An Experimental Study on the Velocity Profile of a Two Parallel 2D 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 two nozzles are measured. The primary objective of the present study is to analyze and compare the experimental data with the theoretical velocity profile reported in literature

2. Theory

The turbulent two-dimensional jet was first calculated by Tollmien who used Prandtl's mixing length hypothesis. After then Reichardt and Geortler gave a short account of a simpler solution (Eq.1-2) based on Prandtl's second hypothesis [1].

$$u = U_c(1 - \tanh^2 \eta) \tag{1}$$

$$v = (U_c / 2\sigma) \cdot \{2\eta(1 - \tanh^2 \eta) - \tanh \eta\} \tag{2}$$

In the above equations the assumptions that the rate of increase in the width of the jet is proportional to the distance from the nozzle, x, and the centerline velocity (U_c) decreases in proportion to $U_c = U_s(x/s)^{-1/2}$ are employed. Here s is a fixed characteristic distance from the nozzle and U_s is the velocity of that point. The η is defined as $\eta = \sigma y / x$ and y is the distance from the centerline ($y = 0$), and σ is the experimental constant. The above equations can be used for a jet with one nozzle and can not be used for a jet with two nozzles like in the present study. In order to overcome this deficiency, two parameters, $\eta_1 = \sigma(y - y_1)/x$ and $\eta_2 = \sigma(y - y_2)/x$, are introduced where y_1 and y_2 are the distances of the centers of the two nozzles. After on introduction of $\eta_1 = \sigma(y - y_1)/x$ and $\eta_2 = \sigma(y - y_2)/x$, the velocity components u_1, u_2, v_1, v_2 are calculated and u, v are changed as follows to conserve the momentum;

$$u = (u_1 \cdot |u_1| + u_2 \cdot |u_2|)/(|u_1| + |u_2|) \tag{3}$$

$$v = (v_1 \cdot |v_1| + v_2 \cdot |v_2|)/(|v_1| + |v_2|) \tag{4}$$

3. Experiment

The length and area of the inlet nozzle are 1500mm and 15x180mm respectively and the nozzles are separated by a glass plate whose thickness is 5mm. The air is supplied by two loops and the air ejected from the nozzle enters a test section whose area and length is 360X360 mm and 2000m. The two sides of the test section are made by glass that can be used for a high temperature situation. In each loop, a filter, heater, flow meter, strainer and three step blower are installed. The flow rate of the air injected to the test section is measured by the turbine flow meter whose error range is ±1%. The temperature is controlled and measured by a k-type thermocouple. The local air velocity is measured by the LDV and 1000～4000 velocity data are obtained per one second. The Olive oil whose diameter is 5㎛ is used as a particle for measurement. The lower magnitude of the velocity of the air is fixed at 10m/s and the higher range of the velocity of the air is 10～40m. The temperature of the air is kept at 60℃. In each experiment 25 data are obtained in the horizontal direction and 12 data are obtained in the vertical direction for each horizontal location. A total of 300 experimental data are obtained

4. Result and Discussion

Fig. 1 shows the distribution of the centerline velocity when the velocity of the two nozzles are 10m/s and 9.6 m/s. This measured data shows that the centerline velocity of the two nozzle jet does not follow the trend of $U_c = U_s(x/s)^{-1/2}$ and is described by the following equation.

$$U_c = U_s[1 - \tanh(0.105(x/s - 1))] \tag{5}$$

In the above equation s is the fixed characteristic distance from the nozzle where the jet core disappears. According to Idelchik [2], s is proportional to the width of the nozzle and can be expressed as $s = aw$. The proportional constant a is about 4.29□5.72 in the plane parallel jet and is 5.42 in the present experiment. Therefore the U_s, the velocity at s, is the initial velocity at the nozzle. The experimental constant σ is set at 7.67, which is used by Reichardt and Geortlerlf. First, insert Eq.(5) into Eqs.(1)-(2) and then calculate u , v by Eqs.(3)-(4). Fig.2 and Fig.3 show the comparisons with the measured data. The axial velocity component (u) agrees well with the measured data except for the side regions where the reverse velocity component occurs. The vertical velocity component shows a similar trend with the measured data, but deviates from the measured data except for the center region close to nozzle..

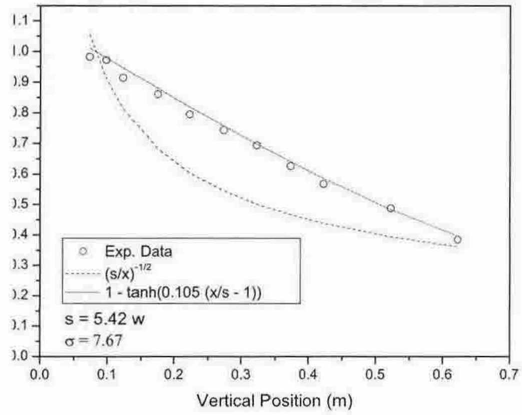

Fig.1 Comparison of the measured data for the centerline velocity with the theoretical equations.

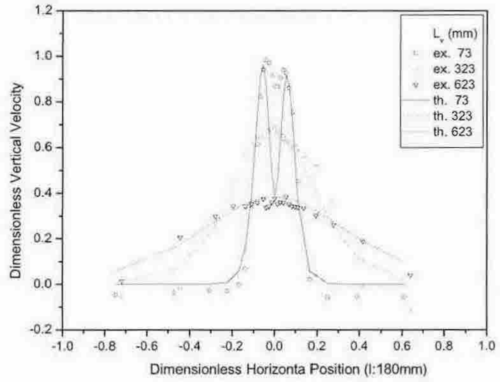

Fig. 2 Comparison of the measured longitudinal velocity component with the theoretical equations.

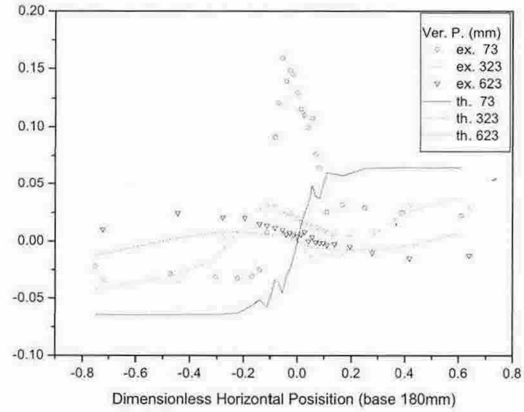

Fig. 3 Comparison of the measured vertical velocity component with the theoretical equations.

5. Conclusion

The centerline velocity component measured from the two parallel nozzles is not proportional to $x^{-1/2}$ and is described by Eq.(5). The modified theoretical equation predicts well the average longitudinal velocity component from the two parallel nozzles, but shows a deviation from the measured data for the vertical velocity component although the same trend is observed near the nozzle region.

Ackowledgement

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