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** See annex of F. Romanelli et al, “Overview of JET Results”,*
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INTRODUCTION

A fully self-consistent predictive simulation of the typical ITER 15MA scenario with Q = 10, which is based on the type-I ELMy H-mode discharge, is performed for the flat top part of the scenario starting from the end of current ramp-up phase using the GLF23 and Bohm/gyroBohm transport model implemented in JINTRAC [1]. This work has a purpose to investigate the characteristic time delay between ITER plasma entering the H-mode after onset of full heating and reaching the burning conditions with Q = 110. Therefore, the sensitivity parametric scans are carried out with the variation of pellet fuelling rate (Γ_{pellet}, dn_e/dt), inward particle pinch (V) and particle diffusivity (D).

1. SIMULATION SET-UP.

The condition of L- to H-mode transition is prescribed using the method, which reduces the heat transport within the edge barrier region to the neoclassical level when the heat flux to the separatrix exceeds the multi-machine experimental power threshold scaling [2]. Two kind of approaches for the description of inherently transient phenomena like pellet ablation and type-I ELM are used: continuous and discrete description. The continuous description [3] is needed in case when we use GLF23 model, which often fails during fast transients. The critical normalised pressure gradient αcr for simulating the type-I ELM is assumed to be a constant with its level consistent with the EPED model prediction [4]. In the pellet simulation, the deposition profile and the injected speed are determined by HPI2 ablation code. They are assumed to be $\rho_{pellet} = 0.85\text{-}0.87$ and $V_{pellet} = 5km/s$, and the cubic 5mm side of ITER fuelling pellet is corresponding to $r_{pellet} = 0.286$ mm in spherical. The wall recycling is set to zero, because the evolution of plasma density in this simulation is limited to the region inside separatrix only and for ITER discharge the cold neutrals should not penetrate through the SOL effectively.

2. SIMULATION SCHEME.

Firstly, the steady state physics-based solution is produced for ITER 15MA H-mode plasma with Q = 10 by applying GLF23 model, continuous ELM model and continuous pellet injection model. The physics-based solution of Q = 10 ITER plasma can be obtained in the conditions of $\Delta_{ETB} = 10cm$, $\alpha_{cr} = 2.0$, $\Gamma_{pellet} = 3.0\times10^{22}\ s^{-1}$, $P_{NBI} = 33MW$ and PRF = 7MW. Then, in order to get similar solution with Bohm/gyroBohm model compared to GLF23 model case, the transport multipliers in Bohm/gyroBohm model are manipulated. This solution obtained by using Bohm/gyroBohm model is going to be the physics-based. Furthermore, it makes the computing time fast and stable in the calculation of ELM and pellet injection. Next, the L-H transition is simulated from ITER L-mode at the end of the current ramp-up to ITER H-mode in the steady state including the dithering phenomena by using Bohm/gyroBohm model, discrete ELM model and discrete pellet injection model. Finally, the sensitivity scans to investigate characteristics of L-H transition are explored how the result changes with the variation of dne/dt and of the magnitude of particle inward pinch (V) and particle diffusivity (D) but keeping the ratio of V and D in same.

3. RESULT AND DISCUSSION.

Figure 1 represents the effect of dne/dt to the characteristic time delay (τdelay) in L-H transition with $P_{NBI} = 33MW$ and $P_{RF} = 20MW$. In this simulation, the pellet fuelling is automatically adjusted by feedback control of volume averaged electron density. In Fig.1, the red line indicates the reference in all simulations and it shows that τdelay is almost 7 seconds. As shown in Fig.1 clearly, the difference of dn_e/de makes the difference of L-H transition characteristics. High dn_e/dt (blue colour in Fig.1) induces long τdelay and it needs more time to achieve steady state W_{th} compared to low dn_e/dt. It is the reason that to reheat/maintain the plasma requires more times for the sudden increased plasma density in the higher dne/dt case. It is also shown in Q_{DT} with similar trend. From this result, characteristic time delay and fusion power increase can be controlled by pellet fuelling speed.

In the purpose of understanding effects of particle diffusivity (D) and particle pinch (V) to the L-H transition, D and V profile are scanned by multiplying some values, but the value of V/D is kept same as 0.6 to make similar electron density profile as possible in steady state. Figure 2 shows not only the variation of (V, D) profiles for the sensitivity scan but also the effect of (V, D) to τ_{delay} in L-H transition. In Fig.2 (a)-(c), the particle diffusivity multiplier is varied from 0.5 to 5.5. At the same time, the particle pinch profile also is varied with 0.6 times of the particle diffusivity profile. From Fig.2 (d)-(g), even in the same value of dne/dt, as increasing the magnitude of (V, D) profiles, τdelay is also increased gradually. It is because the variation of (V, D) makes different pellet fuelling. As shown in Fig.2 (h), the higher value of (V, D), the more pellets are induced to the plasma.

Finally, the combination effect of both dne/dt and (V, D) to the characteristics of L-H transition is investigated. As shown in Fig.3, the higher (V, D) profiles with the higher dn_e/dt are, the longer τ_{delay} presents. In addition, the effect of (V, D) is maximized with the condition of high dn_e/dt in order to make the long τ_{delay}.

SUMMARY

In this work, the fully self-consistent predictive simulation of the typical ITER 15MA scenario with Q=10 is performed for the flat top part of the scenario starting from the end of the current ramp-up phase. Also, the characteristic time delay between ITER plasma entering the H-mode after onset of full heating and reaching the burning conditions (reaching steady state) is investigated with variation of dne/dt and (V, D). Besides, this work show that plasma fuelling by pellet injection is a powerful instrument in controlling the speed of fusion power increase in ITER after L-H transition and the way of plasma evolution towards steady state burn.

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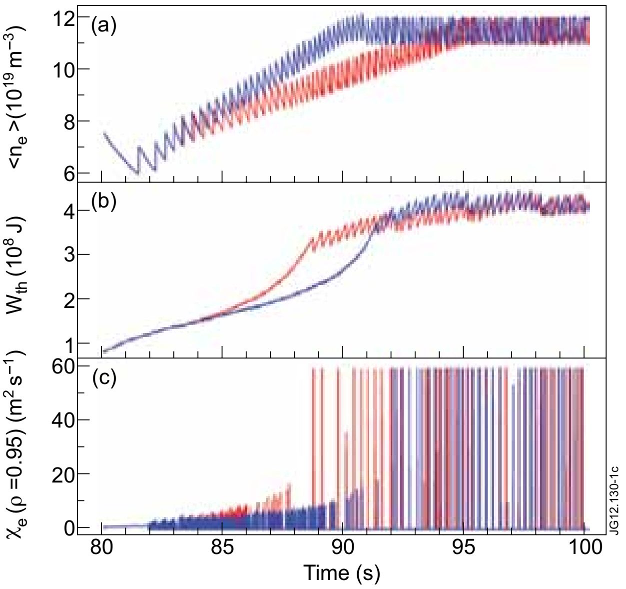

Figure 1. The effect of dne/dt to τdelay in L-H transition. (a) volume averaged electron density, (b) plasma stored energy and (c) electron heat diffusivity in the cases of low dne/dt (red colour) and high dne/dt (blue colour).

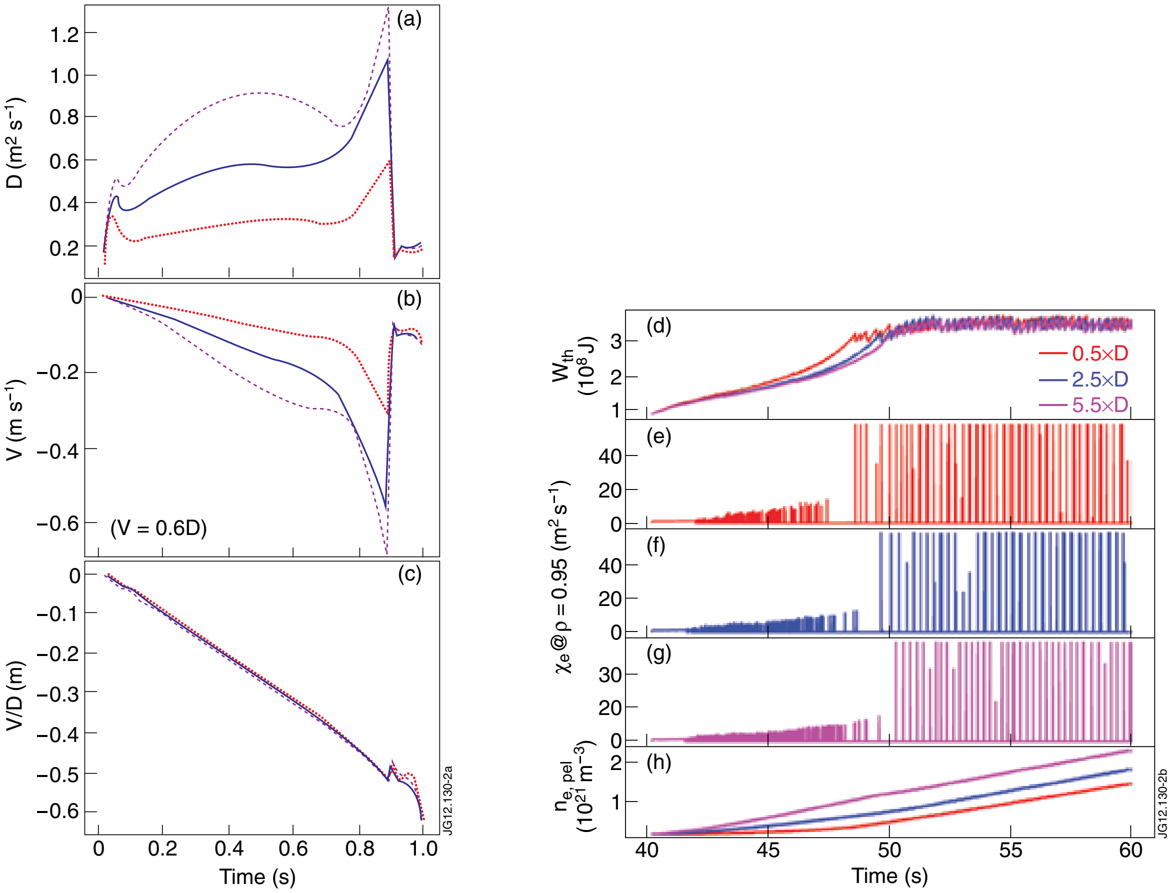

Figure 2. The variation of the particle diffusivity (D) and the particle inward pinch (V) for the sensitivity scan. (a) particle diffusivity, (b) particle inward pinch and (c) ratio of V and D. The effect of (V, D) to τdelay in L-H transition. (d) plasma stored energy, (e)-(g) electron heat diffusivity in each particle diffusivity and (h) total amount of injected pellet particles in the cases of 0.5 time of D case (red colour), 2.5 times of D case (blue colour) and 5.5 times of D case (pink colour).

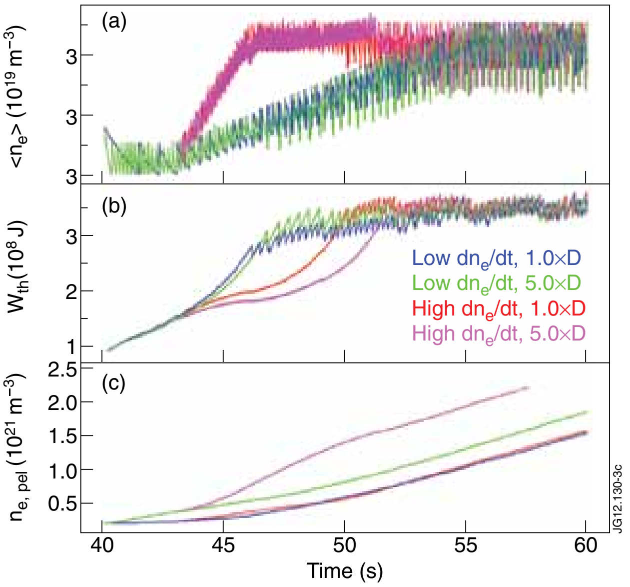

Figure 3. The combination effect of dne/dt and (V, D) to τdelay in L-H transition. (a) volume averaged electron density, (b) plasma stored energy and (c) total amount of injected pellet particles in the cases of low dne/dt with low (V, D) (blue colour), low dne/dt with high (V, D) (green colour), high dne/dt with low (V, D) (red colour) and high dne/dt with (V, D) (pink colour).