CRYOGENIC VISCOUS COMPRESSOR DEVELOPMENT AND MODELING FOR THE ITER VACUUM SYSTEM

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A specialized cryopump known as a cryogenic viscous compressor (CVC) is being developed for the ITER vacuum system to pump hydrogenic exhaust gases from the fusion reaction chamber and compress them to a high pressure by regeneration for pumping to the tritium exhaust processing facility. Several of these pumps will operate in parallel and are staged to maintain continuous pumping and regeneration during plasma operation. The pumps are cooled to operating temperatures by flowing supercritical helium at 4.5K outside the tubular pumping region. Helium impurity gas in the pumping stream that is a byproduct of the fusion reactions passes through the CVC and is pumped by conventional vacuum pumps. A conceptual design of the CVC has been developed and is undergoing concept testing before the detailed design is completed. To verify the concept of the full-scale CVC, a representative prototype has been designed, fabricated, and is undergoing testing. While cooling is provided by either cold helium gas or supercritical helium, hydrogen with trace amounts of helium gas is introduced into the central column of the cryopump at 100 Pa and 80 K at flow rates of 8 mg/s. Heat transfer between the laminar flowing gas and the cold pump tube is being enhanced with the use of internal petal fins. Temperature and pressure measurements are made along the pump gas stream in order to benchmark with design values and measure the heat transfer characteristics. Comparison with published tubular heat transfer phenomenological models and a fluid dynamics code is under way.

Modeling of the gas flowing into the pump and through the precooler heat exchanger and freezing zones is accomplished with the CFX computational fluid dynamics code [1]. The flows into the pump are at low pressure (~100 Pa) and are in a laminar, low Reynolds number regime, (Re < 300) that is handled well with the CFX code. As the gas begins to desublimate in the cold zone of the pump, it reaches a rarified gas regime where the CFX model for flow and heat transfer breaks down. An ad hoc method of changing the hydrogen properties is presently used to model this part of the pump operation. A more refined method is desired for higher accuracy to better optimize the design. The modeling results are being compared with the prototype testing and will be used to further optimize and ensure reliable operation of the full CVC in the ITER application.

[1] ANSYS CFX, ANSYS, Inc., Canonsburg, PA 15317, USA

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