Mechanical Properties of Different Refractory Materials for Nuclear Fusion Applications

Michael Rieth[1], B. Dafferner[1], Andreas Hoffmann[2], Claus Petersen[3], Hugo Sandim[4]

[1] Forschungszentrum Karlsruhe, Institut für Materialforschung I, Karlsruhe, Germany, michael.rieth@imf.fzk.de
[2] PLANSEE Metall GmbH, Development Refractory Metals, 6600 Reutte, Austria, andreas.hoffmann@plansee.com
[3] Forschungszentrum Karlsruhe, Institut für Materialforschung II, Karlsruhe, Germany, claus.petersen@imf.fzk.de
[4] USP-Lorena, Dept. of Materials Engineering, Lorena-SP, Brazil hsandim@demar.faenquil.br

Refractory materials, in particular tungsten base materials are considered as primary candidates for high heat load applications in future nuclear fusion power plants. Promising design outlines make use of the high heat conductivity and strength of W-1%La_2O_3 (WL10) as structural material. Here, the lower temperature range is restricted by the transition to a steel part and the upper operation temperature limit is defined by the onset of recrystallization and/or loss of strength, respectively. The most critical issue of tungsten materials in connection with structural applications, however, is the ductile-to-brittle transition. Another problem consists in the fact that especially refractory alloys show a strong correlation between microstructure and their manufacturing history. Since mechanical properties are defined by the underlying microstructure, refractory alloys can behave quite different, even if their chemical composition is the same. For fusion applications only low activation materials are considered which excludes elements like niobium and molybdenum.

The present work gives a detailed overview of the problematic connected with the selection of an optimum structural material for high heat load fusion components. A systematic screening study of instrumented impact bending properties was performed on different grades of pure W, W-1%La_2O_3 (WL10), potassium doped tungsten (WVM), WL10 with 1% Re, W-FeNi (Densimet D180), pure tantalum, Ta-10%W. For comparison, further tests on the molybdenum material TZM as well as on single crystals of pure tungsten and W-1%Ta were carried out. Furthermore, the investigations included the characterization of the influence of the microstructure and of the lattice and/or load orientation on the mechanical properties. Therefore, rods and plates were used for specimen fabrication and testing. For a determination of the influence of the deformation rate, tensile properties were also tested.

With that, a review on the advantages and drawbacks of different refractory materials for the use as structural material can be given.