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Multiphysics Modeling of the FW/Blanket of the U.S. Fusion Nuclear Science Facility (FNSF)

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The dual coolant lead-lithium (DCLL) blanket concept, which is utilized in the Fusion Nuclear Science Facility (FNSF) conceptual design, is based on a helium-cooled first wall and blanket structure with RAFS (Reduced Activation Ferritic Steel) and a self-cooled LiPb breeding zone. The objective of this work is to develop a multiphysics modeling process in order to optimize the design and achieve long lifetime, maintainability, and high reliability. 3D finite element multiphysics modeling of the DCLL first wall and blanket (midplane of one sector) has been performed using COMSOL 5.2. The multiphysics aspect of the design is demonstrated via coupling of Computational Fluid Dynamics (CFD), conjugate heat transfer and solid mechanics. Both normal and off-normal loading conditions have been analyzed. The results of velocity, pressure, and temperature distributions of helium flow, as well as the primary and thermal stress of the structure were obtained. This was followed by determination of the factors of safety along three critical paths based on the ITER Structural Design Criteria for In-vessel Components (ISDC-IC). We show here that the structural design meets the ITER-ISDC design rules under both normal and off-normal operating conditions, though the safety factors under off-normal condition with 8 MPa helium pressure are marginal. Thus simple design optimization was conducted based on a parametric study on first wall dimensions to improve the design.

Eligible for student paper award?

Yes

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