Modification of the canonical profiles transport model based on new DIII-D experimments

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Recent DIII-D experiments have shown that the stiffness of ion temperature profile *i* increases by order of magnitude along the radius in the region 0.4 <  < 0.7 [1]. In the region  < 0.4 the stiffness is small and the ion temperature profile is “soft”. The stiffness of profile also increases, when the toroidal rotation is retarded. Authors of [1] defined dependencies of ion heat fluxes on the gradient of ion temperature in four radial points with various heating power. Combination of Co- and Counter- NBI heating allowed them to perform measurements with different rates of toroidal rotation, and to find radial dependencies of *i* with fast and slow rotation. Results of the report [1] are background of presented work.

The profiles of safety factor *q*() presented in [1] everywhere have *q*() > 1. For discharges with fast rotation of the plasma core, the *q*() profile is monotonic and slightly exceeds unity. For discharges with slow rotation the *q*() profile has a small minimum at  ~ 0.2 – 0.3. Such *q*() profiles are typical for “hybrid” (or “advanced”) regimes in tokamaks.

In the linear version of the canonical profiles transport model [2] the heat flux has the form:

*qk* = -κ*k* *Tk*(*Tk*′/*Tk* – *Tc*′/*Tc*) *Н*(│*Tk*′/*Tk*│–│*Tc*′/*Tc*│) – κ*k*0*Tk*′ – 3/2*Tk* *n* – *n*χ*k*MHD *Tk*′, (1)

where *k* is stiffness of the temperature profile (*k* = *e*, *i*),

κ*k* =*k*/*M* (1/*A*)3/4 *q*(=max/2) (*q*cyl / *B*)*Tk*1/2(=max/4) (3/*R*0)1/4 = const(). (2)

Experimental profiles of ion temperature stiffness κi obtained on DIII-D allows us to modify the transport model. In a new model we suppose that stiffness of the ion temperature profile can be presented as:

* *i*mod *= i S(**) G*(*V*tor), (3)

where *S*() and *G*(*V*tor) are dimensionless functions which describe variability of i along the radius and its dependence on the toroidal rotation rate. The function *S*() was defined from [1] by extrapolation of its values in four radial points. The function *G*(*V*tor) was defined by approximation of its values in discharges with fast and slow rotation. The background ion heat diffusivity *i*0 in the plasma core, where stiffness is small was defined by minimization of RMS deviations of calculated ion temperatures from experimental ones. Also this procedure allows us to define dependency of *i*0 on the central ion temperature. The modified model reasonably describes the evolution of ion temperature in seven DIII-D discharges with fast and slow toroidal rotation of plasma.

References

1. Luce T.C., et al. Experimental Tests of Stiffness in the Electron and Ion Energy Transport in the DIII-D Tokamak. 24-th FEC, 2012, San Diego, Rep. EX/P3-18.
2. Dnestrovskij Yu.N. Self-organization of hot plasmas. NRC ’Kurchatov Institute’ Publishing, 2013, 172 p. (in Russian).