UKAEA Material Research Facility – Mechanical Testing Capability

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Introduction

As part of its mission in leading the delivery of sustainable nuclear fusion energy the UK Atomic Energy Authority (UKAEA) operates the Materials Research Facility (MRF) to prepare and examine radioactive materials to assess their performance in nuclear applications. The motivation for this is to understand the effects of the intense irradiation of materials by the high energy neutrons produced by DT fusion reactions which damage materials that the reactor is made of, leading to embrittlement, swelling and other failure mechanisms, reducing the lifetime of components and of the reactor itself. The MRF is equipped with hot-cells which can receipt and prepare individual radioactive samples up to the 3.75 TBq Co-60 equivalent facility inventory limit.

A recent hot cell extension has installed a 20kN load frame within a hot cell allowing mechanical testing on high activity samples. Tensile testing can also be performed outside the hot cell on samples up to the MRF's 3.75 GBq Co-60 equivalent sample activity limit in separate shielded "research rooms".

The MRF also hosts a suite of microstructural and thermophysical characterisation instruments for irradiated materials. This allows the mechanical tests to be correlated with microstructural characterisation and thermal effects.

Mechanical test capability in hot cell

The two new MRF hot cells incorporate a removable inner containment within the radiological shield allowing the rapid reconfiguration of hot cells depending on experimental needs. The initial containment box contains a Walter + Bai LFV-20kN servo-hydraulic test machine for performing mechanical tests on irradiated test specimens. Tests can be performed in the range 150°C - 600°C using a climate chamber with LN_2 supply. For testing at temperatures up to 1000°C, two different inert-gas furnaces are available. Strain measurement is available via a non contact Digital Image Correlation system, planned to be use between 150°C - 1000°C.

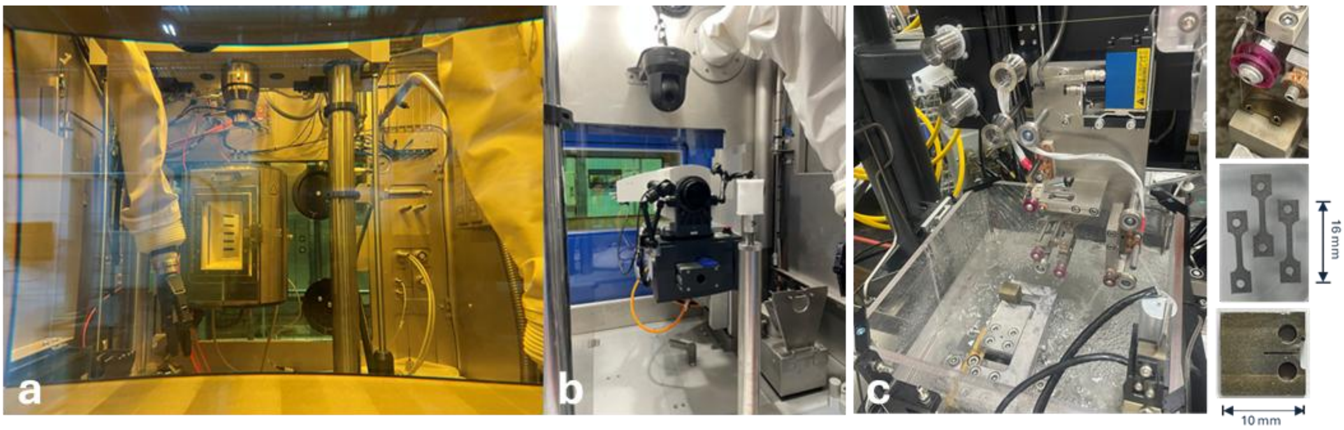

Fig. 1 (a) and (b): In hot cell mechanical testing with non-contact strain measurement and (c) sample fabrication by WEDM cutting, milling and laser cutting.

Sample preparation in hot cell

A second hot cell and containment contains a Viteris sample fabrication machine allowing in cell machining and test specimen fabrication of highly active materials. Specimens of irradiated materials can be machined using wire EDM (Electrical Discharge Machining), milling, and laser cutting. Samples frabricated on this system can include SS-J3 and larger tensile specimens, small 3 mm diameter laser cut ultrasonic resonent fatigue cantilevers made from foil and 0.16T C(T) specimens for fracture toughness testing.

Mechanical test capability in research rooms

Lower active specimens below the 3.75 GBq sample limit can be tested in concrete Research Rooms which have less shielding than the hot cells. The samples are transferred by a lead shielded trolley from the hot cell line to the scientific equipment in the Research Room where the specimen is loaded into the scientific equipment by a robot.

A Small-Scale 5 kN Mechanical Tester, shown in Fig. 2, enables mechanical testing of small, mm-scale, specimens in a temperature range from 25°C - 470°C. Non-contact strain measurement is possible using the LaVision Stereo Microscope Digital Image Correlation system which views the specimen through the chamber window. Fixtures are currently available for SS-J3 tensile specimens.

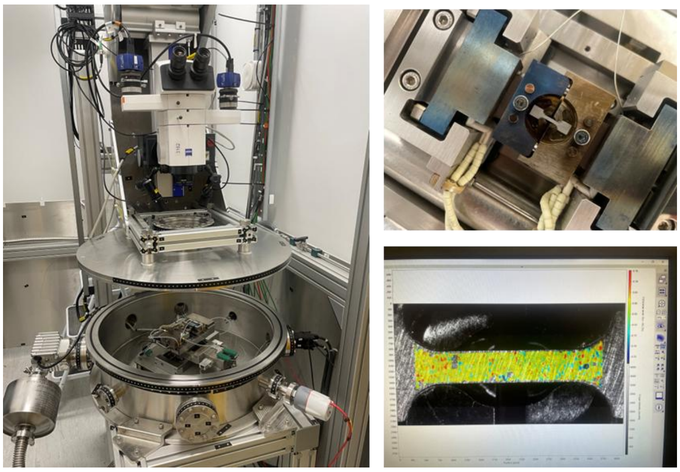

Fig. 2: Tensile testing inside vacuum chamber with DIC within shielded research room in the MRF.

The MRF also houses an ultrasonic fatigue rig allowing small 3 mm diameter foil samples with laser cut cantilevers to be tested at 20 kHz. An optical laser system is used to measure the cantilever deflection and number of cycles to failure. Thus allowing the S-N curve indicating the fatigue resistance of the material can be produced from the collected data.

The MRF also houses a micromechanical capability utilising Alemnis AG *in situ* indenters within the facilities SEM and PFIB instruments to allow testing of specific microstructural features and FIB fabricated specimens. Specimen fabrication can be targeted using EBSD on both MRF FIBs. The system is capable of both compression testing of cantilevers, pillars and indentation of the surface along with tensile testing of dogbones at on the micron scale. Compression testing can be performed between liquid nitrogen temperature and 1000°C although this does limit the sample size.

This presentation will introduce the MRF and demonstrate the capabilities to perform mechanical testing on unirradiated and irradiated materials.