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Crystallographic texture before and after post weld heat treatment of high-frequency electric resistance welded API X65 linepipe

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Abstract

The microstructure and crystallographic textures of API X65 grade linepipe steel were studied in the base metal, the weld interface after high-frequency electric resistance welding (HF-ERW), and the weld interface following post-weld heat treatment (PWHT). Optical microscopy, scanning electron microscopy (SEM), and electron-backscattered diffraction (EBSD) were used to study the microstructure and texture evolution and correlated with Charpy V-notch impact toughness. The Charpy values were 172.9 ± 5.2 J for the base metal, 7.5 ± 1.6 J for the as-welded weld interface, and 69 ± 24 J after PWHT, with the latter still significantly lower than the base metal. Base metal showed a low fraction of low-indexed cleavage planes at about 9% and major texture components were (113)[110], (112)[110], and (332)[113]. In the as-welded condition, major intensities of rotated Cube (001)[110] and Goss (110)[001] texture components were observed near the weld interface. Although PWHT reduced the texture intensities, rotated Cube and Goss components were still observed. The fraction of cleavage planes was about 44% for the as-welded and about 30% for the PWHT-ed weld interface. Clearly, PWHT has reduced but not eliminated the detrimental rotated Cube and Goss textures at the weld interface. These detrimental textures likely have contributed to the low Charpy toughness after welding and continuing after PWHT.

Keywords

API X65 steel, high-frequency electric resistance welding, post-weld heat treatment, microstructure, crystallographic texture, toughness

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Introduction

High-frequency electric resistance welding (HF-ERW) is used to manufacture longitudinal seam-welded steel line pipes with diameters less than 24 inches. These linepipes are used for the long-distance transportation of oil and natural gas products (Figure 1(a)).[1] In HF-ERW, heat is generated through the resistance to the flow of applied electric current (Figure 1(b)). Subsequently, the steel edges are pressed together to form a solid-state weld interface, eliminating any melted material.[1–3] Following HF-ERW, the weld joint is water-quenched, and the flash is removed from the pipe surfaces.[2] It has been well documented that the as-welded joints usually possess poor Charpy V-notch (CVN) impact toughness.[3–6] Therefore, post-weld heat treatment (PWHT) is required.[3,7–11] During the PWHT, the weld interface and the heat-affected zone (HAZ) are heated to above Ac3 temperature followed by air cooling (normalizing).[12] This is usually performed at an induction heating stage immediately following flash removal.

Even after PWHT, the CVN impact toughness of HF-ERW linepipe steel welds is consistently lower than that of the base metal.[12,14,15] Yan et al.[5] observed that, after PWHT, CVN impact toughness for HF-ERW API X65 steel fell below the acceptance limit, when the V-notch is at the weld interface. Similarly, Anderson

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