§50. Orbit Study of Energetic Particles on QUEST (Q-shu University Experiment with Steady State Spherical Tokamak)

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The plasma boundary dynamics experimental device (QUEST) is a low aspect ratio spherical tokamak (ST), which is under construction at Kyushu University. The objectives of the QUEST are to realize long-pulse steady-state plasmas and to investigate their plasma properties including the related engineering aspects. In order to achieve high-density steady-state plasmas, the plasma heating and current drive by 40-keV neutral beam injection (NBI) is considered [1].

To investigate the confinement properties of energetic particles produced by the NBI, we have developed an orbit following code for QUEST. Since the magnetic field strength is extremely low on QUEST ($B_t=0.25\,[\text{T}]$), we have used a full-orbit following method by solving the Lorentz-force equation instead of a guiding-center method.

As a first trial, we have calculated energetic particle orbits in the QUEST magnetic configuration of $B_t=0.25\,[\text{T}] / I_p=100\,[\text{kA}]$, which will be applied to the steady-state operation sustained mainly with the RF current drive. Figure 1 shows the poloidal projection of the typical orbits for co-going particles in this configuration. The particles are launched from $(R, Z) = (0.5\,[\text{m}], 0.0\,[\text{m}])$ in this figure. The confinement of 40-keV protons is poor in this configuration. We need to optimize the confining magnetic field and the structure of in-vessel components for the NBI heating in this magnetic configuration.

Figure 2 shows the results of the poloidal field scan in the orbit following calculations. As is shown in this figure, an increase in the poloidal field is effective for confining 40-keV protons since it reduces the width of a banana-orbit. It is necessary to increase the poloidal field strength at least 5 times larger than the original one.

We are going to apply this orbit following code to the magnetic configuration of $B_t=0.5\,[\text{T}] / I_p=300\,[\text{kA}]$ for the NBI heating and current drive. Further calculations of the energetic protons in the QUEST second-phase configuration are also necessary to determine the shape of the plasma facing wall and to optimize the NBI-heating scenario on QUEST.

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Fig.1 Poloidal projection of the typical orbits in the first-phase configuration of QUEST ($B_t=0.25\,[\text{T}] / I_p=100\,[\text{kA}]$). The energies of the particles are 40-keV (lines with closed circles), 20-keV (lines with open circles), 10keV (lines with closed squares) and 5-keV (lines with open squares).

Fig.2 Poloidal field dependence of the calculated life time for 40-keV protons in the QUEST plasmas. The launching points are set at $(R, Z)=(0.5\,[\text{m}], 0\,[\text{m}])$ in these calculations. Lines with open circles show the case with the original poloidal field strength of QUEST $I_p=100\,[\text{kA}]$ configuration. Those with closed circles, open squares and closed squares show the cases where the poloidal field strength is multiplied by a factor of 2, 5 and 10 from the original one.

Reference