T-3

# Physics Frontiers Opened by Burning Plasmas

# 燃焼プラズマが切り開く物理

Yutaka Kamada

鎌田　裕

Japan atomic Energy Research In stiturte, Naka Fusion Research Establishment,

801-1, Mukouyama, Naka-machi, Naka-gun, Ibaraki-ken, 311-0193, Japan

日本原子力研究所　那珂研究所　311-01 茨城県　那珂郡　那珂町　向山 801-1

The nuclear fusion research is now ready to challenge demonstration of the burning plasma utilizing ITER. From the physics point of view, the burning plasma system is characterized as the nonlinear self regulating combined / complex system. In order to realize the nuclear fusion energy, we need to understand and control this burning plasma system. At the same time, this research area gives us an opportunity to open physics frontiers. This presentation introduces the key aspects of the burning plasmas in the magnetic fusion research.

## 1. Self-regulating System

The first important aspect is that the burning plasma is a highly self-regulating system. In the burning plasmas, a large amount of the heating power is generated by so called self-heating. The DT fusion reaction produces high energy alpha particles, and the alpha particles transfer their kinetic energy to the background thermalized plasmas with the typical temperature of ~ 10keV. The plasma temperature, density and pressure are determined basically by the balance of heating and diffusion. The diffusion processes show both continuous and bifurcational (such as H-mode transition, generation of internal transport barriers etc.) dynamics and produces a characteristic spatial structure of the plasma kinetic parameters following a global loop of the parameter linkages. Simply speaking, the neoclassical transport determines the pressure profile. The pressure profile determines the self generated bootstrap current profile ( thus the magnetic field line structure) and, at the same time, the radial electric field and the plasma rotation profile. The produced equilibrium determines the microscopic and macroscopic fluctuations (both electromagnetic and electrostatic) in the real and velocity spaces, and alters the transport again. As the results of this parameter linkage (Fig.1), the plasma reaches a new equilibrium. In this self-regulating linkage, the key points appearing in the burning high pressure plasma is that the large fractions (>70%) of the heating power and the plasma current is generated by the plasma itself.

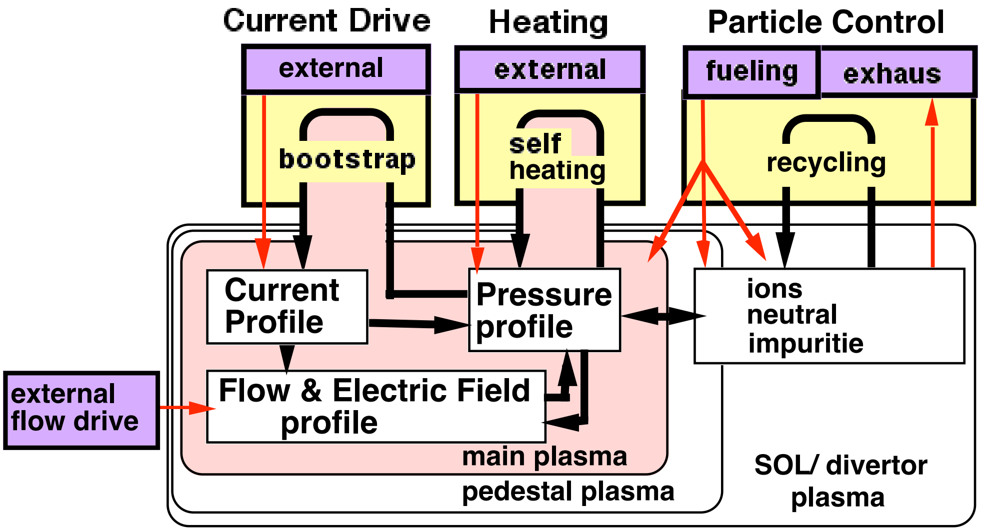


Fig.1 Parameter linkages in the burning plasmas

**2. Combined Complex System**

The second point is that the burning plasma is the combined / complex system. i) Looking at the physics phenomena, fluctuations in electrons / ions and MHD instabilities exhibit collective nonlinear behaviors. ii) As for the global structure, the confined plasma system consists of multiple plasma regimes; 10keV-class of the core plasma, keV-class pedestal plasma, and eV-class divertor plasma. These plasma regimes are connecting to each other but governed by different dominant processes with different origin and time constant. For example, the pedestal structure and its dynamics are determined by both the plasma process and the atomic process. The scale length of the pedestal parameters are in the same order of the ion orbits and the penetration depth of the neutrals. Furthermore, the spatial distribution of the pedestal parameters and behaviors show two or three dimensional structures. iii) The time scales of the leading phenomena span from the growth time of ideal MHD / turbulence(~ micro second), parallel and perpendicular transport time (~ms - second) , plasma current profile growth time (second - 10 second) to the wall saturation time (10 sec. - min. / hr.) .

**3. High Energy Particle Physic s**

In the burning plasmas, another important and new aspect is that a large amount of high energy particles (alpha particles) are produced and these energetic ions can kick instabilities due to wave-particle interactions. In toroidal magnetic configuration system, the Alfvén wave appears as an eigenmode in a frequency gap induced by the toroidicity, which is similar to the band gap in the semiconductor. This type of Alfvén wave is called as TAE. The TAE modes, once destabilized, interact with energetic ions and causes diffusion of the energetic ions. Since the plasma heating power strength and profile is largely affected by the alpha particle heating distribution, a feedback control schemes for the energetic particle distribution is an important challenge.