Void Fraction Measurement at Premixing Stage in the TROI

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1. Introduction

A lot of effort [1] has been made to examine the mixture distribution for pre-mixing stages. However, the available information for the void fraction for integral tests using prototypic materials is very limited, and the code validation shows the large scattering that is due to the inaccurate experimental information for the void fraction. In this paper, the void evaluation by detection of the differential pressure in the TROI test facility was checked and compared with alternative methods such as a level-swell meter and a high-speed visualization system for confirmation by scoping tests. The void fraction by differential pressure sensors in TROI tests are also compared with the void fractions by the video images.

2. Verification of Void Fraction

2.1. TROI Facility

The TROI test facility was composed of a furnace, a furnace vessel, an interaction vessel, a pressure vessel, and an intermediate melt catcher. In the interaction vessel of the TROI facility, three differential pressure transmitters are mounted on the interaction vessel to measure the average void fractions between 0.2 m to 0.4 m, 0.4 m to 0.6 m, and 0.6 m to 0.8 m from the bottom of the interaction vessel (Rosemount 3051S, VFDP101 ~ VFDP103), as shown in Fig. 1.

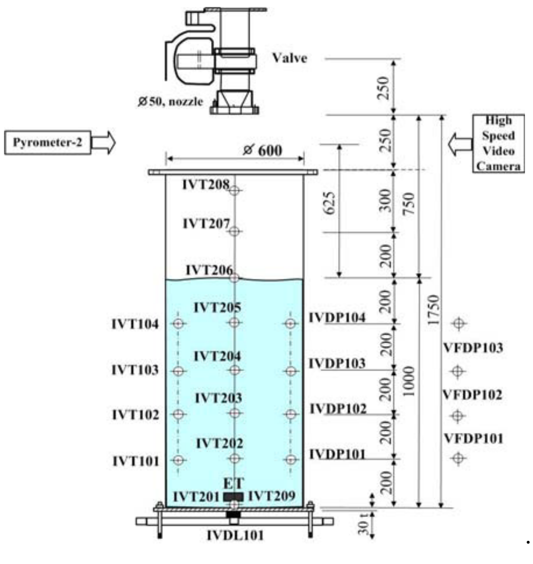

Figure 1 Schematic diagram of the interaction vessel in the TROI facility (unit : mm).

2.2 Principle of Void Fraction Measurement

Fig. 2 shows the schematic of volume-average void fraction measurement by DP. The void fraction between point 1 and point 2 of the Fig. 2 can be derived as below.

$$P_3 = P_1 + \rho_c g(H + H_0) \quad (1)$$

$$P_4 = P_2 + \rho_c g(H + H_0) \quad (2)$$

$$DP_{sensor} = P_3 - P_3 \quad (3)$$

$$DP_{sysytem} = P_2 - P_1 \quad (4)$$

$$\alpha = \left[\rho_f - DP_{sys}\, gH\right] / \left(\rho_f - \rho_g\right) \quad (5)$$

$$\text{If } \rho_f >> \rho_g \quad (6)$$

$$\alpha = 1 - \left(\rho_c gH - DP_{sensor}\right) / \rho_f gH \quad (7)$$

When assumed, $\rho_c \approx \rho_f$ (8)

$$\rho_c \approx DP_{sensor} / \rho_f gH \quad (9)$$

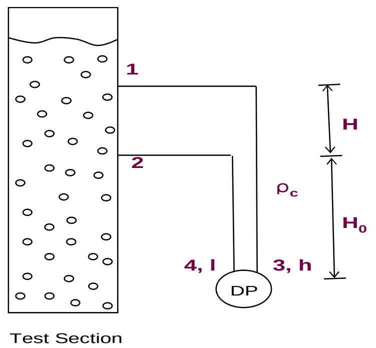

Figure 2 Schematic of void fraction measurement

Meanwhile, the principle of radarmeasurement with very high frequency is known in traffic-velocity measurement, and distance evaluation in automation and control. For the measurement of a liquid level an electrical pulse can be sent to the surface of the liquid [2]. The delay-time between the emitted signal and its echo from the liquid surface allows for the determination of the level of the liquid. When the electrical pulse is transmitted through a cable length, l, its propagation speed, Vp, is determined by the distributed inductance, L, and capacitance, C, of the cable;

$$V_p = \frac{l}{\sqrt{LC}} \quad (10)$$

2.3 Scoping Test

The void fraction in the scoping test vessel was measured by both the three differential pressure transmitters and a level swell meter simultaneously.

By using the scoping test, the central void fraction was calculated as 0.054 based on the water level swell measurement which was obtained by the high-speed video camera. The volume-averaged void fraction measured by the VFDP103 at the upper volume was 58% of the central (maximum) void fraction measured by the high speed camera. Therefore, the void fraction by differential pressure is plausible in TROI tests. The void fraction from the level swell is similar to them of differential pressure transmitters.

Table 1 Scoping test results

Time (sec)	Maximum signal (instrument)
2.0185	VF 0.0436 (VFDP101)
2.3040	VF 0.0445 (VFDP102)
2.6555	VF 0.0313 (VFDP103)
2.8040	Level 1,040mm (level swell meter)

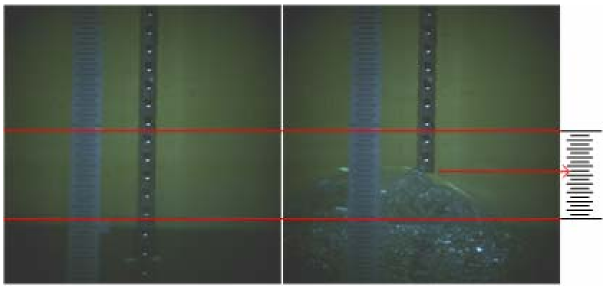

Figure 3 Scoping test results

2.4 TROI application of DP

The validation result of the void fraction measured from the differential pressure sensors in the scoping tests is applied to the TROI visualization test where the void fractions are measured by using the differential pressure sensors and are compared with the results estimated from the level swell by the high speed camera. As shown in Figure 4, the void fractions measured from differential pressure sensors are very similar to them estimated from the level swell by high speed camera, as seen Table 2 and Fig. 5. Therefore, it was found that the void fractions measured by differential pressure sensors in TROI are reasonable.

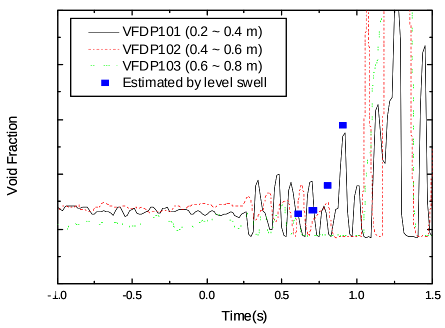

Figure 4 Void Fraction in TROI test

Table 2 Void fractions in the interaction vessel estimated by the level swell

Time(sec)	Level swell (m, α_{max})	$\overline{\alpha} = \alpha_{max} / 2$
0.6	0.0293	0.0147
0.7	0.0350	0.0175
0.8	0.0812	0.0406
0.9	0.1898	0.0949

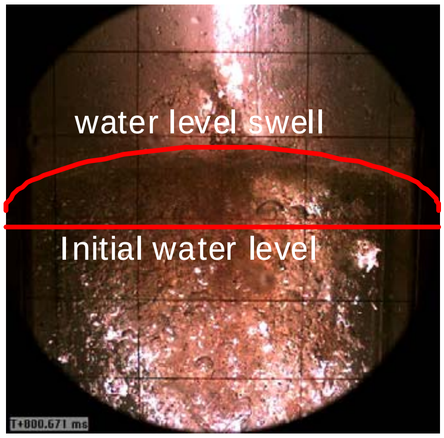

Figure 5 Level Swell from Video image

3. Conclusions and Recommendations

The void evaluation by detection of differential pressure was checked and compared with alternative methods such as a level-swell meter and a high-speed visualization system for confirmation by scoping tests. From the scoping test using differential pressure transmitters, a water level swell meter, and a high-speed video camera, the void-fraction measurement technique by a differential pressure is plausible quantitatively. In addition, when the validation result of the void fraction using differential pressure sensors in the scoping tests is applied to the TROI, differential pressure sensors in TROI were reasonable working.

ACKNOWLEGEMENTS

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