EFFECT OF HEAT TREATMENTS ON THE 4 K FRACTURE AND FATIGUE PROPERTIES OF 316LN AND HAYNES 242

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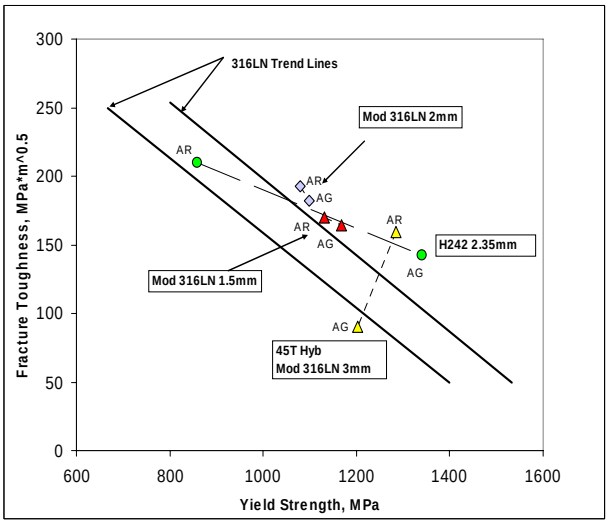
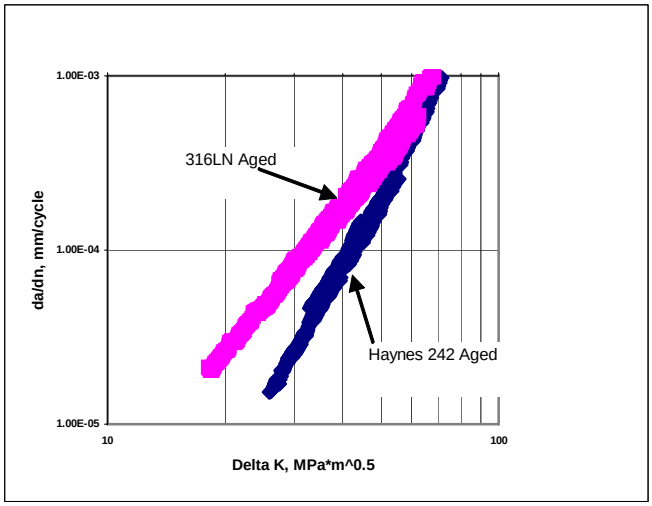
Introduction

When cable-in-conduit conductor (CICC) magnets use Nb3Sn superconductor, the conduit alloy must retain good mechanical properties after exposure to the superconductor's reaction heat treatment. Here we present data from cryogenic fracture toughness and fatigue crack growth rate tests on 316LN and a Cr-Mo-Ni base super-alloy (Haynes 242) at 4 K before and after the exposure to the heat treatment. These alloys are presently being considered as candidates for use in the series-connected hybrid magnet for the NHMFL.

Experimental

Two alloys (Haynes 242 and modified AISI 316LN) are tested in two conditions (As-Received and Aged). The materials are in sheet form, the Haynes is 2.35 mm thick and the modified 316LN is 1.5 mm thick. The Haynes material (a Ni-Mo-Cr age hardenable alloy) and the 316LN material is an austenitic steel. The as-received conditions for both materials are verified by room temperature tensile tests. The aged condition of the material is the state of the material after a 100hr at 700C heat-treatment in an argon atmosphere to simulate the effect of a Nb_3Sn reaction heat treatment.

Results and Discussion

AISI 316 austenitic steel is susceptible to carbon sensitization from long-term exposure to high temperatures (673 to 1073 K). The 316LN has modifications to the chemistry (very low carbon plus the addition of Nb) designed to minimize the sensitization problem caused by aging. Haynes 242 on the other hand is a precipitation-hardening alloy that increases in strength when aged but may also experience loss of toughness at 4 K. While the tensile property measurements are preliminary indicators of the effect of aging, the 4 K fracture toughness and fatigue crack growth rate of both materials are of primary concern and desire. The 4 K yield strength/fracture toughness inverse relationship for 316LN steel is depicted by the scatter band in FIGURE 1. The modified 316LN follows this trend and exhibits a slight increase in yield strength and decrease in fracture toughness upon aging. FCGR tests of modified 316LN (1.5 mm) and Haynes 242 have been conducted to determine the Stage II (Paris Regime) crack growth behavior. The FCGR test results are shown in FIGURE 2 plot of the da/dn vs ΔK for both alloys in the aged condition, Although the exponent (m) parameter for 316LN is smaller than the Haynes 242, the Haynes has lower FCGR for a any given ΔK less than approximately 70 MPa*m$^{\wedge 0.5}$. The large (two order in magnitude) difference in the "C" parameter dominates the respective crack growth rates. The two curves converge at somewhere around 70 MPa*m$^{\wedge 0.5}$, at the end of the useful stage II FCGR data.