3-4 Mechanism of Confinement Improvement in Tokamak Plasmas
－Control of Turbulent Transport by Zonal Flow Modification－

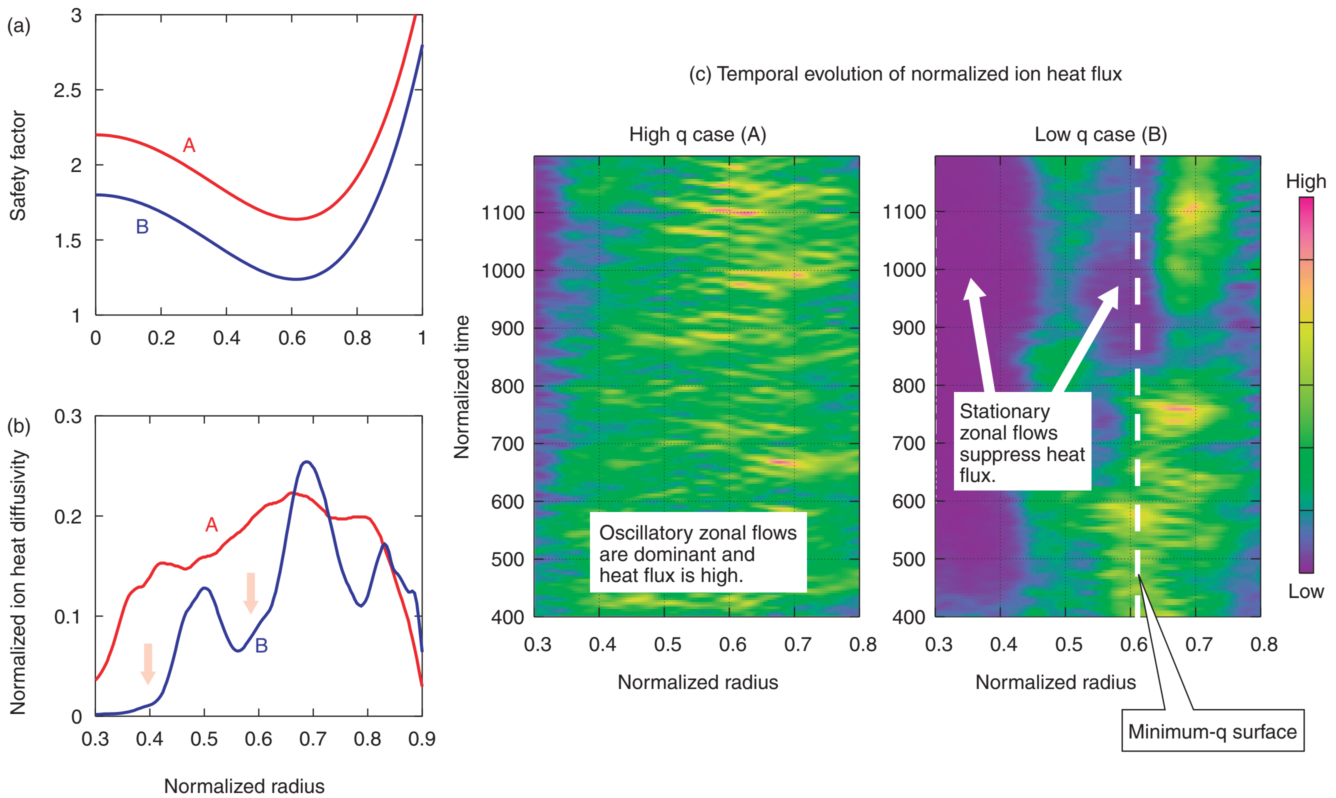

Fig.3-9 Effect of safety factor profile on ion turbulent heat transport
(a) Safety factor (q) profile used in simulation. (b) Normalized ion heat diffusivity. For low q, the heat diffusivity decreases around the circumference where q is minimum. (c) Temporal evolution of normalized ion heat flux. For high q, the heat flux is high and oscillates in time due to oscillatory zonal flows. On the other hand, the heat flux is suppressed by stationary zonal flows which strengthen when q is low.

In magnetically confined fusion plasmas, a pressure gradient generates turbulence. The turbulence causes loss of heat and particles and plasma confinement deteriorates. In recent years it has been shown experimentally that the plasma confinement is improved by control of plasma safety factor (q) profile. It is important to find a mechanism of confinement improvement for realization of efficient nuclear fusion power generation.

So far, theoretical and numerical simulation studies have shown that zonal flows (ZFs) are generated nonlinearly from microturbulence in the plasma, and can suppress the turbulence. ZFs are also observed in the atmosphere of Jupiter and Earth. Two kinds of ZFs, stationary ZFs appearing in a low q region and oscillatory ones in a high q region which are called geodesic acoustic modes (GAMs), are possible in tokamaks like “JT-60U”.

In the Numerical Experiment of Tokamak (NEXT) research, simulation of microturbulence driven by ion temperature gradient was performed. It was found that ion turbulent heat transport can be controlled by the change of ZF behavior accompanying change in the q profile.

Fig.3-9 shows effect of the q profile on the ion turbulent heat transport. In a high q case, the GAMs are dominant throughout the plasma. Since the GAMs are less effective in suppressing the turbulence than the stationary ZFs, the turbulent heat transport is high over a broad radial region. When q is decreased, the GAMs are damped at the minimum q region and the stationary ZFs become dominant instead. The stationary ZFs suppress the turbulence effectively and the heat transport is reduced. Outside the minimum q region, the GAMs are still dominant, so the turbulent heat transport is high.

Thus, control of the q profile is effective in changing the zonal flow behavior and thereby restraining the ion turbulent transport.

Reference
Miyato, N. et al., Study of a Drift Wave-Zonal Mode System Based on Global Electromagnetic Landau-fluid ITG Simulation in Toroidal Plasmas, Nuclear Fusion, vol.45, no.6, 2005, p.425-430.