H-Mode-Like Discharge under the Presence of 1/1 Rational Surface at Ergodic Layer in LHD

MORITA Shigeru, MORISAKI Tomohiro, TANAKA Kenji, GOTO Motoshi, MASUZAKI Suguru, OSAKABE Masaki, SAKAKIBARA Satoru, SAKAMOTO Ryuichi, TOI Kazuo, ASHIKAWA Naoko, FUNABA Hisamichi, IKEDA Katsunori, KANEKO Osamu, KAWAHATA Kazuo, KUBO Shin, MUTO Sadatsugu, NAGAOKA Kenichi, NISHIMURA Kiyohiko, NOZATO Hideaki[1)], OKA Yoshihide, SHIMOZUMA Takashi, TAKEIRI Yasuhiko, TOKUZAWA Tokihiko, TSUMORI Katsuyoshi and LHD Experimental Group

National Institute for Fusion Science, Toki 509-5292, Gifu, Japan

[1)] Department of Frontier Science, University of Tokyo, Tokyo 113-0033, Japan

(Received 16 March 2004 / Accepted 24 March 2004)

H-mode-like discharge was found in LHD with a full B_t field of 2.5 T at an outwardly shifted configuration of R_{ax} = 4.00 m where the m/n = 1/1 rational surface is located at the ergodic layer. The H-mode-like discharge was triggered by changing the P_{NBI} from 9 MW to 5 MW in a density range of 4–8 × 10^{13} cm^{-3}, followed by a clear density rise, ELM-like H$_\alpha$ bursts, and a reduction of magnetic fluctuation. These H-mode-like features vanished with a small radial movement of the 1/1 surface.

Keywords:

H-mode, edge-localized mode, rational surface, H$_\alpha$, helical plasma

H-mode-like discharges have been found in both W7-AS [1] and CHS [2,3] helical devices by adjusting external coil currents in net-current-free ECH plasmas and by using an additionally introduced ohmic current in NBI plasmas to change an edge rotational transform, $\iota/2\pi$(a), respectively. In the last year, similar discharges were successively obtained in CHS NBI plasmas [4] and Heliotron-J ECH plasmas [5] without externally induced plasma current, by varying the $\iota/2\pi$(a) values.

In LHD, on the other hand, an H-mode-like discharge was found in high-β plasmas (β ~ 2%) with a low magnetic field (B_t < 0.75T) at R_{ax} = 3.60 m ($\iota/2\pi$(a) = 1.56) [6]. The growth of m/n = 2/3 modes appeared at the edge barrier region with the saturation of plasma performance. However, the operational range of such discharges was limited to a special case such as low B_t and high-β. Recently, an H-mode-like discharge has been newly obtained in a full B_t field (B_t = 2.5 T) by shifting the R_{ax} outwardly (R_{ax} = 4.00 m).

One of edge plasma features in LHD is characterized by the existence of m/n = 1/1 rational surface which is located at ρ = 0.88 (in vacuum) in a standard configuration of R_{ax} = 3.60 m. The radial position of the 1/1 surface can be moved by shifting the R_{ax}. Figure 1 shows edge $\iota/2\pi$ profiles at a horizontally elongated position in R_{ax} = 3.90, 4.00 and 4.10 m. The positions of the 1/1 surface in R_{ax} = 3.90 and 4.00 m are located near the LCFS and outside of ergodic layer, respectively. No 1/1 surface exists substantially in R_{ax} = 4.10 m.

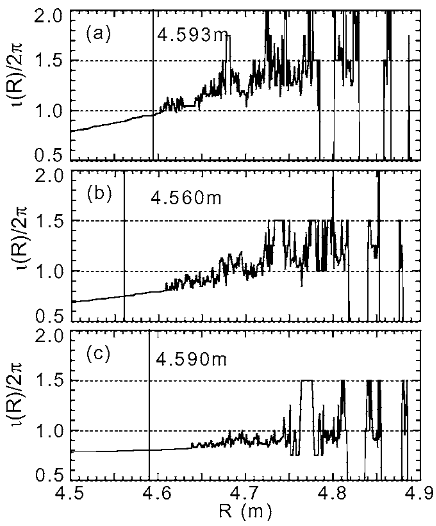

Fig. 1 Rotational transform in (a) R_{ax} = 3.90 m, (b) 4.00 m and (c) 4.10 m. Solid lines show LCFS position.

In LHD, at present, the LCFS positions indicated in the figure are defined by the outermost flux surface on which the deviation of the magnetic field line is less than 4 mm while it travels 100 turns along the torus [7]. Then, the precise position of the LCFS is affected considerably by the presence of small islands near LCFS, as did appear in the case of R_{ax} = 4.00 m. The distance between the 1/1 rational surface and the LCFS defined in this manner is about 12 cm at the

author's e-mail: morita@nifs.ac.jp

horizontally elongated plasma position in the case of R_{ax} = 4.00 m.

Many experiments have been performed regarding these three configurations. As a result, the H-mode-like transition was found in R_{ax} = 4.00 m by changing the NBI input power while maintaining a relatively high density. No transition was obtained in R_{ax} = 3.90 and 4.10 m. This result strongly suggests the importance of the 1/1 surface at the plasma edge for the H-mode-like discharge.

A typical waveform is shown in Fig.2. One of three NBIs is turned off at t = 1.25 s. After turning off the beam line, the H_α signal quickly drops in intensity and the density gradually rises, showing a clear turning point. ELM-like bursts appear in the H_α signal. Similar bursts are also observed in an electrostatic probe on the divertor plate and a magnetic probe. Enlarged signals are traced in Fig.3. Reduction of the magnetic fluctuation is seen after the H-mode-like transition.

This H-mode-like feature, however, disappears after turning off the second NBI at t = 2.1s. A narrow window exists in the NBI power. When the P_{NBI} is increased from one beam to two beams, the plasma behaves as in Fig.2. In addition, the H-mode-like discharges cannot be obtained in low- and high-density ranges, appearing only in a density range of 4–8 $\times$ 10^{13} cm^{-3}. This fact indicates that this phenomenon is very sensitive to edge plasma parameters of density and temperature in relation to the $\iota/2\pi(a)$. Unfortunately, there are presently no precise data regarding edge profiles, although the foot position of the edge pressure moves inwardly when the edge temperature decreases.

The energy confinement in such an outwardly shifted configuration is always much smaller than in ISS-95 scaling due to less central heat deposition. The energy confinement times obtained in the discharge shown in Fig.2 are 17 ms (τ_{E_ISS95} = 36 ms) and 41 ms (τ_{E_ISS95} = 65 ms) at t = 1.2 and 2.0 s, respectively. A clear confinement improvement is not observed at present.

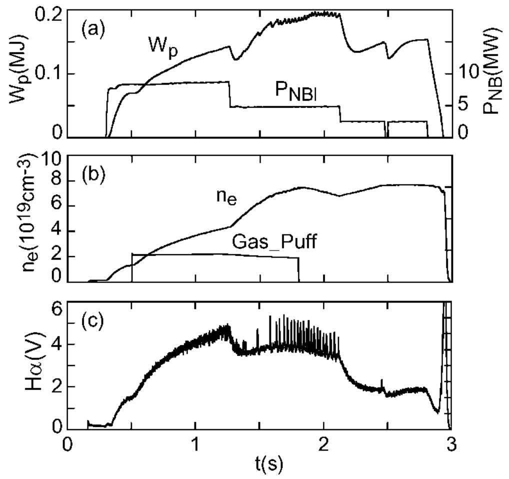

Fig. 2 H-mode-like discharge obtained in R_{ax} = 4.00 m configuration; (a) plasma stored energy and NB power, (b) density and (c) Hα signal.

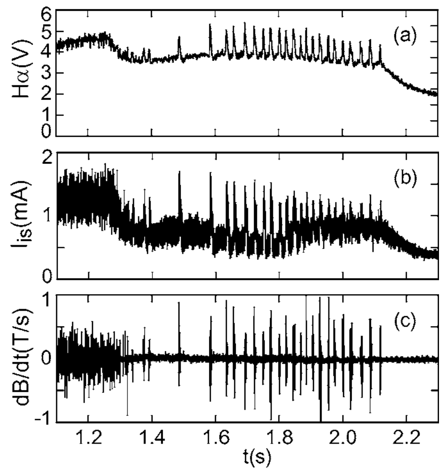

Fig. 3 Enlarged signals of discharge shown in Fig.1; (a) Hα, (b) divertor ion saturation current and (c) magnetic fluctuation.

[1] V. Erckmann *et al.*, Phys. Rev. Lett **70**, 2086 (1993).
[2] K. Toi *et al.*, Proc. 14th Int. Conf. on Plasma Physics and Contr. Nucl. Fus. Res. vol. **2**, 461 (Vienna, 1993).
[3] K. Toi *et al.*, Plasma Phys. Control. Fusion **38**, 1289 (1996).
[4] S. Okamura *et al.*, J. Plasma Fusion Res. **79**, 977 (2003).
[5] F. Sano *et al.*, J. Plasma Fusion Res. **79**, 1111 (2003).
[6] K. Toi *et al.*, Nucl. Fusion **44**, 217 (2004).
[7] T. Morisaki *et al.*, J. Nucl. Mater. **313-316**, 548 (2003).