Miniaturized Charpy impact toughness assessment of a friction stir welded bead-on-plate API-5L-X80 steel

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Abstract: Friction-stir welded (FSW) joints for pipeline applications have exhibited increased yield strength and hardness when compared to the parent metal. In addition, sound welds have been reported for different thicknesses and welding configurations when joining high-strength low-alloy steels. Nevertheless, there are still mechanical assessments to be address regarding the typical coarse bainite package microstructure formed at the stirred and hard zones after FSW. In order to determine its lower temperature application bound, FSW bead-on-plate welds were characterized, focusing on the resultant impact toughness. To do so, miniaturized Charpy-V notch tests were performed over 27 x 4 x 3 mm^3 samples (Kleinstprobe, KLST). Samples with localized notches at the stirred and at the hard zones were extracted. Results showed that ductile-brittle transition temperatures for both regions were around -60°C, meaning that this kind of FSW joints might be applied for subzero applications.

Keywords: Friction stir welding, API-5L-X80 steels, impact toughness, miniaturized Charpy-V notch, KLST, DBTT

Material

The chemical composition and mechanical properties in a transversal direction at room temperature of the used API-X80 steel are show in Table 1. A 9.5 mm long threaded conical pin tool, made of polycrystalline cubic boron nitride (PCBN)-WRe was used to obtain the welds [1]. Plates of 15 mm thickness and rectangular area of 95 x 350 mm^2 was used to produce bead-on-plate welds. Travel speed, spindle speed, and downward force during welding process were 100 mm min-1, 300 RPM and 34 kN respectively. Welding was performed using force control mode and the welding direction was parallel to the plate rolling direction.

Table 1. Chemical composition of API 5L X80 steel (Wt.%) and mechanical properties. *ppm and Carbon Equivalent (CE P_{cm})

C	Si	Mn	Cu	Cr	Al*	Mo	Nb	Ni	P*	Ti	V	N*	B*	S*	CE P_{cm}
0.04	0.32	1.56	0.24	0.06	< 330	0.19	0.03	0.24	<100	0.01	0.01	<6	5.00	60.00	0.15
															σ_{YS} = 615 MPa
															σ_{TS}=658 MPa
															σ_{YS}/σ_{TS}=0.93
															E=205 GPa

Experimental procedure

Miniaturized Charpy-V notch specimens (27x4x3 mm3, Kleinstprobe, KLST) were used to performed an impact toughness assessment in localized microstructural regions, find the complete dimensions and surface finishing details in [2]. The test and data analysis were conducted according with the standards [3–5]. Notches were located over the stirred zone (SZ) and hard zone (HZ) of the FSW welded joints [1], the crack grew parallel to the welding direction, as show in Figure 1.

Results

Figure 1 shows the position of notches within a schematic view of the welded joints. In addition, regarding the microstructural assessed regions, hardness, microstructure features and impact energy have been reported in the same chart.

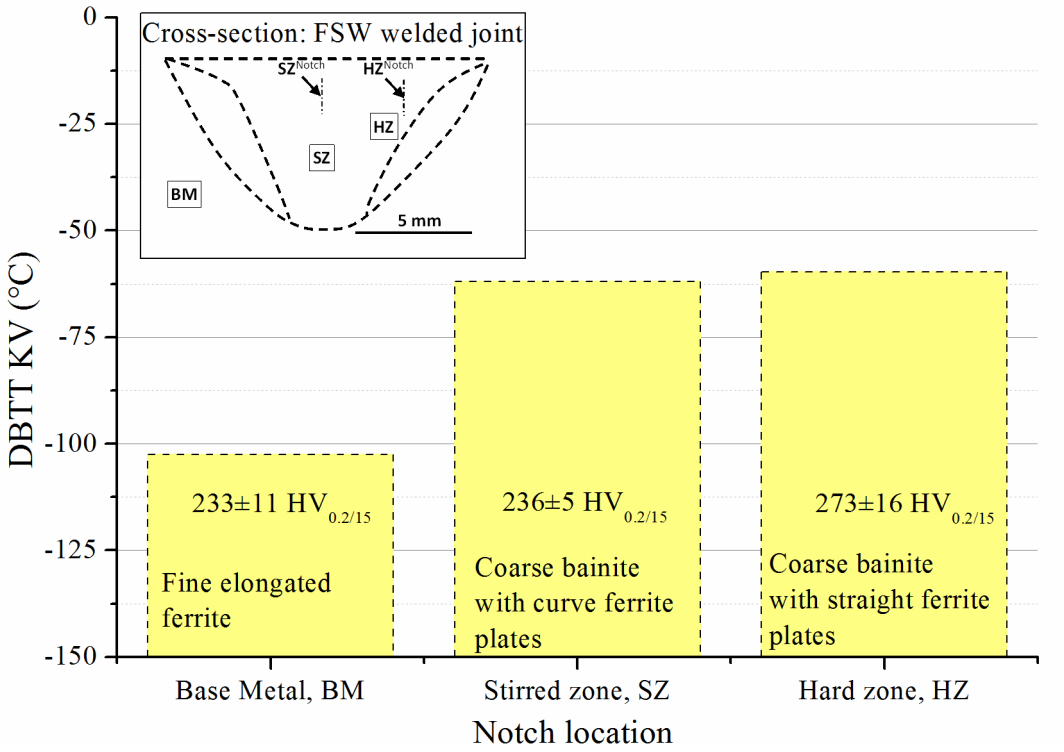

Figure 1. Columns chart showing the ductile-brittle transition temperatures (DBTT), hardness and main microstructure features where notches were located.

Conclusion

Regarding the FSW welded joint of an API-X80 steel, it could be conclude that the stirred zone and hard zone presented a DBTT below -60ºC. However, the base material presented a DBTT below -100 ºC.

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