MODELING OF SOME NONSTATIONARY PROCESSES IN TOKAMAK PLASMAS

M.A. Borisov[1], S.V. Cherkasov[1], A.V. Danilov[1], Yu.N. Dnestrovskij[1], A.Yu. Dnestrovskij[1], A. Field[2], S.E. Lysenko[1], H. Meyer[2], V.A. Vershkov[1]

[1]NRC "Kurchatov Institute" Institute of Tokamak Physics, Moscow, Russia;
[2]Euroatom/CCFE Fusion Association, Culham Science Centre, Abingdon OX14 3DB,UK

The results of modeling of shots from two series of experiments in two tokamaks with rather different geometric parameters are presented. The first one includes two shots from the spherical tokamak MAST with current ramp up, and the second one, a number of T-10 shots with periodic gas puffing. The modeling was performed with the ASTRA code in the framework of Canonical Profiles Transport Model (CPTM).

PACS: 52.55.Fa, 52.55.Dy

1. CURRENT RAMP UP IN MAST

1.1. OHMIC DISCHARGE

The motivation for the current ramp up pulses modeling was the solution of the issue, whether the neoclassical conductivity is suitable for the description of the current diffusion in the MAST. The results of modeling for two MAST discharges: Ohmic (#24433) and NBI-heated (#24434) are presented. For both pulses the plasma current ramped up during 170 ms until value $I_p = 0.85$ MA, while the chord averaged plasma density until 3.5×10^{19} m^{-3} during 200 ms, the magnetic field was $B_T = 0.5$ T, the NBI power deposition for the pulse #24434 was at the level of 1.5 MW.

The modeling was performed in two stages. In the first stage only the plasma current distribution was modeled with prescribed experimental electron temperature and plasma density. Then the full transport CPTM model [1] was used. Two expressions for neoclassical conductivity were under study: Hirshman [2] and Sauter-Angioni conductivity [3].

The results of Ohmic shot modeling with prescribed electron and ion temperatures and plasma density are presented in Fig. 1 for four time slices $t = 30$, 75, 130 and 250 ms. Hirshman expression for plasma conductivity was used in this run. The simulated safety factor profiles (q) met the measured profiles obtained by MSE diagnostics during the whole time period under consideration. This conclusion is somewhat different from the results of previous work on this topic [4]. One of the possible reasons might be the different representation of plasma boundary in the codes (3 moments in ASTRA and 6 moments in TRANSP). The same reason may respond for some deviations of calculated q profiles from measurements at the plasma edge. The clarification of this variance needs further investigation with wider set of pulses.

Similar results were obtained with T_e and n_e modeling by means of CPTM transport model. This similarity is connected with the proximity of the modeled electron temperature to the experimental one (Fig. 2).

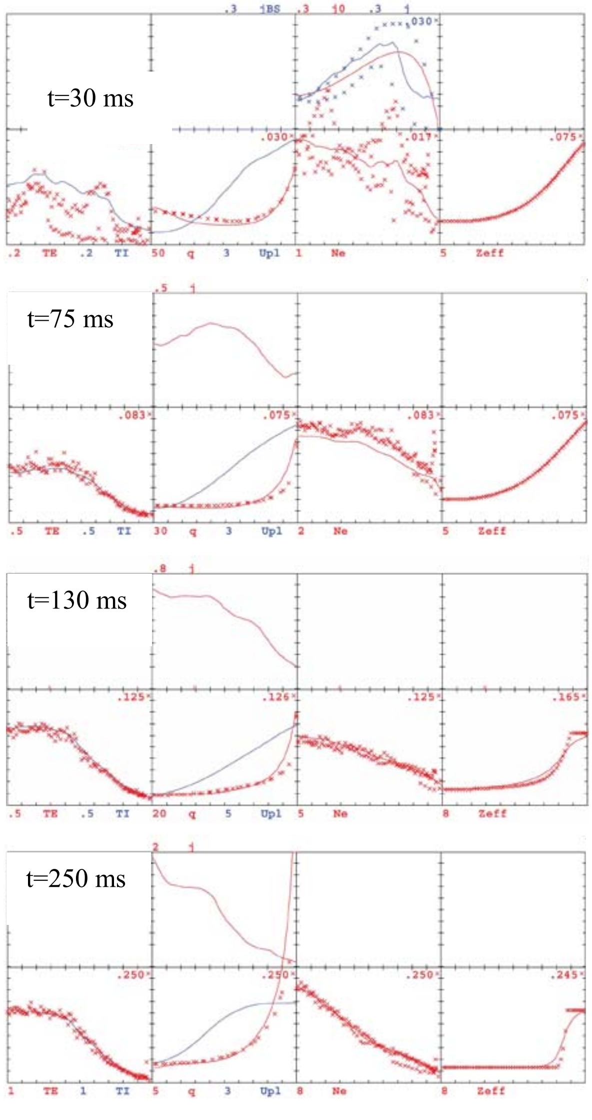

Fig. 1. Profiles of plasma values at different times for Ohmic shot #24433. Crosses are measurements, solid lines are calculations. Notations: j is current density (MA/m^2), TE, TI are electron and ion temperatures (keV, TI = TE), q is safety factor, Ne is density (10^{19} 1/m^3), Zeff is effective charge, Upl is voltage (V), j_0 is j profile at the start of the run (t = 25 ms)

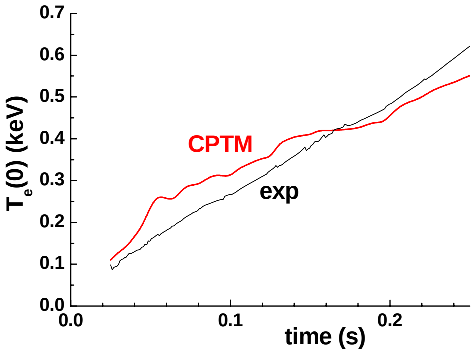

Fig. 2. Comparison of modeled (CPTM) and experimental (exp) central electron temperature values for the Ohmic discharge

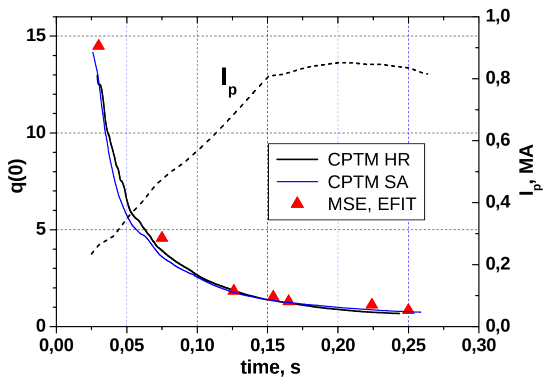

Fig. 3. Comparison of central safety factor values for Hirshman (HR) and Sauter-Angioni (SA) conductivities with experiment (MSE) for Ohmic discharge

During the CPTM Ohmic discharge modeling, the comparison of Hirshman and Sauter-Angioni conductivities has been performed. The results are presented in Fig. 3. As it can be seen, the central safety factor values are very similar in these cases and the agreement with experiment is even better for more simple Hirshman expression.

1.2. NBI-HEATED DISCHARGE

The results obtained for NBI-heated pulse #24434 are very similar for those for Ohmic discharge. We consider here only the results of CPTM modeling of electron temperature and plasma density. The safety factor calculated with Hirshman conductivity is compared with MSE measurements in Fig. 4 for the time instant 250 ms. The simulated electron temperature profile at the same time is presented in Fig. 5.

2. PERIODIC GAS PUFFING IN T-10

The experiments with periodic gas puffing have proved to be a powerful tool for plasma diffusion investigation [5]. The new series of T-10 experiments was carried out in 2011 in Ohmic discharges with $B_T = 2.4$ T, current $I_p = 200$ kA and densities $\bar{n}_e = 1.7$, 2.5 and 3.5×10^{19} m^{-3}, and for $\bar{n}_e = 2.5\times10^{19}$ m^{-3} with $I_p = 130$, 200 and 300 kA [6]. Periodic D_2 puffing was made though piezoelectric valve in the stationary stage of the discharge with modulation periods of $T = 60$ and 90 ms.

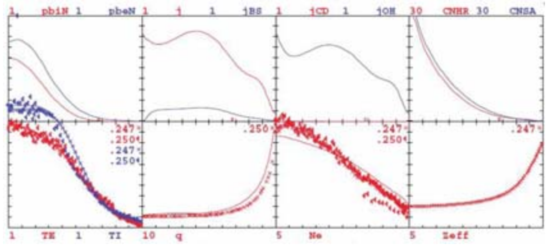

*Fig. 4. Profiles of plasma values at t=250 ms for NBI-heated shot #24433. Notations: pbiN, pbeN (MW/m^{3}s) – NBI power input to ions and electrons, jBS, jOH – bootstrap and Ohmic currents (MA/m^2), CNHR, CNSA - Hirshman and Sauter-Angioni conductivities (μΩ*m); other notations as in Fig. 1*

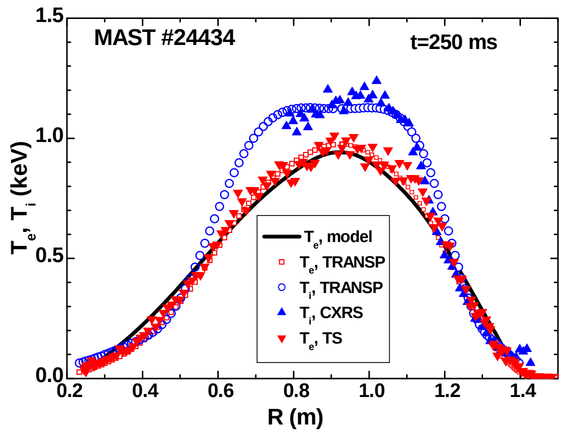

Fig. 5. Modeled electron temperature profile for NBI-heated pulse vs measurements

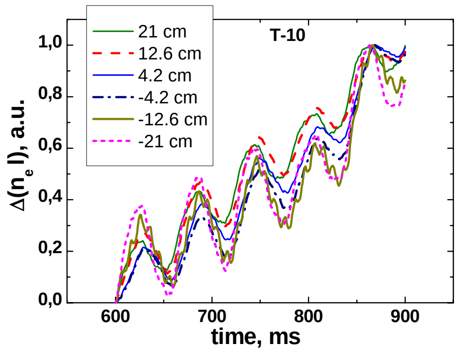

Fig. 6. The modulation of plasma chord density (interferometer signals)

The modulation of chord density signal is clearly seen over the whole plasma cross section (Fig. 6).

The attempt to explain the experimental spatial distribution of modulation amplitudes and phases by means of simple diffusion model with constant in time diffusion coefficient and pinch velocity failed in the case of higher densities, so a complex model with periodic variation of parameters has to be constructed. However, the usual version of the CPTM with constant in time coefficients has demonstrated the capability to meet the experimental profiles of modulation amplitude and phase shift as presented in Fig. 7.

The gas puffing was simulated by 1 % modulation of wall cold neutrals influx and antiphased modulation of electron temperature and density boundary values.

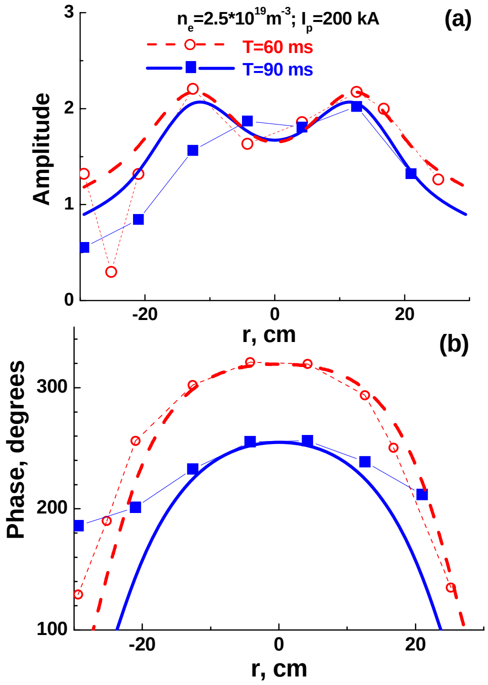

Fig. 7. Relative chord densities modulation amplitudes (a) and phase shifts (b) profiles for two modulation periods T = 60 And 90 ms. Points are measurements, curves are CPTM modeling

The runs reveal strong dependencies of observed modulation amplitudes and phases on the ratio of temperature and density boundary disturbances. Namely, amplitudes and phases agree with experiment, when the relative value of the boundary temperature modulation is about twice the density one. It should be mentioned that the excess of temperature disturbances over the density ones was observed experimentally for the average plasma density under consideration.

CONCLUSIONS

The comparison of modeling results with TS, CXRS and MSE measurements for both Ohmic and NBI-heated MAST discharges confirmed the adaptability of neoclassical conductivity in this case. This conclusion is somewhat different from the results of previous work on this topic [4]; one of the possible reasons might be the different representation of plasma boundary in the codes. Particular form of neoclassical conductivity (Hirshman or Sauter-Angioni expression) has a weak effect upon the safety factor profile and other values.

The analysis of periodic gas puffing experiments in T-10 demonstrated the capability of the usual version of the CPTM to meet the experimental profiles of the chord density modulation amplitudes and phase shifts.

ACKNOWLEDGEMENTS

The authors thank D. Keeling for discussion. The work is supported by Rosatom contract H.4x.45.90.12.1023, Rosnauka contracts 16.518.11.7004 and NSh 5044.2012.2, and by Consultancy Agreement with UKAEA 3000160385.

REFERENCES

1. Yu.N. Dnestrovskij et al. // *Nucl. Fusion.* 1995, v. 35, p. 1047.
2. S.P. Hirshman, R.J. Hawryluk, B. Birge // *Nucl. Fusion.* 1977, v. 17, p. 611.
3. O. Sauter, C. Angioni, and Y.R. Lin-Liu // *Phys. Plasmas.* 1999, v. 6, p. 2834.
4. D. Keeling et al. // *38-th EPS Conf. on Plasma Physics.* 2011, Rep. 05.130.
5. V.A. Vershkov, N.L. Vasin, V.A. Zhuravlev // *Fizika Plazmy.* 1984, v. 10, p. 1125 (in Russian).
6. M.A. Borisov et al. // *38-th EPS Conf. on Plasma Physics*. 2011, Rep. 05.127.

Article received 19.10.12

МОДЕЛИРОВАНИЕ НЕКОТОРЫХ НЕСТАЦИОНАРНЫХ ПРОЦЕССОВ В ПЛАЗМЕ ТОКАМАКОВ

М.А. Борисов, С.В. Черкасов, А.В. Данилов, Ю.Н. Днестровский, А.Ю. Днестровский, А. Филд, С.Е. Лысенко, Х. Мейер, В.А. Вершков

Представлены результаты моделирования импульсов из двух серий экспериментов на двух разных токамаках, существенно отличающихся геометрическими параметрами. Первая серия включает два импульса с нарастанием тока сферического токамака MAST, а вторая – несколько импульсов Т-10 с периодическим газонапуском. Моделирование осуществлялось с помощью кода ASTRA в рамках транспортной модели канонических профилей (ТМКП).

МОДЕЛЮВАННЯ ДЕЯКИХ НЕСТАЦІОНАРНИХ ПРОЦЕСІВ У ПЛАЗМІ ТОКАМАКІВ

М.А. Борисов, С.В. Черкасов, А.В. Данилов, Ю.М. Дністровський, А.Ю. Дністровський, А. Філд, С.Є. Лисенко, Х. Мейер, В.А. Вершков

Представлені результати моделювання імпульсів з двох серій експериментів на двох різних токамаках, що істотно відрізняються геометричними параметрами. Перша серія включає два імпульси з наростанням струму сферичного токамака MAST, а друга – декілька імпульсів Т-10 з періодичним газонапуском. Моделювання здійснювалося за допомогою коду ASTRA в рамках транспортної моделі канонічних профілів (ТМКП).