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Research on burn control of core plasma with the transport code
輸送コードを用いたコアプラズマ燃焼制御に関する研究

Yuya Miyoshi, Yuichi Ogawa, Makoto Nakamura
三善悠矢[1], 小川雄一[1], 中村誠[2]

[1]Graduate School ofFrontier Science, 5-1-5 Kashiwanoha, Kashiwa-shi, Chiba 277-8568, Japan
[2]Japan Atomic Energy Agency, 2-166 Oaza-Obuchi-Aza-Omotedate, Rokkasyo, Kamikita, Aomori 039-3212
[1]東大新領域 〒277-8568 千葉県柏市柏の葉5-1-5
[2]日本原子力研究開発機構 〒039-3212 青森県上北郡六ヶ所村大字尾駮字表舘2-166

For the fusion reactors or experimental devices, one will be required to control several plasma parameters, like fusion power, heat flux, neutron flux, beta-value and so on. To control these parameters, many diagnostics and actuators are needed, but in Demo reactors or commercial reactors, the attachable diagnostics and actuators are limited because of the high heat or neutron flux. For these reasons, to realize the fusion reactors, the construction of the reactor control logic is required. We are developing the burn control logic in the core plasma with a 1.5D transport code. In this article, we introduce the simulation results on the control of the fusion power and the safety factor profile with the gas-puff and NBI.

1. Introduction

To operate the fusion reactors or fusion experimental devices, controlling many plasma parameters is required. One is required to keep the plasma density, temperature, fusion power, presser, etc to the target value with taking many constraints like the limitation of the heat flux into account. For satisfying this requirement, the combination of the diagnostics and actuators is very important. It is, therefore, required to identify the ideal combination of diagnostics and actuators and to construct the control logic [1-3].

In our research, the simulation of core plasma control has been developed. The analysis of the plasma shape, position and vertical instability is shown in ref.4. In this article, we will introduce the core plasma control simulation. Similar analyses are done in some researchers; e.g., the current drive simulation with the measurement of current profile peaking factor[5], the current drive and control simulation in ITER[6,7], the density profile control analysis in ASDEX[8], and plasma burn control simulation in JT-60U[9]. In most of these researches, they control one parameter with one actuator. For the future reactors, however, controlling multiplex parameters with multiplex actuators is needed. To do this, one must take the interaction between the actuators into account. In this article, we will show the control simulation of the fusion power and safety factor profile with gas-puff and NBI for the ITER like plasma, aiming to achieve Q>5.

2. Fusion power control

The simulation is done with 1.5D transport code. We control the fusion power with PID gas-puff control. Here we adopt the ITER steady-state operation mode. The main input parameters are as follows:

Rp=6.3m, ap=1.75m, κ=1.8, δ=0.4
Ip=9MA, Bt=4.76T,
$Pnbi$=70MW, $Enbi$=1MeV,

where Rp, ap, κ, δ are the plasma major radius, minor radius, elongation, triangularity, respectively, and Ip, Bt, $Pnbi$, $Enbi$ are the plasma current, the toroidal magnetic field, the power of NBI, the energy of NBI, respectively. The transport coefficients are below.

$D_j=0.02/n_e(10^{20}m^{-3})$
$\chi_j=0.08T_e(kev)/n_e(10^{20}m^{-3})$

The simulation result is shown in Fig. 1 and 2.

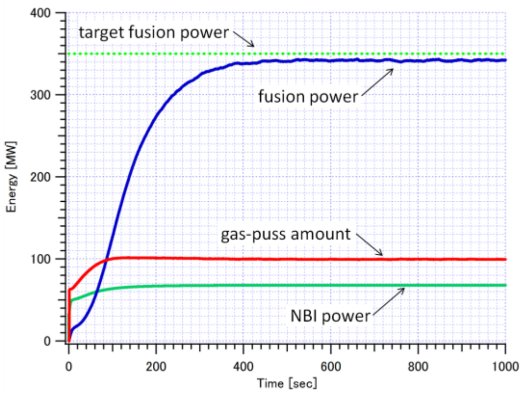

Fig 1. The blue, red and green solid lines are fusion power, gas-puff amount and NBI power respectively, and green dashed line is target fusion power.

Figure 1 shows the control of burning plasma with the fusion power of about 350MW. Since the NBI power is 70 MW, the achievement of Q > 5 plasma is demonstrated. Figure 2 shows the minimum q-value and its location. Since the location of the minimum q-value is in the region of r/a = 0.45, the reversed shear profile is observed. In addition, it is identified that the safety factor becomes less than 1.5 between 60 sec and 180sec. It seems that some current control is needed to avoid this instability.

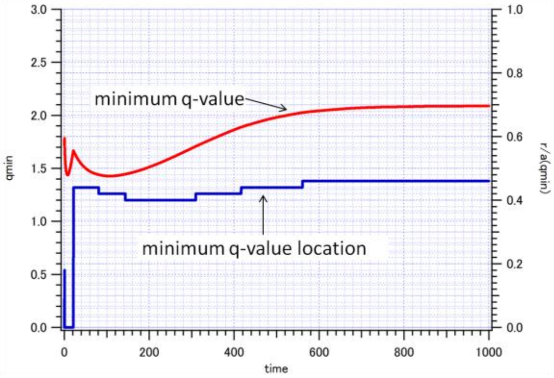

Fig 2. The red line and blue line are minimum q-value and r/a where q-value is minimum

3. Combination control

To avoid safety factor q<1.5, we increase NBI power to 85MW, and decrease to 70MW slowly. The simulation results are shown in Figs. 3 and 4.

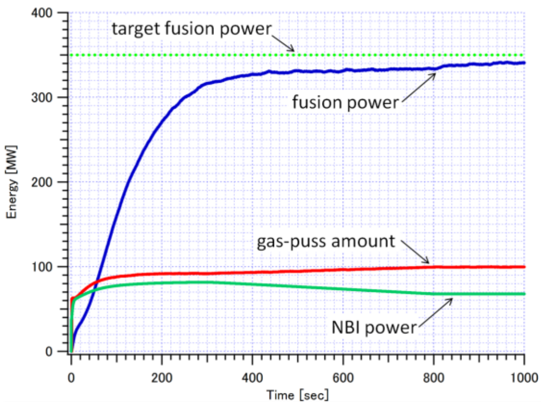

Fig. 3. The blue, red and green solid lines are fusion power, gas-puff amount and NBI power respectively, and green dashed line is target fusion power.

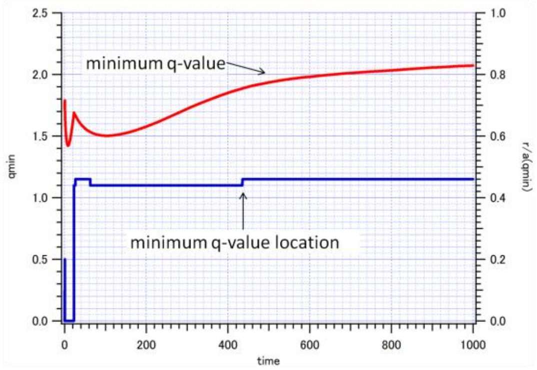

Fig. 4. The red line and blue line are minimum q-value and r/a where q-value is minimum

Figure 4 shows q>1.5 after 30 sec, and it means avoiding instability. At the same time, in Fig. 3, fusion power is maintained constantly because gas-puff feedback is faster than NBI decrease. Then, Q>5 is achieved without instability.

4. Summary and discussion

For the future reactors, the control of many plasma parameters is indispensable. To satisfy this requirement, the construction of the ideal control logic with the combination of the multiplex diagnostics and the multiplex actuators is needed. In this article, we show the example of the combination control simulation. We control the fusion power and the safety factor with gas-puff and NBI. The fusion power is controlled by gas-puff with the PID logic. Then, 85MW NBI is injected to avoid safety factor q<1.5 and controlled to 70MW slowly, then we achieve Q>5. This result shows the possibility that the large NBI power is needed only in startup phase.

In this simulation, we assumed the ITER steady-state operation mode. The analysis of the Demo reactors or the commercial reactors is future work. More detailed discussion of the diagnostics is also needed. The extrapolation of the diagnostics of the neutron will be available in demo or commercial reactor, but plasma current or current profile measurement will be difficult.

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