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THE EFFECT OF HEAT INPUT ON THE WELD METAL TOUGHNESS OF SURFACE WELDED JOINT

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ABSTRACT
The welding heat input has a great influence on the weldments properties. This paper describes the influence of welding heat input on the weld metal toughness of high-carbon steel surface welded joint. The steel is surfaced with self-shielded wire, with three different heat inputs (6.5; 10.5 and 16 kJ/cm). Total impact energy, as well as crack initiation and crack propagation energies, are estimate at three testing temperatures. It has been established that with heat input increase toughness decreases and that heat input of 7 kJ/cm is optimal for weld metal toughness of investigated steel. Crack initiation energy is higher than crack propagation energy at all testing temperatures, and due to its temperature insensitivity, these joints have satisfactory and safe exploatation up to -40^{0}C.
Keywords: heat input, toughness, high-carbon steel, suface welding,

1. INTRODUCTION

The welding heat input has a great influence on the weldments properties. Mechanical properties and toughness of weldment depend of microstructure of weld metal. [1][2] In Figure 1. is shown affect of heat input on the cooling rate, and cooling rate is primary factor that determines the final metallurgical structure of the weld.[3] The cross sectional area of a weld is generally proportional to the amount of heat input. As more energy is supplied to the arc, more filler material and base metal will be melted per unit length, resulting in a larger weld bead.

The most important characteristic of heat input is that it governs the cooling rates in welds and thereby affects the microstructure of the weld metal. A change in microstructure directly affects the mechanical properties of weld. Therefore, the control of heat input is very important in arc welding in terms of quality control.

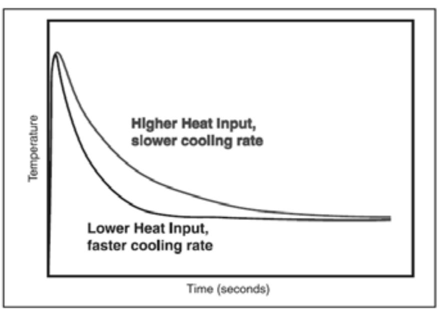

Figure 1. Heat input influences cooling rate,[3]

The change in toughness is not just tied to the heat input, but is also significantly influenced by the weld bead size. As the bead size increases, which corresponds to a higher heat input, the notch toughness tends to decrease. In multiple-pass welds, a portion of the previous weld pass is refined, and the toughness improved, as the heat from each pass tempers the weld metal below it. If the beads are smaller, more grain refinement occurs, resulting in better notch toughness.

At surface welding, heat input affects on the mixture degree, as relevant parameter of weld quality. Mixture degree increase with higher heat inputs, which results in different microstructures of obtained layers, and in different toughness values.

The weld metal toughness of surface welded joint is the result of complex influence of many factors: type of filler material, heat input, mixture degree of base metal and filler material, post heat treatment with next layer, because each subsequent pass alters the structure in regions of the previous pass that are heated.[4]Having on mind interactions of all mentioned parameters, it doesn′t surprise insufficient literature data about obtained results, i.e. toughness.

2. EXPERIMENTAL PROCEDURE

Base metal used in present work is pearlitic steel. It's chemical composition and mechanical properties are given in Table 1. The steel is surface welded by semi-automatic process, with self-shielded wire. Chemical composition of filler material is given in Table 2. Surface welding is carried out with three different heat inputs. Values of heat input during welding, with corresponding sample designations and welding parameters, are given in Table 3. Preheating temperature in all three cases was 230^{0}C, since the CE equivalent was CE=0.64, and controlled interpass temperature was 250^{0}C.

Table 1. Chemical composition and mechanical properties of base metal

Chemical composition, %							Tensile strength R_m (N/mm^2)	Elongation A_c (%)
C	Si	Mn	P	S	Cu	Al		
0.52	0.39	1.06	0.042	0.038	0.011	0.006	680-830	≥14

Table 2. Chemical composition of filler material

Wire designation	Wire diam. mm	Chemical composition							Hardness, HRC
		C	Si	Mn	Cr	Mo	Ni	Al	
OK Tubrodur 15.43 (self-shielded wire)	1.6	0.15	<0.5	1.1	1.0	0.5	2.3	1.6	30-40

Table 3. Sample designation and welding parameters

Sample designation	Welding current (A)	Voltage (V)	Welding speed (cm/s)	Heat input (J/cm)
1	235	30	40	10 520
2	280	30	31.8	15 850
3	180	28	47	6 440

Surface welding was carried out in three layers (samples 1 and 3), except for sample 2, where due to high heat input, required thickness was made in two layers.

Specimens for further investigation were prepared from weld metal of surface welded samples. Impact testing is performed according to EN 10045-1, i.e ASTM E23-95, with Charpy specimens, V notched in WM, on the instrumented machine SCHENCK TREBEL 150 J. Specimens were tested at 20^{0}C, -20^{0}C and -40^{0}C. The total impact energy, as well as crack initiation and crack propagation energy, were estimated at all tested temperatures, and for all heat inputs.

3. RESULTS AND DISCUSSION

Impact testing results, obtained by instrumented Charpy pendulum, are given in Table 4. Total impact energy, as well as crack initiation and crack propagation energies, at all testing temperatures (20^0C, -20^0C and -40^0C) are presented in Figure 2.

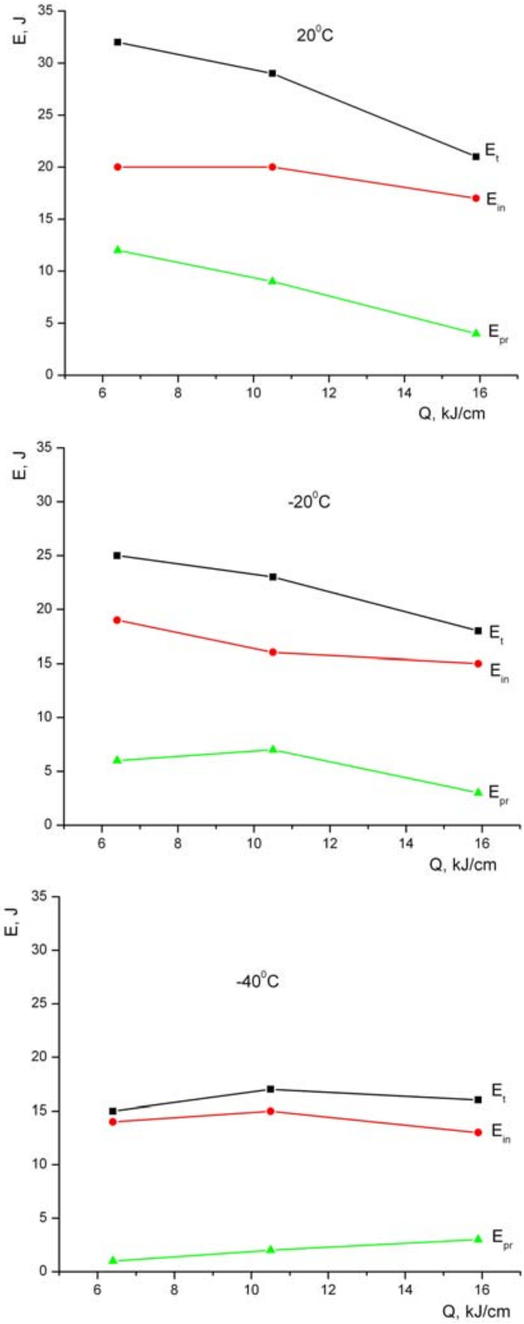

Figure 2. Dependence heat input vs. impact energies at all testing temperatures

At room temperature, the total impact energy E_t is the highest for the lowest heat input (sample 3), and is equal to 32 J. With an increase of heat input toughness decreases and is equal to 21 J at sample 2. Crack propagation energy, E_{pr}, for samples 2 and 3 amounts to 4 J and 12 J, respectively, and is lower than the crack initiation energy, E_{in}, in all cases. At -20^{0}C, the lowest tougness is obtained with the highest heat input (sample 2, 18 J). Crack initiation energy is equal to 15-19 J. It also notes that the most of total impact energy is spent on the crack initiation, while the proportion of crack propagation energy is minimal. At -40^{0}C the total impact energy amounts to 15-17 J , and proportion of crack propagation energy at this temperature is negligible. Due the unsensitivity of crack initiation energy to temperature decrease, these joints have satisfactory and safe exploatation up to -40^{0}C (15 J).
Based on the obtained results, it could be concluded that the total impact energy, as well as its components, decrease with temperature decrease. Since this steel is very brittle material, it is difficult to determine a transition temperature, though at -20^{0}C significant drop of total impact energy is noticable.
The toughness decreases with an increase of heat input in all cases, so the value of 7 kJ/cm can be recomended as optimal. That is explained by the displacement in transformation diagram, so increase of heat input brings out appearance of more proeutectoid ferrite and Widmanstatten ferrite, which affect to toughness decrease. The mixture degree increases the added heat, and comes to greater mixing of highcarbon base metal with lowalloyed filler material at sample 2. The consenquance of that are different portions of ferrite, pearlite and bainite in final microstructure.
One of the reasons of the lowest toughness of the sample 2 is the fact that the two other samples were surfaced in three layers, resulting in fine-grained structure. On the other hand, due to high heat input, required thickness of the sample 2 was made in two layers, so that there was any additional tempering.

4. CONCLUSIONS

Considering performed examinations the following is concluded:

1. The welding heat input is important welding parameter, which affects on the structure and properties of the weld metal. Weld metal tougness is extremely sensitive to the welding heat input.
2. Values of heat input were chosen on the base of literature data for similar steels. It was shown that optimum values of heat inputs are within the limits of the assumed, i.e. that value of 7 kJ/cm is optimal for applied welding procedure.
3. Comparing the samples surfaced with different heat inputs, noted that with heat input increase comes to slightly decrease of impact energies, and lower values are obtained with higher heat inputs.

5. REFERENCES

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