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Development and testing results of water-cooled divertor target concepts for EU DEMO reactor

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Power handling is one of the most critical scientific and technological challenges for a nuclear fusion power plant. Divertor is a key in-vessel component of a fusion reactor being in charge of power exhaust and removal of impurity particles. For the European demonstration reactor (EU-DEMO), divertor targets local peak heat flux is expected to reach more than 20 MW/m2 during slow transient events. Sufficient heat removal capacity of divertor targets against normal and transient operational scenarios is the major requirement. Material degradation due to neutron irradiation has to be also considered (cumulative dose for the structural material: up to 14 dpa for lifetime). To find a feasible technological solution, an integrated R&D program for the European DEMO reactor was launched since 2014 in the framework of the EUROfusion Consortium Work package "Divertor"(WPDIV).

The preconceptual phase was concluded in 2018 where six different water-cooled target concepts were developed and evaluated. For all concepts a common R&D approach was adopted, namely, design study, failure simulation, design rules, materials definition, mock-up manufacturing, non-destructive inspection, high-heat-flux tests and microscopic examination of damage.

Textured pure tungsten was used as reference armor material. Each concept was characterized by 1) tungsten wire-reinforced copper composite heat sink, 2) thin and thick graded interlayer, 3) thermal barrier interlayer, 4) flat-tile armor with W-Cu composite heat sink block, and 5) conventional ITER like monoblock, respectively. Extensive high-heat-flux tests were performed under DEMO-relevant operational condition (heat flux: 20MW/m², coolant: 130℃, 4MPa) up to 500 load cycles after screening test up to 25MW/m². Furthermore, overload tests were carried out to explore the maximum loading limit (heat flux: >25MW/m², coolant: 20℃, 4MPa).

The final results of R&D program are presented focusing on the overall technology achievement in this preconceptual phase highlighting materials technology, mock-up fabrication and high-heat-flux qualification accompanied by non-destructive inspection and microscopic damage examination. The comparison of results of each design concepts candidate is presented. Correlation of non-destructive test and eventual thermal performance degradation is reported with evidences coming from metallographic investigations.

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