§5. 3D Edge Transport Analysis of ITER Start-Up Configuration for Limiter Power Load Assessment

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Two beryllium limiter modules, toroidally localized at the low field side (LFS), are foreseen to be used to sustain the plasma start-up phase in the current ITER design, as shown in Fig. 1. The 3D edge transport code, EMC3-EIRENE, has been implemented on the ITER start-up limiter configuration, in order to analyze 3D transport properties in geometry of the toroidally discrete limiter and to investigate the power load on the limiter surface. The main results of the analysis are summarized as follows:

1. Because of the finite shear in the edge, the interaction of the toroidally discrete limiters with flux surfaces of different q-values introduces a complex 3D pattern in the connection length profiles, where long and short flux tubes co-exist in the scrape-off layer (SOL), as shown in Fig. 2.

2. The severity of problems associated with very long flux tubes in the edge, which can bring a large amount of energy (proportional to $\sqrt{L_C}$, where L_C is the connection length), and cause a hot spot on the limiter, was mitigated and no significant localized power load was found.This is justified as follows: (i) For long flux tubes, at the region of s > 500 m, (where s is a distance along flux tube measured from the limiter) the perpendicular energy transport time becomes shorter than the parallel energy transport time, resulting in no net energy input to the flux tube. (ii)Additionally, perpendicular transport was found to be very effective to smear out the difference in// energy flux conducted by the various flux tubes, if they interact within a perpendicular transport scale, ~ a few cm, which is usually the case in high plasma current ITER start-up configuration. These two effects significantly make weak dependence of energy deposition on $\sqrt{L_C}$.

3. The results presented are affected by the existing uncertainties of the transport coefficients, $D_\perp$ and $\chi_\perp$. A parametric scan was carried out within a range estimated from the JET limiter discharge. At a smaller plasma current (e.g. I_p = 2.5 MA) , because of the larger $D_\perp$ and $\chi_\perp$, the power decay length becomes longer and the power is deposited at the limiter edge, increasing the peak power load. Due to the low SOL input power in the smaller I_p, however, the peak power load is still far below the engineering limit. At higher plasma currents (e.g., I_p = 6.5 MA), the peak power load is found to be close to the engineering limit, 8MW/m^2, especially for the lowest values $D_\perp$ & $\chi_\perp$ and highest SOL input power.

4. The radial decay of the power flux to the limiter obtained by the 3D modelling was found to be not a simple exponential decay. There exists also decay in the poloidal direction, which is not taken into account in a simple model.

The results of this assessment with those obtained by modelling with a simple model, it is found that by neglecting the 3D geometrical effects, the simple model overestimates peak power load by ~30% for the same input power and λ_p (Fig. 3).

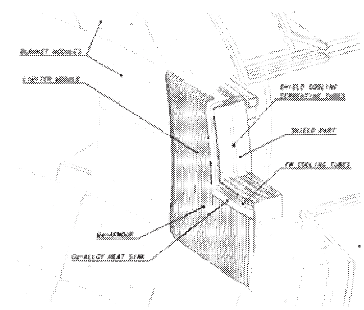

Fig. 1 ITER start-up limiter module.

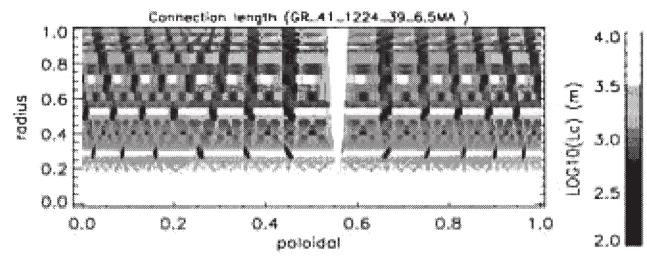

Fig. 2 Connection length profile (logarithmic scale) at Ip=6.5 MA.

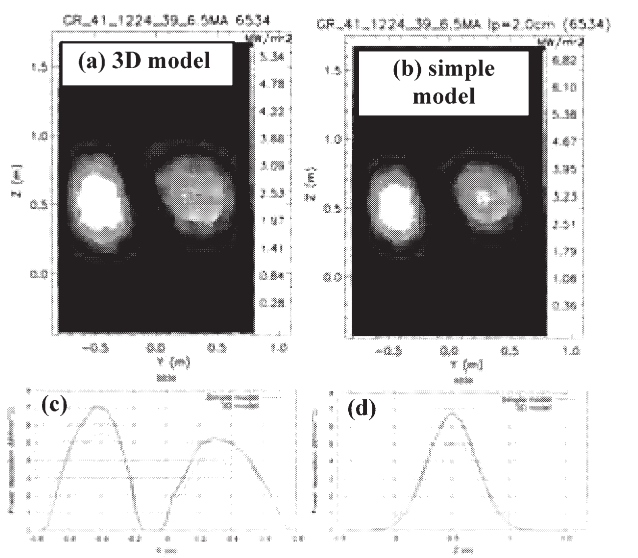

Fig. 3 Comparison of power deposition pattern (a & b) between 3D and simple exponential decay model. (c) & (d) horizontal & vertical cut.