High Temperature Fatigue Crack Growth evaluation for performant c

Tungsten is one of the strongest materials and is very important for fusion reactors because of its ability to remain strong at elevated temperatures. Nevertheless, its fracture properties have to be understood for making it fusion-ready. The research group at Erich Schmid Institute of Materials Science (ÖAW) tests the damage tolerance of high-heat flux materials and static fracture experiments have been state-of-the-art at the institute for a long time. Recently, due to a newly built experimental setup, it is now possible to apply dynamic mechanical loading to the sample simultaneously in vacuum and at high temperatures. The results of this work (equipment, scientific knowledge) is essential for life-time estimation of future (experimental) fusion reactors but and is applicable for other materials that are subjected to repeated mechanical loading at elevated temperatures

Description of the technology

The research group at Erich Schmid Institute of Materials Science (Austrian Academy of Sciences) is very experienced in the field of microstructural characterisation, fracture mechanical testing (fracture toughness and fatigue crack propagation experiments) and interpretation of the results of tungsten alloys. The team has developed a strong knowledge in understanding and analysing the damage tolerance of tungsten and the fatigue crack growth (FCG) behavior of tungsten-based samples.

The microstructure (i.e. grain size, texture, grain shape, ...) is of importance for fracture toughness and FCG behavior. These properties are essential for the assumed application in fusion. Consequently, microstructural investigations techniques such as EBSD in a SEM are applied for the investigated tungsten-based materials.

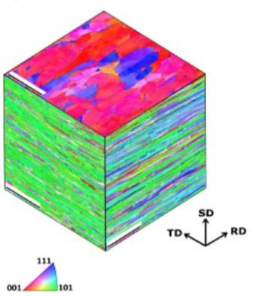

Figure 1: Typical tungsten microstructure for rolled material. Data was generated using the in-house EBSD system and shows the three principal direction of a rolled tungsten, which is now being considered most interesting for fusion application. Color code / standard triangle is attached

New experimental setup has been built to determine the fatigue crack propagation behavior in vacuum and elevated temperature : the FCG behavior of tungsten samples is investigated in vacuum (p<10-5mbar) and temperatures up to 600°C, taking into account different testing direction, FCG directions respectively. At the moment, sample of compact tension geometry of millimeter size are used. The continuous determination of the crack length is based on the direct current potential drop method.

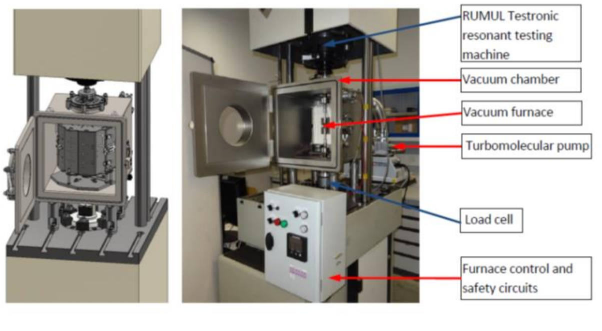

Figure 2: Newly-built experimental setup, to determine the fatigue crack propagation behavior in vacuum and elevated temperature.

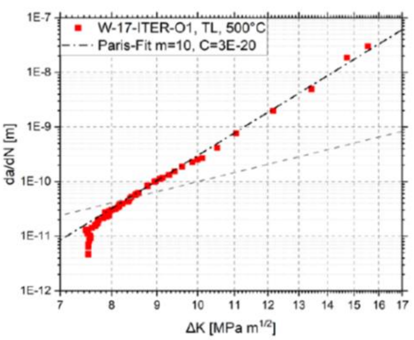

Figure 3: Schematic depiction of results of fatigue crack propagation behavior of ITER tungsten at 500°C in vacuum.

EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

High Temperature Fatigue Crack Growth evaluation for performant high-heat flux materials

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Innovation and advantages of the offer

Up to know, the research of fracture behavior of tungsten-based materials mainly focused on static loading. For fatigue loading, only room temperature tests were available. This newly-built scientific equipment enables the investigation of FCG behavior of tungsten close to later fusion conditions.

However, the applicability is not limited to tungsten-based materials, but many other (electrically conductive) materials can be tested. Sample handing and operation of the equipment needs specific training and a well-educated operator. For final judgement on the acting fracture mechanisms in the fatigue-loaded materials, an assessment of resulting fracture surfaces using a scanning electron microscope (available at the institute) is highly recommended.

Non-fusion Applications

Investigating and understanding the fatigue crack growth behavior is not only important for tungsten-based relevant for fusion applications but is of general importance for materials that are subjected to repeated mechanical loading at elevated temperatures.

EUROfusion Heritage

As a promising plasma facing material in nuclear fusion reactors, tungsten is subject to completely new demands in terms of failure safety and damage tolerance. Plasma events, for instance edge-localized modes, as well as the production process of plasma facing materials inevitably initiate cracks. Combined with thermocyclic loading during the pulsating operation of Tokamak reactors, cracks in these critical components are subjected to an additional driving force.

With these fatigue crack propagation experiments, the reliability and remaining service life of pre-cracked structural components can be evaluated, and with comparative results of different tungsten qualities, Erich Schmid Institute of Materials Science contributes to the EUROfusion material selection process. This development was motivated by non-existing data on the FCG of tungsten at elevated temperatures.

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