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THE OPTIMIZATION OF THE STATE OF WELDING PARAMETERS TO OBTAIN METALIC STRUCTURES FROM THE OL 52.4k STEEL

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The metallic structures realized from OL 52.4k have a very wide use, but they are used especially in case of tools used in mining plants. Due to the important constraints these welded structures are submitted into practice, it is very important to determine a set of optimal parameters of the welding system, so the obtained welded joints have an tensile stress R_m as big as possible. Among the experimental research there were obtained a series of results which, by statistically processing, it has been allowed the determination of a set of mathematical models which offers the dependence of tensile stress of welded joints in function of the welding system parameters.

Key words: steel, welding, tensile stress, mathematical modeling

INTRODUCTION

The welding joint suppose the deposition of a filler material over an material support in order to obtain the desired characteristics and dimensions. (high tensile stress and to erosion abrasion and/or corrosion) [1].

The efficiency of the technological process of the welding joints depends first by the behavior mode of the main layer- addition layer couple and by the mode that the homogenous linkage between the peripheral atoms of the two materials in the contact zone and the close to that. The making of the homogenous linkage is the result of the technological stages of the deposit material addition over the support material. The most important technological stages of the welding process are: the specifical processing of the surface on which the addition material is deposed; the cleaning, the paint or varnish removal, the degreasing process in order to create the optimal adhesion conditions between the addition material and the main material in order to reduce the temperature gradient; the specifical deposition; the ensurance of solidification conditions avoiding the appearance of rifts; the apply of proper heat treatment according to the desired operating characteristics and the processing according to the operational dimensions [2].

The use of welding structures has become more and more signifiant in the last two decades, because of the advantages that these posess, in comparison with other structures obtained with different technological processes, the main advantages are: material economy (20-60 / %), and also a bigger resistance instead of clinching or infusing, better working conditions in which those are made and the superior quality of the welded joints has determined in the last years the replacement of the clinching in most over 90 / % of cases and infusing in over 60 / % of cases, the structures are reduced weight and having a easy constructive model, the technological and processing addings are smaller with 70-90 / % related to the infusion or forgery, the technological operations can be completely mechanized and automated so that the productivity is greater than other processing methods, there can be mixed or combined structures, realized from more parts, separately made, from different materials, by using different processing method and assembled threw the welding process, it is realize an important reduction manual work (30-75 / % related to infusion or forgery) and the increasing of the working conditions, easy to handle devices are used, more cheaper, easier mentenance and with a smaller impact on the envirement. By his specifical mode, the technological process of realizing of joint structure products presents a series some disadvantages that result, mostly, from the working with liquid state materials [3].

The joint structures used in mining work explotations are heavily stressed from the mechanical point of view, but at the same time they are submitted to the influence of the particular factors of the working place [4].

A big problem of these equipments is represented by the metallic joint structure who was not updated along the time and is up to be replaced [5].

These joint structures life are strong influenced by the materials properties evolution of their structure. Thus, an important property which must be considered in order to obtain joint structure refers to the tensile stress of the welded joint [6].

The main used steel for structures, related to carbon steels, gained a wide use in building the machines used in mining plants, due to their characteristics and which allows an appropriate behavior to combine stress respectively mechanical with the corrosive environment

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[7]. According to the conditions of technological explotation of joint structures, the breakages or cessions due to breakages are caused by the obtaining of some inferior mechanical characteristics for the joint welding or the extension of the fault dimensions appeared during the welding process [8].

MATERIALS

The recent research was focused on the possibility of obtaining welded structures with a high resistance, realized from the OL 52.4k steel. The use of the mentionned steel is recommended to produce resistance elements (beams, piles, cut-ends, traverses, back-legs, etc.). In order to be able to obtain the desired results, in the initial state of research there was established for the OL 52.4k steel the mechanical characteristics. They are presented in Table 1 and in Table 2 there are presented the chemical composition.

Table 1 **The mechanical characteristics of the OL52.4k steel**

R_m / MPa	R_{02}/ MPa	z / %	A / %	K_{CV} 20°C / J	K_{CV} 0°C / J	K_{CV} -20°C / J
568	402	23	31	79	64	52

Table 2 **The chemical composition of the OL52.4k steel / %**

C	Mn	Si	S	P	Al
0,217	1,6583	0,053	0,025	0,021	0,011

The obtaining of the welded joints has beed realized by using the automated welded under physical flux layer procedure. For welding it was used the basic crowded flux, whose characteristics are shown in Table 3, intended for the use at the single-sided welding of low- alloy steels and for high tensile stress steels used with non-alloyed wire-rod or low alloyed.

Table 3 **The characteristics of the basic flux**

Name of the flux	Density / kg/dm^3	Index of basicity
OK Flux 10.30 - Bazic - EN 760: SA Z1 65 AC	1,1	1,8

The basic flux offers the advantage of use with higher joint currents. The content of iron powder of approximately 35 / % contributes to his high rate of deposition. For base material thickness greater than 25 / mm it can be used the 3 wired-rod joint ensuring the filling of the backlash from a single by-pass.

The addition material has the form of electrode wire-rod built in hanks type OK Autrod 12.10 – AWS 5.17 – EL 12, EN 756 S1. The necessary main properties of the electrode wire-rod used are presented in Table 4 – the mechanical properties, respectively Table 5 – the chemical composition.

Table 4 **The mechanical characteristics of the addition material**

R_m / MPa	R_{02}/ MPa	K_{CV} 0°C / J
540	650	50

Figure 1 The welding under flux layer equipment, model ESAB-LAF1250DC

Table 5 **The chemical composition of the addition material / %**

C	Si	Mn
0,12	0,08	1,9

RESULTS AND DISCUSSIONS

For all the experimental tests, it has beed used sheet made from OL 52.4k steel, with 10/mm thickness, properly prepared for joint process. The hauling test, in order to determine the welded joints tensile stress was made on a hydraulic device test type WE 100. In order to realize the welded stitches the joint equipment ESAB-LAF 1250 DC was used (Figure 1). The current source used for welding is a power source for tri-state welding, controlled by remote control, bilt to have a high efficiency. Also, this source was used in combination with the control panel ESAB, A2-A6 Process Controller (PEH).

In the deployment of the experiments it was proposed to follow two basic steps: the proper deployment of the experimental tests; the analysis of the obtained experimental data.

The study of a phenomenon from a certain domain of activity takes place with an analysis of the influence of different parameters on this phenomenon, and this can be realized by studying the influence of every parameter among this phenomenon, by maintaining constant values for the other parameters. Thus, the used method was the factorial experiment method. To simplify the experimental research program there were used for every influence parameter about three levels. So, for every parameter of the welding system as the welding current I_w it has been accounted a minimum level of 220 / A an average level 231 / A and a maximal level of 242 / A, and for the welding tension there were accounted a minimum level of 25 / V, an average level of 29 / V and a maximal level of 33 / V. By considering of two parameters of experimental of influence and three levels for each of them, it has been resulted an experimental program that includes a number 3^2 experiments.

Also, to avoid certain errors that might appear during the experimental process, for every experiment made with a certain welding technique three samples were manufactured, and the resulted value of the tensile stress was considered the average of the three samples: X_m = (X1+ X2+ X3) /3.

So, the total number of samples obtained during the experimental search was 27 that is three for each of the nine experiments. The results for the tensile stress R_m, during the experimental tests are presented in Table 6.

Table 6 **The values of the tensile stress of the welded joints made from OL 52.4k**

No.	No. of the samples	The welding current I_w / A			The welding tension U_w / V			R_m / MPa
		220	231	242	25	29	33	
I	X_1	1	0	0	1	0	0	519
	X_2							521
	X_3							518
	X_{mI}							519,3
II	X_1	0	1	0	1	0	0	516
	X_2							517
	X_3							520
	X_{mII}							517,6
III	X_1	0	0	1	1	0	0	523
	X_2							520
	X_3							517
	X_{mIII}							520
IV	X_1	1	0	0	0	1	0	518
	X_2							521
	X_3							515
	X_{mIV}							518
V	X_1	0	1	0	0	1	0	516
	X_2							525
	X_3							520
	X_{mV}							520,3
VI	X_1	0	0	1	0	1	0	520
	X_2							522
	X_3							517
	X_{mVI}							519,6
VII	X_1	1	0	0	0	0	1	516
	X_2							523
	X_3							524
	X_{mVII}							521
VIII	X_1	0	1	0	0	0	1	517
	X_2							517
	X_3							523
	X_{mVIII}							519
IX	X_1	0	0	1	0	0	1	527
	X_2							518
	X_3							521
	X_{mIX}							522

In order to realize a proper processing of the experimental data presented in Table 6, an entire series of elements should be considered. By the processing of statistical experimental data it is followed the obtaining of some concluding results about the evolution of different response sizes which are constituted in independent variables, related to independent variables. Generally, in order to realize the statistical data processing, a specifical technique and a calculus program are used.

The calculus program used for the statistical experimental data processing was STATISTICA, and the experimental data gathered during the measurements have constituted the input values for the utilized calculus program. Thus the experimental data processing was realized considering a specific graphical processing which gives the dependencies presented in Figure 2, Figure 3 respectively Figure 4.

Also, after the statistical data processing regression equations there were obtained for the dependent variables related to every independent variable, R_m = f (I_w), R_m = f (U_w), but also equations which present the dependence between the two independent variables R_m = f (I_w,U_w), presented in Table 7. In the same time, an analysis of a multiple regression was realized in Table 8 which allows the observation of the accuracy of the determined mathematical models, also the way which the welding current I_w, respectively the welding tension U_w influence the joint welding tensile stress R_m. Also, obtaining regression equations which could describe better the studied phenomenon is one of the main goals of the statistical experimental data processing.

In order to analyze the accuracy of the mathematical models presented in Table 7, a residual analysis was made, which reveals the difference between the values

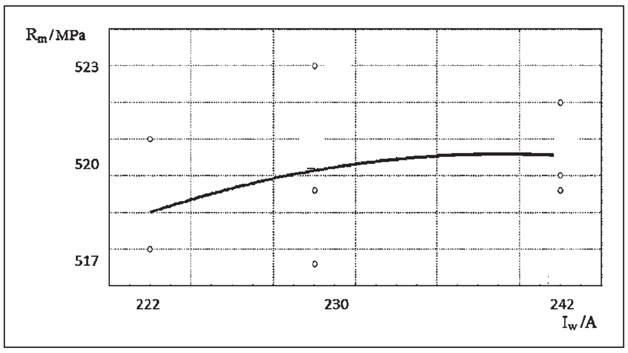

Figure 2 The dependence between the tensile stress R_m and the welding current I_w

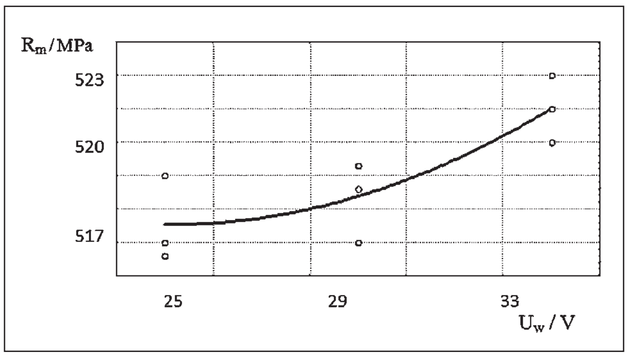

Figure 3 The dependence between the U_w and the tensile stress R_m

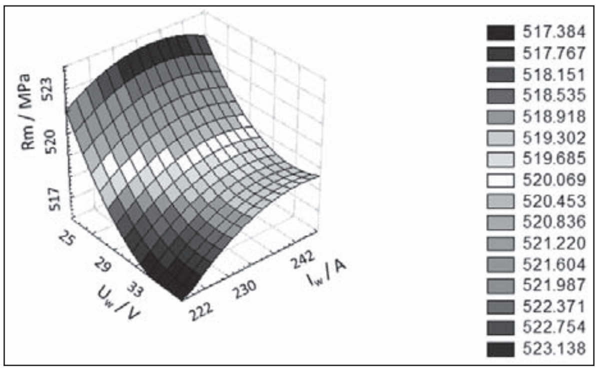

Figure 4 The dependence between the tensile stress R_m, the welding current I_w and the welding tension U_w

Table 7 **Mathematical models which gives the dependences $R_m = f(I_w)$, $R_m = f(U_w)$ respectively $R_m = f(I_w, U_w)$**

Modelele matematice
$R_m = 215{,}645 + 2{,}55 \cdot I_w - 0{,}005 \cdot I_w^2$
$R_m = 553{,}677 - 2{,}799 \cdot U_w + 0{,}056 \cdot U_w^2$
$R_m = 105{,}213 + 3{,}586 \cdot I_w - 1{,}136 \cdot U_w - 0{,}007 \cdot I_w^2 - 0{,}009 \cdot I_w \cdot U_w + 0.061 \cdot U_w^2$

Table 8 **The analysis of the multiple regression for the obtained experimental results**

Dep. Var. : Rm	Multiple R: 0,86964		F = 10,8607
R^2: 0,765227713			df = 2,7
No. of cases: 10	Adjusted R^2: 0,6866		p = 0,007147
Standard error estimate: 0.9888933896			
Intrecept: 490,549	Std. Error: 9,71707	t(7)=50,483 p<0,001	
$I_{wbeta} = 0{,}338$ $U_{wbeta} = 0{,}801$			

of the tensile stress of the welded joint experimentally and those obtained by mathematical modeling, Table 9.

Table 9 **The residual analysis**

Measured Value	Predicted Value	Residual Value
518,0000	517,5084	0,49164
517,6000	518,0895	-0,48950
520,0000	518,9611	1,03888
518,0000	519,2417	-1,24170
520,3000	519,8228	0,47717
519,6000	520,6945	-1,09448
521,0000	520,9750	0,02496
523,0000	521,5562	1,44385
522,0000	522,4278	-0,42780

CONCLUSIONS

At the final of the analysis of the evolution of mechanical characteristics of the welded joint related to the welding process parameters (I_w, U_w), in the case of welded joint parts realized from OL52.4k using the automated joint under flux layer, the following conclusions result:

- the tensile stress(R_m) has an increasing evolution same as the welding current (I_w), but very slow until it reaches values of 230 / A and after that, it is observed an aplatization of that is observed, thus it remains almost constant, Figure 2;

- the tensile stress has an increasing value given by the welding tension (U_w), but with an evolution especially until it reaches 29 / V, Figure 3, after this value the increasing process is accelerated;

- in order to observe the evolution of the tensile stress related to the welding current and the arc supply voltage, there was built a graphical 3D system, Figure 4. In the mentionned figure we can observe the fact that the I_w and U_w has an influence on the mechanical resistance in increasing mode, but the tension has a bigger influence proportion, at values of over 28 / V. Also, the intensity of the current influences the mechanical resistance, but in a lot lower proportion and only until 230 / A, afterwards, although the current increases, the mechanical resistance increases very little;

- the data presented in Table 6 has allowed us to realize a multiple regression analysis given by the current's intensity (I_w) and the welding tension (U_w), on tensile stress (R_m), so it can be observed that, the welding tension and the welding current have a positive influence about the ultimate tensile stress. So, within the increase of those mentionned, the tensile stress increases. The influence of the welding tension is a lot bigger in comparison with the influence of the welding current. ($U_{wbeta} = 0{,}801 > I_{wbeta} = 0{,}338$);

- the mathematical modelling of the influence given by the dependence of the tensile stress in function of the welding current is good to be made, within the meaning of, if it give up the experimental research and we use only the mathematical models (Table 7), the results would not differ too much in comparison with those obtained experimentally. This thing can be observed in Table 9, where the residual values, meaning the difference between the observed experimental value and the one obtained by mathematical modelling is very small, below 5 %.

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