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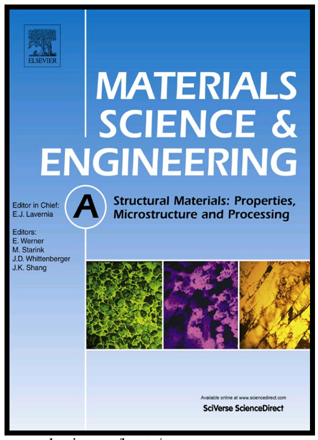

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Microstructural characteristics and mechanical heterogeneity of underwater wet friction taper plug welded joints for low-alloy pipeline steel

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Abstract

Underwater wet friction taper plug welding experiments have been performed on X52 pipeline steel with 6500-7500rpm rotational speeds at 30-45kN axial forces, and the microstructural characteristics and mechanical heterogeneity of defect-free friction taper plug welded joints are discussed thoroughly. It is found that the microstructure of welded joint is remarkably inhomogeneous and very different from the base metal. The welded joint has dramatically coarse grains and is dominantly characterized by a mixture of quenched martensite, upper bainite and various types of ferrites including Widmanstätten ferrite. Unlike the traditional solid-state friction welding processes, the relative homogeneous microstructure with fine and equiaxed grains cannot be obtained in the friction taper plug welding process. The axial force has a greater impact on microstructure of welded joint as compared to rotational speed. The hardness profiles measured in cross-section of welded joints are severely non-uniform, ranging from 200~400HV1, due to the inhomogeneity of microstructure. The impact absorbed energy of welded joint with V-notch in the bonding zone was considerably lower than that of base material (about only 20% of parent metal) because of the local obviously coarse grain, Widmanstätten ferrite and banding ferrite defect. The microstructural inhomogeneity results in mechanical heterogeneity.

Keywords: Friction Taper Plug Welding; Low-alloy pipeline steel; Microstructural characteristics; Mechanical heterogeneity

1. Introduction

Underwater arc welding technologies have been currently achieved a great development. Many underwater welding techniques such as underwater wet welding, local dry welding and dry chamber welding have been developed and become important repair tools for underwater fabrications [1-4]. However, underwater arc welding is accompanied by arc instability, hydrogen diffusion and high cooling rate because of water media and pressure, resulting in a significant decrease in weld strength, plasticity and toughness [5-7]. Friction Hydro Pillar Processing (FHPP) was invented and patented by The Welding Institute (TWI) in 1992. This process is also known as Friction Taper Plug Welding (FTPW) when conical holes and taper plugs are used to perform welding experiments. Compared with underwater arc welding, underwater FHPP has many advantages such as insensitivity to water depth, highly efficiency and automatic operation, so that FHPP has a great application potential in joining and repairing offshore platform, submarine pipelines and structures and is considered as the most promising join and repair technology in deep water [8-11].

FHPP/FTPW can be simply described as follows. Before the welding process, a blind hole is drilled on the base plate. A plug with high rotational speed is inserted into the hole under certain axial force during the welding process, generating heat owing to mutual friction. Thermal plasticized layers are produced continuously at the bottom of hole and extruded into the gap between the plug and the hole. Since the speed of formation of thermal-plastic metal is higher than the feeding speed of plug, viscous metal rises around the plug and fills the gap. With the thermal-mechanical coupling effects, diffusion occurs between the plug and the base plate, so that metallurgical bonding is realized between plug and the base plate ultimately. There are four main welding parameters during the FHPP/FTPW process: welding speed, axial force, burn-off and forging force. Welding speed and axial force refer to the rotational speed of spindle and axial force applied to the plug, respectively. The burn-off is the consumption of the plug during the welding process. The forging force is the axial force