ANALYSIS OF SOL BEHAVIOUR IN MAST USING AN ADVANCED ONION-SKIN SOLVER (OSM2)

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Introduction

In order to understand cross-field transport in the MAST spherical tokamak, modelling of the SOL plasma has been performed using the advanced onion skin method code OSM2 [1] which is implemented within DIVIMP [2], together with transport of neutral particles by EIRENE[3]. The method used in OSM2 relies on solving the plasma transport equations along individual flux surfaces and adjusting the cross-field source terms to best match spatially localised measurements of plasma parameters. In MAST, these measurements are provided from arrays of Langmuir probes embedded in the targets at each of the strike points. The arrays have a spatial resolution of 3 mm on the inboard side and 10 mm on the outboard side and operate in a voltage sweep mode to yield electron temperature and density profiles.

The DIVIMP code has previously only been implemented for Single-Null Divertor (SND) plasmas and for Connected Double Null (CND) configurations. In MAST, up-down power asymmetries have been observed in CND discharges [4]. To achieve a symmetric power loading it is necessary to explore discharges that have a Disconnected Double Null geometry (DDN), that is one in which, due to slight asymmetries, there are two disconnected separatrices. In order to model such discharges this configuration must be introduced into DIVIMP.

The input to DIVIMP is via a 2-D poloidal geometry grid. In this implementation, the DDN geometry is input to OSM2 via the CARRE quasi-orthogonal mesh generator [5] using magnetic reconstructions of the MAST plasma from EFIT. A mesh for a typical MAST DDN plasma is shown in fig. 1. The asymmetric DDN geometry significantly complicates analysis of the SOL, increasing the number of regions that must be considered from 3 in the SND case (core, SOL and private flux region) to 6.

In order to start modelling the MAST SOL we have chosen a time point within a MAST discharge for which the separation between the two separatrices (δR_{sep}) is a maximum: δR_{sep} at the mid-plane for the inner side is 11 mm and at the outer side 5 mm. This can be compared with the ion-gyro radius, which is 0.5 mm at the inner side and 3.5 mm at the outer side. In addition, the 1/e length for the power fall off, calculated using the target values and mapped back to the mid-plane, is 2.6 mm for the outboard side. Hence > 70% of the power into the SOL is confined within this region between the two separatrices. Therefore we have treated this DDN configuration as an SND one as shown in fig. 2. This grid together with the j_{SAT} and T_e from the target Langmuir probes has been input to DIVIMP.

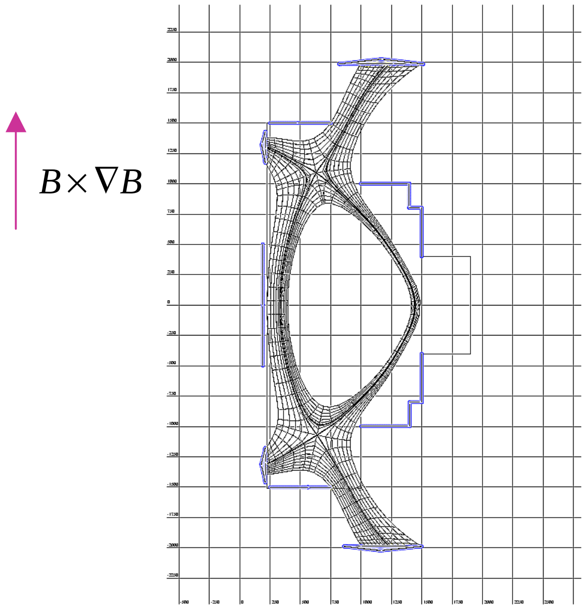

Figure 1 A typical MAST DDN grid.

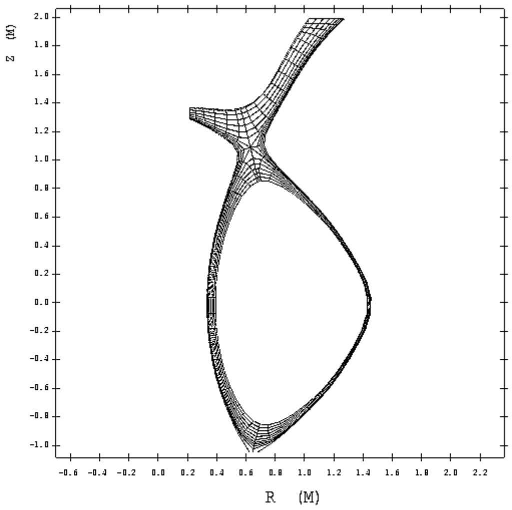

Figure 2 The grid as input to DIVIMP.

Tests of convergence

The plasma transport equations are discretised on an adaptive parallel grid and solved on each flux surface. The plasma solution is then transferred onto a coarser poloidal grid and neutral deuterium transport is simulated using EIRENE [3]. Neutral and cross-field sources are then adjusted to try to match the input target probe conditions. It requires many (>250) iterations of the OSM2/EIRENE code to reach a converged solution. Tests of convergence are that the input target T_e and n_e should agree with the computed vales within 1 %. The Mach number at the targets should be > 0.95 – this requires an adaptive grid which can change the grid geometry near the targets. The sources from EIRENE should change by less than 1 % per iteration.

Output

The output from the OSM2 code is n_e, T_e, T_i and information on the convective and conductive fluxes and volumetric sources as a function of distance along the flux tube.

Conservation of particles, momentum and electron and ion energy is achieved at all points along the flux tube.

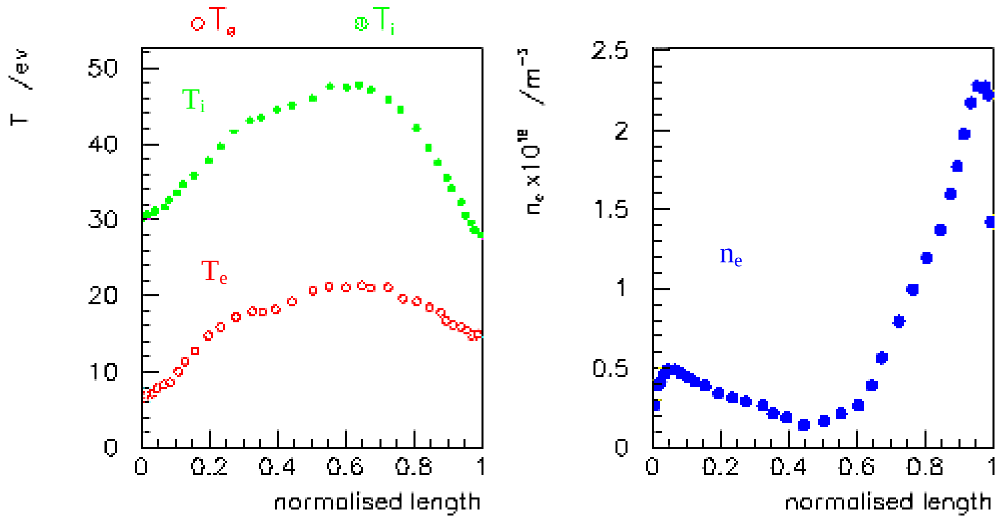

Figure 3 The electron and ion temperatures and density distributions as a function of distance along the flux tube adjacent to the separatrix; 0 corresponds to the outer target and 1 to the inner target. These results are for MAST discharge 2952 at 0.215 seconds in H-mode.

Fig. 3 shows the electron and ion temperatures and the density distribution as a function of normalised distance along the flux tube; 0 corresponds to the outer target and 1 to the inner target. Using these values the collisionality (ν^*_e) at each point along the flux tube has been calculated. Taking into account the distribution of particle sources the average value of $\nu^*_e \approx 6$. It can be seen that the ion temperature is approximately twice the electron temperature. Hence the collisionality for ions is a factor 4 less than for electrons and therefore, as is observed, the temperature difference between the two targets is less for the ions than electrons. In addition, this large ion temperature may explain why only 35 % of the power into the SOL is measured as electron power at the targets [4].

The density shows a very large gradient from inner target to outer target and hence there is a large pressure imbalance between inner and outer target. Output from OSM2 reproduces the factor of 10 difference in pressure observed at the target Langmuir probes [4] and shows that this is mainly due to magnetic flux expansion. This is a novel feature of tight aspect ratio tokamaks such as MAST, where the B field at the SOL changes by a factor of 5 between the inboard and outboard mid-plane

Another interesting feature is the particle flow, which is shown in fig. 4. The stagnation point is very near to the inner target and the flows are observed to be large near to the mid-plane. It will be possible to validate these features using a reciprocating probe, which will be available in the current campaign.

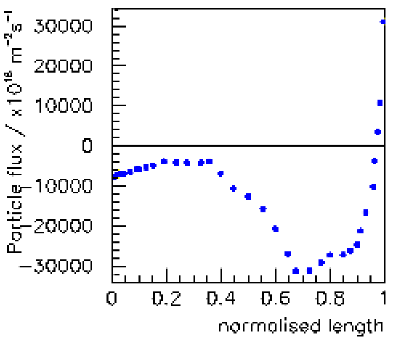

Figure 4 The particle flux as a function of distance along the flux tube.

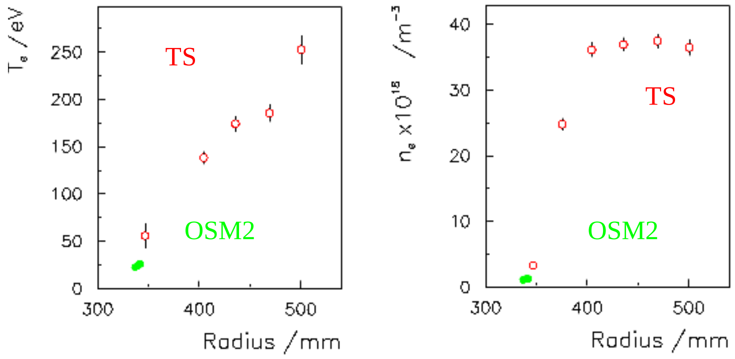

Figure 5 Comparison of the T_e and n_e distributions from the Thomson scattering system at the mid-plane for the inboard side with the output from OSM2.

Comparison with the mid-plane Thomson data

The T_e and n_e values at the mid-plane have been compared with the measured values detected using a Thomson scattering system. As can be seen from fig. 5 the values from OSM2 are found to be in agreement within the errors with the extrapolated Thomson data for the inboard side. At the outboard side there is insufficient overlap to allow a meaningful comparison to be made.

Summary and future studies

A self-consistent solution of OSM2 has been obtained for the first time in a Spherical Tokamak. The output is found to be in agreement with other diagnostics. The large B-field variation in an ST plays an important role. The next plan is to study a Connected Double Null discharge and then to move onto simulating full MAST DDN discharges.

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