THE INFLUENCE OF WELDING PARAMETERS ON CHARACTERISTICS OF WELD METAL IN HIGHLY EFFICIENT GMA WELDING

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INTRODUCTION

Gas Metal Arc welding is at present the principal method of joining steel in welded structures fabrication. As far back as in the early part of 1980's the consumption of electrode wires for welding by this method in advanced countries exceeded the consumption of covered electrodes. In the last decade GMA welding has been intensively developed as a result of introducing new power sources and new welding consumables. At present, works in order to increase the effectivity of GMA welding are focused on two problems.

- an improvement in arc stability, control of metal transfer and control of the whole of welding process,
- an increase in welding productivity.

This purpose is achieved by bringing into practice electronically controlled power sources, development of new welding consumables (shielding gases and wires, including flux cored ones) as well as by development of new variants of the welding processes providing an increase in arc efficiency and welding speed. Highly efficient welding processes are brought into practice by a number of manufacturers of semi-automatic welding machines and shielding gases in a complex form comprising delivery of welding stations and technological know-how. It enables to master new processes and to achieve the planned effects in a short time.

Highly efficient variants of GMA welding are characterized by high electrical parameters of welding arc, high wire feed speed and by application of arc shielding gas mixtures having sometimes fairly complicated formula. It results in high costs of welding machines and shielding gases, what is unpropitious for propagation of these processes. At the same time it can be read in some publications that it is possible to run these processes with use of standard welding machines and cheaper shielding gases. This information became a ground for undertaking at the Institute of Welding in Gliwice a study of GMA welding with wire feed speed up to 25m/min and welding current up to about 450 A.

Characteristics of GMA welding process with application of high parameters of welding arc

The study was carried out with use of a semi-automatic thyristor power supplied welding machine (Imax= 550A) and a wire feeder with the feeding speed up to 25 m/min. It was used with SG2 type welding wire, 1.2 mm in dia, and the shielding mixtures as follows :

1. Ar + 10%CO_2 (90/10)
2. Ar + 15% He + 10% CO_2 (75/15/10) [75/15/
3. Ar + 30% He + 10% CO_2 (60/30/10) [60/30/

The technological study was started from deposition of weld metal under each of tested gas mixtures using short circuit, transition and spraying mode of metal transfer in welding arc. Welding current and arc voltage were recorded by means of a microprocessor device. The obtained data were analysed by means of a computer programme and the following parameters were determined.

Table 1 : Results of calculations of current-voltage characteristics in MAG welding under Ar+15%He-10%CO_2 shield

Oscillogram Symbol	Welding parameters				
	Mean arc voltage [V]	Mean welding current [A]	Mean short circuit time [ms]	Mean shortings number [n/20s]	Mean dI dT [A. ms]
B-1	22.43	167.22	4.398	529	33.05
B-2	35.43	178.91	39.25	2	33.58
B-3	35.01	204.65	11.15	11	58.50
B-4	24.38	217.69	4.195	512	35.62
B-5	34.53	229.25	39.93	4	51.25
B-6	26.50	249.95	2.924	298	36.97
B-7	27.07	284.35	2.560	128	36.95
B-8	28.12	298.35	2.667	17	38.89
B-9	31.06	379.74	0.000	0	0
B-10	34.49	419.04	0.000	0	0
B-11	39.02	352.38	4.475	8	35.47

- mean arc voltage,
- mean welding current

  During short-circuit arc welding and transition arc welding the following parameters were registered additionally.
- mean short-circuit time
- mean short-circuit number
- mean speed of short-circuit current upslope

As an instance, some results of calculations of current-voltage characteristics in welding under 75/15/10 gas mixture are given in Table 1.

It results from this analysis that in normal short-circuit arc the mean time of short-circuit ranges from 2.58-4.69 ms (90/10 mixture) and from 2.70-4.34 ms for 60/30/10 shield. The helium content in shielding gas does not affect this time clearly. The parameters of the stable spraying arc range from 280A(60/30/10) to 370A(90/10), Fig -1.

In these tests the deposition rate during welding under tested shielding mixtures was also determined (Table 2).

At most tested welding parameters the deposition rate under 90/10 shielding gas mixture was lower than that when welding under helium containing mixtures.

Weld deposits were subjected to macroscopic examination in order to determine the influence of shielding gas composition on the shape and dimensions of weld reinforcement and the depth of

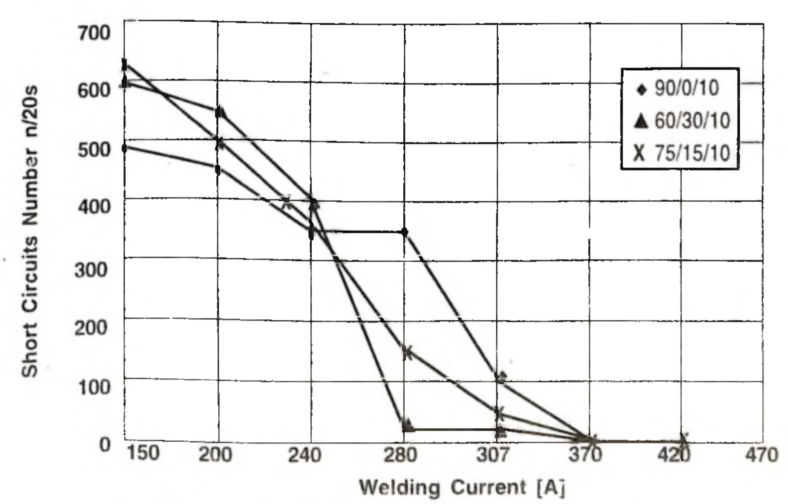

Fig.1. Number of shortings versus welding current

Table 2 : Deposition rate [g/A h]			
Amperage	Shield 90/10	Shield 60/30/10	Shield 75/15/10
150A	6.93	6.95	7.67
200A	7.90	7.89	7.15
240A	8.32	9.37	8.38
280A	9.82	10.21	11.15
307A	11.57	11.96	12.28
370A	12.55	14.18	13.77
420A	14.04	14.63	14.31

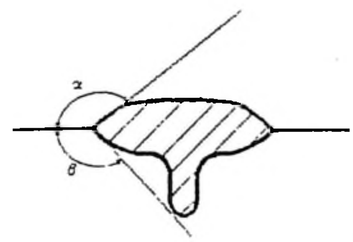

Fig. 2 : Measurement principle of α and β angles on microsections

penetration. The results of measurements of penetration depth are given in Table 3.

The welds shape, in view of the susceptibility to lack of fusion, was analysed on the basis of measurements of α and β angles shown in Fig.2. It was assumed that the right fusion occurs when $\beta < 170°$ whereas α cannot exceed 90°.

When welding was done with spray metal transfer these requirements were met for all tested gas mixtures and, at the same time, the β angle was within the range of 155°-165°.

Characteristics of all weld metal obtained during highly efficient welding

In order to determine all weld metal properties it was made test plates, 20 mm in thickness. Welding operations were carried out with 300, 350 and 400A welding current and all mentioned gas mixtures were used, one after the other, to shield welding arc. For comparison with the properties of weld metal obtained with common (trade) shielding gas, it was additionally used Ar+12% CO_2+2% O_2 mixture (86/12/2).

The welded plates were subjected to radiographical and metallograp-hical examination, chemical analysis (including determination of O_2,N_2 and H_2) and tensile and impact tests. The results of chemical analysis are given in Table 4, whereas the results of mechanical testing in Table 5.

The carbon, manganese and silicon content are very similar in weld metal deposited with the use of tested shielding gases, except 86/12/2 mixture. Content of gases was also not clearly different when the composition of gas and welding current were changed. These results do not correspond completely with mechanical properties of all weld metal.

The yield point and the ultimate tensile strength of weld metal deposited under tested gas mixtures differ insignificantly. Test results for these properties are ambiguous - in the mixtures containing helium R_e and R_m increased with an increase in the heat input, whereas in the helium-free mixtures they decreased.

Table 3 : Penetration depth versus welding parameters and arc shielding mixture composition.

Welding Parameters		Shielding gas 90/10	Shielding gas 60/30/10	Shielding gas 75/15/10
150A	21.5V	1.26	1.16	1.36
200A	24V	1.73	2.03	1.47
240A	26V	2.23	2.56	2.64
280A	28V	4.8	4.66	3.60
307A	29V	4.12	4.27	4.60
370A	32,5V	8.21	7.91	7.56
420A	35V	8.84	8.56	8.60

The results show that the high energy welding can be successfully applied to joining of carbon steels and common carbon-manganese ones. The ultimate tensile strength of weld metals is, irrespective of chemical composition of shielding mixture, higher than the required minimum value for parent material (for St 52-3 Steel:

Re_{min} = 345 MPa, Rm = 490 MPa and for welding wire (SG2 wire) Re_{min} = 460 MPa, Rm = 530 MPa.

The impact strength tested, according to the specifications of a number of standards, at temperatures of +20 or −60° C meets also, in general, the requirements specified in these standards. It has been confirmed a well-known occurrence of a decrease in the impact strength value with an increase in the heat input (increase in welding current).

In microscopic examination an attempt was made to find reasons of differences in properties of particular weld metals. The structure of weld metals magnified 100 and 200 X was observed and the quantitative analysis has been made by means of a stand for automatic image assessment. In weld metals it was found globular non-metallic inclusions of the type of complex oxides and oxide-sulfides. It was not found any relation between inclusions surface fraction on one hand, and welding parameters and chemical composition of shielding mixtures, on the other.

Having analysed primary structure of weld metals it was found that the number of dendrites decreases while an increase in the heat input takes place. In weld metals, recrystallized and not recrystallized (20%) structures occur. In recrystallized regions there is ferrite-pearlite structure with about 36% of ferrite. Any regular relationships between primary and secondary weld structure have not been found.

Technological conditions of high-energy welding

Welding parameters of some T- and butt joints are given in Table 6, as examples.

Large size of welding pool restricts the best effective application of highly-efficient welding, mainly to making fillet welds in flat or horizontal-vertical posi-

Table 4 : Chemical analysis of all weld metals and wires.

Shielding gas	Welding current	Content					
		%			ppm (mean values)		
	A	C	Mn	Si	O_2	N_2	H_2
60/30/10	300	0,09	1,11	0,67	289	71	1,15
	350	0,095	1,10	0,66	297	68	1,12
	400	0,09	1,10	0,62	329	132	0,37
75/15/10	300	0,095	1,14	0,67	246	74	0,36
	350	0,095	1,09	0,64	249	105	0,33
	400	0,085	1,15	0,60	323	71	0,20
90/10	300	0,09	1,08	0,66	314	66	0,57
	350	0,095	1,05	0,59	271	64	0,30
	400	0,095	1,15	0,66	329	60	0,41
86/12/2	300	0,10	0,64	0,32	422	61	0,45
	400	0,10	0,71	0,33	371	68	0,71
	220	0,10	1,25	0,78	504	69	0,68
	Wire with Cu coating	0,10	1,40	0,90	159	62	7,60
	Wire without Cu coating				126	62	4,50

Table 5. : Results of tensile and impact tests (mean values).

Shielding gas	Welding current A	Yield point Re MPa	Tensile strength Rm MPa	Elongation A_5 %	Impact strength KCV[J]			
					+20°C	–20°C	–40°C	–60°C
60/30/10	300	437,2	581,9	26,2	175,6	102,6	71,6	51,5
	350	436,3	586,0	26,0	157,5	73,1	58,8	27,0
	400	520,2	660,9	13,2	86,8	45,4	35,3	19,2
75/15/10	300	462,9	580,5	30,3	195,7	107,9	104,1	39,7
	350	459,4	583.2	26.6	108.7	116.7	61.9	39.2
	400	539,8	670,3	18,0	63,2	32,6	24,8	21,4
90/10	300	528,5	615,2	25,5	140,2	94,1	76,5	26,0
	350	473,0	598,2	24,8	158,9	117,6	56,5	40,2
	400	465.3	588.2	18,0	162,3	74,2	54,2	18,7
86/12/2	300	581,9	652,8	17,4	129,5	69,8	39,5	30,4
	400	542,6	637,2	21,6	74,8	35,6	22,8	15,1
	220	554,9	644,4	24,5	131,4	69,7	55,3	42,6

Table 6. : Technological conditions of welding of T- and butt joints.

Shielding gas	Weld size	Welding position	Layer no	Welding current A	Arc voltage V	Welding speed cm/min
Ar+10% CO_2	Δ 9	flat	1	460	44,8	30
Ar+15%He+10%CO_2	Δ 12	flat	1	460	45.2	30
			2	460	45.2	30
			3	460	45.2	30
Ar+15%He+10%CO_2	Δ 11	horizontal–vertical	1	338	34	50
			2	338	34	50
			3	338	34	50
Ar+30%He+10%CO_2	Y 12	Flat	1	220	25,8	50
			2	310	34,2	45
			3	310	37,4	45

tions. There are also other restrictions namely,

- difficulties in making tack welds and in elimination of craters.
- difficult working condition for welders being exposed to strong arc radiation and heated metal.

In practice, welding current higher than 400 A may be used, almost exclusively, in mechanized welding stations.

Summary

The study made at the Institute of Welding in Gliwice has proven a possibility of MAG welding with use of welding current up to about 450 A and conventional welding power sources. The machines must provide stable feeding of 1,2 mm wire at the speed up to 25 m/min and high thermal resistance of welding torch.

The mentioned welding parameters enable to achieve deposition rate of the maximum of 12,7 kg/h, with some small differences resulting from shielding gas composition. The shielding gas does not influence substantially the properties of weld metal obtained in high parameters welding. It results from the investigations that helium containing gas mixtures are more advantageous in consideration of penetration depth and lower susceptibility to form poor fusion defects than it is in helium-free mixtures. On the other hand, helium containing mixtures are more expensive. Both types of mixtures enable,however,to make correct welded joints with satisfactory properties of weld metal. The most effective areas of highly efficient welding application are heavy constructions of carbon and carbon - manganese steels where this type of welding provides a possibility of making repeatable joints by mechanized way. ■