EUROPEAN FUSION DEVELOPMENT AGREEMENT

JET

EFDA–JET–CP(06)03-35

V. Petrzilka, G. Corrigan, V. Parail, K. Erents, M. Goniche, Y. Baranov, P. Belo, A.Ekedahl, J. Mailloux, J. Ongena, C. Silva, J. Spence, F. Zacek and JET-EFDA Contributors

SOL Ionization by the Lower Hybrid Wave during Gas Puffing

SOL Ionization by the Lower Hybrid Wave during Gas Puffing

V. Petrzilka[1], G. Corrigan[2], V. Parail[2], K. Erents[2], M. Goniche[3], Y. Baranov[2], P. Belo[4], A. Ekedahl[3], J. Mailloux[2], J. Ongena[5], C. Silva[4], J. Spence[2], F. Zacek[1] and JET-EFDA Contributors*

[1] *Association EURATOM-IPP.CR, Za Slovankou 3, 182 21 Praha 8, Czech Republic*
[2] *Association EURATOM-UKAEA, Culham Science Centre, Abingdon, OXON OX14 3DB, UK*
[3] *Association EURATOM-CEA-Cadarache, DRFC, 13108 Saint Paul-lez-Durance, France*
[4] *Association Euratom-IST, Centro de Fusao Nuclear, Lisboa, Portugal*
[5] *Plasma Physics Laboratory, Royal Military Academy, Association EURATOM - Belgian State, Brussels, Belgium*
** See annex of J. Pamela et al, "Overview of JET Results ",*
(Proc. 20th IAEA Fusion Energy Conference, Vilamoura, Portugal (2004).

Preprint of Paper to be submitted for publication in Proceedings of the
33rd EPS Conference,
(Rome, Italy 19-23 June 2006)

1. INTRODUCTION

Gas puffing with a gas pipe situated near the JET Lower Hybrid (LH) antenna increases the Scrape-Off Layer (SOL) electron density, ne,SOL, in the region magnetically connected to the gas pipe, which improves the LH wave coupling [1],[2]. This is important namely for ITER relevant shots with a large distance between separatrix and the LH grill mouth. Numerical modelling with the fluid code EDGE-2D [3] suggested that enhanced edge radial plasma transport [4] can play a role in the ne,SOL increase, but the agreement with the measured profiles was reached by using ad hoc modifications of the transport. The modelling also did not take into account direct ionisation by the LH wave, which is thought to contribute [1], either because of the oscillatory motion in the LH wave, or due to the fast electrons created parasitically in front of the grill mouth [5], or both. In the work presented here, EDGE-2D was used to include a simple representation of the LH wave and used to explore its effect on $n_{e,SOL}$. Since EDGE-2D includes only 2 dimensions, it was assumed that the ionisation by the LH wave is produced due to the local SOL electron heating by the wave in a radially narrow belt in SOL near the separatrix, with poloidal width corresponding to the LH grill height, in which heating the above mentioned locally generated fast particles can participate, too. We supposed that the overall SOL heating (the input in the code) is about 20 times higher. This coefficient of 20 was obtained as the ratio of the toroidal tokamak circumference 2.*pi*R (R taken as 3m) to the grill toroidal width L (L taken as 1m). As we assume, this option might give a better estimate of the sources due to ionisation. The ionisation is computed in the code under the assumption that the electron velocity distribution is Maxwellian. Modifications to EDGE-2D were required to accommodate the large SOL widths in the discharges which are of interest for LH wave coupling in ITER, where the distance between the separatrix and the LH launcher $d_{PL} > 8$cm. The effects of varying the LH heating and the gas puffing rate on $n_{e,SOL}$ are shown, and compared to experiments. For example, the slope and magnitude of the measured ne profile for two shots with $d_{PL} = 8$ and 9 cm, are reproduced by the modelling, with the SOL temperature locally elevated by the LH power. Let us note that the maximum ionisation cross section for hydrogen is about 30eV, and slowly decreases to higher temperatures. Also, the ionisation sources were calculated for various LH heating and puffing rates. Two values of the plasma density at the separatrix were chosen: 5.e18 and 10^{19} m^{-3} in the modelling. They correspond to typical values measured in JET in scenarios similar to those modelled.

2. COMPUTATIONAL RESULTS AND COMPARISON WITH EXPERIMENTS

We will illustrate the EDGE2D modelling results on two shots with a long distance between separatrix and the LH grill mouth. First, it is the Pulse No: 58667 from series of shots with long distance coupling [2]. We note that this shot exhibited also hot spots on the divertor apron, caused by the fast particles locally accelerated in front of the grill mouth [5]. Second, it is the Pulse No: 59187, from the series of shots, in which effects of gas puffing on the LH wave coupling were studied [6]. The comparison of the SOL density profiles from modelling and measurements was done for these two shots, Pulse No's: 58667 and 59187, as there are available good SOL density measurements by the reciprocating probe. The probe was in the time of the density measurements magnetically connected to the LH grill mouth, and to the gas pipe GIM6. Some magnetic surfaces from the locations in front of the grill mouth hit the inner wall. EDGE2D can only cope with intersections of magnetic flux surfaces in the divertor region, and consequently the intersections with the inner wall were approximated by introducing particle and energy sinks [7]. The actual computational grid extends outside the vessel, but in regions where the vessel intersects the grid, recombination was greatly enhanced. The resulting neutralisation of the plasma creates sharp ion and electron pressure gradients at the plasma-vessel interface, which drives a plasma flow to the vessel where it is recycled as neutrals via recombination.The exact radial profile and the rate of the LH wave dissipation in the boundary plasma is not known. Therefore, in the computations, two values of the width (2 and 7cm) of the SOL layer with LH wave heating were considered, between 2 – 4cm, between 6 – 8cm, and between 2 – 9cm from the separatrix (the wall is 9.5cm from the separatrix in the midplane in the modelling). LH heating rates beteween 100kW and 1MW in the JET SOL plasma were considered in the computations. The case of 300 kW heating in the SOL appears to give the best comparison with experiments, cf. Figs. 1 – 3, for the plasma density at the separatrix 10^{19} m^{-3}. Let us note that 300kW does not simply mean 300 / 20 = 15 kW in front of the grill mouth (the factor of 20 is explained in the Introduction). Because of the large parallel transport, in a 3d model the 300kW dissipated would also be distributed along a much larger length than is the toroidal grill width. The D2 gas puffing was varied between 10^{21} el/s and 10^{22} el/s.

DISCUSSION AND CONCLUSION

The numerical modelling presented in this work shows the importance of taking into account an effect of the LH power on the SOL temperature, and hence on the ionisation, when modelling the SOL plasma. In addition to the modelling presented in the figures, we studied the results of variations of the gas puff and of the SOL heating rate. The gas puff without or with a low LH heating cools the SOL, and therefore, can even result in the plasma density decrease. On the contrary, large enough LH heating enhances the SOL plasma temperature and also the density. This SOL temperature enhancement is maximum without the gas puff. However, when the gas puff is accompanied by a large enough SOL heating, the SOL plasma density strongly rises, which can explain the observed improvement of the LH wave coupling. The modelled density growth is consistent with the modelled SOL ionisation source profiles, which for puff and heating are strongly enhanced and extend into the far SOL, contrary to the case without heating and/or without the gas puff. We note that EDGE2D can not model the density decrease behind the limiter, which is important for the LH coupling predictions. Therefore, we plan to introduce into EDGE2D features enabling estimates of the density profile also behind the limiter. Supported partly by the project GACR 202/04/0360.

REFERENCES

[1]. V. Pericoli-Ridolfini et al, Plasma Phys. Contr. Fusion **46** (2004) 349-368.

[2]. A. Ekedahl et al., Nucl. Fusion **45** (2005) 351-359.

[3]. R. Simonini et al., Contrib. Plasma Phys. **34** (1994) 2/3 368-373.

[4]. G.F. Matthews et al.,.Plasma Phys. Contr. Fusion **44** (2002) 689.

[5]. K.M. Rantamaki et al., Plasma Phys. Contr. Fusion **47** (2005) 1101-8.

[6]. G. Granucci et al., 30th EPS Conf., St. Petersburg, Russia, ECA 27A (2003), P-1.191.

[7]. R. Zagorski and H. Gerhauser, Physica Scripta Vol. **70** (2004) 170-186.

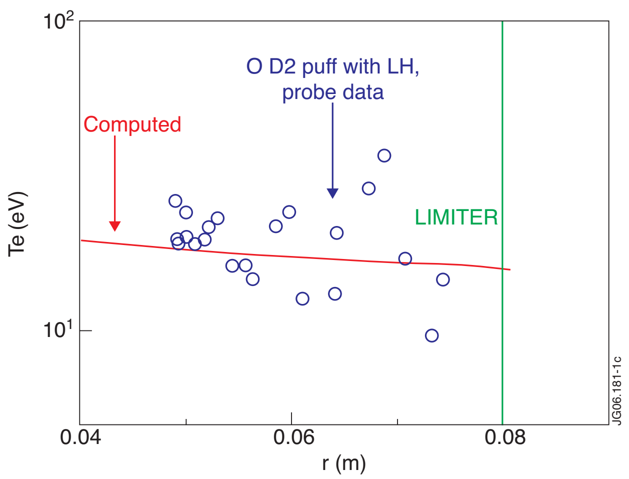

Figure 1: Blue circles: SOL temperature measurements by the reciprocating probe, Pulse No: 58667, LH heating 2.5MW, B=3T, I_p ramp from 1.5 to 2.7MA. The red curve is the computed curve, puff 10^{22} el/s, heating 300kW in the slab between 2–4cm from the separatrix.

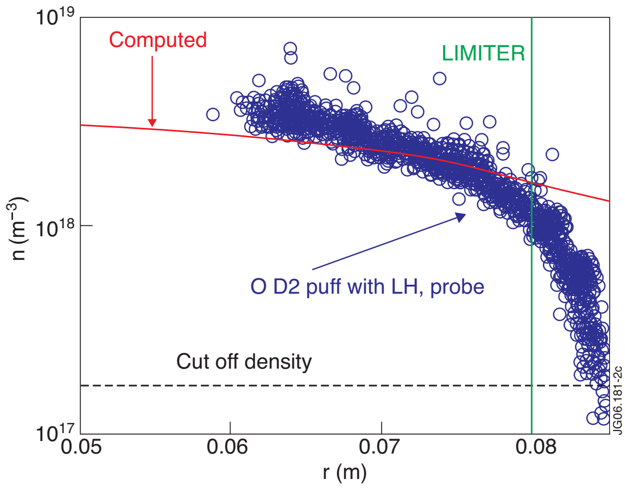

Figure 2: Electron density profile (blue circles) measured by the reciprocating probe, Pulse No: 58667, D2 puff 8.e21 el/s. The red curve is the computed curve, puff 10^{22} el/s, heating 300 kW in the slab between 2-4 cm from the separatrix. Edge2D can not model the density decrease near and behind the limiter, which is seen in the experiment.

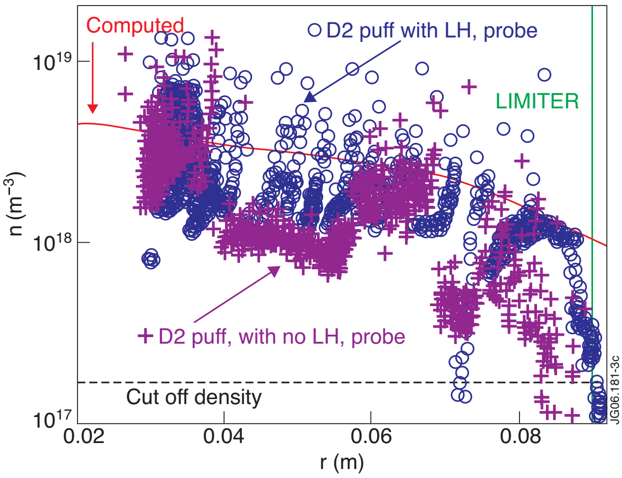

Figure 3: Electron density profiles measured by the reciprocating probe, Pulse No: 59187, LH heating 2.5MW, B=3T, I_p 1.5MA: blue circles - D2 puff 5.e21 el/s with LH; magenta crosses – D2 puff without LH. The red curve is the computed curve, puff 10^{22} el/s, heating 300 kW in the slab between 2-4cm from the separatrix.