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# Review on Natural Convective Heat Transfer from Inclined Narrow Plates

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**Abstract:** In many engineering situations, the equipment is placed at different geographical locations which are not accessible to regular maintenance and which requires cooling of the surfaces continuously and natural/free convection heat transfer process is preferred for this applications. Natural Convection is one of the major modes of heat transfer that can be classified in terms of being natural, forced, gravitational, granular, or thermomagnetic. In the past decade, several studies on convection heat transfer in much geometry, enhancement of heat transfer by adding narrow strip (fin), effects of the magnetic field in heat transfer, heat transfer in a porous medium have been reported. The effects of Prandtl (Pr), Reynolds (Re), Grashof (Gr), and Rayleigh numbers (Ra), fin length, fin height, fin spacing, and their orientation have also been investigated. This paper reviews various researchers work on fluid flow and heat transfer behavior which is carried out by means different types of fin attachments, their orientation & angle of inclination of the base plate.

**Keywords:** Natural Convection, Inclined Narrow Plates, Aluminum Material

## I. INTRODUCTION

Natural convection occurs when the fluid circulates by virtue of the natural differences in densities of hot & cold fluid; the denser portion of the fluid moves downwards because of a greater force of gravity, as compared with the force on the less dense. Heat transfer by natural convection between a system and surrounding can be increased by using an extended thin strip of metal called fin. Fins are used where the available surface is found inadequate to transfer the required quantity of heat with the available temperature drop and where the heat transfer coefficient is low. The selection of fin depends on different parameters like geometrical shape, fin spacing, fin height, base thickness, kind of material, surface finish, etc. There are different fin geometries like a uniform straight fin, annular fin, splines, pin fin, etc. are used to increase the heat transfer rate from the surface. Fins orientation and geometry of fins array are the main parameters which affect the enhancement ratio of heat transfer.

## II. REVIEW ON THE INCLINED NARROW PLATE

The present paper contributes to the review of heat transfer from the inclined narrow plate under natural convection. The main objectives of this paper are to review the work carried out on inclined narrow plat (fin)

- A. Dr.I.Satyanarayana[1] investigate steady-state natural convection from heat sink with narrow plate-fins having parallel arrangement mounted on an inclined base by using CAD tool. The effects of fin height, the inclination of the base with the same boundary conditions for two different materials were analyzed thermally & dynamically using CAE tool. The results concluded that al-alloy and steel both materials maintain the same amount of total temperature distribution but heat flux is high for al-alloy. And when increases the fins length, temperature distribution remain the same for both materials but the total heat flux has been increased compared to the existing model.
- B. GanduSandeep [2] investigated Natural convective heat transfer from flat plates inclined at an angle to the vertical in laminar flow regions analytically. The inclinations were 15°, 30°, 45° & 60°. The fluid flow characteristics considering laminar flow under natural convection was analyzed using CFD analysis. The heat transfer rates by using different materials (Copper and aluminum alloy 6061) for plates were analyzed using thermal analysis. By observing the CFD analysis results, the pressures, velocity, Nusselt's Number were increased with increase in inclination angles. By thermal analysis results, the heat transfer rates were almost similar for 30° and 45° inclination angles and increased for the 60° angle. So maximum plate inclination will result in higher heat transfer rates.
- C. PallavarapuHari [3] investigated heat transfer & fluid flow characteristics for two cases under natural convection. In one case, the plates were horizontally adjacent to each other, the plates being horizontally separated while in the other case, one plate was symmetrically placed above the other plate the plates being vertically separated. 3D models were prepared by using

- Pro/Engineer. Thermal analysis has been done for both the cases using two different materials like Aluminum and Copper. 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. Results showed that the heat transfer rate was more for horizontally separated plates than vertically separated and copper had high heat transfer rates.
- D. AbdulrahimKalendar [4] 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 were aligned with each other but were separated from each other by a relatively small gap. Results for the case where the plates were vertical and where they were inclined at positive or negative angles to the vertical have been obtained. It has been assumed that the fluid properties were 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 was 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 were 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 width-to-height ratios of between 0.15 and 0.6, for a gap between the adjacent edges to plate height ratios of between 0 and 0.2, for angles of inclination between  $+45^\circ$  and  $-45^\circ$ .
- E. VankarDurgesh [5] developed the model of parts of the inclined plate's engine by using solid works and converted into IGES (integrations graphical element system). The analysis was done on a master rod of modal analysis and static structural analysis was completed and behavior of the master was examined from this analysis and the natural frequencies, equivalent stress and total deformation were calculated. Thermal analysis was completed and total heat flux and directional heat flux were calculated by using Ansys 14.0 workbench.
- F. Md. Shamim Hossain [6] fabricated the pin fin array to perform the heat transfer analysis on it. For the fabrication of pin fin arrangement, aluminum metal was used as fin material as well as the base plate. In this case, seven fins were used having 8.2 mm diameter and 70 mm length arranged in-line manner. The experiments were conducted for the various mass flow rate of air. In the experimental investigation, the heat transfer coefficient for free convection  $h=31.6, 35.39, 38 \text{ w/m}^2\text{c}$  and for force convection  $h=54.14, 58.85, 64.78 \text{ w/m}^2\text{c}$  were investigated. With the increase in fan speed the heat transfer coefficient increases. It also observed that the efficiency of the fin will decrease if the velocity of the fan increases because an increase in fan velocity occurs less time of contact between fin and air. As a result of this decrease in actual heat transfer from fin and consequently decreases fin efficiency in case of forced convection. The fin efficiency for pin fin shapes for free convection  $\eta=52.87, 60.16, 55.88\%$  and for force convection  $\eta= 23.6, 20.84, 16.17\%$  were obtained. Pin fin becomes helpful to enhance heat transfer within a suitable performance.
- G. Dr. N.P. Salunke[7] investigated heat transfer coefficient enhancement in natural convection from horizontal rectangular fin arrays with perforations. In this study, perforations through the fin base were introduced to improve ventilation with cold air from below the fin base. Aluminum fin arrays with length  $L= 380\text{mm}$ , fin height  $H = 38\text{mm}$ , fin thickness  $t_f = 1\text{mm}$ , and fin spacing  $S = 10\text{mm}$  were analyzed experimentally and numerically using ANSYS 14.0 so as to obtain the temperature distribution along with the fin height and fin length. In this work, the fin array configurations are tested experimentally with two different heater input as 50W and 65W. For both the fin array configurations, the mechanism of enhancement of heat dissipation has been discovered by examining the temperature distribution along with the fin height and fin length. Experimental and numerical results for the temperature distribution show a difference of 5-9%.
- H. Ilker Tari<sup>1</sup> [8] investigated the steady-state natural convection from hot heat sinks with parallel plate fins protruding from an inclined base in both upward and downward facing orientations. The examined inclination angle range includes ten angles in each orientation. It was observed that, within small inclinations from the vertical in both directions, the inclination does not reduce the convection heat transfer rate. The heat transfer rate stays almost the same. It even slightly increases in very small downward inclinations, due to the thinner boundary layer. At larger angles, the phenomenon was investigated for the purpose of determining the flow structures forming around the heat sink. For the inclination angles of  $\pm 4^\circ, \pm 10^\circ, \pm 20^\circ, \pm 30^\circ, \pm 45^\circ, \pm 60^\circ, \pm 75^\circ, +80^\circ, \pm 85^\circ, \pm 90^\circ$  from the vertical, the extent of validity of the obtained vertical case correlation was investigated by



modifying the Grashof number with the cosine of the inclination angle. It was observed that the correlation is valid in a very wide range, from  $-60^\circ$  (upward) to  $+80^\circ$  (downward).

### III. CONCLUSION

The presented review paper in natural convective heat transfer from inclined narrow plates provides Natural convective heat transfer from flat plates inclined at an angle to the vertical in laminar flow regions have been investigated.

The pressures, velocity, Prandtl (Pr), Reynolds (Re), Grashof (Gr), and Rayleigh numbers (Ra), have been investigated. The above notations are increasing with the increase of inclination angles. So placing the plate with maximum inclination is better since the heat transfer rates are increasing. So it can be concluded that by increasing inclination the plates yields better results.

Attention has been given both to the case of plates having a uniform surface temperature and to the case of plates having a uniform surface heat flux. Results are presented for a Prandtl number of 0.7, this being approximately the value for air at ambient conditions. A brief review of the solution procedure used in obtaining the numerical results. Empirical equations for the mean heat transfer rate from narrow plates have been derived from the numerical result.

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