FREE Convective Heat Transfer from Inclined Narrow Plates

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Abstract:

Natural convection has attracted a great deal of attention from researchers because of its presence both in nature and engineering applications. In nature, convection cells formed from air raising above sunlight-warmed land or water are a major feature of all weather systems. Con-vection is also seen in the rising plume of hot air from fire, oceanic currents, and sea-wind formation (where up-ward convection is also modified by Coriolis forces). The main object of the paper is to provide an analysis based on the effect of inclination angle from vertical on the heat transfer from flat plates is determined. Natural convec-tive heat transfer from flat plates inclined at an angle to the vertical in laminar flow regions has been analytically investigated. The inclination angles are 150, 300, 450 and 600. The models are done in Pro/Engineer. The fluid flow characteristics considering laminar flow under natu-ral convection is analyzed using CFD analysis. The heat transfer rates by using different materials for plates are analyzed using thermal analysis. The materials taken are Copper and aluminum alloy 6061.In many applications, convection is commonly visualized in the formation of microstructures during the cooling of molten metals, and fluid flows around shrouded heat-dissipation fins, and so-lar ponds. A very common industrial application of natu-ral convection is free air cooling without the aid of fans: this can happen on small scales (computer chips) to large scale process equipment.

Index terms:

Types of convection, Natural convection, inclined plates, copper material.

I.INTRODUCTION:

Natural convection is a mechanism, or type of heat trans-port, in which the fluid motion is not generated by any external source (like a pump, fan, suction device, etc.) but only by den-sity differences in the fluid occurring due to tempera-ture gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process contin-ues, forming a convection current; this process transfers heat energy from the bottom of the convection cell to top. The driving force for natural convection is buoyancy, a result of differences in fluid density. Because of this, the presence of a proper acceleration such as arises from re-sistance to gravity, or an equivalent force (arising from acceleration, centrifugal force or Coriolis effect), is es-sential for natural convection. For example, natural con-vection essentially does not operate in free-fall (inertial) environments, such as that of the orbiting International Space Station, where other heat transfer mechanisms are required to prevent electronic components from overheat-ing.

Convection:

Convection is the concerted, collective movement of groups or aggregates of molecules within fluids (e.g., liq-uids, gases) and rheids, through advection or through dif-fusion or as a combination of both of them. Convection of mass cannot take place in solids, since neither bulk cur-rent flows nor significant diffusion can take place in sol-ids. Diffusion of heat can take place in solids, but that is called heat conduction. Convection can be demonstrated by placing a heat source (e.g. a Bunsen burner) at the side of a glass full of a liquid, and observing the changes in temperature in the glass caused by the warmer fluid mov-ing into cooler areas. Convective heat transfer is one of the major types of heat transfer, and convection is also a major mode of mass transfer in fluids. Convective heat and mass transfer take place both by diffusion –

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the ran-dom Brownian motion of individual particles in the fluid
– and by advection, in which matter or heat is transported by the larger-scale motion of currents in the fluid. In the context of heat and mass transfer, the term "convection" is used to refer to the sum of advective and diffusive transfer. In common use the term "convection" may refer loosely to heat transfer by convection, as opposed to mass transfer by convection, or the convection process in gen-eral. Sometimes "convection" is even used to refer spe-cifically to "free heat convection" (natural heat convec-tion) as opposed to forced heat convection. However, in mechanics the correct use of the word is the general sense, and different types of convection should be qualified for clarityConvection can be qualified in terms of being natu-ral, forced, gravitational, granular, or thermo magnetic. It may also be said to be due to combustion, capillary action, or Marangoni and Weissenberg effects. Heat transfer by natural convection plays a role in the structure of Earth's atmosphere, its oceans, and its mantle. Discrete convec-tive cells in the atmosphere can be seen as clouds, with stronger convection resulting in thunderstorms. Natural convection also plays a role in stellar physics.

Natural Convection:

In natural convection, the fluid motion occurs by natural means such as buoyancy. Since the fluid velocity asso-ciated with natural convection is relatively low, the heat transfer coefficient encountered in natural convection is also low.

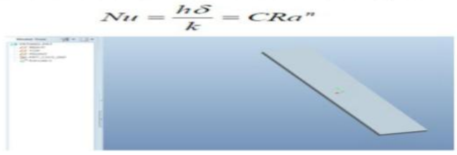
Mechanisms of Natural Convection:

Consider a hot object exposed to cold air. The tempera-ture of the outside of the object will drop (as a result of heat transfer with cold air), and the temperature of adja-cent air to the object will rise. Consequently, the object is surrounded with a thin layer of warmer air and heat will be transferred from this layer to the outer layers of air. Natural convection heat transfer from a hot body is the temperature of the air adjacent to the hot object is higher,

$$Ra = Gr\,Pr = \frac{g\beta(T_s - T_\infty)\delta^3}{\nu^2}Pr$$

al convection is in the following form:

$$Nu = \frac{h\delta}{k} = CRa^n$$



1. Convection current:

That in the absence of this movement, heat transfer would

thus its density is lower. As a result, the heated air rises. This movement is called the natural

2. Effect of Fin Length:

A vertical enclosure the dependence of the Nusselt num-ber (Nu) on fin length (L/H) for different values of Ray-leigh number(Ra) ranging from 104 to 3x105 is shown in fig. 2. Nu is plotted against Ra for different values of L/H as a parameter. It can beclearly seen that at any Rayleigh number the effect of in creasing/H increases Nu. This in-crease in Nu with Increasing L/H can be attributed to the increase of heat transfer surface area with increasing L/H. Possibility of formation of separate convection cell be-tween two adjacent fins increases due to increase in L/H for a vertical enclosure and this leads in an enhancement of heat transfer rate

3. Natural Convection over Surfaces:

Natural convection on a surface depends on the geom-etry of the surface as well as its orientation. It also de-pends on the variation of temperature on the surface and the thermo physical properties of the fluid. Note that the velocity at the edge of the boundary layer becomes zero. It is expected since the fluid beyond the boundary layer is stationary.

4. Natural Convection Correlations:

The complexities of the fluid flow make it very difficult to obtain simple analytical relations for natural convection. Thus, most of the relationships in natural convection are based on experimental correlation. The Rayleigh number is defined as the product of the Graphs of and Pr and tl number.

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be by conduction only and its rate would be much lower. In a gravitational field, there is a net force that pushes a light fluid placed in a heavier fluid upwards. This force is called the buoyancy force. Buoyancy force keeps the ship float in water. The magnitude of the buoyancy force is the weigh to fluid displaced by the body.

Fig 1: Image of 3D MODEL of inclined plates

II. LITERATURE REVIEW:

The idea behind the proposed system is to design extended surfaces of fins that are used to increase the heat transfer rate from a surface to a fluid Numerical Analysis of Natu-ral Convection in Rectangular Enclosure with Heated Finned Base Plate. In this paper, steady laminar natural convection heat transfer in 3-D horizontal narrow rectan-gular enclosure, with heated finned base plate is studied numerically using FLUENT 6.3. The variable parameters used in this study are fin spacing (S/H=0.875-1.75) and fin height (L/H=0.25-0.75). The enclosure is heated from bottom wall and is cooled from the opposite top wall while the other walls of the enclosure are assumed to be adiabatic. 3-D steady state continuity, Navier-Stokes and energy equations using Boussinesq approximation are solved. For each case Rayleigh number range ranging from 104 to 3x105 is used. This paper presents the effect of fin height and fin spacing on the fin effectiveness and heat transfer in enclosure. Flow field characteristics in the form of velocity vectors are presented for different cases.

Natural Convective Heat Transfer from Two Adjacent Narrow Plates:

Numerical studies of the interaction of the natural convec-tive flows over two adjacent vertical and inclined narrow isothermal flat plates in the laminar flow region are dis-cussed. Two cases are considered. In one case, the plates are horizontally adjacent to each other, the plates being horizontally separated while in the other case, one plate is symmetrically placed above the other plate the plates being vertically separated. Attention has been given to the effects of the inclination angle of the plates to the vertical, to the effects of the vertical or horizontal dimensionless gap between the heated plates, and to the effects of the dimensionless plate width on the mean heat transfer rates from the two heated plates for a wide range of Rayleigh numbers.

It is shown that when there are two adjacent narrow flat plates with a relatively small gap between the plates the flow near the adjacent plates is altered compared to that over a single narrow plate and this can lead to a signifi-cant change in the mean heat transfer rate compared to that from a single isolated plate under the same condi-tions. Empirical equations for both the case of horizon-tally separated and vertically separated plates are given

An Interaction of Natural Convective Heat Transfer From Two Adjacent Isothermal Nar-row Vertical and Inclined Flat Plates:

Natural convective heat transfer from a two narrow ad-jacent rectangular isothermal flat plates of the same size embedded in a plane adiabatic surface, the adiabatic sur-face being in the same plane as the surfaces of the heated plates, has been numerically investigated. The two plates have the same surface temperature and they are aligned with each other but are separated form each other by a relatively small gap. Results for the case where the plates are vertical and where they are inclined at positive or negative angles to the vertical have been obtained. It has been assumed that the fluid properties are constant ex-cept for the density change with temperature which gives rise to the buoyancy forces, this having been treated using the Boussinesq approach. It has also been assumed that the flow is symmetrical about the vertical center plane between the two plates. The solution has been obtained by numerically solving the full three-dimensional form of governing equations, these equations being written in dimensionless form. The solution was obtained using the commercial finite volume method based cfd code, FLUENT. The solution has the Rayleigh number, the di-mensionless plate width, the angle of inclination, the di-mensionless gap between two flat plates, and the Prandtl number as parameters. Results have only been obtained for a Prandtl number of 0.7 Results have been obtained for Rayleigh numbers between 103 and 107 for plate width-to-height ratios of between 0.15 and 0.6, for gap between the adjacent edges to plate height ratios of between 0 and 0.2, for angles of inclination between +45° and −45°.

NEW ANALYSIS OF NATURAL CONVEC-TION BOUNDARY LAYER FLOW ON A HORIZONTAL PLATE WITH VARIABLE WALL TEMPERATURE :

In this study, steady laminar free convection boundary layer flow on a horizontal plate is investigated through analytical solutions. By transforming the governing non-dimensional boundary layer equations into an ordinary differential equation, the application of the Homotopy Analysis Method can be practical. So in this case, the ana-lytical results for different Prandtl numbers and constant M values which portray the power index are achieved.

The trend goes on large amounts of (M 1) and the results are compared with other efforts. Furthermore, the effects of different values of Prandtl number and M values on temperature and velocity profiles are verified. Key words: free convection, HAM (Homogony Analysis Method), analytical solution.

Natural convection heat transfer above heated horizontal surfaces MASSIMO CORCIONE :

An extensive reasoned review of the results available in the literature for free convection heat transfer from a heated flat plate facing upwards, is conducted. The re-view is organized in the form of a table, so as to give the reader the opportunity to compare the heat transfer data, expressed through dimensionless equations, as well as the conditions under which these data were obtained. A com-parative survey of the results which may be derived at different Rayleigh numbers by the use of the heat transfer correlations presented, is also reported, showing that in some cases the discrepancies may amount to ±50%.

Imported model

Fig 2: Figure of Imported model of inclined plates

III.ANALYSIS OF PROPOSED MODEL:

In this paper we presented a Thermal and CFD analysis on natural convection heat transfer.

A. THERMAL ANALYSIS Inclined Plates At Angle 150 MATERIAL - ALUMINUM 6061

Thermal conductivity: 0.21w/mmk
Specific heat: 900 J/kgk
Density: 0.00000269 kg/mm3

VELOCITY CALCULATIONS:

$$\text{Velocity} = \frac{\propto}{h}\sqrt{R_a P_r}$$

P_r=0.7

R_a=10^4

$$U_f = \frac{15}{100}\sqrt{1000 \times 0.7}$$

$$= 3.9686 \text{m/s}$$

$$U_{30} = \frac{30}{100}\sqrt{1000 \times 0.7}$$

$$= 7.9372 \text{m/s}$$

$$U_{45} = \frac{45}{100}\sqrt{1000 \times 0.7}$$

$$= 11.9058 \text{m/s}$$

$$U_{60} = \frac{60}{100}\sqrt{1000 \times 0.7}$$

$$= 15.8745 \text{m/s}$$

Meshed model

Fig 3: Figure of Meshed model of inclined plates

Temperature – 303K
Loads – define Loads – Apply – Thermal – Convection – on areas
Bulk Temperature – 313 K
Film Coefficient – 0.222W/mm2 K

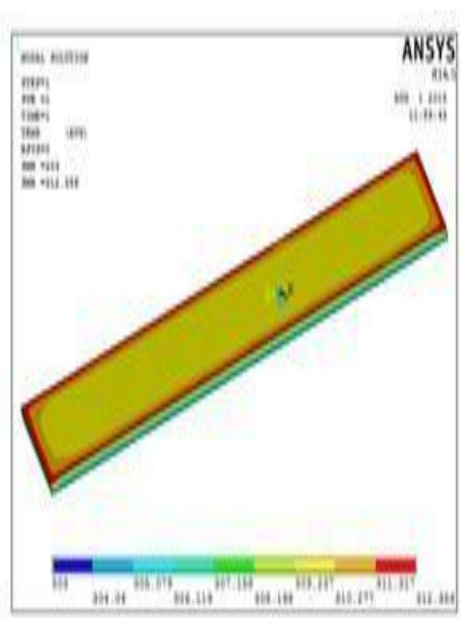


Fig 4: Figure of inclined plates at Nodal temperature

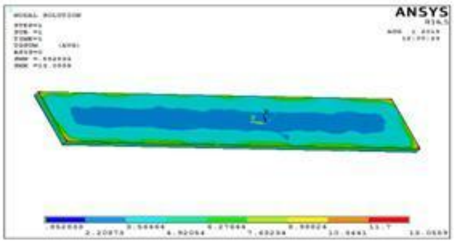


Fig 5: Figure of inclined plates with thermal gradient Thermal flux

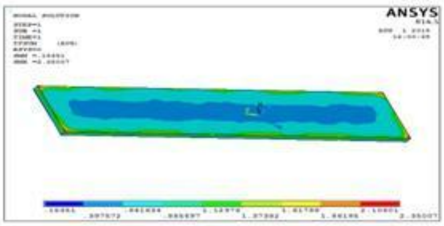


Fig 6: Figure of inclined plates with thermal flux

B. CFD ANALYSIS ON NATURAL CON-VECTION HEAT TRANSFER

Velocity 3.9686 m/s

Meshed model

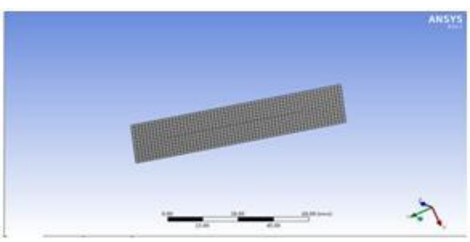
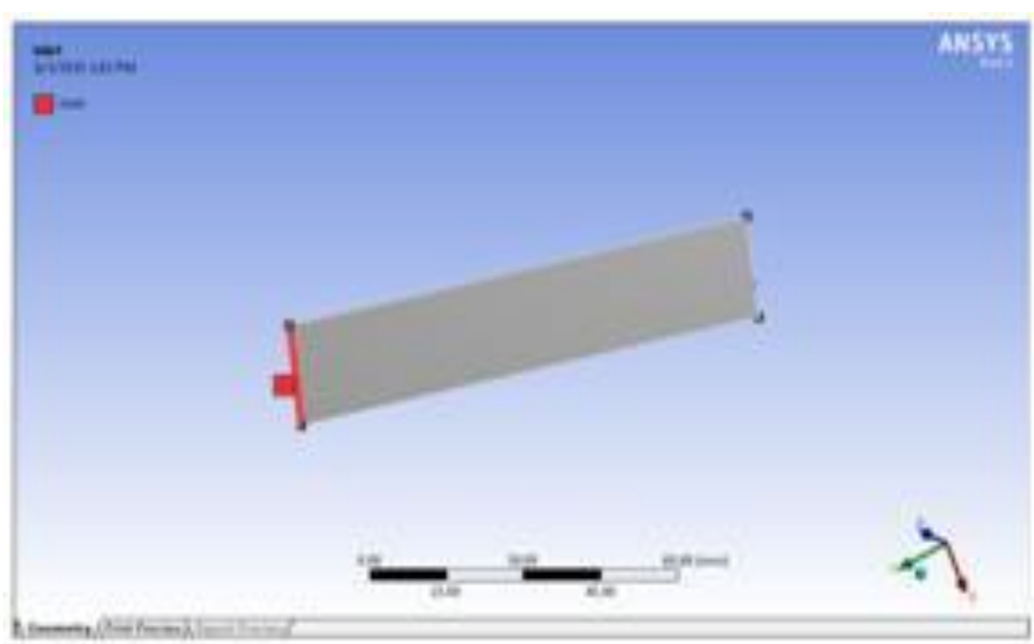


Fig 7: Figure of inclined plates with meshed model in CFD analysis

Select faces → right click → create named section → en-ter name → air inlet



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Select faces → right click → create named section → en-ter name → air outlet

Nusslet's number

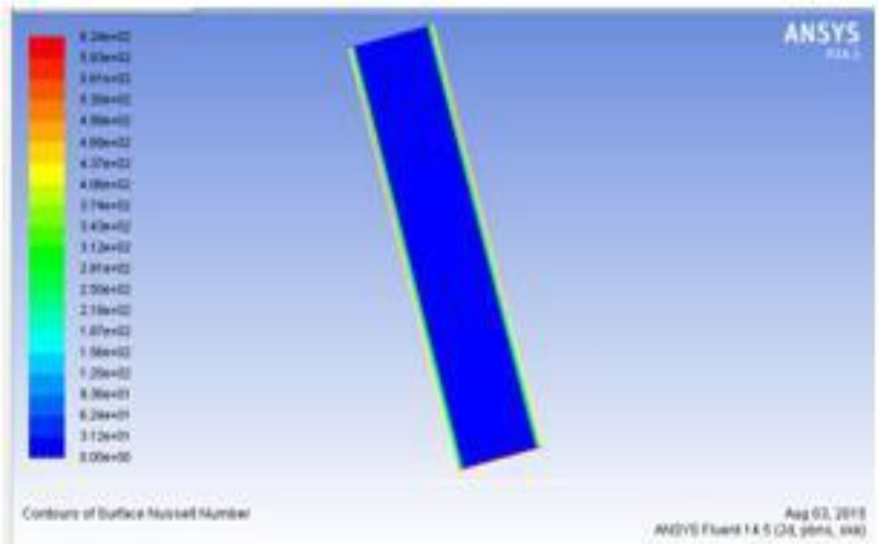

Fig 9: Figure of Nusselt's numbers

Reynolds number

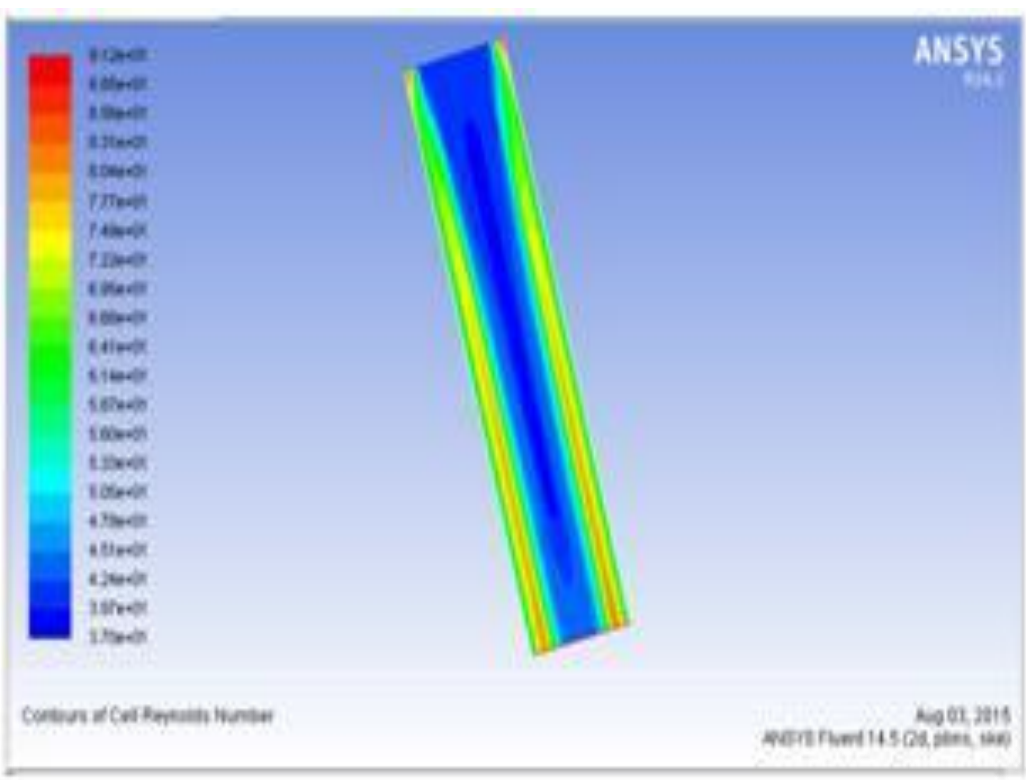

Fig 10: Figure of Reynold's numbers

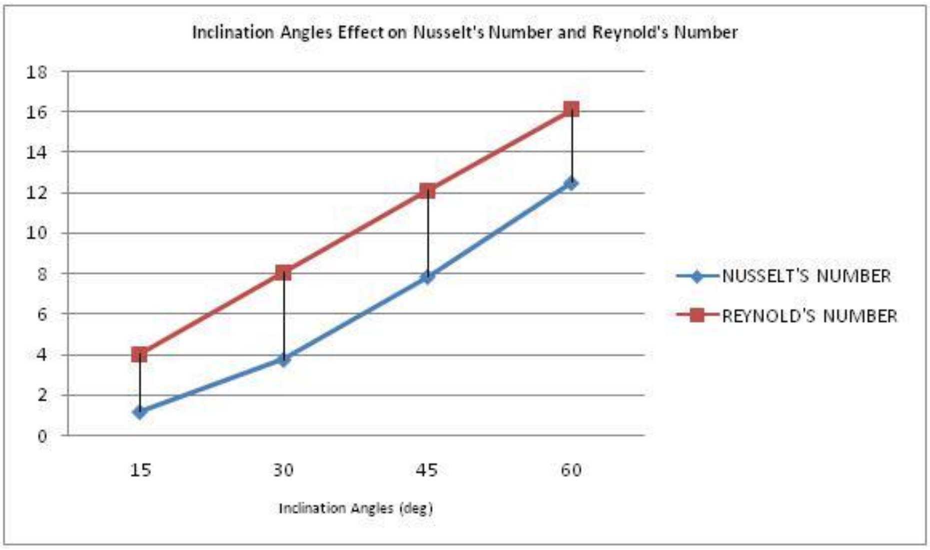

Fig 11. Graph of Inclination angles Effect on Nusselt's and Reynold's numbers

RESULTS TABLE

CFD analysis results on natural convective inclined plates

Angle	Pressure (Pa)	Velocity (m/s)	Temperature (K)	Nusselt's number	Reynolds number
15^0	1.15e+00	4.04e+00	3.15e+02	6.24e+02	9.12e+01
30^0	3.74e+00	8.07e+00	3.15e+02	9.92e+02	1.20e+02
45^0	7.85e+00	1.21+01	3.15e+02	1.32e+03	1.94e+02
60^0	1.25e+01	1.61e+01	3.95e+02	1.64e+03	2.76e+02

Thermal analysis for Aluminum 6061

Angle	Nodal temperature (K)	Thermal gradient (K/mm)	Thermal flux (W/mm^2)
15^0	312.356	13.0559	2.35007
30^0	312.319	12.8724	2.31703
45^0	312.299	14.5569	2.62023
60^0	312.368	12.8724	2.31703

Thermal analysis for copper

Angle	Nodal temperature (K)	Thermal gradient (K/mm)	Thermal flux (W/mm^2)
15^0	311.326	9.5762	3.68469
30^0	310.073	9.0215	2.77142
45^0	310.067	9.79591	2.77142
60^0	311.376	9.51138	3.66186

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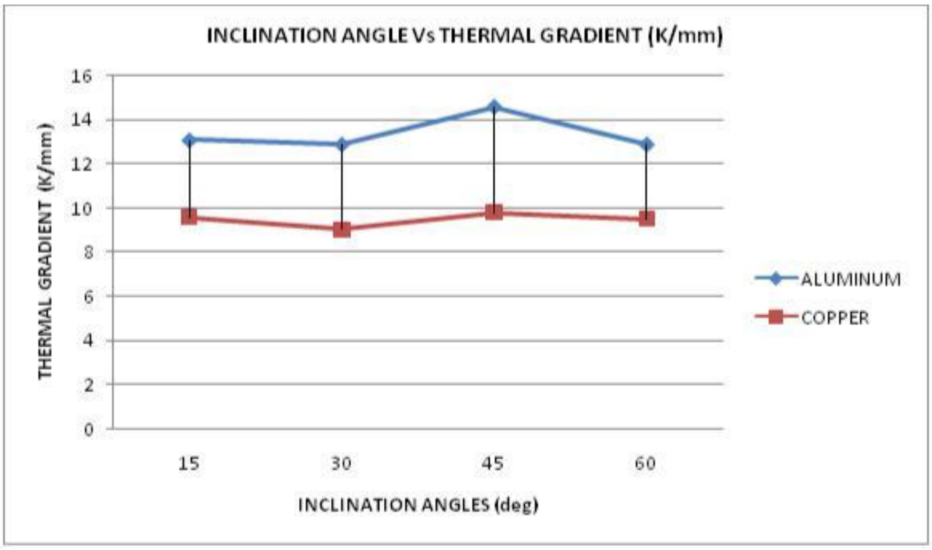

Fig 12. Graph of Inclination angle vs thermal gradient

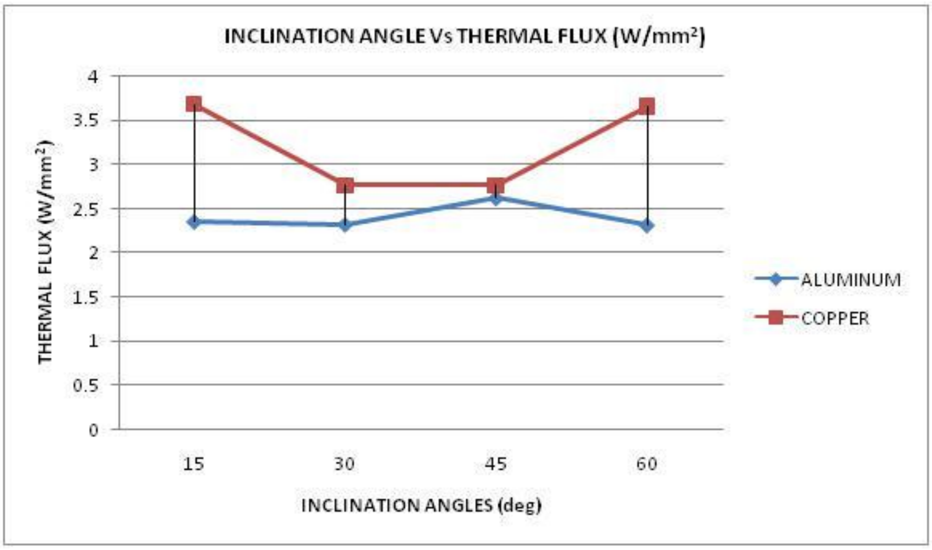

Fig 13. Graph of Inclination angles vs thermal flux

IV.CONCLUSION:

The presented paper of "CFD and Thermal analaysis of NATURAL CONVECTIVE HEAT TRANSFER FROM INCLINED NARROW PLATES" provides analysis of Natural convective heat transfer from flat plates inclined at an angle to the vertical in laminar flow regions have been analytically investigated. The inclination angles are 150, 300, 450 and 600. The models are done in Pro/En-gineer. The fluid flow characteristics considering laminar flow under natural convection is analyzed using CFD analysis. The heat transfer rates by using different mate-rials for plates are analyzed using thermal analysis. The materials taken are Copper and aluminum alloy 6061.

By observing the CFD analysis results, the pressures, ve-locity, Nusselt's Number are increasing with increase of inclination angles. So placing the plate with maximum inclination is better since the heat transfer rates are in-creasing. By observing the thermal analysis results, the heat transfer rates are almost similar for 300 and 450 in-clination angles and increasing for 600 angle. So it can be concluded that by increasing inclination the plates yields better results.

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