Stellarator Plasma Start-up Model Based on Energy Confinement Time Scaling Laws, Experimental Verification and Numerical Simulation Results

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Based on the energy confinement time scaling law of stellarator [1], combined with energy balance equation and the TRAVIS ray tracing code [2-3], a new zero-dimensional start-up model including electron cyclotron resonance heating (ECRH) and impurity line radiation power loss is established for stellarator plasmas in this paper.

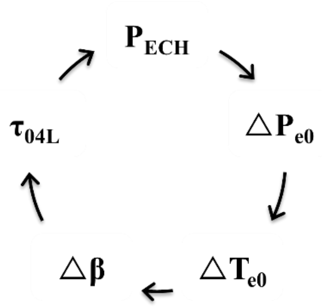

Fig1. Start-up model for stellarator plasmas

The model is verified against experimental results of W7-X stellarator [4-5], the temporal evolution of both electron temperature and radiation power loss exhibits close agreement with experimental measurements, which verified that the model can correctly give the plasma start-up results of the stellarator under ECRH.

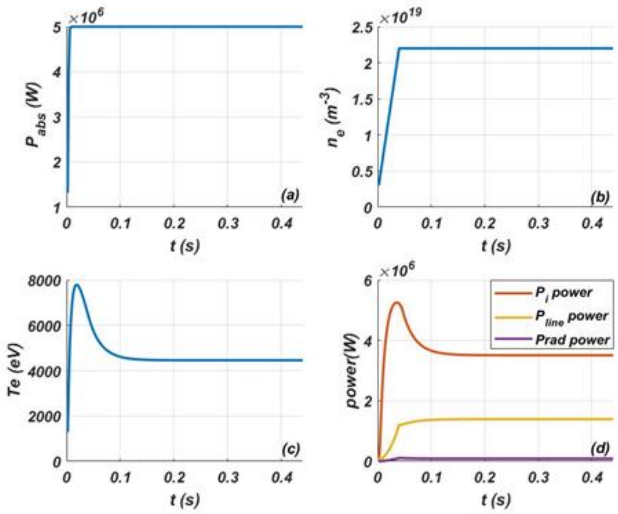

Fig2. Simulation results provided by the model under the experimental parameters of W7-X stellarator. (a) Temporal evolution of ECRH power absorption, (b) temporal evolution of electron density, (c) temporal evolution of electron temperature and (d) Temporal evolution of radiation power and diffusive power.

This model is used to predict the results of plasma start-up under 28 GHz ECRH for CN-H1 stellarator [6] which is currently being restored and reconstructed by University of South China using the disassembled components of the H1-NF stellarator [7] in the Australian National University. The effects of the electron-to-ion temperature ratio (T_e/T_i), ECRH injection power (P_0), ECRH power deposition position, and impurity concentrations (carbon and iron) on start-up are systematically studied and analyzed. Under the condition of T_e/T_i=1, P_0=200 kW with core-localized ECRH deposition, 1% carbon and 0.1% iron impurities, the plasma startup is successful, and the ECRH power absorption efficiency quickly ramp-up to 94.8%. When the plasma density ramp-up to 2×10^{18} m^{-3}, the electron temperature could reach 373.3eV, and peak impurity line radiation power is 1.1 kW.

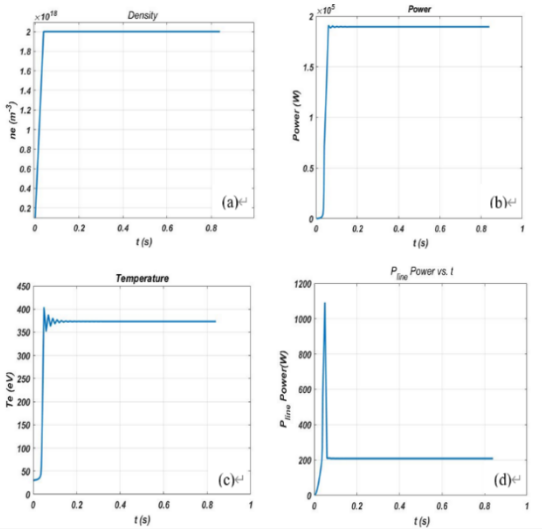

Fig3. Start-up results for CN-H1 stellarator predicted by the model under 28 GHz ECRH. (a) Temporal evolution of electron density, (b) ECRH power absorption, (c) electron temperature and (d) impuraty line radiation power.

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