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ASCOT simulations of fast ion wall loads on the ITER first wall in the presence and absence of port limiters

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Introduction The ASCOT code [1] is used to simulate fast ion wall loads in ITER in the presence of TF ripple and localized perturbations. ASCOT is a neoclassical guiding center following code that has been developed as a joint effort between Helsinki University of Technology and VTT, the Technical Research Center of finland. In previous modeling efforts [2, 3] compensation of TF ripple by ferritic inserts was found very effective. This paper concentrates on the roles of the port limiters and Test Blanket Modules (TBMs) on the heat load to the Plasma Facing Components (PFCs). The TBMs create toroidally and poloidally localized perturbations to the magnetic field, removing the remaining toroidal periodicity. The TBMs have been modeled in detail [4] and we use this model in our ASCOT simulations.

Background Data The vacuum magnetic background used in these simulations is a discrete map, 360 degrees in the toroidal direction. This magnetic field includes the effect of Ferritic inserts and three TBMs, located 40 degrees apart in equatorial ports at 20°, 300° and 340° in toroidal angle. The maximum ripple strength in this field along the separatrix is 1.52%, which surpasses the maximum uncompensated TF ripple without TBM of 1.1% as is shown in figure 1.

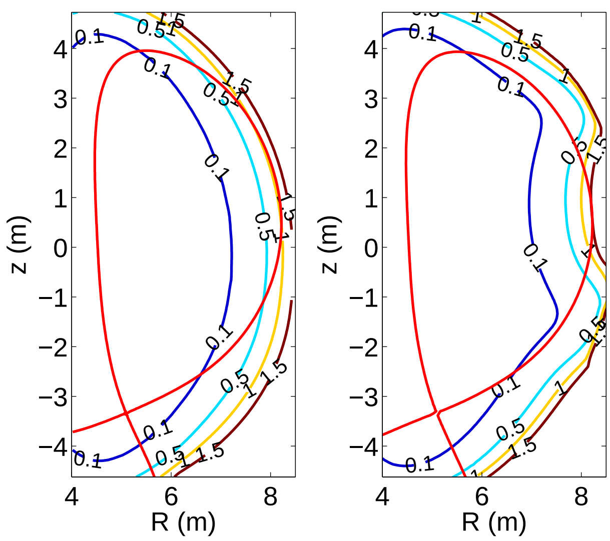

Figure 1: Contours of the TF ripple in the absence (left) and presence (right) of TBMs and FIs.

The equilibrium magnetic field was calculated from the EQDSK file SCEN4_BN2.57_129X129XBOX4. The equi-

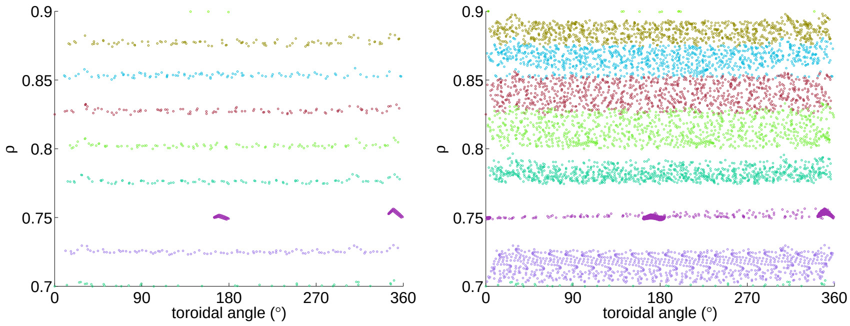

Figure 2: Poloidal Poincar plots of field line tracing over 100 poloidal orbits (left) and 1000 poloidal orbits (right).

librium field is generated by a plasma current of 9 MA in the clockwise direction when viewed from the top of the machine. The quality of the field is not ideal for our simulations. While field lines were successfully followed for 100 poloidal orbits, they were found to drift significantly when followed for 1000 orbits in figure 2. However, it should be noted that due to Coulomb collisions and drifts, particles are not likely to stay on a flux surface longer than a few orbits.

The ITER 3D wall model in ASCOT simulations consists of 40° sectors, and different types of sectors may be added together to assemble the whole wall. The current model has sectors with port limiters added at 0° and 180° in toroidal angle. The advantage of the 3D wall model is that it consists of flat tiles instead of an axially symmetric wall. In addition, with the 3D wall we are able to perform Larmor orbit checking around the guiding center to pinpoint wall collisions to where the Larmor orbit intersects the wall. A 2D wall model may also be used, in which case the same poloidal contour is rotated to all toroidal angles.

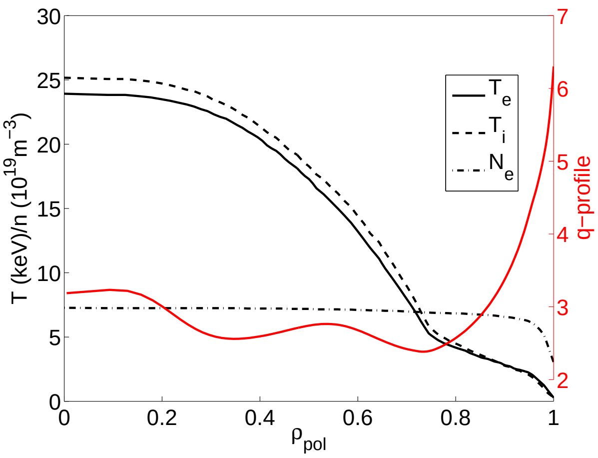

Figure 3: Temperature, density and q-profiles in ITER reference operating scenario 4

The plasma temperature, density and safety factor profiles were obtained from ASTRA data and are presented in figure. 3

Simulation Results Two main results are presented in this paper. We will first present the results of the simulation of the wall loads from fusion alpha particles in ITER Scenario 4 with FI and TBM. Then we will show the comparison between 2D and 3D wall models in the simulation.

The total power load to the walls in the simulation is abut 90 kW. Peak power flux of about 90

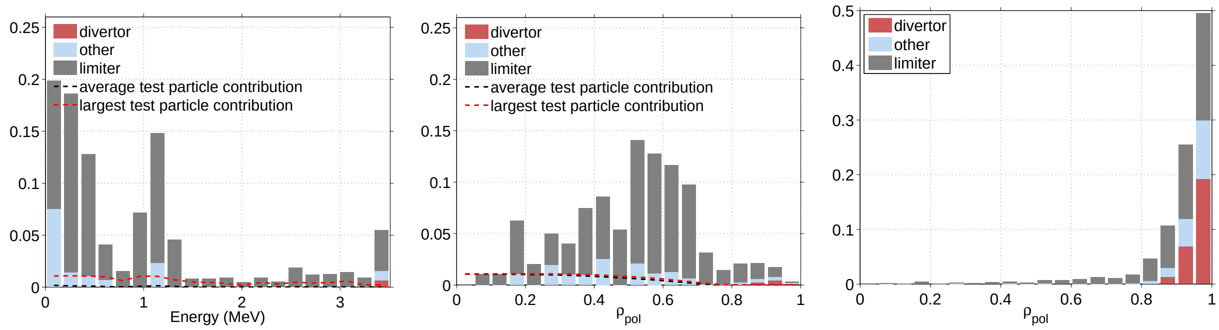

Figure 4: Distribution of energy (left) and birth location (middle) of particles intersecting the PFCs. The loss fraction of particles from all rho-surfaces (right)

kW/m^2 is found on the limiter and the highest off-limiter power flux is about 30 kW/m^2. Figure 4 shows probability distributions of the birth location and final energy of the particles intersecting the wall. The dashed lines show the maximum and average weight of a single test particle found in each interval. They show that towards the center of the plasma, the contribution of single test particles becomes very large, which weakens the statistical reliability of the result. The test particles are distributed uniformly and weighted according to the density and temperature profiles, shown in figure 3. Hence, of the total power flowing to the wall, 40 % comes from inside ρ = 0.6, yet it is carried by only 1 % of the test particles.

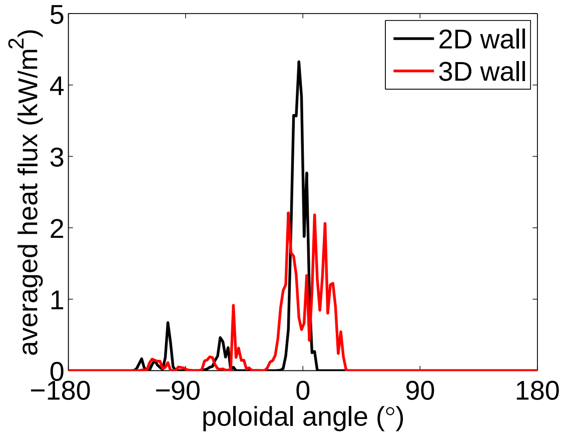

Figure 5: Toroidally averaged wall load as a function of poloidal angle

The alpha particle loss fraction is, as is to be expected, insensitive to the wall model that is being used. We obtain 0.14% loss fraction of the source alpha particle power (310 MW in our simulation). The distribution of the power load, however, depends greatly on the wall model. In figure 6 the alpha particle power densities from simulations with 2D and 3D walls are mapped onto a surface determined by the toroidal and poloidal angles. We observe hot spots at the locations of the TBMs in the 2D wall case only. With the 3D wall, the two port limiters absorb the majority of the power and hot spots are not formed. The toroidally averaged power density, displayed in figure 5, shows that the power load is centered around the horizontal midplane in both cases.

A single beam of NBI ions from an off-axis injector was also simulated in the scenario 4

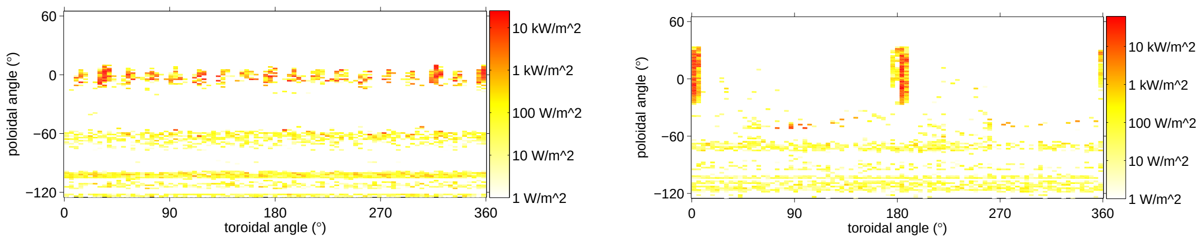

Figure 6: Alpha particle power density with 2D wall model (left) 3D wall model (right) mapped as a function of toroidal and poloidal angle.

background. The wall load from co-injected NBI is only .02 % of the source power of 16.7 MW.

Discussion and Conclusions The TBMs in ITER create a local perturbation that increases the ripple strength of the toroidal field above the periodic uncompensated ripple. However, according to our simulations the power load to the PFCs is not increased at the same rate. The perturbations created by the TBMs diminish much faster inside the separatrix than the periodic ripple as was illustrated in figure 1.

According to our calculations, the fast ion power load to the PFC's is 0.14% of the source power. This power load is almost entirely absorbed by the port limiters, when they are included in the simulation. In the absence of limiters, on an axisymmetric wall, the power load is deposited onto the horizontal midplane and hot spots are found at the minima of the ripple period. These hot spots are amplified by a factor of 4 in power at the TBMs. Nevertheless, the simulations imply that the power deposited on the wall by alpha particles is well below the material safety limits

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