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REVOLVER-D: The Ergodic Limiter/Divertor Consisting of Molten Tin Shower Jets Stabilized by Chains

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A new liquid metal divertor concept named the REVOLVER-D (Reactor-oriented Effectively VOLumetric VERtical Divertor) has been proposed for the helical fusion reactor FFHR-d1. The REVOLVER-D consists of molten tin shower jets stabilized by chains set inside each jets. These are installed in 10 inner ports of FFHR-d1 to intersect the ergodic layer surrounding the last-closed-flux-surface. The plasma heading for the divertor region hits the shower and disappears. Then the full-helical divertor as in LHD becomes less necessary. The majority of the heat load is absorbed inside the shower. At least a half of neutral particles generated inside the shower is pumped by the cryopump units installed in the center of FFHR-d1. Maintenance of the REVOLVER-D is easy since it is localized in the inner port and its components are easily removed by simple up/down motion. Pure molten tin is the first candidate of the liquid metal for the REVOLVER-D, because of its low melting temperature, low vapor pressure, low material cost, low toxicity, no explosive reaction with water, and high nuclear stability. Both of the amount and radiation dose of radioactive wastes emitted from the REVOLVER-D are small. Since tin is a high Z material near Xe, the sputtered tin can be an efficient radiator for divertor heat load reduction. On the other hand, contamination of the main plasma by tin should be prevented. In the case of FFHR-d1, the impurity shielding effect of the ergodic layer as observed in LHD is beneficial for this. The permissible heat load of the REVOLVER-D is sufficiently high since it uses the flowing liquid metal as the plasma facing material. For example, in the case of a molten tin jet with 1.2 cm of diameter, 0.012 square meter of plasma wetted area, and 5 m/s of flow velocity, the vapor pressure is < 0.0001 Pa even at a high heat load of 40 MW per square meter. When a jet hits the plasma and connects two regions with different potentials, an electric current flows in the jet. The Lorentz force induced by this current and the toroidal magnetic field of ˜2 T around the shower bend the jet in the radial direction. Since the electric current will be limited by the ion saturation current in the ergodic layer, plasma cooling by inserting the limiter in the ergodic layer and enhancing the radiation loss by tin is effective in mitigating the Lorentz force.

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