The Effect of Heat Input on the Geometric Properties of Welded Joints

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Abstract

The paper discusses the effect of the heat input in the case of welding with solid and cored wire, respectively to the quality of the obtained joints. Formulas used for this purpose do not allow for the form of the filler, which, in the authors' opinion, has an effect on the basic parameters characterizing the welded joint. The paper presents the results of research on the geometric sizes of a joint made with a similar heat input, but using the filler in the form of, respectively, solid and cored wire. Investigations were carried out on fillet-weld joints that were subjected to macroscopic metallographic examinations. Studies have shown that the heat input given without allowing for the form of the filler does not reflect the changes that occur in the welded joint due to the thermal welding cycle.

Keywords: Heat input, Welded joint, Cored wire, Solid wire.

1. Introduction

One of the basis parameter of welding process is the heat input supplied to the welded materials. The problem of the correct determination of the heat input, and thus the amount of heat supplied to the joint, has been considered for quite a long time and is valid and still current [1-3]. Previous studies, as well as experiments carried out, have indicated a great complexity of the problem under consideration. To determine the amount of heat supplied to the joint as best as possible, much more parameters should be taken into account than the currently used formula does[3]:

$$EL_{Sp} = \frac{I \times U \times 60}{V_{sp}} \quad \left[\frac{J}{mm}\right] \qquad (1)$$

where:
EL_{Sp} – linear welding energy [J/mm]

I – welding current intensity [A]
U – welding arc voltage [V]
V_{Sp} – welding speed [mm/min]

Additional variables that should be considered when determining the amount of heat supplied to the joint, are, for example: the type of the basic material and the filler, the welding method, the mode of material transfer in the electric arc, or the type of run to be made. All of the above variables have a significant influence on the effects of action of the input heat and, consequently, on the geometric parameters of the joint and the size and properties of the heat-affected zone (HAZ). For unalloyed steels and steels after basic heat treatment–plastic working, changes occurring in the HAZ do not significantly impair the joint properties. However, the situation is different for alloy steels subjected to advanced metallurgical treatment, where there is a small error margin as far as the welding parameter selection is concerned [4].
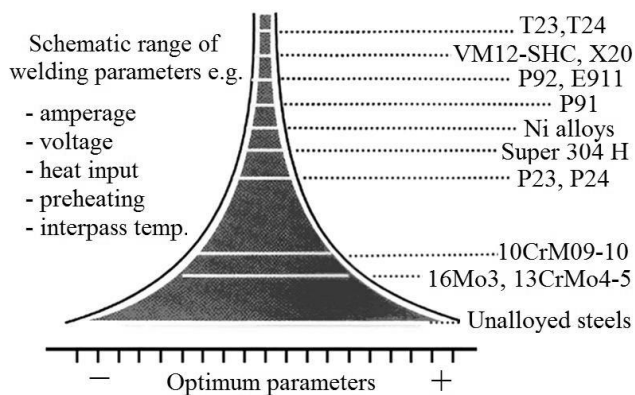
Fig. 1. Ideogram illustrating the narrowing possibility of making correct welded joints of energy steels [4]

2. Research methodology

The primary aim of this study is to investigate whether there is a correlation between the geometric properties of welded joints made using either cored or solid wire with the same amount of input heat.

In order to achieve this aim, 10 fillet welds were made in a side position using a semi-automatic welder with a maximum welding current of 400A and a blowpipe feed system of the PRO DC-20 type. For the tests, S235JR steel specimens of dimensions of 200x40 mm and a thickness of 8 mm were used. As a filler, LINCOLN ELECTRIC brand cored wire of the trade name Outershield 71M-H and ESAB brand solid wire of the designation OK Autrod 12.51 were used. The shielding gas for welding was CORGON 18. The wire diameter in both cases equalled 1.2 mm. It was assumed that parameter changes were limited to the exposed electrode wire length, wire feeding speed and the welding arc current intensity. The other parameters, such as welding speed (35 cm/min), wire diameter, the angle of wire inclination to the joint, gas flow rate and the polarity, remained the same in each case. The exposed length for the cored wire and the solid wire in three samples were assumed to be 20 mm. In the fourth sample, the exposed length was extended to 25 mm, while in the fifth sample, to 30 mm. Table 1 shows data used for determining the heat input of the welding process. Specimens welded with the cored wire are denoted by A, while those welded with the solid wire have the denotation B. Each of the prepared specimens was subjected to macroscopic examination. The examinations were conducted using an image analysis program by Olympus.

Table 1. Welding process parameters

Sample designation	1A	2A	3A	4A	5A	1B	2B	3B	4B	5B
Current [A]	260	249	233	245	224	255	244	235	246	242
Voltage [V]	26.1	25.2	24.3	26.5	26.9	27.2	25.1	24.2	25	24.6
Heat input [kJ/mm]	1.16	1.08	0.97	1.11	1.03	1.19	1.05	0.97	1.05	1.02
Exposed length [mm]	20	20	20	25	30	20	20	20	25	30
Wire feeding speed [m/min.]	3.9	3.8	3.7	3.9	3.9	3.5	3.3	3.3	3.5	3.5

3. Research results and their analysis

The welding process was conducted in such a way as to make a weld using cored wire and, after it cooled down, another weld using solid wire, both being made on one joint. The figure 2 shows the appearance of the obtained welds, which were the subject of subsequent investigation.

One of the weld assessment criteria is the magnitude of the weld surface area. This examination was done on macroscopic metallographic specimens using the Olympus image analysis software.

Figure 3 displays the results of weld surface area measurements. It can be noticed that for each specimen made using solid wire, the weld surface area is larger, and in the case of welds nos. 4 and 5, the differences reach 30%. This is associated with the adopted welding process parameters and with the electrode wire melting efficiency. Using greater current values

and a higher electrode wire feeding speed, a higher melting efficiency can be obtained for the cored wire. This is due to the greater density of the current flowing through the steel coat of the cored wire. In this case, the adopted welding process parameters did not allow the cored wire to reach a good melting efficiency. Obtaining similar results for both wire types under the assumption of no changes in current conditions is due to the change in welding speed and entails changes in linear welding energy.

Comparison of the weld fusion depth was made by juxtaposing the fusion depth in the vertical and horizontal lines (Fig. 4).

The results represented in Figure 5 shows that the fusion depth in the vertical line is much greater for welding with solid wire. Such a situation was observed in each examined case. It was also observed that the drop of voltage and current had the effect of decreasing the fusion depth for welds made using core wire.
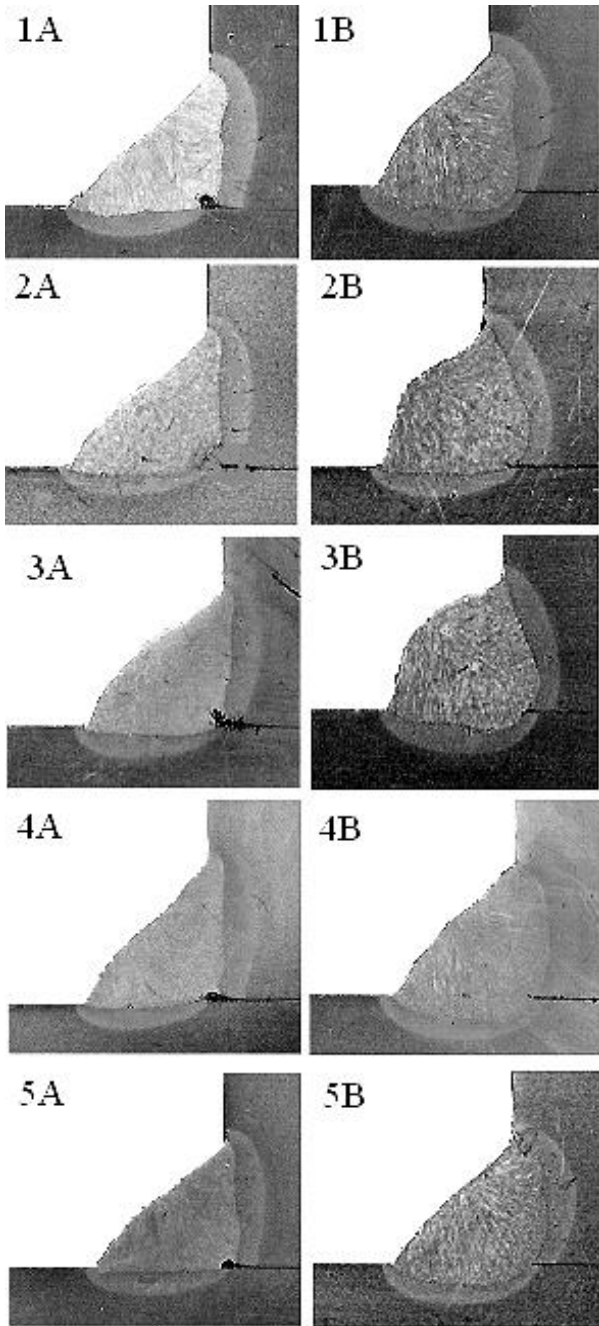
Fig. 2. The view of fillet welds: A - welds made with cored wire, B - welds made with solid wire
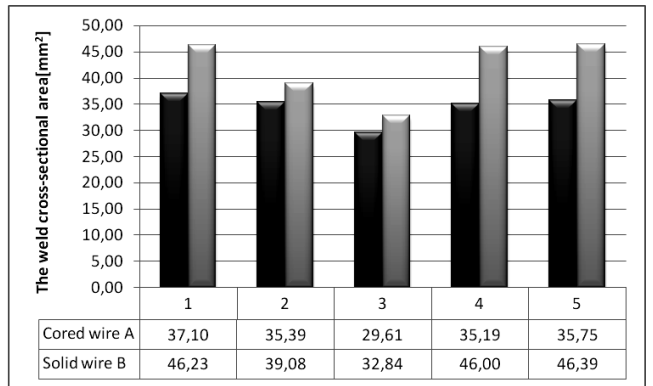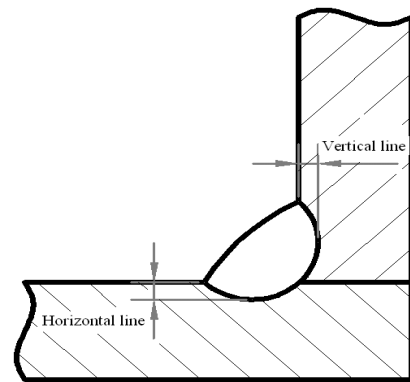

Fig. 3. The weld area

	1	2	3	4	5
Cored wire A	37,10	35,39	29,61	35,19	35,75
Solid wire B	46,23	39,08	32,84	46,00	46,39

Fig. 4 Determination of the weld fusion depth

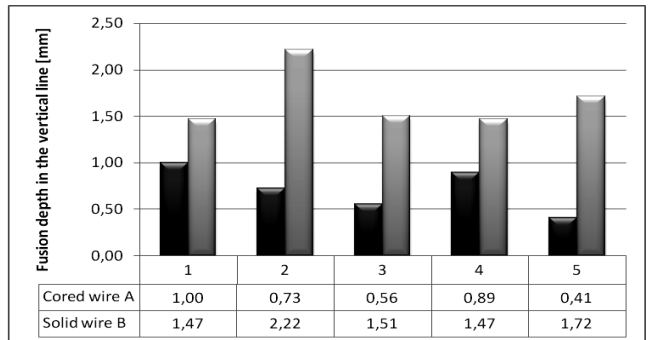|	1	2	3	4	5
Cored wire A	1,00	0,73	0,56	0,89	0,41
Solid wire B	1,47	2,22	1,51	1,47	1,72

Fig. 5. Fusion depth in the vertical line

In the case of solid wire welding, a significant increase in fusion was noticed for specimen 2B. Similarly as for the vertical line fusion, the horizontal line fusion is larger for welds made with solid wire. It was also noticed that following the change in the exposed electrode length in specimens nos. 3 and 4, a considerable increase in the horizontal line fusion took place. For welds made with core wire, the fusions remain on a similar level, with slight deviations resulting from the change in the current

parameters. To sum up, it can be stated that solid wire welding is characterized by a greater fusion depth, both in the vertical and horizontal lines. The fusion is proportional to the weld surface area. A larger weld has a greater amount of heated material, from which it gives up the heat to the environment.

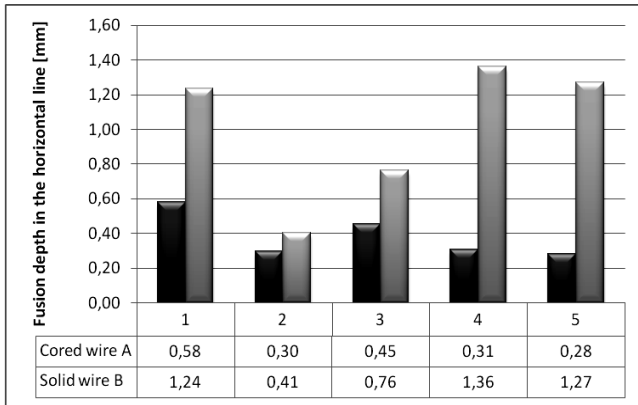|	1	2	3	4	5
Cored wire A	0,58	0,30	0,45	0,31	0,28
Solid wire B	1,24	0,41	0,76	1,36	1,27

Fig. 6. Fusion depth in the horizontal line.

In the majority of instances, the heat-affected zone surface areas joined with one another to form a uniform whole. The results of heat-affected zone surface area measurements are displayed in Figure 7.

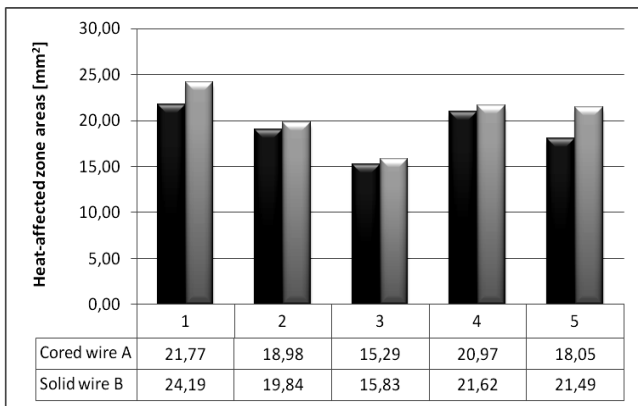|	1	2	3	4	5
Cored wire A	21,77	18,98	15,29	20,97	18,05
Solid wire B	24,19	19,84	15,83	21,62	21,49

Fig. 7. Heat-affected zone areas

The difference in heat-affected zone surface area between welds made with solid wire and core wire is small, ranging from 3 to 19%. In each case, welds made with solid wire had a slightly larger heat-affected zone surface area. The greatest increase in surface area was observed in welding samples nos. 4 and 5. This is related to the exposed wire length, which was, respectively, 25 mm and 30 mm. This was reflected in enhanced resistance heating of the electrode wire end and releasing of a greater amount of heat in the welded material.

4. Conclusions

The research results reported in the paper enable the following conclusions to be drawn:
1. An identical value of heat input results in different values of quantities describing the weld geometry.
2. The heat input given without allowing for the form of the filler does not reflect the changes that occur in the welded joint due to the thermal welding cycle.
3. The heat input estimated without considering the additional welding process parameters does not allow the definite assessment of its effect on the welded joint geometry.

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