Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2015
(ICMERE2015) 26 – 29 November, 2015, Chittagong, Bangladesh

ICMERE2015-PI-268

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

Md. Kamrul Hasan[1] and Kazi Afzalur Rahman[2,*]

[1-2] Department of Mechanical Engineering, Chittagong University of Engineering & Technology,
Chittagong - 4349, Bangladesh
[1]m.k.hasannayan@gmail.com, [2,*]afzalur99@gmail.com

Abstract*-This paper presents a device in which a new technique of fluid flow visualization is introduced. A simple, inexpensive, self-contained and multifunctional 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 suitable for this smoke-wire apparatus for 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: Smoke, Stream line, Reynolds number.

1. INTRODUCTION

Flow visualization is an experimental means of examining the flow patterns around a body or over its surface. It is a qualitative measurement used to analyze flow behavior [1]. Flow visualization can be achieved in many ways. Tufts, neutrally buoyant particles, helium bubbles, surface powders/oils and smoke plumes are widely used for subsonic tests and 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 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. A soldering iron coated in oil and kept across the flow field can produce short bursts of smoke controlled electrically by Joule heating. This sheet of smoke that flows over the object of study that is placed behind the wire moves with the air and deforms. This deformation allows the observer to visualize the airflow 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. Oil 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 the streamline of the air. We observed the flow pattern of smoke which actually exhibits the flow pattern of air.

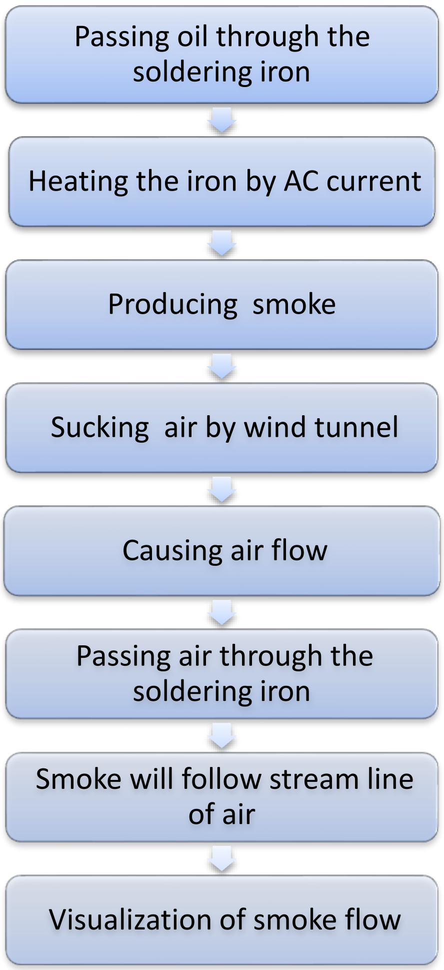


Fig.1: Block diagram of working principle

3. EXPERIMENTAL SETUP

3.1 Wind Tunnel Components

The wind tunnel is comprised of five main parts as- test section, contraction cone, settling chamber, honeycomb, screen, diffuser, and blower. 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 has drilled hole to bolt to the other sections. The second section of the wind tunnel designed is the contraction cone. The size of the large end, nearest the settling chamber was set at 12 " × 12". The small end of the contraction cone was set at 4" × 4" to fit directly onto the test section. The contraction cone made of sheet metal also has drilled holes on each side to bolt together with the other sections The settling chamber's cross section dimensions are 12" ×12 ", and match up with the dimensions of the contraction cone. It is made of 2 mm thick mild steel sheet and will has drilled holes to bolt it to the contraction cone. Its length is 6" to accommodate three different flow straightening devices. The first of the flow straightening devices is the honeycomb. The second and third flow-straightening devices are 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 dimensions of the front opening of the diffuser are 4" × 4" and the dimensions of the end opening are 6.5" × 6.5". The blower or power source, is the final critical component in the design of our low speed wind tunnel. Here a centrifugal blower is used with a 4" diameter, maximum power of 250 w and maximum flow rate of 1500 cfm so that it can pull enough air to reach speeds in the test section. A switch is being considering allowing for a free range of wind velocity. The speed of air inside the test section is manually controlled by keeping steel nets before the blower. Different number of nets is kept for different velocities. The velocity inside the test section is measured by a digital anemometer and 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 [2]. So 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 w is taken as heating element which is heated by 220V A.C. current.

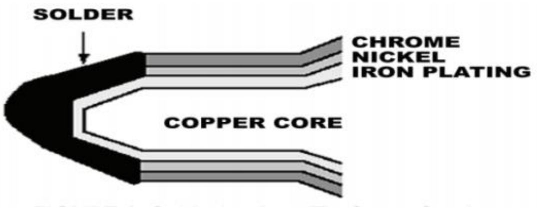


Fig.2: Soldering iron tip cross-section [4]

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 ail experiments was glycerin. The viscosity of glycerin does not change very much with temperature. The toxic problem for using glycerin was also not serious [5].

3.3 Photography and Lighting

There are two methods to get the experiment 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 was 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 best result the light should not illuminate the background or the wind tunnel wall in the test section facing the camera [5]. To achieve this, colorful flashlight is used and aligned parallel to the smoke filament plane.

Fig.3: Full view of the set up

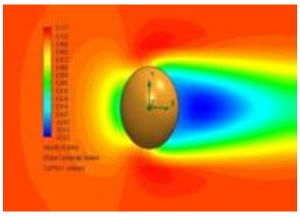
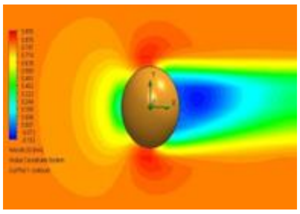
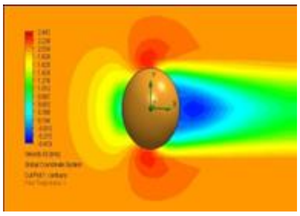
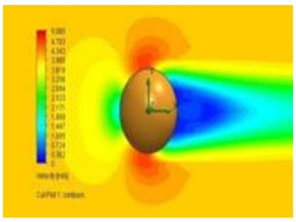
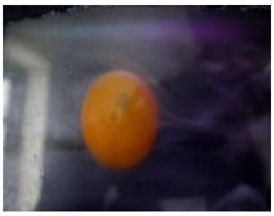
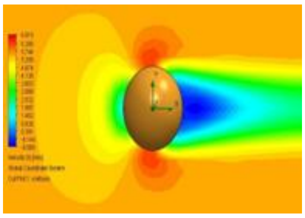
Fig.4: Inside view of the test section

4. RESULTS

For all experiments testing object is chosen as a sphere (table tennis ball) of 40mm diameter. The temperature is recorded by a thermometer about 40°C and the properties of air are taken at this temperature to calculate the Reynolds number (Re). From the result of all experiments of fluid flow visualization it is observed that this soldering iron apparatus is applicable at wind velocities below 4 m/s and Re below 10100. In such velocities and Re, it generates clear, uniform white dense smoke and thus the flow can visualize. But at a velocity higher than 4 m/s as smoke duration came shorter, it is difficult to observe the stream lines.

It is also noticed that the best result is found at wind tunnel test section velocity 2 m/s and Re 4700. In this velocity flow behavior around the object can be analyzed and described smoothly. For computational study over an object we use Solid works. Using Solid works we can analysis various characteristics of the flow. For different velocities and Reynolds number the velocity profile around the object are presented below:

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	1800			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	4700			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 visualize.
2.8	6100			Flow pattern can also visualize as smoke is generated in this velocity is also uniform and clear
4	10100			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	14100			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

We can analyze the flow around an object (at 2 m/s) with the help of Fig 5. Smoke line around the object indicates the stream line. It can be seen that 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, results in the maximum difference in pressure between the front and rear faces. This difference creates a drag.

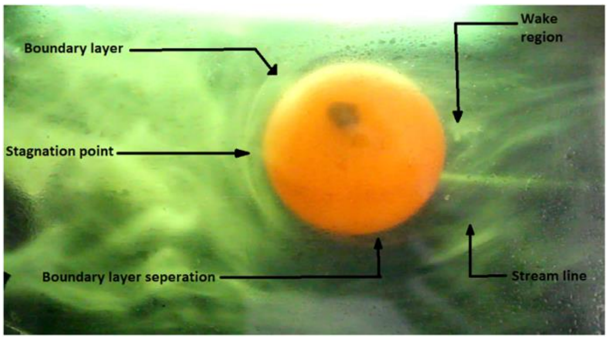


Fig.5: Analysis of flow around an object

5. CONCLUSION

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 visualize 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 introduce to create colored streamline.
- Pressure, drag etc. measuring equipment can be introduced.

6. ACKOWLEDGEMENT

I would a like to express thanks to all the teachers and staff working at workshop of Department of Mechanical engineering of CUET for extending their helping hand for doing this project.

7. REFERENCES

[1] Sharul Sham Dol, Mohd Arief, Mohd Nor and Muhamad Khairun Kamaruzaman, "An improved smoke -wire flow visualization Technique", 4th WSEAS International Conference on Fluid Mechanics and Aerodynamics, Elounda, Greece, August 21-23, 2006 (pp231-236).

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

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

[4] Extending SolderingIron Tip Life,© 2006 OK International. Technical Note v2.2; 05/07/14.

[5] Chen, Wen-king,"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, p. 443 (1979).

[8] Frits H. Post, "Fluid flow visualization", Published in: Focus on Scientific Visualization, H. Hagen, H. Muller, G.M. Nielson (eds.), Springer Verlag, Berlin, 1993, pp. 1 -40 (ISBN 3-540-54940-4).

[9] Fluid Mechanics, Second edition, by- YunusA.Cengel, John M.Cimbala.

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

[11] Andrew Dunbar, Shu Yi Zhou, Prof. Mohammad Taslim,"Design of a Setup for Flow Visualizations".

8. NOMENCLATURE

Symbol	Meaning	Unit
v	Velocity	(m/s)
ρ	Density of air	(kg/m^3)
μ	Viscosity of air	($N\text{-}s/m^2$)
Re	Reynolds number	Dimensionless