An Experimental Investigation on the Velocity Fluctuation Characteristics in a Triple Air Jet

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1. Introduction

The thermal striping which occurs due to a turbulent thermal mixing in the upper plenum of a liquid metal reactor causes a temperature fluctuation on the adjacent solid materials and it is an important parameter in the design of a liquid metal reactor. An experimental apparatus which is a mock up of the fuel assembly in the liquid metal reactor is devised, and the average velocity and the velocity fluctuation in a two-dimensional jet from three nozzles are measured. In the present paper the characteristics of the velocity fluctuation which is used for a validation of a thermal hydraulic computer code is described.

2. Experiment

Figure 1 shows the test section of the triple jet experiment. The dimension of the nozzle is 15x180mm. The interval between the nozzles is 52.5mm and the nozzles are parallel with each other. The length of inlet guide duct to the nozzles is 2000mm. The air ejected from the nozzle enters a test section whose dimension is 360×360mm in area and 2000mm in height. The velocity of the center nozzle is higher than that of the adjacent nozzles. The flow rate of the air is measured by a turbine flow meter whose error range is ±1%. The local air velocity is measured by the 2D LDV and 1000～4000 velocity data which is obtained per one second. Olive oil is used as a particle for the measurement.

Experimental range of the air velocity is 10～40m/s. Measured locations are 26×12 points in the horizontal and vertical direction respectively. The measured points are searched automatically by a transverse machine.

3. Result and Discussion

Both the velocity components in the vertical direction ($U = \overline{U} \pm u$) and in the horizontal direction ($V = \overline{V} \pm v$) are measured by the 2D LDV. The time-averaged vertical velocity fluctuation (u) and Reynolds shear stress (uv) are defined as follows where N is the number of measured data.

$$u = \sqrt{\sum_i (U_i - \overline{U})^2 / N} \quad (1)$$

$$uv = \sum_i (U_i - \overline{U})(V_i - \overline{V}) / N \quad (2)$$

Figure 2 shows the ratio of the vertical Reynolds stress and the horizontal Reynolds stress when the inlet nozzle velocities are 10/20/10 m/s respectively. The ratio of the vertical and horizontal Reynolds stresses varies significantly when the distance from the inlet is relatively small and it has its maximum at the center when the vertical locations are in the 273-323 mm range. When the vertical location is far from the inlet, the ratio becomes constant and the value of the ratio is approximately 0.5, which shows that the Reynolds stresses are not isotropic.

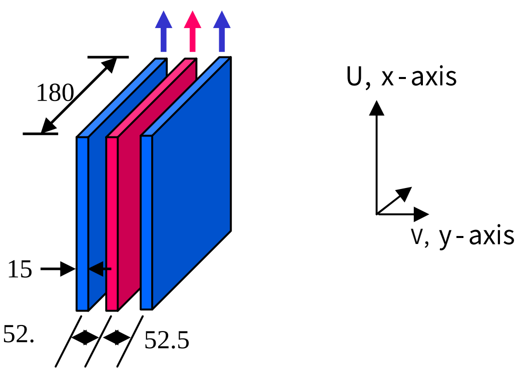

Figure 1. The shape and dimension of the test section for the triple jet experiment.

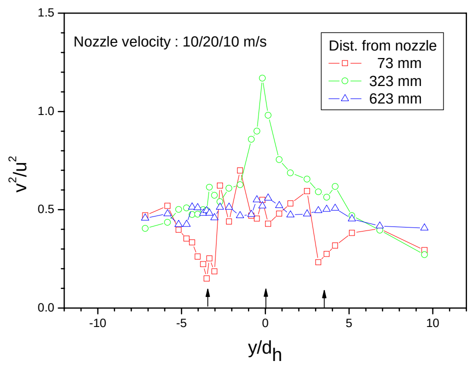

Figure 2. The ratio of horizontal and vertical Reynolds stresses.

Figure 3 shows the ratio between the Reynolds shear stress and the vertical Reynolds stress for the same experiment. In this figure y/d_h is the ratio of the distance from the center to the hydraulic diameter. Here the hydraulic diameter is the width of the nozzle (15mm). The ratio varies significantly near the inlet nozzle and it becomes stable when the vertical distance becomes large (623mm), where the jet is fully developed.

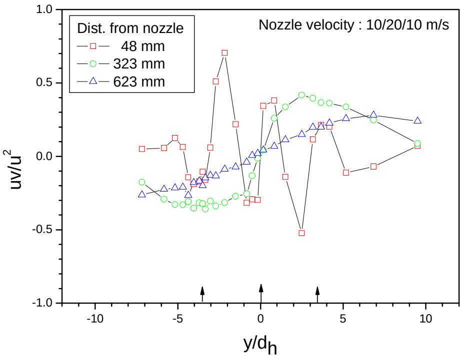

Figure 3. The ratio of the Reynolds shear stress and the vertical Reynolds stress.

Figure 4 shows the dimensionless velocity gradient and the ratio of the Reynolds shear stress and the vertical Reynolds stress at x=623mm for three different experiments where the inlet velocities are different. The dimensionless velocity gradient is obtained by the velocity at the center nozzle (U_o) and the width of the jet. This figure shows that the dimensionless velocity gradient and the ratio between the Reynolds shear stress and the vertical Reynolds stress has a similar trend for the three different experiments. The time-averaged Reynolds shear stress can be expressed in terms of the turbulent eddy viscosity (ν_t) as follows when the vertical velocity is dominant.

$$\overline{uv} = -\nu_t \frac{\partial U}{\partial y} \tag{3}$$

The two variables in the Fig. 4 are created to find the relation given in Eq.(3). The relation between the ratio of the Reynolds shear stress and the vertical Reynolds stress and the normalized velocity gradient can be expressed as follows from Figure 5;

$$\frac{uv}{u^2} = -5.5 \frac{\partial (U/U_o)}{\partial (y/d_h)} + \alpha \tag{4}$$

where α is a constant (-0.05) and is neglected in Figure 5. If we compare Eq.(3) and Eq.(4), we can see that the turbulent eddy viscosity can be expressed as follows in terms of the vertical Reynolds stress, hydraulic diameter and jet velocity.

$$\nu_t = -5.5 u^2 \frac{d_h}{U_o} \tag{5}$$

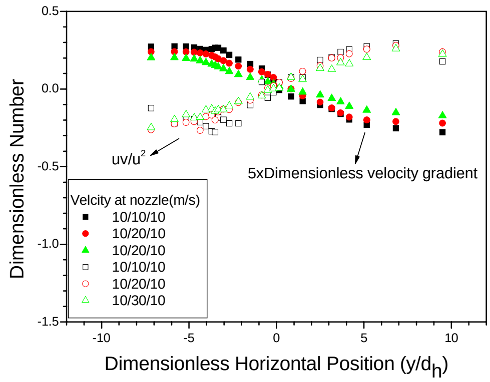

Figure 4. The distribution of the uv/u^2 and the velocity gradient.

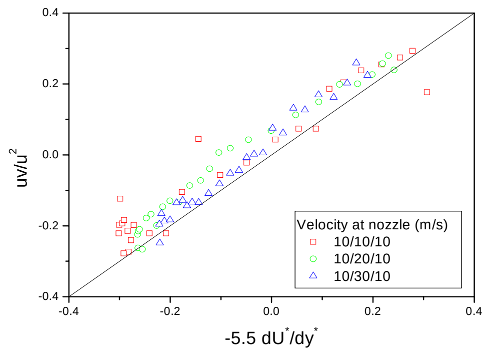

Figure 5. The relation between the uv/u^2 and the dimensionless velocity gradient.

4. Conclusion

From the triple jet experiment we found that the ratio between the vertical and horizontal Reynolds stresses is not constant near the inlet, and it is almost constant and is around 0.5 in a region where the jets are fully developed. In the fully developed region the turbulent eddy viscosity can be expressed as Eq.(5) in terms of the vertical Reynolds stress, inlet velocity and width of the nozzle.

Ackowledgement

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