Materials and Design 32 (2011) 2763–2770

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Microstructure and mechanical properties of dissimilar materials joints between T92 martensitic and S304H austenitic steels

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ARTICLE INFO

Article history:
Received 8 September 2010
Accepted 4 January 2011
Available online 8 January 2011

Keywords:
Microstructure
Mechanical properties
Dissimilar materials joints

ABSTRACT

In this paper, T92 martensitic steel and S304H austenitic steel were welded by gas tungsten arc welding (GTAW) process. Microstructural features and mechanical properties of T92 and S304H dissimilar materials joints were investigated. The results showed that the part of the joints with relatively weak tensile strength was T92 coarse-grained heat affected zone (CGHAZ), while the part of the joints which revealed relatively weak toughness was weld metal. The decrease of tensile strength in T92 CGHAZ was due to its coarse tempered martensite structure. Weak toughness of the joints was resulted from the coarse dendritic austenite of the weld metal. However, the weld metal in transverse direction of the joints was provided higher tensile strength by the orientation distribution of grains compared with T92 CGHAZ.

1. Introduction

Increased heat efficiency and improved environmental protection are always the innovative driving forces in the development of ultra supercritical (USC) boilers for fossil power plants, whose steam temperature is up to 600 °C and pressure exceeds 27 MPa. Under this USC condition, the heat efficiency can rise to around 45%, compared with the value as 41% of supercritical (SC) boilers. However, with the increase of steam parameters, requirements for the materials applied in the USC boilers components are becoming higher. Thus, many new generation steels have been developed in recent years, including T92 (9Cr0.5Mo2WVNb) martensitic steel and S304H (18Cr9Ni3CuNbN) austenitic steel.

T92 steel was developed by the Nippon Steel Corporation of Japan [1] in the late 1990s by modifying chemical compositions upon T91 (9Cr1MoVNb) for even more preferable mechanical properties at high temperatures. This steel has the manufacturer's designation as NF616 (ASTM Stands A213) and contains 0.5% Mo, 1.8% W, as well as small additions of Nb, V and B. Creep strength of T92 at 600 °C increases about 10–20% compared with that of T91 at 600 °C [2–13]. S304H steel was developed by Sumitomo Metal Industries Ltd on the base of TP304H (0Cr19Ni10). As a new type of austenitic steel, S304H possesses not only excellent resistance to high-temperature corrosion and steam oxidation mainly due to high Cr content, but also superior creep strength than martensitic steels [14–17]. Thus, it is widely used for superheaters and reheaters, which have the abominable service environment in USC boilers. Normally, T92 steel can be used as pipes linking superheaters and reheaters. In this case, the welding between T92 and S304H steels will be necessary.

Until now, many researches have mainly focused on the properties of T92 and S304H steels. As for T92 and S304H dissimilar materials joints, however, there almost hasn't any report about it. Since T92/S304H dissimilar materials joints is obtained by using melted filler material to join two steels, the melted filler material will re-crystal to form the weld metal part of the joints after welding. In addition, due to the effect of welding thermal cycles, not only the microstructure of T92 adjacent weld metal but also the microstructure of S304H adjacent weld metal will both change during the welding process. Considering that the mechanical properties of the joints are closely linked with its microstructure. Thus, an in-depth insight into the structure–property relationships of T92/S304H dissimilar materials joints may have great significances for both the dissimilar steels welding process between new generation martensitic and austenitic steels, and the safety of the USC boilers. In our work, on the one hand, mechanical properties of T92/S304H dissimilar materials joints were carried out through tensile and impact tests. On the other hand, the microstructures across the entire joints were also investigated. What's more, the detailed mechanism governing the microstructural evolution of the joints during welding process was analyzed by means of the electron back-scattered diffraction (EBSD) technique, which was firstly used to study the process of grain structure development of dissimilar materials joints.

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doi:10.1016/j.matdes.2011.01.008