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Characteristics of a cryogenic supercritical hydrogen pump with dynamic gas bearings at J-PARC

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At the J-PARC spallation neutron source, supercritical hydrogen with a pressure of 1.5 MPa and a temperature below 20 K is used as a moderator material. The total nuclear heating at the moderators is estimated to be 3.8 kW for 1-MW proton beam operation. The temperature rise at the moderators should be reduced below 3.0 K to provide a pulsed cold neutron beam. A centrifugal pump with dynamic gas bearings was developed to circulate the supercritical hydrogen with the flow rate of more than 0.16 kg/s. The characteristics such as the pump head and the adiabatic efficiency were measured at the hydrogen temperature of 95 K, 45 K and 20 K for various flow rates as parameters. The pump performances that are estimated using dimensionless parameters of pressure and flow coefficient exist on an identical curve, which almost agree with the design values. The adiabatic efficiency has an outstanding peak at the flow coefficient of 0.046. However, it decreases down to 0.2 for flow coefficients higher and lower than 0.046 where the pump casing flange is cooled from 20 oC to a few oC by the supercritical hydrogen. As the first step, the numerical analysis of fluid flow in the hydrogen pump were carried out at the temperature of 95 K using a CFD code, STAR-CCM+. The simulation results agree well with the experimental data. It was clarified that the excess cooling phenomenon was caused by a circulation flow along the sides of the pump casing.

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