Microstructural modelling of creep in Cr-steel

Andersson, T. (Speaker)[1]; Balobanov, V.[1]; Biswas, A.[1]; Lindroos, M.[1]; Callejo, L.M.[2]; Barco Atutxa, J.[3]; Barbero, J.I.[2]
[1]VTT, Espoo (Finland); [2]TECNALIA, Derio (Spain); [3]TUBOS REUNIDOS GROUP, Amurrio (Spain)

F02: High Performance Materials for Sustainable Energy Applications → F02.01: Mechanical behavior of high-performance materials

Good creep resistance is important property for high temperature applications such as pipes for process industry. Ever increasing demands for higher energy efficiency sets increasing performance needs for component and the material of the component. Not only the materials need to perform better but many times the operational conditions of the component are more severe (e.g., higher operational temperature, longer maintenance intervals). At higher temperatures and pressures below yield, materials tend to creep. High chromium martensitic steels (e.g., P91/92, T115) have been widely used in the pipes in high temperature applications due to their good creep and oxidation resistance since the early 1900s.

Several microstructural features, such as grain size (prior austenite, martensite sub features) and carbide structure, affect the creep deformation behaviour. To optimize the microstructure, the heat treatment, and alloy composition need to be tailored such a way that the tempering conditions decrease the concentration of grain boundaries for precipitation of fine carbides, and giving an optimized density of boundary precipitates. Main types of precipitates are M23C6 and MX type carbides and nitrides. The M23C6 particles are precipitated during tempering and their main role is to stabilize the lath microstructure of tempered martensite whereas the MX precipitates are responsible for inhibition and reduction of dislocation mobility, which affects the creep resistance.

To study the effect of microstructure on the creep behaviour, a crystal plasticity finite element model is developed. For predicting the creep behaviour and mechanical performance of differing types of high chromium steels, the evolution of precipitates is incorporated into crystal plasticity material model. The microstructural features, such as grain morphology and texture, is covered by using representative volume elements (RVE) as computational domains. The RVE is constructed based on microstructural statistics of the casted material samples characterized with SEM-EBSD. Carbide densities and distribution are characterized with SEM and TEM techniques of the pre- and post-creep tested samples. The effect of differing carbide and microstructural characteristics is evaluated by using two differently heat-treated material samples.