§4. Study on the Characteristics of Ignition Access to the Density and Temperature Profile Variation in FFHR

Mitarai, O., Takahashi, M. (Tokai Univ., Kumamoto), Matsuura, H. (Kyushu Univ.), Oda, A. (Yatsushiro National College of Technology), Sagara, A., Sakamoto, R., Imagawa, S., Goto, T., Yanagi, N.

i) Introduction

Ignition analysis of FFHR helical demo-reactor has been conducted on the thermally unstable high-density and low temperature ignition regime. The density and temperature profiles are fixed in the previous analysis. Therefore, the density profile is totally lifted up and the temperature profile is lifted down during the pellet injection phase. In this annual report, we describe the local density and temperature change due to pellet injection and its effect on ignition analysis in the high-density and low temperature regime.

ii) Case of total profile change

In 0-D analysis, density deposition profile during the pellet injection is assumed to be similar shape to the original profile. Temperature profile is lifted down with the same profile. Density profile factor of $\alpha_n = 3$ and temperature profile factor of $\alpha_T = 1$ are assumed. For total number of particle $n_{pel} = 82 \times 10^{21}$ in the pellet with 12mm diameter, the density increment is $\Delta n = 1.69 \times 10^{20}$ m^{-3}. Density and temperature profile changes are given by

$$\begin{cases} n(\rho)/n(0) = \left(1+\Delta n/n(0)\right)\left(1-\rho^2\right)^{\alpha_n} \\ T(\rho)/T(0) = \left(1-\Delta n/n(0)\right)\left(1-\rho^2\right)^{\alpha_T} \end{cases} \quad (1)$$

where $\rho = r/a$. Coefficients of bremsstrahlung and alpha heating power, which are normalized by their peak values, are

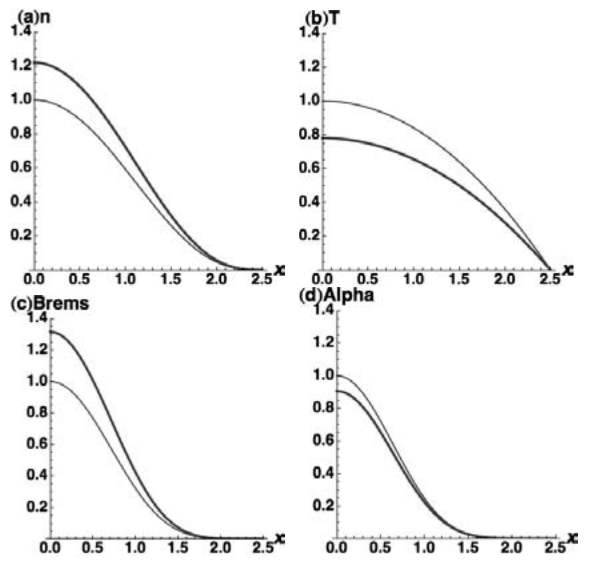

Fig.1 (a) Density (b) Temperature, (c) Bremsstrahlung loss, and (d) Alpha heating profile (Thin line: before injection, Thick line: After injection)

$$\begin{cases} A_b = \left(1+\Delta n/n(0)\right)^2 \sqrt{\left(1-\Delta n/n(0)\right)} / \left(1+2\alpha_n+0.5\alpha_T\right) \\ A_\alpha = \left(1+\Delta n/n(0)\right)^2 \left(1-\Delta n/n(0)\right)^2 / \left(1+2\alpha_n+2\alpha_T\right) \end{cases} \quad (2)$$

For above parameters, they change from $A_b = 0.133$ to 0.166 and $A_\alpha = 0.111$ to 0.105. As shown in Fig.1, Bremsstrahlung loss increases and alpha heating power decreases. As a result, ignition regime is narrowed.

iii) Case of local density profile change

When the pellet is evaporated in the plasma, for example, as shown in Fig.2 at $x_{dep} = 1.2$m with the Gaussian profile having the width $\Delta_{dep} = 0.2$m, the density increment is

$$\begin{cases} n(\rho)/n(0) = \left(1-\rho^2\right)^{\alpha_n} + \Delta n/n(0)\exp\left\{-\left(x-x_{dep}\right)^2/2\Delta_{pel}^2\right\} \\ T(\rho)/T(0) = \left(1-\rho^2\right)^{\alpha_T} - \Delta n/n(0)\exp\left\{-\left(x-x_{dep}\right)^2/2\Delta_{pel}^2\right\}\left(1-\rho^2\right)^{\alpha_T-\alpha_n} \end{cases} \quad (3)$$

$\Delta n = 2.2 \times 10^{20}$ m^{-3}.

Coefficients of Bremsstrahlung and alpha heating power, which are normalized by their peak values, are

$$\begin{cases} \langle A_b \rangle = \int_0^1 \{n(\rho)/n(0)\}^2 \sqrt{T(\rho)/T(0)}\left(2\rho d\rho\right) \\ \langle A_\alpha \rangle = \int_0^1 \{n(\rho)/n(0)\}^2 \{T(\rho)/T(0)\}^2 \left(2\rho d\rho\right) \end{cases} \quad (4)$$

For above parameters, by numerical integration, these values are $\langle A_b \rangle = 0.151$, and $\langle A_\alpha \rangle = 0.105$. While increment of the bremsstrahlung is smaller than the total profile change, the decrease in alpha heating power is almost the same. Therefore, the ignition regime is not so narrowed compared to the total profile change. Therefore, it is inferred that 0-dimensional analysis treats the worst case.

However, final conclusion should be made upon the time dependent numerical integration on the fine profile change in the time dependent calculation.

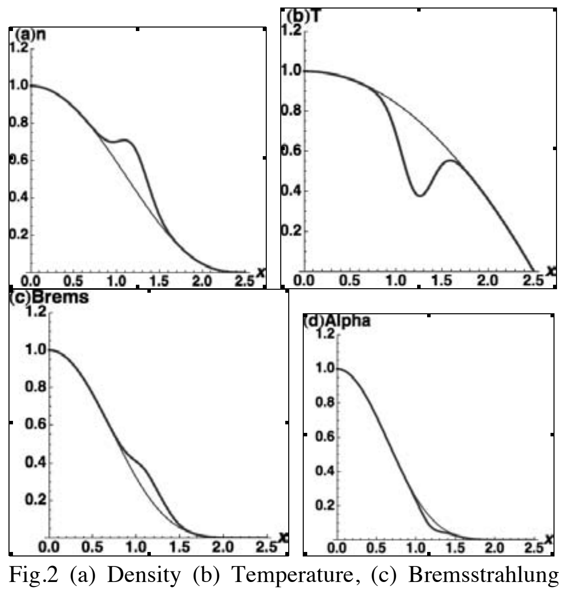

Fig.2 (a) Density (b) Temperature, (c) Bremsstrahlung loss, and (d) Alpha heating profile (Thin line: before pellet injection, Thick line: After pellet injection)

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