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Dynamic Divertor Concept by Plasmoid Ejection in TS-4 Spherical Tokamak Experiment

TS-4球状トカマク実験のプラズモイド放出を用いた動的ダイバータの提案

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This paper proposed a new type of dynamic divertor by use of intermittent plasmoid ejection from a main plasma to a divertor coil. Our 2-D MHD simulation demonstrated for the first time how the plasmas and coil conditions could control plasmoid dynamics for this divertor action. This dynamic divertor has four essential steps. First, current drive and heating causes the main detached plasma to expand around the divertor region, causing a plasmoid formation. Second, the expanding core plasma finally pinches off the small plasmoid. Next, the plasmoid isolated from the main plasma is cooled down by Argon gas puffing and finally is connected with the divertor plate. The series of divertor actions are expected to reduce the heat road to divertor plate significantly, suggesting a new type divertor useful for heavy heat road from type I Edge-Localized Mode (ELM). We will present its simulation result and the corresponding experiments of plasmoid ejection in TS-2 and TS-4 merging experiments.

1. Introduction

Two essential issues for future divertors of fusion reactors is to reduce heat load to divertor plate and also to exhaust efficiently the helium ash which pile up in core plasma. A serious problem is concentration of high-energy heat flux damages divertor plate, generating impurities from divertor wall. Especially, a large heat flux such as Type I Edge-Localized Mode (ELM) damages the divertor plate heavily, resulting in replacing divertor plate frequently. Currently, various schemes such as detached divertor or pebble divertor has been tested and improved for this purpose [1]. We developed a new dynamic divertor to solve this problem. Its new concept is to utilize periodic plasmoid ejection from the main plasma to the divertor coil, improving significantly insulation of the divertor plate from the main plasma [2]. This paper addresses the basic motion of dynamic divertor with simulation and experimental data.

2. Concept of Dynamic Divertor

This paper describes the basic concept and motion of dynamic divertor in comparison with classic divertor. While the classic divertor's plate is connected with main plasma by divertor coil's magnetic field line. On the other hand, the plasmoid connects indirectly the dynamic divertor's plate with the main plasma. The dynamic divertor action has 3 essential steps.

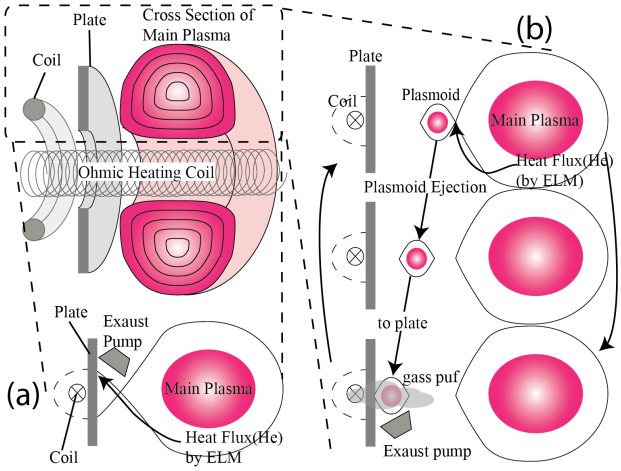

Fig.1. (a)Classic divertor. (b) Dynamic divertor.

First, current drive and heating causes the main detached plasma to expand around the divertor region, forming a plasmoid which is a magnetic island ejected from main plasma together with Helium ashes. Second, the expanding core plasma finally pinches off the small plasmoid and obviously Helium ashes are also emitted with plasmoid. The plasmoid isolated from the main plasma is cooled down by Argon gas puffing and finally is connected with the divertor plate. The influence of impurities is suppressed because of distance from the plate to the main plasma much longer than the classic divertor and argon gas cooling of plasmoid under the condition isolated from the main plasma.

3. Simulation Model

The main plasma has to produce plasmaid periodically for the dynamic divertor motion. At first, we solved magnetohydrodynamic equations to study global plasma motion, of main plasma and SOL/Divertor plasma. Our two dimensional MHD simulation [3] proved for the first time basic motions of the dynamic divertor and controllability of plasmoid ejection cycle [4]. The equation to be solved is the resistive MHD equations based on the explicit finite difference method with second-order accuracy both in space and time. The spatial derivative of a variable was based on the Taylor expansion up to the second order of the grid separation Δx and the temporal evolution is solved by the second-order Lax-Wendroff method. The initial condition of the MHD simulation is provided by the Grad-Shafranov equation and we apply the perfect conducting wall as boundary condition. We also add ohmic coil heating effects at boundary as generating electric field.

4. First results of experiment and simulation

Figure 2 shows simulation data of one cycle operation for the dynamic divertor. From 0.63 to 1.51[T_A], the main plasma is amplified by the Ohmic heating coil, causing a plasmoid formation. The plasmoid is pushed by PF1 coil and is detached from the main plasma in 1.56[T_A]. Finally, the plasmoid is pulled by PF2 coil and connected to divertor plate on the simulation boundary. This MHD simulation does not include the gas puff's effect or ionization effects. In the series of motion, the divertor plate is connected indirectly to main plasma through the ejected plasmoid, removing direct heat flow into the divertor. The distance from main plasma to the divertor plate is longer than the classic's, improving the shield effect for our divertor plate and also space for argon gas puff.

5. Summary

We show our initial experimental and numerical results of the proposed new dynamic divertor useful for heavy heat load from Type I ELM. In poster session, we will present the concept of dynamic diverter and how to obtain such divertor motion by coil current using both of numerical simulations and TS-4 experiment.

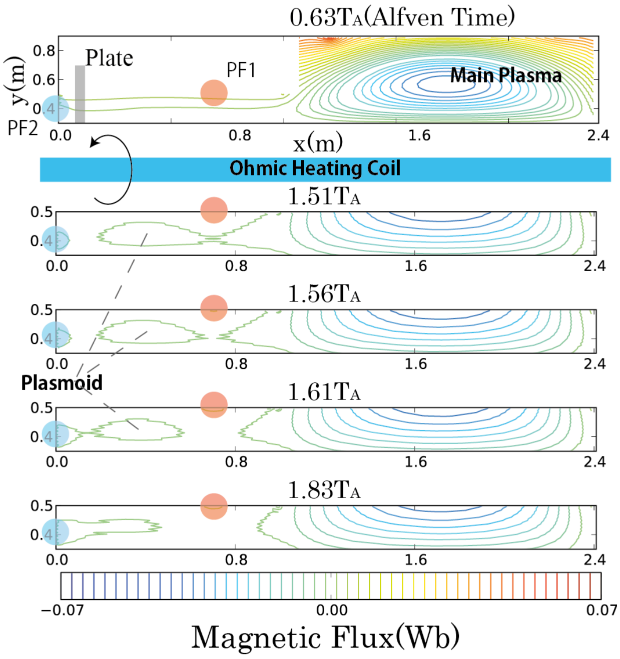

Fig.2 Time evolution of poloidal flux contour during intermittent plasmoid ejection. The PF1 coil current is used to produce the plasmoid and the PF2 coil current to connect the plasmoid with the divertor plate.

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