§22. Tail Effects on D-^{3}He/FRC Startup

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An intense neutral beam injected into a plasma creates a tail (i.e. non-Maxwellian component) in distribution function of the same species as the one injected with enhacing (or reducing) fusion reactivities from the values for Maxwellian plasmas[1,2]. An optimal D-^{3}He plasma startup scenario , to bring the plasma up to the operating temperature by lower input power as much as possible , is investigated[3] in field reversed configuration (FRC)[4] , in consideration of tail creation in fuel-ion distibution functions.

A D-^{3}He/FRC startup due to deuterium beam injection heating is simulated by simultaneously solving the plasma power , density , pressure and trapped field balance equations , together with the Fokker-Planck equations.

A typical magnetic field profile $B(r)$ in FRC equilibrium can be expressed , for example , by using the following equation :

$$B(r) = -\mathrm{sign}(1 - \frac{2r^2}{r_s^2})B_e|1 - \frac{2r^2}{r_s^2}|^{\nu}, \tag{1}$$

and then trapped magnetic flux ϕ is written as :

$$\phi = \pi r_s^2 B_e \frac{1}{2(\nu + 1)}, \tag{2}$$

where $\nu = (2 - x_s^2)/2x_s^2$, plasma radius r_s is normalized to coil radius r_c , i.e. $x_s = r_s/r_c$. B_e represents external magnetic field. From the plasma pressure and trapped field balances we can derive the following equations to calculate temporal behaviors of plasma length l_s and normalized radius x_s.

$$\frac{\dot{l}_s}{l_s} = \frac{\dot{W}}{W} - 2\frac{\dot{B}_e}{B_e} - \frac{4(1 - x_s^2)}{2 - x_s^2}\frac{\dot{x}_s}{x_s}, \tag{3}$$

$$\frac{\dot{x}_s}{x_s} = \frac{2 + x_s^2}{2(4 + x_s^2)}\left[\frac{\dot{\phi}}{\phi} - \frac{\dot{B}_e}{B_e}\right], \tag{4}$$

where $W = \frac{3}{2}\sum_j n_j T$,

$$\dot{W} = P_{\mathrm{NBI}} + P_{\mathrm{f}} - P_{\mathrm{syn}} - P_{\mathrm{blems}} - \frac{W}{\tau_{\mathrm{E}}}. \tag{5}$$

Here P_{NBI} , P_{f} , P_{syn} and P_{blems} are , respectively , the NBI input power , the rates of energy deposition by fusion produced ions , synchrotron radiation power loss , and , bremsstrahlung power loss.

The velocity distribution functions for deuterons and tritons are determined by solving the Fokker-Planck equations[5].

Throughout the calculations , the classical confinement scaling is assumed. The beam injection energy E_{NBI} is determined so that its penetration length becomes less than plasma radius.

Owing to the deuterium beam injection , initial plasma (T=3keV) is heated to ignition (T=83.5keV) in 50 sec. Figure 1 illustrates the optimal startup scenario for both Maxwellian and tail-created plasma in n-T diagram. When Maxwellian plasma is assumed , a startup keeping the plasma density lower during initial heating phase has more advantages to reduce the NBI heating power. This is because we can get higher values of both confinement time and reactivities , as a result of rapid rise of plasma temperature. On the other hand , when the tail effect is considered , plasma density during initial phase should be kept higher. Although plasma temperature takes lower values during initial phase , higher reactivity can be expected as a result of tail effect. Furthermore high-density startup causes higher reaction rate (fusion power) to heat the plasma.

In Maxwellian plasma , at least 110 MW of P_{NBI} is required to stably bring the plasma up to the operating temperature. As a result of tail formation , the required P_{NBI} is reduced to 40 MW ; a reduction of 64 % from the Maxwellian value.

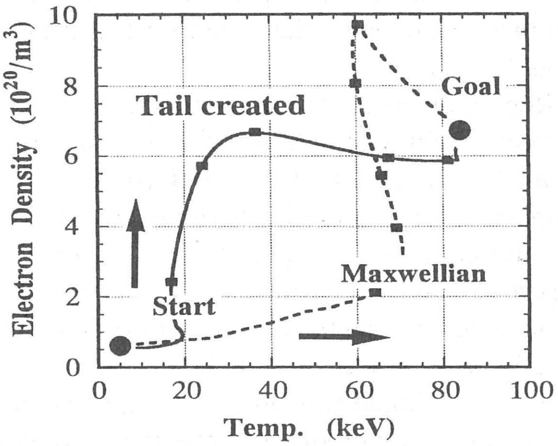

Fig. 1. Optimal Startup Scienarios for Maxwellian and tail-created plasmas.

References

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