

Simulation of ITER Improved H-mode Operation with the Integrated Core Pedestal SOL Model Using MMM95 and GLF23 Core Transport Models

G.W. Pacher¹, H.D. Pacher², G. Janeschitz³, A.S. Kukushkin⁴, G. Pereverzev⁵, A. Pankin⁶,
I. Voitsekhovitch⁷

¹ *Hydro Quebec (IREQ), Canada*

² *INRS, Quebec, Canada*

³ *FZK-PL-Fusion, Karlsruhe, Germany*

⁴ *ITER International Team, Garching, Germany*

⁵ *Max-Planck-Institut für Plasmaphysik, EURATOM Assoc., Germany*

⁶ *SAIC, San Diego, USA*

⁷ *Euratom/UKAEA Fusion Association, Abingdon, United Kingdom*

Introduction

ITER improved H-mode operation has recently been modelled [1] with self-consistent parameters for the core and edge using the Integrated Core Pedestal SOL Model (ICPS Model [2]) in the 1.5D Astra code. For those simulations, the core energy transport was given by the MMM95 transport model [3], with a transport reduction related to the sparseness of low-order rational surfaces for such flat-q discharges [4]. The stabilisation parameters were adjusted to give reasonable agreement with an improved H-mode discharge in Asdex-UG. The simulation of improved H-modes in JET with the same model then exhibits reasonable agreement at medium heating power [1].

At higher heating power, however, the agreement was not satisfactory: the simulated ion and electron temperatures remained almost equal, in contrast to the experimental result that ion temperature was appreciably higher than electron temperature. In [1], we had speculated that this resulted from the characteristics of the core transport model used (MMM95), since it seemed that hot ion H-modes (without stabilisation) were not well simulated. Accordingly, we have investigated the effect of using a different core transport model (GLF23 [5]), by first attempting to simulate hot-ion H-modes with the different transport models

Description of the simulations

The basis for core energy transport for MMM95 transport is the module from the NTCC website [6] and for GLF transport it is the routine of Kinsey (v1.61, 12-feb-03). Transport is assumed to be stabilized by $E \times B$ velocity shear as described in [2], and also by the effect of magnetic shear, as shown below. The particle transport coefficient is taken as $0.1 (\chi_e + \chi_i)$. The effect of ELM's is represented in a time-averaged sense by limiting the pressure gradient to the ballooning limit [2]. The effect of sawteeth is approximated here by increasing the transport coefficients by a factor of four inside the q=1 surface.

The transport coefficients are thus given by

$$\chi = \chi_{\text{model}} / \left\{ \left[1 + (\omega_{E \times B} / (G \gamma_0))^2 \right] \cdot \max \left(1, (s - t)^2 \right) \right\}$$

where the second factor in curly brackets is the magnetic shear stabilization, and the first represents the $E \times B$ velocity stabilization. For the MMM95 and GLF transport models, the parameters used were $G=0.5$ and $t=0.5$.

For comparison, we have also simulated hot-ion H-modes with the critical gradient (CG) model used previous to the MMM95 simulations described in [2]. This model [7], based on critical gradient expressions from the IFSPPL and RLW models for ions and electrons, gives results similar to those of the MMM95 model.

Hot-ion H-mode simulation

A JET hot-ion H-mode (shot 40305, [8]) has been simulated with the different core transport models. Our previous conclusion that such H-modes are not well represented by MMM transport was based on the parameters obtained in fully-relaxed conditions. In contrast to this, the present simulations are time-dependent and the transient behaviour in the MMM simulation is closer to experiment. For these simulations, the density profile shape was held fixed, corresponding to a typical JET density profile, and was ramped up, along with the heating power, so as to obtain the experimentally measured central density evolution.

The addition of strong beam heating produces a small change of the current profile, resulting in the disappearance of the $q=1$ surface and the associated flattening of the temperature profiles by sawteeth. Two models (MMM95 and GLF) then produce central ion temperatures reasonably similar to those observed; CG is a bit higher. The central electron temperature evolution, however, is best reproduced with the GLF simulation. (Fig.1)

MMM95 energy transport results in electron temperatures appreciably higher than those observed. In contrast, the energy content obtained with the GLF model remains appreciably below that of the experiment, whereas the two other models fit relatively well. Examination of the profiles (fig.2) showed that the discrepancy in energy content may result from the lower pedestal obtained with the GLF model. For comparison, we thus carried out simulations with GLF core transport for which the temperatures near the edge (and thus the pedestal energy content) were forced to be similar to those obtained in the MMM simulation. The discrepancy in energy is then seen to be strongly reduced, albeit at the cost of degrading the comparison of central ion temperature.

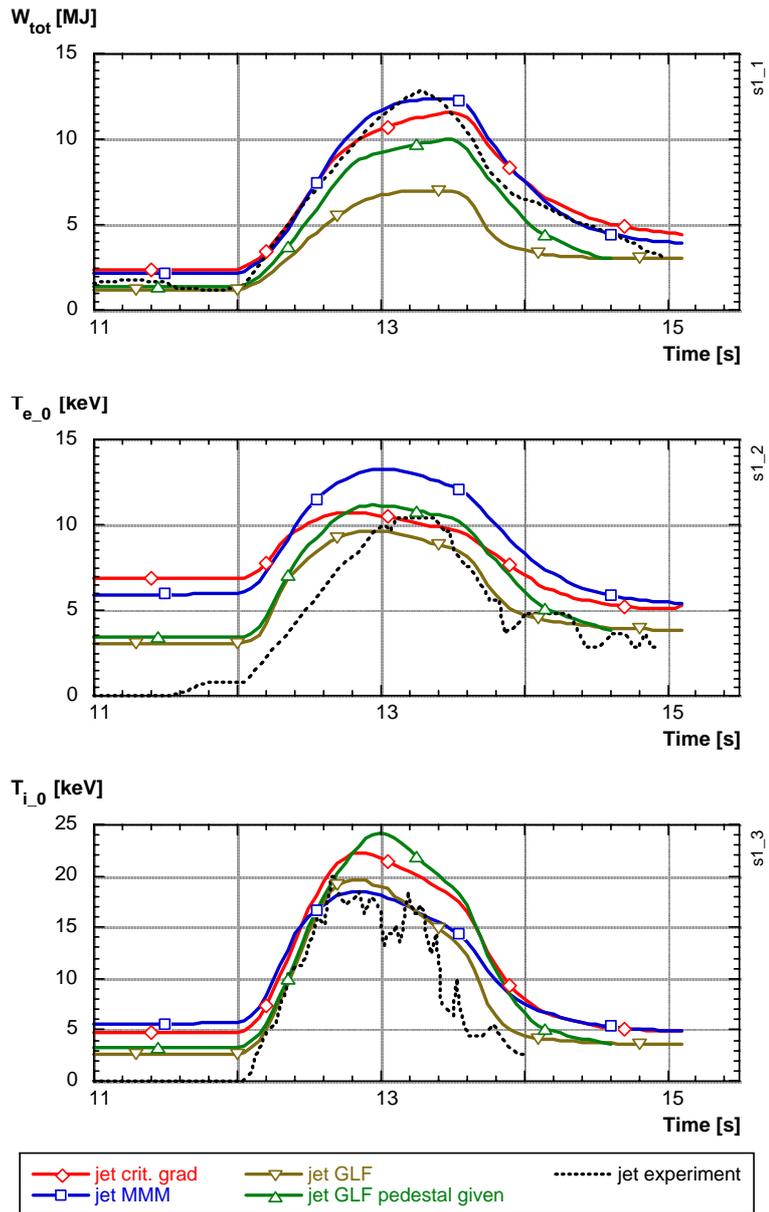


Fig. 1 - Time evolution of energy content and central T_e and T_i for hot-ion H-mode simulation for the following simulations: CG (red), MMM95 (blue), GLF (khaki), and GLF with adjusted edge temperature (green). Experimental curves are black dashed

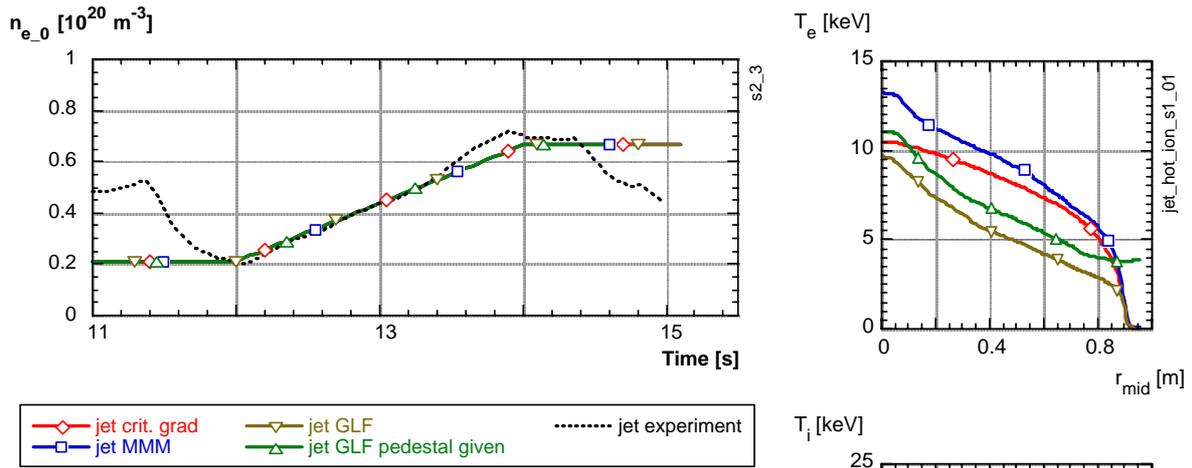


Fig.2 - above - Programmed evolution of central density: right - profiles of electron and ion temperatures obtained with the models at $t=13$ s for the following simulations: CG (red), MMM95 (blue), GLF (khaki), and GLF with adjusted edge temperature (green) .

Simulation of Improved H-mode

For the simulation of improved H-modes, we apply the stabilization function defined in [1],

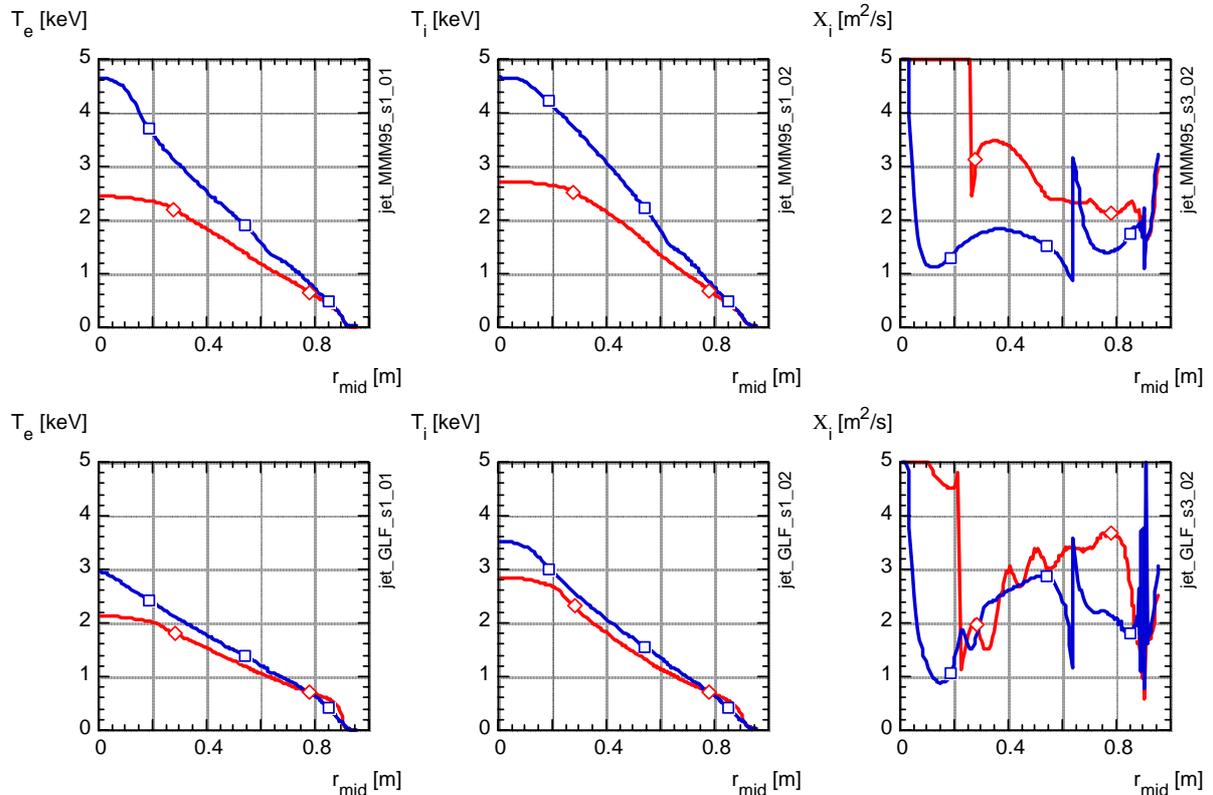


Fig. 3 - Electron and ion temperature profiles and ion energy transport coefficient for JET with MMM95 (top) and GLF (bottom) models (red - normal, blue - flat q profile and IHM improvement inside ~ 0.6 m radius)

which multiplies the transport obtained with the model by 1/5 in the flat q-profile region. Simulations carried out for JET with the two models show (fig. 3) that the confinement improvement obtained with the stabilization function for the MMM model is not found in the GLF simulations because the stiffness of the latter model increases the transport coefficients in such a way as to compensate the reduction due to the stabilization function. A similar effect probably applies near the edge, explaining the lower pedestal obtained for the hot-ion H-mode simulations with the GLF model compared with the other models with the same stabilisation function.

Similarly, for ITER, no notable improvement of net transport with the GLF model is obtained in the region where the stabilization function due to low rational surfaces is active (fig. 4).

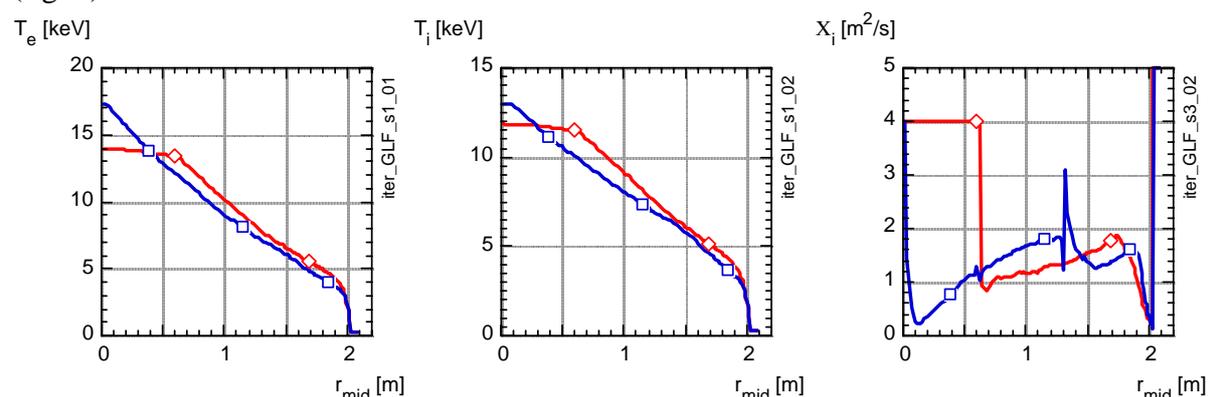


Fig. 4 - Electron and ion temperature profiles and ion energy transport coefficient for ITER with GLF model (red - normal, blue - flat q profile and IHM improvement inside ~1.3 m radius)

Conclusion

A transient hot-ion H-mode shot in JET could be satisfactorily simulated with the MMM95 model when the transient behaviour of the discharge was correctly modelled. The GLF model gave a similar agreement when the pedestal height was adjusted to that obtained in the MMM95 simulation. Improved H-modes could not be simulated with GLF using the same approach as had been employed previously, because the extreme stiffness of the GLF transport model strongly reduced the improvement. Therefore, for the GLF model, both the stabilisation responsible for the pedestal and that yielding the improved H-mode require that stabilisation of the individual unstable modes be implemented, resulting in modified critical gradients.

References

- [1] G.W. Pacher, et al., IAEA-CN-116_ITP3-25, (Proc. 20th IAEA Conf. Vilamoura, 2004), Nucl. Fusion (in press)
- [2] G.W. Pacher, et al., Plasma Phys. Contr. Fus. **46** (2004) A257
- [3] G. Bateman, A.H.Kritz et al., Phys Plasmas **5** (1998) 1793
- [4] I. Voitsekhovitch, et al., Phys. Plasmas **9** (2002) 4671
- [5] R.E. Waltz et al., Phys. Plasmas **4** (1997) 2482
- [6] <http://w3.pppl.gov/NTCC/MMM95/>
- [7] G.W. Pacher, et al., Nucl. Fusion **43** (2003) 188
- [8] R. BALET, et al., 25th EPS Conf. on Contr. Fusion and Plasma Physics, ECA Vol. **22C** (1998) 325-328.