19PA-026

Development of a new TESPEL injector with a variable injection angle mechanism in LHD
LHDにおける入射角可変機構付きTESPEL入射装置の開発

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A new injector for a tracer-encapsulated solid pellet (TESPEL) is currently under development on LHD. The primary purpose of this injector is to invoke a large perturbation on electron temperature with a small perturbation on electron density even by the larger TESPEL injection. To realize this feature, the new injector enables us to inject the TESPEL into LHD plasmas obliquely with a bended guide tube, which is installed inside a vacuum vessel of LHD. The in-vessel bended guide tube can be moved up and down by a remote-controlled drive mechanism, and then the injection angle to the LHD plasmas can be changed within a typical time interval between LHD plasma discharges (~3 minutes). This injector will be tested soon and operated from the LHD experiment in FY2014.

1. Introduction

Even though we are facing an age of International Thermonuclear Experiment Reactor (ITER), it is still highly important to investigate the transport property of heat and particle in magnetically confined high temperature plasmas. In such studies, it is significantly important to perform a dynamic (perturbative) analysis, as well as a static (power-balance) analysis, because it is well known that high-temperature turbulent plasmas exhibit a fast and global response (sometime beyond the standard local diffusive paradigm) to a change in plasma parameters at a location. In the experiments for the dynamic transport analysis, electron temperature and/or density are usually perturbed by modulations of heat and/or particle source (e.g. an electron cyclotron resonance heating, a gas puff, a pellet and so on). In LHD, a tracer-encapsulated solid pellet (TESPEL) [1] is extensively utilized as a plasma perturbation tool and produces significant results [2,3]. The one of the disadvantages of the TESPEL method as the plasma perturbation tool is that a large electron temperature perturbation, which can be invoked only by the large TESPEL injection is accompanied by a large electron density perturbation. This is because the current TESPEL injection axis is set on the equatorial plane of LHD aiming the LHD plasma center. In this contribution, a new TESPEL injector under development is introduced to overcome the above disadvantage.

2. Basic Concept of a new TESPEL injector with a variable injection angle mechanism

In order to invoke the large electron temperature perturbation by the TESPEL method, the larger TESPEL should be injected into the LHD plasma, and consequently the large electron density perturbation is also invoked in the core plasma region, because of its deeper penetration. This situation will make it difficult to perform the dynamic analysis on the electron heat transport accurately. In addition, in order to increase the amount of the impurity tracer in the TESPEL, the outer diameter of the TESPEL is inevitably increased under existing conditions, and thus the shallow deposition of the impurity tracer cannot be achieved. This is currently an issue to be solved for the detailed analysis of impurity transport in the edge region. For the solution of these drawbacks, we adopted an oblique injection of the TESPEL to the LHD plasma. Since the current TESPEL injector has no room for being added such a function, we decided to install a new dedicated TESPEL injector on LHD.

3. Apparatus

A basic design of the new TESPEL injector is almost the same as the existing one [4], which consists of the TESPEL injection system and the differential pumping system. In the TESPEL injection system, the TESPEL will be accelerated through the gun barrel (with the inner diameter of 1mm and its length of ~ 410 mm) by a helium gas with a typical pressure of several MPa. The differential pumping scheme works for preventing the high-pressure helium gas for the TESPEL acceleration from penetrating into the LHD vacuum vessel. Here, a three-stage differential pumping system is installed. The volume of the expansion chambers are 0.05 m^3 (1st, farthermost from LHD), 0.06 m^3 (2nd) and 0.06 m^3 (3rd, nearest to LHD), respectively. The 1st expansion chamber is evacuated by a helical groove pump (0.27 m^3/s for He) and the 2nd/3rd expansion chambers are done by turbo-molecular pumps (0.16 m^3/s for He, 0.32 m^3/s for He, respectively). The 1st expansion chamber is connected with the 2nd expansion chamber through an ultrafast shutter valve (closing time, less than 10 milliseconds), and then the 2nd expansion chamber is connected with the 3rd expansion chamber through a gate valve (closing time, 1 second). After the ejection of the TESPEL, these valves will be closed immediately.

In order to realize effectively the oblique injection of the TESPEL, the final guide tube (i.e. nearest to the LHD plasma) for the TESPEL is installed in the vacuum vessel of LHD, as shown in Fig.1. And this final guide tube can be moved up and down by a remote-controlled drive mechanism for controlling precisely the penetration depth of the TESPEL. As can be seen in Fig. 1, the TESPEL injection axis can be set only in the edge ergodic region. This will be extremely useful for the study of an edge-radiation-enhanced operation scenario. The TESPEL entering LHD plasma will be observed by the existing spectroscopic diagnostics [5] for confirmation of its penetration depth.

4. Summary

The new TESPEL injector is currently under development for achieving the oblique injection of the TESPEL. This injector has the bended guide tube inside the LHD vacuum vessel, which can be moved up and down by the remote-controlled drive mechanism. This function enables us to invoke various amplitudes of electron temperature perturbation with the small electron density perturbation. Moreover, the TESPEL can be injected only toward the edge ergodic region; i.e. the impurity tracer can be deposited only in the edge ergodic region by this new injector. The test of this new injector will be performed soon and the first operation in the LHD experiment is planned in FY2014.

Acknowledgments

We would like to thank to all of the technical staff of NIFS for their excellent support. This work is supported by a Grant-in-Aid for Young Scientists from a Toray scientific foundation.

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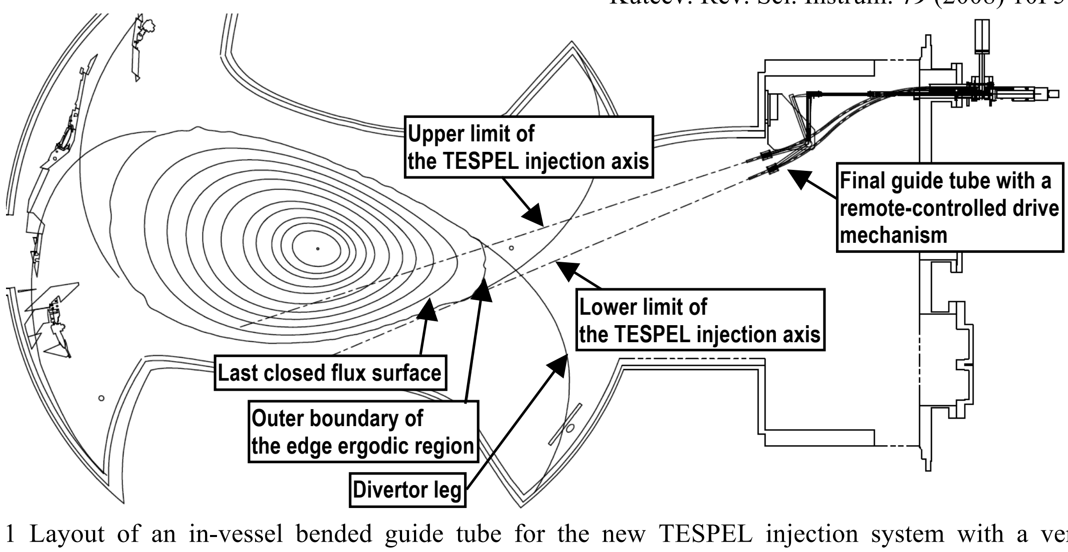

Fig. 1 Layout of an in-vessel bended guide tube for the new TESPEL injection system with a vertical cross-sectional view of LHD vacuum vessel, together with a typical LHD plasma (magnetic axis R_{ax} = 3.75m). The guide tube can be moved up and down by a remote-controlled drive mechanism. The upper and lower limits of the TESPEL injection axis of the new TESPEL injection system are indicated by the chain lines.