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Review Article

Review on Enhancement of Heat Transfer by Active Method

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Abstract

This paper features a full discussion on the application of enhanced heat transfer surfaces to compact heat exchangers. The encouragement for heat transfer enhancement is discussed, and the principles later than compact heat exchangers are summarized. Next, various methods for comparing different types of heat transfer enhancement devices using first or second law resolution are presented .Heat transfer enhancements of both experimental and analytical studies have been reported in view of their industrial and domestic significance. The heat transfer enhancement can be increases by both active and passive method. In that we focus mainly on active method, they require external power, such as electric or audile fields and surface vibration. The way to improve heat transfer achievement is referred to as heat transfer enhancement nowadays a forceful number of thermal engineering researchers are seeking for new enhancing heat transfer methods between surfaces and the surrounding fluid. Due to this phenomenon, enhancement of heat transfer is divided as active or passive methods. Those which require external power source to maintain the enhancement mechanism are named active methods. Examples of active enhancement methods are well stimulating the fluid or vibrating the surface. The principal active methods, i.e. methods involving the supply of external energy, are then detailed. The physical mechanisms growing to heat transfer enhancement are pick out from the analysis.

Keywords: *Active method, enhance heat transfer, Surface vibration, Electrohydrnamic, Jets, Fluid vibration.*

1. Introduction

Active method those which require external power to maintain the enhancement mechanism are named active methods. Passive techniques mostly consist of increasing the transfer surface area. Examples of active enhancement methods are well stirring mechanical aid, surface vibrations, electrostatic fields, jet impingement, and spray. Furthermore, the passive enhancement methods are those which do not require external power source to enhancements characteristics. Examples of passive enhancing methods are smooth surfaces, rough surfaces, extended surfaces, displaced enhancement devices (M. Siddique , 2010).

A. Motivation for Heat Transfer Enhancement

From last few years, efforts have been made to produce more efficient heat exchangers by employing different scheme of heat transfer enhancement. The study of enhanced heat transfer has taken into weighty momentum during recent years. Due to increased demands by industry for heat exchange equipment that is less expensive to constitution and operate than standard heat exchange devices. Savings in materials and energy use also provide strong motivation for the advancing of improved methods of enhancement. When conspiring cooling systems for spacecraft, automobiles, it is importunate that the heat exchangers are especially small in size and light weight .Also, enhancement devices are important for the high heat service exchangers found in power plants i. e. nuclear fuel rods, air cooled condensers. These applications, as well as numerous others, have force to the development of various enhanced heat transfer surface (K. M. Stone, 1996).

Enhanced heat transfer surfaces can be used for three purposes: (1) to make heat exchanger compact(small in size) in order to reduce their overall volume, and their cost. (2)to minimize the pumping power required for a given heat transfer process. (3) to increase the over all UA value of the heat exchanger. A higher UA value can be expressed in either of two ways: (i) to obtain an enhanced heat exchange rate for fixed fluid inlet temperatures. (ii) to decrease the mean temperature difference for the heat exchange; this maximize the thermodynamic process efficiency, which can result in a retaining of operating costs. Enhancement techniques can be separated into two types: passive and active. Passive methods no required direct application of external power .In place of, passive techniques employ special surface geometries

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or fluid additives which account heat transfer enhancement. On the other hand, active method such as electromagnetic fields and surface vibration require external power for operation (K. M. Stone , 1996).

Mainly commercially interesting enhancement techniques are passive ones. Active techniques have attracted little financially interest because of the costs involved, and the problems that are profitably associated with vibration or acoustic noise. Special surface geometries contribute enhancement by establishing a higher hA per unit base surface area. There are three basic ways of accomplishing this: 1. Increase the effective heat transfer surface area (A) per unit volume without changing the heat transfer coefficient (h). Plain fin surfaces enhance heat transfer in this way. 2. Increase h without changing A. This is accomplished by using a special channel shape, such as a wavy or wrinkled channel, which provides mixing due to secondary flows and boundary-layer separation into the channel. Vortex generators also increase h without a significant area increase by creating longitudinally zigzag vortices exchange fluid between the wall and core regions of the flow, resulting in increased heat transfer. 3. Increase both h and A. Interrupted fins i. e. louvered fins and offset strip act in this way. These surfaces increase the effective surface area, and enhance heat transfer through repeated growth and extinguishing of the boundary layers (K. M. Stone , 1996).

2. Active Method

There are some limitations of passive methods so we use active method from last few year. Active method are those ,which require external power supply to maintain the enhancement of mechanisms. The examples of active method for heat transfer are:(1) Electrodynamics (2)Jet (3) Spray (4) Mechanical aid:(5)Surface Vibration (6)Fluid vibration.

2.1 Electro hydrodynamics

Electro hydrodynamic (EHD) heat transfer enhancement which uses joint of electric field with flow field. In this technique high voltage and current is applied to fluid. It refers to the joint (coupling)of an electric field with the flow field in a dielectric fluid medium. One of the main aims of the electro hydrodynamics technique is to convert electrical energy into kinetic energy: Electro hydrodynamics forces set the dielectric fluid in motion. Many reviews of this technique is found .This electro hydrodynamic technique convert electrical energy into kinetic energy. If we induced electro hydrodynamic force between the fluid , fluid displacement occurs due to volumetric electric forces which will be obtained by:

$$\vec{F}_e = q_c\vec{E} - \frac{1}{2}E^2\vec{\nabla}\epsilon + \frac{1}{2}\vec{\nabla}\left(\rho E^2\left[\frac{\partial\epsilon}{\partial\rho}\right]_T\right) \quad (1)$$

Where ,E the electric field strength(v/m), Fe is the electro hydrodynamic force (N/m^2), qc is free electric charge density(C/m^3), the fluid permittivity(F/m), q the fluid density(kg/m^3), and T the temperature in (K). The second term of Eq. (1) is the dielectrophoretic force. It results from non-homogeneity or spatial change in the permittivity of the fluid. It can be present in the single phase if there is a temperature gradient which brings about a permittivity gradient .In this technique first important parameter is force induced. Heat transfer occurring in this method is due to this force induced.

$$\vec{F}_e = q_c\vec{E} - \frac{1}{2}E^2\vec{\nabla}\epsilon + \frac{1}{2}\vec{\nabla}\left(\rho E^2\left[\frac{\partial\epsilon}{\partial\rho}\right]_T\right) \quad (2)$$

Above equation gives charge density which will affect electrostatic force. The third term of Eq. (1) is the electro stricture force which involves electrostriction based on the presence of different electric fields within the dielectric fluid. Because they are charged differently so they are attract to each other in the presence of an electric field. Also nucleate boiling occurring in material is another one point which is need to be consider in EHD technique. nucleate oboiling increases electrostatic force which will again increases heat transfer .Some another stated that pool boiling is another parameter to study EHD method. pool boiling induces two types .first type of pool regime will increases heat transfer while another one decreases heat transfer .In this type heat transfer increased by inducing electric field Also we studied effects of heat transfer on condensation when electric field is applied on it, applied electric field disturb accumulation at vapour, liquid phase interference. Because of that convection at condensate film increases .while electrorstrictive force increases at vapour state. From survey it can be concluded that EHD method is efficient for material having electrical properties. it is effective method of heat transfer enhancement. According to survey heat transfer enhancement of boiling and condensation is between 20 to 60.another active method of heat transfer enhancement are discussed below.

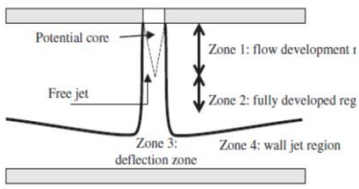

Fig.1 Schema of the various flow zones in an impinging jet

2.2 Jets

It forces a single-phase fluid normally or obliquely toward the surface. Single or multiple jets may be used, and boiling is possible with liquids. Another method used as active method for enhancement of heat transfer is use of jet in between fluid flow. It uses principle that increase in projection of fluid at high velocity increases heat transfer coefficient. it automatically increases heat enhancement. Jet having property to give higher heat transfer at stagnation point. Jets are used in many industrial applications thermal control of high flux devices such as electronics, X-rays, optics, gas turbines, cooling of internal combustion engines .this technique uses multiple impingement jets to heat or cool the surface uniformly and widely. In the following, the main mechanisms of flow and heat transfer enhancement are described for both single and multiple jets .Jets are well-known to give a high heat transfer coefficient near the stagnation region where the jet impinges on the target plate. According to jet used it has following types which are discussed below (L . Lal , 2013).

2.2.1 Single steady impingement jet:

Single jet impingement uses only one jet to heat transfer the following figure shows how single jet work for heat transfer .The single steady impingement jet, i.e. the simplest configuration, It is widely studied because it contain academic case of the multiple-jet cooling process. The flow and heat transfer characteristics of a jet impinging on a surface orthogonal to the main flow axis. There are three zone which are explained in detailed (L. Lal , 2013).

(i) Zone 1 is also called the flow development region. So it is made up of a free jet region and a core region. The region core is where the velocity is approximately equal to the nozzle exit bulk velocity.

(ii)The fully developed region (zone 2) it is seen at the end of the core. Axial jet velocity reduces as the distance from the nozzle Increases. The region near the wall (zone 3)is show by an increase in the static pressure and a sharp decrease in the axial velocity. This region is also called the deflection zone .Center of the deflection zone point called The stagnation point. Jambunathan used the data from Gordon to plot the Nusselt number versus the distance from the stagnation point ,which is explained earlier. For very short distances between the jet nozzle and the impingement plate ($z/D < 6$), the flow is laminar near the stagnation point inducing a local minimum in heat transfer at the stagnation point (L. Lal , 2013).

(iii)The wall jet region (zone 4) is characterized by an increase the transverse velocity up to a maximum value, followed by a steady decrease. The deceleration brings a transition from 3 laminar to turbulent flow because the stabilizing effect of the acceleration reduces. For low values of the separation distance, this laminar-to-turbulent transition in the flow regime increases the more heat transfer and a secondary peak can be observed on the Nusselt number changes . So, the heat transfer coefficient depends on multiple parameters. The main ones are nozzle geometry, nozzle-to-plate distance, jet Reynolds number, heat flux, velocity profiles, turbulence intensity. Last region of this impingement is maximum velocity point due increased velocity heat transfer also increases by increasing projection of fluid as per principle of jet. From above study it is concluded that third region gives stagnation point which will increases heat transfer. Drawbacks of this technique are reduced by inducing multiple jet impingement method which is discussed below (L. Lal , 2013).

2.2.2 Multiple steady impingement jet heat transfer:

If there is no interaction between the jets, heat transfer for multiple jets is similar to that of a single jet. With interaction, heat transfer is changed by two main factors: jet interaction prior to impingement and head-on collision of surface flow after impingement. Single jet impingement creates problems which will be overcome by using multi jet impingement. it is better active method which increase heat transfer coefficient by higher amount. Due multiple jets, it cancel the effect adjacent jet which will reduces heat transfer. Multiple jet create stress on each other which will reduces chances of reduction of heat transfer. In multiple jet regions obtained are same as a single jet impingement. Jet interaction prior to impingement is due to the entrainment of the fluid present between two adjacent jets by shear stress. It occurs for small inter-jet spacing and high separation distances. Such an interaction can weaken the jet strength and shorten the jet core so that the overall heat transfer on the target plate may be degraded compared to the case with no interaction between two adjacent jets prior to their impingement on the substrate (L. Lal , 2013).

To summarize, multiple jets enhance heat transfer in many ways. The heat transfer coefficient is greatly enlarge near the impingement zone. Thus, increasing the number of impingement zones improves heat transfer and temperature same the target plate. For small jet-to-jet spacing, a second type of intensification is induced by the appearance of secondary dullness zones due to interactions between jets which generate turbulence (L. Lal , 2013).

2.2.3 Unsteady jet heat transfer

Unsteady impingement is higher issue occurring in jet impingement. So There is necessity of study new method which is unsteady jet impingement. Various literature study reported about mechanism which affects unsteady state of impingement. The mechanism which create this impingement they are: heat flux, frequency and amplitude, structure of nozzle. Oscillate flow could enhance heat transfer by disrupting hydro dynamic and thermal boundary layers through flow alternation and higher turbulence. Thus, the pulsing impingement jet was studied by many authors in order to compare its heat transfer performance. For instance, in their numerical study, Xu reported significant heat transfer enhancement due to intermittent undulation in a turbulent impinging jet. Nozzle structure is a parameter which increase or reduces heat transfer as surface is rough or smooth. By heat flux as zero is another one method to remove unsteady condition and increases heat transfer rate. From above study it seen that while inducing simple improvement to remove mechanism creating. Unsteady condition we will increase enhancement in unsteady jet impingement. The target plate effects heat transfer studied heat transfer on smooth and non-smooth surfaces. For the range of parameters studied, roughness only had a less effect on heat transfer for steady jets whereas it had a significant effect on heat transfer for unsteady jets. From above study it seen that while inducing simple improvement to remove mechanism creating unsteady condition we will increase enhancement in unsteady jet impingement (L. Lal , 2013).

2.3 Spray

A spray consists of liquid droplets generated by air or by a pressure-assisted atomizer. Because the drops spread over the surface and evaporate or form a thin film of liquid Impinging on the heated surface with droplets increases the heat transfer .It another active method of increase enhancement by use spray. Spray uses droplet in air which contains moisture, which will then spread over heated surface thus heat transfer occur. By evaporation, convection and secondary nucleation heat transfer is more even at low temperature. The heat transfer behavior (heat flux versus wall temperature) using spray cooling presents the following specification: For low wall temperature ,the heating plate temp is reduced or cooled by a single-phase regime. Because the flow is rapidly expelled from the heating surface ,in that temperature range, the liquid does not have time to warm up enough to attain the boiling condition at the heating wall (Prof. Min Zeng , 2005).

Convection heat transfer is increased because droplets acts on the liquid film thus mixing the fluid better. Below the saturation temperature, the curve slope may increase due to the evaporation of a thin liquid film formed on the heating surface When liquid near the heating wall becomes superheated, heat transfer may be increased by secondary nucleation or boiling which increase the heat transfer coefficient, the evaporation rate and the turbulence When the motion of flow increases further, the surface start to dry. The vapor generated by phase change is quickly removed Because the critical heat flux is higher for spray cooling than for pool boiling Spray cooling is very difficult because it depends on many parameters .for example, ,nozzle-to-heating surface distance, incident angle, droplet size ,air pressure, droplet velocity, droplet density, surface roughness and orientation, non condensable gas, air pressure, etc (Prof. Min Zeng , 2005),

2.4 Mechanical aids

Equipment with rotating heat exchanger tube is found in commercial practice .They involve gripping the fluid by mechanical means or spin the surface. Mechanical surface Scrapers, can be applied to tube flow of gases, viscous liquids in the chemical process industry (Prof. Min Zeng , 2005).

2.5 Surface vibration

Surface vibration may be at low or high frequency has been used firstly to rise or increase single-phase heat transfer. To vibrate a surface and spray few droplets onto a heated surface to promote "spray cooling" ,a piezoelectric devices are used. There are three main heat transfer enhancement techniques involving Cyclic movement of a solid wall are considered here: acoustic waves formed by high frequency oscillations of a membrane; synthetic jet where the flow is imposed by the motion of a diaphragm bounding a void; dynamic deformity of a solid at high amplitude. high amplitude vibratory motion through the solutions using the deformation of a wall to increase shift, one is particularly studied. It consists in evaluating the impact of an oscillation of a movable blade constituting a" piezoelectric fan". Such a piezoelectric fan could be reduce which is consistent with the objective of compactness (Prof. Min Zeng , 2005).

The oscillation of the blade causes motion of the surrounding fluid. Piezoelectric fans are used to impose motion on a fluid locally in a globally stagnant fluid area, increasing heat transfer in a hot spot, and so reducing local temperature. Other studies about heat transfer enhancement using wall morphing have been conducted. For example, using a plate oscillating in a channel enhances natural and forced convection. In the same way, a vibration can be imposed directly on the wall of a channel. repeatedly moving a wall strongly enhances heat transfer, either with or without boiling of the moving fluid (Prof. Min Zeng 2005).

An acoustic wave reduces cavitations phenomena which in turn enhance heat transfer through a mixing effect. In the boiling structure, acoustic waves increase both heat transfer and critical heat flux. Increasing the amplitude at lower frequencies sets the fluid in motion and thus enhances the convective effect (Prof. Min Zeng ,2005).

2.6 Fluid vibration

It is more experimental type of vibration enhancement because of the mass of most heat exchangers .The vibrations spread from pulsations of about 1 Hz to ultrasound. Single phase fluids are of primary task. They are applied in many variant ways to dielectric fluids. Generally speaking, electrostatic fields can be directed to cause greater mixing of fluid in the vicinity of the heat transfer of surface (Prof. Min Zeng , 2005), The control of fluid motion in the vicinage of the wall is essential to increase heat transfer rate. Active techniques act on the fluid in touch with the wall. The most efficient methods of heat transfer enhancement are those generating a rebirth of the fluid in the immediate vicinage of the wall. A possible technique is the use of movable walls at the location where the taking out of heat takes place. But, wall deformation is not without its disadvantages (Prof. Min Zeng , 2005).

Conclusions

1) Active method such as electromagnetic fields and surface vibration do require external power for operation.
2) Active technique are identified as a possibility for enhancement. The active technique depends on external power or activation, this technique have power cost .power cost must be considered and micro system designer have to carefully consider their implementation
3) During nucleate boiling with EHD, heat transfer enhancement is governed by different mechanisms. The electric field is not uniform in the liquid close to the interface because density and temperature are not uniform. This generates electro restrictive forces. The electric force of the liquid far from the heating wall is more than the electric force of liquid near the heating wall which generates electro convective movements .So that heat transfer increases.
4) A important conclusion of single jet studies is that the heat transfer is very high near to the impact zone, but reduces rapidly away from it.
5) Increasing the number of impingement zones improves heat transfer enhancement and temperature homogeneity on the target plate. Increasing the amplitude at lower frequencies sets the fluid in motion and thus enhances the convective effect of heat transfer
6) There is great deal of research needed to bring this propose into accomplishment.
7) Considerable enhancement of heat transfer is reported in the summary for active techniques.
8) Another conditions is that heat transfer enhancement' studies, in particular those involving a phase change process, are usually performed on trial.

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