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JT-60SAにおけるEC補助加熱によるプラズマ着火に関する1次元輸送解析
1-D Analysis of ECRH Assisted Plasma Start-up in JT-60SA

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There is considerable interest in plasma start-up assisted by electron cyclotron resonance heating (ECRH) in superconducting tokamaks, because, in general, available loop voltage is low compared with conventional normal-conducting tokamaks. On JT-60SA superconducting tokamak (R_0 = 2.96 m, a = 1.18 m, B_T = 2.25 T), a 7 MW ECRH system is equipped for heating and current drive as well as for plasma start-up. The main purposes are to clarify the dominant physical process in the start-up phase and to examine the conditions for the reliable start-up. We have previously studied the plasma start-up using a zero-dimensional model [1], which is solved on the assumption of spatially uniform plasma. The calculation using JT-60U parameters qualitatively reproduced the time evolution of the experimental results. In order to include the radial transport and consider the localized ECRH power deposition profile (including the ECRH absorption efficiency), we are developing a one-dimensional model. This model consists of energy transport equations for electron and ion, particle transport equations for electron and deuterium atom, and the toroidal current equation. Figure 1 shows the time evolution of electron density and temperature at ρ = 0 and power densities of electron energy source and sink terms at ρ = 0. The Ohmic heating (OH) is turned on at t = 0.00 s and then the electron density starts to gradually increase. These electrons are additionally heated by on-axis injection of EC wave of 1 MW (2nd harmonic X-mode) from t = 0.01 s, where its absorbed power is consumed in the ionization of deuterium atom, and therefore the ionization is the dominant loss. From $t \approx 0.04$ s, the electron temperature promptly increases since EC wave absorption becomes more efficient by an increase of the electron density, where error field and drift are the dominant losses. Then, the electron temperature reaches a steady state value form $t \approx 0.06$ s, where thermal conduction is the dominant loss. Figure 2 shows a dependence of electron temperature (ρ = 0.5, t = 0.15 s) on the *injected* ECRH power and error field B_{err}. This calculation shows that (1) the threshold ECRH power for plasma start-up is observed, (2) the ECRH power of around 1 MW is required to start up the plasma for $n_D = 3.0 \times 10^{18}$ m^{-3}, error field B_{err} of about 1 mT and EC beam radius of about 5 cm, and (3) the threshold ECRH power increases with error field (B_{err} up to around 7 mT).

[1] K. Hada *et al.*, Plasma Fusion Res. **7**, 2403104 (2012)

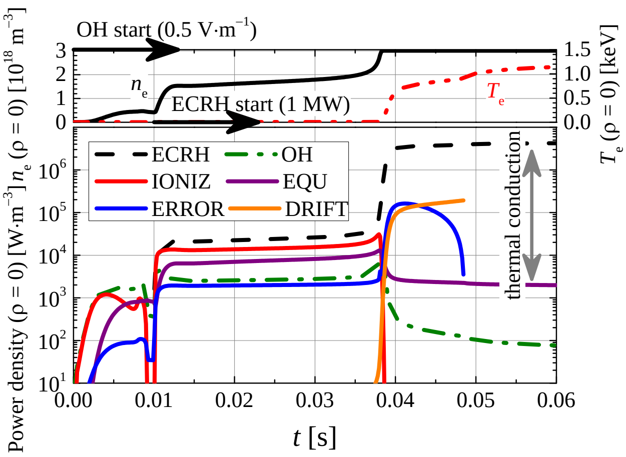

Fig. 1 Time evolution of electron density and temperature at ρ = 0 and power densities of electron energy source and sink terms at ρ = 0. n_D (t = 0) = 3.0×10^{18} m^{-3}. B_{err} = 1.0 mT.

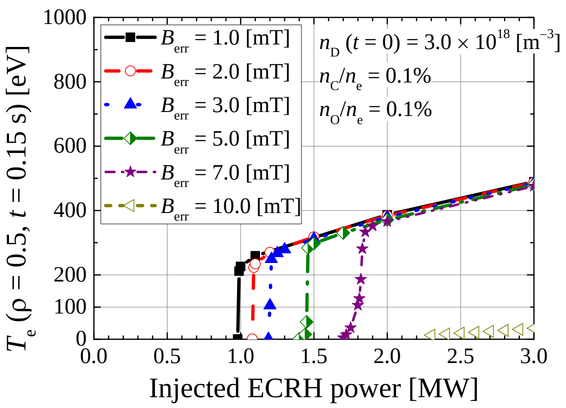

Fig. 2 Dependence of electron temperature (ρ = 0.5, t = 0.15 s) on injected ECRH power and B_{err}.