BREEDER MATERIALS FOR THE HCPB TEST BLANKET MODULE: MECHANICAL CHARACTERIZATION OF CERAMIC PEBBLES

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Abstract

A technical challenge for the successful development of the nuclear fusion plants is the development and qualification of breeder materials. Several breeder materials have been developed in the European Countries and in Japan for the DEMO reactor. These breeders will be tested in ITER in special Test Blanket Modules (TBM), located in the equatorial ports. Lithium Orthosilicate (Li_4SiO_4) and Lithium metatinate (Li_2TiO_3), in form of pebbles, are promising breeder material candidates in the so called 'solid breeding blanket module'. A solution of this type is the Helium-Cooled Pebble Bed (HCPB) blanket. This paper deals with the mechanical characterization of Lithium Orthosilicate and Lithium Metatinate pebbles by means of cyclic compression tests and crush tests at different temperatures. The Li_4SiO_4 pebbles have a diameter ranging between 0.6-0.3 mm and have been produced by FZK-Schott while the Li_2TiO_3 pebbles, produced by CEA, have a diameter ranging between 1.-1.2 mm. The main aim of the pebble mechanical characterization is to define a constitutive equation of the pebble ensemble or the pebble bed. Two aspects have to be considered in order to find a model which describes the mechanical behaviour of the pebble bed: - the microscopic phenomena, that is, the stress-strain law of a single pebble compressed by the surrounding pebbles or by the container walls in the contact points; - the global behaviour of the pebble bed. The global behaviour of pebble bed has been analyzed by the author by means of several standard tests (used for the mechanical characterization of soil material) on samples of pebble beds. Mono-axial compression test (oedometer test), triaxial and shear compression tests have been performed on Li_4SiO_4 and Li_2TiO_3 pebble beds.

The cyclic compression tests and the crush tests have been performed at several temperatures in the range 20-200°C. The pebbles were analyzed by SEM before the tests in order to verify the actual shapes and dimensions and after the tests in order to determine the fracture mode.

Two types of elaboration of the experimental results were performed. Initially the test results were used for determining the parameters of theoretical models of soil (Clam-Clay and Drucker-Prager with cap models) implemented in FEM codes. Subsequently three-dimensional numerical models of the single pebble and of a pebble bed (described by means of the Clam-Clay model) were implemented in a commercial FEM code. The numerical results were compared with the experimental ones. The comparison showed a good agreement in the case of a single pebble. Some improvements are requested in the case of a continuum model of pebble bed. The ongoing activity foresees the implementation of a regular lattice of pebbles (simulating a section of pebble bed) in order to simulate in detail the behaviour of an ensemble of pebbles.