Experimental Study of a Turbulent Jet Induced by a Steam Jet Condensation through a Hole in a Water Tank

Nam-Hyun Choi, Young-Jung Youn, Jong-Kook Park, and Yeon-Sik Kim
Korea Atomic Energy Research Institute, Thermal Hydraulic Safety Research Division, P.O.Box 105, Yuseong, Daejeon, 305-600, Korea, nhchoi@kaeri.re.kr

1. Introduction

A turbulent jet induced by a steam jet condensation in a water pool was investigated experimentally. An experimental apparatus equipped with a steam boiler, a single-hole steam sparger, and a water pool, etc. was used. For the measurements, a pitot tube and thermocouples were used for the turbulent flow velocity and temperatures, respectively. Overall flow shapes of the turbulent jet by the steam jet condensation are similar to those of axially symmetric turbulent jet flows. The angular coefficients of the turbulent rays are quantitatively comparable between the traditional turbulent jet flows and the turbulent jet flows induced by the steam jet condensation in this work. Although the turbulent flows were induced by a steam jet condensation, the general theory for turbulent jets was found to be applicable to the turbulent flows of this work.

2. Experimental Apparatus

The experimental apparatus consists of a steam boiler, a water tank, a steam sparger with a single hole, instruments for a temperature and velocity measurement, and a data acquisition system as shown in Fig. 1. And there are several thermocouples near the tank wall to measure the bulk temperature and a traverse system is provided to manipulate the pitot tube/thermocouples for measuring water velocity in the downstream region of steam jet as shown in the figure. Detailed geometric informations for the single-hole sparger and the pitot tube/thermocouples is shown in Fig. 2.

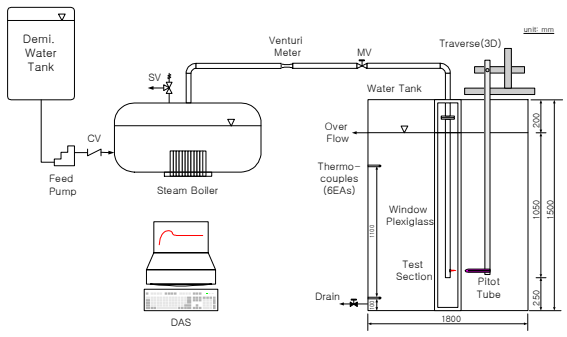

Figure 1. Schematic diagram of the experimental apparatus

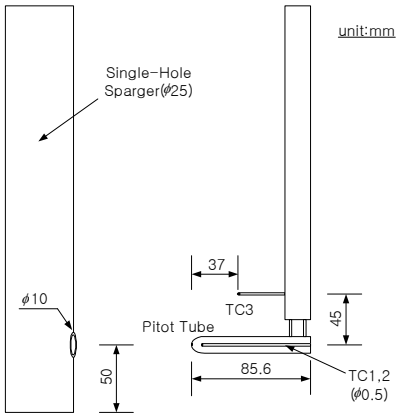

Figure 2. Single-hole sparger and pitot tube/thermocouples.

3. Experimental Results

There are several condensation modes for a steam jet condensation in a water pool. In this work, a turbulent jet flow induced under a stable condensation mode was focused on to investigate its turbulent characteristics. In Table 1, a total five cases were described for turbulent jet investigation. As shown in Table 1, pool temperature ranges of 15~48℃ and steam flow condition, at around 1,000kg/m2-sec, whose test conditions are in a stable condensation mode in a steam jet condensation in a water pool. In general, the steam jet flow of stable condensation mode shows relatively calm and stable jet flow and nearly a single phase liquid flow.

In Fig. 3, one of horizontal velocity distributions, e.g. Case 1, is shown. The overall velocity distributions of the turbulent jet show that the velocity profile of the turbulent jet flow induced by the steam jet condensation is very similar to that of the traditional single phase turbulent jet flow.

Using the axial velocity distributions of the turbulent jet flow, several parameters, which are used to define the characteristics of the turbulent flow, were calculated. The characteristic length or jet half width is calculated from the axial velocity distribution, which is a vertical or radial distance from the centerline of the jet flow, where the axial velocity is a half of the centerline velocity. For each jet flow, three or four characteristic lengths were calculated for respective axial positions. Actually, a line connecting all the points of each half jet width represents the shape of a jet ray and a pole, which can be the starting point of the jet ray, was calculated using the jet ray.

Table 1. Test matrix for the steam condensation induced turbulent jet flow

Test I.D.	Pool Temperature	Steam Conditions[a]	Measuring Positions[b]	Remark
Case 1	31~36℃	G~1,000kg/m^2-sec T_{sat}~166℃	8,12,16cm	
Case 2	36~41℃	"	"	
Case 3	15~22℃	"	"	
Case 4	27~35℃	"	"	
Case 5	39~48℃	"	8,12,16,20cm	

Note a: Quasi-steady condition of steam flow
b: horizontal distance from the steam hole exit

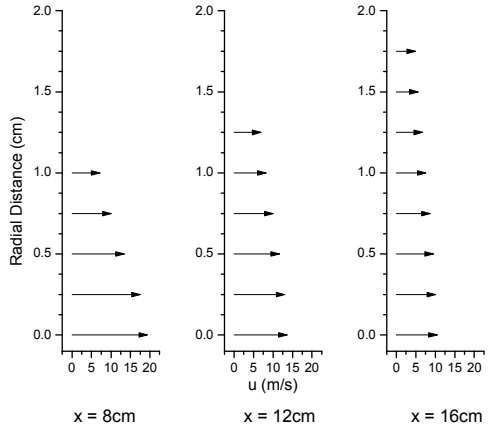

Figure 3. Turbulent jet axial velocity distributions for Case 1

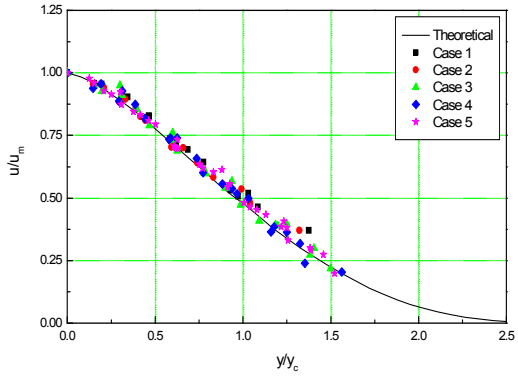

Figure 4. Comparison of dimensionless velocities with the theoretical profile

With this assumption, the theoretical jet profile was compared with experimental dimensionless velocities as shown in Fig. 4. The figure shows that the turbulent jet profile induced by the steam jet condensation is very similar to the theoretical profile of an axially symmetric submerged jet.

4. Conclusion

In this study, an experiment was conducted to investigate the characteristics of a turbulent jet flow induced by a steam jet condensation, which is discharged from a single hole in a water tank. Measured parameters were the steam flowrate at the hole, and the axial velocity and temperature distributions of the turbulent jet.

Measured velocity and temperature distributions were compared with a theoretical model and it was found that the turbulent jet profile induced by the steam jet condensation was very similar to those of Tollmien's axially symmetric source jet model. And a correlation was suggested for a central velocity distribution of a turbulent jet flow induced by a steam jet condensation with steam and jet conditions.

Suggested model and experimental results of this work might be used as verification and validation data for a multi-dimensional CFD analysis in its development of boundary and/or source models for a turbulent jet calculation, which is induced by a steam jet condensation.

Acknowledgement

This work has been performed under the fund of Korea Ministry of Science and Technology as Mid- and Long-Term Nuclear Research and Development Program.

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