An Investigation of the High Strength Structural Steel Mechanical Properties

Monisha Manjunatha*, Tugrul Comlekci, Donald Mackenzie, Yevgen Gorash

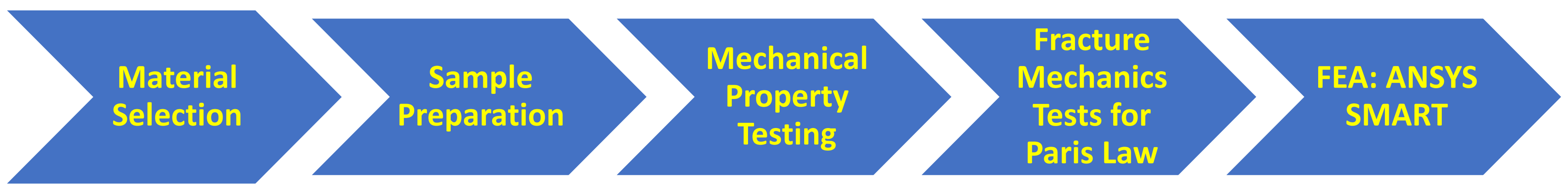
Department of Mechanical and Aerospace Engineering, University of Strathclyde, Glasgow

University of Strathclyde Glasgow

Introduction

- The application of low alloy steels (e.g. S690, S700, S960) that has higher yield strength than the conventional steels (e.g. S275, S355) has increased over the years to achieve lighter structures with a focus on sustainability.
- The selection and usage of material can be optimized by balancing the manufacturing and operating costs, weight and durability, and weldability of the designs. This contributes to the sustainability of heavy industrial machines and constructions.
- Material data available in the literature regarding the fracture mechanics properties of high strength steels (HSS) is limited and mostly proprietary.
- This study aims to provide insights of crack propagation tests on a selected HSS. The methodology followed for test procedure is based on the ASTM E647 standard and a compact tension (CT) test sample design.

Methodology



- High strength steel S700 selected and acquired for different thickness plates.
- Test samples prepared according to the ASTM standards to find the mechanical properties e.g.:
  - Tensile strength, hardness, chemical composition, Charpy impact strength, crack propagation rates and fracture toughness.
- Material properties are being tested at the Advanced Materials Research Laboratory (AMRL) (Figure 1).
- Tensile testing and fracture mechanics crack propagation tests based on ASTM E647 focused on in this poster.
- Finite Element Analysis (FEA) of components with ANSYS SMART fatigue crack propagation tool.

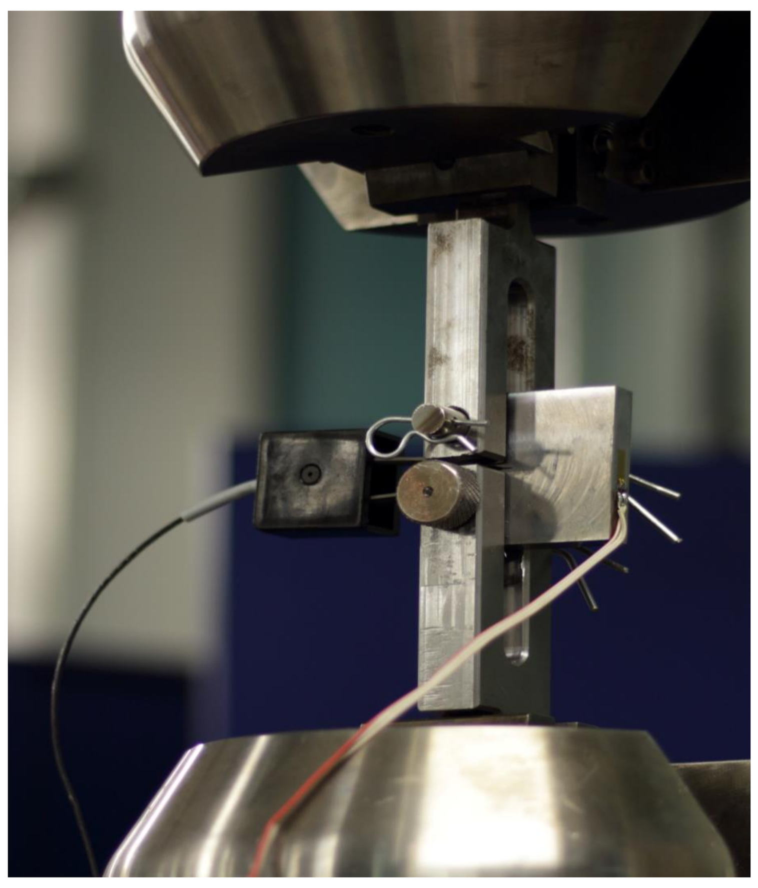


Figure 1: CT test piece assembly on the AMRL Instron 8801 grips

Fracture Fatigue Testing

- Experimental crack growth analysis is based on the ASTM E647 standard.
- The crack propagation rate is measured for S700 steel.
- Stepped load shedding at 3 levels applied in blocks of 100 cycles (5Hz) and 10k cycles (20Hz).
- CT test piece and front face compliance-based crack length estimation used (Figure 5).
- Experimental crack mouth opening displacement (CMOD) results are post processed to obtain crack length vs cycles (Figure 6).
- da/dN vs ΔK and the Paris law constants m & C are estimated with a logarithmic regression analysis (Figure 7).

Figure 5: Crack propagating on the CT test piece

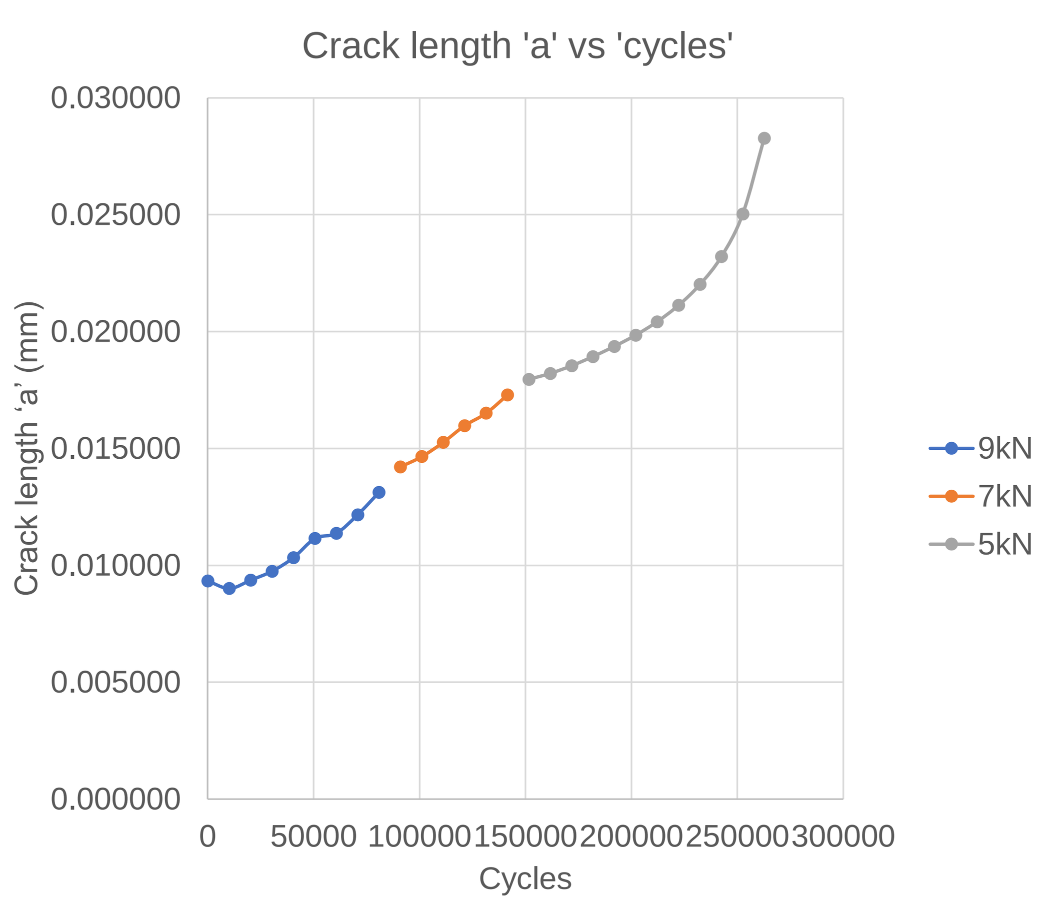


Figure 6: CT test piece crack length a vs number of cycles for three load levels

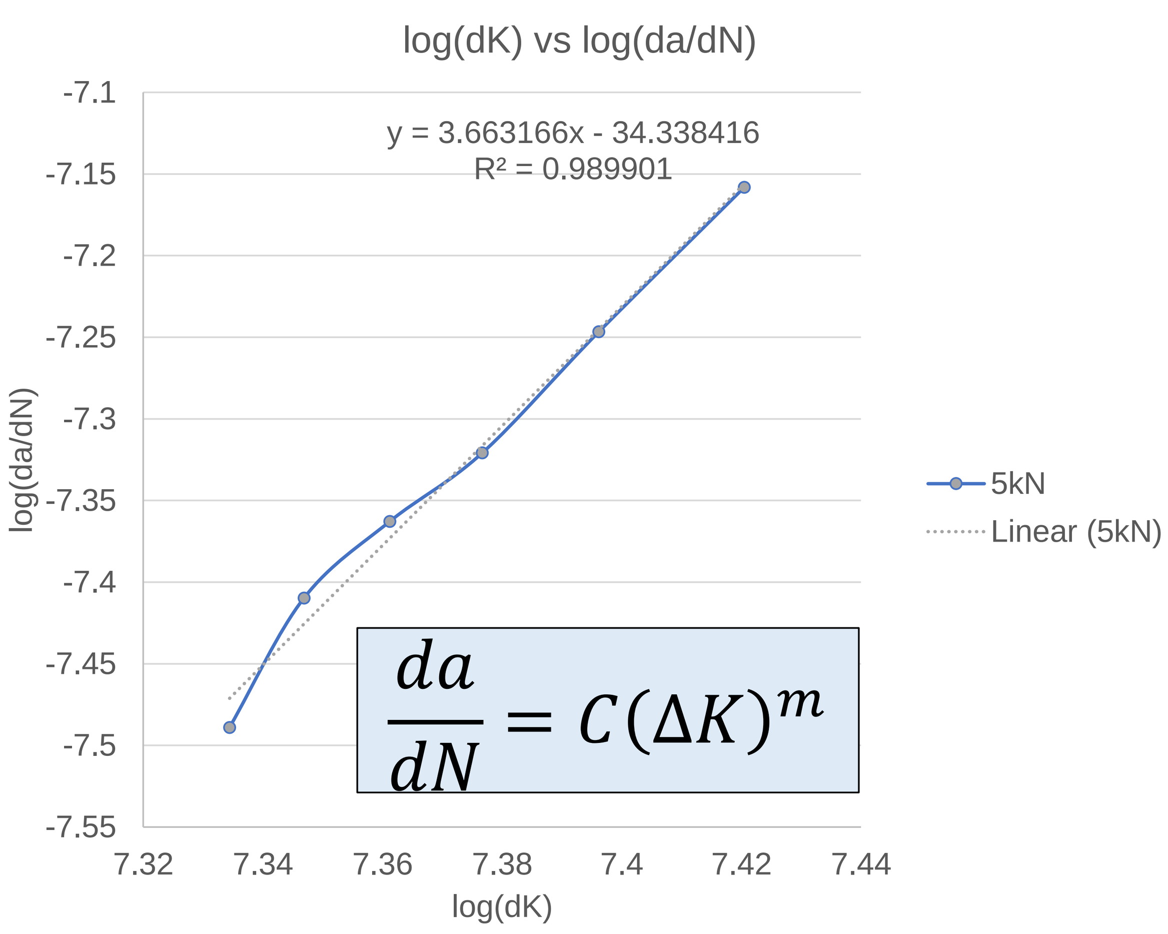


Figure 7: Sample Paris Law m & C evaluation for S700 steel

Tensile Testing

- Tensile test sample on AMRL Instron 8801 near failure (Figure 2).
- SEM images of failure surfaces obtained (Figure 3).
- Young's modulus, yield strength and stress-strain material properties evaluated for CT test piece designs using finite element analysis (Figure 4).

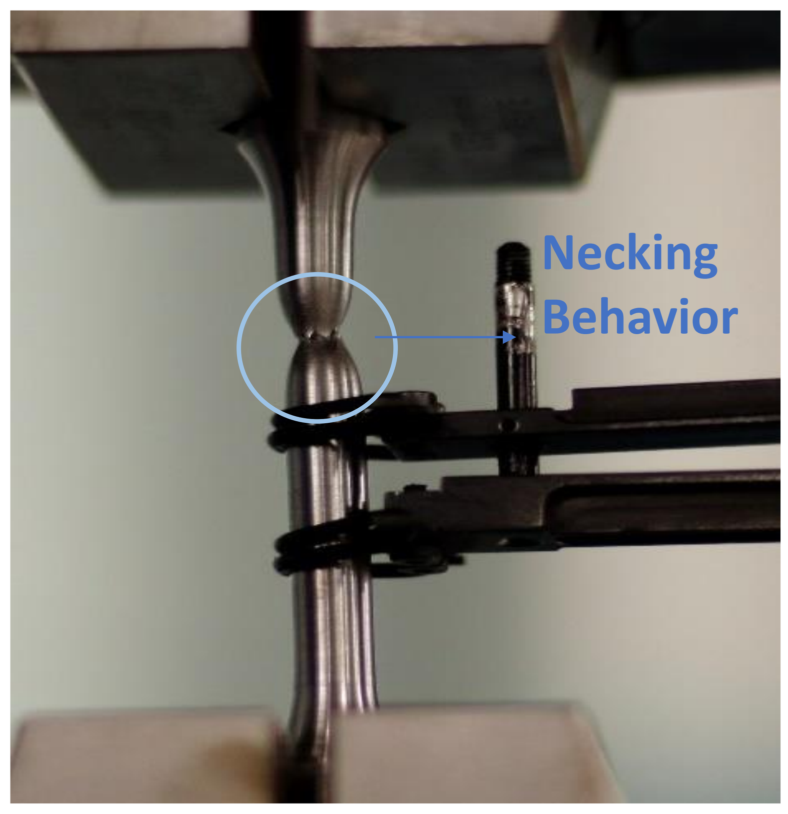


Figure 2: Onset of Necking

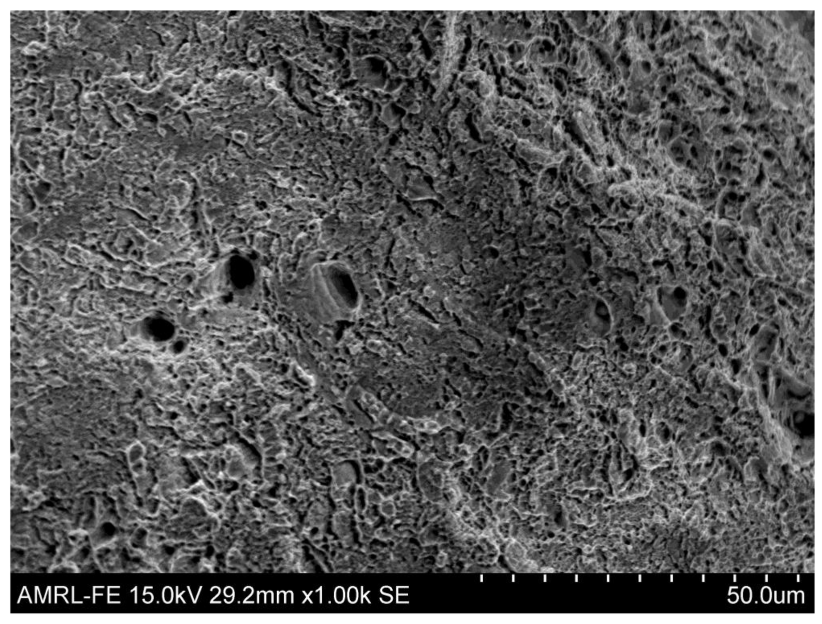


Figure 3:Typical ductile failure with dimple features

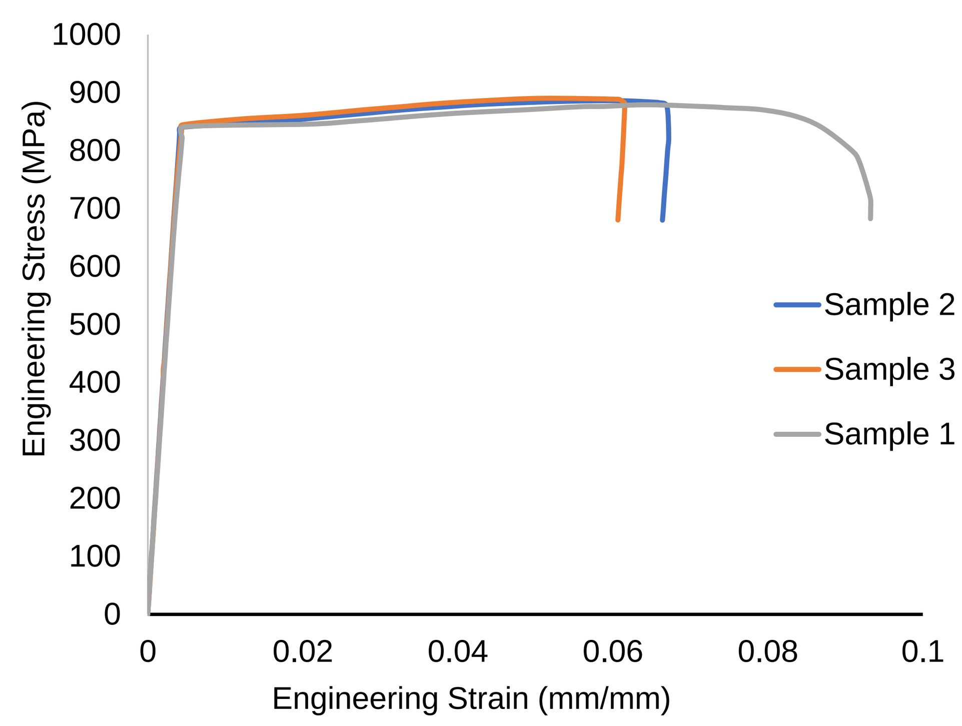


Figure 4: Stress – Strain Curve for S700

Future Work

- Determine fracture mechanics fatigue crack propagation rates using the back face compliance method & compare.
- Pre-crack CT samples and evaluate critical J integral fracture toughness property of the steel material based on the ASTM E1820 standard.
- Compare the crack propagation rates for different environments / steel grades.
- Apply the experimental results on finite element numerical models of components & optimize application.

WEIR

NMIS National Manufacturing Institute Scotland

References

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[2] de Jesus, A.M.P., Matos, R., Fontoura, B.F.C., Rebelo, C., da Silva, L.S., Veljkovic, M., 2012, "A comparison of the fatigue behaviour between S355 and S690 steel grades," Journal of Constructional Steel Research, Vol 79, pp140-150.

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** If you require further information regarding this research investigation, please contact:*
monisha.manjunatha@strath.ac.uk