§8. Measurement of Neutral Particles by Means of Sound Wave

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In a large diameter plasma such as the HYPER-I device [1], the spatial distribution of neural particles is expected to be important for a plasma production. In order to measure the local properties of the neutral particles, we have developed a new method using sound waves with two different frequencies.

Figure 1 shows that the propagation speed of the pressure perturbation caused by the vibrating prate depends on the gas parameter r ($= p / \mu\ \omega$) where p is the ambient pressure in Pa, μ is the viscosity in Pas, and ω is the angular frequency of the perturbation in rad/s. Here, the propagation speed, v, is normalized by sound speed c_s [$= (\gamma p / \rho)^{1/2}$, ρ: the mass density in kg/m^3, γ : the specific heat ratio]. The open circles and the open squares are the measurements by Greenspan in helium with $\omega / 2\pi =$ 1 MHz [2] and in argon with $\omega / 2\pi =$ 11 MHz [3], respectively. The closed squares and triangles are our measurements in helium with $\omega / 2\pi$ =120 kHz and 40 kHz, respectively. The solid curve, $v/c_s = (r+0.3) / (r+0.15)$, is found to fit these measured measurements.

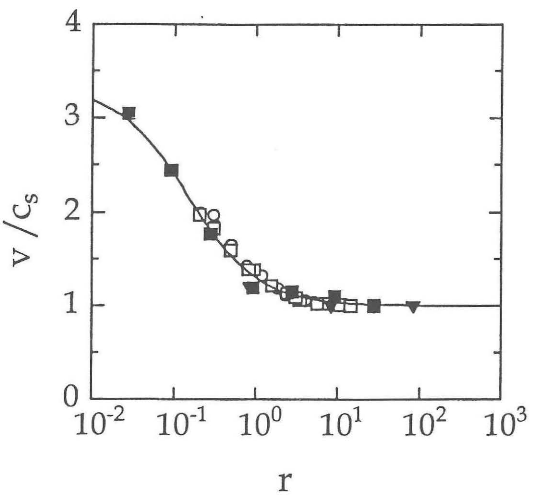

Fig.1 Propagation speed versus gas parameter.

Now, we suppose that we have measured the propagation speeds of the pressure perturbation with different frequencies, say, ω_1 and ω_2 ($\omega_1 > \omega_2$), and the results are v_1 and v_2, respectively. Then, we can find the ratio p/μ by the following equation:

$$p / \mu = \{ \omega_2 / [40(R_v - 1)] \} [[(10R_\omega + 3) - (3R_\omega + 10)R_v + \{[(10R_\omega + 3) - (3R_\omega + 10)]^2 - 120\, R_\omega (R_v - 1)^2\}^{1/2}]],$$

for $p / \mu > (3\ \omega_1 \omega_2 / 40)^{1/2}$.

Here, $R_\omega = \omega_1 / \omega_2$ and $R_v = v_1 / v_2$. We also find the ambient gas temperature, T, using the equation:

$$T = (m\, v_1^2 / \gamma k_B) \cdot [(p / \mu) + 0.15\, \omega_1]^2 / [(p / \mu) + 0.5\, \omega_1]^2.$$

From this value of T, we can estimate the viscosity, given by [4]

$$\mu = 2.7x10^{-6} (MT)^{1/2} / \sigma^2 \Omega,$$

and, simultaneously, the pressure p, since we have the value of p/μ in the procedure.

In summary, by measuring the propagation speeds of the pressure perturbation with different two frequencies, we can estimate both p and T of the low pressure ambient gas.

References

1) Tanaka, M. : J. Phys. Soc. Jpn. 60(1991)344.

2) Greenspan, M. : J. Acoust. Soc. Am. **22** (1950) 568.

3) Greenspan, M. : J. Acpust. Soc. Am. **28** (1956) 644.

4) Reid, R. C. Sherwood, T. K. : *The Properties of Gas and Liquids* (McGrow-Hill, New York, 1958).