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The effects of functionally graded material structure on wear resistance and toughness of repaired weldments

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ABSTRACT

To perform a long lasting, crack-free repair welding on ultrahigh strength steels, the filler metal must be chosen and applied properly. Avoiding several short-term repairs or replacements, the repaired weldment should reveal comparative characteristics such as wear resistance, toughness and hardness to base metal. In the present study, a novel functionally graded material have been introduced to obtain enhanced wear resistance and hardness at surface as well as improved fracture toughness at fusion line of repaired weldments. A comparative study of wear resistance of repaired weld metals has been carried out by pin-on-disk apparatus at 5 N normal load and 0.14 ms^{-1} sliding speed. Fracture toughness of weld metal was also evaluated by charpy absorbed fracture energy tests and scanning electron microscopy fractograghs. The results show that by employing functionally graded layers, toughness was enhanced significantly while retaining the surface wear resistance.

1. Introduction

Ultrahigh strength, low alloy steels with medium carbon content and various amounts of chromium, molybdenum, nickel, and vanadium have been used for high-performance pressure vessels, rotors, and etc. These steels can be successfully used at yield strengths equal or greater than 1400 MPa. Generally, quenching and tempering are well-established means to increase the strength of steel. This can be achieved mainly through the martensitic structure produced by quenching and the precipitation of a fine dispersion of alloy carbides during tempering [1,2]. These steel compounds and equipment are employed in harsh working environments, causing component wear and even equipment failure.

Repair welding offers an economical way to add life to a tool when it is damaged, requires reengineering or when wear has rendered it unusable. For the weld to perform well in its application, the filler metal must be chosen and applied properly [3].

In general, the main negative effects caused by welding of these steels to be avoided are excessive grain growth and the formation of non-tempered martensite with a high level of hardness in the heat affected zone (HAZ), which when associated with the presence of hydrogen and tensile residual stresses can cause cold cracking [2,4]. In the previous study, it was shown that by applying precise welding heat treatment cycle in order to obtain lower bainitic microstructure in HAZ welding in quench–tempered condition could be successfully performed [2]. However, apart from this promotion in HAZ microstructure and characteristics, in repair welding the selection of filler metal which satisfy metallurgical and mechanical criteria (i.e. wear resistance, fracture toughness, hardness and ...) of the weld metal (WM) should also be considered. Wear resistance usually tends to increase with hardness, but it decreases as toughness increases. This is an important relationship in applications that require both wear resistance and impact toughness [5].

Moreover, welding with a filler metal different from the base metal creates a heterogeneous structure likely to enhance the stress intensity factor and the resulting stress level locally. It is generally assumed that welding a material with no risk of induced crack requires a minimum ductility assessed by an elongation to rupture in tension of 4% or more [6]. In order to slightly enhance ductility if required, buttering technique can be employed so as to deposit a soft intermediate layer, which can accommodate thermal strains and release stresses [7]; nevertheless this technique does not always prevent cracking [8].

Today, the importance of the effect of fracture toughness on wear resistance of steels has been recognized by many researches [9,10]. However, little information is available on the effects of fracture toughness and wear resistance on reliability of the repair welded steels.

The present paper focuses on the weld-repair processes of the new ultrahigh strength low alloy martensitic 35NiCrMoV123 steel by employing new approach. As Shah et al. proposed [11]; the material property gradient that results because of welding can be used to study the behavior of functionally graded materials

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