Effect of Microstructure and Crystallographic Texture on Impact Toughness in Low Carbon Ferritic Steel

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Abstract:

Combined effect of inclusion, microstructure and crystallographic texture on Charpy impact properties of low carbon ferritic steels has been studied after different finish rolling (935 °C - 650 °C) and normalizing (1250 °C - 940 °C) treatments. Finish rolling within the austenite-ferrite two phase region leads to the formation of low-angle boundaries, which strengthen ferrite matrix but are ineffective in restricting the cleavage crack propagation; thereby deteriorate the upper shelf energy (USE) and increase the ductile to brittle transition temperature (DBTT). The presence of coarse cuboidal TiN particles (>1µm) also increase the DBTT, whereas, stringer shaped MnS inclusions deteriorate the USE. In spite of the presence of large TiN particles, refinement in 'effective grain size' of ferrite can improve the impact toughness. Finish rolling just above the austenite to ferrite transformation start temperature (~820 °C) or normalizing of as-rolled plates at low austenitization temperature (~940 °C) develop fine strain-free ferrite grains with small 'effective grain size', and therefore, can be recommended for achieving high USE and low DBTT.

Crystallographic texture can influence the general yield temperature through its effect on the plastic constraint factor. Local texture also determines the 'effective grain size', which is found to be dependent on the angle between {001} cleavage planes of the neighbouring crystals, rather than the grain boundary misorientation angle considering angle-axis pair. The severity of delamination on the fracture surface of Charpy impact tested samples of low carbon steel has been found to be dependent on finish rolling temperature and texture. Strain incompatibility between the through thickness texture bands of cube (ND ‖ <001>) and gamma (ND ‖ <111>) orientations developed during the inter-critical rolling treatment causes fissure cracking on the main fracture plane in an intergranular fashion. The crack subsequently propagates through the transverse 'fissure plane' in transgranular fashion, due to the lower cleavage fracture stress of that plane. Presence of strong crystallographic texture results in non-uniform distribution of crystallographic planes along the different directions of the rolled plates, which causes anisotropy in Charpy impact properties. The volume fraction of grains having {001} plane parallel to fracture plane control the DBTT, whereas, the volume fraction grains having {011} plane parallel to shear plane dictates the USE.

Keywords: Low carbon ferritic Steel, Crystallographic texture, Inclusions, Charpy impact testing, Effective grain size, Fissure, Anisotropy.