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DETERMINATION OF OPTIMAL PARAMETERS FOR SELF-SHIELDED FLUX-CORED WELDING PROCESS

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ABSTRACT
Self-shielded flux cored welding wires have become very popular over the last decade, because of the various benefits they provide in relation to coated stick electrodes and welding wires with solid cross-section. Determination of optimal parameters for self-shielded flux-cored welding process is crucial for achieving the required level of quality of welded joints. Wire feed speed, welding current and arc voltage were measured in real-time during the welding and optimal functional relations between these parameters were formed using regression analysis. The results and comparison of established regression models with generally known models applicable to the wires with solid cross-section are presented in this paper.

Keywords: self-shielded flux-cored wires, optimal welding parameters, wire feed speed, welding current, arc voltage, real-time measurements, regression analysis

1. INTRODUCTION
Self-shielded flux-cored wires combine the characteristics of coated electrodes intended for manual metal arc welding and electrode wires with solid cross-section. The welding process which uses these wires resembles the combination of manual arc welding and MAG/MIG welding processes. Self-shielded flux-cored wire can be considered a continuous hollow electrode wire filled with protective materials in the form of powder. The powder which the wires are filled with has a similar role to the coatings of the electrodes intended for manual arc welding. In comparison to the manual arc welding, the benefits of welding with self-shielded flux-cored wires are: higher deposition rate, continual addition of electrode wire which eliminates the time needed for the replacement of the stick electrode,

there are no unused leftovers of stick electrodes and it lowers the number of interruptions of the welding process. The main advantage compared to the MAG/MIG welding processes is that mixtures of shielding gases are not used. Instead of the mixtures of shielding gases the powder which the electrode wires are filled with serves to protect the weld bead and simultaneously decreases the cooling rate, because it forms a protective layer in the form of slag on the surface of the weld seam. Therefore this welding process is suitable for field work.

All of the above affects increase the productivity and reduce the total cost of welding. For these reasons the use of self-shielded flux-cored wires is on a constant rise.
The selection of welding parameters has a significant impact on the characteristics and quality of welded joints [1,2]. This is especially evident when self-shielded flux-cored wires are used for welding, but the impact has not been sufficiently investigated [3]. In this paper, the method of determination of the optimal dependencies between the wire feed speed, welding current and arc voltage is shown based on the measurement of these parameters in real-time during welding [4].

2. EXPERIMENTAL PROCEDURE

The plates of microalloyed steel of grade P460NL1 and 14 mm thick were used as a base material for welding. The chemical composition of the base material is: 0,15% C – 0,38% Si – 1,70 % Mn – 0,015% P – 0,0021% S – 0,031% Al – 0,63% Ni – 0,037% Cr – 0,099% V – 0,038% Nb – 0,004% Ti. This steel is meant to produce pressure vessels designated for work at low temperatures. The welding was performed with the self-shielded flux-cored wire Coreshield 8, with the diameter of Ø1,6 mm, which is produced by a Swedish manufacturer "Esab". This electrode wire is designed to weld critical demand structural applications.

Two welded joints, each 500 mm long, have been made. A multi-pass welding has been performed in both cases. Before welding, the edges of steel plates were prepared to form a "Y" groove. Preheat temperature of the base metal and interpass temperature were 150 °C. During the welding the nominal parameters of the process were adjusted in the following range: wire feed speed was set between 2 m/min and 6 m/min and the arc voltage was set between 20 V and 26 V.

For welding and monitoring the parameters of the welding process the devices of the Finnish manufacturer “Kemppi" were used as follows: current source - Fast MIG Pulse 350, wire feed unit - Fast MIG MXF 65 and a device for monitoring the welding parameters in real-time - Fast DLI 20.

To determine the optimal functional dependences between the wire feed speed, welding current and the arc voltage, wire feed speed and arc voltage were fine-tuned before performing each of the passes in order to achieve the following: the greatest possible arc stability, minimized bursting of additional material, the ease of leading the arc and satisfactory visual quality of the weld seam. After the completion of fine adjustments of parameters and conduction of trial welding which reaffirmed the characteristics of the arc and weldment quality, the welding of steel plates was performed during which the values of mentioned parameters were measured in real-time.

3. RESULTS AND DISCUSSION

On the scatter plots, figures 1 and 2, are shown the results of real-time measurements of the parameters of the welding process. Based on the obtained data the regression analysis was done and mathematical models were formed describing the optimal mutual dependence of the wire feed speed, welding current and arc voltage:

$$I = 285 \cdot \log V + 23 \quad \text{... (1)}$$

$$U = 0{,}05 \cdot I + 14{,}4 \quad \text{... (2)}$$

where:
I - welding current, in Ampers,
U - arc voltage, in Volts and
V - wire feed speed, in meters per minute.

In order to analyze the representativeness of the regrational direction, the coefficient of determination was used. Coefficient of determination is a relative measure of compliance of the regrational direction with the measured values. This coefficient can have values in range from 0 to 1. The higher the value of the coefficient of determination, the more representative the regretional direction is. In cases of regresional models (1) and (2), coefficients of determination are over 0,9. Based on the values of coefficients of determination it can be concluded that the formed regretional models describe the functional dependencies between the measured values of the welding parametars well.

Formed functional dependences (1) and (2) are indicated by a solid line in figures 1 and 2, while the dashed lines on the same figures show generally known dependencies (3) and (4) applicable to the electrode wires with solid cross-section and with the diametar of Ø1,6 mm, which can be found in the relevant literature [5]:

$$I = 378 \cdot \log V + 26 \qquad \text{... (3)}$$

$$U = 0{,}05 \cdot I + 14 \qquad \text{... (4)}$$

where:
I - welding current, in Ampers,
U - arc voltage, in Volts and
V - wire feed speed, in meters per minute.

Comparing the models, shown in figure 1, it is evident that at the same wire feed speed the welding current is different for the compared types of wires. Due to the increase in wire feed speed this difference becomes more pronounced. The existence of this difference can be explained by the geometry of the cross-section of electrode wires. The cross-sectional area of self-shielded flux-cored wire is significantly smaller than the cross-sectional area of the electrode wires with solid cross-section. Therefore, at the same wire feed speed of the electrode wire, density of the current required for melting the self-shielded flux-cored wire is achieved at lower currents, while melting of the wire with a solid cross-section requires higher amperage [5].

Comparing the models shown in figure 2, a similarity in mathematical functions that describe the optimal dependence between the arc voltage and the welding current for both the types of the electrode wires can be noted.

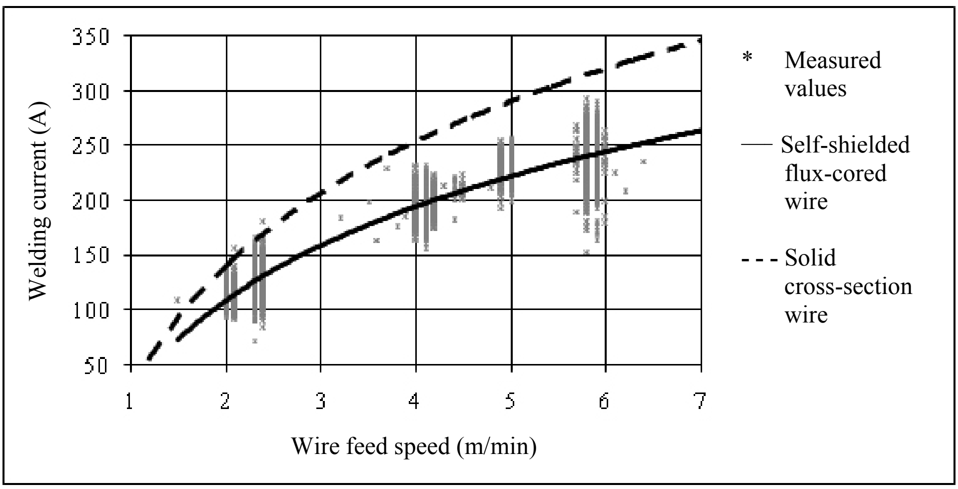

Figure 1. Dependence in-between the wire feed speed and the welding current

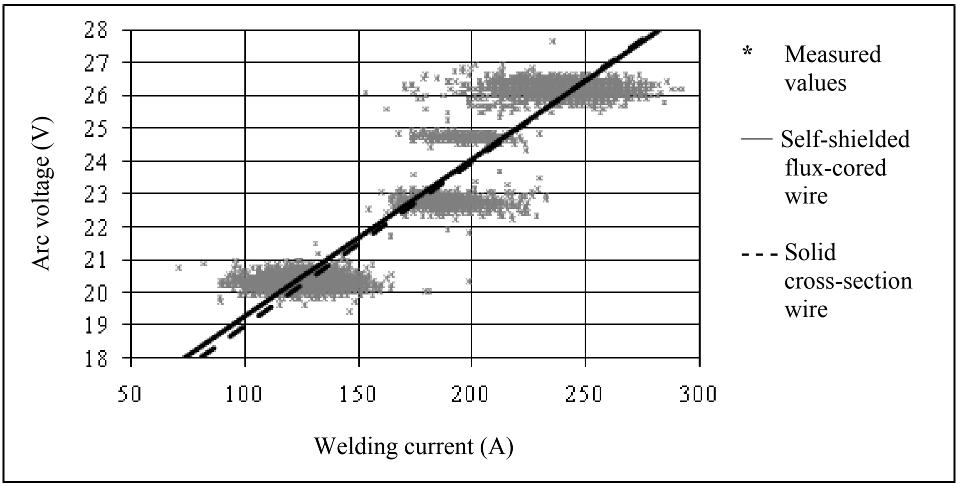

Figure 2. Dependence in-between the welding current and the arc voltage

4. CONCLUSIONS

Based on the analysis of experimental results, the following conclusions can be derived:

1) The mathematical models formed by the performed regression analysis describe the relations between measured values of wire feed speed, welding current and arc voltage well;
2) Formed mathematical equations can be used in practice to evaluate the welding parameters. Based on the required value of the welding current the wire feed speed necessary to achieve the required value of the welding current can be calculated, while the optimal value of arc voltage can be estimated;
3) At the same wire feed speed, the welding current is different for the compared types of wires that were used for welding. This difference becomes more pronounced due to the increase in wire feed speed. The geometry of the electrode wires is responsible for the existence of these differences;
4) The type of electrode wire, in this case, has no significant impact on the functional dependency that describes the relation between optimal values of the welding current and the arc voltage.

5. REFERENCES

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