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MAG WELDING PROCESS - ANALYSIS OF WELDING PARAMETER INFLUENCE ON JOINT GEOMETRY

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ABSTRACT
Quality of welded joint at MAG welding process depends of numbers of influences, like type and thickness of base metal, groove type, welding position etc., but the proper selection of welding parameters is also very important. Due to that, the analysis of weld bead geometry at MAG welding process with regard to weld current, voltage and weld speed (heat input) and the type and shielding gas flow is analyzed in this paper. The assumption that the proper selection of gas flow and heat input will reflect trough weld joint with satisfactory geometrical characteristics will be researched in this paper.
Keywords: MAG process, welding parameters, weld bead width

1. INTRODUCTION
Metal active gas welding (MAG) is, due to its good characteristics (above all flexibility and low price), one of the frequently used welding processes; in welding and surfacing in production, but also at reparation welding of most metal materials. Besides its other advantages, like, wide range of weldable materials and filler metals, the possibility of welding in all welding positions, good quality and mechanical properties of weld joint, it is necessary to mention the possibility of automation and robotization. At MAG welding process, the selection of main welding parameters (welding current and voltage, filler wire diameter, welding speed, shielding gas composition and flow rate, wire stick out etc.) has great influence on weld joint properties, but the selection itself depends of type and material thickness, joint geometry and welding position. Also, the correct choice of filler material, shielding gas and welding parameters will result with stabile welding process without appearance of welded joint failures and quality deviations.

The primary reason for shielding gas application during arc welding process is to protect the melted metal in electric arc area. Shielding gasses often used for MAG welding are (a) carbon dioxide and (b) mixtures of carbon dioxide and argon, sometimes with small amounts of oxygen. The choice of shielding gas composition will have effect not only on shielding efficiency, but also on: electric arc properties (arc with, metal transfer type and arc stability), metallurgical processes in molten material (reaction with oxygen and combustion of alloying elements as well as reactions with nitrogen and carbon), technological welding parameters (some gasses allow higher welding speed, some demand surface cleaning of welded joint), welded joint characteristics (weld shape geometry, weld surface appearance, mechanical properties), environment pollution (emission of the combustion products) [1,2,3,4]. It is obvious from the above mentioned that the choice of shielding gas type also depends on mentioned criteria, among others on: base metal type, welding position and joint geometry, required metal transfer type, welded joint shape and appearance, acceptable costs, possibilities of supply etc. [5].

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The goal of this investigation was to confirm the assumption that the proper selection of gas flow and welding speed (heat input) will reflect trough weld joint with satisfactory geometrical characteristics, therefore, the hypothesis of this paper is: there is the influence (connection) between heat input (weld speed) and gas flow on the weld bead width at MAG welding process.
Experimental research of MAG welding process with two types of filler material and two types of gas shielding composition are provided in this paper.

2. PLANNING AND SET UP OF EXPERIMENT INVESTIGATION

Since the dimensions of the bead on plate at MAG welding process is influenced by number of factors, in this investigation the two of them are selected: gas flow (l/min) and heat input (kJ/mm). The type, filer metal marks and diameter of welding wire used in experiment are shown in table 1. With cited filler materials, the experimental welding was performed: using shielding gas – carbon dioxide (C1 according to EN 439) as well as mixture of 18 % carbon dioxide and 82 % argon, called Krysal 18 (M21 according to EN 439).

Table 1. Filler materials used in experimental welding

Filler metal type	Filler metal mark according to standard	Wire diameter, ø mm	Producer mark	Producer
Solid wire	G Mo Si (EN 12070)	1,2	DMO-IG	Böhler, D
Rutile flux cored wire	T MoL P M 1 H5 (DIN EN 12071)	1,2	Fluxofil 25	Oerlikon, D

Measurement of welding parameters and monitoring of electric arc stability was performed by acquisition of welding current and voltage with *on-line* monitoring system. Figure 1 shows block diagram of experimental setup. Surfacing was performed by automatic MAG welding process with TPS 4000 power source (Fronius International GmbH, A). Tracking Vehicle FTV 4 connected to Control Unit FCU – 4 – RC remote control (both made by Fronius International GmbH, A) was used for the welding speed setup.

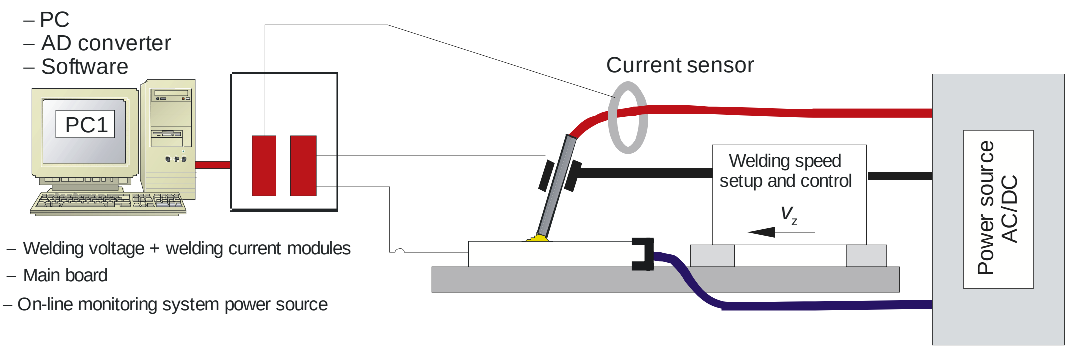

Figure 1. Block diagram of the experiment

Welding was performed on horizontal position on 16 Mo 3 steel plates (according to DIN standards, EN 10028-2 according to EN). In this paper the influence of the selected welding parameters on the weld bead width was analysed on two examples: welding wit solid wire with shielding gas CO_2 and with rutile flux cored wire with shielding gas Krysal 18 (table 2). The selected factors are varied on three levels so for every combination of the filler metal and shielding gas there are 9 experiment levels. The scheme of experimental investigation plan and the values of welding parameters for individual experiment levels are shown in table 2. Since full factorial designs in three levels 3^2 with 3 replication were used to obtain the required information, there was totally 2×27 specimens with different heat input and gas flow welded and the bead width was measured for all cases.
After finishing the welding processes, the specimens were cut in order to measure the bead width *b*, mm. The macro-structure photos were taken from the etched surfaces, and the bead width measurements were done by using a UTHSCSA ImageTool (**IT**); Department of Dental Diagnostic Science at The University of Texas Health Science Center, Texas USA [6]; program. A schematic illustration of bead penetration measurement is shown on figure 2. The results of measurements and welding parameters are shown in table 3. The factors (A – heat input and B – gas flow) and their

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levels are defined. The values of the welding current and voltage are specified as the mean values of the measurement obtained by on-line monitoring system (sampling frequency was 10 kHz). For individual experimental levels the heat input E_{ef} (kJ/mm) was calculated according to equation:

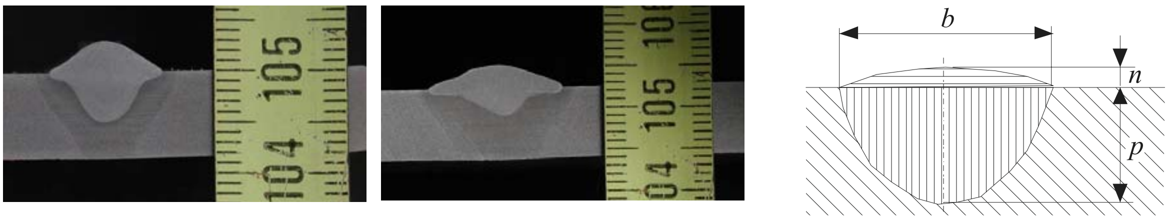
$$E_{ef} = \frac{U \cdot I}{\eta} \cdot v \, , \tag{1}$$

and the value η = 0,85 (thermal efficiency factor related to the type of welding process used) was taken from literature [7,8].

Table 2 Plan of experiment and welding parameters

Experimental name: PC (Filler metal: Solid wire, Shielding gas: CO_2)					
Weld No.	Gas flow f_g l/min	Welding speed v, cm/min	Arc voltage U, V	Welding current I, A	Heat input E_{ef}, kJ/mm
PC11	5	7,5	33,8	313,44	1,201
PC12	15				
PC13	25				
PC21	5	10			0,901
PC22	15				
PC23	25				
PC31	5	12,5			0,720
PC32	15				

Experimental name: RK (Filler metal: Rutile flux cored wire, Shielding gas: Krysal 18)					
Weld No.	Gas flow f_g l/min	Welding speed v, cm/min	Arc voltage U, V	Welding current I, A	Heat input E_{ef}, kJ/mm
RK11	5	5	26,89	314,23	1,436
RK12	15				
RK13	25				
RK21	5	7,5			0,957
RK22	15				
RK23	25				
RK31	5	10			0,718
RK32	15				



a b c

Figure 2. Photograph of weld bead of the specimens PC11 (a), RK 11 (b) and the cross-section of an ideal weld bead, where p is penetration, mm; n is reinforcement, mm; b is width of the bead, mm

Table 3. Measured values of weld bead width

Experimental name: PC (Filler metal: Solid wire, Shielding gas: CO_2)									
Factor A (heat input)	A_1 E_{ef} = 1,201 kJ/mm			A_2 E_{ef} = 0,901 kJ/mm			A_3 E_{ef} = 0,720 kJ/mm		
Factor B (gas flow)	B_1 f_g=5 l/min	B_2 f_g=15 l/min	B_3 f_g=25 l/min	B_1 f_g=5 l/min	B_2 f_g=15 l/min	B_3 f_g=25 l/min	B_1 f_g=5 l/min	B_2 f_g=15 l/min	B_3 f_g=25 l/min
Level combination	A_1B_1	A_1B_2	A_1B_3	A_2B_1	A_2B_2	A_2B_3	A_3B_1	A_3B_2	A_3B_3
Repetition	11,08	13,46	13,67	11,29	11,46	11,11	9,42	9,08	8,58
	11	13,62	13,72	11,42	11,41	11,08	9,34	9,08	8,53
	11,05	13,62	13,69	11,21	11,24	11,05	9,29	9,11	8,55

Experimental name: RK (Filler metal: Rutile flux cored wire, Shielding gas: Krysal 18)									
Factor A (heat input)	A_1 E_{ef} = 1,436 kJ/mm			A_2 E_{ef} = 0,957 kJ/mm			A_3 E_{ef} = 0,718 kJ/mm		
Factor B (gas flow)	B_1 f_g=5 l/min	B_2 f_g=15 l/min	B_3 f_g=25 l/min	B_1 f_g=5 l/min	B_2 f_g=15 l/min	B_3 f_g=25 l/min	B_1 f_g=5 l/min	B_2 f_g=15 l/min	B_3 f_g=25 l/min
Level combination	A_1B_1	A_1B_2	A_1B_3	A_2B_1	A_2B_2	A_2B_3	A_3B_1	A_3B_2	A_3B_3
Repetition	15,93	16,3	16,85	13,29	12,74	12,71	11,08	11,18	10,86
	15,93	16,27	16,9	13,32	12,82	12,71	11,15	11,13	10,86
	15,9	16,32	16,85	13,24	12,79	12,76	11,08	11,13	10,86

3. ANALYSIS OF EXPERIMENTAL RESULTS

Analysis of the values of the weld bead width at this experiment is conducted by Analysis of Variance [9,10] (since the information on significance of effects can be gained by this analysis) and the results are shown in table 4.

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Table 4. Analysis of variance

Experimental name: PC (Filler metal: Solid wire, Shielding gas: CO_2)					
Source of variation	Degr. of freedom *DF*	Sum of squares *SS*	Mean of square *MS*	Variance ratio v_o	*F* (95% confidence)
A	2	64,78	32,38	7029,66	3,55
B	2	2,85	1,42	309,26	3,55
AB	4	11,68	2,92	634,07	2,93
Error	18	0,083	0,00		

Experimental name: RK (Filler metal: Rutile flux cored wire, Shielding gas: Krysal 18)					
Source of variation	Degr. of freedom *DF*	Sum of squares *SS*	Mean of square *MS*	Variance ratio v_o	*F* (95% confidence)
A	2	131,11	65,56	70799,72	3,55
B	2	0,03	0,01	14,27	3,55
AB	4	2,04	0,51	551,58	2,93
Error	18	0,02	0,00		

From the comparison of the calculated variance ratio v_o with the value F for 95% confidence it is visible that factors A (heat input) and B (gas flow) are meeting criteria $v_0 > F$. The interaction of these two factors also meets this criterion for 95% confidence.

4. CONCLUSION

After conducted experimental welding and preparation of the specimens for macrograph analysis the bead on plate dimensions are measured (table 3, figure 2). The influence of the two effects: heat input (welding speed) and gas flow on the values of the bead on the plate width are investigated by analysis of variance for two cases: (a) welding with solid wire with gas shielding CO_2 and (b) welding with flux cored wire with gas shielding Krysal 18.

The results of mentioned analysis have shown that in both cases (welding with solid wire with gas shielding CO_2 and welding with flux cored wire with gas shielding Krysal 18) there is a significant influence of heat input and of mutual effect of heat input and gas flow. So in the following analysis, which would include the regression analysis, both of the researched effects should be taken in consideration.

Also, in a case of further investigation of the mutual effect of heat input and gas flow on the weld geometry at MAG welding process, the plan of experiment should be redefined and more researches conducted. Also, the attention should be given to porosity and other types of defects that appears on the weldments due to deficient or oversize quantity of the gas flow.

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