§6. Up-grade of Positive-ion Based Neutral Beam Injector for Perpendicular Injection on LHD

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Positive-ion based perpendicular neutral beam (NB) injector was installed and had started its operation since the 9th-experimental campaign of LHD. The injector had 2 ion-sources and the injection power of each ios-source was 1.5[MW/ion-source] (3[MW] in total). The injector was operated successfully without any major troubles during the experimental cycle, but it had two major problems as shown below:

1. Introduction of neutral hydrogen gas to LHD vacuum vessel(VV) was significant compared to the existing tangential NB-injectors. (The base pressure of the torus increases 6.1×10^{-3}[Pa] from 5.7×10^{-4}[Pa]. with the usage of perp.-NB.)
2. The beam pulse duration was limited to 0.5[s] at the full power injection. This pulse duration is limited by the temperature rise at residual ion beam dump in the injector.

Especially, the first problem was very serious in performing high-beta discharges with NBI start-up scenario and/or in performing high-Ti scenario with low density discharges.

During the maintenance period before the 10th experimental campaign, the perp.-NB injector was upgraded to increase its injection power up to 6MW by increasing the number of ion-sources from two to four. Figure 1 shows the injection history of the perp.-NB during the 10th-cycle. As shown in the figure, we have successfully fulfilled the requirement of 6[MW] injection and have achieved the injection power of 6.9[MW] at the end of experimental cycle.

With the upgrade of injection power, we have also modified the structures and the components of the injector to diminish the problems listed above.

The problem on the pulse duration is modified by changing the material of the beam dump from simple copper tubes to copper swirl tubes and by increasing the pressure of cooling water to 1.5[MPa] from 1[MPa].

To reduce the hydrogen-gas introduction to the LHD, we have made following modifications as follows:

A) The number of cryo-sorption pumps per single ion-source were increased about 30[%]. The pumping speed was increased to 500 from 375 [m3/s/ion-source].

B) To reduce the gas-introduction to the ion-sources and the neutral-gas-cell, the number of the beam extraction holes and the widths of the neutral-gas-cell were reduced to the 90[%] of the original.

C) To reduce the gas-flow from the injector to LHD-VV, the shape of beam-limiter for injection-port was modified. A vertical dividing plate was installed in the limiter and the length of the limiter was increased from 20 to 30[cm]. With this modification, conductance of the limiter was reduced to 90[%] of the original.

Taking all of these modification on the vacuum system into an account, we had estimated that the introduction of hydrogen neutral to LHD-VV would be reduced to a half of the original.

The effect of the upgrade and these modifications was significant to the performance of LHD-plasmas. This enables us to achieve the beat-value of 5[%] and the central ion tempearature of 5[keV].

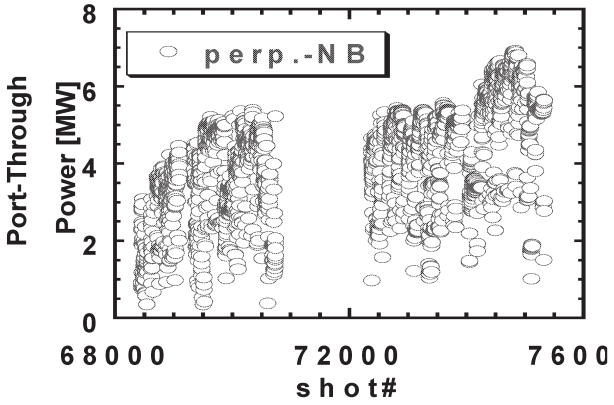

Fig.1 Thehistory of the perpendicular NB injection power.

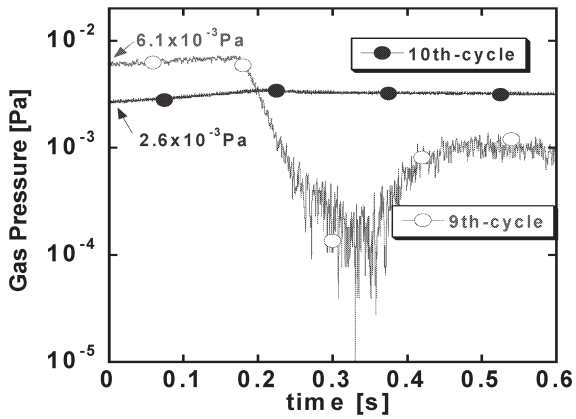

Fig.2 The LHD-VV base pressure with the operation of the perpendicular NB-injector. Lines with open circles(○) show the vacuum pressure during the 9th-cycle, while lines with closed circles(●) show that during the 10th-cycle. The base pressure was reduced from 6.1×10^{-3} to 2.6×10^{-3} [Pa].