EFDA–JET–CP(13)03/06

P. Belo, J. Strachan, M. Groth, G. Corrigan, D. Harting, S. Brezinsek
and JET EFDA contributors

EDGE2D/EIRENE Simulations of the W Event after X-Point Formation with the New JET-ILW

EDGE2D/EIRENE Simulations of the W Event after X-Point Formation with the New JET-ILW

P. Belo[1], J. Strachan[2], M. Groth[3], G. Corrigan[4], D. Harting[4], S. Brezinsek[5]
and JET EFDA contributors*

JET-EFDA, Culham Science Centre, OX14 3DB, Abingdon, UK

[1]EURATOM/IST Fusion Association, IPFN, Av. Rovisco Pais 1049-001 Lisbon Portugal
[2]PPPL Princeton University, Princeton, NJ 08543, USA
[3]Aalto University, Association EURATOM-Tekes, Espoo, Finland
[4]EURATOM-CCFE Fusion Association, Culham Science Centre, OX14 3DB, Abingdon, OXON, UK
[5]IEK-4, Forschungszentrum Jülich, Association EURATOM-FZJ, Germany
** See annex of F. Romanelli et al, "Overview of JET Results",*
(24th IAEA Fusion Energy Conference, San Diego, USA (2012)).

Preprint of Paper to be submitted for publication in Proceedings of the
40th EPS Conference on Plasma Physics, Espoo, Finland.
1st July 2013 – 5th July 2013

1. INTRODUCTION

Early in the 2011-12 JET ITER Like Wall (ILW) campaign, large tungsten (W) spikes were observed within 400ms after the X-point formation. The influx of W from the W divertor during this period can lead to significant changes on the evolution of the current profile and, in two extreme cases caused even disruptions. Although it was possible to reduce the occurrence of these events by 30% and minimize the impact on the plasma during the campaign, it is important to understand the physics behind the peaked W release and to find a way to avoid them in the first place. In this paper, EDGE2D/EIRENE [1] is applied to reproduce this transition phase with strong W release and to compare it with experimental observations.

2. EXPERIMENTAL OBSERVATIONS

A representative case (JET Pulse No: 80295) with a peaked W release during the X-point formation is shown in fig.1. During the limiter phase with contact point on the Be limiters and transition to the X-point, the line integrated density (neav) in the main plasma decreases and has its minimum exact at the time the X-point is formed. At the same time, the BeII (528nm) line intensity from the horizontal line-of-sight (H) in the main chamber was reduced by more than a factor of 10. While the WI (400.90nm) line intensity at the outer target (OT and also at the inner) increases strongly, followed by an increase of the total radiation (P_{rad}) in the plasma a few hundred milliseconds after the X-point is formed (see fig. 1). A database of 1957 discharges showed in 1507 cases the W release in the transition phase. In the database plasma with neav in the range of 6.0×10^{18} m^{-3} to 8.6×10^{19} m^{-3}, plasma current between 1.17 and 2.72MA.

The most likely explanation for the peaked W influx can be described as follows: during the limiter phase, Be sputtering at the limiters occurs and is leading to a high concentration of Be (cBe) in the main chamber plasma [3]. This enriched Be plasma reaches the divertor region during the X-point formation and the impinging Be ions are causing the W sputtering. The divertor plasma in this case is hot and thin providing high impact energies for the Be ions (E_{Be}). Figure 2 shows that the peaked W release is not observed for plasmas with low c_{Be}, characterised by Z_{eff}<1.5. In addition, plasmas with $n_{eav} > 5.3\times10^{19}$ m^{-3}, thus low central electron temperature (T_e) and in the consequence also low E_{Be}, show no appearance of the peaked W release. No clear correlation between the W source, represented by the WI, and P_{rad} in the centre has been identified. The actual WI is function of the neutral W, but needs conversion factors (which depend primarily on T_e) to provide the sputtered flux [5].

3. EDGE2D/EIRENE SIMULATION SET UP AND PROCEDURE

The simulations of the Scrape-Off-Layer (SOL) for JET discharges were done using the 2D multi-fluid edge transport code EDGE2D [1] coupled to the Monte Carlo code EIRENE [2]. EIRENE solves the kinetic set of equations for the neutral particles, D and impurity neutrals. The EDGE2D code solves in the parallel-**B** direction the Braginskii's fluid equations for each ionized particle, D and up to two impurities. In the radial direction the transport coefficients were assumed to be purely diffusive and were defined at the outer mid plane (OMP), (see fig.3).

To simulate the observations during the X-point formation with EDGE2D/EIRENE, a two-step strategy with diverted plasmas was developed as it is currently not possible to simulate the limiter phase with the code.

1) W sputtering at the targets by D or Be is suppressed, and a Be source from the main chamber wall is introduced by sputtering run-byrun from the factor of 1 to 40. This leads to a variation in c_{Be} from 0.7% to 17.0%.
2) Upon reaching steady-state, W sputtering at the divertor target plates by D and Be is activated, while reducing the main chamber Be source to those predicted by physical sputtering of Be due to D atoms. The simulations were continued until fully converged.

A scan of the D fuelling rate (Γ_D) was increased run-by-run from $2.0\times10^{21}\,s^{-1}$ to $8.0\times10^{21}\,s^{-1}$, which corresponds to an increase of the electron density at the OMP separatrix from $n_e(a) = 1.2\times10^{19}\,m^{-3}$ to $n_e(a) = 2.4\times10^{19}\,m^{-3}$, the same range of $n_e(a)$ observed experimentally. The D injection was localized at the inner wall for all EDGE2D/EIRENE simulations, while experimentally a wider range of locations were used. The core input power was assumed to be the same for the electrons and ions. To take into account the experimental range of Ohmic power three values of input power of 1.0MW, 2.0MW and 4MW were used.

Figure 4 shows the time evolution of synthetic diagnostics for the WI(OT) and BeII (H) for one of the simulations, which are qualitatively in agreement with experiments after the xpoint was formed. Experimentally P_{rad} increases after the X-point formation (see fig.1) while in the simulation it decreases and can't reproduce the experimental behaviour. In the EDGE2D/EIRENE simulations the plasma is already in X-point configuration, and an increase of Be sputtering leads to an increase of c_{Be} not only in the main chamber but also in the divertor region. Therefore, a significant contribution of radiation from Be is observed during the higher Be sputtering phase. Nevertheless just taking into account only the contribution of W on radiated power, P_{rad} increases in time after the X point formation as experimentally observed.

Figure 5 shows that the c_W in the computational domain increases with c_{Be} for the same input power of 1.0MW (for ions and electrons). c_{Be} decreases with GD for a constant Be yield which lead to a more significant decrease of c_W due to less impinging Be ions to the target This indicates that, both the presence of Be ions and their E_{Be}, reflected by T_e in the divertor is an important factor for the W sputtering at the divertor plates. In addition the c_W was higher for the simulations with higher input power with the same D gas injection rate and c_{Be}.

CONCLUSIONS

Although it was not possible to mimic completely the transient phase with change of the magnetic configuration from limiter to divertor configuration, it is possible to explain with the EDGE2D EIRENE simulation the W sputtering source which occurs during the X-point formation. The W source is mainly caused by Be ions impacting on the W target plate. In the EDGE2D/EIRENE simulations no significant increase of c_W with the Be sputtering yield but with the neav which is inverse proportional to Te if pressure in preserved. T_e at the divertor plate reflects the impact energy, hence E_{Be} on the W source. This was observed experimentally by increasing the GD which minimised the impact of the peaked W source and even removing it completely in the later phases of the campaign.

ACKNOWLEDGMENTS

This work, which has been supported by the European Communities and the Instituto Superior Técnico (IST) under the Contract of Association between the European Atomic Energy Community and IST, was performed under the European Fusion Development Agreement. This work was also partly funded by the United Kingdom Engineering and Physical Sciences Research Council and by the European Communities under the contract of Association between EURATOM and CCFE. The views and opinions expressed herein do not necessarily reflect those of the European Commission and IST.

REFERENCES

[1]. Simonini, R., et al, Contribution to Plasma Physics **34** (1994) 368;

[2]. www.eirene.de;

[3]. Groth, M., et al, Journal of Nuclear Materials, http://dx.doi.org/10.1016/j.jnucmat.2013.01.072;

[4]. Brezinsek, S. this conference;

[5]. Rooij, G. et al, Journal of Nuclear Materials Volume **438**, Supplement, July 2013, Pages S42-S47

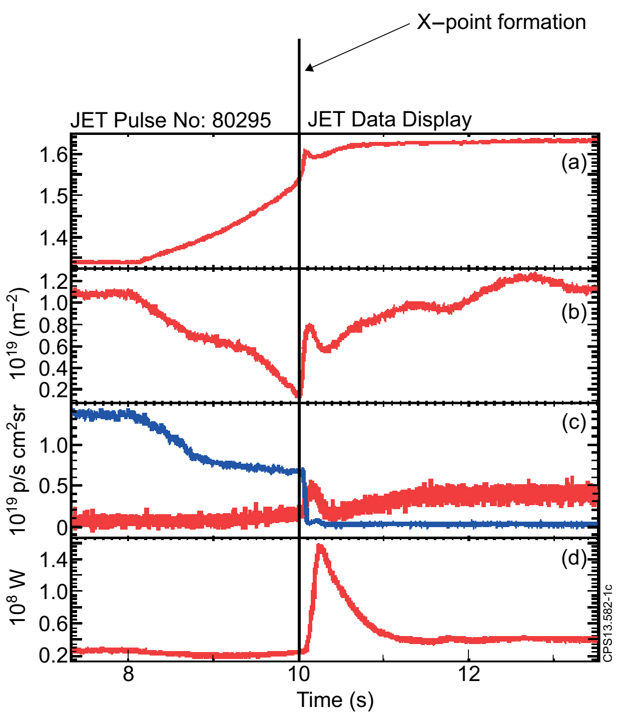

Figure 1: Experimental time traces of: a) elongation; b) core line integrated density; c) line intensities of BeII at the horizontal plane (blue) and the WI at the OT (red); d) the radiated power during the X point formation.

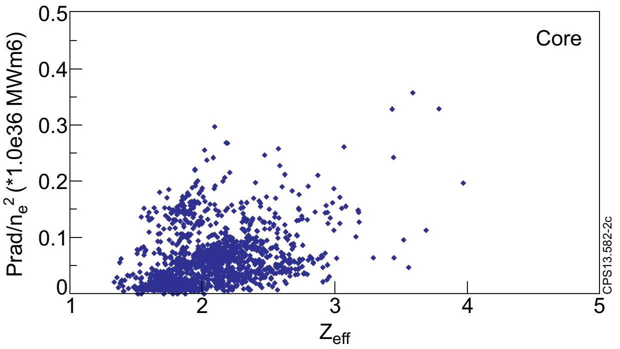

Figure 2: Core W spike radiation loss normalised by n_e^2 for the plasmas were the event was clearly observed as a function of the max core Z_{eff} during the 0.5s before the X-point formation.

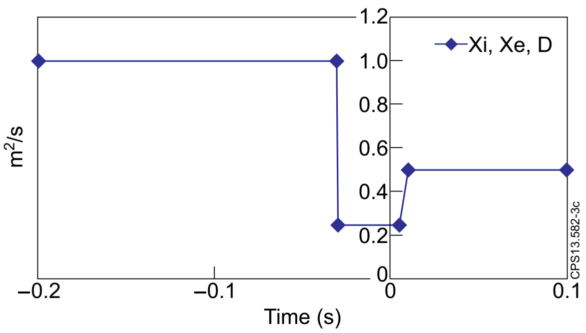

Figure 3: Radial transport coefficients at the OMP used in EDGE2D/EIRENE simulations.

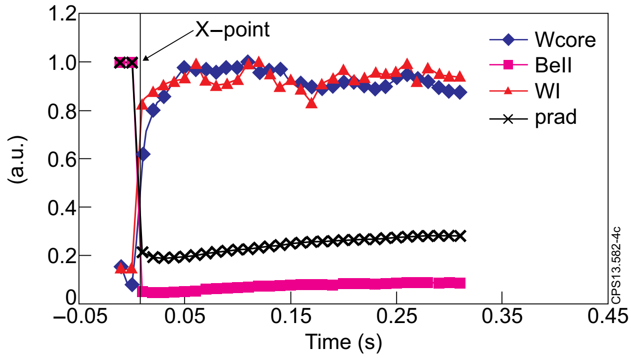

Figure 4: Time evolution of the syntetic diagnostic normalised by its maximum from the VUV core W15-25 line intensity feature (blue), the outer divertor WI (red) line, the horizontal plane BeII line (pink) and the total radiation (green).

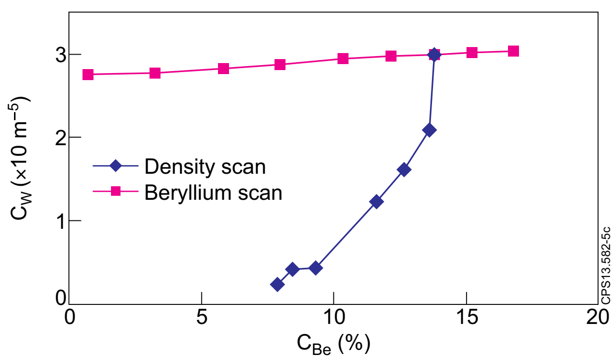

Figure 5: W concentration in function of Be concentration. c_{Be} for the same ne(a) and increasing Be sputtering yield factor (pink line) and for the same sputtering yield factor and increasing density.