Electron Temperature

The plasma current density is given by relation

$$j = E\sigma \tag{1}$$

where σ is the specific conductivity of plasma given by

$$\sigma(r) = 1.544 \cdot 10^3 \frac{T_e(r)^{3/2}}{Z_{eff}} \tag{2}$$

and E is the electric field, which we assumed constant in the poloidal cross-section of plasma:

$$E = \frac{U_{loop}}{2\pi R} \tag{3}$$

The total plasma current is obtained by integration of current density over the plasma cross-section:

$$I_{pl} = \int_0^a E\sigma(r) 2\pi r \, \mathrm{d}r \tag{4}$$

where a is the distance from the centre to the edge of the plasma. Using (2), (3) and (4) we obtained

$$I_{pl} = \int_0^a \frac{U_{loop}}{2\pi R} 1.544 \cdot 10^3 \frac{T_e(r)^{3/2}}{Z_{eff}} 2\pi r \, \mathrm{d}r = \frac{U_{loop}}{2\pi R} 1.544 \cdot 10^3 \frac{2\pi}{Z_{eff}} \int_0^a T_e(r)^{3/2} r \, \mathrm{d}r \tag{5}$$

If we assume a parabolical profile with the peaking factor ν=2 for the electron temperature

$$T_e(r) = T_e(0) \left(1 - \frac{r^2}{a^2}\right)^{\nu} \tag{6}$$

then the integral in (5) could be written as

$$\int_0^a T_e(0)^{3/2} \left(1 - \frac{r^2}{a^2}\right)^3 2\pi r \, \mathrm{d}r = 2\pi T_e(0)^{3/2} \frac{a^2}{8} \tag{7}$$

It is possible to express the electron temperature in the center of plasma after the substitution (6) into (5) as

$$T_e(0) = \left(\frac{8RZ_{eff}}{1.544 \cdot 10^3 a^2}\right)^{2/3} \left(\frac{I_{pl}}{U_{loop}}\right)^{2/3} \tag{8}$$

We consider a=78mm for the tokamak GOLEM geometry (plasma shift is 7 mm downwards from magnetic axis) and the effective ion charge Z_{eff}=2,5. The final equation for the central electron temperature is given by

$$T_e(0) = 89,8 \left(\frac{I_{pl}[kA]}{U_{loop}}\right)^{2/3} \tag{9}$$

The equation 9[1] is used in the program `ElectronTemperatureTime.pl` for the evaluation of the central electron temperature in each time step. The evaluated data are saved in files `ElectronTemperatureTime.txt`(dot point) and `ElectronTemperatureTimecp.txt`(comma point) and plotted in graphs `ElectronTemperatureTime.eps` and `ElectronTemperatureTime.png`.

[1]There were used following assumptions in derivation: the electron temperature has a parabolic shape with the peak factor ν=2, the plasma position (from which is derived the plasma cross-section) is not calculated from the data from Mirnov coils but is set fixed, as well as the effective ion charge which is estimated

References

[1] BROTÁNKOVÁ, J. *Study of high temperature plasma in tokamak-like experimental devices*, Disertation theses, Charles University in Prague, Faculty of Mathematics and Physics, 2009