VOLUME 7 NUMBER 2 December 2018 ISSN 2304-7445 (Print)
ISSN 2304-7461 (Online)

Journal of Mechanical and Industrial Engineering Research

ELITE HALL PUBLISHING HOUSE

Journal of Mechanical and Industrial Engineering Research

ABOUT JOURNAL

The Journal of Mechanical and Industrial Engineering Research (J. mech. ind. eng. res. / JMIER) was first published in 2012, and is published semi-annually (May and November). JMIER is indexed and abstracted in: **ProQuest, Ulrich's Periodicals Directory, EBSCO Open Access Journals, Scientific Indexing Service, getCITED, ResearchBib, IndexCopernicus, NewJour, Electronic Journals Library, Directory of Research Journals Indexing, Open J-Gate, CiteFactor, JournalSeek, WZB Berlin Social Science Center**. Since 2013, the JMIER has been included into the ProQuest, one of the leading full-text databases around the world.

The Journal of Mechanical and Industrial Engineering Research is an open access peer-reviewed international journal to be of interest and use to all those concerned with research in various fields of, or closely related to, mechanical and industrial engineering disciplines. Papers reporting original research or extended versions of already published conference/journal papers are all welcome. Papers for publication are selected through peer review to ensure originality, relevance, and readability.

ISSN 2304-7445

Journal of Mechanical and Industrial Engineering Research

Publisher: **Elite Hall Publishing House**

Web: http://jmier.elitehall.com
ISSN 2304-7445 (Print)
ISSN 2304-7461 (Online)

Journal of Mechanical and Industrial Engineering Research, Vol. 7, No.2, 2018

EXPERIMENTAL STUDY OF THE MEAN FLOW CHARACTERISTICS OF SWIRLING JET

S. M. Rakibur Rahman[1], S.M Al Mamun Or Roshid[2], Ishtiaque Ahmed Nishan[2] and M. A. Taher Ali[3]

[1]Lecturer, Department of Aeronautical Engineering,

[2]Department of Aeronautical Engineering,

[3]Professor, Department of Aeronautical Engineering,

Military Institute of Science and Technology, Dhaka 1216, Bangladesh

Abstract. In the present investigation, the axial mean flow characteristics of a swirling jet are compared with that of a plane circular jet. The swirling effect is imparted by installing a twisted plate at the nozzle exit as swirl generator. The effect of swirl on the velocity profiles and spread rates of both the jets are studied. It is found that the influence of swirl is significant in the near flow field where it shifts the velocity maxima away from the jet centreline forming an annular potential core. The swirl increases the jet spread rate resulting its earlier diffusion than the plane circular jet. This phenomenon is found by observing the decay of centreline velocity of both the jets.

Keywords: swirling jet, potential core, spread rate

NOMENCLATURE

D	Exit diameter of the nozzle
U	Axial velocity
U_{ec}	Exit centreline velocity
Re_d	Reynolds number (Based on D and U_{em})
x& y	Coordinate system
U_m	Local maximum velocity
U_{em}	Exit maximum velocity

INTRODUCTION

Circular jet is produced when fluid is ejected from a circular orifice, an aperture or a nozzle into an external ambient fluid, which can be either at rest or co-flowing. In the downstream of the jet the free

ISSN 2304-7445

shear layer spreads in the radial direction both outwards and towards the centerline. The region inside the axis-symmetric shear layer characterized by an unchanged axial velocity is called the jet “potential” core. Centerline velocity decays after potential core region [1]. Further downstream, in the intermediate region of the jet, the different eddy structures interact in a non-linear behavior engulfing fluid from the surrounding environment and eventually collapse leaving the jet fully turbulent [2].

Swirling jet is produced when fluid is ejected in a rotational pattern by using various methods like rotating pipe, rotating honeycomb, tangential slots, tangential nozzles, deflecting vanes, coil insert etc. at the exit of a circular orifice, an aperture or a nozzle.
The near field of a non-swirling jet is mainly driven by instabilities or turbulent mixing and the pressure plays a minor role. However, in swirling jet where a tangential velocity component is superimposed on the axial one of circular jet, both radial and axial pressure gradients are generated. Those gradients may significantly influence the flow changing the structure of flow geometry, with evolution and interactions between the vortical structures. For swirling jets, different flow regimes may be identified depending on the degree of swirl present in the jet [2]. High spreading rate and displacement of the location of the maximum axial velocity from the axis [3] are some important characteristics of swirling jets.

THE EXPERIMENTAL SETUP

The air flow in the free jet flow facility is generated by two axial fans of 300mm diameter axial fans. It is 2.75 m long and is mounted on a rigid steel frame shown in figure-1. Each fan has seven blades made of plastic. The flow from each fan is directed to the next section by guide vanes to ensure shock free entry to the fan located in the downstream position.

The outgoing airflow from the fan section is directed to the first settling chamber. The settling chamber provides time for the reduction of turbulence level which is generated in the fan and become stable.

The flow from the first settling chamber is channelled to the 150 mm air duct through a reducer. The purpose of using the reducer is to connect two ducts of different diameters and to increase the flow velocity with minimum loss. At the discharge side of the air duct a honeycomb section with wire screen mesh is attached. The purposes of using straightener and wire mesh are to straighten the flow and to ensure that the axial flow is free from any eddies which may still be present in the flow.

ISSN 2304-7445

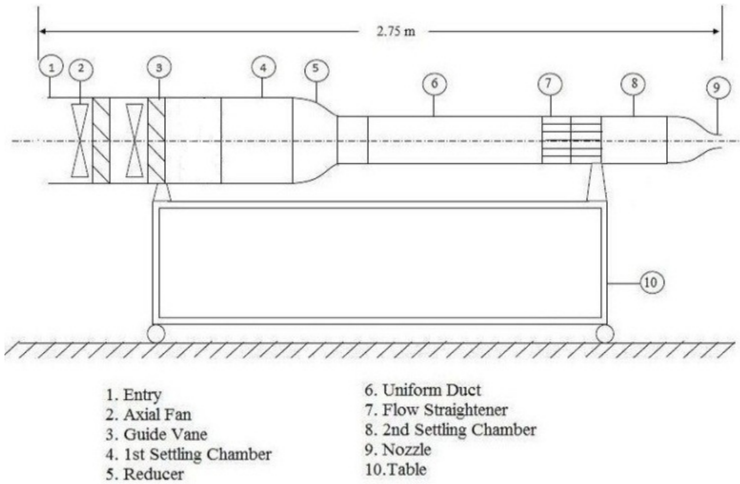


Figure 1. Different sections of Jet Nozzles

Flow is then passed through the second settling chamber to the discharge nozzle. The discharge nozzle has a parabolic profile with inlet diameter of 150mm and exit diameter 50mm as shown in figure-2. The parabolic profile ensures shock free discharge at its exit. Velocity of fluid increases on the expense of its pressure energy in nozzle [4].

(a)

(b)

Figure 2. (a) Side view, (b) Inner view of the discharge nozzle

A 200mm × 5mm MS metal plate is twisted to 300mm pitch to construct the swirl generator shown in figure 3. At the blacksmith's shop the plate is heated to red hot and is twisted to the desired pitch. As the nozzle is 150mm long so the half pitch length of the twisted plate is used as the swirl generator.

ISSN 2304-7445

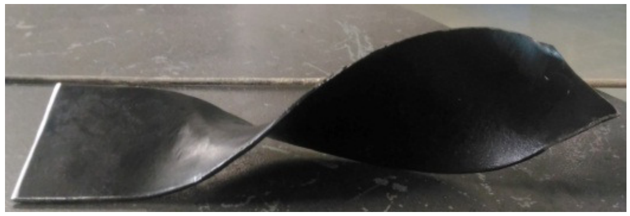


Figure 3. Swirl Generator

To install the twisted plate in the nozzle, a rod and metal glue was used as shown in the Figure 4(a) and at the exit it is glued directly to the nozzle inside surface. Finally the existing plane nozzle is converted into a swirling one producing swirling jet as shown in Figure 4(b). The twisted plate is fitted in the plane nozzle such that its cross section is horizontal at the nozzle exit. So, the swirling jet is symmetrical about horizontal plane.

(a) (b)

Figure 4. (a) Installation of the swirl generator, (b) Front view of the nozzle with swirl generator

MEASUREMENT SYSTEM

During the measurement of mean flow velocity of the jet, it's flow direction is taken as the x-axis and the direction perpendicular to it as the y-axis. The centerline of the nozzle at its exit is taken as zero position and all x and y positions are taken with this reference point. The flow velocity of the jet is recorded by the specially designed pitot tube made by using Coopers's Needle (U.K.) hyperdermic and a variable angle inclined tube manometer. The pitot tube is mounted on a two co-ordinate traversing mechanism (figure-5). So that the pitot tube can be placed in any position of the jet flow field during the measurement. The traversing mechanism has the capacity to move 1000 mm in x-direction and 400 mm in y-direction.

ISSN 2304-7445

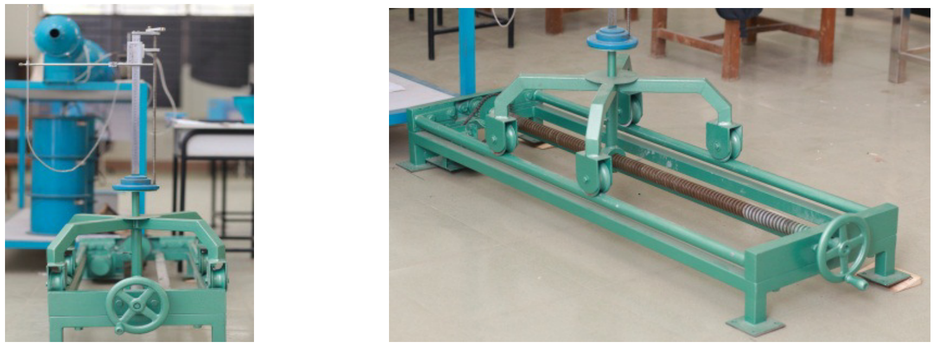
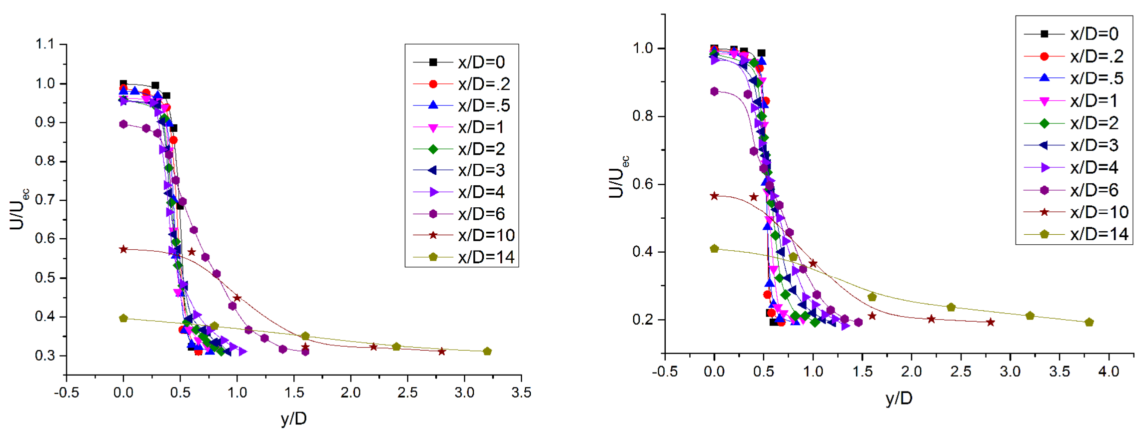


Figure 5. Traversing Mechanism

RESULTS AND DISCUSSIONS

Velocity profiles for plane jet at two Reynolds numbers ($Re_d = 6.4\times10^4$and $Re_d= 1.03\times10^5$) and ten axial positions are shown in Figure 6. It is observed that the trend of the velocity profiles for the two cases is almost similar. Also, velocity profiles for axial positions up to x/D =4 are similar with centreline velocity being almost constant. This indicates that potential core of this jet extends up to x/D = 4.After that they start to spread. Spreading increases as axial distance from nozzle exit increases. At x/D =14 almost constant velocity is found for all vertical positions indicating the starting of self-preserving zone from that axial position of the jet flow field



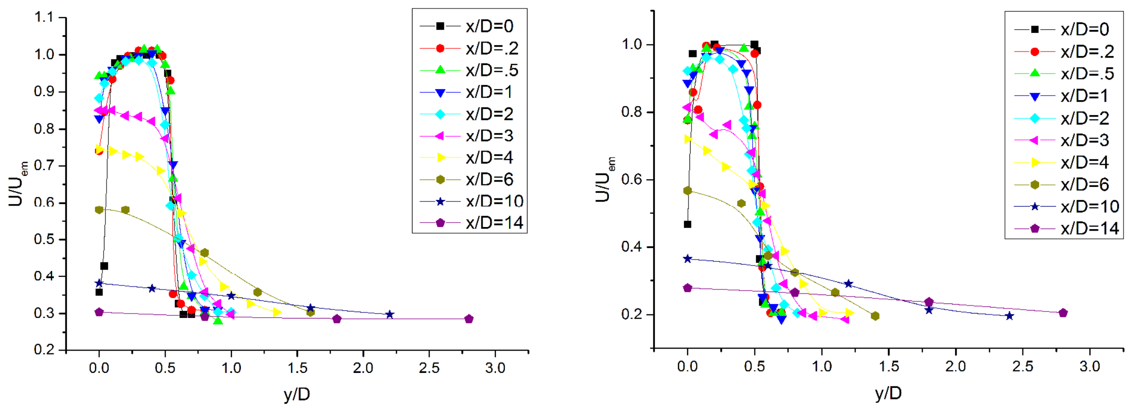
(a) (b)

Figure 6. Mean velocity profile of plane jet at (a) $Re_d=6.4\times10^4$ and (b) $Re_d=1.03\times10^5$

Velocity profiles for swirling jet at two Reynolds numbers and ten axial positions are shown in figure 7. Here also, trend of the velocity profiles for the two cases are almost similar. In their profiles the effect of

ISSN 2304-7445

swirl generator is clearly observed. Due to the swirl generator, initially centreline velocity is lower than the peak velocity. This is due to the obstruction caused by the swirl generator plate itself because it extends along the nozzle exit diameter and the centrifugal force which carries the flow outward. Velocity peaks are thus found away from the centreline in the range y/D=.25 to .5. After reaching the peak values, velocities sharply decrease and then start the asymptotic decay. The effect of swirl is found to decrease at x/D = 3 and this continues up to x/D = 14 where the flow attains the self preserving condition. Flow gradually overcomes effect of swirl generator and eventually after a certain axial distance, centreline velocity becomes peak velocity. At x/D =14 an almost constant velocity is obtained for all vertical positions similar to plane jet.



(a) (b)

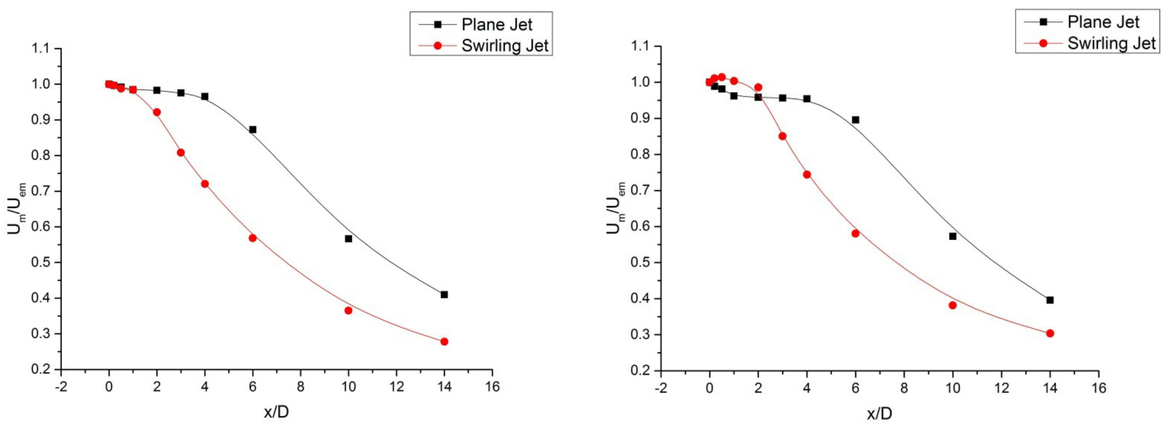
Figure 7. Mean velocity profile of swirling jet at (a) Re_d=6.5×10^4 and (b) Re_d=1.06×10^5

After comparing velocity profiles of plane jet and swirling jet it can be seen that –

- In case of plane jet, potential core region is found to extend up to x/D =4 from the nozzle exit where centreline velocity remains nearly constant in case of plane jet. In case of swirling jet, no such potential core exists but the velocity peaks shift outward in the zone y/D=0.25 to 0.5 and remain constant throughout the region extending up to x/D=2 in a sense that peak velocity remains constant throughout this region.
- In case of plane jet, as the distance increases from the nozzle exit the centreline velocity decreases in case of plane jet. In swirling jet, centreline velocity starts to increase initially when flow gradually overcomes the blockage effect of swirl generator. After a certain axial distance it starts to decrease.

Figure 8 shows the decay of peak velocity with axial position. It can be seen that, rate of decay of peak velocity is higher in case of swirling jet. This indicates higher spread rate.

ISSN 2304-7445



(a) (b)

Figure 8. Comparison of decay of centreline velocities of plane jet and swirling jet at (a) $Re_d=6.4\times10^4$ and $Re_d=6.5\times10^4$ respectively (b) $Re_d=1.03\times10^5$ and $Re_d=1.06\times10^5$ respectively

CONCLUSIONS

- The effect of swirl generator is very significant in jet flow. The centerline velocity is greatly affected due to the presence of swirl generator.
- Potential core region reduced in case of swirling jet when compared to plane jet.
- Spread rate of swirling jet is higher than that of plane jet.

REFERENCES

[1] Simulation of vertical plane turbulent jet in shallow water by T. N. Aziz and A. A. Khan, Hindawi Publishing Corporation, Advances in Civil Engineering, Volume 2011.

[2] A study on axially rotating pipe and swirling jet flows by Luca Facciolo, February 2006, Technical Reports from, Royal Institute of Technology, Department of Mechanics, S-100 44, Stockholm, Sweden.

[3] An experimental investigation of swirling jets By HANZHUANG LIAN G AND T. MAXWORTHY, Department of Aerospace and Mechanical Engineering, University of Southern California, CA 90089, USA..

[4] "Jet nozzles, Type DUK" from TROX company, retrieved 15th October 2013.

ISSN 2304-7445

ELITE HALL PUBLISHING HOUSE

Journal of Mechanical and Industrial Engineering Research
http://jmier.elitehall.com