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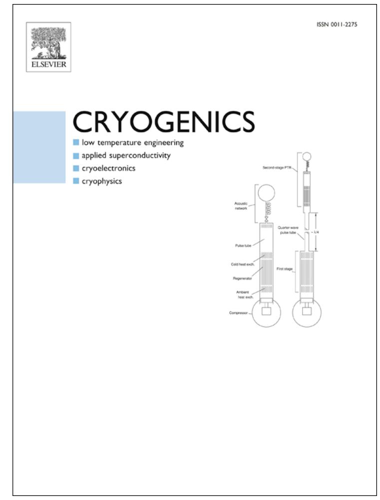

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Tensile properties and impact toughness of S30408 stainless steel and its welded joints at cryogenic temperatures

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Abstract

Designing a cryogenic pressure vessel based on the mechanical properties of the austenitic stainless steel (ASS) at its cryogenic operating temperature fully utilizes the potential of the material at low temperatures, resulting in lightweight and compact products. A series of tensile tests and impact tests were carried out in a wide range of 77 K to 293 K, to investigate the mechanical properties of S30408 base metal (BM) and welded joints (WJ) at cryogenic temperatures. As the temperature decreases, yield stress ($R_{p0.2}$) and ultimate tensile stress (R_m) increase significantly thanks to the low-temperature strengthening effects. To estimate strengths at cryogenic temperatures, quadratic polynomial model was used to accurately predict the variations of $R_{p0.2}$ and R_m from 77 K to 293 K. As an important phase in the WJ, ferrite presents a radial pattern and an inhomogeneity in the WJ's cross-section. Due to the formation of ferrite in the WJ, the WJ has higher $R_{p0.2}$ and lower R_m, Charpy absorbed energy and lateral expansion compared with the BM. Strain-induced martensite transformation is an important role influencing the deformation of ASS at low temperatures. In this study, less martensite amount was measured in the weldment zone with higher Nickel equivalents which stabilize the austenite phase at cryogenic temperatures. Additionally, due to higher ferrite content and more precipitates forming, the SAW joints has lower R_m and impact toughness than PAW+GTAW joints. To ensure the structural integrity and safety, the PAW+GTAW method should be chosen and ferrite content be controlled.

Keywords: Austenitic stainless steel; Cryogenic mechanical properties; Welded joints; Ferrite distribution; Martensitic transformation

1. Introduction

A transition to clean energy and acceleration of decarbonization goals drive a dramatic investment to alternative energies, among which natural gas and hydrogen are competitive candidates for the short-term and long-term solutions to the energy problems respectively [1, 2]. On the other hand, more industrial gases, such as oxygen, nitrogen, argon, etc., are demanded nowadays as the modern industry develops rapidly. The key technical challenge to the application of those energy and industrial gases is how to store and transport them efficiently and safely. Storing and transferring in the form of cryogenic liquified gases are advanced technologies that are widely adopted because of the high density of the liquefied contents [3]. Cryogenic pressure vessel [4] is the major equipment associated with such technique.

The mechanical properties of the material, which the design and fabrication of the products will based on, are critical to the economy and safety of the cryogenic pressure vessels. Austenitic stainless steel (ASS) is widely used for fabricating cryogenic pressure vessels because of its excellent mechanical properties at low temperatures. In addition, the welded joints (WJ) are critical components that determine the vessel structure integrity and safety. The mechanical performance of both base material (BM) and WJ is dramatically influenced by the decreasing temperature down to cryogenic region. Many studies [5, 6, 7, 8, 9, 10] have illustrated that the strength including yield stress ($R_{p0.2}$) and ultimate tensile

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