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GLASS/EPOXY COMPOSITE USED AS A BASE OF METALFORMING TOOL'S DESIGN

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ABSTRACT

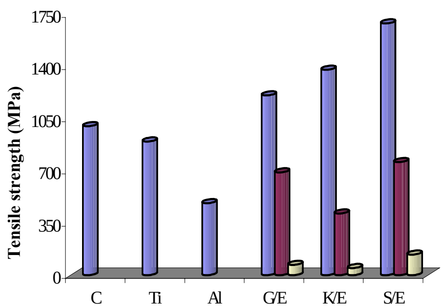
This paper outlines new approach for the development of a new composite material used and implemented for designing of metalforming press tools for producing a wide range of products.

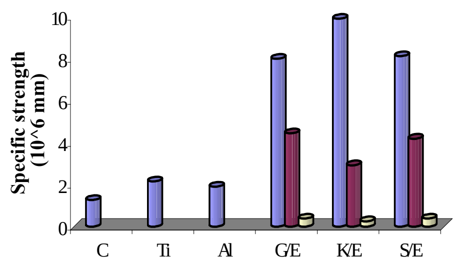
Therefore, there are made experimental investigation for improvement of strength and stiffness of the composite material and composite die sets at all.

The composite material is treated experimentally(planned experimental method) and the optimal matrix-reinforcing material relation has been defined.. Also, the correlation between the composite production process's parameters and the mechanical properties or responses of the composite, as well as its compositions, was the main point of the mathematical treatment and optimization of the composite. The corresponding response surface equations are calculated by means of multivariable analysis technique.

1. INTRODUCTION

The fast development of metalforming technology gives obligations to all engineers to increase knowledge and find solutions for using some new materials, which should be applied in the metalforming industry. Namely, it is necessary to find adequate materials with technological parameters and mechanical properties better than those of conventional metals and metal alloys are. Such a materials are composite materials, which offer many potential advantages when compared to metals. Composites can be tailored so to be nearly perfectly linear and elastic to failure. Composite structure may have fewer component parts, and thus may be less expensive and more reliable than its metallic counterparts. Although specific strength and stiffness are often important factors, composites also offer many other potential advantages when compared to metals. The advantages of composite materials become evident when material weight is considered. The specific strength of a material is defined as its tensile strength divided by its density. The specific strength of the materials listed in Figure 1 (a) are compared in Figure 1 (b). The figures show that the composite laminates are in all cases clearly superior to the metal alloys listed.





The main aim in this paper is to present composite material and mathematical design of the production's process of glass fibers reinforced composite material. The new developed composite is used for design of metalforming press tools. The mechanical properties and comparison analysis to metal's and metallic alloy's characteristics are also presented.

2. EXPERIMENT

The mathematical model of composite material has been made by using planned experimental method. The correlation between the composite production process's parameters and the mechanical properties or responses of the composite, as well as its compositions, are the main point of the mathematical treatment and optimization of the composite.

The corresponding response surface equations are calculated by means of multivariable analysis technique. Establishing of processing parameters such as independent variables reinforcement/matrix relationship, noted $X_{1,}$ deformation temperature, noted X_2, and deformation pressure, noted X_3 in correlation with mechanical properties of the composite material (ultimate tensile strength, tensile modulus, ultimate compression strength and modulus, impact resistance, flexural strength and modulus) is done by using well-design factorial experiment. It gives a chance for substantially reducing the number of required experiments. A design consisting of eighth experiments has been used to develop the model and for defining correlation between the composite's production's process parameters and mechanical characteristics of the composite.

Table No.1 Full three factorial experiments for the correlation between composite material's processing parameters and composite's mechanical characteristics

No. of experiment	Plan experiment's matrix								Characteristics (experiment's conditions)		
	x_0	x_1	x_2	x_3	$x_1 x_2$	$x_2 x_3$	$x_1 x_3$	$x_1 x_2 x_3$	x_1(%)	x_2(^{0}C)	x_3(MRa)
1	+1	-1	-1	-1	+1	+1	+1	-1	40	150	4
2	+1	+1	-1	-1	-1	+1	-1	+1	60	150	4
3	+1	-1	+1	-1	-1	-1	+1	+1	40	170	4
4	+1	+1	+1	-1	+1	-1	-1	-1	60	170	4
5	+1	-1	-1	+1	+1	-1	-1	+1	40	150	6
6	+1	+1	-1	+1	-1	-1	+1	-1	60	150	6
7	+1	-1	+1	+1	-1	+1	-1	-1	40	170	6
8	+1	+1	+1	+1	+1	+1	+1	+1	60	170	6
Basic level		50	160	50							
variation's interval		10	10	10							
upper level		60	170	60							
down level		40	150	40							

2.1. *Test samples (specimens) parameters*

All specimens were prepared from glass/epoxy composite in correlation with DIN and ASTM standards for testing plastics (Charpy test, Impact resistance test, High speed tensile impact, Tensile test, Wedging test, Compressive test, Flexural-three bending test). For each level of the experiment five specimens are used for each test respectively and the strength and the modulus of elasticity are calculated by standard procedure.

Specimens are made with size proposed by testing methods, and the thickness is varied in the range 3-10 mm. The specimens are cutted from the plane table in longitudinal and transversal direction considering the fiber direction.

3. RESULTS OF EXPERIMENTS

All mechanical characteristics are investigated and the mathematical models are given in a canonical form by polynomial equation, such as following:

$$y(x)=-434537.75+8143.06X_1+3083.72X_2+7623.07X_3-55.67X_1X_2-137.56X_1X_3-49.95X_2X_3+0.89X_1X_2X_3 \quad (1)$$

Equation 1 represents the dependence of the tensile force from the technological parameters of the composite material. The compressive strength is presented by the polynomial equation:

$$y(x)=-6540.4423+127.8344X_1+46.4647X_2+112.2921X_3-0.8498X_1X_2-2.0398X_1X_3-0.6908X_2X_3+0.0124X_1X_2X_3 \quad (2)$$

The statically determination of the coefficients was verified with Student criterion and the adequacy of the regression equation was checked with Fisher criterion.

By using above mentioned polynomial equation it is possible to determine and define the particular mechanical characteristic of the composite material. Namely, experimental investigation gives an opportunity to composite engineer to tailor the material such it could meet the specific stiffness or strength requirement of a particular application.

Some of the experimental results are presented in the following pictures:

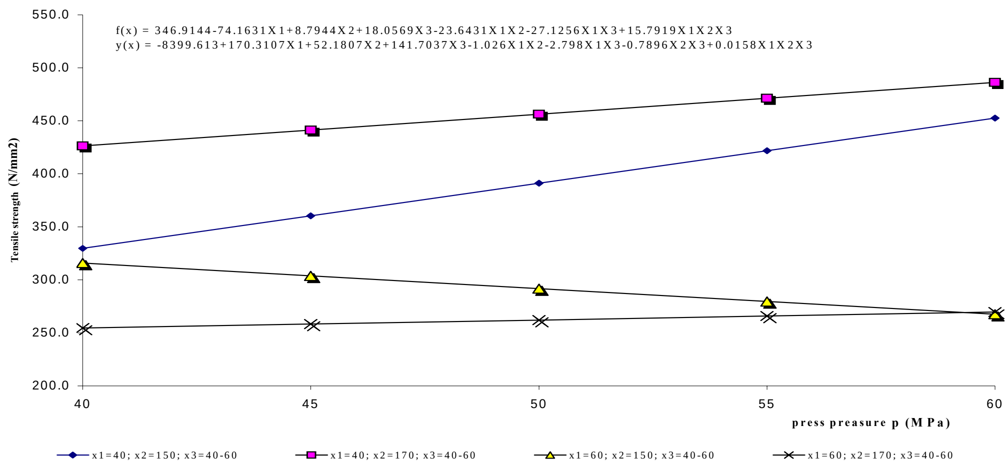


Fig.1. Tensile strength vs press preasure

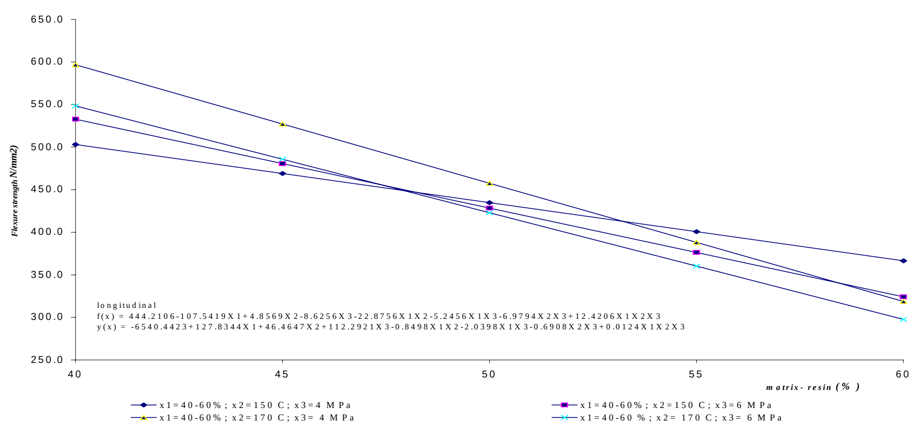
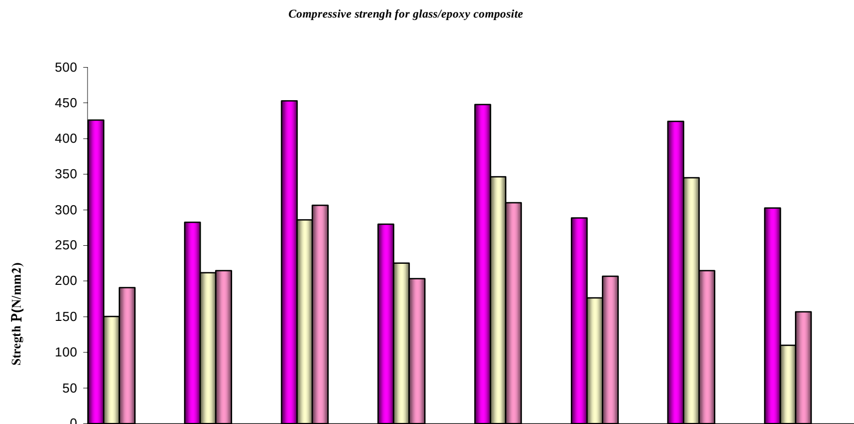


Fig.2 Flexure strength vs precent of resin



	1	2	3	4	5	6	7	8
strength-normal	425.98	282.55	453.06	279.595	448.085	288.455	424.32	302.465
strength-longitudinal	150.3	211.68	285.9	225.435	346.45	176.32	345.195	109.99
strength-transversal	190.72	214.845	306.2	203.29	309.955	206.545	214.405	156.95

Fig. 3 Compressive strength of the composite material for different level of the experiment

Since, the aim of this study was to establish and define the optimal matrix-reinforcing material relation by experimental treatment of the composite material. This experiment gives the optimal parameters in the range of:

- reinforcement 60 % (matrix/reinforcement 40/60)
- press temperature 150 ^{o}C
- press pressure 4 MPa

According to these production process parameters, the mechanical characteristics of the composite are:

Design data:

Resin: epoxy

Filler: woven glass

Characteristics: *Mechanical properties:*

- *Cross breaking strength:* *345 MPa*
- *Impact strength-Charpy method:* *100 KJ/m2*
- *Compressive strength* *200 MPa*
- *Shear strength* *140 MPa*
- *Tensile strength* *220-230 MPa*
- *Flexural module* *18 GP*

4. CONCLUSIONS

Experimental investigations proved the strength and stiffness of the composite materials and there is a good agreement for material's requirement for designing press tools by using composite materials. It makes press tools main characteristics such as: low specific weight associated with high stiffness, strength, fatigue and wear resistance.

As a main conclusions it could be stressed that the die sets which are available in a wide range of standard sizes by the different producers. They are all supplied in steel, aluminum, cast iron and other materials. With all examinations: experimental and numerical, it is found that all they could be replaced with die sets made by composite materials. The very closed tolerances, which are necessary for those kinds of press tools, can be attained.

The guide elements are also, available in various shapes and size. Method of their mounting can be push-fit, epoxy-bonding or screw clamping. Elastomers are used more and more in the field of metal forming, because they have very special properties and they could be used in tools, dies, jigs and even in machine applications. They could be employed as buffers strippers, ejectors and springs.

The experimental investigations on composite based press tools has confirmed the stiffness and strength of the tools. The stress analysis is made by using strain gages and system 5000 by Measurement group VISHAY. The stress analysis has confirmed the good distribution of stresses in all parts of the press tools. There are examined press tools for fine blanking, deep drawing and extrusion.

The finite elements analysis, made by using ALGOR FEA package, improved good stress-strain distribution in all parts off press tool. There is made a comparison between the results gotten by experimental and numerical investigation. It is obvious that there is better stress-strain distribution in tool made on the base of composite material then in tools made by using conventional materials: metals and metal alloys.

As a suggestion at the end of this paper could be stressed that investigations for new materials for designing press tools should be directed in the way of using composite materials and elastomers, because the press tools with be with a low specific weight and much better strength and stiffness. Also, there is an economical excuse of using composite, because the time spend for designing tools could be reduce and also the total price of the tool could be lower then for units made by metals and metal alloys.

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KORIŠĆENJE KOMPOZITA STAKLO/EPOXI KAO OSNOVE ZA IZRADU ALATA ZA OBRADU DEFORMISANJEM

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REZIME

Brzi razvoj tehnologije plastičnog deformisanja zahteva od stručnjaka u ovoj oblasti stalno usavršavanje radi nalaženja optimalnih rešenja. Posebno se to odnosi na primenu različitih materijal radnog komada i alata. Na tom planu učinjeni su značajni pomaci. Kreirani su novi materijali koji su svojim tehnološkim osobinama znatno nadmašili konvencionalne materilaje. Jedan od tih primea su kompozitni materijali koji nude čitav niz potencijalnih prednosti u odnosu na klasične materijale. Specifična čvrstoća kompozitnih materijala znatno je veća od metalnih a, pod određenim usovima, cena im je niža.

Glavni cilj ovog rada je da prikaže kompozitne materijale kao i matematički postupak pri procesu produkcije kompozitnih materijala ojačanim staklenim vlaknima. Ovakav novo razvijeni materijal koristi se za izradu alata za obradu deformisanjem. Izvršena je i komparacija ovih materijala sa klasičnim sa raznih aspekata. Analiziran je jedan broj setova alata urađenih od čelika i drugih materijala i ustanovljeno je da bi svi takvi setovi mogli biti substtuisani setom načnjenim od kompozitnih materijala, pri čemu bi se ostvarile i značajne tehno/ekonomske prednosti.

Poglavlja rada su: 1.) Uvod, 2.) Eksperiment, 3.) Rezultati eksperimenta, 4.) Zaključak, 5.) Literatura.