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トカマク中のヘリカルフェライト鋼設置による共鳴磁場摂動とペデスタルプラズマ輸送

Resonant Magnetic Perturbation by Helical Ferritic Steel Inserts in Tokamak and Transport of Pedestal Plasma

滝塚知典[1], 清水勝宏[2], 星野一生[2], 福田武司[1]
Tomonori TAKIZUKA[1], Katsuhiro SHIMIZU[2], Kazuo HOSHINO[2], Takeshi FUKUDA[1]

阪大工[1], 原子力機構[2]
Osaka Univ.[1], JAEA[2]

Edge localized mode (ELM) must be eliminated which enhances the erosion of divertor plates in the H-mode operation of tokamak reactors. Suppression of ELM has been experimentally achieved by the resonant magnetic perturbation (RMP) with multipartite coils [1]. In a DEMO reactor with strong neutron flux, however, it is desired the coils near the first wall not to be put in. We proposed an innovative concept of the RMP for tokamak DEMO reactors without installing coils but inserting ferritic steels of the helical configuration [2]. Helically perturbed magnetic field is naturally formed in the axisymmetric toroidal magnetic field through the helical ferritic steel inserts (FSIs). The perturbation amplitude in the plasma pedestal region can easily be set above several 10^{-4} of the toroidal field strength in the DEMO reactor condition ($B_0 \sim 6$ T), which is enough for the RMP to mitigate/suppress ELMs [3]. Figure 1 shows the dependence of the relative perturbation $|\delta H/H_0|^{\mathrm{PED}}$ at the pedestal position ($r = 0.95a$) on the relative radius of the FSIs $b_\mathrm{F} \equiv a_\mathrm{F}/a$ (a: plasma minor radius). FSs are located in the region $a_\mathrm{F} - d < r < a_\mathrm{F} + d$. FS thickness $2d$ is normalized by $\kappa = m/a_\mathrm{F}$ (m: poloidal mode number of helical FSIs). For $m \sim 10$ and $a \sim 2.5$ m, helical FSIs with $2d \sim 0.5$ m ($\kappa d \sim 1$) easily generate the RMP of $|\delta H/H_0|^{\mathrm{PED}} \sim 10^{-3}$, even when FSs are placed not near by the plasma surface $b_\mathrm{F} \sim 1.5$. The helical FS configuration can be attained by the helical arrangement of blanket modules, but the FS materials occupy only a part of the FS region not to reduce the tritium-breeding ratio. A dashed curve in Fig. 1 corresponds to the blanket utilization assuming the 15% FS-occupation. We see that the condition, $|\delta H/H_0|^{\mathrm{PED}} > 3 \times 10^{-4}$, is still satisfied for $b_\mathrm{F} < 1.3$.

Three-dimensional fluid simulations have been performed, and shown that the electron heat transport is much enhanced in the RMP stochastic field [4]. But this result did not agree well with the DIII-D experiments for low-collisionality regime, where the density was appreciable pumped out while electron temperature was affected little [1]. We will discuss about possible models of the reduced heat transport considering the kinetic effects.

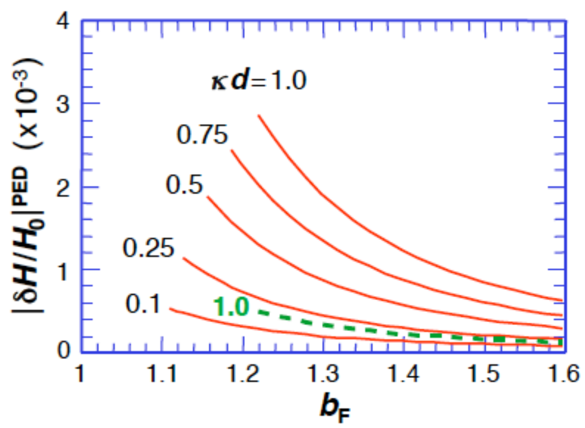

Fig. 1. Relative perturbation $|\delta H/H_0|^{\mathrm{PED}}$ at the pedestal position vs b_F for various κd values. A dashed curve corresponds to the blanket utilization with 15% FS-occupation and $\kappa d = 1$.

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[2] T. Takizuka et al., "Helical Ferritic Steel Inserts for Resonant Magnetic Perturbation to Suppress ELM in Tokamak DEMO Reactor", Plasma Conference 2011 / 28th JSPF Annual Meeting, 2011, Kanazawa.
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