§4. Analysis of CHS Magnetic Configurations Based on the Fourier Modes of Boundary Shape

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In CHS experiments, the most important parameter for the magnetic configuration control is the radial position of the magnetic axis. It is equivalent to the control of vertical magnetic field. With such a control, the neoclassical transport and the magnetic well structure are varied, which are two of the most important properties of the toroidal confinement. Those characteristics of magnetic configurations are not consequences of the geometric parameter of magnetic axis position but the plasma boundary shape of each configuration produces the physical properties of magnetic surfaces. It is exactly the same situation as the tokamak case, where the boundary shape parameters such as ellipticity, triangularity, squareness, etc. configure the confinement properties.

When we take a cylindrical coordinate system (R, Z, Φ), two dimensional cross section of the boundary shape of a torus at a given toroidal angle Φ is described by two variables R(θ, ϕ) and Z(θ, ϕ) with two angle parameters on the boundary surface. We decompose them into Fourier modes as followings.

$$R(\theta, \phi) = \Sigma\, rbc(m, n) \cos(m\theta - n\phi)$$
$$Z(\theta, \phi) = \Sigma\, zbs(m, n) \sin(m\theta - n\phi)$$

Figure 1 shows a comparison of the mode amplitude distribution for two representative configurations of CHS device. These are vacuum configurations with no plasma pressure. We use a non-dimensional parameter R_0 defined as the ratio of the magnetic axis position and the major radius of the poloidal center of the helical coils ($R_0 = R_{ax}/R_h$). The configuration with $R_0 = 0.92$ is the standard one, which was most frequently used in the experiments because of the good global confinement characteristics, and the configuration with $R_0 = 0.99$ is the outward shifted configuration. Largest difference between them is that the outward shifted configuration has the magnetic well in the core region and the standard one does not.

Since the variation of amplitudes is so large, amplitudes in the figure are plotted in the logarithmic scale and abstract values are used (eliminating sign). Modes of larger amplitude determines basic geometry of a torus boundary shape: *rbc*(0, 0) for a major radius (shown in the figure as a tallest yellow column for m=0R and n=0), *rbc*(1, 0) and *zbs*(1, 0) for the aspect ratio and the toroidally averaged ellipticity (two tall yellow columns for m=1Z and n=0), *rbc*(1, 1) and *zbs*(1, 1) for the basic helical structure of the boundary shape (two tall violet columns).

An essential difference between two configurations is the larger Fourier components of *rbc*(0, 1) and *zbs*(0, 1), which create the helical axis structure for $R_0 = 0.99$ configuration. In order to evaluate the helical axis component, boundary cross sections at four toroidal positions are plotted in Fig. 2 and compared to the helical excursion of the center of magnetic surfaces. It is generally understood that the helical axis structure of stellarators is favorable to create the magnetic well while the simple straight helical configuration is intrinsically magnetic hill. In a planar axis stellarator CHS, the small helical axis structure plays an important role for creating the magnetic well for the outward shifted configuration.

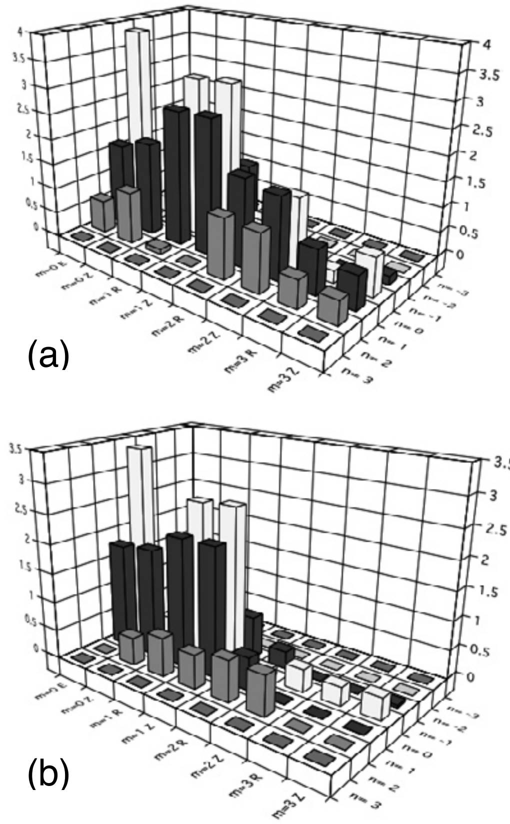

Fig. 1 Fourier mode coefficients of boundary shapes of CHS vacuum configurations. Amplitudes are shown in the logarithmic scale. (a) standard configuration R_0=0.92 and (b) outward shifted configuration R_0=0.99.

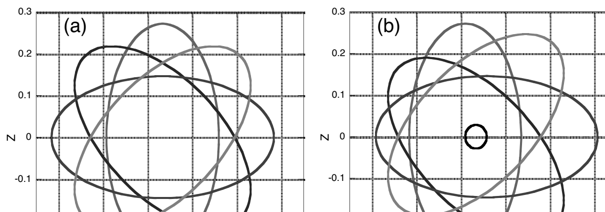

Fig. 2 Cross sections of boundary shape at four different toroidal positions for (a) $R_0 = 0.92$ configuration and (b) $R_0 = 0.99$ configuration with helical axis components. The helical excursion of magnetic surface is also plotted in (b) [a small circle at the center].