

§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

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

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

The mode number  $n$  is set to be that for the least stable mode, and the average  $\langle \dots \rangle$  is defined as

$$\langle \dots \rangle \equiv \int \dots \Phi(\eta)^2 d\eta \left[ \int \Phi(\eta)^2 d\eta \right]^{-1}$$

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

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

$$\frac{\chi}{\mu} = \frac{\mu}{\chi} \left[ 1 + \frac{\langle |a/\partial\eta|^2 \rangle}{fN^6 \langle R^3 \rangle} \right] \quad (4)$$

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  $\mu_e/\mu$  and  $\chi/\mu$  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.