RESEARCH OF COOLING CHARACTERISTICS OF HOT SURFACE USING TWO INCLINED AIR JETS AT 60 DEGREES

Shreyas Patil[1], Arnav More[2], Akshay Indore[3], Ashish Kutval[4]

[1,2,3,4]*B. E.: Mechanical Engineering Dept., Indira College of Engineering and Management, Pune, India*

Abstract – *Electronic components are used in everyday life to make things easy to work. Continuous working of electronic components leads to generation of heat. Due to this, the components either fail to operate efficiently or breakdown. Cooling the components is an effective solution for this problem. This project deals with the cooling of electronic sample, here metallic plate, with air as a fluid medium passing through nozzles. Flow velocity of the air and the height of the nozzle from the metallic plate are the parameters discussed in this paper.*

Key Words: Cooling, Jet Impingement, Reynolds Number, electronic components, air, turbulence

1. INTRODUCTION

In our daily life, we extensively use electronic components which makes the living easy. There has been a massive increase in its application and this leads to heat generation. As a result, heat dissipation from the electronic components causes a major problem in its desired output. As electronics components are the backbone of modern industries, cooling them for better results are of major concern. Various researches have shown that the use of forced convection on the surface of the components is best for cooling. Only 45% of the total working electronic components sustain the excessive heating above their tolerance limit. In this project, we have employed Active Cooling method in which, additional power is used for cooling, i.e. forced cooling.

2 Air jet nozzles are used for jet impingement on the target plate for effective cooling. Jet impingement cooling is a concept in which heat transfer occurs by means of collision of fluid molecules on the surface. This impinging causes turbulence to the flow on the surface of electronic components and this leads to cooling.

2. LITERATURE SURVEY

After referring through many research papers, some of the relevant research papers are listed below:

Ingole S. B. and K. K. Sundaram [Nov-2014] conducted experiment on cooling characteristics of a surface using inclined air jet at 75^0. This paper is mainly focused on thermal profile of flat surface. The target plate was cooled by air jet impinging at an angle 75^0 with Reynolds number of 2000 to 10000 and the jet to target perpendicular distance (H) was varied from 10mm to 55mm. In conclusion, cool ellipse is defined for understanding effectiveness of inclined jet for cooling a target plate. [1]

P. Chandramohan, S. N. Murugesan and S. Arivazhagan [2017] performed an experiment on heat transfer analysis of flat plate subjected to multi jet air impingement using principal component analysis and computational technique. The aim of the project was to investigate the multi air jet flow, heat transfer rate and the obtained Nusselt Number. The conclusion was that lower H/D ratio and higher Reynolds number result in higher heat transfer coefficient. [2]

Hizkan F. Oztop, Yasin Varol, Ahmet Koca and Mujdat Firat [Aug-2011] conducted experiment focusing on cooling of heated circular disc plate using inclined circular jet. The objective of this paper was to determine the heat transfer characteristics of impinging circular jet on a heated circular disc. Experiments were performed under different Reynolds number viz, 2800, 9000 and 36,000. The paper shows the relation between cooling time and stagnation of Reynolds Number. [3]

3. PROBLEM STATEMENT

Electronic devices are used in health sector not only to assist in diagnosis and determination of medical problems, but to also assist in the research that is providing treatment against the ailments. Moreover, thousands of everyday devices that we use consists of electronic technology to keep the world moving. These products range from automotive engines to scanners and robots.

These products are liable to get damaged when used extensively. In hospitals, the doctors rely on the electronic equipment whereas, in the automobile industries, the robots pace the work. Considering these situations, the electronic components are to be maintained so that they perform efficiently, and this can be done by cooling at a specific temperature. This project deals with one of the possible solutions.

4. SETUP

The setup of our project comprises of a centrifugal blower of 0.5 HP and 1500 rpm, a step-up current transformer of 300 amperes, a hose pipe of 25 mm diameter, a flow control valve, 2 wooden nozzles, a support table for the nozzles, 2 hinged plates for angle variation, a target plate of MS having length of 265 mm and with of 110 mm, a height adjustment table and a supporting duct for the hose pipe.

For heating the target plate, we used 90 amperes of current and 2 electrodes connected at opposite ends of the plate diagonally. By using the hinged plates, we fixed the angle at 60 degrees. Reynold's number is varied by closing or opening the flow control valve. The height between the nozzles and target plate is changed with the help of the height adjustment table. For the purpose of temperature measurements, points have been marked on the target plate at equal distance in 9 columns and 7 rows.

Reynold's number is calculated by measuring the flow rate of air using a handheld anemometer and the formula. The range of the anemometer used is 2 m/s to 25 m/s and has an error of 2% for 5 m/s and 4% for 25 m/s. Temperatures of the target plate are measured using an infrared thermometer. For the thermometer, the range is -30^{0}C to 550^{0}C and the error is +/- 2^{0}C for -30^{0}C to 100^{0}C.

Fig - 1: Inclined air jet nozzles at 60 degrees

5. FORMULAE USED

- $\mathbf{Re} = \frac{\rho VL}{\mu}$
  where,
  Re=Reynold's number
  ρ=Density of air (1.177 Kg/m^3)
  V=Velocity of air
  μ=Viscosity of air (1.57 × 10^{-5} m^2 /s)

- $\boldsymbol{h} = \frac{q}{\Delta T}$
  where,
  h = heat transfer coefficient (W/m^2 ^{o}C)
  q = heat flux (W/m^2), (here, 150 W/m^2)
  ΔT = difference in temperature between the solid surface and surrounding fluid area, ^{o}C

- $\boldsymbol{Nu} = \frac{hL}{k}$
  where,
  Nu = Nusselt number
  h = heat transfer co-efficient (W/m^{2}K)
  L = Characteristic Length, (0.016m)
  k = thermal conductivity of the fluid, (0.0262, W/m ^{0}C)

6. OBSERVATIONS AND SAMPLE CALCULATION

Readings were taken at the following conditions:
D=16mm, H=30mm, Re 8671, Angle 60.

Temperature measurements at 63 points:

46.5	35.5	40	47	53.5	48.5	42	36	39
45	35	38	42.5	54	48	45	36	35
45	38	38	45	58	49	43	36	33.5
37	36	38.5	45	54.5	53.5	42.5	36	34.5
38.5	39	38	46.5	57	57	45	38	36
39	36.5	39.5	48	57	52	45	40	36.5
43	39	43	47.5	57	55	45.5	39.5	40

Calculated value of convective heat transfer coefficient (h):

270.83	428.82	395.83	245.04	239.34	197.92	270.83	467.80	302.69
270.83	467.80	367.56	381.17	233.90	214.41	354.88	514.58	514.58
395.83	467.80	395.83	285.88	165.99	187.12	302.69	514.58	514.58
367.56	467.80	302.69	302.69	171.53	183.78	311.87	514.58	428.82
367.56	467.80	331.99	251.01	171.53	158.33	233.90	514.58	428.82
367.56	467.80	331.99	223.73	171.53	183.78	239.34	428.82	428.82
302.69	331.99	294.05	187.12	158.33	177.44	214.41	411.66	343.05

Calculated value of Nusselt number (Nu):

165.39	261.87	241.73	149.64	146.16	120.86	165.39	285.68	184.85
165.39	285.68	224.46	232.78	142.84	130.94	216.72	314.25	314.25
241.73	285.68	241.73	174.58	101.37	114.27	184.85	314.25	314.25
224.46	285.68	184.85	184.85	104.75	112.23	190.45	314.25	261.87
224.46	285.68	202.74	153.29	104.75	96.69	142.84	314.25	261.87
224.46	285.68	202.74	136.63	104.75	112.23	146.16	261.87	261.87
184.85	202.74	179.57	114.27	96.69	108.36	130.94	251.40	209.50

Calculated average Nusselt number (Nu):

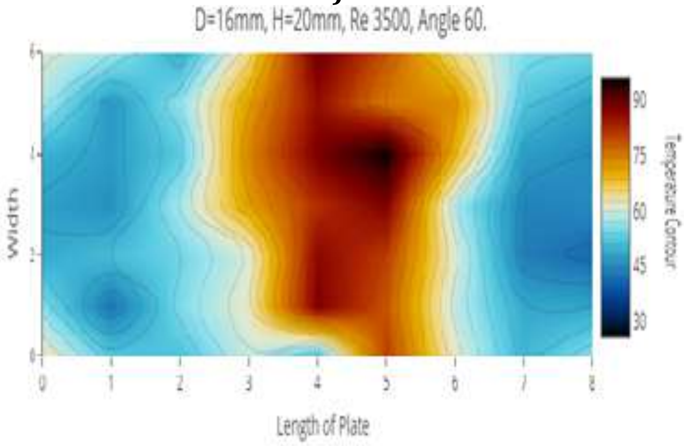
204.39	270.43	211.12	163.72	114.47	113.66	168.19	293.71	258.35

7. RESULTS

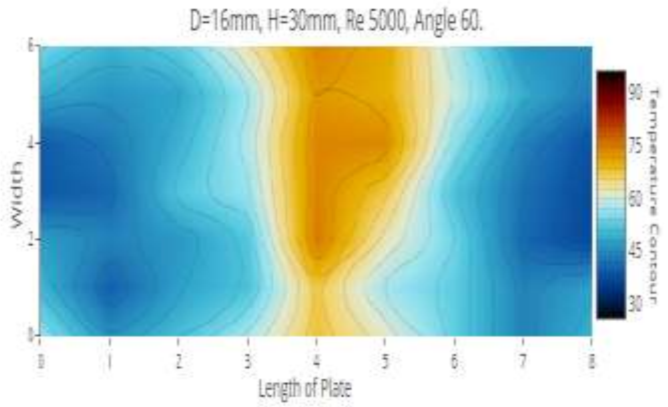
The Reynolds number were 3500, 5000 and 8671 and the variations of height were 10mm, 20mm and 30mm respectively. 9 experiments were carried out, from which 3 optimal results were obtained, in which the cooling gained was maximum as compared to other 6 results. The temperature contours of these 3 results are shown below:

TEMPERATURE CONTOURS

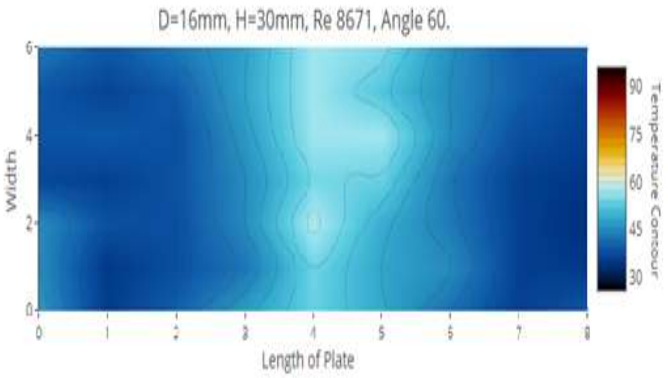
I)



II)



III)



7. CONCLUSION

From the extensive experiments performed it can be concluded that maximum cooling is achieved where higher Reynolds Number was obtained. The temperature contour shows the temperature distribution over the plate. At 60-degree angle with nozzle of diameter 16mm and height of the nozzle tip from the target plate being 30mm with Reynolds number 8671, maximum cooling is achieved. Larger the Reynolds number with sufficient space between the nozzle and the component leads to effective cooling. Cooling below the nozzle tip is maximum, whereas at the centre of the plate, the cooling is less.

8. REFERENCES

[1] Ingole S. B. and K. K. Sundaram, "Experiment on cooling characteristics of a surface using inclined air jet at 75^0", Nov-2014.

[2] P. Chandramohan, S. N. Murugesan and S. Arivazhagan, "Heat transfer analysis of flat plate subjected to multi jet air impingement using principal component analysis and computational technique", 2017.

[3] Hizkan F. Oztop, Yasin Varol, Ahmet Koca and Mujdat Firat, "Experimental investigation on cooling of heated circular disc using inclined circular jet", Aug-2011.

9. BIOGRAPHIES

Shreyas Surendra Patil, B.E. Mechanical, ICEM, Pune

Arnav Pradeep More, B.E. Mechanical, ICEM, Pune

Akshay Shamrao Indore, B.E. Mechanical, ICEM, Pune

Ashish Anil Kutval, B.E. Mechanical, ICEM, Pune