36th EPS Conference on Plasma Phys. Sofia, June 29 - July 3, 2009 ECA Vol.**33E**, P-2.147 (2009)

CURRENT PROFILE MEASUREMENTS IN JET ADVANCED TOKAMAK SCENARIOS

R. De Angelis[1], F. Orsitto[1], M. Brix[2], N. Hawkes[2], E. Rachlew[3], A. Botrugno[1], P. Buratti[1], A. Fonseca[4], D. Howell[2], V. Pericoli[1], O. Tudisco[1] and JET-EFDA Contributors*

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

[1]*Associazione Euratom/ENEA sulla Fusione, CP 65-00044 Frascati, Rome, Italy*

[2]*Euratom/UKAEA Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK*

[3]*Association EURATOM-VR,KTH Royal Institute of Technology,SE-10691Stockholm, Sweden*

[4]*Associacao Euratom-IST, Centro de Fusao Nuclear, Av. Rovisco Pais, Lisbon, Portugal*

[*]*See the Appendix of F. Romanelli et al., Proceedings of the 22nd IAEA Fusion Energy Conference, Geneva, Switzerland, 2008*

Introduction

The evaluation of the spatial profile of the safety factor q is a key point in the analysis of Avanced Tokamak (AT) scenarios, hybrid or steady state. Determinations of q in JET are performed using various diagnostics and the equilibrium analysis constrained on the values of experimental data. In particular the constraints from MSE (Motional Stark Effect) and Polarimetry are routinely used in the EFIT code to optimize the equilibrium evaluation. In some cases the presence inside the plasma of a rational q surface is also evidenced by the occurrence of several types of MHD modes whose mode number ratio (m/n) can be compared with the q value of a particular flux surface. The analysis of signals from several diagnostics (magnetic probes, soft X, Charge exchange spectroscopy, ECE, interferometry and reflectometry) acquired on fast timescales can identify most of these modes and their radial location in the plasma. In particular neo-classical tearing modes (NTM) with m<9, n<4, sawteeth (m/n=1), fishbones (1/1), (2/1) are frequently observed in JET; moreover it is often possible to mark quite precisely the crossing of minimum-q surfaces with rapid successions of modes excited by energetic ions (Alfven Cascades) which can appear only in q reversed discharges. The comparison of the MSE profiles with MHD markers can provide a useful tool for the validation of the measurements. In fact, recently in JET the correction of MSE angle calibrations to match Alfven Cascades and sawteeth, in reference shots, has enhanced the reliability of MSE q-profiles significantly. In this paper we report an extensive comparison of MSE profiles with MHD data for which identification and localization could be obtained.

Discharges in the hybrid scenario

Evaluation of equilibrium in JET is obtained between the shots from the EFIT code, considering data from magnetic measurements only. This gives a first approximation of the flux surfaces behavior and in particular of the profile of the safety factor q. The constraints from experimental data are introduced successively in off line runs of the EFIT-MSE code, which require some assumptions on the choice of experimental data to be used. An accurate review of the calibration and of the fitting parameters [1,2], has led to the definition of methods of data elaboration which match q_{min} from Alfvén cascades, the sawteeth inversion radius in reference discharges and the pressure profiles obtained from experimental density and temperatures. In the present work we have examined a large number of discharges in the hybrid scenario where MHD modes could be identified and localized clearly and we have compared the local values of q(r) with the EFIT reconstruction obtained following the criteria mentioned above. The localization of tearing modes in JET is routinely obtained by comparing the toroidal velocity of the mode with the profiles of impurity toroidal velocity obtained from Charge Exchange spectroscopy; recently a correction to the mode radii, which takes into account the plasma diamagnetic rotation has been included [3]. An example is illustrated in Figure 1 where it appears that the corrected MHD values match quite closely the points obtained by EFIT constrained by MSE and total pressure data. The comparison of time evolutions of the radii of specific q surfaces (most often observed q=3/2) obtained with the two methods is also very satisfactory as illustrated in Figure 2.

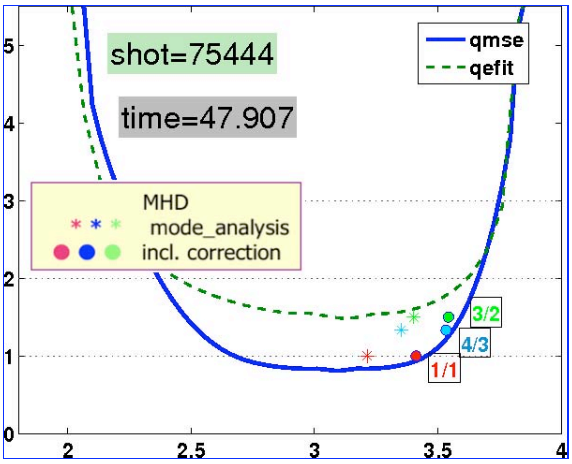

Figure 1 Behavior of q vs. major radius. q_{EFIT}: unconstrained equilibrium
q_{MSE}: with MSE and total pressure constraints.
From MHD analysis: asterisks non corrected, circles with diamagnetic correction

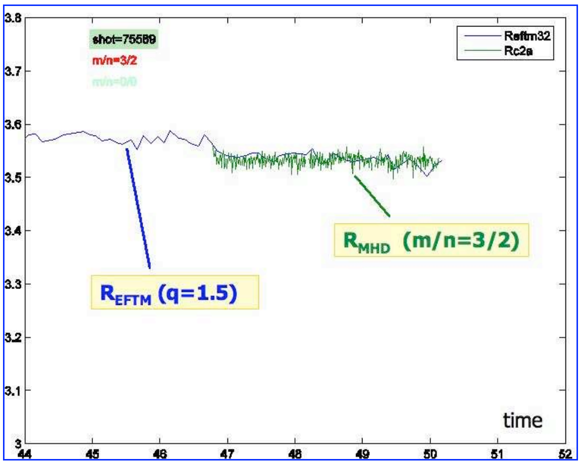

Figure 2 Time behavior of the radii of the q=3/2 and q=5/2 from MHD analysis and from the EFIT reconstruction

The database examined contains approximately 1600 time steps in 225 shots of the Hybrid scenario [4]. The comparison, extended to all possible time steps, is summarized in Figure 3.

The figure shows that the average discrepancy (R_{MSE} - R_{MHD})/ R_{MHD} is reduced from ~ 8% to ~ 1.5% at q=3/2 and the dispersion of data is reduced accordingly when the contribution of the diamagnetic velocity is included in the analysis.

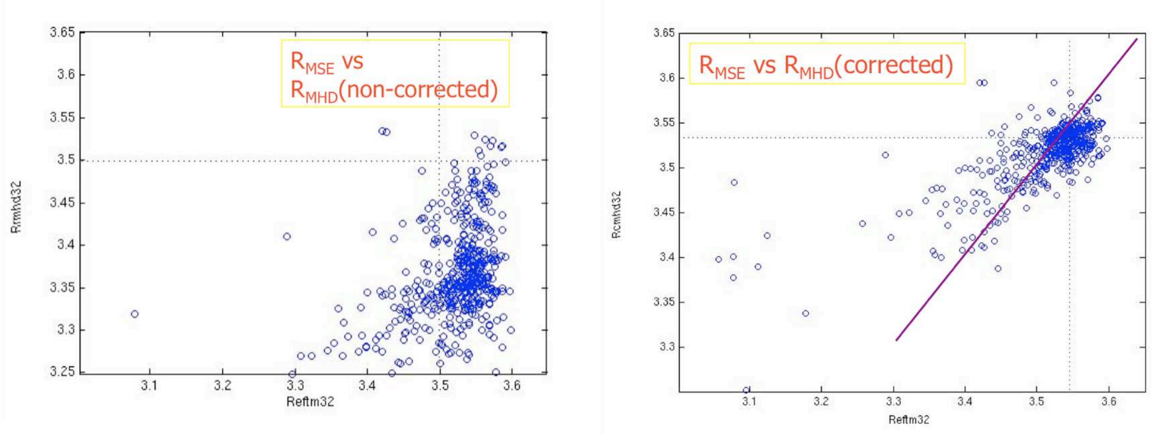

Figure 3 The radii of the q=1.5 surface from the MSE constrained EFIT and from MHD location of the m/n = 3/2 radial location. Without (a)) and including (b)) diamagnetic correction

More general comparison of the q-profiles

The analysis presented shows that monotonic q profiles in JET can be well described by the available measurements of MSE, and MHD. In plasmas with shear reversal, the characterization of q profiles inside the minimum-q surface requires the identification of higher mode numbers, which is more uncertain. In a few cases internal modes have been localized by soft X tomography as in Figure 4, which clearly exhibits the reversal feature. An estimate of the reliability of $q_{EFIT\text{-}MSE}$ can be found in the correspondence in time of the occurrence of Alfvén Cascades (AC) with q_{min} crossing an integer value. This correspondence was found within 0.5 s in 90% of 30 shots exhibiting AC (within 0.1s in 15% cases). The above assures that the original MSE calibration (made against ACs in reference shots) still holds for other pulses. At later times in the same discharges it is generally possible to find radial correspondence with external tearing modes. Figure 5 illustrates the profiles at the crossing of the q_{min}=3 and q_{min}=2 (typically q_{min}=3 is obtained in early phases of the shot when the density is low and neutral beam and MSE are not available). Localization of ACs by reflectometry has been obtained in dedicated shots and compared with $q_{EFIT\text{-}MSE}$ [5].

Localization of magnetic islands by ECE diagnostics shows an agreement with $q_{EFIT\text{-}MSE}$ within□5cm (systematically r_{ECE}< $r_{EFIT\text{-}MSE}$) on a large number of shots [3], the 3/2 surface is typically identified both on the low and the high magnetic field sides of the plasma cross section (Figure 6).

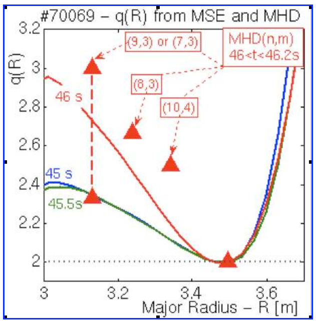

Figure 4. Identification of internal modes by X-tomography

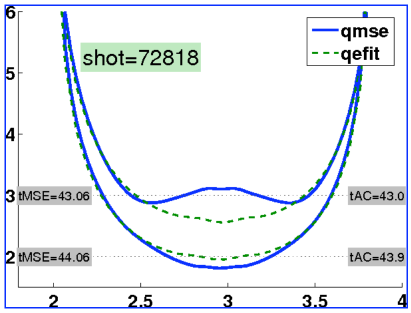

Figure 5 q-profiles at the crossing of the q_{min}=2 and q_{min}=3 surfaces

The study of fishbone modes can also provide the radii of the 2/1 surfaces; in the shots examined (20 time steps) they agree quite precisely with the available MSE profiles (a few percent difference) Figure 7.

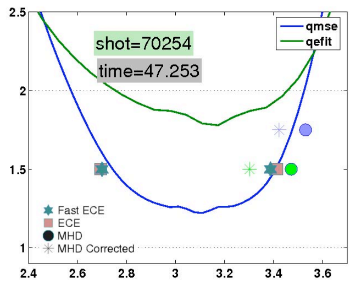

Figure 6 Comparison of q profiles with data from ECE

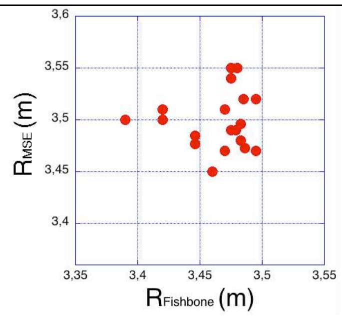

Figure 7 Comparison of the radii of the q=2 from Efit-MSE and from Fishbone modes

Conclusions

The analysis presented in this paper shows that monotonic q profiles in JET can be well described by the available measurements of MSE and MHD. In plasmas with shear reversal, the characterization of q profiles inside the minimum-q surface requires more detailed information. The localization of internal modes by soft X tomography has given useful information in some discharges and will be the subject for further analysis. The results suggest that a better description of the q profile would be obtained by constraining EFIT on some local values obtained from different diagnostic, the required implementations of the code are under study.

References

[1] M. Brix, et al. Rev. Sci. Instrum. **79**, 10F325 (2008); DOI:10.1063/1.2964180
[2] M.A. Makoski et al. 35th EPS Conf. on Plasma Physics ECA Vol **32D**,P-4.085 (2008)
[3] P. Buratti et al. this conference P5.169
[4] J. Hobirg et al. this conference
[5] S. Hacquin et al. PPCF **49** (2007) 1371-1390; doi:10.1088/0741-3335/49/9/002

Acknowledgement. This work, supported by the European Communities under the EURATOM/ENEA contract of Association, was carried out within the framework of the European Fusion Development Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission.