VELOCITY PROFILES ACROSS A SPHERE IN FREE JET

Manoj Kumar Kanji ,
Department of Metallurgical Engineering, Jadavpur University, Kolkata – 700032;
Debojyoti Mitra* and Asis Mazumdar
Department of Mechanical Engineering, Jadavpur University, Kolkata – 700032;

Abstract Extensive experimental study on free jet flow past spheres is carried out. The extent of wake region behind the spheres is qualitatively analysed by plotting velocity profiles at various distances away from the spheres. The whole experiment is carried out for various Reynolds numbers and different sphere diameters placed at various distances away from the nozzle mouth from where the jet is originating. The curves clearly depict the velocity defect created due to the presence of sphere. They also point out the gradually spreading as well as weakening nature of the wake region formed behind the sphere.

Keywords: Free jet, Wake Behind sphere, Velocity defect.

INTRODUCTION

The different aspect of flow past a sphere is a subject of interest from the Fluid Dynamics point of view. Spherical objects are very common in different industrial applications since it has the minimum surface area for a given volume. The prediction of drag or pressure distribution across the sphere subjected to a free jet is more difficult and is rarely found in the literature compared to the wall-bounded controlled flow. This type of jet flow is free and unconfined and involves free turbulence, i.e. high Reynolds number, shear flow in an open ambient fluid, unconfined or uninfluenced by the walls. Since these flows are unconfined the pressure is approximately constant through out the flow.

Experimental results on circular jets were given by W. Zimm [1] and P. Ruden [2] as well as by H. Reichardt [3] and W. Wuest [4]. Some results of measurements in circular jets are also contained in the series of reports published by the Aerodynamics Institute in Goettinen [5]. The first theoretical treatment of a circular jet was given by W. Tollmien [6] who based his study on Prandtl's mixing length theory. Calculation on the velocity and temperature distribution in the circular jets has been carried out by L. Howarth [7]. Sforza et al. [8] carried out an experimental and theoretical investigation of the bulk properties of turbulent three dimensional, incompressible air jets issuing into a quiescent ambient air. Ali et al. [9] investigated the flow characteristics of asymmetric and axisymmetric jets produced by the circular and wedge shaped nozzles. A comparative study has been attempted by Mitra et al. [10] to determine the level of turbulence in a confined jet using sphere method. Kanji et al. [11] observed the effect of free jet on pressure variations across spheres.

The primary objective of the present study is to make an experimental investigation for the determination of velocity distributions behind a sphere subjected to a free circular axisymmetric jet. The velocity defect found out from the profiles gives a qualitative idea about the extent of wake zone and pressure drag on the spherical bodies encountered by free jets.

EXPERIMENTATION

The experiment has been conducted in the Fluid Mechanics and Hydraulics Laboratory of Mechanical Engineering Department, Jadavpur University, Kolkata, India. An experimental set-up (Fig. 1) generating free axisymmetric jet is employed here. This set-up consists of blower, pipe, valves, nozzle etc. the nozzle used is of convergent type (angle: 16.7^{o}), having inside diameter of 32 mm. Air jet is created by the centrifugal blower and it blows pressurized air through the nozzle, open to the atmosphere. The pipeline is provided with two hand-operated valves – one immediately at the exit of the blower and the other at the bottom of the vertical portion of the pipeline. These valves can be regulated to

Email: * dmitra2k@yahoo.com

change the Reynolds number $\mathrm{Re} = \frac{u.d}{\upsilon}$. The nozzle is located at the center of a square table and the nozzle face remains flushed with the table surface. A two-way traversing mechanism is fitted to move the pitot tube horizontally as well as vertically. Stands are fabricated to mount the sphere above the vertical free jet. Velocity is indirectly measured at various points with the help of pitot tube and an inclined tube manometer.

Velocity distributions of unobstructed free jet are obtained at non-dimensional heights of 2.5, 5.0, 7.5, 10.0, 12.5 & 15.0. The vertical distance (y) of the station from the nozzle mouth is divided by the nozzle diameter (d) to get the non-dimensional distances.

Velocity distributions behind sphere are obtained at different non-dimensional vertical distances from the sphere at different non-dimensional stations as before. The non-dimensionalization of distances from the sphere is done by dividing the distances (H) by the sphere diameter (D).

RESULTS AND DISCUSSION

Fig.2 shows the unobstructed velocity distributions of free jet plotted against radial distances (x) at different y/d values. The profiles depict that the maximum velocity occurring at the center of the jet diminishes gradually along the axis, while the diameter of the jet increases in the same direction, as expected. Fig. 3 depicts the same plot with non-dimensional velocities and non-dimensional radial distances (x/d). The velocities are non-dimensionalised by dividing them with the corresponding maximum centerline velocity.

Fig.4 through 9 depicts how the velocity distributions behind a sphere change with increasing distances from the sphere. It is seen that at very near to the sphere, the velocity expectedly falls in the wake region, but recovers a little at the center. This may be explained by the vortex rolls having flow direction in the positive sense near the center. However, this effect diminishes as one goes further and further away from the sphere. In general, all these distributions indicate reduction in velocity inside the wake region that spreads with the distance. At the same time the wake weakens with the distance as is evident from the reduction in velocity defect that is prominently captured in the figures. The extent of velocity defect is also evident from Fig. 10 & 11, where distributions without sphere are compared with distributions with sphere.

CONCLUSIONS

The present experimental study throws some light in the effect of a spherical object on the velocity distribution of a free circular jet at different distances away from the nozzle mouth and the sphere as well. The extent of wake zone behind the sphere is also captured from the velocity defect evident from the velocity distributions. However, the present study can be extended further by varying the diameter of nozzle mouth and the nozzle mass flow rate that were kept constant during the present experimental study.

REFERENCES

[1] W. Zimm, "Uber die stromungsvorgange in freien", *Luftstrahl VDA orschungsheft*, **234** (1921).

[2] P. Ruden, "Turbulente ausbreitung in freistrahl", *Naturwissenschaften*, **21**, 375-378 (1930).

[3] H. Reichardt, "Gesetzima bigkeit under freien turbulenz", *VDI – Forschungsheft*, **414** (1942).

[4] W. Wuest, "Turbulente mischvorgange in zylindrischen angdusen", *Z. VDI*, **92** (1950)

[5] Reports of the AVA Gottingen, "Ergebnissc der Aerodynamuchen visuchsanstalt Gottingen", *Munchen*, **2**, 69-77 (1923).

[6] W. Tollmien, "Berechnung turbulenter ausbreitungsvorgange", *ZAMM*, 468-478 (1926).

[7] L. Howarth, "Concerning the velocity and temperature distributions in plane and axially symmetrical jets", *Proc. Canbr. Phil. Soc.*, **34**, 185 (1938).

[8] P. M. Sforza, M. H. Steigar, N. Trentacoste, "Studies on three-dimensional viscous jets", *AIAA Journal*, **5**, 800-806 (1966).

[9] M. A. T. Ali, M. A. Salim, M. Y. Islam, "Study of the flow structure of an asymmetric jet", *Journal of the Institution of Engineers (India)*, **78**, 70-74 (1997).

[10] D. Mitra, A. Mazumdar, "Study of variation of pressure coefficients for flow past a sphere", *Proc. 5th APM, Chittagong, IEB*, 401-406 (1998).

[11] M.K.Kanji, D. Mitra, A. Mazumdar, "Pressure variation past a sphere in free jet", *International Symposium on Recent Advances in Experimental Fluid Mechanics, IIT Kanpur* (2000).