Tokamak/Stellarator vs. FRC: Transport and Other Fundamentals

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Plasma, highly nonlinear medium consisting of ions and electrons, exhibits prominent characteristic, self-organization and structure formation, once several conditions are fulfilled. In some case, they are expectable and useful in achieving purpose while in some case accidental and eliminated. Fusion device, one of promising plasma applications for future energy resource, is designed so as to minimize macro and micro instabilities in achieving high stability and confinement, so that the characteristics are of specifically importance [1]. When we design some device, we usually reply on linear aspect while not sure whether the characteristics, i.e. the self-organization and structure formation, support the approach or lead contradiction.

Tokamaks and stellarators have strong toroidal magnetic fields and additional magnetic field, i.e. poloidal magnetic field, by plasma current in tokamaks and by external coil in stellarators, so that the latter is more rigid than the former, which possess more freedom in magnetic configuration. Such magnetic structures are designed to have magnetic shear in minimizing various instabilities from the linear aspect while is found to induce the overlap of drift-wave "islands" called streamers, i.e. global modes, and causes avalanche-like intermittent bursts leading to self-organized critical transport [2]. This is peculiar to so called L-mode that causes anomalous ion/electron diffusion known as the Bohm transport. A recipe to prevent such anomalous diffusion is to weaken and/or eliminate the magnetic shear by the reversal of magnetic shear or by the annihilation of streamers by the additional electric field generated shear, which leads to high confinement state, e.g. internal transport barrier.

We compare and understand that the presence of null magnetic shear in stellarator enhances its confinement, much the similar way to the above tokamak's local shearlessness contributing to the enhanced confinement [3]. Namely, through the series of research on fusion devices with strong and then rigid guiding magnetic field, we found a *reciprocal relation* between linear stability and nonlinear turbulent transport as that the configuration with more unstable smaller magnetic shear plasma provides smaller turbulent transport nonlinearly than that with moderate shear. This suggests that softening the "rigidness" of the system is of importance for the plasma to be self-organized in keeping higher stability and confinement.

From this viewpoint, high-energy beam assisted FRC [4] is charming system. FRC is devoid of strong "shell-like" fields and thus is bound to be wobbly. First, the FRC core is devoid of magnetic shear (an agent of the radial extended transport channels). Secondly, the core is devoid of the instability driving mechanism of drift wave due to the finite Larmor radius (FLR), short electron connection length, and reversed grad-B drift. However, the beam-driven FRC has an entirely additional dimension. The beam introduces the backbone to the overall plasma that makes FRC globally stable, while enhanced FLR due to the beam further solidifies the FRC stability. The additional but not yet well-known robustness of the beam-FRC combo is the principle that the beam induced waves with high phase velocity cannot destroy the plasma confinement, just similar to the intense wake field not destroying the plasma accelerator. We are planning to check this point by our gyro-kinetic code of FRC.

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