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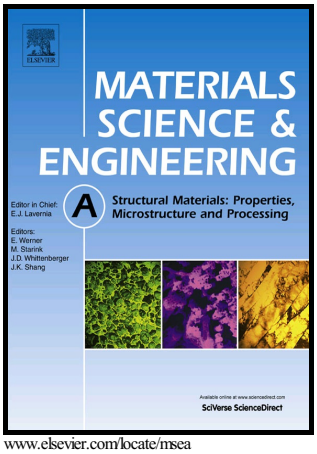

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Effect of thermal aging on mechanical properties of a bainitic forging steel for reactor pressure vessel

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Abstract: Vickers hardness, Charpy impact and tensile properties of 16MND5 steel, a bainitic forging steel that is used for nuclear power reactor pressure vessel, were investigated before and after varied thermal aging durations at 350 ^{o}C up to 3,000 h. After thermal aging for 500 h, the steel exhibits a remarkable increase in the ductile-to-brittle transition temperature (DBTT), a slight increase in the hardness, and slight degradations in the yield stress, ultimate tensile strength and elongation at room temperature. These facts indicate thermal aging induced embrittlement of the steel, which are further evidenced by the intergranular cleavage cracks on fracture surfaces in impact tests and a wheel-spokes like fracture morphology in tensile tests. As thermal aging duration is further extended, the embrittlement seems saturated as manifested by consistent DBTTs and fracture morphologies. Based on the metallographic observations and Rietveld refinements of neutron diffraction patterns under different aging conditions, the possible mechanisms of the thermal aging induced embrittlement are discussed.

Keywords: thermal aging; embrittlement; reactor pressure vessel; low alloy steel; neutron diffraction

1. Introduction

As one of the key components in nuclear power plants, reactor pressure vessel (RPV) is normally operating in harsh environments, including elevated temperature, high pressure and neutron irradiation [1]. Safety design of RPV demands highly reliable mechanical performance of structural materials in these harsh environments [2, 3]. Two critical issues that require special attention are irradiation and thermal aging induced embrittlement of RPV materials, which are typically characterized by an increase in yield and ultimate tensile strength, a decrease in elongation as well as a shift of the ductile-to-brittle transition temperature (DBTT) towards higher temperature. While the effects of irradiation on mechanical properties of RPV materials are relatively well documented [4, 5], the effects of thermal aging still call for more attention [6-10]. As reviewed by the authors from published literatures, available data that are related to thermal aging effects on RPV low-alloy steels can be divided into two categories depending on its thermal aging source: in-service exposure to operating temperature of RPV[11-17] and laboratory