Alpha Particle Loss and Heat Load Assessment for Compact Stellarator Reactors*

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The ARIES Advanced System Study Group has embarked on a multi-year project to assess the potential of the compact stellarator concept as a fusion power plant. The initial phase of this study is to determine the optimum configuration (in terms of number of field periods and modular coils) that meets the physics performance goals and the engineering requirements that are crucial for an attractive reactor. Because of the non-axisymmetric nature of the magnetic geometry, it is possible that a significant number of the fusion-produced alpha particles will be lost from the plasma before complete thermalization. This loss of alpha particle power can affect the plasma power balance and the reactor operating point. More important are the effect of the exiting high-energy (MeV) particles on the design of divertors in terms of the heat load distribution, and the potential of blistering of the divertor coating by these particles.

In this paper, we report on an assessment of the alpha particle heat flux for a typical compact stellarator (CS) reactor configuration, as evaluated at the last closed magnetic surface (LCMS) of the plasma. Further work will be carried out to examine the resultant heat flux distribution in the plasma scrape-off layer in order to determine the optimum divertor design, and this will be reported at a later stage of the project. In the present analysis, we make use of the ORBIT3D particle orbit code [1] that follows the alpha particle guiding center from birth inside the plasma to its exit from the plasma. A CS configuration [2] with two field periods, B_o = 5.5 T, R = 7.5 m and A = 3.5, maintained by 16 coils at a beta value of 4%, is used as the reference equilibrium. In the standard case, an initial burst of lost alpha particles at the birth energy is observed with the subsequent lost energy spectrum moving towards lower values, resulting in an energy loss fraction of around 30%. The bulk of lost energetic alphas are concentrated in a toroidal strip just below the outboard mid-plane. The estimated peak heat load at the LCMS is well in excess of 10 MW/m^2, which can make the design of a divertor very challenging. Various methods to tailor the harmonic magnetic field components are being investigated to reduce the alpha heat loss, and the results will be presented.

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