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Effects of preheating temperature on cold cracks, microstructures and properties of high power laser hybrid welded 10Ni3CrMoV steel

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ABSTRACT

Laser hybrid welding has become one of the most promising welding methods for high strength low alloy steels due to combining the advantage of the laser and arc. A novel Y-groove cold cracking test adapted to laser hybrid welding is designed to assess the weldability of 10Ni3CrMoV steels at room temperature and different preheating temperatures. The experimental results show that the orientation of the predominant root cracks generally follows the contour of the fusion line. As the temperature increases from 25 °C to 150 °C, at first the root crack rate decreases and then slightly increases at 150 °C. The root crack rate obtained at 120 °C is the lowest. The fracture model changes from a brittle cleavage fracture to a mixture fracture with quasi-cleavage facets and dimples. The thermal cycle curves of laser hybrid welding obtained by temperature measurement systems are used to evaluate the crack resistance and microstructure transformation. The microstructures of welded joints obtained at different temperatures are analyzed by optical microscope (OM). The results reveal that the microstructures of the coarse grained region and the fusion zone at 120 °C have higher cold crack resistance and good impact toughness. Mechanical properties of the welded joint obtained at 120 °C and 150 °C are comprehensively evaluated by microhardness test, uniaxial tensile test and charpy V-notch impact test with side notches. Fractographs of the impact specimens are studied by scanning electron microscopy (SEM). The test results show that the welded joints obtained at 120 °C have satisfactory mechanical properties that can meet the technical requirements for shipbuilding industry.

1. Introduction

The field of high strength low alloy steels has experienced rapid growth because of the great progress of modern metallurgy technology in recent 30 years. High strength low alloy steels have become one of the most dynamic steels in the world. 10Ni3CrMoV low-carbon quenched and tempered steel is a type of low-alloy steel that provides better mechanical properties than carbon steel, which is used in the shipbuilding industry. Currently this steel is generally welded using metal inert-gas arc welding, metal active-gas arc welding and submerged arc welding [1]. However, the key issue that inhibits extensive use of the steels in the industry is welding technology. There are two problems needed to be solved. First, we must prevent the cold crack caused by quenched microstructure during welding. Second, we must ensure that welded joints have high strength as well as high impact toughness [2–5]. In order to eliminate cracks, this steel must be preheated before it is welded. However the welded joints obtained have relatively low strength and impact toughness, which cannot fully satisfy the industry requirements. Compared to traditional arc welding, laser hybrid welding with high energy density offers many advantages such as low heat input, higher welding speeds, smooth weld surface, narrow heat-affected zone, small thermal stress and good mechanical properties [6–12]. Therefore laser welding has the potential advantages and application prospects in the shipbuilding industry [13,14]. Because there is great difference for the characteristics of heat sources of laser hybrid welding and arc welding, the thermal cycle of laser hybrid welding is different from that of arc welding [15,16]. Therefore, the preheating temperature used during arc welding is not suitable for laser hybrid welding. We must determine the preheating temperature by cold cracking test [17].

In this paper, weldability of 10Ni3CrMoV steels for laser hybrid welding is investigated by designing a Y-groove cold cracking test. Effects of preheating temperature on cold cracks, microstructures and properties are analyzed.

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