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Natural 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. Convection is also seen in the rising plume of hot air from fire, oceanic currents, and sea-wind formation (where upward 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 convective 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 natural 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 solar ponds. A very common industrial application of natural 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 transport, in which the fluid motion is not generated by any external source

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(like a pump, fan, suction device, etc.) but only by density differences in the fluid occurring due to temperature 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 continues, 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 resistance to gravity, or an equivalent force (arising from acceleration, centrifugal force or Coriolis effect), is essential for natural convection. For example, natural convection 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 overheating.

Convection:

Convection is the concerted, collective movement of groups or aggregates of molecules within fluids (e.g., liquids, gases) and rheids, through advection or through diffusion or as a combination of both of them. Convection of mass cannot take place in solids, since neither bulk current flows nor significant diffusion can take place in solids. 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 moving 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 - the random 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"

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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 general. Sometimes "convection" is even used to refer specifically to "free heat convection" (natural heat convection) 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 natural, 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 convective 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 associated 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 temperature of the outside of the object will drop (as a result of heat transfer with cold air), and the temperature of adjacent 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, thus its density is lower. As a result, the heated air rises. This movement is called the natural

1. Convection current:

That in the absence of this movement, heat transfer would 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. 2. Effect of Fin Length:

A vertical enclosure the dependence of the Nusselt number (Nu) on fin length (L/H) for different values of Rayleigh 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 increase 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 between 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 geometry of the surface as well as its orientation. It also depends 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 the number.

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

al convection is in the following form:

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



Fig 1: Image of 3D MODEL of inclined plates



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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 Natural Convection in Rectangular Enclosure with Heated Finned Base Plate. In this paper, steady laminar natural convection heat transfer in 3-D horizontal narrow rectangular 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 convective flows over two adjacent vertical and inclined narrow isothermal flat plates in the laminar flow region are discussed. 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 significant change in the mean heat transfer rate compared to that from a single isolated plate under the same conditions. Empirical equations for both the case of horizontally separated and vertically separated plates are given

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

Natural convective heat transfer from a two narrow adjacent rectangular isothermal flat plates of the same size embedded in a plane adiabatic surface, the adiabatic surface 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 except 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 dimensionless plate width, the angle of inclination, the dimensionless 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 widthto-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 $+45^{\circ}$ 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 nondimensional boundary layer equations into an ordinary differential equation, the application of the Homotopy Analysis Method can be practical. So in this case, the analytical results for different Prandtl numbers and constant M values which portray the power index are achieved.



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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 review 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 comparative 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 $\pm 50\%$.

VELOCITY CALCULATIONS:

Velocity $= \frac{\alpha}{h} \sqrt{R_a} P_r$ $P_r=0.7$ $R_a=10^4$ $U_r = \frac{15}{100} \sqrt{1000 \times 0.7}$ = 3.9686 m/s $U_{30} = \frac{30}{100} \sqrt{1000 \times 0.7}$ = 7.9372 m/s $U_{45} = \frac{45}{100} \sqrt{1000 \times 0.7}$ = 11.9058 m/s $U_{60} = \frac{60}{100} \sqrt{1000 \times 0.7}$

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

Imported model



Fig 2: Figure of Imported model of inclined plates

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



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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 \rightarrow right click \rightarrow create named section \rightarrow enter name \rightarrow air inlet



Fig 8: Figure of inclined plates with air outlet in CFD analysis

Select faces \rightarrow right click \rightarrow create named section \rightarrow enter name \rightarrow air outlet

Nusslet's number



Fig 9: Figure of Nusselt's numbers

Reynolds number



Fig 10: Figure of Reynold's numbers



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

Angle	Pressure	Velocity	Temperature	Nusselt's	Reynolds
	(Pa)	(m/s)	(K)	number	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

CFD analysis results on natural convective inclined plates

Thermal analysis for Aluminum 6061

Angle	Angle Nodal		Thermal
	temperature	gradient	flux
	(K)	(K/mm)	(W/mm²)
150	312.356	13.0559	2.35007
300	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	Thermal	Thermal
	temperature	gradient	flux
	(K)	(K/mm)	(W/mm²)
150	311.326	9.5762	3.68469
300	310.073	9.0215	2.77142
45 ⁰	310.067	9.79591	2.77142
600	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/Engineer. The fluid flow characteristics considering laminar flow under natural 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.

By observing the CFD analysis results, the pressures, velocity, 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 increasing. By observing the thermal analysis results, the heat transfer rates are almost similar for 300 and 450 inclination angles and increasing for 600 angle. So it can be concluded that by increasing inclination the plates yields better results.



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