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Review of the tungsten thermal conductivity in a fusion power reactor

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Tungsten is considered a main candidate plasma facing material (PFM) for nuclear fusion power reactors. Its high thermal conductivity is considered a major advantage compared to other PFMs. Under reactor conditions, the thermal conductivity will deteriorate significantly below the 170 W/(mK) usually agreed at room temperature and without irradiation damage. In a fusion reactor, PFMs have to be operated within a temperature window restricted, among others, by the mechanical limits and the irradiation damage annealing. This work reviews existing literature on tungsten conductivity and its operational temperature window to provide an estimate for the thermal conductivity in a fusion reactor and evaluate it in a fusion reactor component.

At temperatures relevant for reactor operation, which the displacement defect annealing requires to be above ~900 K, the conductivity drops to ~120 W/(mK) in the pristine state. Irradiation damage, in particular the transmutation to Re and the subsequent W-Re precipitation, is expected to reduce the thermal conductivity to ~50 W/(mK) after an irradiation damage in the order of 10 DPA, corresponding to about two full power years of a DEMO type power reactor.

The impact of this reduction on component design will be discussed. A lower thermal conductivity results in higher temperature gradients across the material thickness, therefore inducing higher stress to the PFC. In combination with the operational window, this limits the tungsten armour thickness and the available set of cooling pipe materials, since an overlap in the operational windows is required for joint materials.

An equation is presented to estimate the thermal conductivity of tungsten, as a function of operational time and temperature. FEM simulations using Ansys 20 and this equation are conducted for monoblock and flat tile plasma-facing components to investigate the effect of the reduced thermal conductivity on the temperature and stress distributions under different power loadings and coolant temperature scenarios. The results and their implications on joining tungsten with CuCrZr, steels, or Mo-based materials will be presented in the contribution.

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