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DEPENDENCE OF THE MECHANICAL PROPERTIES OF JOINTS WELDED ACCORDING TO THE PARAMETERS OF THE METAL ACTIVE GAS (MAG) WELDING REGIME

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The main objective followed in the realization of welded structures is to obtain superior mechanical characteristics for these structures. The research aimed at setting ranges of values for the welding voltage (U_w), respectively for the welding current (I_w) so as to obtain superior mechanical features for welded constructions. The research was carried out using E 36-4 steel as base material and SG2 wire as filler material, whereas the applied welding process was MAG. The optimization was done with the help of a number of 31 test bars considering various welding procedures for each test bar, and the experimental data were processed using the STATISTCA program.

Key words: MAG welding process, steel, parameters of the welding regime, mechanical characteristics, optimization

INTRODUCTION

Welded metal constructions were first used on an industrial scale for road and rail bridges, then for ships. The occurred damages were caused by ignorance and not knowing technology issues, but also by the use of materials with improper properties for the pursued purpose [1]. The frequent embrittlement cracking prompted the need for studies into the causes of damages, in particular with regard to the welding of complex metal constructions. Among the factors that have significant influence on the service life of welded constructions there can be mentioned: the choice of materials and technological welding processes, the chemical composition, the heat affected zone, etc. [2-4]. The choice of the welding processes and of the filler material depends first and foremost on the provisions of the given project and on the technical conditions of the contractor. In general, for heavy assemblies of large sizes made of profiles, metal sheets and other mechanically processed items, the MAG welding process is considered the most favorable process for welding steels [5]. The welding bead is made of the filler metal and a part of the molten base metal, resulting in a composition formed by the mutual diffusion of the two components [6].

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The electric arc is a concentrated source of energy, emitted in the form of electrons into the conductive space between the electrode and the bath, due to ionization. The resulted temperatures due to the Joule-Lentz effect amount to about 3 000 / ^{0}C and the current density amounts to about 100 / A / mm^2 [8]. A welded joint must have minimum thermal stresses, as they adversely affect the whole welded structure. The order of layers in the joint should permit the shrinkage of stresses through the successive strain relief between the layers.

Through the successive depositing of the layers, the regeneration of the microstructure is also achieved, as when a layer is molten, the previously deposited layer is heated above the A_{C3} transformation point**;** thus will be obtained for E 36-4 steel, after cooling in air, a mainly pearlite structure that is finer and stress relieved. The only remaining non-regenerated layers are those that are deposited last. The preparation of joint considers: balancing the shrinkages stresses and avoiding deformation in the assembly area [9, 10].

MATERIALS

The research aimed at establishing the optimum welding parameters so as to obtain the best mechanical characteristics for welded joints made from E 36-4 steel by using the MAG welding process. The use of this steel is indicated for the fabrication of resistance elements (beams, columns, sections, rails, brackets, etc.). In the experimental research it was taken into account the achieving of welded joints of plates with thickness of 10 mm. It also aimed at carrying out the welded joints perpendicularly to the axis of rolling of the plates.

The production technology of welded joints made of E 36-4 steel recommended not to preheat the base material up to thickness values of 10 / mm, as the linear energy during welding is sufficient for a proper welding process. To achieve the desired results in the research, for E 36-4 steel, primarily, was established the mechani-

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cal characteristics shown in Table 1 and the chemical composition shown in Table 2.

Table 1 **Mechanical characteristics of E 36-4 steel**

R_m / N / mm²	R_{p02}/ N / mm²	Z / %	A / %	K_{CV} 20°C / J	K_{CV} 0°C / J
568	402	23	31	79	64

Table 2 **Chemical composition of E 36-4 steel /%**

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

The welded joints were performed by applying the MAG welding process using a wire type SG2 with the diameter of Ø 1,2 / mm as the filler material; the filler material characteristics are shown in Table 3 and Table 4.

Table 3 **Mechanical characteristics of filler material**

R_m /N / mm²	R_{p02} / N / mm²	K_{CV} 0°C / J
535	642	40

Table 4 **Chemical composition of filler material / %**

C	Si	Mn
0,19	0,09	1,8

RESULTS AND DISCUSSIONS

In order to determine the optimal welding process for parts used in machine construction was established a procedure and a set of experiments so as to enable a conclusive analysis of the mechanical properties of welded joints. The MAG welding process is based on welding in shielded gas with consumable electrode and consists in the formation of the arc between the consumable electrode - in the form of a wire - and the part.

The technological process of welding can be used in semi-mechanized, mechanized, automated or robotized variants, with DC in reverse polarity, when the welding source has rigid external characteristic. The electric arc control is achieved through the self-regulation mechanism, while maintaining a constant wire feed value to the melted bath. The degree of universality is given by: the diversity of the weldable base materials and the position of welding. It should be noted that can be achieved a high deposit rate depending on the wire diameter and it can reach up to about 10 / Kg / hr. Another characteristic of this process is the intensive use of filler material, which leads to slag-free seams. The process is currently the most widely used welding process in industrial applications due to the economic advantages as compared to other methods. For the MAG welding procedure, the parameters of the welding regime were chosen as follows:

- the group of welding current, I_w = 195 – 235 / A, was divided as follows:
  a_1. I_w =195 – 210 / A;
  a_2. I_w = 210 – 220 / A;
  a_3. I_w = 220 – 235 / A.
- the range of welding voltages of the U_w = 21 – 35 / V group was divided into three groups:
  b_1. U_w = 25 – 27 / V;
  b_2. U_w = 23 – 24 / V;
  b_3. U_w = 21 – 22 / V.

With the groups of selected welding parameters for MAG welding technology were prepared and welded 31 test bars which were analyzed in terms of mechanical properties. Using the alternation 0 – 1 as method of combining the welding parameters, the results related to the mechanical characteristics are presented in Table 5; based on these results, an optimization of welding procedure of the parameters could be achieved so as to obtain higher mechanical properties of the welded joints.

Applying the MAG welding process by using SG2 solid wire with carbon dioxide shielded gas, was proceeded to taking samples and to executing the test bars; afterwards were analyzed the experimental results obtained and processed them using the "STATISTICA" programme. Thus, was arrived at the following conclusions:

- R_m is influenced by I_w - the influence is considerable up to I_w values of 215 / A, which means that R_m grows as I_w grows; above these values the growth is much slower;
- R_m depends on U_w, i.e. R_m grows up to a value of U_w = 23,5 / V, and above this value R begins to decrease;
- U_w has relatively small influence upon R_m, in the sense that it increases very little with the growth of U_w, and for values exceeding 23,5 / V of U_w it decreases;
- I_w has a greater influence up to the value of 215 / A, in the sense that R_m increases very much along with its growth, whereas above this value the influence is lower;
- U_w influences R_m very little, in a negative direction, i.e. with its growth combined with keeping the value of I_w, R_m shows a decreasing tendency;
- I_w has a very strong influence in a positive direction; with its increase, combined with keeping the value of U_w, R_m increases sharply;
- from the evolution of the values of R_{p02} and of the MAG welding parameters, can be observed increasingly higher values of R_{p02} along with the increase of I_w;
- with the increase of U_w up to a value of 23,5 / V, R_{p02} shows a slight decrease after which it manifests a rather slow growth;
- for values of U_w up to 23,5 / V, R_{p02} decreases with the increase of U_w, and above these values R_{p02} begins to increase. The maximum value of R_{p02} is obtained for I_w = 225 – 227 / A and U_w = 24 – 26 / V;
- I_w influences R_{p02} to a great extent and U_w to a much lesser extent. Both parameters positively influence the increase of R_{p02}. When one is maintained constant, the other has an influence in the sense that R_{p02} increases more sharply;

Table 5 **Mechanical tests of technological research with different parameters of welding procedure MAG**

No. of joint	No. of sample	Welding current I_w / A			Welding voltage U_w / V			Mechanical characteristics				
		202,5	215	227	26	23,5	21,5	R_m / N/mm^2	R_{p02} / N/mm^2	Z / %	A / %	K_{CV} 20°C / J
I	1s	1	0	0	1	0	0	662	457	24	29	37
	2s							648	461	28	31	36
	3s							649	462	26	26	42
	$\bar{X}_{I}$							653	460	26	28,6	38,3
II	4s	0	1	0	1	0	0	724	484	29	30	40
	5s							732	476	30	33	46
	6s							716	480	27	31	41
	$\bar{X}_{II}$							724	480	28,6	31,3	42,3
III	7s	0	0	1	1	0	0	746	490	29	33	41
	8s							743	482	34	39	46
	9s							751	498	32	30	39
	$\bar{X}_{III}$							746,6	490	31,6	34	42
IV	10s	1	0	0	0	1	0	672	461	27	29	40
	11s							669	458	26	28	39
	12s							678	462	29	30	46
	$\bar{X}_{IV}$							673	460,3	27,3	29	41,6
V	13	0	1	0	0	1	0	754	463	32	31	43
	14							760	467	28	30	47
	15							757	462	30	33	47
	$\bar{X}_{V}$							757	464	30,0	31,3	45,6
VI	16	0	0	1	0	0	1	762	476	29	33	48
	17							760	480	32	31	41
	18							760	479	30	35	46
	$\bar{X}_{VI}$							760,6	478,3	30,3	33	45
VII	19	1	0	0	0	0	1	680	454	28	30	47
	20							681	460	26	26	48
	21							680	462	26	27	44
	$\bar{X}_{VII}$							680,03	458,6	26,6	27,6	46,3
$VIII_s$	22	0	1	0	0	0	1	732	476	30	34	49
	23							724	468	28	29	45
	24							734	470	31	30	49
	$\bar{X}_{VIII}$							730	471,3	29,6	31	47,6
IX	25	0	0	1	0	0	1	784	476	32	34	44
	26							789	479	28	29	48
	27							785	474	31	33	48
	$\bar{X}_{IX}$							783	476,3	30,3	32	46,6
X	28	0	1	0	0	1	0	754	468	29	30	47
	29							761	462	30	34	44
	30							757	463	29	31	45
	31							553	467	28	30	46
	$\bar{X}_{X}$							756,25	465	29,0	31,25	45,50

- Z increases to a great extent along with the increase of I_w;
- when is analyzed only the dependence of Z on U_w can be observed that it has a slight tendency to increase up to 23,5 / V and then a slight tendency to decrease;
- the analysis of Z - values depending on I_w respectively U_w shows an increase of the necking for values of U_w above 23,5 / V and I_w between 225 / A and 227 / A. Low values of Z are obtained for U_w up to 23,5 / V and I_w up to 215 / A;
- I_w has huge influence on the value of Z in comparison with U_w;
- the dependence of A on I_w shows us a significant increase up to the values of 215 / A, after which A has a lower increase;
- A evolves depending U_w with a tendency to increase up to 23,5 / V, and above this value the increase slows down, and for the values of U_w above 25 / V, A remains approximately constant with the increasing of U_w;
- A has very high values for values of U_w of 23,5 / V and the values of I_w = 225 – 227 / A. For values of U_w under 23,5 / V and I_w up to 210 / A, as well as values of U_w over 26 / V and values I_w below the value of 215 / A, A decreases. The increase of A is evident for

values of I_w above 215 / A and values of U_w in the range of 23 – 26 / V.

- the evolution of K_{cv} depending on I_w shows that this is a tendency of increasing for the values of I_w up to 218 / A, after which it remains almost constant, with a slight downward tendency for values of I_w over 227 / A.
- from the evolution of K_{cv} depending on U_w can be noted that it has a slight tendency to decrease with the increase of U_w until its values up to 23,5 / V, after which the downward tendency increases.
- I_w influences in a positive way K_{cv} if its value is over 210 / A and U_w has values over 23,5 / V. The maximum value of K_{cv} is obtained at values of U_w in the range of 21 - 23 / V and values of I_w included in the 213 – 217 / A range.

CONCLUSIONS

As a result of the mechanical tests the analyzed samples were subject to, considering the welding parameters, can be could draw the following conclusions:

- R_m has maximum values when U_w has values in the 21 – 24 / V range and when I_w has values in the 220 – 227 / A range, with lower energies of the welding arc;
- the maximum value of R_{p02} is obtained for values of U_w between 24 – 28 / V and when I_w has values within the 215 – 230 / A range;
- Z has the maximum values of U_w in the 23 – 26 / V range and when I_w has values in the 225 – 237 / A range;
- A is maximum for values of U_w in the 23 – 26 / V range and when I_w takes values in the 225 – 227 / A range;
- K_{cv} is maximum for values of U_w in the 21 – 22 / V range and when I_w takes values between 210 – 220 / A.

The synthesis of the five conclusions is presented in Table 6, which presents the maximum values of the obtained mechanical properties for the welded joints made of E 36-4 by using the MAG welding process based on the technical parameters of the welding procedure.

The analysis of the data in Table 6 shows that the maximum values of the mechanical properties obtained for different MAG welding procedures of E 36-4 steel demonstrate that can be obtained superior mechanical properties for relatively small values of the linear energy, which leads to a lesser influence on the metallographic microstructure of the material in the welding bead, respectively of the material in the heat affected zone.

Table 6 **The maximum values of the mechanical properties depending on the welding parameters**

Welding para-meters	R_{mmax} > 520 / N/mm²	$R_{p02,max}$ > 390 / N/mm²	Z_{max} > 25 / %	A_{max} > 23 / %	$K_{cv,max}$ 20 / °C > 39 / J
U_w / V	21 – 24	24 – 28	23 – 26	23 – 26	21 – 22
I_w / A	220 – 227	215 – 230	215 – 230	225 – 227	210 – 220

REFERENCES

[1] ***Esab Welding Handbook, eighth edition – Consumables for manual and automatic welding.

[2] O. Chivu, , The optimization of the state of welding parameters to obtain metalic structures from the OL 52.4 K steel, Metalurgija 52 (2013) 4, 465-468.

[3] F. Kolahan, M. Hedari, Modeling and optimization of MAG welding for gas pipelines using regression analysis and simulated annealing algorithm, Journal of Scientific & Industrial Research 69 (2010) 4, 177-183.

[4] D. Dobrotă, Structural modifications which appear in the area of welds of welded structures made of st 52.3 steel, Metalurgija 53 (2012) 2, 179-182.

[5] D. Min, T. Xin-hua, L. Feng-gui, Y. Shun, Welding of quenched and tempered steels with high-spin arc narrow gap MAG system, The International Journal of Advanced Manufacturing Technology 55 (2011) 5-8, 527-533.

[6] M. Schnick, M. Dreher, J. Zschetzsche, U. Füssel, A. Spille-Kohoff, Visualization and Optimization of Shielding Gas Flows in Arc Welding, Welding in the World 56 (2012) 1-2, 54-61.

[7] P. Patel, S. Patel, Prediction of weld strength of metal active gas (MAG) welding using artificial nueral network, International Journal of Engineering Research and Applications 1 (2011) 1, 36-44.

[8] Y. B. Chen, J. C. Feng, L. Q. Li, Y. Li, S. Chang, Effects of welding positions on droplet transfer in CO2 laser–MAG hybrid welding, he International Journal of Advanced Manufacturing Technology 68 (2013) 5-8, 1351-1359.

[9] Information on http://www.esabna.com.

[10] Information on http://www.twi-global.com.

Note: The responsible translator for the English language is Rontescu Aurora Mădălina, Bucharest, Romania