Seminar

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Institute for Plasma Research

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Title: Experimental and simulation studies of effective thermal conductivity of compressed and uncompressed pebble beds for fusion blankets

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Time: 02:00 PM

Venue: Seminar Hall, IPR

Abstract

Pebble beds have various applications in many industrial and research sectors. Lithium ceramic pebble beds have specific application in fusion reactors as one of the promising candidates for tritium breeding material. During the operation of the fusion reactor, these pebble beds will have to sustain various thermal and mechanical stresses. Therefore, it is necessary to do thermal characterization of these pebble beds under different stress conditions and generate sufficient data on their thermal properties, which is essential for designing breeder units of fusion reactors.

The present work aims to measure the effective thermal conductivity of the lithium ceramic pebble beds as a function of temperature, filling gas pressure and compressive stress. This has been accomplished in two stages. The first setup has been designed based on transient hot-wire method to measure the effective thermal conductivity at high temperature at different helium gas pressure. 0.25 mm diameter tungsten wire was used as hot wire in this setup. The measurements were conducted in helium gas environment up to 3 bar gauge pressure and at temperatures up to 800°C. The final apparatus has been designed based on the transient hot-wire method to evaluate the effective thermal conductivity of pebble beds at high temperature, in helium gas environment, under compressive stress. It can be mounted to any standard universal testing machine with the necessary adjustments. A platinum wire with a diameter of 0.5 mm was used as a hot-wire. Instead of utilizing a thermocouple, the 4-wire approach was used to obtain the temperature. The transient temperature response of the hot-wire was obtained by applying a constant current to it and monitoring the voltage drop along its known length. The thermal conductivity of the water gel was measured to assess the accuracy of the apparatus; the results showed a less than 1.5% variation from the reference value. In this study, the thermal conductivity of Li_2TiO_3 pebbles was measured in an air and helium environment in different stress conditions. In an air environment, measurements were done at atmospheric pressure, whereas in a helium gas environment, they were performed at gauge pressures of

0.05 bar, 0.5 bar, and 1 bar. The measurements were conducted in two scenarios: (i) constant stress condition at 0, 3, and 6 MPa, and (ii) Cyclic loading-unloading of 0.037 – 3 MPa and 0.037 – 6 MPa. It was found that the pebble bed's thermal conductivity rose in tandem with increased compressive stress in both the helium and air environments.

Simulations have been conducted to predict the effective thermal conductivity of different types of pebble beds in different packing conditions. Discrete Element Method (DEM) was used to generate pebble beds for the study. The pebbles are generated in the funnel situated at the top of the container. They are subjected to free fall under the influence of gravity, resulting in a randomly packed pebble bed. These simulations were carried out in different vibration scenarios to investigate its effect on the packing of the bed. The effective thermal conductivities of mono-sized, binary-sized and poly-dispersed Lithium metatitanate pebble beds in different vibration cases have been estimated using Finite Element Method (FEM).

This work provides a design to incorporate 4-wire temperature measurement in the hot-wire method for effective thermal conductivity measurement of compressed pebble beds. It also contributes to the thermal conductivity data of Li_2TiO_3 pebbles in cyclic stress conditions in helium and air environments at high temperatures. The simulations of different types of pebble beds in different packing conditions provides a larger data set for accurately predicting the behavior of such beds in operational conditions.