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Structural analysis of the DEMO Shielding Liner supports: validation of new design criteria

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The components of a tokamak nuclear fusion reactor operate under extreme conditions, facing intense electromagnetic loads, high temperatures, and neutron irradiation.
In this context, the DEMO Divertor is the in-vessel component subject to the most demanding requirements. Specifically, the Divertor comprises multiple substructures directly exposed to the plasma inside the reactor' s vacuum vessel. Among these, the Shielding Liner is the largest. It is a box-like structure designed to absorb heat from the plasma and transfer it to the cooling system via water circulation.
The Shielding Liner is attached to the Cassette Body, which serves as the structural frame housing all the Divertor's subsystems. The connection system between the Shielding Liner and the Cassette Body plays a critical role in ensuring the Divertor's overall structural integrity. These supports must fit within the limited space between the Shielding Liner and the Cassette Body, accommodate their differing thermal expansions, and transfer the substantial electromagnetic loads acting on the Shielding Liner to the Cassette Body.
Several pin joint configurations have been evaluated for the Shielding Liner supports, incorporating different material solutions. However, due to the combination of high temperatures and extreme mechanical loads, none of these configurations could ensure the structural integrity of the supports, as they failed to meet verification requirements.
To address this issue, an enhanced support system is under investigation. This new design consists of four actively cooled pipes made of Eurofer97, which are welded to both the Shielding Liner and the Cassette Body. By integrating the supports into the cooling system, their temperature remains controlled, preventing excessive thermal degradation of material strength.
Additionally, the introduction of actively cooled supports enhances system compliance between the Shielding Liner and the Cassette Body, reducing secondary stresses caused by thermal expansion.
The structural integrity of the actively cooled support system is assessed according to the RCC-MRx international standard for nuclear applications. This standard is currently being expanded to establish assessment strategies for experimental fusion reactors and incorporate material properties relevant to this field, including those of Eurofer97.
Despite the significant improvements introduced by the actively cooled support system, the elastic criteria outlined in the code are not fully met. Consequently, the design must proceed to the next verification stage, which involves applying elastoplastic assessment rules.
The application of elastoplastic assessment methods to nuclear fusion components remains largely unexplored in this field. Therefore, this study represents a significant advancement in validating and demonstrating the applicability of these assessment rules. Additionally, it provides valuable insights into the currently available material properties of Eurofer97 under irradiated conditions, which are essential for accurate structural evaluation.
This work presents the design evolution and structural analysis of the Shielding Liner support system, outlining its current development status within the broader framework of advanced nuclear fusion reactor applications.

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