Magnetic Tensile Testing of Eurofer97 at 550°C

Research area: Structural Integrity

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The Challenge

As part of the Spherical Tokamak for Energy Production (STEP) programme, UKAEA has a requirement to better understand the behaviour of structural materials in the presence of a magnetic field. A breeding blanket and divertor cassette are the key parts in the conceptual design of EU DEMO fusion reactors. These parts will not only be exposed to extreme magnetic fields ranging from 3.7 to 10 T, but also high temperatures of up to 550°C during their service lifetime. A potential material that can withstand such conditions is Eurofer97 steel. It is essential to have a comprehensive understanding of the mechanical properties of this alloy at high temperatures when it is exposed to strong magnetic fields. However, performing tensile tests in a magnetic field at elevated temperatures requires an innovative design. The demagnetisation of magnets at temperatures higher than 250°C poses the greatest challenge. In this study, a practical design was developed for performing tensile tests on miniature dog bone samples made of Eurofer97.

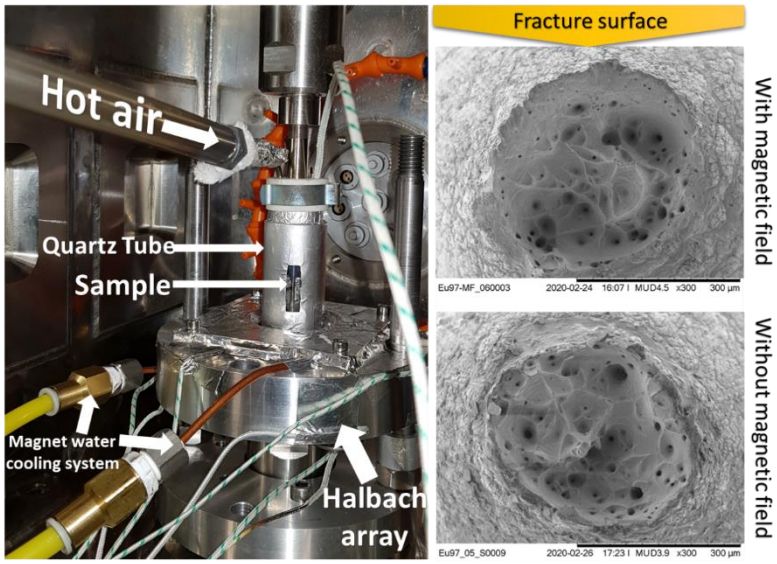

Figure 1 – (left) design rig, (right) fracture surface with and without a magnetic field.

The Solution

By employing an innovative design, a cylindrical Halbach array of neodymium magnets was used to provide the required 0.5 T uniform magnetic field. The sample was placed in a quartz tube and heated locally with a hot air blower to 550°C. The design apparatus made it possible to perform high temperature tensile tests inside a magnetic field with a 0.5 T flux density. The setup offers fast heating and cooling and excellent temperature stability, whilst being simple and inexpensive.

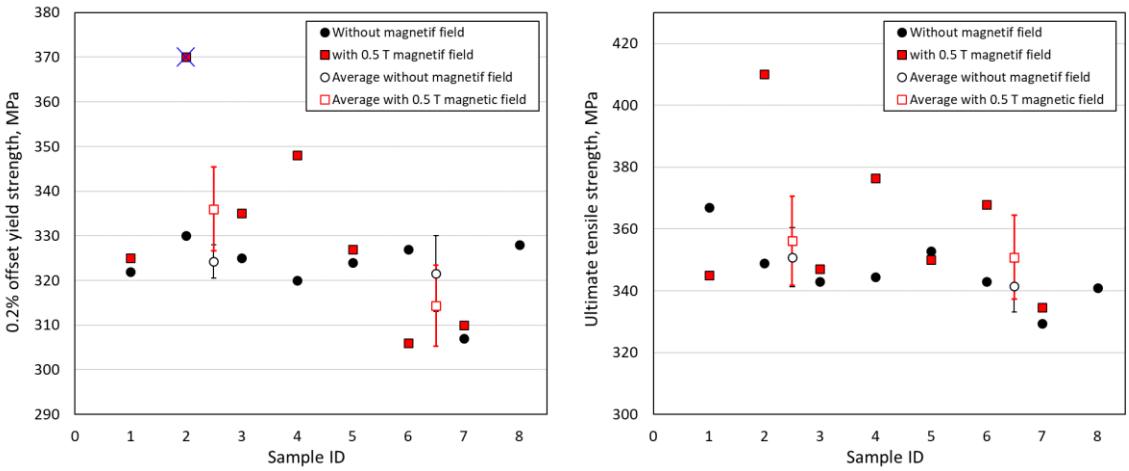

Figure 2 – Yield strength versus sample ID.

The variations in the mechanical behaviour of Eurofer97 with and without magnetic field were within the range of experimental errors. The discrepancies in the evaluated values were slightly higher for magnetic tensile tests. It is important to note that these tests should be repeated on more samples to provide an inferential analysis (e.g. t-test), in order to determine whether these changes are meaningful or not. Fracture surface analysis showed large dimple structures where breaking of inclusions nucleated microvoids. The magnetic field did not have a noticeable effect on the structure and size of the dimples.

The Impact

This project has opened the way to exciting new studies on mechanical behaviour of materials at elevated temepratures in the presence of strong megnetic fields. Such work is of paramount importance in charactrising candidates for structural materials in the STEP program.

To shed light on the interaction between magnetic field and the mechanical response of Eurofer97, further experimental studies on high temperature forward creep, fatigue, and tensile behaviour in even higher magnetic flux densities (~ 1.5 T) in the longitudinal direction could be considered.