FUSION TECHNOLOGY DESCRIPTION

EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

Numerical Simulation of Materials Performance Under Thermal Loads

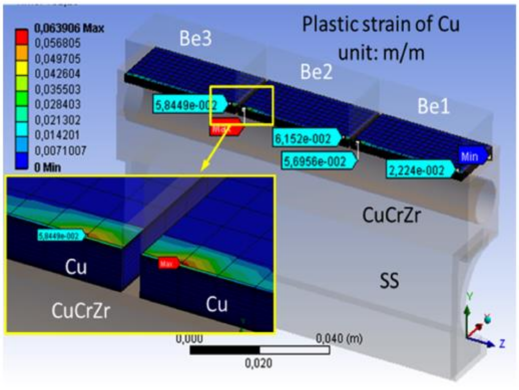
The objective is to provide a method for thermal and thermo-mechanical simulations of stresses in materials exposed to stationary and transient heat load. The Research Centre Juelich has gained substantial expertise in calibrating simulations on the basis of the Finite Elements Method that can be used to establish numerical material models to estimate component lifetime.

Description of the technology

The offer consists of Finite Elements Method (FEM) analyses that allow an accurate prediction of the performance of materials under quasi–stationary and transient thermal loads. Thermal and thermo-mechanical analyses have been conducted for beryllium components under both monotonic and cyclic thermal loadings in a mock– up consisting of stainless steel, CuCrZr, beryllium and a copper layer between beryllium and CuCrZr. Thermal analyses results indicate that the temperature of the beryllium surface is in general well below the maximum allowed temperature (600 °C) of the test facility. Thermo-mechanical analyses results indicate that the rupture of the copper layer or de–bonding between Be and copper are the drivers of the failure of the mock-up. 3D FEM thermo-mechanical analyses have been performed for the tungsten exposed to Edge Local Mode–like heat loads. Material degradation due to recrystallization was implemented by adopting decreased yield stress, tangent modulus, and ductility coefficient. Lifetime predicted by adopting a strain life criterion indicates grain growth from 5 µm to 100 µm and causes a lifetime decrease of 75%. This result was gained by pure mathematical calculation based on material mechanical properties assumptions.

Innovation and advantages of the offer

The method described above allows a highly accurate lifetime prediction of materials exposed to quasi–stationary and transient thermal loads solely on the basis of pure mathematical calculation considering material mechanical properties assumptions. FEM analyses are therefore especially useful for complex system design and projects with safety risks.



Thermo--mechanical analyses of beryllium component loaded with quasi--stationary thermal load of 2 MW/m² for 2 cycles: equivalent plastic strain distribution of copper layer.

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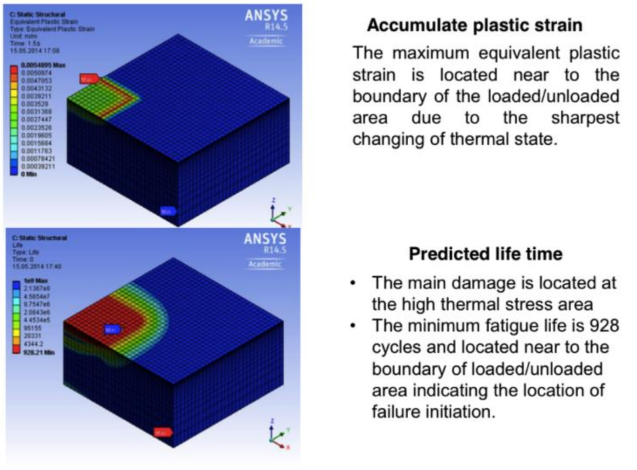
Non-fusion Applications

The numerical simulation of material properties under thermal loads allows applications in complex system design and in fields with safety requirements. Thermal analyses are also applied to the characterization of the heat transfer into hot structures used for space reentry vehicles. Numerical simulation also contributes to optimization of properties of components solely on the basis of mathematical calculation. Since the development of numerical models takes most of the effort in simulations, the material models developed by the Research Center Juelich could be transferred into other fields. Examples of use are manufacturing and testing of materials under high mechanical and thermal stress and the estimation of component lifetime.



Thermo-mechanical analyses of tungsten under trasient heat loadof 1.14 GW/m² for 1 ms.

Fusion Heritage

In the fusion domain, numerical simulations of materials performance under high thermal loads (e.g. heat transfer with active cooling) are needed to compensate the lack of experimentation opportunities. Nonetheless, safety questions are crucial and methods of predictability of fatigue and deterioration of materials necessarily required. Promising laboratory experiments have been conducted at Research Centre Juelich.

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