NUMERICAL ANALYSIS FOR OPTIMIZATION OF CIRCULATION POWER IN FIRST WALL OF INDIAN HELIUM COOLED SOLID BREEDER BLANKET USING HE-CO_2 GAS MIXTURE

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Abstract

Helium (He) gas has been chosen as primary coolant of breeding blanket systems of ITER and Demonstration Plant (DEMO) due to its good transport and thermal properties. It is chemically inert in irradiated conditions due to low neutron cross section and has good compatibility with structural materials. On the other hand, Helium has a disadvantage of low density due to which high circulation power is required.

Mixing of Helium with a relatively dense gas like Carbon dioxide (CO_2), Xenon (Xe), Nitrogen (N_2) may mitigate the low density deficiency. Recent studies have indicated that using various gas mixtures (He-CO_2, He-Xe, He-N_2) in high temperature reactors reduces the circulation power compared to Helium. Further, it is found that He-CO_2 gas mixture at an optimum mole fraction offers the best solution in terms of reducing the circulation power and offering adequate cooling performance. The paper presents thermal-hydraulic performance of First Wall (FW) Channels of Indian Helium Cooled Solid Breeder (HCSB) using He-CO_2 gas mixture as coolant for evaluating the minimum circulation power requirement.

A numerical investigation was performed for single channel of FW using ANSYS CFX tool. Standard empirical formulas were used to evaluate the thermo-physical properties of Helium, CO_2 and He-CO_2 gas mixture. Several mole fractions of He-CO_2 gas mixture were studied and benchmarked against Helium. The minimum circulation power of 7.45 W is estimated at 0.6 mole fraction of additive CO_2 gas in the He-CO_2 gas mixture compared to 332 W of Helium. This massive reduction in circulation power can be attributed to high density of CO_2 gas. Heat Transfer Coefficients values of He-CO_2 mixture were found comparable to Helium (4055 W/m^2-K) in the mole fraction range of 0.4-0.5.

Further to investigate the effect of heat transfer in interconnecting channels, a case of 5 channels of FW was studied using ANSYS Thermal (Steady-State) tool. The objective is to check the permissible FW material temperature (550 °C) limit for He-CO_2 gas mixture. It was found out that FW maximum wall temperature exceeds 550 °C greater than 0.5 mole fraction of additive CO_2 gas.

Thus keeping in view of minimum circulation power and adequate cooling performance of FW, it may be concluded that an optimum mole fraction range of 0.4-0.5 of additive CO_2 gas in He-CO_2 mixture may be considered as primary coolant in FW for heat extraction as a replacement of Helium.

Keywords: Helium, He-CO_2, Gas Mixtures, First Wall, Circulation Power