§31. Prandtl Number of Toroidal Plasmas

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Recently progress has been made in the understanding on the anomalous transport phenomena in toroidal plasmas [1]. The importance of the Prandtl number, i.e., the ratio of the viscosity to the thermal conductivity, has been pointed out. The Prandtl number is calculated self-consistently. The result is obtained both for tokamaks and helical plasmas [2].

By the spirit of the mean field approach, we have the estimates

$$\frac{\mu_e}{\mu} = \frac{\mu}{\mu_e}\left[1 + \frac{\alpha<\{\kappa+\cos\eta+(s\eta-\alpha\sin\eta)\sin\eta\}>}{\hat{\mu}\hat{\chi}<F^3>(nq)^4} \right] \quad (1)$$

$$\frac{\chi}{\mu} = \frac{\mu}{\chi}\left[1 + \frac{\hat{\mu}_e}{\hat{\lambda}} \frac{<|\partial/\partial\eta|^2>}{\hat{\mu}\hat{\mu}_e<F^3>(nq)^6} \right] \quad (2)$$

The mode number n is set to be that for the least stable mode, and the average $<\cdots>$ is defined as

$$<\cdots> \equiv \int\cdots\phi(\eta)^2 d\eta \left[\int\phi(\eta)^2 d\eta\right]^{-1}$$

where $\phi(\eta)$ is the eigenfunction for the least stable mode. The normalized mode number N is introduced as $N^4 = (nq)^4(\hat{\chi}\hat{\mu}/\alpha)$ [1], and Eqs. (1) and (2) are rewritten as

$$\frac{\mu_e}{\mu} = \frac{\mu}{\mu_e}\left[1 + \frac{<\{\kappa+\cos\eta+(s\eta-\alpha\sin\eta)\sin\eta\}>}{N^4<F^3>} \right] \quad (3)$$

$$\frac{\chi}{\mu} = \frac{\mu}{\chi}\left[1 + \frac{<|\partial/\partial\eta|^2>}{fN^6<F^3>} \right] \quad (4)$$

In the weak shear limit, we have

$$\mu_e/\mu \simeq 1.5,$$

$$\chi/\mu \simeq 1.3.$$

In the strong shear case, we have

$$\mu_e/\mu \simeq 1.03$$

$$\chi/\mu \simeq 1.23.$$

The similar analysis has been performed for helical plasmas. We have

$$\mu_e/\mu \simeq 2.3$$

$$\chi/\mu \simeq 2.0.$$

The result showed that μ_e/μ and χ/μ remain close to unity (1∿2) for both tokamaks and toroidal helical plasmas. This confirmed the validity of the approximate estimate $\mu_e/\mu \sim 1$ and $\chi/\mu \sim 1$, which were used in the analysis of the L-mode plasma [1].

References

[1] K. Itoh, et al.: Plasma Phys. Control. Fusion **35** (1993) 543.
[2] K. Itoh et al.: J. Phys. Soc. Jpn. **62** (1993) 4269.