Resonant Field Amplification Testing of Edge Localised Mode stability on JET

J.Pearson[1*], M.P.Gryaznevich[2], P.Lomas[2] I.Nunes[2], D.Yadykin[3], E.Joffrin[2], C.Challis[2], Y.Liang[1], Y.Yang[1,4] and JET EFDA Contributors[*]

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

[1] *Forschungszentrum Julich GmbH, Association EURATOM-FZ Julich, Institut fur Energieforschung - Plasmaphysik, Trilateral Euregio Cluster, D-52425 Julich, Germany*

[2] *EURATOM/CCFE Fusion Association, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK*

[3] *Charles University, Goteborg, Sweden*

[4] *Institute of Plasma Physics, Chinese Academy of Sciences, Hefei*

**j.pearson@fz-juelich.de*

Abstract

Resonant Field Amplification (RFA) has been found as a good indicator of the ideal no-wall stability limit and overall stability of the plasma. It has been observed that a peak in RFA sometimes occurs at β_N below the RFA threshold associated with the ideal no-wall limit. A correlation has been found between shots with extra puffing at the 1st ELM and the suppression of the early RFA peak. This is suggested to be due to the additional puffing effecting the stability of an *n*=1 peeling mode. The result and present ongoing experiments are outlined.

Introduction and Motivation

Resonant field amplification (RFA) [1] is the phenomenon whereby low *n*, low frequency meta stable modes in the plasma amplify externally applied magnetic fields through a resonant response. This can cause a rapid damping of the toroidal rotation through a transfer of angular momentum from the plasma to the surrounding coils. This was observed on the DIII-D tokamak where toroidal rotation was heavily damped as the plasma approached marginal stability. Thus RFA is a useful tool for looking at the plasma stability and can predict the appearance of limiting modes. A. Boozer noted that "*a plasma having a large amplification to a small perturbation is synonymous to a light bulb with a small resistance dissipating more energy than one with larger*

[*]See the Appendix of F. Romanelli et al., Proceedings of the 23rd IAEA Fusion Energy Conference 2010, Daejeon, Korea

resistance".

RFA can be defined as the ratio of the plasma response to the plasma vacuum reference

$$RFA = (B_r - B_r^{vac})/B_r^{vac}. \quad (1)$$

A significant enhancement of RFA is observed when the plasma exceeds the no-wall stability limit [2, 3]. This is most likely due to Resistive Wall Modes (RWMs) which become unstable at higher β_N. However, an increase in RFA has also been observed just before a fast rotating 5 kHz tearing or internal kink mode has been destabilised. This is suggested to be due to a n=1 peeling mode being dominant at the first Edge Localised Mode (ELM) [4].

It is well known that the first ELM has different characteristics and is often larger than the following ELMs and the suppression of this first event could be highly beneficial to plasma operation. Results from JET showing additional gas puffing at the first ELM effecting the stability of this peeling mode will be presented here as well as an outline of the current experiments setup to investigate this phenomenon.

Measurement Setup

JET

Using the Error Field Correction Coils (EFCC) external low-n perturbations are applied to the plasma. The plasma response can be measured using the in vessel saddle coils.

The ratio of amplitudes from the 90^o out of phase tangential pairs (octant's 1 and 5 verses 3 and 7), gives the ratio of the plasma response to the total field including the vacuum perturbation produced by the EFCC coils. As the plasma response is much smaller than the vacuum perturbation this can be neglected from the coils picking up the EFCC contribution and thus this ratio gives the value of RFA. When applying an AC field to the plasma the ratio of amplitudes from these saddle coils yields a good result but phase should be considered when applying a stationary oscillating field.

EAST

On the EAST tokamak the small perturbation coils are due to be tested and a dedicated experiment has been proposed for the RFA measurements. These coils are situated near the lower divertor and consist of 10 small coils at two opposite toroidal positions which will be able to produce a highly localised n=1 perturbation. The plasma response can be measured through the Mirnov coils located 90^o from the coil.

Although the perturbation applied is small (a few Gauss) at low frequencies (e.g. 40 Hz) this is picked up and causes the control system to oscillate the plasma. However, this problem disappears when the perturbation has a high frequency (e.g. 975 Hz).

Puffing at first ELM

Figure 1 shows two shots which have a clear early peak as well as a limit at higher β_N. This high β_N limit has been widely studied and is attributed to the RWM and nicely characterises the ideal no-wall β limit.

The earlier peak corresponds with the first ELM after a L-H transition or after a long ELM free period and will not be dominated by the RWMs as these are stabilised at lower β_N. It has been numerically shown that a marignally stable n=1 peeling mode gives a response with an amplitude matching the experimental data from JET at the 1st ELM peak [4].

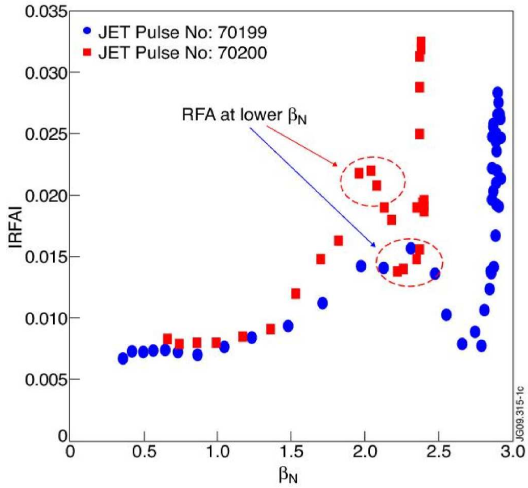

Figure 1: *RFA measurements of two JET pules verses β_N [4].*

The role of this peeling mode is that it couples with an internal mode lowering the stability limit thus increasing RFA. Confirmation of this needs a detailed comparison of the pedestal evolution before the 1st ELM and during the following steady ELMy phase β_N will continue to rise to the no-wall limit and thus the RWMs take over as the dominant mode increasing RFA.

A method of adding extra gas puffing to control the first ELM has been often used on JET. A correlation between the extra puffing at the 1st ELM and the disappearance of the RFA peak at lower β_N can be seen in figure 2. This suggests that the extra puffing at the first ELM is probing the low n peeling mode stability. One possible mechanism for this comes through the puffing

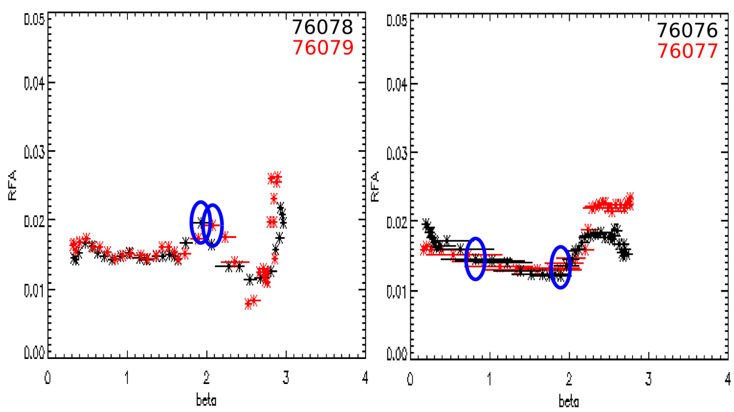

Figure 2: *RFA measurements of four adjacent shots with the same plasma conditions. (left) no additional puffing (right) with additional puffing showing suppression of the early peak. The appearance of the first ELM is highlighted with a blue circle.*

increase convective losses at the plasma edge. This would lead to a decrease in the pedestal mostly through the temperature gradient. The edge collisionality would then be increased and thus the resistivity goes up finally causing a decrease in the edge current density. According to the peeling mode initiated extended Taylor relaxation theory [5, 6] a lowering of the edge current density can lead to higher toroidal mode numbers becoming dominant suppressing the n=1 peeling mode.

Summary

Through measurements of RFA the stability of the plasma can be analysed. The n=1 peeling mode is a good candidate for causing a early peak in RFA corresponding to the first ELM. Recent analysis shows that additional puffing at the first ELM can suppress the early peak. This could be due to the puffing effecting the edge current density allowing higher n to become dominant. Experiments measuring RFA are ongoing on the JET and EAST tokamaks with the aim to develop the understanding of how the application of external fields effects the plasma stability.

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