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On the Improved Current Pulse method for the thermal diffusive characterization of lithiated ceramic pebble beds

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ABSTRACT

Packed pebble beds are granular systems composed of small particles generally arranged in irregular lattices and surrounded by a gas filling their interstitial spaces. They show non-linear and coupled thermal and mechanical behaviours, which are under theoretical and experimental investigation to set-up a realistic constitutive model to be adopted for design-oriented purposes.

At the Department of Nuclear Engineering (DIN) of the University of Palermo a realistic constitutive model of fusion-relevant pebble beds thermo-mechanical behaviour was developed adopting a "continuous" approach, based on the assumption that a pebble bed could be considered as a continuous, homogeneous and isotropic medium, characterized by effective thermal and mechanical properties strictly depending on its temperature, pressure and/or mechanical volumetric strain.

Within this framework, an experimental campaign was launched at DIN to assess the functional dependences of lithium orthosilicate polydisperse pebble bed effective thermal diffusive properties on both temperature and pressure, by means of the purposely-outlined Improved Current Pulse method.

The ATTAR-1 test section was set-up and a test campaign was carried out on a 24 mm high reference polydisperse lithium orthosilicate pebble bed, at temperatures ranging from 20 °C up to 300 °C and pressures up to 30 bar. The functional dependences of the pebble bed thermal diffusive properties on both temperature and pressure were derived and they agree quite well with those shown in literature.

1. Introduction

Packed pebble beds are particular granular systems composed of small particles generally arranged in irregular lattices and surrounded by a gas filling their interstitial spaces. They offer several advantages, including simple assembly into complex geometries, uniform porosity and low temperature sensitivity to cracking or irradiation damage, which contributed to encourage their application both in chemical and nuclear technology [1]. In particular, lithiated ceramics and beryllium packed pebble beds were recently taken into account, respectively as tritium breeder and neutron multiplier of the Helium-Cooled Pebble Bed breeding blanket concept of the DEMO fusion power reactor.

Since experimental tests highlighted that these pebble beds, due to their heterogeneous structure, show complex, non-linear and coupled thermal and mechanical behaviours, the European Fusion Development Agreement promoted intense theoretical and experimental research activities intended to develop a realistic and self-consistent constitutive model to be adopted for design-oriented purposes.

Within the framework of these research activities, at the Department of Nuclear Engineering of the University of Palermo (DIN) a self-consistent theoretical constitutive model was developed for the prediction of pebble bed thermo-mechanical performances under fusion-relevant conditions, assuming that a pebble bed could be considered as a continuous, homogeneous and isotropic medium characterized by effective thermal and mechanical properties which strictly depend on temperature, pressure and/or mechanical volumetric strain. The functional dependences of these properties had to be assessed by means of specific semi-theoretical procedures based on the results of purposely-performed experimental tests.

Therefore, in 2002, an experimental research campaign was launched at the DIN to assess the effective thermal diffusive properties of fusion-relevant lithiated ceramic pebble beds, focussing the attention on their functional dependence on both bed thermal and stress states.

The Current Pulse (CP) method, proposed by A. Sellerio in 1934 [2] as an alternative dynamic method for the assessment of thermal diffusive properties of a poor conductive body, was adopted for the

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