HEAT TRANSFER ENHANCEMENT USING PASSIVE SURFACE MODIFICATIONS: AN OVERVIEW

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ABSTRACT

Heat transfer increasing techniques are mostly used in areas such as thermal power plant, heat exchanger, automobile, transformers, air conditioners etc. Heat transfer enhancement through passive methods is used as this technique does not require any external power source for heat loss. Passive methods use surface modification, surface texturing, and material removal from the surface. In heat exchanger applications when passive methods are adopted there is a significant increase in thermal performance. Earlier research in this area suggested that hybrid enhancement techniques are superior in thermal performance as that of single enhancement technique. Surface modification of fins by dimples or protrusions triggered an intensive research in the field of heat transfer. This technique is found to be promising in augmentation or enhancement of heat transfer rate in various engineering applications.

Keywords: Extended Surfaces, fins, surface texturing, Heat Transfer, Heat Exchanger

I. INTRODUCTION

Removal of excessive heat from heated surface at a sufficient rate is essential to avoid overheating and burning effect. This can only be possible by increasing the effectiveness of heat transfer [1]. It is well known that heat transfer from heated surface can be enhanced by changing the heat transfer surface area, heat transfer coefficient or by increasing the temperature difference. The best technique to intensify the heat transfer rate is increasing the surface area by means of extended surfaces called fins [2]. There are certain limitations in rate of heat transfer from fins and scientific community is engaged in further research to improve the heat transfer characteristics from the fins.

The heat transfer enhancement techniques can be categories in to passive techniques, active techniques and hybrid or compound techniques [3]. Passive techniques include surface modifications such as dimples, perforation and protrusions. In the passive techniques direct input of external power is not required. Active techniques require external power input to cause flow modification which further improves the heat transfer rate [4]. The compound techniques involve the usage of both active and passive techniques for improving heat transfer rate.

Surface modification of fins is a relatively newer strategy for improvement in the heat transfer characteristics. In this process a specific type of pattern of roughness onto the surface is applied in order to enhance its heat transfer characteristics. Dimples or protrusions are employed for improvement in heat transfer rate from the fins. The dimples are usually promote generation of vortex flow or auto oscillations which further enhance the heat transfer rate. This type of passive surface modifications found their applications in internal cooling of turbine

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ISSN 2348 - 7550

airfoils, heat exchanger fins, combustion chamber liners, heat sinks for electronics cooling devices and biomedical devices [5,6].

II. SURFACE MODIFICATION OF FINS

Experimental research indicated that spherical cavities were found to increase the heat transfer 30-40 % as compared to plane surface [6]. In notched fins, it was observed that circular notch is superior as compared to triangular notch in improving heat transfer rate. It was shown that the rate of heat transfer is increased by having a notch in fins as compared to plain fins. Furthermore, circular notch is more effective in increasing heat transfer as that of triangular notch [7]. In some studies perforated dimples were also used and it was found that perforation of dimples enhanced the heat transfer rate as compared to the dimple fin of the same geometry. Furthermore, triangular perforations showed maximum heat transfer rate as that of circular and square shaped perforations. The superior performance of triangular shaped perforation was attributed to the geometry effect of triangular perforation which destroyed the area of thermal boundary layer larger as that of other geometrical shapes [8].

It was found that the pin fin dimple channel with dimples formed at both transversely and streamwisely between the pin fins exhibited improved heat transfer rate by ~ 20 % as that of pin fin channel [9]. Lan et al. [10] showed that thermal performance of both dimple and protrusion in a rectangular microchannel is superior as compared to only dimples in the microchannel. It can be concluded that combined effect of dimple and protrusion enhance the heat transfer rate. Natural convection heat transfer from a rectangular fin with rectangular perforations is studied by Al-Essa et al. [11]. They found that perforated fins enhanced the heat dissipation rates as compared to fin without perforations. The magnitude of heat dissipation enhancement is influenced by the fin thickness, thermal conductivity, the dimensions of perforation and lateral/longitudinal spacing's. The perforations promote the surface turbulence which results in the heat transfer enhancement. The enhancement in heat transfer is ascribed to the disruption and restarting of the thermal boundary layer at each perforation.

The perforated fin with a slot exhibited superior performance in heat transfer along with increase in frictional losses as compared to solid fin. On the other hand, the perforated fin without slot showed relatively higher rate of heat transfer with a reduction in energy loss [12]. In spray cooling condition a heat transfer study was conducted by Wang et al. [13] with treated surface, coated surface and hybrid surface of porous coating containing macro channels. It was found in this study that hybrid surface showed the superior heat dissipation due to increase in surface area and higher boiling site densities. In the study conducted by Chyu et al. [14] hemispherical and tear drop shaped dimples are used to compare the heat transfer rate. Their results indicated that both types of dimples enhanced the heat transfer rate as compared to solid counterpart. However, tear shaped dimples exhibits superior performance as that of hemispherical and solid surface. The heat transfer rate of tear shaped dimple is about 2.5 times more than their solid counterpart.

Katkhaw et al. [15] examined the heat transfer characteristics of external air flow over the surface with ellipsoidal dimples. They examined dimple arrangement and dimple interval effect on heat transfer rate. Their results showed that heat transfer performance is enhanced by 10-22 % in all dimple arrangements.

G. D. Gosavi et al.[16] they experimentally investigated that, fins can be used for increasing heat transfer. The perforated fin may dissipate about 50 to 60 % more heat. Heat transfer becomes more uniform by doing the perforations. The efficiency of perforated fin is greater than the solid fin.

Allan Harry Richard. T. L et al.[17] conclude that the copper has high thermal conductivity than brass and aluminium.

III. CONCLUSIONS

The heat transfer through the plane fin is lesser than that of dimpled, perforated and grooved fins. As the flow passes over the surface of modified fins high degree of turbulence takes place. Sub boundary layer which is formed over the entire heated surface, will get interrupted due to this turbulence and hence overall average heat transfer coefficient get increased. The copper has higher thermal conductivity than brass and aluminium. The heat transfer enhancement is depending on pin fin dimensions, the perforation geometry, and number of perforation and thermal conductivity of material.

IV. ACKNOWLEDGEMENT

In the endeavour of preparing this paper many people gave me a helping hand. So it becomes my duty and pleasure to express my deep regards to them.

I heartily pay my gratitude to my HOD Dr. V. N. Bartaria as he has been constantly helping me in it, and thank him for promoting and helping in research oriented activities.

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