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MHD instabilities limiting beta value and the interaction with error field
ベータ限界を決定するMHD不安定性と誤差磁場との相互作用

Satoru Sakakibara[1,2], Kiyomasa Watanabe[1], Yuki Takemura[1], Yasuhiro Suzuki[1,2], Satoshi Ohdachi[1,2], Yoshiro Narushima[1,2], Katsumi Ida[1,2], Ichihiro Yamada[1,2], Kenji Tanaka[1], Hiroshi Yamada[1,2], Yasuhiko Takeiri[1,2], LHD Experiment Group
榊原悟[1,2], 渡邊清政[1], 武村勇輝[1]、鈴木康浩[1,2]、大舘暁[1,2]、成嶋吉朗[1,2]、居田克巳[1,2]、山田一博[1,2]、田中謙治[1]、山田弘司[1,2]、竹入康彦[1,2]、LHD実験グループ

[1]*National Institute for Fusion Science*
Oroshi-cho, Toki, Gifu 509-5292 Japan
核融合科学研究所、〒509-5292 岐阜県土岐市下石町322-6
[2]*The Graduate University for Advanced Studies (SOKENDAI)*
Oroshi-cho, Toki, Gifu 509-5292 Japan
総合研究大学院大学（総研大）、〒509-5292 岐阜県土岐市下石町322-6

Effects of low-*n* MHD instabilities on plasma performance have been assessed in the regime where an achieved beta value is regulated by instabilities. The unstable regime of an ideal interchange mode is characterized by enhanced magnetic hill and reduced magnetic shear. Experiments have clarified that (i) low-*n* modes are significantly destabilized in the ideal-unstable configurations and lead to degradation of central beta by at most 60%, and (ii) the degree of their damages strongly depends on the mode rotation velocity. The occurrence of the minor collapse is independent of an existence of an error field.

1. Introduction

In stellarators and heliotrons, interchange instability driven by the pressure gradient is most concerned to impose the limit of the achievable beta value. Previous experiments in the Large Helical Device (LHD) show that high beta plasma with more than 5% was successfully achieved in the moderately unstable regime where violated instabilities are benign and do not result in harmful consequence such as disruption [1]. The resistive interchange modes were dominantly observed in the all beta range because of the magnetic hill in the periphery, and it was verified that the amplitudes of modes were suppressed by an increment of the magnetic Reynolds number, *S*, which is favorable in the fusion reactor regime with high electron temperature, T_e [2]. However, since the growth rate of the ideal interchange mode is independent of *S*, verification of the significance of the ideal stability boundary remains a major problem to be solved in helical devices. Here we focus on the effect of the mode on the confinement property in the regime where the destabilization of the ideal interchange mode is predicted by linear theory.

In this study, the effects of low-*n* MHD instabilities on plasma performance have been investigated in two kinds of ideal unstable regimes realized by enhancing the magnetic hill and reducing magnetic shear. Figure 1 shows a schematic view of how to approach the ideal unstable regime. In the experiments, we changed the configurational parameters (R_{ax} and I_p) characterizing MHD instabilities based on the optimized configuration for high-beta plasma production (blue circle).

2. Experimental Results

Figure 2 shows a typical discharge with real-time movement of R_{ax}^v to the inward in order to enhance the magnetic hill at $\iota/2\pi = 1/2$ surface. The central beta value starts to decrease when R_{ax}^v comes close to 3.53 m. The rotating $m/n = 2/1$ mode appears

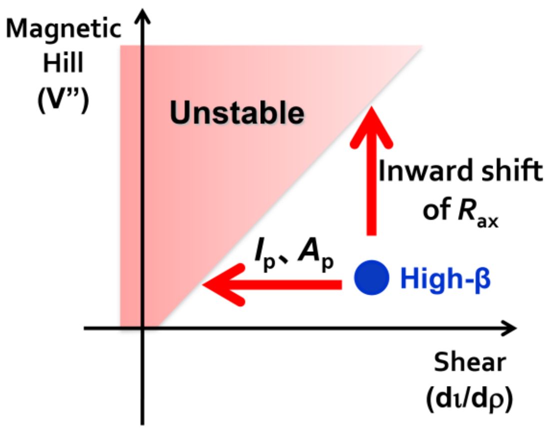

Fig.1 Access to ideal unstable regime

before the drop of the central beta, and the amplitude is increased with deceleration of the mode rotation. At 3.36 s, the mode rotation is completely stopped. Although the mode rotates and stops by turns, no recovery of the central beta is observed. T_e measurements show that the flattening structure is formed at the $\iota/2\pi = 1/2$ resonance before the stop of the rotation (3.3 s), which is caused by rotating $m/n = 2/1$ activity. After the stop of the rotation, the flattening structure is extended to the core region, which drops the central beta by more than 30 %. It has been found out that the mode can be stabilized when the R_{ax}^{v} is moved to the outward during the discharge if the mode rotation is maintained. In the reduced magnetic shear configuration, $m/n = 1/1$ mode is destabilized and leads to minor collapse after the stop of the mode rotation [3], which is similar to the case of the $m/n = 2/1$ mode observed in the enhanced magnetic hill configuration. The onset of the minor collapse is independent of the existence of the error field.

Figure 3 shows changes of central beta and the formation of the profile flattening as a function of the mode frequency. The $m/n = 2/1$ and 1/1 activities were obtained in the enhanced magnetic hill configuration and reduced magnetic shear one, respectively. In the $m/n = 2/1$ case, the flattening structure width normalized by the minor radius is increased to 0.1 when the frequency is decreased to 0.4 kHz, and the central beta starts to decrease simultaneously. The $m/n = 1/1$ mode forms the flattening structure when the frequency is dropped to 0.9 kHz, and it is linearly extended with the decrease in the frequency. When the frequency reaches zero, the flattening width approached to more than 0.5, which causes the degradation of central beta by about 60 %.

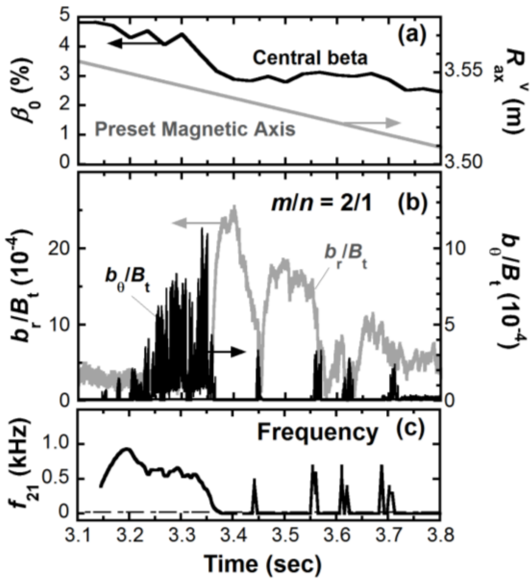

Fig.2 Time evolutions of (a) central beta and preset magnetic axis position, (b) amplitude of $m/n = 2/1$ mode and (c) frequency in a typical discharge in enhanced hill configuration.

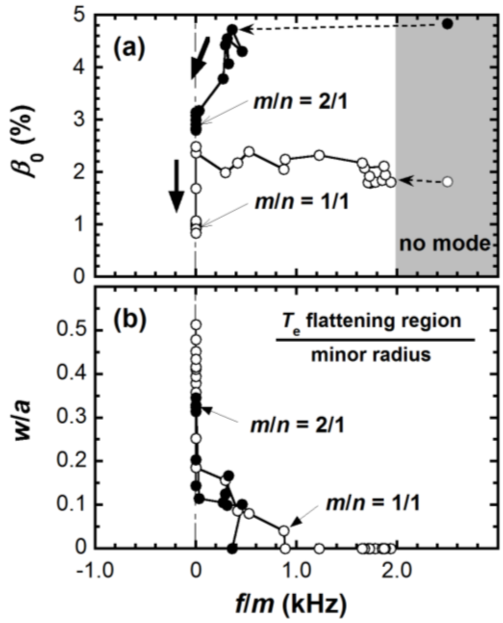

Fig.3 Changes of (a) central beta and (b) ratio of the flattening region to minor radius as a function of normalized mode frequency.

3. Summary

This study clarified the impact of low-n MHD activities on the plasma confinement in ideal unstable regime in order to find the achievable beta regime for helical reactor. The low-n instabilities deforming the plasma profile appeared when the magnetic shear was reduced or the magnetic hill is enhanced. The minor collapse decreasing the central beta to at most 60 % occurred when their mode rotations were stopped.

Acknowledgments

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