Effect of Multi-Pass Absorption of Electron Cyclotron Heating Wave on Initial Stage of Discharge in ITER-like Tokamak

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1. Introduction

- Due to technological issues the ohmic plasma breakdown in tokamak-reactor ITER is only possible over a narrow range of plasma pressure and magnetic field errors [Lloyd B., Plasma Phys. Controlled Fusion, 1996].
- For the reliable plasma start-up in ITER it is planned to use electron cyclotron resonance heating (ECH, ECH-assisted start-up) [Ono T., Fusion Eng. Des., 2011]. The ECH is a standard way for plasma start-up in tokamaks and already showed to be an effective method for plasma breakdown in tokamaks [Stober J., Nucl. Fusion, 2011].
- Modelling of the initial stage of plasma discharge in ITER with the OD model [Lloyd B., Plasma Phys. Controlled Fusion, 1996] showed that in a wide range of initial conditions, taking into account beryllium impurities, the 3 MW of absorbed external EC radiation is needed to achieve the plasma breakdown (the carbon impurities even 5 MW of absorbed power is not enough). However, in [Lloyd B., Plasma Phys. Controlled Fusion, 1996] the efficiency of EC absorption was not calculated.

2. ECRH in ITER

The main functions of the ITER ECH&CD system are as follows [Ono T., et al., Fusion Eng. Des., 2011]:
1. ECH-assisted plasma start-up: assistance to initial breakdown and the heating during the current ramp-up.
2. Auxiliary heating to achieve the H mode and the fusion energy gain factor Q = 10.
4. MHD instabilities control by the localized current drive.

3. Modelling of ECHR


5. Multi-pass absorption of EC radiation

- Multiple reflection of the EC wave from the wall of the vacuum chamber.
- Isotropy/uniformity of the injected EC radiation intensity in plasma (semi-analytical solution of radiative transfer problem for the case of multiple reflection of radiation from the wall)
- We use the OGRAY scaling for single pass absorption of injected EC wave (O-mode) and the above model for multi-pass absorption after first reflection of EC wave from the wall. EC mode mixing in wall reflections.

6. Main Results

Parametric analysis of the efficiency of multi-pass absorption of injected EC radiation for typical values of the electron temperature and density at the initial stage of discharge in ITER-like tokamak.

CONCLUSIONS

- A model is suggested for calculating the efficiency of absorption of external EC power, νECCH, in tokamaks at initial stage of discharge. Results are given for ITER initial stage of discharge for the case:
  (a) multiple reflection of injected EC wave (O-mode) from the wall;
  (b) polarization scrambling in wall reflections;
  (c) full single-pass absorption of the X-mode.
- Parametric analysis for typical values of the electron temperature and density at the initial stage of discharge in ITER shows strong dependence of νECCH on the O-X conversion in wall reflections
- The proposed model of multi-pass absorption of ECH in tokamak-reactors is incorporated in DINA code for self-consistent simulation of plasma ECH-assisted plasma start-up scenarios in tokamak-reactors

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