Influence of Corrosion on Fatigue Crack Growth of High Strength Steels

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Abstract. The increasing use of low alloy steels in heavy industrial machinery and structural applications aims to achieve lighter, more sustainable structures. However, while these high-strength steels (HSS) offer enhanced yield strength, this does not necessarily translate to improved fatigue and fracture resistance. Despite their growing significance, research on the fatigue performance of HSS remains limited, primarily due to the high cost of experimental testing. This study investigates the fatigue crack growth rates in HSS from a fracture mechanics perspective, particularly under corrosive conditions. The findings will contribute to a deeper understanding of fatigue behaviour in HSS when compared to conventional strength steels (CSS).

Introduction

S690, S700 are low-alloy steels highly used in structural applications like offshore, constructions, mining equipment because of high strength and also has the greater impact toughness at low temperatures [1]. Fatigue crack propagation in S355 and S690 steels was compared and concluded that HSS has higher resistance to crack initiation [2]. Fatigue crack growth (FCG) is a critical phenomenon influenced by various factors that dictate the rate of crack propagation and ultimately affect the structural integrity of materials mainly environmental factors like corrosion and temperature. This experimental work focuses on the effect of corrosion on the crack growth rates.

Test Rig Design

Instron 8801,100kN frame is used to carry out the fatigue crack growth test in room temperature. Maximum applied load P_{max} = 10kN is applied at a constant amplitude at 5Hz and 10Hz frequency at a stress ratio of R = 0, R = 0.1. Compact tension sample (CT) is selected for the test and the procedure is according to ASTME647 standard. Crack measurement setup includes a Crack mouth opening displacement gauge (CMOD) is attached to the knife edge on the front face, the back face of CT sample as a strain gauge mounted. Crack growth in both the faces are monitored using a visual technique as shown in Figure 1a.

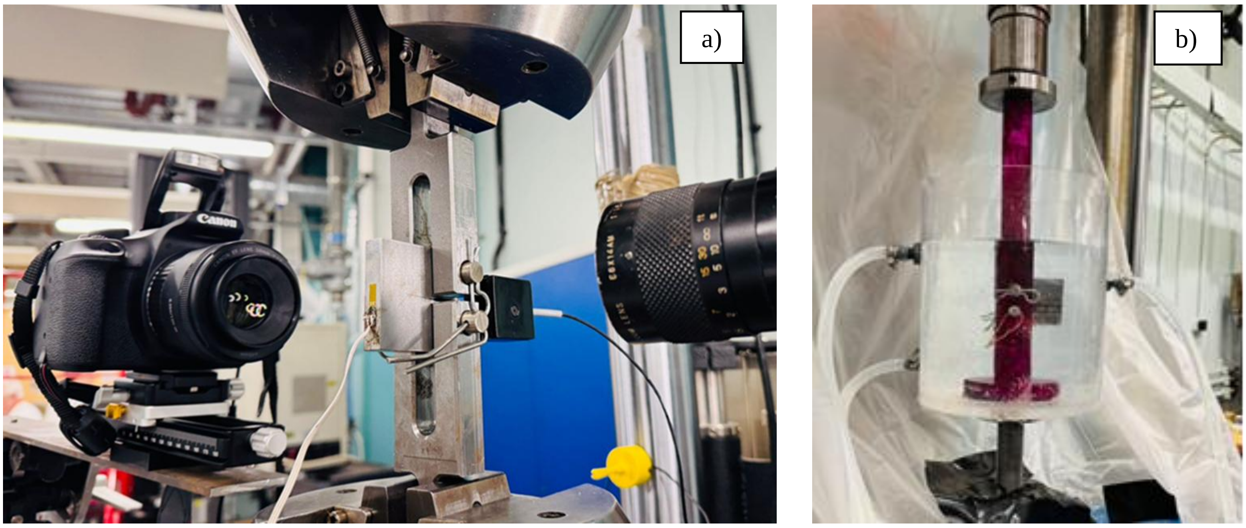

Figure 1: a) Visual Crack growth technique; b) Corrosion test setup

To study the influence of corrosion on the crack growth rates a test rig is built which helps in performing the in-situ corrosion fatigue crack growth test as shown in figure 1b. 3.5% Sodium Chloride is the corrosion fluid circulating within the acrylic tank at the room temperature at a neutral pH. Due to the in-situ test setup the crack growth data is only tracked from the strain gauge on the back face. Before starting the actual test the samples are soaked for 36 hours according to the ASTME647 standard.

Crack Growth Results

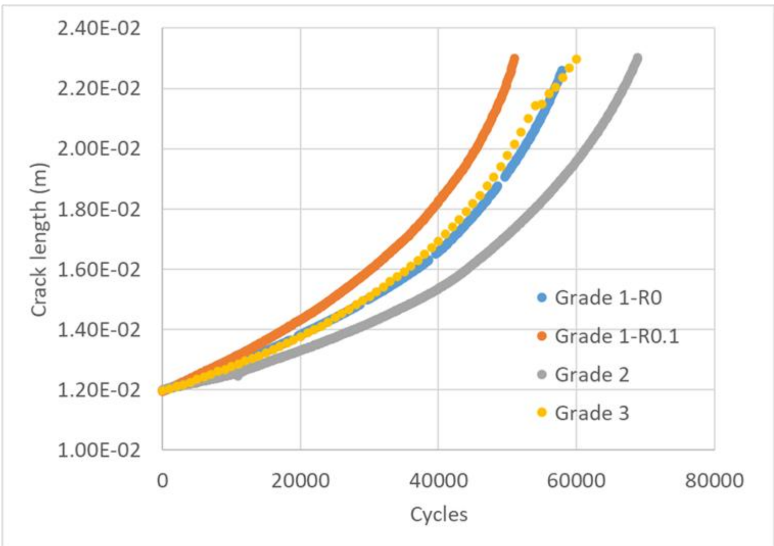

Figure 2: Crack lengths vs Cycles for different grades of steels

Crack length vs cycles for different grades of steels are shown in figure 2. Grade 1 and Grade 2 are the HSS and the Grade 3 is conventional strength steel grade. HSS due to their microstructures seems to offer better resistance to crack initiation but the crack propagation rates are higher when compared to conventional grades steel.

Conclusion

This work focused around the Paris Law crack growth region so there is not much attention on the threshold region and the final fracture region. From the primary observation of the crack propagation data the crack initiation time is longer in the high strength steels with martensite microstructure but propagates faster after initiation when compared to medium strength steels with ferrite - pearlite microstructure. Further work is to investigate the influence of corrosion on the crack growth rates with the newly constructed test rig and also to study the influence of microstructure on the fatigue crack growth rate through SEM fractography.

References

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