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Study of Resonance Helical Field on the Z_{eff} and Impurity Radiation in IR-T1 Tokamak

A. Hojabri[1], F. Hajakbari[1, 2], M. Mahmoodi Darian[1, 2], M. K. Salem[2], M Ghoranneviss[2]

[1]Physics Group, Islamic Azad University, Karaj Branch, Iran.

[2]Plasma Physics Research Center, Islamic Azad University

Science and Research Campus,Tehran, Iran.

The RHF in tokamak is an external magnetic field which can improve the plasma confinement. This field is produced by conductors wound externally around the tokamak torus with a given helicity. In IR-T1, RHF is generated by two of helical coils installed outside the vacuum vessel. The pulsed dc RHF configuration $(\ell = 2,3)$ has the optimal current and variable time. The magnitude of the weak RHFs used in our experiments did not exceed 1% of Bp. The RHFs was not effective in high Z_{eff} discharges. The RHFs could reduce energy and particle losses. The aim that is followed in this article is to understand the effect of RHF on the Z_{eff} in addition to influence on the control of plasma. Probably the RHF produces a fixed helical structure with in the plasma which hinders a rotation of the MHD modes and also there with a convective growth of the perturbation [1]. Since the facts of how RHF can affect on plasma control, is not clear, so it seems to be difficult to understand how RHF can impress Z_{eff}. To investigate this effect, in this article we will outline the calculation of Z_{eff} value through anomaly factor by RHF and without RHF.

The anomaly factor α is defined as the ratio of the measured plasma resistivity η_p to the theoretical resistivity η_{11} predicted by spitzer, for pure hydrogen plasma [2]. The spitzer resistivity is $\eta_{11} = 5.24 \times 10^{-5} \frac{Z \ln \Lambda}{T_e^{3/2}} (\Omega \cdot m)$, Where Z is the ion atomic mass, lnΛ is the coulomb logarithm and T_e is the electron temperature in eV. For the estimation of the electron temperature it was necessary to perform experimental measurements of plasma current, loop voltage and electron density and to take into account the geometrical parameters of IR-T1 tokamak. The coulomb logarithm is $\Lambda = 1.5492\times10^{13}\dfrac{T_e^{3/2}}{Z^2\sqrt{\bar{n}_e}}$,Where $\bar{n}_e$ is the average plasma density in m^{-3}. The electron temperature is calculated according to the energy balance equation for a tokamak discharge: $T_e = \dfrac{I_p V_\ell T_E}{2k\pi^2 R_r^2 \bar{n}_e}$, Where I_p is the plasma current is A, V_ℓ is the loop voltage in V, T_E is the energy confinement time in s, k is the Boltzman constant, R and r are the IR-T1 major and minor radii in m. for ohmic heating, plasma which is not too dense, the energy confinement time is given as $T_E = 7\times10^{-22}\bar{n}_e r R^2 q$,Where q is the safety factor which is given as $q = 5\times10^6\dfrac{B_T r^2}{I_p R}$,Where B_T is the toroidal magnetic field in tokamak. The values of q, T_E, lnΛ, T_e , η_{11} and η_p, for the IR-T1 tokamak were calculated from experimental data as bellow: $I_p = 30kA,\quad V_\ell = 1.5V,\quad n_e = 1.1\times10^{13}\ cm^{-3},\quad B_T = 0.6\,T$ The geometrical parameters of the IR-T1 tokamak are: R= 45 cm, r = 12.5 cm. Thus, the resulting values are: $q = 3.47$, $T_E = 0.7\,ms$, $T_e = 129\ eV$, $\Lambda = 6.9\times10^6$, $\ln\Lambda = 15.75$, For hydrogen plasma in the IR-T1 tokamak (Z=1) the spitzer resistivity is $\eta_{11} = 0.56\times10^{-6}\quad(\Omega m)$,For Ohmic input power, the plasma resistivity is given by $\eta_p = \dfrac{r^2 V_\ell}{2RI_p}$,value of η_p for IR-T1 tokamak is equal with 0.86×10^{-6} and because we have defined Z_{eff} as the ratio of the measured plasma resistivity η_p to the theoretical resistivity η_{11}, the value of Z_{eff} for the IR-T1 tokamak is 1.5 . When RHF is on, the experimental and theoretical results [3] show no Change in the main field components, toroidal. Since the toroidal component mains constant, we expect that the Z_{eff} value will be unchanged through anomaly factor but experimental results show, although I_p and B_T value is unchanged but remarkable change is seen on the value of n_e and T_e. To provide these changes in anomaly factor, there is noticeable decrease at Z_{eff}. Keeping previous experimental conditions, following results are given:

$n_e = 1.6 \times 10^{13}\, cm^{-3}$, $q = 3.47$, $T_E = 0.98\ ms$, $T_e = 99.5\ eV$

$\Lambda = 3.8 \times 10^6$, $\ln \Lambda = 15.15$, $\eta_{11} = 0.86 \times 10^{-6}$, $\eta_p = 0.86 \times 10^{-6}$ and $Z_{eff} = \dfrac{\eta_p}{\eta_{11}} = 1.075$

References

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