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HEAT TRANSFER ANALYSIS BY MULTI AIR JET IMPINGEMENT COOLING PROCESS

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ABSTRACT— This study on analysis of multi air-jet impingement cooling. The nusselt number is defined based on the various nozzle diameters, Effect of distance between the nozzle exit and steel plate, angle of nozzles, velocity of nozzle. Multi air jet impingement method is one of the intensive cooling method to cool the very hot object. Nusselt number and Reynolds number are analyzed with help of convective heat transfer coefficient and conductivity of plate (hl/k). And Reynolds number is varied with the help of four nozzles.

Keywords- multijet impingement, heating very thin stainless steel plate,nozzle.

I. INTRODUCTION

In various industries like plastic, paper pulp, power generation, and Electronic equipments or part fail due to high temperature. So there is the need of dissipation of excess amount of heat by reducing the temperature of the part or equipment. And this can be done by implementing various types cooling system. (1)

The liquid impingement is an effective method for cooling used in many application because of its capacity to transfer very high heat fluxes. But in case of cooling of steel plate as there of chances of corrosion and water or liquid is available in bulk of quantity. If it is available in bulk quantity then there is problem of drainage of liquid after usage or there must be arrangement provided for cooling of liquid in the sense of repeated usage.(2)

Hence air cooling is preferred over water or liquid cooling due to several advantage.in these way there is need for more research in air cooling methods. This very useful method for cooling of combustion engine analyzing furnaces.in this experiment we are going to focus on the air jet impingement by using multi nozzle arrangement. The heat transfer rate is observed a varying the jet velocity of all the nozzle. It will gives different heat transfer rate when the angle of all the four nozzle is varied at the same time or different time it is going to give us newer heat transfer rate. In this we can says that changes in Reynolds number of the air jet would result in variation in heat transfer coefficient (h). (2)

Spray cooling is used for increasing the heat transfer rate an plastic industries. In plastic industries plastic product are produced by using moulds cavity. When the moulds are quenched suddenly then there are some defects associated with quenching. The quenching defects are residual stresses in product excess hardening or brittleness of product. And there for there is needs for elimination of this quenching defects. This can be done by using air sprays witch cool the plastic product gradually than quenching. In this way there for nozzle are used in experiment directing towards the hot flat steel plate. Steel plate is heated by using certain type of heater with fixed rate.

II. EXPRIMRNTAL STUDY

Experimental setup consist of five part namely blower, nozzles and there are element heater, thermometer, and provision for varying the distance of steel plate from nozzle.

A. Exprimental setup

The schematic diagram of experimental setup is given in figure 1. A rectangular heating plate of 350×250 mm, thickness of plate 50 micron, heating capacity of heater 300 watt, a dimmer stat is used to vary the heat supplied to the heating plate. (2)

This surface temperature of heating steel plate is measured with the help of non –contact type infrared thermometer which is exposed to the jet. The heating plate is sandwiched between two plate which are tightened by the nut and bolt and arrangement. For varying the distance between the steel plate and outlet of nuzzles the platform of the plate is moved up and down along vertical axis. (3) This is done by rack and pinion mechanism and moved manually. A centrifugal blower with plenum chamber is used to supply air under pressure to the nozzle. Plenum chamber is used to stable the air flow and reduction in fluctuations. U- Tube manometer and pressure gauge is used for measuring the velocity and pressure of the air jet. A tap is provided for variation in and control of flow of air to the nozzle duct. A sliding mechanism is provided for the angular movement of all the four nozzle for varying geometry of flow of air. Air nozzle of four different sizes

2mm, 4mm, 6mm and 8mm are used for varying flow of fluid on plate for cooling purpose.

B. Exprimental procedure

After fixing a particular nozzle assembly and heating plate. The blower is switched on and air supply is given to the set of nozzle through the hose pipe.

A pitot tube is measuring the velocity of air flow (4). Pressure gauge mounted on the hose for measuring the pressure of the air flow and orifice meter is used to measure the flow of air. In this way air is supplied to the nozzle.

Then heater switched on. For varying the heat capacity, supply is given through the dimmer stat and plate is heated at required temperature. An arrangement of rack and pinion mechanism is provided for varying the distance between the steel plate and nozzles; which operated manually. When the plate is heated, for measuring the temperature of the plate of particular points a non-contact type infrared thermometer is used. After measuring the temperature of plate, nozzles are allowed to cool the steel plate at constant velocity and pressure at which they all have same angle. In this way heated steel plate is cooled by multi air-jet impingement cooling.

After cooling of steel again temperature of particular points on steel plate is measured by the thermometer. These readings of temperature are taken one by one after particular interval of time. Readings are taken by varying the following parameters: (5)

1) Nozzle diameter
2) Nozzle angle
3) Spacing between the nozzle and heating plate
4) Velocity of jet

In this way for every parameter different readings are taken and calculated analytically. It will different values of convective heat transfer coefficient. And will help to know the effective and efficient way of cooling.

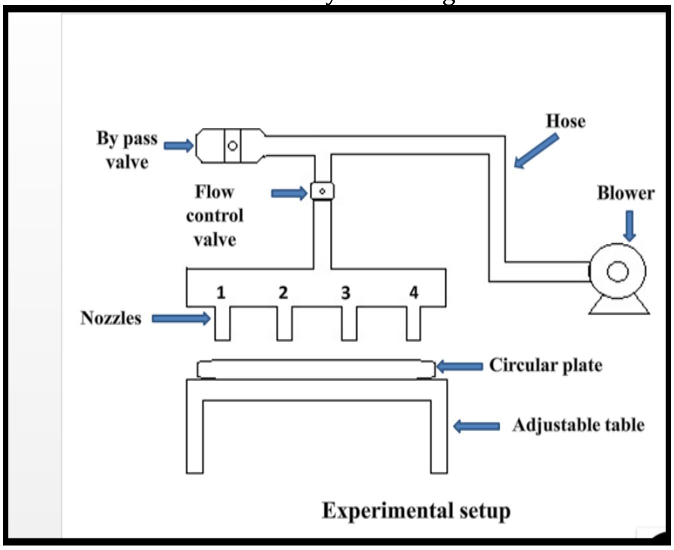

Fig.1 Experimental setup

III. NOMENCLATURE

t	Thickness, (m)
μ	Dynamic viscosity of the fluid, (Pa·s or N·s/m^2)
m·	Mass flow rate, (kg/s)
Q	Heat convection rate, (Watt)
P	Density of the fluid, (kg/m^3)
ν	Kinematic viscosity, (ν = μ / ρ), (m^2/s)
D	Inner diameter, (m)
H	Convection heat transfer coefficient, (w/m^2.^{0}C)
K	Thermal conductivity, (W/m.k)
A	Plate cross-section area (m^2)
C_p	Constant pressure specific heat, (kj/kg.k)
R	Radius of the impingement region,(m)
Lh	Hydrodynamic entry length,(m)
N	Number of jet
Nu	Nusselt number
Q	Volumetric flow rate, (m^3/s)
Re	Reynolds number
S	Exit nozzle to heat source plate distance, (m)
ΔT	Temperature different,(k)

IV. IMPINGEMENT OF JET

There are two types of jet used cooling.

- Free surface jet
- Submerged jet

In this analysis we will focus on only free surface liquid jet (2)

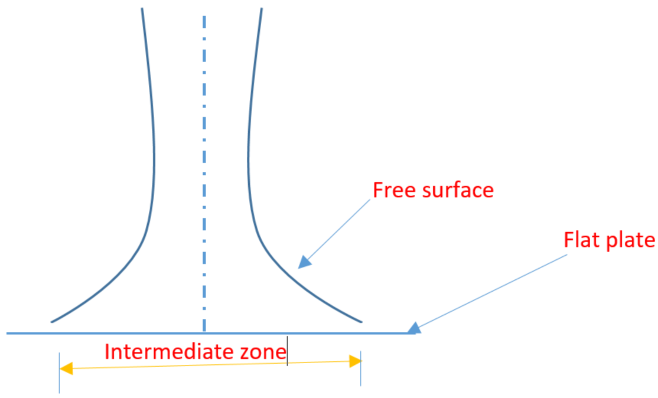

Fig.2 Impingement of jet (2)

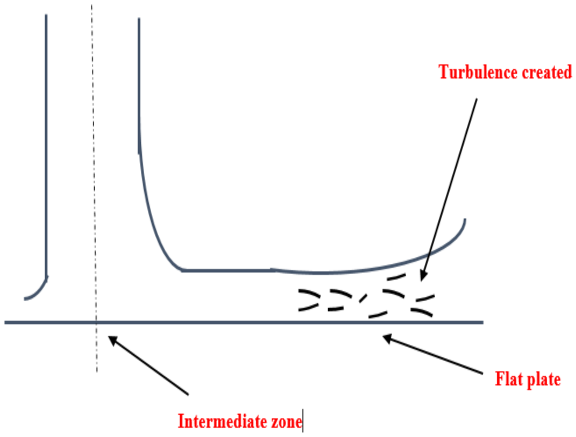

Fig.3. axisymmetric impingement jet (2)

V. EQUATIONS

Flow rate (CFM)

CFM at standard density is defined as 0.075 F^3/min

$$1CFM=1.6990\ M^3/hr \quad (1)$$

Static pressure

$$Q = \frac{60 \cdot q}{\rho \cdot Cp \cdot T} \quad (2)$$

Q=discharge of air (m^3/min)
q=equipment heat generation (W)
T=inner allowable temperature (^{0}C)
ρ =density of air (1.20 kg/m^3)
Cp=specific heat constant (1007 J/kg.k)

$$\textbf{CFM=1.76.P/Tc} \qquad \textbf{(3)}$$

Static pressure loss for straight duct 0.004 of wg
For 45 elbow= 0.1" of wg
For 90 deg elbow =0.2" of wg.

Nusselt is given by,

$$\textbf{Nu}=\frac{hL}{k} \qquad \textbf{(4)}$$

Where
h- Heat transfer coefficient, w/m^2 ^{0}C
L- Length
K – Thermal conductivity w/m^{0}C

VI. SOFTWARE MODELLING

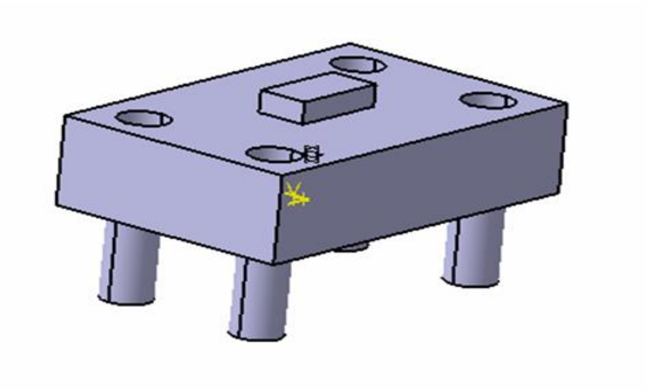

Fig.4. Table setup

VII. ASSUMPTION

1) The discharge is same through all the jet.
2) Heat loss from all the faces except top surface is negligible.
3) The thickness of the plate is same throughout the area.

VIII. CONCLUSION

This paper was performed for investigating effect of various nozzle diameter, velocity, angle, on heat transfer and this effect indicate through the graph paper.

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