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Local transport in density and rotational transform scans in TJ-II ECRH discharges

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Introduction

Aside from a number of analysis devoted to the study of particular discharges, systematic local (flux surface averaged) transport in the TJ-II heliac remains to be done. In this work we present the results of performing interpretative transport on two series of electron cyclotron resonance heated discharges with boronised wall, one belonging to a rotational transform scan, the other one to a density scan. It is known that TJ-II matches reasonably well [1] ISS95 scaling [2] with rotational transform but the density dependence found in TJ-II is stronger than the one in ISS95. Here we seek to gain information on these scans from the perspective of local transport analysis, paying especial attention to heat diffusion. Estimates of particle transport are also presented even though its interpretation is strongly affected by uncertainties on the particle source profiles. Finally, we comment some results obtained with a simple transport model taken from Ref. [3] that, given the strong dependence with trapped particle fraction, captures the main radial dependence of the experimental heat transport coefficient profiles.

Density and rotational transform scans

We have performed interpretative transport analysis on a set of 56 steady state discharges with similar wall conditions (boronized wall) split in two, density and rotational transform, scans. The knowledge of thermodynamic profiles and source/sinks is mandatory for reliable interpretative analysis. Here we are interested mainly in diffusive heat transport, a reason why our region of interest excludes the proximity of the magnetic axis (where the ECRH deposition drives strong pump out losses) and the edge (where magnetic field ripple losses dominate transport). Experimental information considered in this study consists of the profiles of electron density n_e, electron T_e and ion T_i temperatures, and total radiation density P_{rad}. T_e profiles are constructed using smoothed Thomson Scattering data. Electron temperature profiles at the very edge were completed with a parabolic function with edge value of 20 eV. These data were also compared with electron cyclotron emission radiometer data. n_e profiles were taken from Thomson Scattering data as well, but completed with data from the AM Reflectometry diagnostic at Thomson times because the Thomson diagnostic fails to give information at low densities

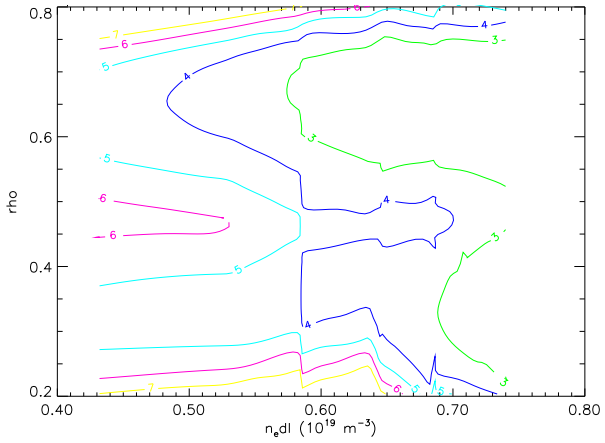


Figure 1: Electron heat diffusivity contour map in a density scan for TJ-II ECRH plasmas. Isolines range from 1 and 7 m^2/s as a function of minor radius and experimental line density.

due to unfavourable signal to noise ratios. Line density integrals were performed to ensure that the integral values for the reconstructed density profiles match the experimental line densities measured with interferometry techniques. Ion density is obtained considering a homogeneous efective charge $Z_{eff} = 1.3$. In the case of T_i, charge exchange data were only available for a few discharges. It is, however, known that T_i profiles in TJ-II ECRH shots are flat with values close to 90 eV. We have then used a same 90 eV flat profile with 12 eV at the boundary for all discharges. 12 discharges in the density scan and 9 discharges in the rotational transform scan have data on total radiation profile obtained from bolometer chords. All the discharges analyzed have the same deposited heating power ($P_{ECH} = 240$ kW of electron cyclotron resonance heating without current drive) and we have assumed a centered gaussian profile of width 0.2 in normalized minor radius. At this respect, it has been checked that the electron cyclotron absorption signals are similar for all discharges. All the analysis has been done with ASTRA [4] after imposing TJ-II flux surface averages of the metrics to calculate gradients and volume integrals properly. Integral values of global confinement time $\tau_G = \int dV(n_e T_e + n_i T_i)/P_{ECH}$ for both scans coincide within a 5% with those obtained in Ref. [1]. The corresponding dependences with line density and rotational transform are found practically the same as well even though the criteria for constructing the profiles are slightly different. The subset with P_{rad} data indicates that radiation losses do not play a significant role in TJ-II ECRH scalings. The density dependence of τ_G when P_{rad} is substracted from P_{ECH} is, as found in Ref. [1], linear.

The most common configuration in TJ-II ECRH discharges has a value of the rotational transform, at normalized radius $\rho = 2/3$, $\iota_{2/3} = 1.607$ and a plasma volume of 1.1 m^3. Since the data base is largest for this configuration, it has been chosen for the density scan. Line densities

Table 1: Location of peaks in χ_e and possible matching low order rational surfaces for different magnetic configurations labelled by $\iota_{2/3}$. These are absent in standard configurations.

$\iota_{2/3}$	1.54	1.55	1.60	1.64	1.75	1.86
$\rho(\chi_{max})$	0.51	0.53	0.46	0.47	0.51	0.53
$\iota(\chi_{max})$	1.51	1.53	1.57	1.60	1.73	1.83
m/n	$\approx 3/2$	NONE	NONE	$= 8/5$	$\approx 7/4$	$\approx 9/5$

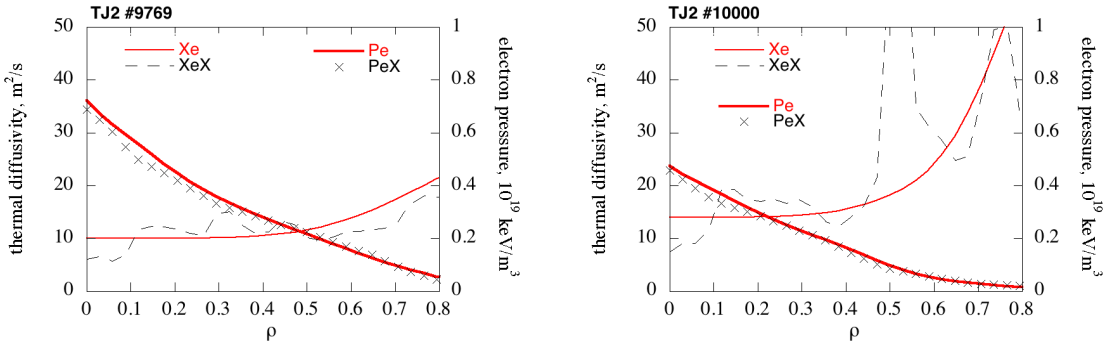
range from 0.4 to 1.0 10^{19} m^{-3}. Fig. 1 shows a contour map of the electron heat diffusivities χ_e as a function of ρ in the bulk plasma ($0.2 \leq \rho \leq 0.8$) and experimental line density. A "ridge" of increased χ_e can be appreciated around $\rho = 0.5$. The general trend observed is that, with the exception of the extreme regions where the analysis is less reliable, χ_e decreases in a rather uniform manner in the whole bulk plasma. Particle diffusivity in the confinement region is ~ 0.01 m^2/s.

In the $\iota_{2/3}$ scan, and in agreement with results in [1], there is no noticeable pattern in the estimated thermal diffusivities. The same peak in χ_e is observed now in slightly varying locations but always near $\rho = 0.5$. Table 1 collects the location of maxima in χ_e for the different configurations of the scan and the possible low order rational vacuum ι values. It is noteworthy that the most common configurations do not have a low order rational in the analyzed region. The location of maxima in χ_e, however, always corresponds within experimental accuracy with the maximum density location, which for these ECRH plasmas is $\rho \approx 0.5$. Particle transport is ~ 0.01 m^2/s again.

Discussion

The feature of the peak in χ_e had been observed already in other analysis of this kind for TJ-II ECRH plasmas, but could not be assesed due to the uncertainties in evaluating gradients from smoothed Thomson data. The fact of having a larger statistics makes us gain confidence on this feature. Considering that the rotational transform scan does not give a clear indication that such increased χ_e is due to the presence of low order rational ι flux surfaces, we have checked that this position coincides quite sistematically with the maximum of the hollow density profiles, always present in ECRH discharges. It has been checked, although for a reduced set of discharges for which data are available, that the radial electic field in this region estimated from heavy ion beam probe voltages approaches zero or inverts sign from positive to negative.

The steady decrement of χ_e with density can guide us to look for an inverse dependence between χ_e and some plasma magnitude that depends directly on density, like the collisionality.



(a) (b)

Figure 2: Steady state experimental χ_e (dashed line) and electron pressure profile (crosses); and model χ_e (thin solid line) and electron pressure (thick line) for discharges corresponding to magnetic configurations with volume of 0.5 and 1.1 m^3.

The analytic approach for transport that we have found to better link experimental density and T_e takes dependences from a model for turbulent transport based on trapped electron modes [3]. Fig. 2 shows transport calculations for the TJ-II based on such dependences: $\chi_e \sim f_t^3 (\rho a)^2 \frac{\nu_e}{1+\frac{\nu_e^2}{\nu_0^2}}$, and $D_e \sim f_t^2 \chi_e$; where a is the average plasma minor radius, f_t is the fraction of trapped particles, ν_e is the collisionality and ν_0 is a reference frequency to mark the change of tendency of these coefficients with collisionality. This reproduces reasonably well the region of abrupt change in diffusion for $\rho \gtrsim 0.5$ but not the trend of the χ_e-profile in the bulk plasma towards smaller diffusion in the density scan (see Fig. 1). It is compatible with the ι scan because there is no ι dependence in the formulation. The feature of the peak of χ_e in the density maximum cannot be reproduced with this formulation. For now, however, we take the model results as an indication of the strong impact of trapped particle fraction in TJ-II plasmas. More work on local transport is now aimed at refining these results with the objective of finding local features and dependences that can be contrasted with theory-based formulations.

References

[1] E. Ascasíbar *et al.*, Nucl. Fusion **45** 276-284 (2005).

[2] U. Stroth *et al.*, Nucl. Fusion **36**, 1063 (1996).

[3] B. B. Kadomtsev, O. P. Pogutse, Nucl. Fusion **11**, 67 (1971).

[4] G.V. Pereverzev *et al.*, ASTRA: Automatic System for Transport Analysis, Max Plank Institut für Plasmaphysik, Rep. IPP 5142, Garching (1991).