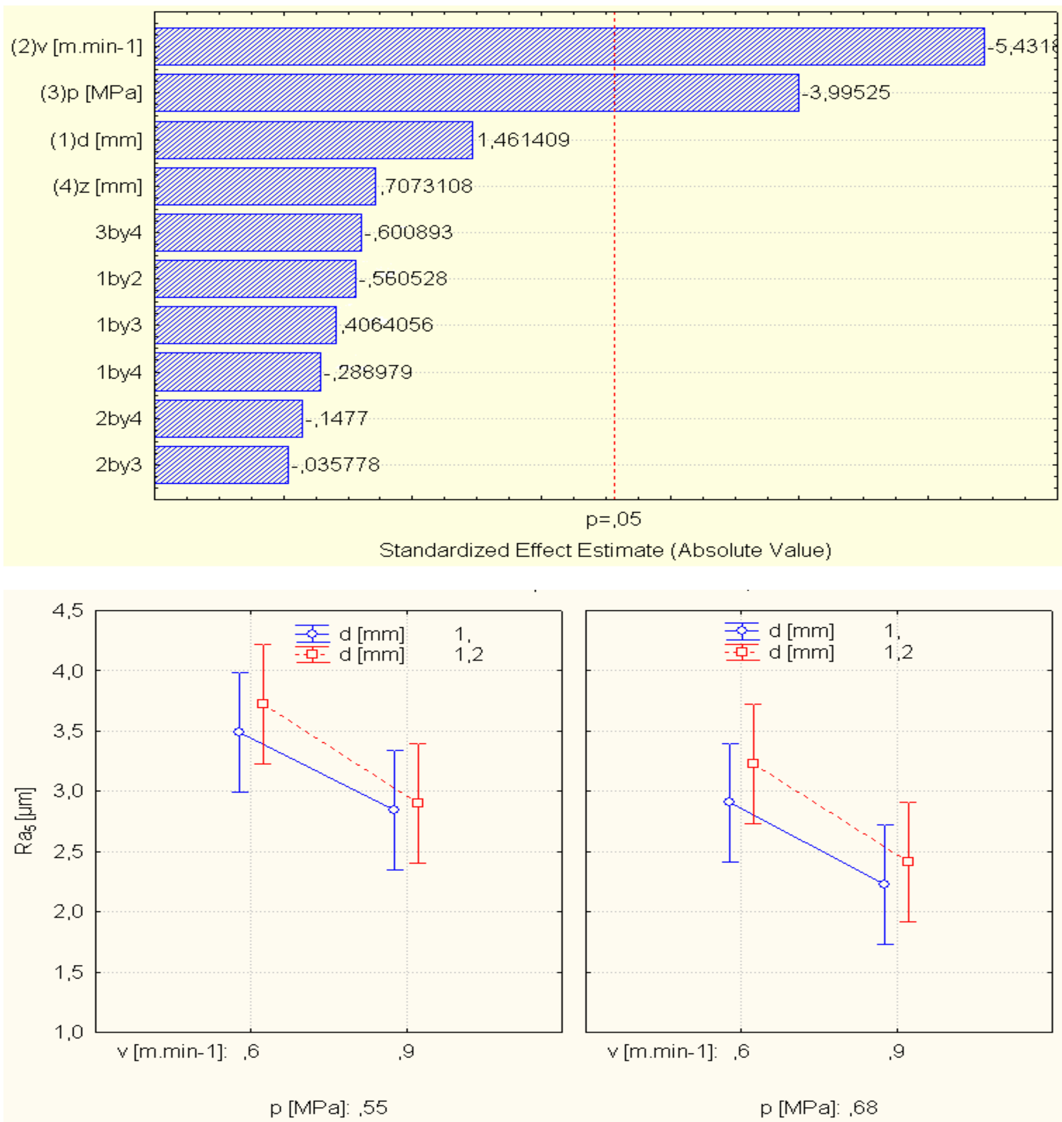

Fig. 4. The Paret´s graph for distance five millimetres from the upper edge

3. HEAT AFFECTED ZONE (HAZ) AFTER CUTTING

Investigations of micro-hardness showed that, the maximum value immediately increases at the cut surface approximately on 255 HV1 in the deposit across a distance of 0.7 mm (thickness 20 mm), on 240 HV1 in the deposit across a distance of 0.5 mm (thickness 15 mm) and on 110 HV1 in the deposit across a distance of 0.4 mm (thickness 10 mm) (Fig. 5). The micro-hardness is connected basically to the local changes in the mechanical properties of the material [6].

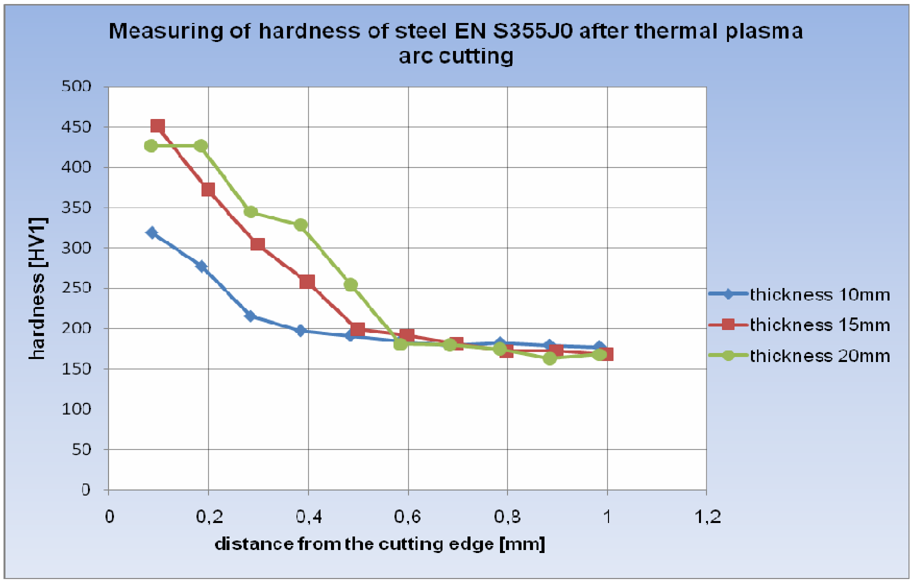

Fig. 5. Measuring of hardness after plasma cutting

It can be seen little difference in micro-hardness that results in a narrow heat affected zone.

The micro-structural damage zone (heat – affected zone) is approximately to 0.7 mm depth. The heat affected zone is narrower than plasma cutting and the peak hardness is higher compared with the flame cutting.

Austenite formation is found to be complex while the material is heated to a temperature of 741 ºC (between Ac1 and Ac3 temperatures). The result of this shows continued growth of austenite.

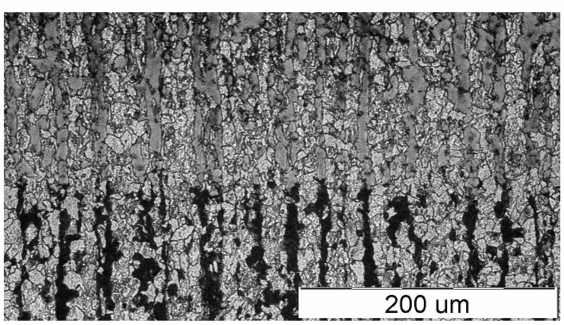

Fig. 6. Heat affected zone – magnification 200×

Passing the eutectoid temperature during cooling requires a radical change. Practically all the homogeneously dissolved carbon now has to go to the inhomogeneously distributed cementite – by diffusion. The austenite is quenched, i.e. rapidly cooled. The carbon stays in place, more or less, and this necessarily prevents pearlite and ferrite formation. Instead, a new lattice type is found, called "martensite". Its volume is getting down to the core of the base material. Heat affected zone goes through the narrow zone of normalization with fine – grained structure and considerably wider zone of partial pre – crystallization. This is damage created by a plasma torch cut. Before plasma cutting, the microstructure was a banded pearlite and ferrite (Fig 6).

4. CONCLUSION

This paper deals with definition and evaluation of the process factors and parameters of the cutting surface of the material EN S355J0 cut with plasma arc. Methods of planned experiments are used for these evaluations. By using the factor experiment, the influence of four factors on the parameter of the profile roughness Ra was observed (feed rate of plasma torch, plasma gas pressure, nozzle diameter and distance between nozzle mouth and material).

By using the results that were analytically estimated by the factor analysis, it can be concluded that the impact of process parameters during the material plasma arc cutting is different for particular depths. The following factors such as feed rate of plasma torch and plasma gas pressure have the most significant impact on the machined surface roughness. Other factors that are less important are diameter of the nozzle and the distance between the nozzle mouth and the material. From the experimental results we can conclude that it is recommended to use higher pressures of plasma gas and appropriate feed rate of plasma torch in order the achieve higher quality of cut surface.

All measurements in the heat affected zone (HAZ) were done on depth between 0.4 – 0.7 mm.

The size of the heat affected zone (HAZ) depends on process variables, such as cutting speed and power of the plasma arc, as well as the material thickness.

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Р е з и м е

АНАЛИЗА НА ПОВРШИНСКАТА РАПАВОСТ И ТЕРМИЧКИ ОПТОВАРЕНАТА ПОВРШИНСКА ЗОНА НА ЧЕЛИКОТ EN S355J0 ПО СЕЧЕЊЕТО СО ПЛАЗМА

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Клучни зборови: сечење со плазма; факторен експеримент; термички оптоварена зона

Овој труд се занимава со проучување на термичкото сечење на материјалите со помош на плазма. Во првиот дел од трудот се дадени теоретските основи на принципите на сечењето со помош на плазма и користењето на оваа технологија во современата индустрија. Сечењето на производите со оваа технологија е прецизно, но нејзиното користење влијае на промените во микроструктурата на материјалот, како и на длабочината на термички оптоварената зона. Во овој труд е прикажана и експериментална анализа на технолошкиот процес на сечење со плазма. Влијанието на технолошките фактори врз параметарот на површинската рапавост *Ra* на челикот EN S355J0 беше проценето со употреба на планирани експерименти. Со користење на факторен експеримент беше анлизирано влијанието на четири главни фактори на технолошкиот процес: брзината на поместот на горилникот со плазма, притисокот на плазма-гасот, дијаметарот на млазницата и растојанието помеѓу отворот на млазницата и материјалот. Регресионите модели добиени со повеќекратна линеарна регресија укажуваат на нивото на квалитет на набљудуваните факторни функции. Топлината од сечењето со плазма влијае исто така врз микроструктурните промени на материјалот.

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Original scientific paper

KEY FACTORS FOR MANAGING TURNAROUND IN THE MACEDONIAN ENTERPRISES

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A b s t r a c t: This paper analyzes the need of new managerial staff in companies which are facing problems, or more precisely whose continuous existence is brought in question. The actions required during the turnaround process, or in the process of making corporate recovery are essential and serious, but also quite more rigorous and severe compared to those performed in the past when the organization had excellent performance. The impact of the managing style of companies which are facing crisis has been analyzed focusing primarily on those who intend to implement the process which that will lead to a reversal performance and make of a turnaround.

Key words: recovery; organization decline; changes' turnaround

1. INTRODUCTION

A "turnaround" is to produce a noticeable and endurable improvement in performance, to turnaround the trend of results from down to up, from not good enough to clearly better, from underachieving to acceptable, from losing to winning, action taken to prevent a situation of financial distress [1] [2] [3]. Permanent changes are common in today's business world and everything that used to be a recommendation until yesterday, from today it is an obligation. Businesses that are eager to slow adaptation expose their cost-effectiveness to high risks. Thus, "turnaround management" helps companies implement realistic, operational and revitalization solutions, aspiring to regain stability and sustainable profitability. More precisely, the philosophy includes several different types of leadership, pointing out to the need of different managerial activities compared to the activities that the managers are taking during a stable business situation [4].

2. THEORETICAL BACKGROUND ON TURNAROUND MANAGEMENT

Turnaround is often an overused word and should not be confused with crisis stabilization or cash management projects, although these can form key components of a turnaround process. Turnaround is not something that is achieved in a matter of months or when a cash crisis is resolved, it is about developing and implementing a long-term plan which creates value for the organization, greater than the pass. Fundamentally, it is important to draw the distinction between managing a crisis and implementing a long-term strategic plan [5]. A common pitfall is that management gets over the first hurdle, but does not think clearly enough about the longer term. All that happens then is that the crisis comes back at some future point and you enter a downward spiral again which perhaps would lead to the closing and dissolution of the employees. Therefore there should be managerial activities that can "cure" the companies which are in trouble and can keep them healthy in future. One of the most effective methods (which can make a situation) where the performance is in decline and is followed by performance of improvements, or takes a company from a situation of poor performance to a situation of good sustained performance [6] is actually a turnaround management. When business performance suffers there are few options for owners, shareholders or top management that is to watch the decline in performance and keep fingers crossed for something to happen, to bring the end of the haemorrhaging, to sell the business off to someone else, the worst is to liquidate or to *turn the performance around*.

Before formulating a possible effective turnaround strategy, there is a need to determine the reasons that caused the crisis. Most commonly, these reasons occur from the internal or external nature. The internal one comes out from the company, such as revenue downturn caused by a weak economy, overly optimistic sales projections, poor strategic choices, poor execution of a good strategy, high operating costs, high fixed costs that decrease flexibility, insufficient resources, unsuccessful R&D projects, highly successful competitors, excessive debt burden, inadequate financial controls, and inefficient human resources.

The surrounding of the organization or more precisely the working environment in which the organization exists, is limited with resources, implying that only the most capable once will survive. Organizations that fail to fit into the business environment, decline in their performance [7]. On the other hand, what is much worse is that organization management justifies the failure of the company quite often, mostly because of external factors which are largely beyond their control. Often these factors are general economic situation, unfavourable legislation (legal provisions), fluctuations in interest rates, labour strikes, increasing labour costs, competition, reduction of the market, increasing costs of raw materials and other resources. When all factors from the external environment are taken into consideration such as economic, sociocultural, global, technological, legal and political, as well as demographic ones thousands of variables might be identified that have an influence and may change for or against the company's operations.

3. RESEARCH METHODOLOGY

In order to gain some aspects that are important for the process of "turnaround" in the organizations, a research was conducted in the Republic of Macedonia [8]. Data for this study were acquired through a questionnaire that was delivered to companies in the Republic of Macedonia and the entire procedure was electronically collected, completely confidential for the respondents. The total number of answered questionnaires is 42, the surveyed managers were from 41 companies in nine cities, with most respondent companies being situated and established in Skopje, followed by Štip, Tetovo, Bitola, Prilep, Veles, Kočani, Vinica. Varieties of industrial activities of enterprises were included, or more precisely about 17 different industrial activities were studied (Fig. 1). According to the classification of enterprises by the number of employees, most of the companies surveyed are with 51 to 250 employees and 93% are from the private sector, 5% are holding companies and only 2% are state enterprises.

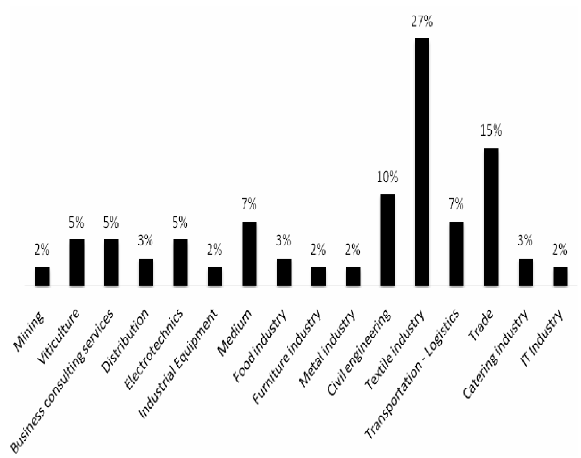

Fig. 1. Industrial sector of enterprises

In order to achieve the goals of this research, to determine whether a change on the organizational leadership is necessary and how the management style influences the process of turnaround, the regression analysis was used. In statistics, regression analysis includes any techniques for modelling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps us to understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed.

4. RESULTS AND DISCUSSION

If top management decides to take action for the turnaround process, they should realize and understand almost all situations that turnaround team might or will be facing. Turnaround manager does not exist because things are running well, but rather because they are broken and things have to change. Therefore, managers need to have a great experience and ability to come into a chaotic situation, ascertain what the business needs most, recharge a beaten-down staff and start piling up the wins quickly. What companies seek in a turnaround manager is someone who has the intestinal fortitude and political savvy to know how to cut and grow at the same time. That's no an easy task.

Before beginning with the process of turnaround, it is important to understand why the company works unsuccessfully. The answer often lies in poor management of the company. Furthermore, a set of internal and external factors mostly controlled by the management is given:

- Ineffective communication between the managers and their team;
- Neglecting human resources, which is manifested by their frequent change, which results in low morale, decreased productivity, not functional teams and at the end, a general unsuccessful performance of the organization;
- Ineffective programs for compensation, stimulation and motivation of the employees;
- Not understood or underachieved organizational goals;
- Inadequate analysis on the market and the strategies;
- Insufficiency of the punctual and accurate financial information;
- History of successful enlargement plans which take advantage over the cash resources of the company, the time and moral of the employees, and create a shortage and luck of willingness to undertake future expansion plans. The efforts for enlargement most often fail, due to the insufficiency of cash resources, managerial expertise or insufficient analyzes of the market.
- Uncontrolled or an expansion which is not managed. In this case, the business functions do not support each other and the business is not supporting the expansion. Many companies focus exclusively on one business aspect (growth in sales, operations and infrastructure) and leave behind all other aspects.

From the aforementioned, the following thesis related to the management of the company was created:

H1: Company that has poor performance and has declining results, does not require "new life" in the management board, and does not need to hire new executives at top positions in order to return back again and be successful.

In order to explore the necessity of a replacement of the executive managers to improve situation, to change the organization and make it recover, and respectively to realize the organization's turnaround, regression analysis was undertaken at the 0.05 level of significance.

The results indicate that the model is significant (Sig. 0,000), and has an R square of 44.13%. The general model is:

$$Y = 0.169 + 0.885\, X_1$$

The model suggests a positive relation between the replacement of the executive managers and the improvement (Table 1), advising that if a replacement of the managers is made, one shall expect an improvement in the situation prevailing in the organization.

Table 1

Assessing the possibility of new managers

Model		Unstandardized coefficients	Sig.	R square	Sig.
1	(Constant)	.169	.710	.441	.000
	Replacement leads to recovery	.885	.000		

The recognition of the significant influence that this replacement has on the possibility of improvement of the organization overall, or more precisely, whether turnaround will be undertaken in the organization, is initiated from the capability of the managers to pin point, identify and accept the mistakes that they are making, and consequently to take the responsibility and corrective measures. This responsibility mostly can be translated in a replacement of the current manager with one goal only, managers that are capable to lead the organization towards improvement to be able to enter it. From the aforementioned, it can be concluded that hypothesis H1 shall be rejected, and the alternative hypothesis: "The company that has bad performances and has declining results, has the need of a new breeze in the management board, of new executive directors and other crucial figures; in order to return back on the right track and to become successful again" shall be accepted.

This conclusion is supported by majority of foreign researchers and practices of turnaround management further confirming that the same is valid and applicable for the organizations existing in the Republic of Macedonia. Furthermore, this conclusion is supported by the fact that almost every second manager, who participated in the research, had a positive opinion claiming that a change in the leading positions is crucial for a successful turnaround to be performed. With this, the importance of the replacement and the undertaking of responsibility for the actions that are leading towards decline are underlined.

When one organization as a unity is examined, a mutual conclusion is that its most valuable possession are the people. In brief, without people there is no business. If the human resources of the company are motivated, committed and innovative in their leading intentions, if they undertake business activities in most effective and most efficient way compared to the one of their competitors; then one might say that there is a base for a profitable business. However, if the human resources are under the ordinary, are not committed and do not have an interest, the business can't reach its optimal level, thus it results and generates losses instead of profit.

In brief, all of this implies the crucial importance of the managing style, or more precisely the way that the manager will succeed together with his employees to make a turnaround in the company. The managing style that was analyzed in this research is the autocratic style of managing an organization, or more precisely the manager is an autocrat, giving orders, undertaking punishments and restrictions if the goals are not met, or give out rewards when the aims are met. For this style, it is typical that there are one way relations, or more precisely the information flow is from the manger towards the employees. The autocratic managers do have a powerful position, do not ask but rather give out orders, use dictatorial style in order to achieve what he/she wants because for this type of character, the most difficult thing is to communicate in an open way. In order to examine whether this kind of managerial way is needed for the revitalization of the organization and the achievement of a successful turnaround, the following hypothesis is stated:

H2: A company that has poor performance and is declining, requires a manager with autocratic style of management in order to return back again and become successful.

In order to demonstrate whether necessary or not autocratic style of a manager to realize successful process of turnaround in performance of the company, regression analysis was undertaken at the 0.05 level of significance. The results indicate that the model is significant (Sig. 0.000), and has an R square of 44.9%. The general model is:

$$Y = 1.776 + 0.483\,X_1 - 0.72\,X_2 - 0.224\,X_3$$

The model shows that communication between employees and managers in the decision making process is positively related with the negative impact of communication in one direction when making decisions which are essential for overcoming the crisis of the company, but negatively related with the practice of unilateral decision-making, and as for quick decisions it does not need communication. It can be concluded that during the process of making decisions, the managers use communication with subordinates, but do not practice unilaterally making decisions, because they think the communication in one direction has a negative influence on the process of making important decisions, even those that should be made for shorter time.

From what is said earlier, we can conclude that hypothesis *H2* is rejected, and we accept the alternative one, which means that a company that has poor performance and is declining, but wants to return back again and be successful, it does not require a manager with an autocratic style of management. Because of this, we can reject this style of management, when it comes to make a turnaround and overcome problems in Macedonian enterprises.

5. CONCLUSION

This paper represents a part of wider research [8] that was conducted in 41 Macedonian companies in order to analyse understanding of the management philosophy of "turnaround management" and what is the managers' expectation from this philosophy. Several factors derived as crucial for successful implementation of "turnaround", and in this paper two of them were analyzed. The main conclusions from the research are:

– New management is needed in order to improve company performances.

– A more participative approach (with greater involvement of all employees in the key decision making process) instead of an autocratic management style is necessary in order to have successful "turnaround".

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Р е з и м е

КЛУЧНИ ФАКТОРИ ЗА МЕНАЏИРАЊЕ НА ПРЕСВРТ ВО ПРЕТПРИЈАТИЈАТА ВО МАКЕДОНИЈА

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Клучни зборови: надоместување на загубеното; организациско опаѓање; промени; менаџмент за пресврт

Во овој труд се анализира потребата од нов менаџерски кадар во компании кои се соочуваат со проблеми или, кога е во прашање нивниот опстанок. Потребните акции кои се преземаат за време на пресвртот, односно правењето пресврт, се многу посериозни, построги и поригорозни од оние кои ќе требало да се направат во минатото. Поради тоа, е претставено и анализирано влијанието на стилот на менаџирање во компаниите кои се во криза и сакаат да реализираат успешен процес кој би довел до пресврт во перформансите на работењето.

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WELDING TECHNOLOGY OF BUTT WELDS AT ASSEMMBLING THE MAIN GRID BEAMS FROM THE SPORTS HALL IN SKOPJE

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A b s t r a c t: The subject of this research is the theoretical and experimental research of technology of welding at assembling the main steel beams from the sports hall in Skopje, as the most vital elements of the structure. Some details from this analysis and experimental research have been presented in reference [1].

Key words: welding technology; butt welds; metallographic analysis; steel grid beam; ultimate strength; toughness

1. INTRODUCTION

The steel structure of sports hall located in the city of Skopje is a grid roofs structure which contains two main grid beams (GN1 and GN2) with length (span) of 73 m (Fig. 1).

Fig. 1.

The main space grid beams are made from piped profiles with a squared section.

Hot shaped piped profiles with the squared section of 400.400.16 and 400.400.20 mm are used for the upper and downer layer.

2. MATERIAL FOR THE MAIN GRID BEAMS

For manufacturing the grid beams the project predicted steel S355J2H (St.52-3N) according to EN10210 (DIN 17100), also known as C.0563 according to MKS (JUS) C.BO.500 [2].

According to this standard the following features, that are given in Table 1 and Table 2, are recommended for the predicted material.

T a b l e 1

Chemical components

Chemical element	(%) max
C	0.22
Mn	2.60
Si	0.15 ÷ 0.25
P	0,035
S	0.03

T a b l e 2

Mechanical features

Yield strength, f_y (N/mm^2)	355
Ultimate strength, f_u (N/mm^2)	470÷630
Δl (%)	22
Toughness, ρ (J) –20 ^{o}C	27

The manufacturer has an attest for the material S355J2H (St 52-3N), that is Č.0563 in which the chemical and the mechanical features are specified. The material is retested, and the chemical and the mechanical characteristics are confirmed. They are in the limits that are recommended by the standard EN 10210.

3..TECHNOLOGY OF WELDING THE BUTT WELDS

According to the responsibility of the object the "S" category from the quality from the welded connections from the steel welds according to the MKS standards that fit the "B" category according to the European Norms (EN) is predicted.

While the welding technology was being designed, the material was considered, the quality of the welds that was required ("S" quality), the conditions for producing in the workshop and the restriction, as in the available technical and other company resources that are given the sports hall performance.

Because it is all about the "S" quality, it is made an experiment confirming the technology for the bigger number of rehearsals (examples), until the chosen quality is being reached. The final technology results will be presented in the text.

3.1. Theoretical analysis of the welding technology of the butt welds

Specification of the welding technology WPS. The specification of the welding technology and the experiment confirming the technology are done completely according to the European Norms (EN).

Because the elements that are being welded are with piped profiles with squared section, the origin must be taken care and well checked. Because of that, for welding the origin electrode with deep penetration is predicted and for welding the other and the ending passage base electrode is predicted. Base electrode is accepted, because the base electrodes characteristics are high mechanical with high toughness and ductility.

After the test method of the technology, that is according to the quests from the EN 288-3, a selection from the optimal welding technology is done.

The 12 examples (test-specimens) were welded (profiles and sheets with thickness = 16 mm) with more combinations of the extra materials:

1. Welding the profile 400×400.16 mm:
   – Origin weld-electrode ELE Mo
   – Full-electrode EVB Mo
2. Welding the profile 400×400.16 mm:
   – Origin weld-electrode EVB Mo
   – Full-electrode EVB Mo
3. Welding the profile 400×400.16 mm:
   – Origin weld-electrode EVB 50
   – Full-electrode EVB Mo
4. Welding the plate 360×400×16 mm:
   – Origin weld-electrode ASB 248
   – Full-electrode ASB 248
5. Welding the plate 360×400×16 mm:
   – Origin weld-electrode ELE 50 CMo
   – Full-electrode ASB 248
6. Welding the plate 360×400×16 mm:
   – Origin weld-electrode ELE 50 CMo
   – Full-electrode EVB 50
7. Welding the profile 400×400.16 mm:
   – Origin weld-electrode ELE 50 CMo
   – Full-electrode ASB 248
8. Welding the profile 400×400.16 mm:
   – Origin weld-electrode ELE 50 CMo
   – Full-electrode EVB 50
9. Welding the plate 360×400×16 mm:
   – Origin weld – TIG
   – Full-electrode EVB 50
10. Welding the plate 360×400×16 mm:
   – Origin weld-electrode EVB 50
   – Full-electrode EVB 50
11. Welding the plate 360×400×16 mm:
   – Origin weld-electrode ELE 50 CMo
   – Full-electrode ESAB OK 48.60
   – Before heating temperature $T = 159$ °C
12. Welding the profile 400×400.16 mm:
   – Origin weld-electrode ELE 50 CMo
   – Full-electrode ESAB OK 48.60
   – Before heating temperature $T = 150$ °C.

For all 12 examples (plates and profiles) the research of the mechanical features and the toughness is complete and from the examples 1, 2, 7, 8, 9 and 12 a metallographic analysis is made and measurements from the hardness in the characteristic points from the welds section as well. On the other hand these tests are marked in the following way:

Test 1 – Example no. 2, Test 2 – Example no. 1,
Test 3 – Example no. 7, Test 4 – Example no. 8,
Test 5 – Example no. 12, Test 6 – Example no. 9.

The examples 3, 4, 5, 6, 10 and 11 that are welded on the plates with dimensions of 330×400×16, for which only mechanical researches are made, gave results which satisfy the criteria for material toughness on –20 °C. With the additional extra materials the profiles 400×400×16 are welded, but significantly smaller values are obtained for the toughness, that triggered us, having the dimensions and chemical features of the material, to think in a way that can be welded by heating it before.

The before heating temperature is measured by the Seferian method and it is:

Ch = 0.40 – equivalent is with carbon according to the chemical features,

$C_{ekv} = C_h\,(1 + 0.005 \cdot d)$

$C_{ekv} = 0.40\,(1 + 0.005 \cdot 16) = 0.432$

$T_P = 350\sqrt{0.432 - 0.25} = 149\ ^{o}\mathrm{C}$,

Appropriate: $T_p = 150\ ^{o}\mathrm{C}$.

Welding technique. The welding with different combinations of extra materials (Test 1 to Test 4 and Test 6) is predicted to be complete without heating it before, but the welding with some extra material (Test 5) should be complete by heating it before.

Research. The criteria for estimating the welded circuit is according to EN 25817, with the type of quality B.

Every single research for the welded circuit should be done by the rules that are stated in EN 288-7 particle 7, Table 1, for the frontal weld for the piped profile.

4. EXPERIMENTAL TECHNOLOGY CONFIRMING WELDING THE BUTT WELDS

Before the welding of the test examples started, according to the already predicted technology (6 examples for the mechanical and metallographic analysis) the retest of the base material is completed.

1) Research on the base material for proving the chemical components and the mechanical characteristics

The material from which the structure is made was retested, so its chemical components and its mechanical characteristics (that are given in the technical report) are confirmed for the already produced and used profiles.

For the laboratory researches the examples were taken and appropriate tubes were made from the profile that was randomly chosen, at random.

The results for the mechanical characteristics and the chemical components that were completed were according to the written standards by EN 10210, and the valid standards in Republic of Macedonia MKS C.BO.500.

2) Experimental research of the welded tests for confirming the welding technology

The provided welding technology can only be used after being qualified and after granting the valid certificate.

The test examples were welded according to the provided technology (WPS).

The welded examples were researched so that the requested characteristics and quality of the welded connections can be confirmed.

The next researches need to be completed such as visual control, penetrating control, radiographic control, mechanical testing.

a) *Visual control*

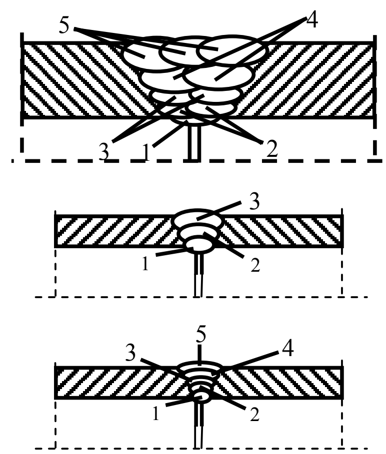

Fig. 2.

Table 3

Example of the report for the visual and dimensional control

Visual and dimensional control of the research specimen no. 12		Profile
Used electrode	Root	ELE 50 CMo
	Passage	ESAB OK 48.60
Short-welds on four places		From 95÷105 mm
Partition between the research pieces		3 (mm)
Root weld (position 1, Fig. 2)		Completely
Passage order (position 2, 3, 4 and 5		Completely
Width of the weld		From 20 ÷24 mm
Weld overtop		From 1.5÷3.0 mm
Graphic presentation of the short-welds, root welds and radiograms		Addition

b) *Penetrating control*

A research has been done for all length tests of the welds with penetrates. Surface cracks were not discovered.

c) *Radiographic control*

The 100% radiographic control of the welds is done in all tests, and a radiographic report is made.

d) *Mechanical testing*

Every mechanical research was done separately for each test (from example 1 to example 6) according to the standards: EN 875, EN 895, EN 910, EN 1043 and the valid Macedonian MKS – standards.

e) *Metallographic analysis*

The metallographic analysis is done according to the EN 288-3 separately for every test (from example 1 to example 6).

The characteristic example is given (Fig. 3).

Example no. 5

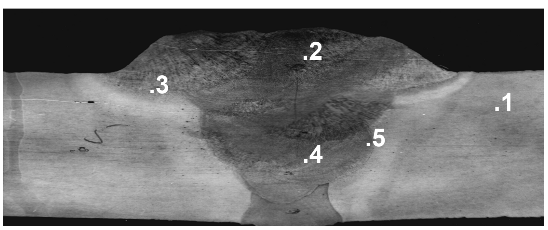

Fig. 3. Microstructure of a weld; × 2,5

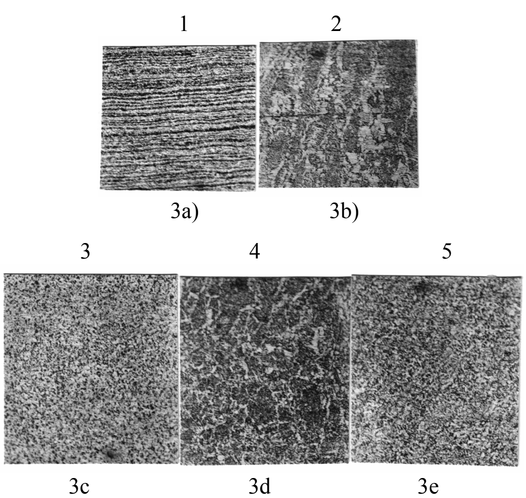

Fig. 3 a, b, c, d, e. Microstructure in the separate parts
1. Base material – ferit-perlit; 2. Weld – microstructure of a weld layer – dendrite; 3. Normalized zone microstructure; 4. Weld microstructure (root); 5. Microstructure in transitional zone

5. COMPARABLE ANALYSIS FOR THE COMPLETED RESULTS, DISCUSSION AND ARRANGING THE WELDING TECHNOLOGY

The entire welded test examples are researched according to the conditions of EN 288-3 so that the most useful welding technology it can be confirmed.

On the diagram (vertical axis) that is on Fig. 4, we can see the values of the welds and their ultimate strength (f_u) for all of the cases.

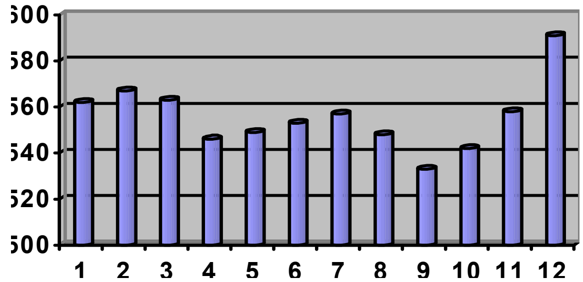

Fig. 4. Ultimate strength (f_u) in N/mm^2

In all welded tests, the ultimate strength (f_u) of the welds satisfies the criteria for $R_{m_{\min}} = 470$ N/mm^2. The biggest values are got for 12 (test no. 5) $R_m = 595$ N/mm^2, for the welds that were welded in horizontal position (PA), and $R_m = 586$ N/mm^2, for the welds that were welded in a vertical position (PF), in the diagram the middle value of $R_m = 591$ N/mm^2 is taken.

The bending of the tubes in all cases in the research, according to the EN 910 satisfies the criteria. In all cases the angle of bending is 180°.

The toughness ρ (J) was researched in all welding tests.

The minimal toughness for the material S355J2H on –20 °C is 27 J.

The tenacity VHT (weld) in all cases satisfies the criteria predicted with the standards for the already given material ($\rho > 27$ J).

On the diagram on Figure 5 we can see the graphic representation of the toughness VWT for the separate examples (minimal value).

The highest minimal toughness on –20° for welding the profile 400×400.16 is obtained for test 5.

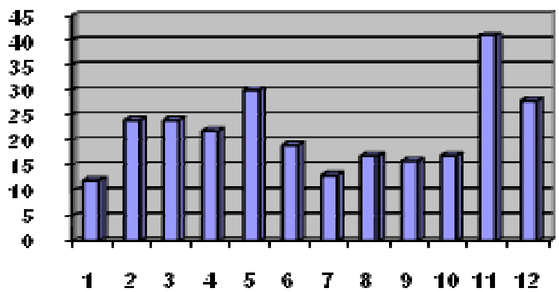

Fig. 5. Toughness ρ (J)

While welding the test 5 it is heated before so the speed of cooling is reducing and the best structure is acquired, wich can be confirmed by the metalographic tapes. Because of that, the welded connection for this test has the best mechanical features. The technology of welding is obtained and it is used for welding the test 5 that contains the following:

– Welding procedure

The REL procedure was predicted for the welding that contains the mark "111" according to the ISO 4063 or the EN 24063.

– Connecton preparations

The connector preparations are predicted according to EN 29692. On Figure 6 the needed preparations for the same and different thicknesses are shown.

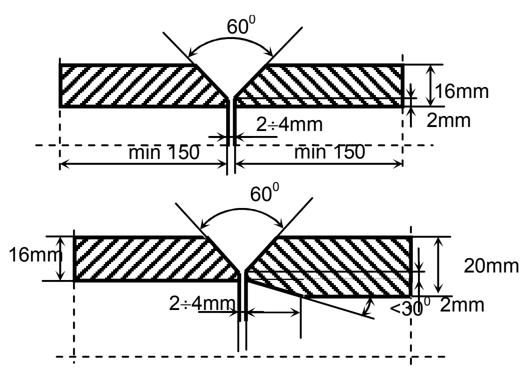

Fig. 6. The preparation for welding

– Welding position

The welding will be done in a PF position according to the ISO 6947, a fixed pipe, a horizontal axis that was welded from the bottom to the top.

– End preparations

The ends will be done by a mechanical treatment – grinding, cleaning it from corrosion, fat and other useless items, and cleaning the ends in length from ~20 mm mechanically with a brush. If the profile has a protection coat, he is put down in length that is not smaller than 40 mm to 50 mm from its end.

.– Welding technique

Before the welding is started, the ends that need to be welded must be heated on 150÷180 °C and that temperature must be maintained. The preheating must be inductive or with propane–butane. If the room temperature is under +5 °C, the welding must not start. In case it is windy, the electric arc must be protected.

Before the beginning of welding the connectors are connected with 4 short welds not smaller than 80 mm.

The origin weld is applied with an electrode with cellulose coating.

When the origin weld is going to be done, the next weld (passage) must be started with welding within 5 min.

After the root welding, the following welds are made by an electrode that is with a basic cover with two passages, and the face of the weld with three passages.

The welding is completed with the following method from the bottom to the top.

Care must be taken of the beginnings and the ends of every single passage, on the other hand it must not be overlapped. In the end of the root welding, the entire weld is cleaned by grinding it.

Every next passage is cleaned by a spinning steel brush, and if it is necessary by grinding.

The welds must be tested according to the EN 287-1 for the steel pipe connection by the electrode with basic and cellulose coating.

– Research

The criteria for evaluation for the welded connector are according to the EN 25817, group of quality B. All researches for the welded connection must be completed as it is said in the EN 288-3 particle 7, for the steel pipe profiled connection.

– Regions of validity

It is determined according to EN 288-3 and it provided a certificate from the committee which correspond to A by the EN 288-3

6. CONCLUSION

Regarding the basic material for the main beam, and dimensions and the shape of the cross section, as well as the type of loading, the most appropriate welding technology among all the technologies considered in this paper is the technology noted as Example No. 12 (Probe No. 5).

The most advanced characteristics by means of strength and toughness of the main girder joints in the real conditions are achieved with this technology.

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Р е з и м е

ТЕХНОЛОГИЈА НА ЗАВАРУВАЊЕ НА ЧЕЛНО ЗАВАРЕНИ СПОЕВИ НА ГЛАВНИТЕ РЕШЕТКЕСТИ НОСАЧИ НА СПОРТСКАТА САЛА НА ГРАДОТ СКОПЈЕ

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Клучни зборови: технологија на заварување; челно заварени споеви; металографска анализа; челична решеткеста конструкција; гранична цврстина; жилавост

Предмет на ова теоретско и експериментално истражување е технологијата на заварување при изработка на главните носачи на спортската сала на градот Скопје, како највитални елементи од конструкцијата. Детали од овие анализи и експериментални истражувања се презентирани во литературата [1].

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PREDICTION OF MOIST AIR SPECIFIC ENTHALPY

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A b s t r a c t: Prediction of moist air specific enthalpy is realized through the analysis of hourly air temperature and relative humidity long term observation. With climatic information for the outdoor air states in the past twenty-five years, a new climatic curve of the Skopje region is provided. A comprehensive database containing hourly weather records is prepared for calculation of others elements of the Macedonian thermal basis.

Key words: moist air; enthalpy; climatic curve

1. INTRODUCTION

The specific enthalpy is a most important property in psychrometric calculations of thermal processes.

Accurate enthalpies values are important, because the total heat content of the air determines the total energy needed to change the conditions of the air from its current condition to the desired condition.

Enthalpy cannot be directly measured. Accurate values of enthalpy have been determined in research laboratories by measuring the change of properties during a carefully controlled process and, from these properties, enthalpies relative to an arbitrary reference state point (0 ^{o}C for moist air psychrometrics) are calculated. The value of enthalpy at the arbitrary reference point is usually designated as having zero enthalpy. The resultant enthalpy values are published in the form of tables or graphs.

The specific enthalpy of moist air is the sum of the enthalpy of the dry air component, and the enthalpy of the water vapor component,

$$i = i_{da} + i_{wv} = c_{pa}\, t + x\,(r_o + c_{pw}\, t). \qquad (1)$$

In psychrometric practice, the graphical calculation of enthalpy is very common. The chart "specific enthalpy – humidity ratio" displays the key thermodynamic characteristics of air, and lets thermal engineers quickly estimate the energy required to change the temperature or humidity of air.

This chart uses an oblique enthalpy grid. The oblique enthalpy coordinate was developed by Richard Mollier from Germany. In his solution, the nonsaturated area of the graph, which is the real working zone for thermal engineers, was enlarged. Similar psychrometric chart was proposed by Willis Carrier from the USA. Since 1963 ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) has developed seven such psychrometric charts [1].

All these charts are accurate enough for most engineering calculations in psychrometric practice, and are readily adapted to either hand or computer calculating methods, [2].

In this paper the chart "specific enthalpy – humidity ratio" is used to present the results of the moist air specific enthalpy prediction method.

Why do thermal engineers need predicted values of specific enthalpy?

The design of the energy system for any thermal device has a direct impact on the cost of its building and operating. The procedures for calculating energy requirements are very different, but they all depend on local climatic conditions. Therefore, the first step in every method of estimating energy use is to insure correct climatic information.

This information, which includes dry-bulb temperature, wet-bulb temperature, humidity ratio, specific volume and specific enthalpy of air, is influenced by the state in atmosphere.

In recent years, more and more attention has been paid to the detailed study of phenomena which occur in the layers of the air nearest the ground.

The climate of the region and the weather which it experiences from day to day derive directly from the movements of great air masses. The outstanding feature of such a motion is that the flow is normally turbulent, so that considerable mixing takes place. This phenomenon is chiefly responsible for the heat transfer between the ground and the air.

The change of the air temperature and relative humidity in space and time is permanently observed in meteorology. With these data and with the help of psychro-metric chart thermal engineers can predict the values of specific enthalpy of moist air.

2. CLIMATIC CURVE

A climatic curve graphically represents the behavior of atmospheric air.

From the experience in keeping under observation the weather conditions for a long period of record, the possible future state of local atmospheric air can be predicted.

In general, the period of record used in calculations spanned 25 years. The choice of period is a compromise between trying to derive local weather conditions from the longest possible period of record, and using the most recent data to capture climatic trends from the past two decades.

Weather records of national weather services include values of temperature, relative humidity, barometric pressure, wind speed.

The psychrometric quantity such as enthalpy is not contained in the weather data sets.

Thermodynamic properties of binary mixture, named moist air, are used in psychrometrics to analyze conditions and processes involving moist air. At least two properties of moist air must be known to determine the remaining characteristics. The air temperature and relative humidity are the needed properties for estimation of moist air states by the climatic curve.

A three steps action is conducted in development of a climatic curve: 1) providing long term observation for the temperature and relative humidity of the moist air, 2) statistical elaboration of collected data, 3) transferring the values with maximum frequency of occurrence into the chart “specific enthalpy – moisture ratio”.

Data sources for the first step are national weather services. The minimum period of record for this analysis is limited to twelve continuous years of hourly observations. Simultaneous measurements for dry-bulb temperature and relative humidity are needed, [3]. The temperature and humidity conditions previously provided for the twenty-five years (values at 7, 14, 21 o’clock), [4], are lately replaced by twelve years hourly observations, [5].

For the actual activity, weather conditions are provided from two locations in the Skopje region: (1) the meteorological station “Skopje-135880” (period of records from 1986 to 2006), (2) the meteorological station “Skopje-135860” (period of records from 1982 to 1985).

Simultaneous values for ambient dry-bulb temperature and relative humidity are recorded in pairs for the total number of hours in a year, 8760.

Although the nominal period of record selected for analysis was 25 years (1982–2006, which is the same selected period of record in the recent ASHRAE approach, [1]) some variation and gaps in observed data meant that some months’ data were unusable because of incompleteness. Some months were also corrected during quality control checks.

Finally, 438336 input values were included in the statistical data processing. Their examination and interpretation are conducted for drawing the annual climatic curve.

A climatic curve for shorter period also exists. For example, the estimation of weather conditions in the layers of the air adjacent to the earth surface, for the warmest season of the year, can be realized by the summer climatic curve.

The extreme values, obtained from the second step, are presented in the graph “temperature – relative humidity” (Fig. 1), [6].

Figure 2 shows the final view of the climatic curve, [7].

In accordance with this climatic curve, the range of predicted values for moist air specific enthalpy is between 54 kJ/kg and 60 kJ/kg, for the temperature level from 30 to 40 ^{o}C.

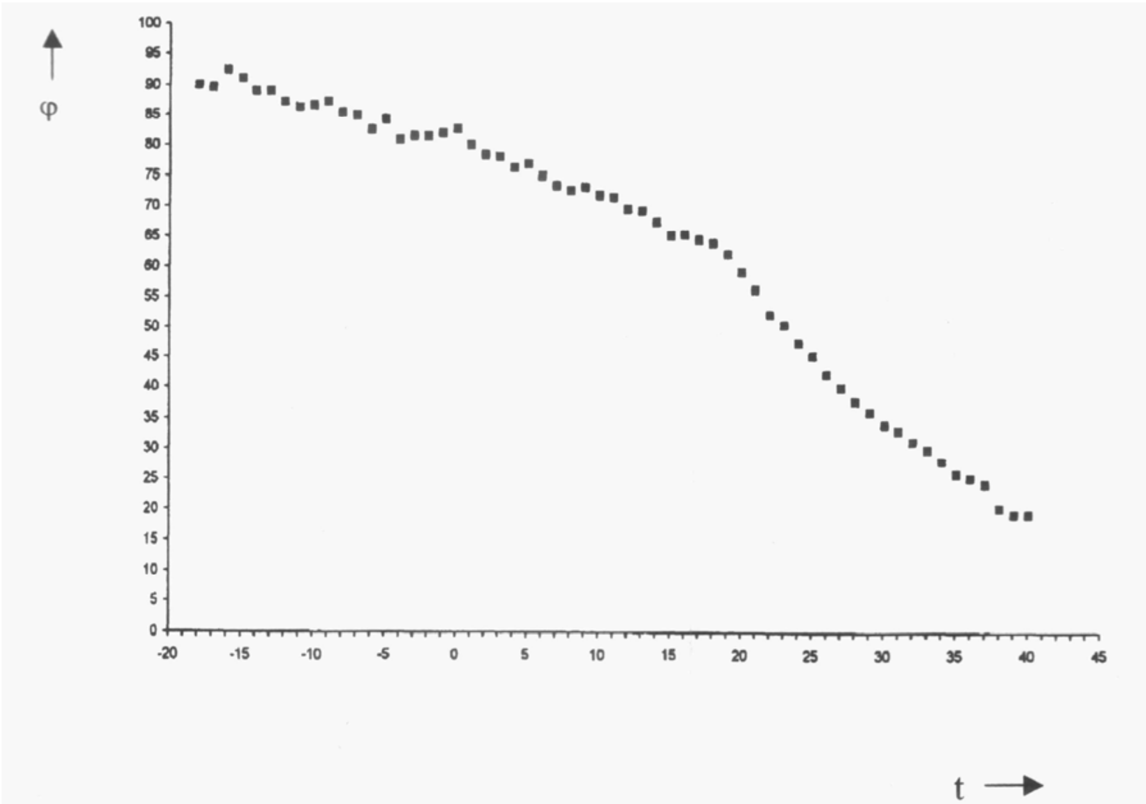

Fig. 1. Extreme values curve

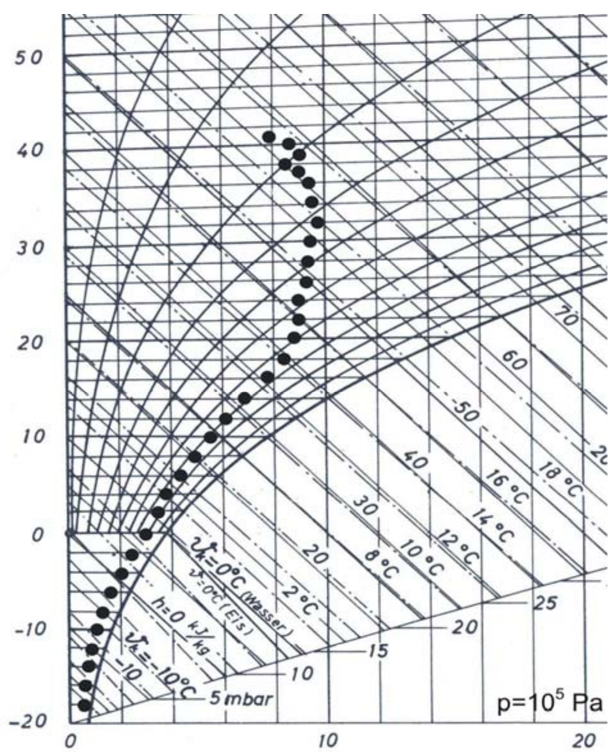

Fig. 2. Climatic curve for Skopje region

Now, thermal engineering have the opportunity to calculate the basic needs for their energy devices. Moreover, with the value of predicted moist air specific enthalpy, wet-bulb temperature of the actual air state can be graphically calculated.

Selected from the psychrometric practice, cooling tower behavior in different climatic conditions is investigated, as an example.

A cooling tower cools water by atmospheric air. The thermodynamic process is simultaneous heat and mass transfer.

There are five cooling towers, for large power installations in our country. They are direct contact counterflow non-mechanical-draft cooling towers. One of them is used in the research. This hyperbolic cooling tower is built in Bitola. Two other possible locations were under investigation, in Skopje and in Ljubljana.

Some data from the undertaken analysis are summarized in Table 1 and Table 2.

Table 1

Identification data for hyperbolic cooling tower, Bitola 1

Hyperbolic cooling tower	Design of the L. T. Mart company Ltd, England, a subsidiary of Marley International Inc
Performance diagram	Marley No. D 1005 – 77, Drawing No. 16098/03
Hot water temperature	t_{w1} = 38 ^oC
Cold water temperature	t_{w2} = 29 ^oC
Wet-bulb temperature	t_{f1} = 20 ^oC
Dry-bulb temperature	t_{L1} = 25 ^oC
Range	z = 9 ^oC
Approach	a = 9 ^oC
Flow rate	m_w = 8,3 ^oC

Table 2

Predicted cold water temperatures (^oC)

	t_{f1}	t_{L1}	t_{w2}
Skopje	20,2	35,2	32
Bitola	19	27	27
Ljubljana	20	30	22

Every producer offers standard capacity cooling towers with its own cooling tower performance chart. Deviations from design operating conditions are dictated by the local climatic conditions. The thermal performance of a cooling tower depends principally on the entering air wet-bulb temperature. The amount of heat transferred from the water to the air is proportional to the difference in enthalpy of the air between the entering and leaving conditions.

3. CONCLUSION

In accordance with the latest correction of the actual issue in the ASHRAE approach, a new climatic curve for the Skopje region is published.

Psychrometric quantities such as moist air specific enthalpy and wet-bulb temperature are predicted using the psychrometric chart.

The influence of different climatic conditions on cooling equipment is emphasized.

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Р е з и м е

ПРЕДВИДУВАЊЕ НА СПЕЦИФИЧНАТА ЕНТАЛПИЈА НА ВЛАЖЕН ВОЗДУХ

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Клучни зборови: влажен воздух; содржана топлина; климатска крива

Извршено е предвидување на специфичната топлина содржана во влажен воздух врз основа на анализата на часовни вредности на температурата и релативната влажност добиени со долготрајно набљудување. Обезбедена е нова климатска крива на скопската област преку климатските податоци за состојбите на надворешниот воздух. Подготвена е квалитетна база на податоци, со вредности од часовни мерења, за пресметка на другите елементи на термичката основа на Македонија.

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PREDICTING THE DENSITY AND VISCOSITY OF BIODIESEL–DIESEL BLENDS

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A b s t r a c t: In this study, biodiesel produced from rapeseed oil was blended with commercially available diesel fuel at ratios of 2, 6, 8, 10, 20, 50 and 75 % on a volume basis. In order to analyze the key fuel properties such as density and viscosity, the experiments were carried out at various temperatures. Obtained results from biodiesel blends were compared with the properties of fossil diesel fuel. According to the results, the density of the blends proportionally increases with biodiesel fraction and decreases with temperature. The proposed empirical equation showed excellent agreement between the measured densities and estimated values. Viscosity of the biodiesel blends increased with the increase of biodiesel fraction in the fuel blend. The experimental data were correlated as a function of the biodiesel fraction by the empirical second-degree equation. Very good agreement between experimental and estimated values was observed.

Key words: biodiesel; blend; density; viscosity

1. INTRODUCTION

Vegetable oils are a promising alternative among different diesel fuel alternatives. However, the high viscosity and density of vegetable oils can cause some problems which have directly effects on the engine performance characteristics. These problems can be minimized by transesterification of the vegetable oils to form monoesters, known as biodiesel.

Biodiesel is a renewable fuel which has many characteristics of a promising alternative energy resource. An alternative fuel must be technically feasible, economically competitive, environmentally acceptable, and readily available [1]. Biodiesel is oxygenated and essentially free of sulfur making it a cleaner burning fuel than petroleum diesel with reduced emissions of SOx, CO, unburned hydrocarbons and particulate matter [2]. However, the heating value of biodiesel is little lower than that of diesel fuel and due to the poor cold flow properties the use is limited in cold climates [3, 4].

The most common process for making biodiesel is known as transesterification. In this process, the vegetable oil or animal fat (triglyceride) reacts with an alcohol in the presence of a catalyst and produces glycerol and the biodiesel (a monoester). This process has been widely used to reduce the high viscosity of triglycerides [1]. The viscosity of vegetable oils is 10–20 times that of diesel fuel. When it is used as fuels, they cause injector fouling and other engine problems [5].

Biodiesel can be used in modern engines without any modification if the fuel properties meet the EN-14214 Europe specifications [6]. The biodiesel fuel properties are dependent on feedstock, alcohol and catalyst. According to Lefebvre the physical properties of a liquid fuel that affects its atomization in a diesel engine are viscosity and density [7]. Hence a suitable fuel in a diesel injection (DI) engine requires balanced values of viscosity and density, for a given atomizer to function properly [8]. In a diesel engine, the liquid fuel is sprayed into compressed air, and atomized into small drops near to the nozzle exit [6].

Viscosity is one of the most important fuel properties and it has effects on the atomization quality, the size of fuel drop and the penetration. High viscosity causes poor fuel atomization during the spray, increases the engine deposits, needs more energy to pump the fuel and wears fuel pump elements and injectors, but low viscosity can cause leakage in the fuel system [3].

Density is a fuel property which directly has effects on the engine performance characteristics such as cetane number and heating value. High value of fuel density reflects to bad combustion and exhaust emission. Diesel fuel injection systems measure the fuel by volume, so the changes in the fuel density will influence engine output power due to a different mass of fuel injected [9]. The density of biodiesel depends on its molecular weight, free fatty acid content, water content, temperature and it is significantly lower than that of the source oil [10]. For different alkyl ester made for the same vegetable oil, the density decreases in the order of methyl > isopropyl > ethyl > 1 butyl esters [5]. Data of biodiesel density as a function of temperature are needed to model the combustion processes and other applications. Biodiesel obtained from vegetable oils demonstrates temperature-dependent behavior. The density of ethyl esters decreases linearly with the increase in temperature [10].

The fuel properties of biodiesel differ from those of diesel fuels. To reduce the viscosity, and density of a biodiesel fuel, a blend (or mixture) of pure biodiesel with diesel fuel can be used. Density and viscosity are key fuel properties, which need to be characterized before using biodiesel–diesel fuel blends in a diesel engine.

This study deals with determination and predicting density and viscosity of biodiesel blends.

2. EXPERIMENTAL: MATERIALS AND METHODS

2.1. Biodiesel production

Commercially available rape seed oil obtained from the market was used for experimental work. The experiment was performed in a laboratory scale apparatus in previously optimized conditions. Transesterification was carried out in a two-stage reaction with separation of the glycerol after each stage and adding alcohol and catalyst. The glycerol layer formed during the reaction inevitably had to be separated from the methyl ester content after each transesterification stage because of the rate of the reaction and an occasion of the foul-up of the diesel engine. Transesterification was carried out in a 250 cm^3 three-necked glass flask with a water-cooled reflux condenser. The reaction flask was charged with 135 cm^3 of rape seed oil, then it was heated at 65 ^{o}C in a temperature-controlled water bath. Methanol (CH_3OH) as an alcohol and sodium hydroxide (NaOH) as a catalyst were used in the reaction of transesterification. The molar ratio between alcohol and rape seed oil was 6:1, where the amount of catalyst was 0.8% based on oil weight. At the beginning the catalyst was dissolved into methanol and added to the rape seed oil. The mixture of seed oil, methanol and sodium hydroxide was mixed with a mechanical stirrer at 250 rpm. Because of the solubility of the methyl esters in glycerol and inhibition of the reaction, two-stage adopted (2 × 30 min) for obtaining high conversion. After the first stage the mixture was put into a separating funnel and was kept at ambient temperature for 2 h. The upper phase methyl ester, was removed and put into the flask. A precise amount of catalyst of 0.06 g dissolved into 2 cm^3 methanol was added into the flask. Then, the second stage of transesterification started at the same conditions. When the reaction of transesterification was finished the glycerol was separated. Obtained biodiesel was three times washed with warm water, the residue of sodium hydroxide was removed and biodiesel subjected to a heating at 100 ^{o}C to remove excess alcohol and water.

2.2. Density measurement

Commercially available diesel fuel was purchased from Makpetrol A.D. Skopje and used for the fuel blends. Biodiesel–diesel fuel blends (BD/D) were prepared at proportion 75:25; 50:50; 35:65, 20:80; 10:90; 8:92; 6:94; 2:98, estimated on a volume basis. The density of the diesel fuel, biodiesel and their blends was determined using the standard test method ASTM D941. The measurements of density were performed at 15 ^{o}C by using the Anton Paar (DMA 35N) density meter. There was a linear increase in density with the blending ration of biodiesel. The experimental data were correlated as a function of biodiesel fraction by the empirical linear equation obtained from regression analysis [6]. The measured and calculated values for each fuel and blend are shown in Table 1. The general form of the equation as a function of the biodiesel fraction was given as:

$$\rho = Ax + B \quad (1)$$

where ρ is density (g/cm^3), A = 5.26E-04 and $\underline{B}$ = 0.8317 are coefficients obtained from the regression analysis, and x is the biodiesel fraction.

Table 1

The calculated and measured density values of biodiesel fuel blends

Biodiesel (%)	Diesel (%)	Experimental (g/cm^3)	Calculated (g/cm^3)	Absolute error
100	0	0.8840	0.8843	8.39E-08
75	25	0.8719	0.8711	5.82E-07
50	50	0.8580	0.8580	2.49E-10
35	65	0.8493	0.8501	6.28E-07
20	80	0.8420	0.8422	4.04E-08
10	90	0.8370	0.8369	3.62E-09
8	92	0.8360	0.8359	1.26E-08
6	94	0.8350	0.8348	2.71E-08
2	98	0.8329	0.8327	2.86E-08
0	100	0.8322	0.8317	2.72E-07
				Σ = 1.68E-06

The temperature dependence of the blend B8 (8%), prepared in a laboratory, was compared with the commercially available blend from Makpetrol A.D. Skopje. The obtained results are shown in Table 2. The linear regression equation (2) was used to correlate experimental data where T is a temperature in ^{o}C, A and B are coefficients shown in Table 3.

$$\rho = A \cdot T + B \qquad (2)$$

Table 2

The temperature dependence of density for the biodiesel blend B8

Temperature (^{o}C)	Commercially (g/cm^3)	Experimental (g/cm^3)	Calculated (g/cm^3)	Absolute error
15	0.8309	0.8360	0.8358	3.5E-08
20	0.8271	0.8320	0.8322	4.74E-08
30	0.8198	0.8250	0.8250	7.41E-10
40	0.8127	0.8179	0.8178	3.99E-09
				Σ = 8.71E-08

Table 3

Commercially	Experimental
A = –0.0007	A = –0.0007
B = 0.8466	B = 0.8417
R^2 = 0.9995	R^2 = 0.9999

2.3. Viscosity measurement

Viscosity is defined as the resistance to flow of a fluid. The ASTM Standard D445 test method was used to measure viscosities of fuels and blends. Viscosity was determined at 40 ^{o}C with the Cannon-Fenske viscometer tube. Each sample was run in triplicate and an average value is reported. The precision is in the limits of the ASTM method specification.

The experimental data were correlated as a function of biodiesel fraction by the empirical second-degree equation (3), [6]. The linear equation does not fit the data well. The coefficients of the equation were obtained with the regression analysis by using the measured values. The measured and calculated values of kinematic viscosity for each fuel and their blend are shown in Table 4.

$$v = Ax^2 + Bx + C \qquad (3)$$

where v, is the kinematic viscosity (mm^2/s), A = 5.44 E-06, B = 7.94 E-03 and C = 2.3413 are coefficients obtained from the regression analysis.

Table 4

The calculated and measured viscosity values of biodiesel fuel blends

Biodiesel (%)	Diesel (%)	Experimental (mm^2/s)	Calculated (mm^2/s)	Absolute error
100	0	3.2040	3.1896	2.09E-04
75	25	2.9693	2.9673	4.04E-06
50	50	2.6745	2.7518	5.98E-03
35	65	2.6382	2.6258	1.53E-04
20	80	2.5225	2.5022	4.10E-04
10	90	2.5106	2.4212	7.99E-03
8	92	2.51006	2.4052	1.10E-02
6	94	2.34768	2.3891	1.72E-03
2	98	2.3297	2.3572	7.56E-04
0	100	2.1064	2.3413	5.52E-02
				Σ = 8.34E-02

3. RESULTS AND DISCUSSION

3.1. Density results

The density of biodiesel prepared in a laboratory and used for blending was 0.8840 g/cm^3 at

15 °C. The calculated density values from Eq. (1) are validated by using the measured density values for all the blends. There is an excellent agreement between the experimental and estimated values. The maximum absolute error between the experimental and estimated values is 2.72E-07. In many studies, it is observed that biodiesel density has not changed a lot, because the densities of methanol and oil are close to the density of the produced biodiesel [11]. The density of diesel fuel is lower than that of biodiesel.

Figure 1 presents the density values of the biodiesel–diesel blends. The density of the biodiesel blends increased proportionally with biodiesel fraction. Namely, as the biodiesel fraction increased, the density values also increased linearly.

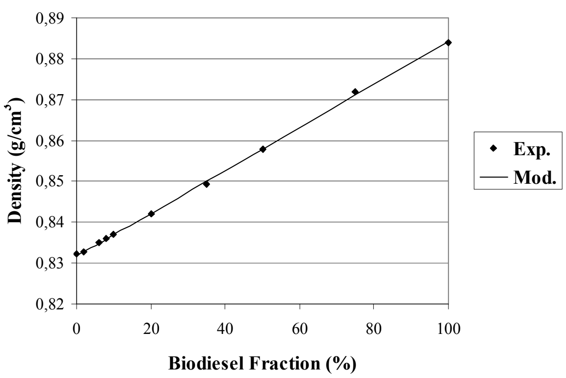

Fig. 1. The density of biodiesel–diesel fuel blends

The relation between density and temperature is investigated in a temperature range of 15 ÷ 40 °C and the obtained results are shown in Figure 2.

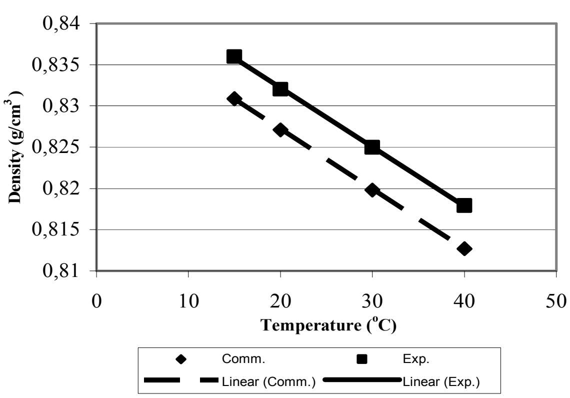

Fig. 2. Relation between densities and temperature of commercial and experimental B8 biodiesel blend

The difference between the density of commercial and laboratory prepared blend is evident, but the curves are parallel. So, the temperature dependence of densities for both curves is similar. The density of the experimental blend B8 is higher than the density of commercially available blend. Decreasing the temperature reflected in increasing the density. Anyway, the difference in density could be due to some additives in the commercial blend.

3.2. Viscosity results

The measured value of the biodiesel viscosity is 3.2040 mm^2/s at 40 °C and it is much higher than viscosity of diesel fuel (Table 4). The viscosity of the biodiesel blends increases with the biodiesel fraction (Fig. 3). The little amount of biodiesel fraction (2%) in diesel fuel results in a big difference of viscosity. In Table 4 the experimental and calculated values for the viscosity are presented. The calculated values of the viscosity using Eq. (3) are validated with the measured values of the viscosity for all blends. The maximum absolute error between the measured and calculated values is 5.52E-02. There is a good agreement for the viscosity between the experimental and estimated values for each blend.

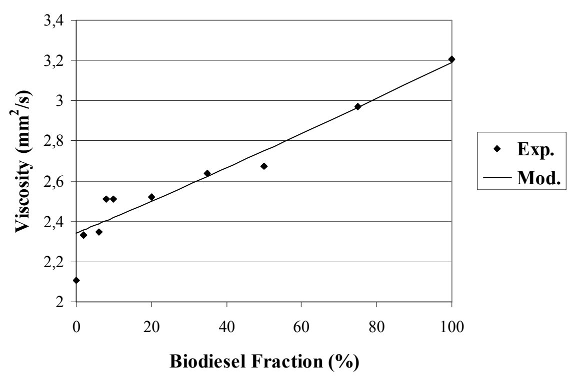

Fig. 3

4. CONCLUSION

The purpose of this study was to investigate the effect of various temperature conditions on biodiesel and its blended fuel properties, density and viscosity. Therefore, seven different biodiesel blends were prepared and subjected to measuring. According to the results, the following conclusions were obtained.

- Fuel properties of biodiesel blends can be significantly modified through blending with different biodiesel fractions.
- Significant relationship is found between density, viscosity, temperature and biodiesel fraction.
- The density of diesel fuel is lower than that of biodiesel. It increases linearly with the biodiesel fraction in the fuel blend.
- Increasing temperature results in decrease in density of the biodiesel blend B8. However, there is a significant difference in density of the experimental and commercial blend. The values of the experimental obtained blend are higher than the commercial blend B8.
- The viscosity of diesel fuel is lower than that of biodiesel and it increases with the biodiesel fraction.
- Generalized and empirical equations, validated by using the measured values, are used for predicting the density and viscosity of the blends. There is an excellent agreement between the measured and estimated values.

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Р е з и м е

ПРЕДВИДУВАЊЕ НА ГУСТИНАТА И ВИСКОЗИТЕТОТ НА БЛЕНДИТЕ ДОБИЕНИ ОД БИОДИЗЕЛ–ДИЗЕЛ

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Клучни зборови: биодизел; бленда; густина; вискозитет

Во овој труд биодизелот добиен од репкино масло беше мешан со комерцијално достапно дизелско гориво во волуменски однос 2, 6, 8, 10, 20, 50 и 75 %. Со цел да се анализираат основните горивни својства како што се густината и вискозитетот, експериментите беа изведувани на различни температури. Добиените резултати од блендите на биодизел беа споредувани со својствата на фосилното дизелско гориво. Според резултатите, густината на блендите пропорционално расте со уделот на биодизелот и опаѓа со температурата. Предложената емпириска равенка покажува одлично совпаѓање помеѓу измерените густини и пресметаните вредности. Вискозитетот на блендите од биодизел растеше со порастот на биодизелската фракција во горивната бленда. Експерименталните податоци беа корелирани како функција од биодизелската фракција со емпириска равенка од втор степен. Забележано е многу добро совпаѓање помеѓу експерименталните и пресметаните вредности.

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GROWING RAPID PROTOTYPING AS A TECHNOLOGY IN DENTAL MEDICINE

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A b s t r a c t: The main idea of this article is to present recent rapid prototyping views as a modern additive manufacturing process and explanation how to eliminate the confusion over terminology, design, materials and processing differences of that. In future, computers will be used to automatically manufacture objects, products and systems of every description and kind with no limit to material and geometrical complexity. The inputs to these fabrication systems will simply be raw materials and usually CAD data. This technology will be reminiscent of desktop publishing – but instead of documents and printed matter, the diverse products that we need to use in our lives will be manufactured immediately. Also, we will be able to efficiently make near-net shape products in small volumes without tooling.

Key words: rapid prototyping; stereolithography; laminated object manufacturing; layered manufacturing; 3D printing

1. INTRODUCTION

Rapid prototyping is the name given to a host of related technologies that are used to fabricate physical objects directly from CAD data sources [1]. Rapid prototyping means many things i.e. to explore the process of conceptual modeling, functional prototyping, and manufacturing tools to the end-use parts. It is very useful to know how additive fabrication systems such as 3D printers, rapid prototyping systems, and direct digital manufacturing systems are changing future product development and manufacturing. These methods are unique on behalf of add and bond materials in layers to form objects. Such systems are also known by the names of additive fabrication, three dimensional printing, solid freeform fabrication and layered manufacturing. Some characteristics of the process can be mentioned as:

– objects can be formed with any geometric complexity without elaborating machine setup or final assembly;

– objects can be made from different kind of compounds as composites, or materials can even vary in a controlled manner at any location in an object;

– additive fabrication systems reduce the construction of complex objects to a manageable, straightforward, and relatively fast process.

These properties have resulted in their wide use as a way to reduce time to market in manufacturing. Today's systems are heavily used by engineers to better understand and communicate their product designs as well as to make rapid tooling to manufacture those products. Surgeons, architects, artists and individuals from many other disciplines also routinely use the technology.

The names of specific processes themselves are also often used as synonyms for the entire field of rapid prototyping [2]. Among these, processes are as follows:

– stereolithography SLA (Fig. 1),

– selective laser sintering SLS (Fig. 2),

– fused deposition modeling FDM (Fig. 3),

– laminated object manufacturing LOM (Fig. 4),

– inkjet-based systems (Fig. 5),

– three dimensional printing 3DP (Fig. 6),

– laser engineered net shaping LENS (Fig. 7).

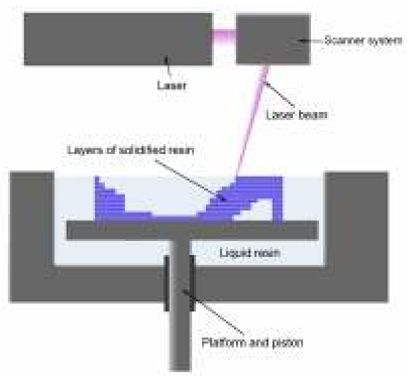


Fig. 1. Stereolithography apparatus [1]

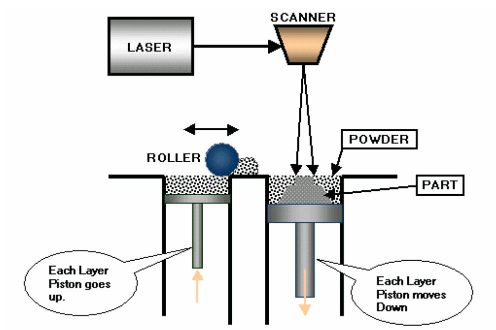


Fig. 2. Selective laser sintering [1]

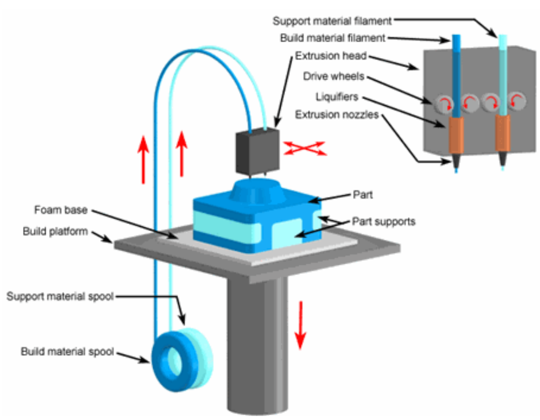


Fig. 3. Fused deposition modeling [1]

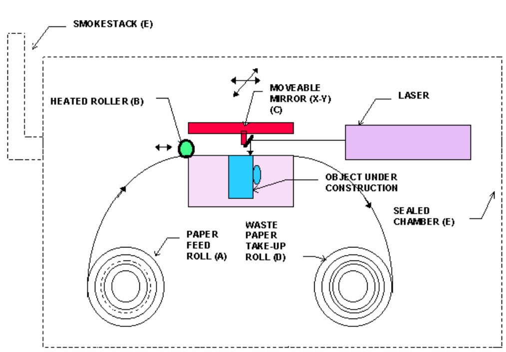


Fig. 4. Laminated object manufacturing [1]

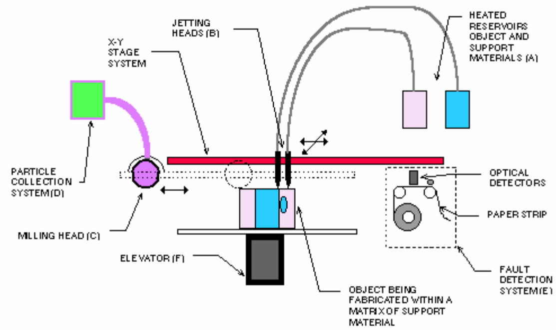


Fig. 5. Inkjet-based systems [1]

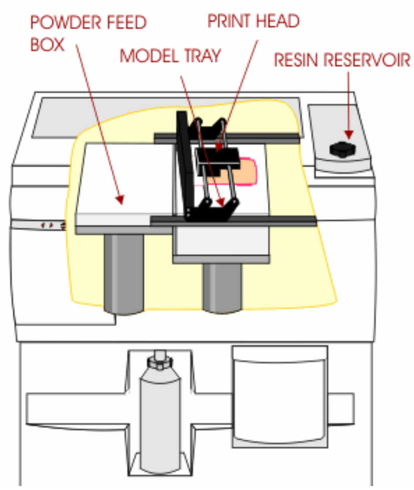


Fig. 6. Three dimensional printing [1]

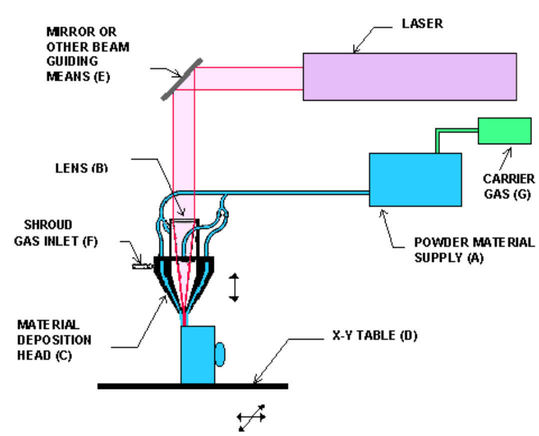


Fig. 7. Laser engineered net shaping [1]

Each of these technologies, and many other rapid prototyping processes, have their singular strengths and weaknesses. They offer advantages in many applications compared to classical subtractive fabrication methods such as milling or turning.

On a corporate level, the benefit of rapid prototyping is instrumental in cutting time to market while protecting product quality. The bottom line is increased market share and revenue. The obvious benefit of rapid prototyping is generally speed of product development. However, working closely with product development professionals, the companies have found that the real value of the rapid prototype is quickest and delivers a better design communication tool.

The physical prototype quickly and clearly communicates all aspects of a design [2]. Eliminating ambiguity, rapid prototyping facilitates the early detection and correction of design flows.

In its simplest form, the benefit of rapid prototyping is confidence in the integrity of the design. This confidence is best expressed as a peace-of-mind which results coming from completing design on time. Furthermore, rapid prototyping techniques can deliver parts in resins and alloys and that materials bridge production and time.

The terminology that is used to describe many technologies and applications of additive fabrication is extremely confusing. The purpose of this article is to provide a roadmap and enough etymological history and show their relationships.

2. PROCESS DESCRIPTION

Several different additive fabrication processes are commercially available or currently being developed [3]. Each process may use different materials and different techniques for building the layers of a part. However, each process employs the same basic steps, listed below.

- *Create CAD model* – For all additive processes, the designer has to use the Computer-Aided Design (CAD) software to create a 3-D model of the part.
- *Convert CAD model into STL model* – Every CAD software saves the geometric data representing the 3-D model in a different file format. However, the STL format (initially developed for Stereolithography) has become the standard file format for additive processes. Therefore, CAD files must be converted to this file format. The STL format represents the surfaces of the 3-D model as a set of triangles, storing the coordinates for the vertices and normal directions for each triangle.
- *Slice STL model into layers* – Using specialized software, the user prepares the STL file to be built, first designating the location and orientation of the part in the machine. Part orientation impacts several parameters, including build time, part strength, and accuracy. The software slices the STL model into very thin layers along the 2D plane. Each layer will be built upon the previous layer, moving upward in the perpendicular direction.
- *Build part one layer at a time* – The machine builds the part from the STL model by sequentially forming layers of material on top of previously formed layers. The technique used to build each layer differs greatly amongst the additive processes, as does the material being used. Additive processes can use paper, polymers, powdered metals, or metal composites, depending upon the process.
- *Post-processing of part* – The final part made from a photosensitive material, has to be cured to attain full strength. Minor cleaning and surface finishing, such as sanding, coating, or painting, can be performed to improve the part's appearance and durability. Generally, the rapid prototyping process is shown in Figure 8.

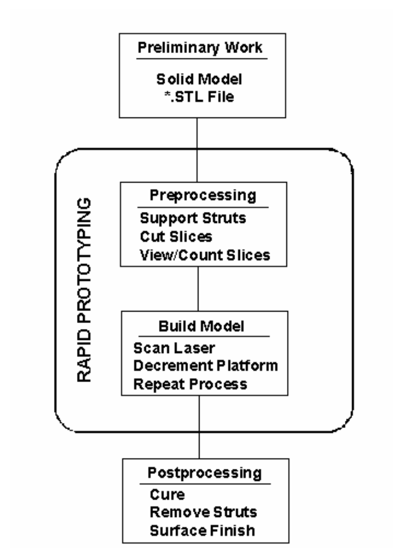


Fig. 8. The rapid prototyping process [11]

3. PROTOTYPE MANUFACTURING TECHNOLOGY

Additive fabrication refers to a class of manufacturing processes, in which a part is built by adding layers of material upon one another [2]. These processes are essentially different from subtractive processes or consolidation processes. Subtractive processes, such as milling, turning, or drilling, use carefully planned tool movements to cut away material from a workpiece to form the desired part. Consolidation processes, such as casting or molding, use custom designed tooling to solidify material into the desired shape. Additive processes, on the other hand, do not require custom tooling or planned tool movements. Instead, the part is constructed directly from a digital 3-D model created through the CAD software. The 3-D CAD model is converted into many thin layers and the manufacturing equipment uses this geometric data to build each layer sequentially until the part is completed. Due to this approach, additive fabrication is often referred as layered manufacturing, direct digital manufacturing, or solid freeform fabrication.

The most common term for additive fabrication is rapid prototyping. The term "rapid" is used because additive processes are performed much faster than conventional manufacturing processes. The fabrication of a single part may only take a couple of hours, or can take a few days depending on the part size and the process. However, processes that require custom tooling, such as a mold, to be designed and built may require several weeks. Subtractive processes, such as machining, can offer more comparable production time, but that time can increase substantially for highly complex parts. The term "prototyping" is used because these additive processes were initially used solely to fabricate prototypes. However, with the improvement of additive technologies, these processes are becoming increasingly capable of high-volume production manufacturing.

Started out nearly twenty years ago, the process was called "rapid prototyping" (RP). At the time, that was fairly descriptive of what it did. Early machines were used to make things that represented the general physical shape of some final part or other items. Since these parts or objects did not have the material properties nor probably the accuracy that were required for the actual use, they were just prototypes – examples. The next step of the process would find the corrections added. Perhaps another prototype was made. One prototype might be all that was required. Seeing and feeling something in the approximate form it would ultimately take turns out to be a very good way of short-circuiting the process of going from an idea on paper or a screen, to making something that actually works.

This is the reason why the process of design became faster and put the rapid in "rapid" prototyping, but not the only one. Instead of having cutting material to sculpt a part, we could just give a 3D modeled digital file to the machine and its task is to throw out a very complicated part fairly quickly. This shows much lower time cutting material. So these additive processes were rapid in comparison to that, which leads to manufacturing same parts on behalf of calling them "rapid."

4. RAPID PROTOTYPING

Of course, whoever started using the term "rapid prototyping" for these additive fabrication technologies twenty years ago, either did not know, or did not care, that others in completely unrelated fields were using it, as well [4, 5]. Some computer programming techniques are called rapid prototyping, as are the ways to generate quickly web-sites. Individuals designing advanced control systems for aircraft and similar applications sometimes describe the process as rapid prototyping. Biologists use rapid prototype microfluidic systems using a variety of methods such as stamp lithography. Sometimes it is not easy to distinguish rapid prototyping and additive fabrication.

Rapid prototyping has been called by several additional names provided by corporations, writers and the scientific community. We can find them in [1, 12]:

- Desktop manufacturing (DTM) – This was an early term from which one of the early companies in the field derived its name (DTM, Inc.), [6, 7]. Only in recent years have any additive fabrication machines been able to fit on anything resembling furniture, shown in Figure 9.

Fig. 9. Desktop manufacturing process [7]

- Solid freeform fabrication (SFF) / freeform fabrication (FFF) – The science community often uses it in academic papers and patents.
- Solid imaging / solid imager – 3D Systems and some Japanese companies have used these

terms (www.rpjp.or.jp), often applying them specifically to stereolithography, but sometimes meaning the entire field.

- Layered manufacturing / layered fabrication – All commercial systems do indeed operate by making layers and bonding them – some thicker, some thinner. The term seems mostly to come up in trade magazines when writers are explaining the field to an unfamiliar audience [8].

- New capabilities, but old terminology – the next thing that unavoidably happened was that materials and accuracy are improved, so rapid prototyping could be used to make functional parts. There are things as functional prototypes, and even though some parts may have been used in final applications, "rapid prototyping" still was not a complete self named at this point [8].

- Lower prices, but new terminology – some rapid prototyping machines could still not make functional parts and these were called "concept modelers" once other machines could [9]. These technologies were only appropriate for the original application of rapid prototyping, to check the form of something. The term remained current for a few years, and is still seen once in a while. So, some additive fabrication machines got much less expensive. To differentiate this segment of the market from more costly machines, people started calling these machines "3D printers" or "three dimensional printers." Now, there already was a specific technology with a very similar name called Three Dimensional Printing (3DP) (TM) which had been developed and trademarked by MIT (www.mit.edu). One of its licensees, Z Corporation (www.zcorp.com), actually makes 3D printers using Three Dimensional Printing (TM) technology. But other manufacturers make 3D printers using other technologies.

5. PROCESS OF RAPID TOOLING AND MANUFACTURING

Rapid prototyping started out by making parts mostly out of plastic in one form or another [10]. It wasn't very long before some of the technologies were extended to making things out of metals and other more durable substances, as well. That meant that rapid prototyping could then be used to make complex tools like injection molds and die casting molds. The natural extension of the terminology was to call this rapid tooling (RT) – especially so since the speed of fabrication was a dominant reason for the existence of the application in the first place. Figure10 shows the flowchart of engineering and rapid prototyping design with design phases.

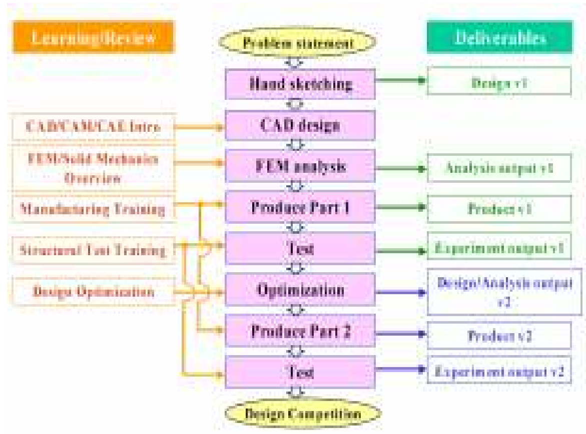


Fig. 10. Flowchart of engineering and rapid prototyping design [11]

A number of rapid prototyping technologies, such as selective laser sintering and laser powder forming, can be used to make tools directly in metals and other materials. Applying the term "rapid tooling" to these processes in such applications seemed quite correct. But other additive fabrication methods could be used to make a pattern – or model – from which a tool could also be made using a secondary process. Some of these so-called indirect methods deposit a final material for the tool such as metal right on the pattern. When the pattern is removed, the tool is largely complete. In other cases, these added steps involve a material transfer process. The pattern may be first used to make a mold and a harder final material for the tool is formed from that. Several such transfer steps may be required depending on the particular process.

Sometimes these material transfer processes themselves have also been called rapid tooling. Many of them existed long before additive fabrication was ever thought of, and virtually all of them can utilize patterns made in any way, whether using additive technology or not. There are many such processes. Among them are RTV silicone rubber molding, aluminum-filled epoxy tooling, KelTool(TM), EcoTool(TM) and others. They can use patterns made by additive fabrication technologies and they could also use patterns made by hand.

Some additive fabrication technologies that are mostly used for rapid tooling applications are described as rapid tooling technologies. This is also incorrect because they can, and often are used to make other things besides tooling. For example, laser powder forming technologies are frequently used to make injection mold tooling, but they can also be used to make hip implants.

Among the methods that are often thought of as "rapid tooling" technologies are Direct Metal Deposition (TM), ProMetal (TM), electron beam melting (EBM), selective laser melting (SLM) – shown in Figure 11 which is used in dental applications. Actually, they are just additive fabrication processes that are often used to make tools.

Fig. 11. Selective laser melting in dental applications [6]

If rapid prototyping materials and accuracy are improved, then it becomes possible to make functional parts that could be used in final applications. The name "mass customization" consequently arose as a new possibility – manufacturing a product for a limited number of customers or for just one individual. Additive processes are turning out to be good prospects for many of applications, particular that involve complex geometrical shapes [12].

The term "rapid manufacturing" is developed as a way to differentiate it from rapid tooling. It describes how rapid prototyping avoids the usually-required lengthy and expensive process of making a manufacturing tool. Of course, just as rapid prototyping is not necessarily rapid, rapid manufacturing can be quite slow, too. In some cases it is very slow indeed in practical uses. The certainly relation between RP and conventional technologies in according to producing time and costs in the function of product complexity is presented by Figure 12.

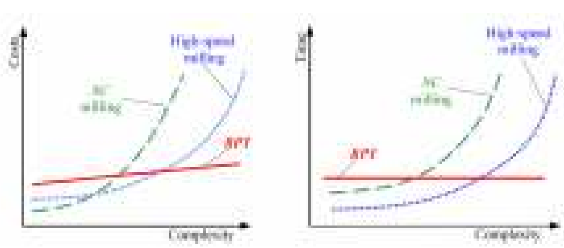


Fig. 12. Relation between RP and conventional technologies [4]

6. GENERAL USE OF RP

Just as with rapid prototyping, a number of synonyms for rapid manufacturing are used [1, 14, 15]. None of them call it rapid, and all of them are now presented in the literature for supremacy:

- Additive fabrication / additive manufacturing – Additive fabrication is a somewhat more general term than additive manufacturing [9, 11]. It is probably best used as the cover term that contains all of the technologies and applications described herein. But both terms are used to mean rapid manufacturing and are often seen in literature. Additive manufacturing is probably the most precise term for what is being done in rapid manufacturing. But in early 2009 the ASTM placed its approval on the term after a specially-called meeting of 70+ industry experts hotly debated the topic and almost no one has used additive manufacturing [1].
- Toolless manufacturing – This was an early term for rapid manufacturing, but has become less used recently, possibly because no one knows how to spell tooless, or whether tool-less should be hyphenated [1].
- Digital manufacturing / direct digital manufacturing / digital fabrication / Advanced Digital Manufacturing (ADM) (TM) – The latter is a trademark of 3D systems, but the other variations are much more often seen [1]. They are reasonably descriptive and put the emphasis on the fact that computation is the driving force. But then, computation is the driving force behind nearly everything in modern life and the terminology may not survive because it is insufficiently specific with respect to the technology [1].
- Direct fabrication / direct manufacturing – Not very often used, but the emphasis is on the fact that the use of manufacturing tooling is avoided [1, 2].

7. USE OF RP IN DENTAL MEDICINE

The authors of this article are particularly interested in design and fabrication of prosthetic implants, improving and simplifying the entire process using three-dimensional biomodels especially in the field of dental implants. The process of dental rapid prototyping is presented in Figure 13 and Figure14, as follows respectively:

1. The process begins with a CT scan of the patient made on a multi-slice (MDCT) or cone-beam (dental) CT scanner [9, 13–15]. A specialist specifies the appropriate CT scanning protocol, whether he/she uses the new dental (cone-beam) CT, or conventional CT (MDCT).

2. A skilled specialist precisely differentiates hard tissue from soft tissue via a masking process to produce a 3D computer rendering.

3. A specialist uses a UV laser and photopolymer resin to build a stereolithographic biomodel, layer by layer. After manually removing the support material, he/she delivers a finished biodental model, which can be used for diagnosis and treatment planning.

4. One indicates the treatment plan by marking or drilling the biodental model, then returns the biodental model to an approved laboratory, along with impressions, waxup, and bite registration.

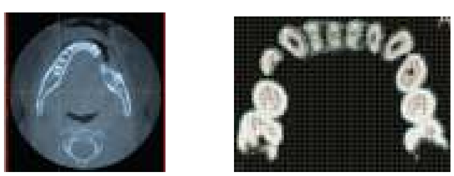
5. The custom drill guide is fabricated and is returned to the customer for surgery, together with the biodental model and other materials.

All phases of the process in dental medicine can be shown in Figure 13, as follows in three phases:

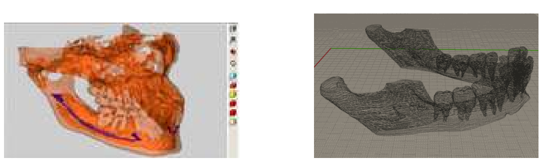
– Phase I. Digital geometry processing.

– Phase II. 3D digitalization.

– Phase III. 3D RP model and model ready for the MKE analysis.



Phase I



Phase II

Phase III

Fig. 13. Dental implants – the RP process [6]

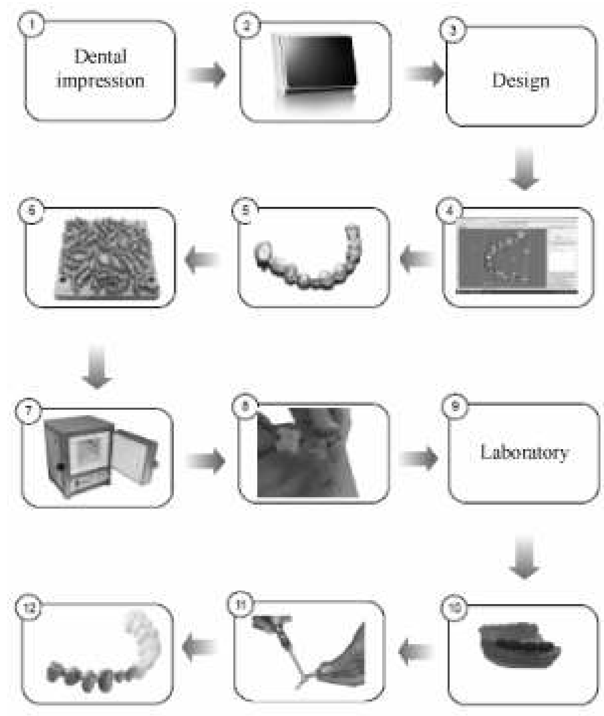


Fig. 14. Process of the dental bridge or crown production [6]

To eliminate the confusion over terminology, design, testing methods, materials and processing differences, SME's Rapid Technologies and Additive Manufacturing (RTAM) community approached ASTM to develop the industry first standards. They developed rapid manufacturing industry first standards for terminology, design and testing methods [1]. Some call it rapid prototyping, others rapid technology, while in some circles it is referred to as layered manufacturing. All are referring to the same technology. But a recent collaboration between the Society of Manufacturing Engineers (SME) and International American Society for Testing and Materials (ASTM) has finally decided on the name of rapid technology.

In Dearborn, MI, Jan 13, 2010 is made an effort to eliminate the confusion over terminology, design, testing methods, materials and processing differences, SME's Rapid Technologies and Additive Manufacturing (RTAM) community approached ASTM to develop the industry first standards [1].

ASTM has formed the Committee F42 on Additive Manufacturing, including members of the RTAM community, to write new standards. The initial result from that is the publication, "Standard Terminology for Additive Manufacturing Technologies". Members of Committee F42 issue an explanation that terminology standards will help to clarify communications especially in industries such as medical manufacturing and aerospace where consistency is a must. Test methods will more than likely be their next effort, but the additive manufacturing industry design, materials, and processes are also in the works and will be developed in parallel [1].

According to ASTM, these new standards will allow manufacturers to compare and contrast the performance of different additive processes and enable researchers and process developers to provide repeatable results.

As a result of the above mentioned, below in Figure 15 the schematic visualization of the additive manufacturing AM field of interests and research opportunities today and in future is shown.

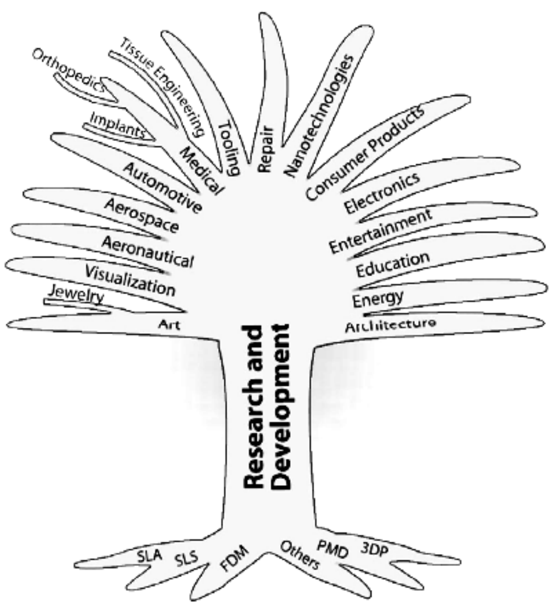


Fig. 15. Schematic visualization of the AM field

8. CONCLUSION

To eliminate the confusion over terminology, design, testing methods, materials and processing differences, SME's Rapid Technologies and Additive Manufacturing (RTAM) community approached ASTM to develop the industry first standards. Rapid prototyping, also known as additive fabrication, three dimensional printing, solid freeform fabrication, early prototyping, low conformity to a standard prototyping, and layered manufacturing, has to be standardized and finally is decided to be used in the future by the name of rapid technology.

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Р е з и м е

УПОТРЕБА НА БРЗА ИЗРАБОТКА НА ПРОТОТИПОВИ ВО ДЕНТАЛНАТА МЕДИЦИНА

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Клучни зборови: брза изработка на прототипови; стереолитографија; ламинирање; производство со надодавање; тродимензионално штампање

Во овој труд е обработена проблематиката на брза изработка на прототипови во денталната медицина. Дадени се детали за процесите кои се застапени при изработката, како и опис на материјали кои се користат за таа намена. Процесот на брза изработка на прототипови има своја примена и економска оправданост, бидејќи овозможува да се увидат недостатоци на одреден производ уште во фазата на развој и тие да се отстранат во понатамошни фази на проектирање и дизајн на тој производ. Дадени се поедини толкувања на поимите кои се користат во индустријата со заклучок дека брза технологија (Rapid technology) е универзално име кое треба да се користи од страна на производителите и луѓето кои се занимаваат со проучување на проблематиката на брза изработка на прототипови.

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ICT-BASED SOLUTION FOR TRADE FACILITATION ALONG INTERNATIONAL SUPPLY CHAINS

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A b s t r a c t: This paper aims to present how new technologies can be introduced in order to improve the performances of the established processes using the existing procedures. In this way, we fully use the advantages of the technology and we avoid the necessary change of the established processes and procedures, and in that way avoid the associated resistance of change. The customs procedures are in place for a long time and although they add cost and consume time to the international trade activities they are necessary for each country to monitor and control the flow of goods. In today's environment the only way a country can protect itself from hazardous materials, smuggling goods and human trafficking etc. is through effective customs procedures. On the other hand, the rigorous procedures may affect the effectiveness of the international trade and create additional burden for the business sector. In such recession times, when companies are fragile, such burden may be an "economy killer". Is advanced technology up to the task and can it provide what we need?

Key words: RFID technology; logistics information systems; supply chain management systems; customs procedure

1. INTRODUCTION

The process of international trade is one of the activities that makes this world go round and the execution of these activities is done by making decisions. The increased number of decisions needed to be made and the increased complexity of the decision making process resulted in increase of the needed amount of information. This phenomenon interfered to all aspects of our lives. We ended up in a "need to know" world where the consequences of a lack of information or a misinformation can be devastating. This "need to know" crosses the fields of economics, intelligence, military applications, the public and private sector [4]. The rise of the Internet, web-based technologies and the exponential increase in computing power provides the ability to explore the complex relationships of the global supply chains and build dynamic models that can better explain these interdependencies [1]. Today's matrix of the global commerce consists of multiple, integrated supply chains that crisscross the globe to form a system comprised of multiple actors (consumers, governments, SMEs, multinationals) and the transportation and communication links that connect them [2]. This system has to provide effective flow of information, materials and money to both directions and at the same time, has it provide the necessary reliability and security and satisfy the customer continuous need for speed and accuracy. In order to achieve all these tasks and demands the system has to complete a vast number of operations, to process a huge amount of data and to present the results in a form and structure understandable for each user [5].

Each activity in the international trade process along the international supply chains has its own complexity (Fig. 1). At this paper we will address the complexity and challenges of the customs procedures in that process. According the United Nations Council on Trade and Development it is estimated that the average customs transaction involves

30 different parties, 40 documents, 200 data elements (30 of which are repeated at least 30 times) and the re-keying of 60% to 70% of the data at least once [1]. This is more than a signal that with a minor intervention in the way how the information flow is handled, we can achieve time and cost savings.

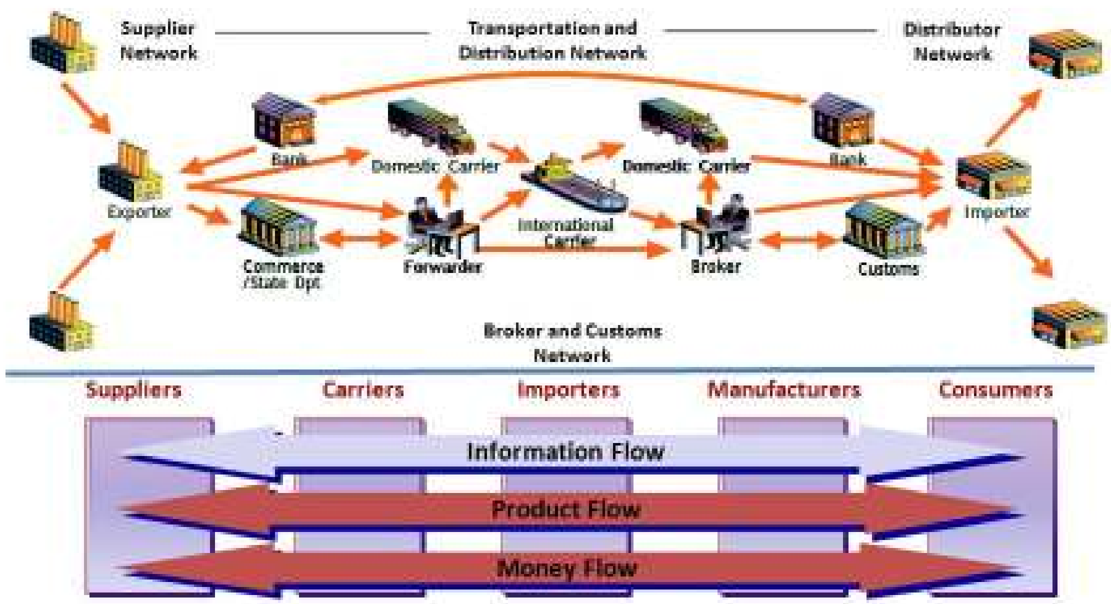

Fig. 1. Complexity of international supply chains

2. THE CHALLENGE

The customs procedures are in place for a long time and although they add cost and consume time to the international trade activities they are necessary for each country to monitor and control the flow of goods. In today's environment the only way a country can protect itself from hazardous materials, smuggling goods and human trafficking is through effective customs procedures [1]. On the other hand, the rigorous procedures may affect the effectiveness of the international trade and create additional burdens for the business sector [9]. In such recession times, when companies are fragile, such burden may be an "economy killer". The backbone of the customs procedures is information. Based on it, customs authorities make the necessary decisions. The quality and expedition of these decisions depend on the quality and expedition of the information [6]. In that way the challenge is to come up with a solution that will enable the right information to reach the right target at the right time.

3. THE SOLUTION

With the available ICT today in the world, it looks like the solution for the above described problem is easily achievable. Hence Thomas L. Friedman's conclusion that *The World is Flat*. But in fact the World is still round, and maybe the ICT technologies that are flattening the world in the end are making it even rounder [3]. Still, the ICT is the base technology that will provide the tool for solving the above described problem. By combining several technologies into one integral solution we can satisfy customer's need for the right information, in the right time, in the right format, in the right language on the right officer's monitor.

The core of the solution is into deploying a net-centric trade facilitation tool that links multiple country "single window" architectures between the Customs Administrations of Bulgaria, Macedonia, and Serbia. The technology and processes employed result with simplified trading procedures for the business community and allow greater communication between the three Governments. The solution integrates automatic identification and data capture (AIDC), global positioning system (GPS), and RFID technologies with electronic trade documents (Fig. 2). Added flexibility is obtained by enabling these combined data elements to be entered and distributed in multiple languages for operations oriented data reporting and analysis.

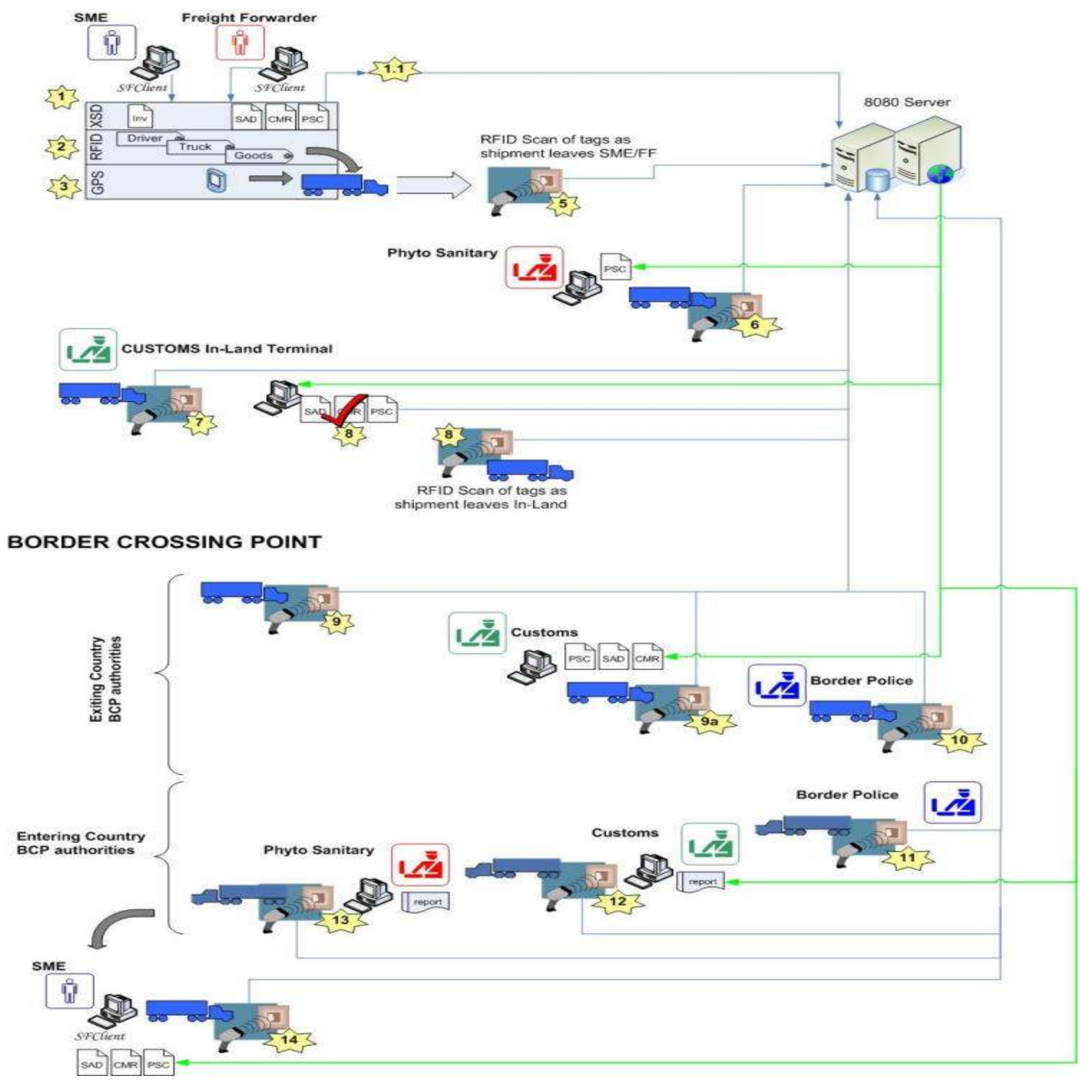

Fig. 2. Experimental design flow chart of multiple country "single window" architectures

The design of this multinational supply chain system allows diverse, stand alone databases and applications systems that vary in sophistication to "communicate" through the use of Core, Common, and Unique information sets [8]. This simplifies the web-based process complied with current data harmonization efforts by using 'core' UN electronic document (UNeDoc) formats as well as 'common' (EU, WCO, SEE) requirements and 'unique' country and business partner ICT structures to exchange trade documentation in the multiple languages and formats required by participants. The solution is designed to meet the requirements of global standards in trade and complex document requirements using a Graphical User Interface (GUI) with multiple search functionality that handles integration between trading partners and across governments [1].

At each step of the developed solution, supply chain data is available prior to each shipment's arrival at required verification points using a transmission portal that has multilevel security contorols. The web-based tool kit provides seamless data transmission and allows for real-time upload of documents to Virtual Relational databases (VRdb) by required authorities and company representatives. Each VRdb accumulates data in real-time from multiple sources (Shipper, Customs, Border Police, Phyto-sanitary, RFID, GPS) throughout the cross-border movement of goods and stores the data elements that populate reports and analysis systems. This trade data is linked and combined to create web-services reports originating from multiple legacy systems and web-based relational databases that presents data in a multitude of useable formats for real-time decision making capability (Fig. 3).

Fig. 3. Dynamic web service reporting

4. CONCLUSION

The growth, evolution and infiltration of the "network phenomenon" across the global community create an imperative for improved understanding of complex systems and evolution of the tools capable of multi-functional analysis. Integrated supply chain efforts are focused on enterprise resources planning (ERP), distribution resources planning (DRP), and global purchasing systems as examples of the many different 'systems' in use. Governments are able to offer Network Systmes solutions for Border Control Points (BCP) only through a "Single Window" type portal in an attempt to offer access to their integrated Customs, Border Police, Phyto-Sanitary and other agencies with different 'systems' and legacy environments [5]. The challenge was integration of these different Network Systems into a SoS ICT Architecture. The success was achieved by first, understanding the business requirements and then the information which needed to be exchanged in a SoS. The ICT Architecture was then developed which would allow the exchange in multiple formats and structures of the individual systems. The resulting SoS allowed successful exchange of data and documents along with the associated reporting. The effects of this capability have far reaching implications for overcoming the challenges of linking multiple trade systems into a truly adaptive and collaborative SoS for global supply chains [7]. This architecture provides insights into the development of a wide range of complex, 21st Century network applications.

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Р е з и м е

ИКТ-БАЗИРАНИ РЕШЕНИЈА ЗА ОЛЕСНУВАЊЕ НА ПРОЦЕСОТ НА ТРГОВИЈА ДОЛЖ ИНТЕРНАЦИОНАЛНИТЕ СНАБДУВАЧКИ СИНЏИРИ

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Клучни зборови: РФИД-технологија; логистички информативни системи; системи за менаџмент на снабдувачки синџири; царински процедури

Овој труд има за цел да покаже како новите технологии можат да бидат употебени за подобрување на перформансите на постојните процеси користејќи ги постоечките процедури. На тој начин, можеме целосно да ги искористиме предностите на новата технологија и во исто време ги избегнуваме неопходните промени на постојните процеси и процедури со што се избегнува одбивноста кон промените која секогаш ги пропратува измените на процесите. Царинските процедури се во функција веќе долго време и покрај тоа што тие додаваат трошоци и одземаат време тие се неопходни за секоја земја и следењето и контролиањето на протокот на стоки. Во денешното окружување, единствен начин на кој една држава може да се заштити од штетни материи, шверц на стока, трговија со луѓе итн., е преку ефективни царински процедури. Од друга страна, ригорозните процедури можат да влијаат на ефикасноста на интернационалната трговија и да додаваат дополнителен товар за бизнис секторот. Во вакви рецесиски вемиња, кога компаниите се лесно ранливи, ваков дополнителен товар може да биде Іубиец на економијатав во една земја. Дали напредната технологија е на врв на својата задача и може ли да го пружи она што на корисниците им е потебно?

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INFLUENCE OF THE SURFACE QUALITY DUE TO A HOLE DERIVED IN INITIAL MATERIAL PROCESSING OF COLD SHEETS WITH DRAWING

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A b s t r a c t: A research was performed about the influence of the surface quality due to a hole derived in initial material processing of cold-rolled steel sheets with drawing. This influence was researched through the surface quality obtained by the type of preparation of the hole surface without prejudice to the precise measurements of the achieved quality (asperity). The aim is to indicate how the type of manufacturing the holes can improve the workability of cold-rolled sheets and help solve technical production problems of drawing parts with previously made holes in the initial material.

Key words: drawing; effective deformations; effective stress: quality of the hole surface; punched; ground and unscrewing holes

1. INTRODUCTION

Openings without stringent requirement for their shape, position and dimensions and for various purposes: holes for ventilation, drainage holes for water and dirt, various exemptions for access assembly tools, forming a flat surface near a vertical wall often are found on the walls of parts made from sheets by drawing.

Their manufacturing after the process of drawing, especially in arias with complex form is quite difficult, sometimes impossible, requiring preparation of complex and expensive tools, increases the time of creation and thus the cost of the product. Therefore it is much better and more economical these openings to be performed in the initial material before drawing.

In such cases the process of drawing is different from the process of drawing with continuous surfaces. Long years of work experience with technological processes of drawing showed that very often the openings a critical place in the process of drawing are. Cracks appear on the drawing parts starting from the surface of the openings. It is therefore necessary to study the influential factors that can enhance the process of drawing and to improve utilization of available plastic properties of the material. Practice has shown that one of the influential factors is also the quality of the surface of the previously derived hole in the initial material.

2. PREPARATION FOR EXPERIMENTAL RESEARCH

The test was carried out with cold-rolled steel sheet Č 0147(RSt 13 according to DIN 17006), 1 mm thick. The sheet metal is cut in thin sheets from which with presser tools circular plates with diameter of 179 mm are cut. For the survey five thin flat circular plates with diameter of 179 mm from the examined material are prepared. One without a hole, and four with holes. At the center of four thin plates circular holes with diameter 12 mm are derived. The holes are made with unscrewing grinding and piercing. Circular plates with four different qualities of the hole surface are prepared in that way. Table 1 is gives the plates marked, dimensions of openings and the method of manufacturing.

On the drawing boards a measurement network of concentric circles and circles with d_o = 5 mm in radial directions is mechanically applied.

Table 1

Plate marked	Diameter of hole (mm)	Method of manufacturing the hole
2.4	Without hole	
3.2	12.04	unscrewing
3.4	12.14	grinding
4.2	12.0	Pressed by tool
4.3	12.0	Pressed by tool

3. PERFORMING THE EXPERIMENTS

The experimental research is carried out with hydraulic drawing on the Erickson test machine. A drawing of a flat plate without a hole until the emergence of a crack is carried out for results comparison [4].

First in the test tool a plate without a hole is inserted, and then a plate with a hole is placed on it. The plate marked 4.2 in which the hole is performed by presser tools during the drawing is positioned so that the entrance of the puncher is on the outside of the convex spherical surface. The plate marked 4.3 in which the hole is performed by the same tool is during the drawing is positioned so that the exit of the puncher is on the outside of the convex spherical surface. The drawing is performed until the emergence of a crack in the drawn plate with a derived hole.

Figure 1 shows the photograph of a drawn piece of initial material marked 3.2 on which a hole was derived by unscrewing.

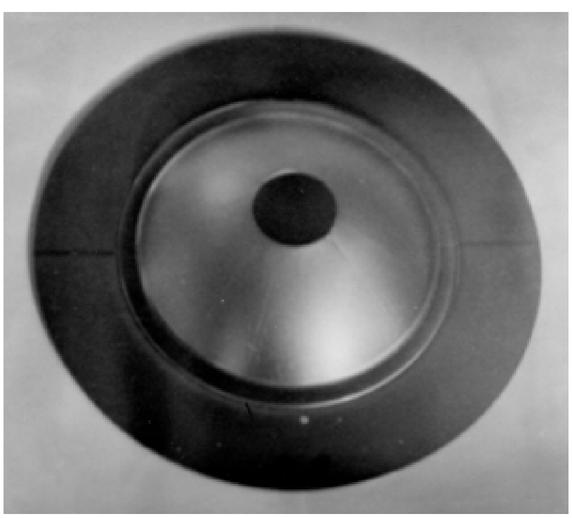

Fig. 1

4. MEASUREMENT AND PROCESSING THE RESULTS

After drawing, circles from the measurement network with a diameter d_0 are deformed into ellipses with axes d_1 and d_2. The longer axis is marked with d1 and it lies in the tangential direction, while d_2 is the shorter axis and it lies in the radial direction. The ellipse axes are measured to the nearest 0,1 mm. The measurement was carried out in the direction of rolling. By measuring deformations in one direction anisotropy impact of the material (metal sheet) is avoided. Accordingly, it is possible to compare the stress-deformational ratio for different qualities of the hole surface and compare them with the stress-deformational condition while drawing a metal sheet without a derived hole.

After measuring the ellipses' axes are determined:

1. Logarithmic deformations φ_1, φ_2 and φ_3 according to the equations [5]:

$$\varphi_1 = \ln\frac{d_1}{d_n}, \quad \varphi_2 = \ln\frac{d_2}{d_0} \quad \text{and} \quad \varphi_3 = -(\varphi_1 + \varphi_2)$$

2. Effective deformations (intensity of deformations):

$$\varphi_e = \frac{2\sqrt{1 - m + m^2}}{2 - m}\varphi_1$$

where $m = \frac{\sigma_1}{\sigma_1}$ is the stress ratio.

3. Effective stress (stress intensity)

$$\sigma_e = R_m e^{\varphi_m}\left(\frac{\varphi_e}{\varphi_m}\right)^{\varphi_m}$$

where:

R_m – tearing strength of the material previously examined experimentally determined

φ_m – maximum steady logarithmic deformation of material previously examined experimentally determined

4. Stress σ_1

$$\sigma_1 = \frac{\sigma_e}{\sqrt{1 - m + m^2}}$$

5. Stress σ_2

$$\sigma_2 = m\sigma_1$$

5. RESULTS

Figure 2 shows a diagram of the change of experimentally obtained effective deformation fie depending on the radius of the measuring network of the initial flat metal plate for the part (piece) drawn from the initial material without a hole derived, curve marked 2.4. The same diagram gives the hanges of effective deformation fie for the parts (pieces) drawn from the initial material with a hole derived. Curves are marked 3.2, 3.4, 4.2 and 4.3 as per Table 1.

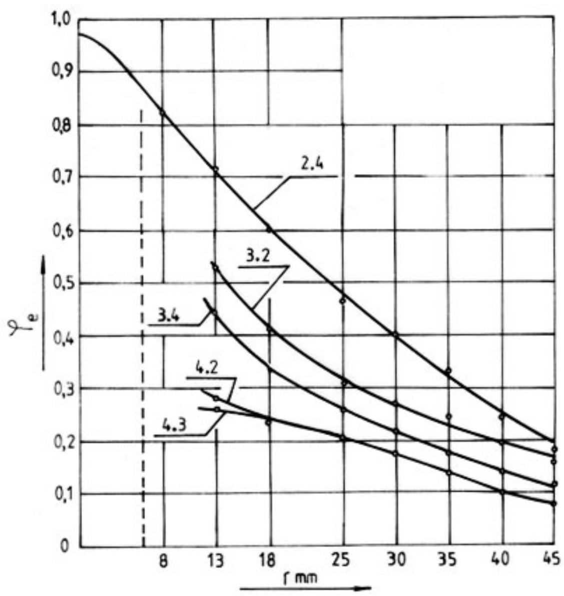

Fig. 2

Figure 3 shows a diagram of the change of experimentally obtained effective stresses σ_e depending on the radius of the measuring network of the initial flat metal plate for the part (piece) drawn from the initial material without a hole derived, curve marked 2.4 [1]. The same diagram gives the changes of effective stresses σ_e for the parts (pieces) drawn from the initial material with a hole derived.

The diagrams in Figure 2 and Figure 3 show that the smallest effective deformations and the smallest effective stresses are obtained for the drawn parts (pieces) bearing 4.2 and 4.3 [1]. These are pieces made of the initial material with presser tools made holes. This means that the smallest use of available plastic properties of the material is obtained when in the initial material a hole is derived by puncturing. The effective deformations and the effective stresses on the parts drawn with a punctured hole in the initial material starting from the outer radius derived in the direction of the derived hole are matched to $r \approx 18$ mm. In the vicinity of the hole they are different. This means that the effective size of the deformations and the effective stress for holes derived with presser tools are influenced by the way the work parts are set in the tools. This is due to the quality of the surface obtained with the technological operation penetration (crush zone and the zone of tearing the material), taking (into consideration) the thickness of the material (the side of the entrance and the exit of the puncher). Better use of plastic properties of the material is obtained if the initial material is placed so that the side of the entrance of the puncher is on the side of the material whisker with higher tensile stresses when the hole is derived. In this case that is the on the convex side.

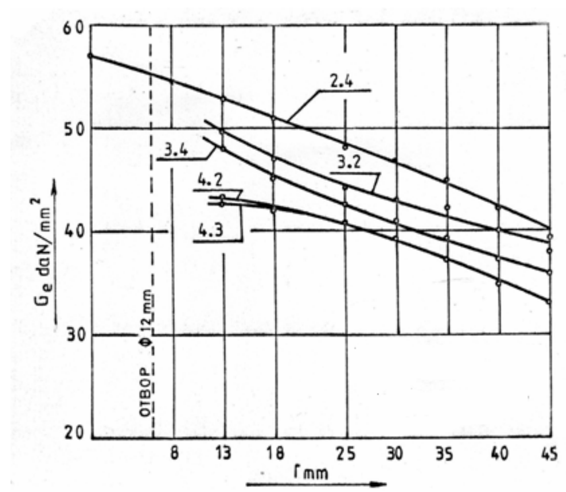

Fig 3

From the diagram it can be concluded that more effective deformations and effective stresses and thus better utilization of plastic properties of the material is obtained if the hole is performed with grinding, curve 3.4.

The biggest effective deformations and effective stresses and thus the best utilization of available plastic properties has the piece drawn from the initial material with a hole made by unscrewing, curve 3.2.

The change of deformations φ_1, φ_2 and φ_3, for the most favorable case (piece 3.2) is shown in Figure 4 [2, 3. 5].

The curves in the diagram in Figure 4 show that tangential deformation φ_1 and the deformation of the thickness of the wall φ_3, starting from the crown halo towards the hole, are steadily increasing in absolute value. While the radial deformation φ_2 from the crown halo increases up to the diameter $d = 70$ mm, and then decreases until it reaches zero on the hole surface.

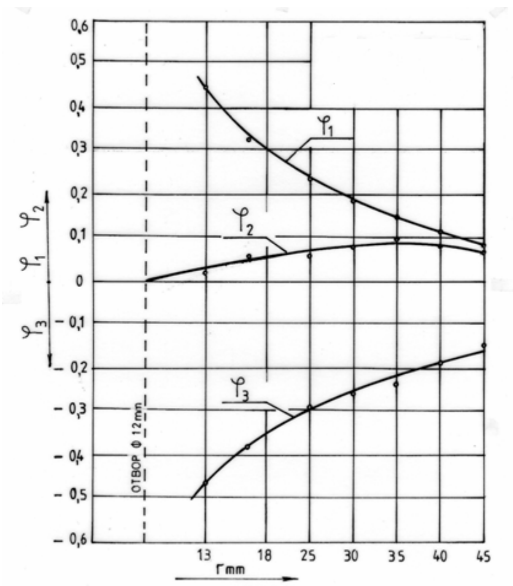

Fig. 4

Figure 5 shows the change of the effective stress σ_e and stresses σ_1 and σ_2. From the diagram means that starting from the crown halo, and in direction of the hole, the effective stress σ_e increases, stress σ_1 increases, and stress σ_2 starting from the crown in the direction of the hole increases slowly, and then decreases so that it reaches zero on the hole surface.

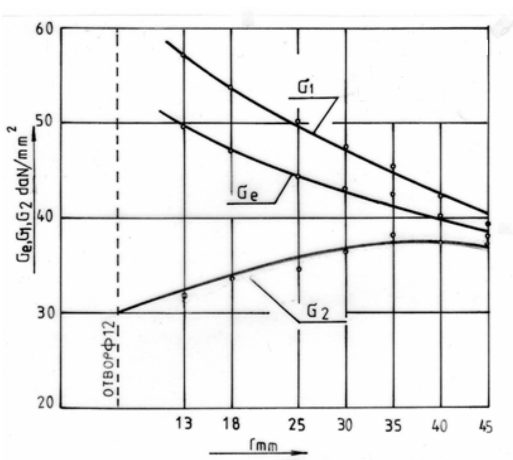

Fig. 5

6. CONCLUSION

– Holes derived in the initial material produce deterioration of the workability of cold-rolled metal sheet by drawing.

– The quality of the hole surface derived in the initial material has impact on the utilization of the plastic properties of the sheet metal while processing cold-rolled sheets by drawing.

– With holes derived in the initial material by piercing with presser tools the workability, in other words the utilization of the plastic properties of the material during the drawing process, is the worst. The placement of the initial material has also influence. Better results are obtained if the entrance side of the puncher tool after the drawing is on the side of the wall whose surface fibres are exposed to higher tension.

– The holes in the initial material made by grinding increase the workability of cold-rolled metal sheets by drawing.

– The holes in the initial material made by unscrewing allow best utilization of the plastic properties of cold-rolled metal sheets.

– If in the technological process of manufacturing parts with punctured holes in the initial material cracks appear at the hole for some reason in the drawing process, with additional processing, such as unscrewing of the holes in the initial material can significantly improve the process of drawing and overcome the problems.

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ВЛИЈАНИЕ НА КВАЛИТЕТОТ НА ПОВРШИНАТА ОД ИЗВЕДЕНИОТ ОТВОР ВО ПОЈДОВНИОТ МАТЕРИЈАЛ ВРЗ ОБРАБОТЛИВОСТА НА ЛАДНО ВАЛАНИТЕ ЛИМОВИ СО ИЗВЛЕКУВАЊЕ

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Клучни зборови: Извлекување; ефективни деформации; ефективни напони; квалитет на површина на отвор; пробиени; брусени и развртени отвори

Извршено е истражување на влијанието на квалитетот на површината на изведениот отвор во појдовниот материјал при извлекување на ладно валани челични лимови. Ова влијание е истражувано преку квалитетот на површината што се добива со видот на изработката на површината на отворот без да се навлегува во прецизно мерење на постигнатиот квалитет (рапавост). Има за цел да укаже како преку видот на изработката на отворите може да се подобри обработливоста на ладно валаните лимови и да помогне при решавање на производни технолошки проблеми при извлекување на делови со изведени отвори во појдовниот материјал.