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THE INFLUENCE OF SPECIMENS CUTTING DIRECTION ON THE CRACK RESISTANCE OF SURFACE WELD METAL

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ABSTRACT
It is well known that the mechanical properties of materials depend of the rolling direction, which means that the direction of specimen cutting affect the obtained values. This feature also exists in the welded joint, where the anisotropy is caused by direction of the deposit welded layers.
One high-carbon steel is surface welded by flux-cored wire and specimens were cut in order to determine the toughness and crack growth parameters for longitudinal and transversal directions. Total impact energy, crack initiation energy and crack propagation energy were estimated at room and lower temperatures. It is shown that at all temperatures higher toughness values were obtained for specimens cut from the transversal direction, i.e. with notch in welding direction. Also in this case were obtained higher threshold values and lower fatigue crack growth rate, indicating a better resistance to crack growth.
Keywords: cutting direction, impact energy, crack growth rate, fatigue threshold

1. INTRODUCTION
It is well known that the mechanical properties of materials depend of the rolling direction, which means that the direction of specimen cutting affect the obtained values [1,2]. The influence of specimens direction on impact energy is shown in Figure 1. The impact energy is the highest in the rolling direction, i.e. for specimens cut from the transversal direction and with notch in rolling direction. Somewhat lower values are obtained for specimens cut from longitudinal direction, and the lowest impact energy is in the direction of plate thickness. This feature also exists in the welded joint, where the anisotropy is caused by direction of the deposit welded layers. The aim of this paper is to show that surface weld metal anisotropy has considerable influence on the total impact energy and its components, as well as crack growth rate.

2. EXPERIMENTAL PROCEDURE
Base metal used in present work is pearlitic steel (0,52C-0,39Si-1,06Mn-0,042P-0,038S-0,011Cu-0,006Al). The steel is surface welded by semi-automatic process, with flux-cored wire. Chemical composition of filler material is given in Table 1. Heat input during welding was 10 kJ/cm and preheating temperature was 230^{0}C, since the CE equivalent was CE=0.64 [3,4]. Controlled interpass temperature was 250^{0}C. For surfacing of sample 2 were used two types of wires, but both flux-cored: one for buffer layer and the second one for last two layers. As shieleded gas for welding of sample 2, CO_2 was used, with gas flow of 16 l/min.

Specimens for further investigation were cut from surface weld metal, according to Figure 2.

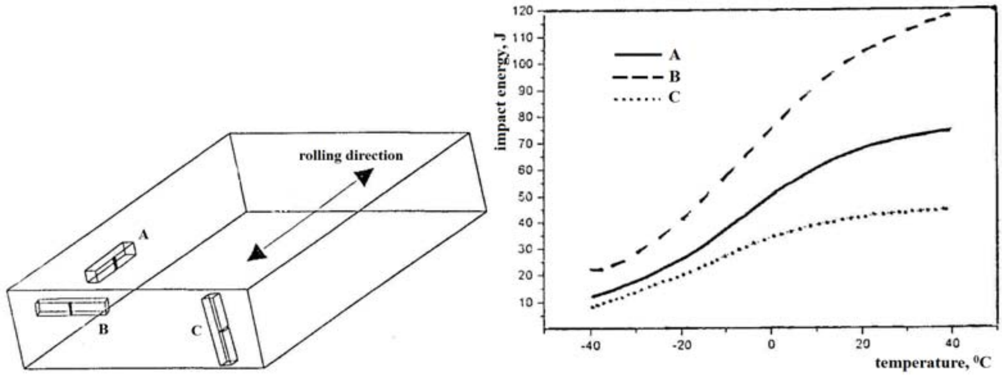

Figure 1. Influence of specimens direction on the impact energy

Table 1. Chemical composition of filler material

Wire designation	Wire diam. mm	Chemical composition, %				
		C	Si	Mn	Cr	Mo
Filtub 12B	1.2	0.05	0.35	1.4	-	-
Filtub dur 12	1.6	0.12	0.6	1.5	5.5	1.0

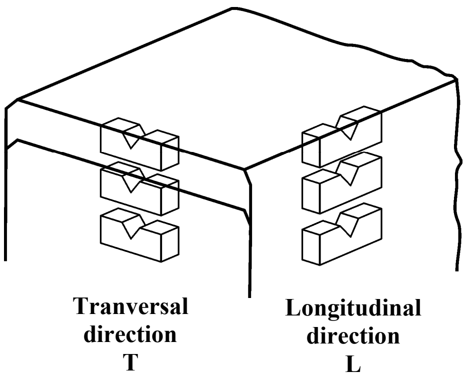

Figure 2. Cutting direction of specimen

3. RESULTS AND DISCUSSION

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 20^0C, -20^0C and -40^0C. The total impact energy, as well as crack initiation and crack propagation energy, were estimated at all tested temperatures, for longitudinal and transversal directions, and presented in Figure 3.

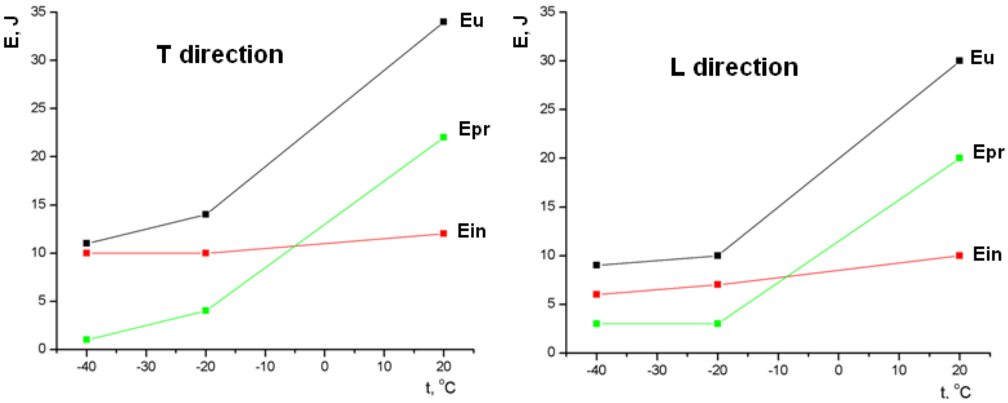

Figure 3. Dependence heat input vs. impact energies at all testing temperatures

Based on the obtained results, it could be concluded that the total impact energy, as well as its components, decrease with temperature decrease. At room temperature, the total impact energy E_u is the highest for the transversal direction, and is equal to 34 J, with respect to the longitudinal direction of 30 J. Crack propagation energy, E_{pr}, and crack initiation energy, E_{in}, amounts to 22 J and 12 J, respectively, and are higher than the energy values from L direction. (20 and 10 J). At -20^{0}C, impact energies in T direction are higher, and in both cases 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 11 J (T direction) and 9J (L direction), and proportion of crack propagation energy at this temperature is negligible [5]. Due the unsensitivity of crack initiation energy to temperature decrease, these joints have satisfactory and safe exploitation up to -40^{0}C .
Fatigue crack growth tests had been performed on the CRACKTRONIC dynamic testing device in FRACTOMAT system, with standard Charpy size specimens, at room temperature, under the ratio R=0.1. A standard 2 mm V notch was locate in third layer of WM. Crack was initiated from surface (WM) and propagated into HAZ, enabling calculation of crack growth rate *da/dN* and fatigue treshold ΔK_{th} [6].
Results of crack growth resistance parameters, i.e., obtained relationship *da/dN* vs. ΔK for T and L direction are given in Figure 4. Parameters *C* and *m* in Paris law, together with fatigue threshold ΔK_{th} and crack growth rate values are given in Table 2 for both cases as obtained from relationships given in Figures 4, for corresponding ΔK values.

Table 2. Parameters C, m, ΔK_{th} and crack growth rate values for all zones of surface welded joints

	Fatigue threshold ΔK_{th}, MPa m$^{1/2}$	Parameter C	Parameter m	Crack growth rate da/dN, m/cycle for ΔK=25 MPam$^{1/2}$
L	8,6	$3.51 \cdot 10^{-13}$	3.93	$2.44 \cdot 10^{-07}$
T	8,9	$3.85 \cdot 10^{-13}$	3.88	$2.07 \cdot 10^{-07}$

The crack growth rate in L direction is higher than in T direction ($2.44 \cdot 10^{-07}$, $2.07 \cdot 10^{-07}$, respectively), i.e. the growth of the initiated crack will be slower in T direction. Beside crack growth rate, fatigue threshold value ΔK_{th} is also representative parameter for comparison. Fatigue threshold value in L direction is lower than in T direction (8,6 and 8,9). Therefore, the crack in L direction will be initiated earlier, i.e. after less number of cycles, than in T direction.

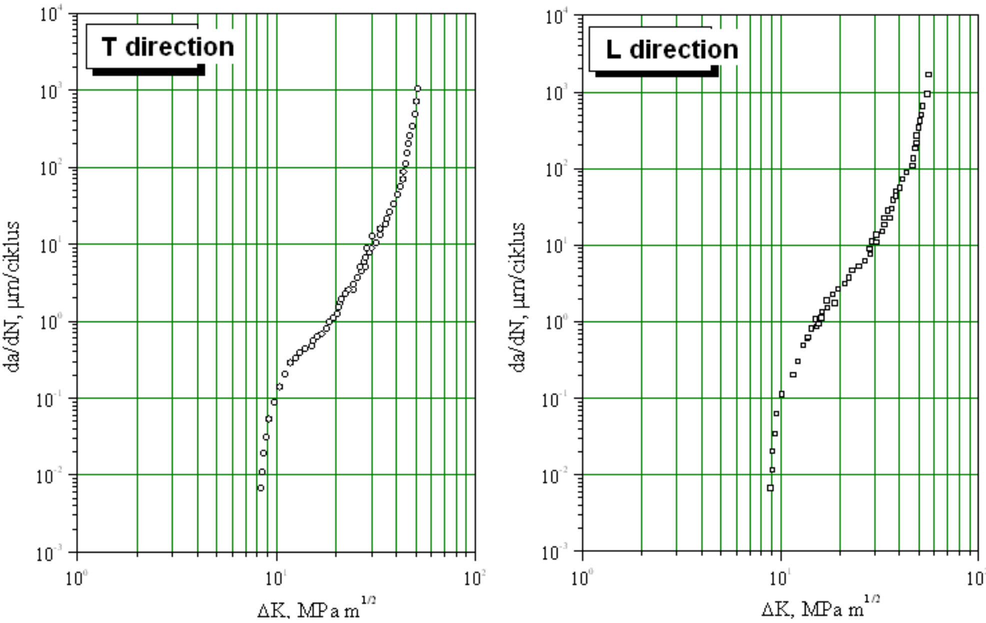

Figure 4. Diagram da/dN vs. ΔK for T and L direction

4. CONCLUSIONS

Considering performed examinations the following is concluded:

1. Anisotropy in surface weld metal is caused by direction of the deposit welded layers. As a result, mechanical properties of weld metal depend of specimen cutting direction.
2. Weld metal tougness is extremely sensitive to the cutting direction. At all testing temperatures the higher impact energies were obtained for specimens cut from T direction, as a result of crystallization direction during solidification. Namely, the initiated crack at its growing cuts column crystals of surfaced welded layers, thereby consuming more energy fracture.
3. Comparing the cutting directions, noted that higher threshold values and lower fatigue crack growth rate were obtained for specimens cut from the transversal direction, i.e. with notch in welding direction, indicating a better resistance to crack growth. That confirms that the crack growth rate also depends of the specimens cutting direction.

5. ACKNOWLEDGEMENT

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