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COMPUTATIONAL STUDY OF THE OPERABILITY OF THE FLEXIBLE CARTRIDGE ASSEMBLY OF THE ITER BLANKET DURING DIFFERENT MODE OPERATION [*)]

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The ITER reactor blanket consists of 440 blanket modules (BMs), each of which is attached to the vacuum vessel (VV) by means of four Flexible Cartridge (FC) Assemblies, the main element of which is a FC – a hollow perforated cylinder with two flanges. The lower flange is connected to VV housing and the upper one is connected to a shield block (SB). To ensure the electrical isolation of FC Assemblies from the VV, an electrical insulating coating (EIC) based on aluminum oxide is used.

The normal mode of reactor operation is a periodic sequence of pulse modes with a neutron flux to in-vessel components for 450 s and pause modes with zero energy release for 1800 s (Inductive I mode). According to calculations, in this mode, the maximum temperature in the FC Assembly reaches 189 °C in the central bolt, while in the FC the maximum temperature is 156 °C.

During plasma disruptions, alternating electromagnetic forces of 500-600 kN acting on the FC in the axial direction are induced in BMs for two scenarios of plasma disruption: the Fast VDE II type and the Slow VDE III type. The calculation of the stress-strain state (SSS) of the FC in consideration for the combination of loads in the Inductive I and Fast VDE II modes showed that the FC design meets the SDC-IC static and cyclic strength standards.

As required by the IO ITER, the preliminary bolt tightening force can vary in the range of 600-1200 kN. The SSS calculation for the FC Assembly showed a decrease in the axial force in the Inductive I mode from 600 kN to 504 kN, which, under the action of a 600 kN axial force, leads to the opening of the joint at the "conical insert-FC" interface. In the cyclic mode of reactor operation, this may cause EIC damage and transition to the emergency operation of the blanket when the current induced in the BM goes through the FC Assembly.

In the Slow VDE III mode, the maximum current reaches 137 kA. Within 300 ms the corresponding ohmic heating, which exceeds the neutronic-induced heating by 4 orders of magnitude, leads to a strong local increase in the FC temperature up to 966°C and an average heating of the spokes up to 600°C. The FC cooling to operating temperatures via heat conduction mechanism occurs over 2250 s. Due to high temperature difference between the VV seat cooled by 100°C water and the FC, radiant heat exchange between them reduces the cooling time to 1500 s; however, this value remains significant.

Current flow through the FC spokes induces its own magnetic field and, consequently, electromagnetic forces acting in the transverse direction, with their magnitude not exceeding 250 N, and thus the effect on the total SSS being negligible. In turn, the magnitude of the transverse forces induced by the toroidal component of the reactor magnetic field of up to 9 T reaches 12.6 kN on one spoke, which is comparable to the force that causes buckling of the FC in the transverse direction.

Long-term effect of high temperatures leads to significant thermal stresses, degradation of thermophysical and mechanical properties, which, together with the induced electromagnetic forces acting on the FC spoke, may result in FC stability loss. Thus, it is necessary to ensure a preliminary tightening force for the FC Assembly bolt, which guarantees non-opening of the joint at the "conical insert-FC" interface.

[*)] abstracts of this report in Russian