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Experimental and CFD analyses of a thermal radiation shield dimple plate for cryogenic pump application

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Large customized cryogenic pumps are used in fusion reactors to evacuate the plasma exhaust from the torus. They usually consist in an active pumping surface area cooled below 5 K and shielded from direct outer thermal radiation by plates cooled at about 80K. Cryopumps are exposed to excessively high heat fluxes during pumping operation and follow regeneration cycles with rapid warm-up and cool-down phases. Therefore, high cryogenic mass flows are required to operate the cryopumps and thus pressure drop and heat transfer characteristics become key issues in the design of the pump cryogenic circuits.
For optimal flow distribution and enhanced heat transfer, actively cooled dimple plates are a preferred design option for the thermal radiation shield. A test dimple plate of 2310 mm x 520 mm with a typical rhomb pattern of circular welding spots has been manufactured and tested against pressure drops with a dedicated test facility using a water loop. In the present work, computational fluid dynamics (CFD) simulations of the test dimple plate have been performed and pressure drops have been compared to experimental results. Despite the complexity of the geometry and the size of the model, a good agreement with the experimental results was found. Then, the tried and tested CFD approach has applied for further calculations with relevant operation conditions, using gaseous helium at cryogenic temperature as working fluid. The resulting pressure drop and heat transfer characteristics are finally presented.

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