New Results of Supersonic Molecular Beam Injection on HL-2A

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Recently, a new gas supply system with pressure measurements was installed in the Supersonic Molecular Beam Injection (SMBI) system on the HL-2A tokamak. The quantity of injected particles varies with parameters of SMBI has been measured. Using plasma density profile measured by the multi-channel high power DCN laser interferometer, the mean particle increment in the plasma could be calculated after an SMBI pulse. Fuelling efficiency is estimated as the particle increment of the plasma divided by the quantity of injected particles.

Fuelling efficiency depends on Injection depth which is not only a key issue for fuelling techniques but also an important physical significance. The study on the penetration depth of SMBI has been carried out on the HL-2A tokamak through tangential Dα arrays. The Dα signals show that the SMB consists of a fast component (FC) and a slow component (SC) after passing through a conic nozzle, which is installed on SMB valve to improve the beam performance. The FC can penetrate more deeply such as 8.5 cm inside the separatrix, while the SC is around 4 cm inside the separatrix. Some valuable phenomena with SMBI fuelling in H-mode discharges on HL-2A are also presented.

Keywords: SMBI, fuelling efficiency, injection depth, tokamak fuelling, HL-2A.

1. Introduction

Plasma fuelling is one of a critical task for the next generation experiment, such as ITER, since the fusion fuel, such as deuterium and tritium, has to be supplied into the plasma core as deep as possible; and for nowadays tokamaks, it is important to understand the particle balance and plasma density control. Three fuelling methods have been developed to meet the demand depicted above; there are gas puffing (GP), pellet injection (PI) and SMBI, respectively. As an efficient fuelling method and an important auxiliary diagnostic means for fusion plasma, SMBI was successfully developed on the HL-1M tokamak [1-3], and then it was applied to HT-7 [4], HL-2A [5], Tore Supra [6], W7-AS [7], ASDEX-Upgrade [8], and JT-60 [9].

The quantity of injected particles is an important parameter for SMBI and the fuelling efficiency is a common concern for researchers. On Tore Supra [6] and ASDEX-U [6, 10], the DCN interferometer is applied to measure the fuelling efficiency detecting the increment of the line integrated electron density and hence the fuelled particle amount. The reciprocating probe provides the edge profiles of electron temperature and density simultaneously. It is observed that the fuelling efficiency of SMBI is around 30 ~ 60 %, about three to four times as high as that of the conventional gas puffing but not as good as that of pellet injection [11, 12].

Injection depth related with fuelling efficiency is a key issue for fuelling techniques. The SMBI fuelling depth was studied by means of electron-cyclotron emission and soft-X ray diagnostics; and the results indicate that the perturbation depth of heat pulse is poloidally asymmetric and electron temperature (Te) pulses cannot propagate to the plasma centre. Another commonly used diagnostics is Hα/Dα array to determine the injection depth [5, 13]. Simulations based on the transport of neutral hydrogen have been carried out on the HL-1M tokamak, and the main deposition area is outside the normalized radius of 0.75, which means the SMBI can penetrate about several centimeters, such as 5 cm, into the plasma [14]. The SMBI depth is also a key issue to understand its fuelling features.

H-mode discharges have been obtained on HL-2A, with the combined heating of ECRH and NBI. Plasma density profile has clear relationship with plasma confinement mode. It is reported that PI triggers ELMy emission in H-mode discharges [15]. On DIII-D obtain PIH-mode with PI fuelling [16]. The SMBI fuelling plays an important role in the H-mode discharges on HL-2A, including density and fuelling control, reducing the recycling of impurity and particles. Compared to PI, SMBI is not so efficient due to less injection depth, but it still has some benefits to promote H-mode discharges.

This paper focuses on the fuelling efficiency of SMBI on HL-2A. The performance of SMBI in H-mode discharges and the new injection features are also