§7. Alpha Particle Loss Fraction in the FFHR

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Self-heating from alpha particles and control of the alpha ash removal are essential for the FFHR[1] steady state ignited operation, where all of the required plasma heating is provided by alpha particles.

The characteristics of the LHD magnetic field that is the basis of the FFHR magnetic design, are the high magnetic shear configuration in the peripheral region and the existence of the chaotic field line layer which surrounds the last closed magnetic surface(LCFS). An excellent confinement characteristic for high energetic particles has been achieved in the LHD by the coalition of closed magnetic surface and the chaotic field line layer.[2]

The loss fraction of alpha particle R_α is defined as

$$R_\alpha = \frac{2\pi a^2 \times 2\pi R_{\rm ax} \int_0^1 Q_{\rm nf} R(\rho')\,\rho'\,{\rm d}\rho'}{2\pi a^2 \times 2\pi R_{\rm ax} \int_0^1 Q_{\rm nf}\,\rho'\,{\rm d}\rho'} \qquad (1)$$

where a and $R_{\rm ax}$ are the minor and the major plasma radius, ρ' is the normalized minor radius position, $R(\rho')$ the local loss rate of alpha particles, $Q_{\rm nf}$ the alpha particle production rate.

Collisionless orbits of 3.52 MeV alpha particles produced by DT fusion reaction are studied numerically in the magnetic configuration of the FFHR. Birth positions of 3.52 MeV alpha particles are assumed to be uniform in the range $0 \le \rho' \le \rho$, and a loss rate $R_{\rm cal}(\rho)$ (FIg.1 and Fig.2) is calculated.

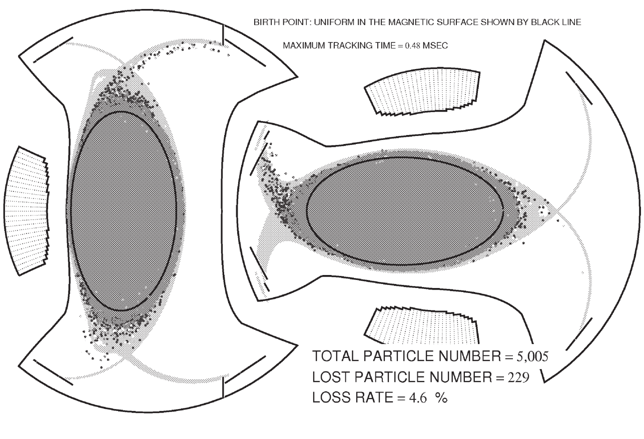

Fig.1 Poincaré plots of 3.52 MeV alpha particles for the case of $R_{\rm ax} = 3.6 \times 14/3.9\,$m, $B_{\rm ax} = 6\,$T. Birth positions are uniformly distributed in the range $\rho \le 0.838$(shown by bold lines). Magnetic field line Poincaré plots are also shown by thin dots.

For the case of standard magnetic field configuration of the coil pitch parameter ($\gamma = 1.254$), the blanket space become narrow as shown in Fig.1.

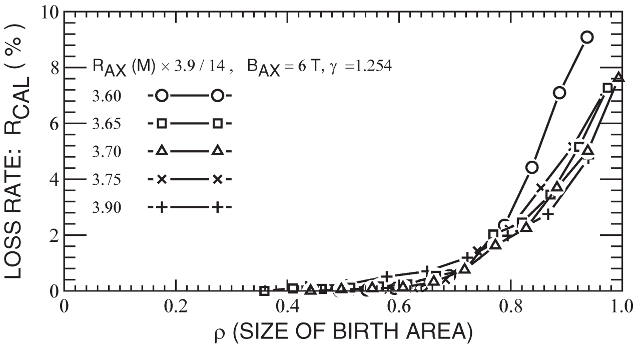

Fig.2 Numerically obtained alpha particle loss rate $R_{\rm cal}$ under the assumption of uniform birth population. The position of magnetic axis $R_{\rm ax}$ is treated as a parameter. Magnetic field intensity and the coil pitch parameter are fixed to $B_{\rm ax} = 6$T and $\gamma = 1.254$.

The loss fraction of alpha particle R_α defined by (1) can be calculated from $R_{\rm cal}(\rho)$ as follows.

$$R_\alpha = \frac{\displaystyle\int_0^1 -\frac{{\rm d}Q_{\rm nf}}{{\rm d}\rho'}\rho'^2 R_{\rm cal}(\rho')\,{\rm d}\rho'}{\displaystyle 2\int_0^1 Q_{\rm nf}\,\rho'\,{\rm d}\rho'} \qquad (2)$$

Numerical results are shown in Fig.3. Plasma density is assumed to be uniform. The plasma temperature is assumed to be 20 keV in the core region, and 0 at the LCFS, as shown in Fig.3.

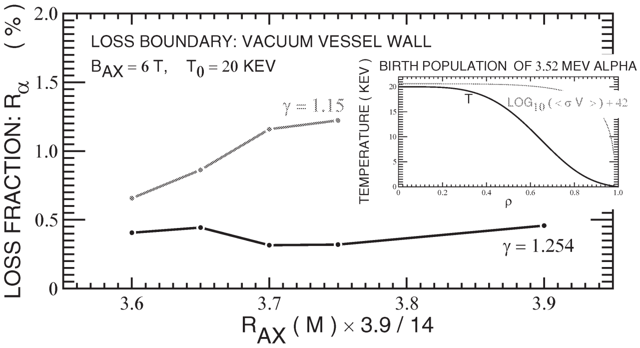

Fig.3 The loss fraction of alpha particle R_α in the FFHR. Horizontal axis shows the position of the magnetic axis. The coil pitch parameter is assumed to be $\gamma = 1.254$, or $\gamma = 1.15$. The performance of alpha particle confinement shows a slight decrease compared with the case of $\gamma = 1.254$ at $\gamma = 1.15$.

References

1) A. Sagara, S. Imagawa, O. Mitarai, et al., *Nucl. Fusion*, **45** (2005) pp.258-263.

2) T. Watanabe, Y. Matsumoto et al., *Nucl. Fusion*, **46** (2006) pp.291-305.