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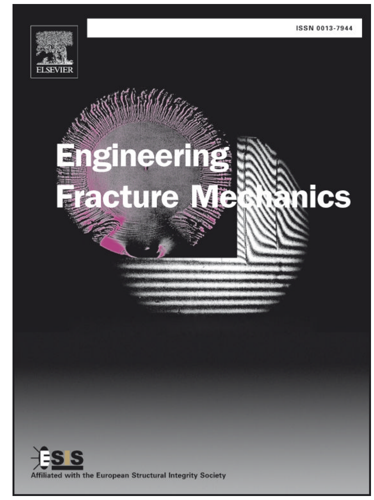

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Applications of Fracture Mechanics in Assessing Integrity of Hydrogen Storage Systems

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ABSTRACT

This paper addresses the challenges in designing high pressure, durable, safe, and cost-effective vessels for storage of gaseous hydrogen and the role of fracture mechanics in meeting those challenges. The design life limiting material property for vessels made from tempered martensitic steel is the environment assisted fatigue crack growth rate (FCGR) that depends on ΔK, the load ratio, loading frequency, and the H_2 pressure. The effects of these variables individually and synergistically are explored in this paper. FCGR behavior at negative load ratios, R, of -1.0 and -0.5 were found to be comparable to those at load ratios of 0.1 and 0.2; the effects of load ratio appear to become stronger for R > 0.2. The effect of decreasing loading frequency, ν, on the FCGR behavior in H_2 gaseous environment is small for frequencies less than 1 Hz. FCGR behavior is shown to increase with gas pressure and the effect appeared to be highest in going from air environment to 10 MPa H_2 pressure and then it saturated at 45 MPa. The impact of these variables and others such as autofrettage, on the design life of H_2 storage vessels are explored.

Key words: A 372 Class J steels, Fatigue crack growth, Environment assisted cracking, Hydrogen embrittlement

1. INTRODUCTION

Safe and low-cost, high-pressure hydrogen storage systems are a critical need for refueling stations for fuel-cell powered vehicles, for back-up power in residential and office buildings, and for fork-lifts in warehouses. These systems are also essential for harnesing clean power for reducing greenhouse gas emissions by tapping vast amounts of energy available from wind and sun [1-3]. Excess energy during high generation periods can be stored in the form of compressed hydrogen and can be made available on demand to power fuel cells during the low generation periods. Additionally, H_2 powered vehicles can reduce harmful pollutants in large metropolitan areas.

Figure 1 shows a comparison of the energy stored in one liter volume and in one Kg mass for various fuel types including hydrogen [4]. The stored energy density of H_2 can be competitive with other fuels only at very high pressures. Since the density of compressed hydrogen continues to increase significantly up to pressures of 100 MPa, Fig. 1b [5], it has become the target design pressure for H_2 storage systems. The combination of high pressures, the potential for hydrogen embrittlement, and the need