§ 3. Gas Flow Velocity of the Direct Gas Puff

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A piezo-valve has been inserted inside the vacuum vessel of LHD. The gas flux puffed from this inserted piezo-valve directly reaches the plasma surface. Therefore we call this a 'direct gas puff' (DGP). DGP experiment on LHD has been successfully carried out in the 6th experimental campaign [1]. After that, the gas flow velocity, v_{gas}, of the piezo-valve used in LHD has been measured in a test chamber of 3.6 m long [2]. The experimental results are briefly reviewed here. To simulate the DGP configuration, the piezo-valve is set on a side of the test chamber and a pressure gauge (MKS Baratron® capacitance manometer, MODEL# 617A) is set on another side. Therefore, the gas flux directly reaches the pressure gauge. Various gasses of hydrogen, helium, methane, neon, nitrogen and argon are used in the experiment. Example waveforms obtained in the experiment are shown in Fig. 1. Here, v_{gas} is determined from delay of the time where the pressure signal reaches its maximum to the end time of the gas puff pulse (0.02 s). Shaded region in Fig. 1 denotes the time-shifted gas puff pulse, where the time-shift is determined from the sound velocity, c_s. If $v_{gas} = c_s$, it is expected that the pressure signal begin to rise (or, reaches its maximum) at the front (end) of the shaded region.

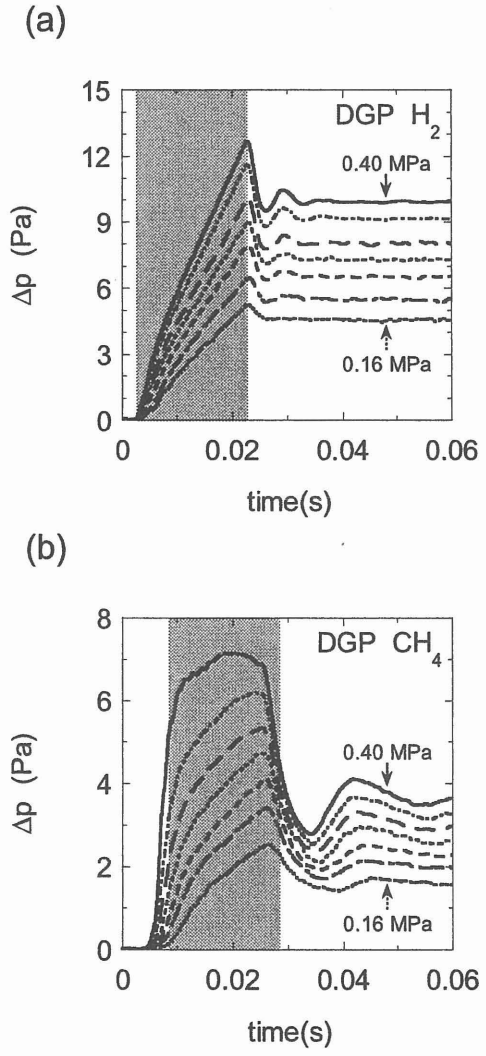

Fig. 1. Waveforms of (a) hydrogen DGP, and (b) methane DGP. Shaded region denotes the time-shifted gas puff pulse, where the shift is determined from the sound velocity. The absolute primary pressure is increased from 0.16 to 0.40 MPa, with an increment of 0.04 MPa.

The Mach number ($M = v_{gas} / c_s$) increases with the mass of the gas molecule and/or the primary pressure of the piezo-valve as shown in Fig. 2. $M > 1$ is obtained with methane, neon, nitrogen and argon, while $M \sim 1$ with hydrogen and helium. Paying attention to the rare gas groups of helium, neon and argon, it can be recognized that M linearly increases with the mass number. Large M of over 1.5 is obtained with the methane.

v_{gas} of the normal gas puff has been also estimated for hydrogen and methane, where another piezo-valve is set vertically on a cross-tube and therefore the gas flow does not directly reach the pressure gauge. In both cases, v_{gas} is identical to the sound velocity. This means that the direct gas puff configuration is essential to achieve the supersonic gas flow.

Reference

1) Miyazawa, J. et al., submitted to Nucl. Fusion.
2) Miyazawa, J. et al., submitted to NIFS memo.

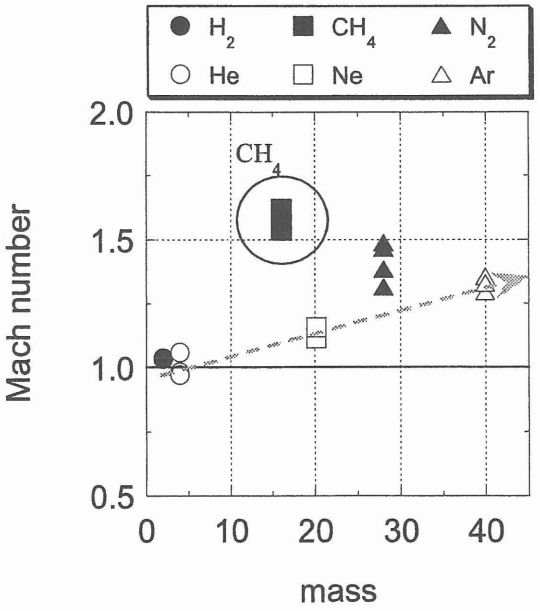

Fig. 2. Mass dependence of the Mach number. The primary pressure of the valve is fixed to 0.27 – 0.34 MPa.