Published Online April 2017 (http://www.cuet.ac.bd/merj/index.html)

Mechanical Engineering Research Journal

Vol. 10, pp. 31-34, 2016

Dept. of Mech. Eng. CUET

ISSN: 1990-5491

FLUID FLOW VISUALIZATION WITH A SOLDERING IRON IN A SUBSONIC WIND TUNNEL

M. K. Hasan[1] and K. A. Rahman[2,*]

[1]Trainee Engineer, Ministry of Power, Energy and Mineral Resources, Bangladesh
[2]Department of Mechanical Engineering, Chittagong University of Engineering & Technology, Chittagong - 4349, Bangladesh

Abstract: In this paper a small scale laboratory based fluid flow visualization device is introduced. A simple, inexpensive, and self-contained fluid flow visualization device is designed and fabricated for the Department of Mechanical Engineering of Chittagong University of Engineering and Technology. This device is helpful in studies and research of fluid dynamics. Air is selected as the flow medium, Soldering iron as the heating element and Glycerin as the smoke fluid. Assorted wind velocities below 4 m/s were found suitable for this smoke-wire apparatus in generating clear, uniform white dense smoke. It was difficult to observe the stream lines when wind velocity became higher than 4m/s as smoke duration came shorter. The technique developed proved to be very useful for wide applications particularly for studying flow visualization.

Keywords: *Flow visualization, Smoke, Stream line, Reynolds number*.

NOMENCLATURE

v = Velocity (m/s)
ρ = Density of air (kg/m^3)
μ = Viscosity of air (N-s/m^2)
Re = Reynolds number

1. INTRODUCTION

Flow visualization is an experimental means of examining the flow patterns around a body or over its surface. In analyzing the fluid flow behavior, it is a qualitative measurement technique [1]. Flow visualization can be achieved in many ways for both subsonic and supersonic regimes. Tufts, neutrally buoyant particles, helium bubbles, surface powders/oils and smoke plumes are widely used for subsonic tests whereas Schlieren, birefringence and interferometric techniques cover the supersonic regime [2]. One way is through introducing smoke into the airflow can be used for low speed flows. The smoke follows with the air currents, allowing the observer to visualize the flow. There are several ways to introduce the smoke into the system. One such way is by using a soldering iron. In this work, a soldering iron coated with glycerin is kept across the flow field that can produce short bursts of smoke. The smoke is generated and controlled electrically by Joule heating. This sheet of smoke flows over the object of study that is placed behind the wire. By this way, the smoke moves with the air and deforms. This deformation allows the observer to visualize the air flow around the object. The soldering iron technique is limited for low wind tunnel velocities. High velocities produce unacceptable turbulence.

2. WORKING PRINCIPLE

The soldering iron is heated by AC current inside the tunnel. Oil such as glycerin is passed through the iron. Glycerin is vaporized and produces smoke. Air is sucked by the centrifugal blower of the tunnel. This causes air flow inside the tunnel. The air flow passes through the soldering iron. The smoke follows with the streamline of the air. We observed the flow pattern of the smoke which actually exhibits the flow pattern of air.

3. EXPERIMENTAL SETUP

3.1 Wind Tunnel Components

The wind tunnel is comprised of five main parts such as- test

* **Corresponding author:** afzalur99@yahoo.com; Tel: 880-1680453267

section, contraction cone, settling chamber, honeycomb, screen, diffuser, and blower as shown in Fig. 1. The test section is designed as 8" × 4" × 4". It is made of 2 mm thick mild steel sheet and has three acrylic viewing windows. Each end of the test bed is bolted to the other sections. The second section of the wind tunnel is designed as the contraction cone. The size of the large end, nearest the settling chamber is set at 12 " × 12". The small end of the contraction cone is set at 4" × 4" to fit directly onto the test section. The contraction cone made of sheet metal has also bolted together with the other sections. The dimension of the settling chamber is 12" ×12 " that matches up with the dimension of the contraction cone. The settling chamber is made of 2 mm thick mild steel sheet and has bolted to the contraction cone. Its length is 6" to accommodate three different flow straightening devices. The primary flow straightening device is the honeycomb. The secondary and the tertiary flow straightening devices are the screens. The two screens are approximately 1.5" apart from each other and is placed 1.5" behind the honeycomb. The diffuser is 18" long and is connected to the test section with bolts. The dimension of the front opening of the diffuser is 4" × 4" and the dimension of the end opening is 6.5" × 6.5". The blower or the power source is one the important component in designing a low speed wind tunnel. Here a centrifugal blower is used with a 4" diameter with maximum power of 250 watt and maximum flow rate of 1500 cfm so that it can pull enough air to gain a reasonable speed in the test section. A variable speed control switch is also installed allowing a range of wind velocity. The speed of air inside the test section is manually controlled by keeping steel nets before the blower. A different number of nets are kept for different velocities. The velocity inside the test section is measured by a digital anemometer and the temperature is measured by a thermometer.

3.2 Smoke Producing Component

A soldering iron is composed of a heated metal tip and an insulated handle. Heating is often achieved electrically, by passing an electric current through a resistive heating element [3]. Soldering iron tip typically consists of a solid copper core, a plated layer of iron, a plated layer of nickel behind the working surface, and a plated chrome layer [4]. Therefore, it can dissipate the large amount of heat to boil the smoke fluids and is very suitable as a heating element. Here a soldering iron of 60 watt is taken as heating element which is heated by 220V A.C. current. There are several factors in choosing the coating oil. The first factor is the viscosity of the oil. Another factor considered for choosing coating oil is the safety problem, that is, if the oil smoke is toxic, or unpleasant to breathe. The oil chosen for this experiment is glycerin. The viscosity of glycerin does not change very much with temperature. The toxic problem for using glycerin is also not serious [5].

3.3 Photography and Lighting

There are two methods to get the experimental records. One method is using a still camera to get discrete records and another is using a video camera to get a continuous record. For a flow condition that is slowly changing, a still camera is used. But when the flow behavior changes quickly, a video camera is used. A DSLR camera is used for these purposes.

The lighting method designed for this experiment is to illuminate almost all of the test section. It should be noted that for better result the light should not illuminate the background or the wind tunnel wall in the test section facing the camera [6]. To achieve this, colorful flashlight is used and aligned parallel to the smoke filament plane.

Fig. 1 Full view of the experimental set up.

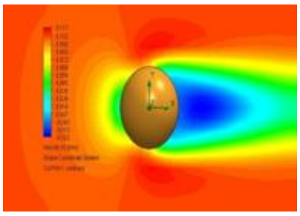
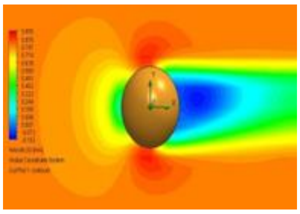
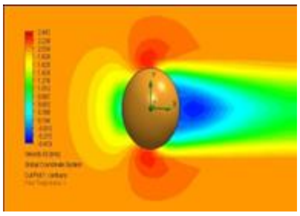
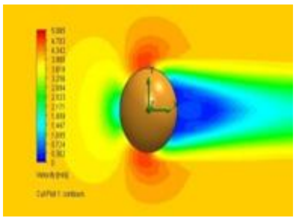
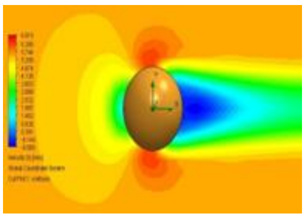
Fig. 2 Inside view of the test section.

4. RESULTS AND DISCUSSION

For the experiment, the testing object is chosen as a sphere (table tennis ball) of 40 mm diameter as shown in Fig. 2. The temperature is recorded by a thermometer about 40^0C and the properties of air are taken at this temperature to calculate the Reynolds number (*Re*). From the result of the experiments of fluid flow visualization, it is observed that this soldering iron apparatus is applicable at wind velocities below 4 m/s and *Re* number below 10,100. In such velocities and *Re* number, it generates clear, uniform white dense smoke and thus the flow can visualize. However, the smoke duration comes shorter at a velocity higher than 4 m/s and therefore, it is difficult to observe the stream lines.

It is noticed that the most notable results are found at wind tunnel test section velocity of 2 m/s and Re = 4,700. In this velocity, flow behavior around the object can be analyzed and described smoothly. For computational study over an object, Solid Works simulation tools are used. Various characteristics of the flow can be analyzed using Solid Works. For different velocities and Reynolds number the velocity profile around the object are presented in Table 1.

Table 1 Description of smoke generated at different velocities

Air velocity, *v* (m/s)	$Re = \frac{\rho v d}{\mu}$	**Experimental Results**	**Simulation Results**	**Remarks**
0.8	1,800			Clear, dense and uniform smoke is generated. The liquid is easily attached to the tip due to low wind velocity. Smoke duration is pretty good.
2	4,700			This is the best results yet. Clear, white and uniform smoke is generated. The liquid is easily attached to the tip. Smoke duration is long. Flow pattern can easily be visualized.
2.8	6,100			Flow pattern can also be visualized as smoke is generated in this velocity is also uniform and clear
4	10,100			Clear and uniform smoke is generated for short duration. However, the liquid is hardly attached to the wire due to high wind tunnel velocity.
5.4	14,100			The liquid cannot attach to the tip due to high wind tunnel velocity. This difficulty causes this wire is unpractical to be used for wind tunnel velocity higher than 4.0 m/s.

4.1 Flow Analysis

The flow steam line around the object (at 2 m/s) is presented in Fig. 3. Smoke line around the object indicates the stream line. It can be seen that the stagnation point, at which the flow velocity is locally zero, forms in front of the object. Moreover, a thin boundary layer covers the front side of the obstacle. The thickness of this layer is smallest at the stagnation point, and increases towards the back side of the object. However, at some point on the back side, the boundary layer separates from the object's surface to form a wake region. This wake maximizes the region of low pressure and, therefore, it results maximum difference in pressure between the front and rear faces. This difference creates a drag [7-11].

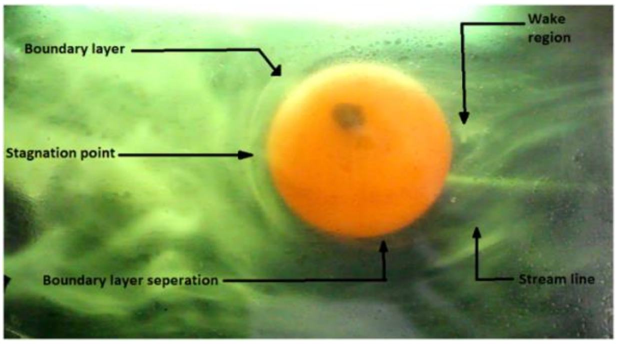


Fig. 3 Analysis of flow around an object.

4. CONCLUSIONS

The soldering iron technique is fabricated to be capable of continuously generating of smoke streamlines for flow visualization in the low speed wind tunnel. Hence turbulent flow can't be visualized rather laminar. Further improvement of this set up will make it more applicable for the study of fluid mechanics. The recommendations are mentioned below:

- Use of High Speed Camera will confirm much clear image of flow.
- 2 or 3 pieces of soldering iron can be used for better result.
- A compressor can be used to supply continuous flow of oil into the soldering iron.
- Mixture of Glycerin with colored dye may be introduced to create colored streamline.
- Pressure, drag etc. measuring equipment can be introduced.

5. ACKNOWLEDGMENTS

The authors would like to express their gratitude to all the Faculty members and research staffs working at Department of Mechanical engineering, CUET for extending their help in doing this project.

REFERENCES

[1] S. S. Dol, M. Arief, M. Nor and M. K. Kamaruzaman, "An improved smoke-wire flow visualization Technique", 4th WSEAS International Conference on Fluid Mechanics and Aerodynamics, Elounda, Greece, pp. 231-236, August 21-23, 2006.

[2] http ://www.aerospace.utoronto.ca/pdf_files/lowviz (Last access at 10/8/2015)

[3] https ://en.wikipedia. org/wiki/Soldering_iron (Last access at 10/8/2015)

[4] Extending Soldering Iron Tip Life, 2006, OK International. Technical Note v2.2; (Last access at 05/07/14)

[5] W. -K. Chen, "Visualization of the flow around a pitching airfoil using the smoke-wire technique", M.S.A.E, The University of Texas at Arlington, 1990.

[6] How To Build Your Own Wind Tunnel, http://ldaps.arc.nasa.gov/Curriculum/tunnel.

[7] R. D. Mehta and P. Bradshaw, "Design Rules for Small Low-Speed Wind Tunnels", Aero. Journal (Royal Aeronautical Society), Vol. 73, pp. 443, 1979.

[8] Frits H. Post, "Fluid flow visualization", Published in: Focus on Scientific Visualization, H. Hagen, H. Muller, G. M. Nielson (eds.), pp. 1-40, Springer Verlag, Berlin, 1993.

[9] Y. A. Cengel, Fluid Mechanics, 2nd ed., John M. Cimbala, 2010.

[10] D. J. Szarko, "Smoke wire visualization of an oscillating flow in a gas spring", Massachusetts Institute of Technology, May 1993.

[11] A. Dunbar, S. Y. Zhou and M. Taslim, "Design of a Setup for Flow Visualizations".