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FRACTURE ANALYSIS OF MICROALLOYED STEEL WELD METAL AT DIFFERENT TEMPERATURES

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ABSTRACT
In this paper is shown behaviour of steel weld metal micro alloyed with niobium during impact testing. Impact tests were conducted on instrumented Charpy pendulum at room temperature and at -55^{0}C. At room temperature, crack propagation energy is much higher than crack initiation energy, while at -55^{0}C crack growth energy is lower than crack initiation energy. Fractographic investigation of the fracture surfaces indicated that at room temperature ductile trans granular fracture is dominant, with a small amount of brittle trans granular fracture. At lower temperature, the portion of brittle fracture is increased, and inter granular brittle fracture becomes dominant.
Keywords: weld metal, fracture analysis, microalloyed steel, toughness

1. INTRODUCTION
Instrumented Charpy pendulum enables separation of the total impact energy into crack initiation energy $\mathbf{E_{inic}}$ and crack propagation energy $\mathbf{E_{lom}}$. The result is the possibility of more accurate assessment material toughness [1]. If two materials exhibit the same toughness value, i.e., total impact energy, their behavior can be different. From the point of view of toughnes will be better material whose crack initiation energy is low and crack propagation energy is high. In some cases, although obtained total energy may surpass the critical value, the initiation energy may be dominant, leaving only a small contribution for the propagation energy. In such a case, the value of the total energy is in itself not enough to guarantee the avoidance of catastrophic fracture. Thus, if a crack already exists, which is a reasonable assumption for many welded joints, the critical toughness value should take into account only the crack propagation energy [2]. The final outcome of Charpy testing is the fracture. What mechanism will take place depends of the base material and the test temperature. Unlike the slow ductile fracture, brittle fracture occurs at high speed.
Transgranular brittle fracture involves cleavage in certain planes, while intergranular fracture develops due to brittle phases on grain boundaries or due to soluted atoms in the vicinity.

2. EXPERIMENTAL PROCEDURE

Hot rolled plates of steel microalloyed with Nb, of thickness 11 mm, were used. The chemical compositions of base material and filler material are given in Table 1. Mechanical properties of both materials are given in Table 2. As filler material, electrode wire denoted as VAC60Ni (made by Jesenice, Slovenia) ∅1,2mm and shielding atmosphere Ar+5% CO_2+0,91% O_2 were used. The wire is alloyed with Ni, intended for welding of unalloyed and alloyed steels, with guaranteed mechanical properties at low temperatures.

Table 1. Chemical compositions of base material and filler material

	Chemical composition, %									
element	C	Si	Mn	P	S	Cu	Al	Nb	Ti	Cr	Ni
steel	0.07	0.15	0.66	0.016	0.010	0.13	0.092	0.077	-	0.042	0.036
Electrode wire	0.08-0.10	0.70-0.85	1.40-1.60	<0.025	<0.025						1.00-1.20

Table 2. Mechanical properties of base material and filler material

	Re, [N/mm^2]	Rm, [N/mm^2]	A_5, [%]	KV(20°C), [J]
steel	448-456	543-551	33-34	129-156
Electrode wire	440-510	560-630	22-30	80-125; 30-35 (at -40°C)

Coupon plates with V grooves were welded, with one root pass and three filler passes, with heat input of 7 kJ/cm. The specimens for weld metal toughness were cut out, as shown in Figure 1. Testing was performed at instrumented Charpy pendulum, at room temperature (20^{0}C) and - 55^{0}C.

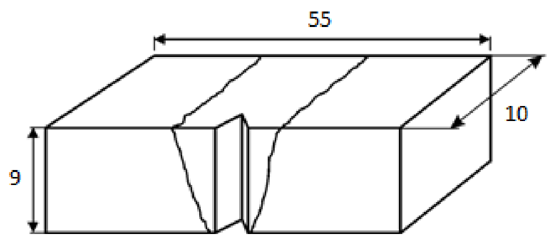

Figure 1. Sketch of Charpy specimen with V notch in weld metal

Diagrams force (F)- deflection (D_f), obtained by instrumented Charpy pendulum for both testing temperatures are shown in Fig. 2a and 3a, while in Figs. 2b and 3b are given macroscopic appearance of Charpy fracture surfaces.

By analyzing the force-deflection diagrams, can be seen that portion of ductile fracture is 100%. At -55^{0}C, diagram shows that with temperature decrease total impact energy decreases (area under the curve), whereby the proportion of brittle fracture component increases, and reduces the portion of crack growth energy as a ductile fracture component [3].

Fractographic investigation of the Charpy specimens indicates that at room temperature ductile transgranular fracture is dominant, with a small amount of brittle transgranular fracture (Fig 2c). At lower temperature, intergranular fracture becomes dominant [4]. This is in agreement with the measured energy values, indicating that brittle fracture becomes dominant when the propagation energy becomes smaller than the initiation energy [5]. Total impact energy for both material at room temperature is extremly high, and crack growth energy is higher than crack initiation energy, as shown in Figs.2 and 3. At -55^{0}C, crack growth energy is lower that crack initiation energy.

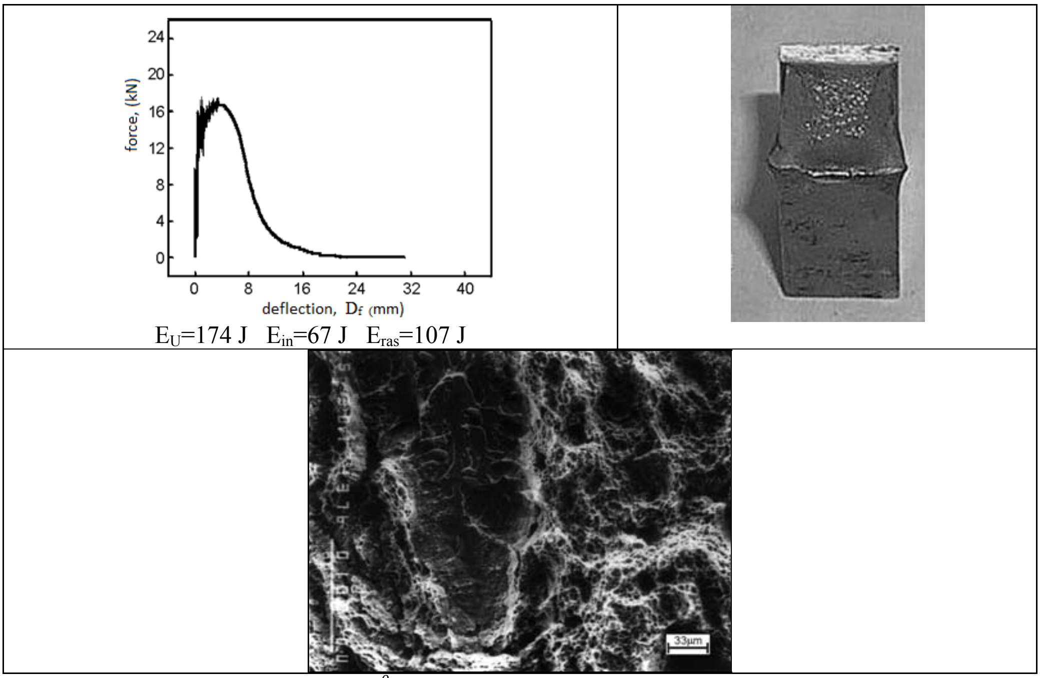

Figure 2. Fracture analysis at 20^{0}C: a) diagram F-D$_f$; b) fracture surface of Charpy specimen; c) fractography- mixture fracture; ductile and brittle fracture at room temperature

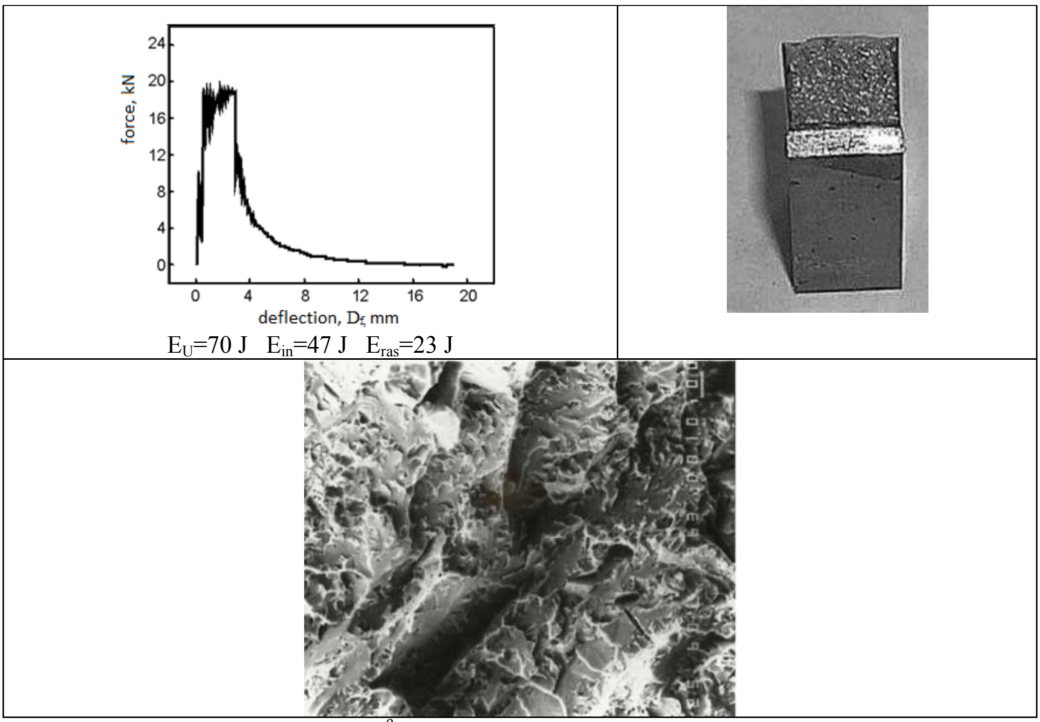

Figure 3. Fracture analysis at -55^{0}C: a) diagram F-D$_f$; b) fracture surface of Charpy specimen; c) fractography- brittle intergranular fracture at lower temperature

3. CONCLUSIONS

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

- At room temperature, crack growth energy is higher than crack initiation energy, while at -55°C is contrary, i.e., the crack initiation energy is higher than crack growth energy.
- With temperature decrease, the portion of brittle fracture increases, what is confirmed by diagram F- D_f
- Fractographic investigation of the Charpy specimens indicates that at room temperature ductile transgranular fracture is dominant, with a small amount of brittle transgranular fracture. At -55°C, the portion of brittle fracture is higher, and both transgranular and intergranular components of brittle fracture were observed.
- Intergranular brittle fracture becomes dominant when the propagation energy becomes smaller than the initiation energy.

4. REFERENCES

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