Seminar

==

Institute for Plasma Research

==

Title: Design and development of experimental setups for measuring anisotropic effective thermal conductivity and coefficient of thermal expansion of ceramic pebble beds for fusion blankets

Speaker: Dr. Harsh Patel
Institute for Plasma Research, Gandhinagar

Date: 30th April 2026 (Thursday)

Time: 10:30 AM

Venue: Seminar Hall, IPR

Join the talk online: URL: https://bharatvc.nic.in/viewer/5992138016
(Conference ID: 5992138016; Password: 232142)

Abstract

Understanding the thermo-mechanical behaviour of lithium-based ceramic pebble beds is essential for the reliable design of solid breeder blanket systems in fusion reactors. Among the governing parameters, the effective thermal conductivity plays a critical role in determining heat transfer characteristics. During reactor operation, cyclic thermal loading induces mechanical compaction in the pebble bed, resulting in direction-dependent (anisotropic) thermal conductivity. Neglecting this anisotropy can lead to inaccurate prediction of temperature distributions, potentially causing localized overheating and reduced performance of the breeding and heat extraction systems.

In this study, an experimental setup based on the transient hot-wire technique was developed to quantify anisotropy in the effective thermal conductivity of ceramic pebble beds. The setup incorporates two hot wires oriented along the axial and radial directions of a cylindrical bed, enabling directional measurements. Experiments were conducted on lithium metatitanate (Li_2TiO_3) pebble beds under compressive stresses up to 6 MPa at room temperature in an air environment. Two initial packing conditions (i) loosely packed and (ii) vibration-packed beds were investigated to assess the influence of packing on anisotropy. The measurement methodology was validated using a standard reference material. Results indicate that the effective thermal conductivity is inherently direction-dependent, with the degree of anisotropy influenced by both initial packing fraction and applied compressive stress. At higher stresses, the anisotropy tends to converge to 6-7% for different initial packing conditions.

In addition to thermal conductivity, the coefficient of thermal expansion (CTE) of Li_2TiO_3 pebble beds was experimentally determined over a temperature range of 50°C to 600°C using a custom-designed setup. The system employs a cylindrical container with constrained pebble beds, where axial expansion is measured using a high-precision Linear Variable Differential Transformer (LVDT) coupled via quartz rods to isolate the sensor from high temperatures. To ensure high accuracy, comprehensive corrections were applied to account for the thermal expansion of the experimental setup, quartz components, and radial expansion of the container. The results show that the CTE of the Li_2TiO_3 pebble bed is lower than that of solid material (Li_2TiO_3 pellet) due to particle rearrangement during thermal expansion. The average secant CTE of the Li_2TiO_3 pebble bed was found to be 17.38×10^{-06} °C-1, approximately 11.8% lower than reported values for solid pellets. The experimental methodology demonstrated high accuracy and repeatability, with calibration against a standard aluminium sample showing deviations within ~3%.
