*International Conference on Mechanical, Industrial and Materials Engineering 2017 (ICMIME2017)*
*28-30 December, 2017, RUET, Rajshahi, Bangladesh.*

***Paper ID: FM-266***

# Design and Construction of a Jet Impingement Apparatus

Amitav Roy, Pial Das, Md.Omar Faruk

Department of Mechanical Engineering, Khulna University of Engineering & Technology, Khulna-9203, Bangladesh.
*E-mail: farukme14@gmail.com*

## Abstract

The current thesis focuses on the analysis of temperature distribution over a heated impingement surface for an impinging cold air jet for different relative orientations between the surface and the nozzle. The distance between the impingement surface and nozzle is also varied and temperature data is also recorded for the sake of analysis. In this thesis, Z/D varied to 0.25cm, 0.5cm and 1cm and was varied to $90^0$ and $60^0$ .From this thesis, it is observed that after a certain period of time, the temperature of the heated plate moves towards steady state temperature condition as long as the jet impinges the hot surface. When the jet impinges the plate, the temperature of the plate starts falling until it reaches to another steady state temperature. The temperature distribution is shown to be changed with different orientation of the plate as well as with the change of spacing between the nozzle and impingement surface.

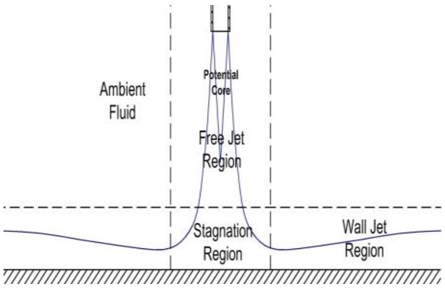
## 1. Introduction

Impinging jet is a directed liquid or gaseous flow released against a surface that can efficiently transfer large amounts of thermal energy or mass between the surface and the fluid. Impinging jet in an important tool in various heat transfer apparatus and fluid flow instruments. When a jet impinges a surface, thin hydrodynamic and thermal boundary layers form in the region directly beneath due to the jet deceleration and the resulting increase in pressure. Jet cooling is used in various types of configurations. It may be a single injector type or in the shape of a multiperforated plate.

## 2. Methodology

### Impinging Jet Regions

There are three regions that can be identified in an impinging jet flow. Firstly, there is the free jet zone, which is the region that is largely unaffected by the presence of the impingement. A potential core exists within the free jet region, within which the jet exit velocity is conserved and the turbulence intensity level is relatively low. A shear layer exists between the potential core and the ambient fluid where the turbulence is relatively high and the mean velocity is lower than the jet exit velocity. The shear layer entrains ambient fluid and causes the jet to spread radially. Beyond the potential core, the shear layer has spread to the point where it has penetrated to the centerline of the jet. At this stage, the turbulence intensity increases.



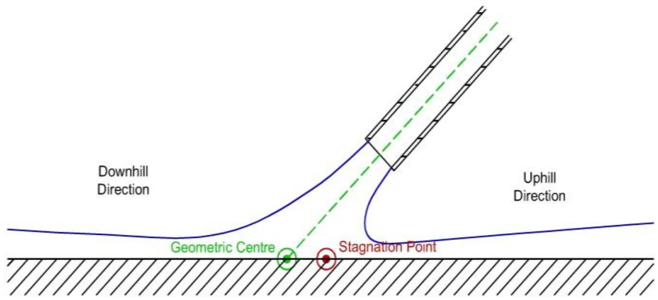




Fig :2.1 In the case of an obliquely impinging jet configuration Jet

**Figure** 2.2: Schematic of obliquely Impinging

The geometric center is the center about which the jet nozzle pivots. The uphill direction is towards the acute angle that the jet makes with the impingement surface. Consequently, the downhill direction is the direction of the main flow. In this schematic the stagnation point is displaced in the uphill direction from the geometric center.

The experimental setup implementing a cold air jet impacting on a hot surface is presented schematically:

**Figure** 2.3: Schematic of the experimental setup.

1. First, atmospheric temperature is measured with the help of thermometer.
2. AC supply is then provided to heater so that the impingement can be heated and reach to a steady state temperature.
3. After reaching the impingement plate to a steady state temperature, the temperatures are recorded. Then, air compressor is started and air is allowed to flow through the air supply line followed by the nozzle to the impingement plate.

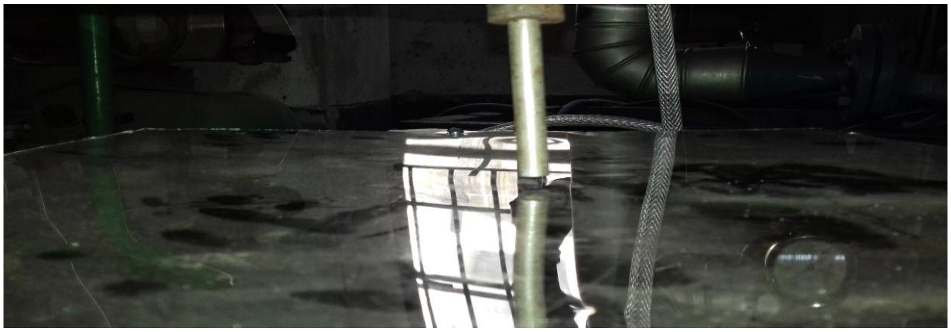


**Figure** 2.4: Analysis with Jet Impingement Apparatus.

- A certain time is allowed to the plate to become to reach the steady state temperature all temperature readings are recorded from the digital temperature recorder.


**Figure 2.5:** Data Collection from digital temperature recorder**.**

Then, the nozzle exit to plate distance is changed and the same procedure is accomplished.

Then, the same procedure was repeated for various orientation between the nozzle and the plate.

## 2(a): Data for the impingement surface to reach steady state temperature

(Ambient Temperature: $27^0$ C)

| Time (minute) | | Distance of from Geometric Center (in cm) | | | |
|---|---|---|---|---|---|
| | | 0 | 0.3 | 0.6 | 0.9 |
| | | | | | |
| 0 | | 22 | 22 | 22 | 22 |
| 3 | | 24 | 26 | 24 | 27 |
| 6 | | 30 | 32 | 33 | 33 |
| 8 | | 34 | 36 | 36 | 37 |
| 10 | | 37 | 39 | 38 | 39 |
| 12 | | 39 | 41 | 40 | 40 |
| 14 | | 40 | 42 | 41 | 41 |
| 16 | | 40 | 43 | 42 | 42 |

| | | | | | |
|---|---|---|---|---|---|
| 18 | | 41 | 43 | 42 | 42 |
| 20 | | 41 | 43 | 42 | 42 |
| 22 | | 41 | 44 | 42 | 42 |
| 24 | | 42 | 44 | 42 | 42 |
| 26 | | 42 | 44 | 42 | 42 |
| 28 | | 42 | 44 | 42 | 42 |
| 30 | | 42 | 44 | 42 | 42 |
| 32 | | 42 | 44 | 42 | 42 |

**2(b): Data for Jet Impinging Perpendicularly On the Plate when Z/D = 0.50 cm**

| Time (minute) | | Distance of from Geometric Center (in cm) | | | |
|---|---|---|---|---|---|
| | | 0 | 0.3 | 0.6 | 0.9 |
| 0 | | 42 | 40 | 40 | 42 |
| 2 | | 24 | 21 | 21 | 21 |
| 4 | | 25 | 23 | 22 | 22 |
| 6 | | 27 | 24 | 23 | 23 |
| 8 | | 28 | 24 | 23 | 23 |
| 10 | | 28 | 25 | 23 | 23 |
| 12 | | 28 | 25 | 25 | 25 |
| 14 | | 28 | 25 | 25 | 25 |

**2(c): Data for Jet Impinging On the Plate when Z/D = 0.5 cm and $60^0$**

| Time (minute) | | Distance of from Geometric Center (in cm) | | | |
|---|---|---|---|---|---|
| | | 0 | 0.3 | 0.6 | 0.9 |
| 0 | | 37 | 37 | 36 | 38 |
| 2 | | 21 | 22 | 21 | 23 |
| 4 | | 22 | 22 | 23 | 24 |
| 6 | | 22 | 24 | 23 | 25 |
| 8 | | 24 | 24 | 24 | 26 |
| 10 | | 25 | 25 | 25 | 27 |

## 3. Results and discussion

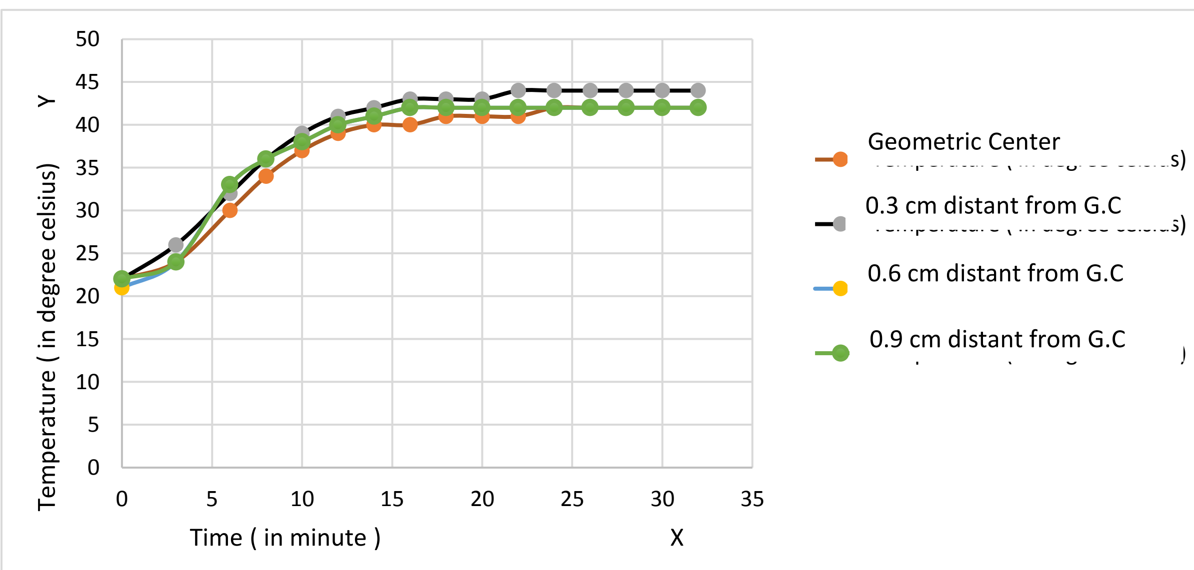


**Figure** 3.1: Temperature rise with time.

The curves shows that when the impingement surface approaches to the steady state temperature the curves followed different path but at the steady state temperature of the points is nearly the same.

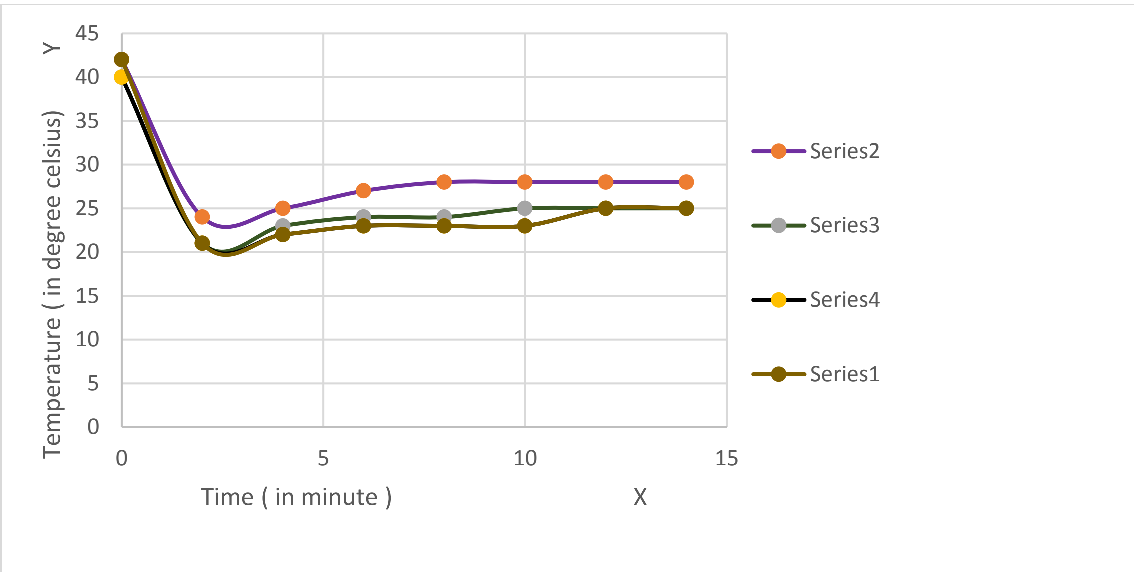



Figure 3.2: Temperature fall with time for Z/D =0.5cm and $\theta = 90^0$

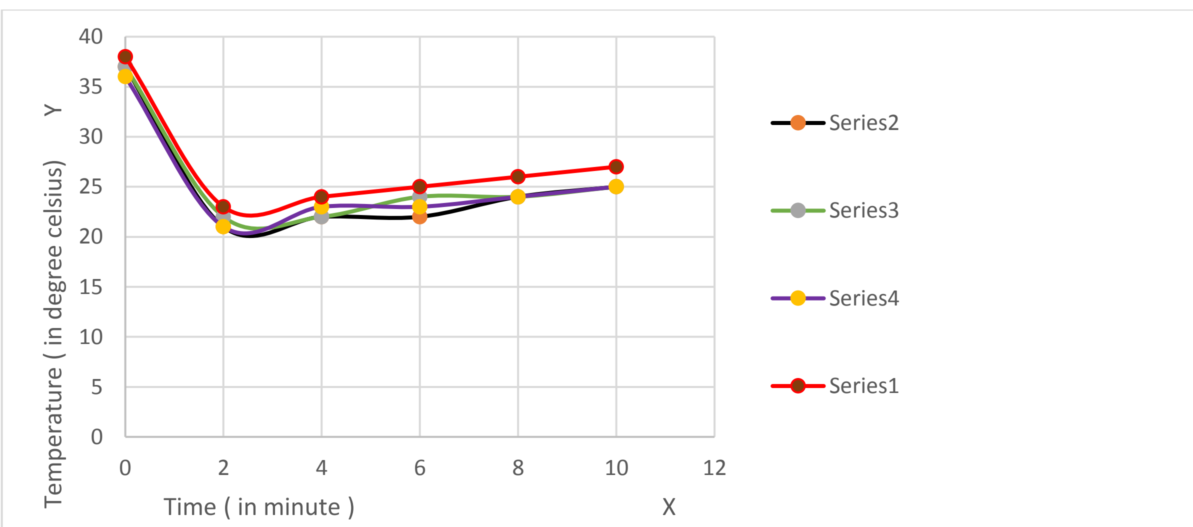



**Figure** 3.3: Temperature fall with time for Z/D =0.5cm and $\theta$ =$60^0$

From the above curves, it is observed that when the jet impinges the impingement surface the temperature falls below the room temperature and rises up slowly to the temperature around the temperature of the jet. When the impingement surface is at horizontal position the temperature of the geometric center is slightly higher than the temperature of outer points as the temperature of the center was high when it was in steady state temperature.

## 4.Conclusions

Jet impingement apparatus can demonstrate the phenomenon that occurs due to the impingement of jet. In this thesis, jet impingement for different condition of is jet analyzed. Temperature distribution is found to be changed with the spacing between the impingement surface and nozzle. The heat transfer coefficient is found to be increased ucertain limit with the increasing distance of nozzle from the impingement plate and then decreases.

## 5. References

[1] Hollworth, B. R., and Durbin, M., 1992, “Impingement cooling of electronics,” ASME Journal of Heat Transfer, pp. 607 – 613.

[2] Roy, S., Nasr, K., Patel, P., and Abdul Nour, B., 2002, “An experimental and numerical study of heat transfer off an inclined surface subject to an impinging airflow,” International Journal of Heat and Mass Transfer, pp 1615 – 1629.

[3] Babic, D. M., Murray, D. B., and Torrance, A. A., 2005, “Mist jet cooling o onal Journal of Machine Tools and Manufacture, pp. 1171 – 1177.

[4] Goldstein, R. J., and Behbahani, A. I., 1982, “Impingement of a circular ow,” *International Journal of Heat and Mass Transfer,* pp. 1377 – 1382.

[5] Goldstein, R., and Timmers, J. F., 1982, “Visualisation of heat transfer from arrays of impinging jets,” *International Journal of Heat and Mass Transfer,* pp. 1857 – 1868.

[6] Jeevanlal. V. M, 2014, “Experimental Investigation of Heat Transfer from a Flat and Surface Indented Plate Impinged with Cold Air Jet- Using Circular Nozzle”, International Journal of Emerging Engineering Research and Technology, pp 160-170,

[7] Behnia. M., 1997, “Accurate modeling of impinging jet heat transfer”, *Center for Turbulence Research,* pp 149-164