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A REVIEW ON HEAT TRANSFER ENHANCEMENTTECHNICS

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ABSTRACT :
Heat transfer augmentation techniques are commonly used in areas such as heating, cooling in evaporators, process industries, thermal power plants, refrigerators, automobiles, radiators for space vehicles, air-conditioning equipment. In Passive techniques, inserts are used in the flow passage to augment the heat transfer rate are more effective as compared with active techniques, because the insert manufacturing process is simple and these techniques can be easily employed in an existing heat exchanger. In design of compact heat exchangers, passive techniques of heat transfer augmentation can play an important role if a proper passive insert configuration can be selected according to the heat exchanger working condition. The present paper is a review on progress with the heat transfer augmentation techniques in the recent past and will be useful to designers implementing passive augmentation techniques in heat exchange. Twisted tapes, wire coils, ribs, fins, dimples, etc., are the most commonly used passive heat transfer augmentation tools. The thermo hydraulic behaviour of an insert mainly depends on the flow conditions (laminar or turbulent) apart from the insert configurations.

KEY WORDS*- Heat Transfer, Argumentation Techniques, Performance Evaluation Criteria*

1. Introduction

The argumentation techniques used to increase heat transfer coefficient are classified as either active or passive techniques. Active techniques require an external power input to cause the increase in heat transfer coefficients passive techniques do not require a power input. It typically relies on a modification of surface or tube geometry such as by adding fins or by roughening the tube surface. The heat transfer enhancement methods are classified in the following section.

A.Classification of Various Heat Transfer Enhancement Techniques-

They are broadly classified into three different categories:

i. Passive Techniques
ii. Active Techniques
iii. Compound Techniques

i. Passive Techniques

a)Treated surfacesare heat transfer surfaces that have a fine-scale alteration to their finish or coating. The alteration could be continuous or discontinuous, where the roughness is much smaller than what affects single-phase heat transfer, and they are used primarily for boiling and condensing duties.

b)Rough surfacesare generally surface modifications that promote turbulence in the flow field, primarily in single-phase flows, and do not increase the heat transfer surface area. Their geometric features range from random sand-grain roughness to discrete three-dimensional surface protuberances.

c)Extended surfacesmore commonly referred to as finned surfaces, provide an effective heat transfer surface area enlargement. Plain fins have been used routinely in many heat exchangers. The newer developments, however, have led to modified finned surfaces that also tend to improve the heat transfer coefficients by disturbing the flow field in addition to increasing the surface area.

d)Displaced enhancement devicesare inserts that are used primarily in confined forced convection, and they improve energy transport indirectly at the heat exchange surface by “displacing” the fluid from the heated or cooled surface of the duct with bulk fluid from the core flow.

e)Swirl flow devicesproduce and superimpose swirl or secondary recirculation on the axial flow in a channel. They include helical strip or cored screw-type tube inserts, twisted ducts, and various forms of altered (tangential to axial direction) flow arrangements, and they can be used for single-phase as well as two-phase flows.

f) Coiled tubesare what the name suggests, and they lead to relatively more compact heat exchangers. The tube curvature due to coiling produces secondary flows or Dean vortices, which promote higher heat transfer coefficients in single-phase flows as well as in most regions of boiling.

g)Surface tension devicesconsist of wicking or grooved surfaces, which direct and improve the flow of liquid to boiling surfaces and from condensing surfaces.

h)Additives for liquidsinclude the addition of solid particles, soluble trace additives, and gas bubbles in single-phase flows, and trace additives, which usually depress the surface tension of the liquid, for boiling systems.

i)Additives for gasesinclude liquid droplets or solid particles, which are introduced in single-phase gas flows in either dilute phase (gas–solid suspensions) or dense phase (fluidized beds)

ii. Active Techniques

In these cases, external power is used to facilitate the desired flow modification and the concomitant improvement in the rate of heat transfer. Augmentation of heat transfer by this method can be achieved by

(i) Mechanical Aids: Such instruments stir the fluid by mechanical means or by rotating the surface. These include rotating tube heat exchangers and scrapped surface heat and mass exchangers

(ii) Surface vibration: They have been applied in single phase flows to obtain higher heat transfer coefficients.

(iii) Fluid vibration: These are primarily used in single phase flows and are considered to be perhaps the most practical type of vibration enhancement technique

(iv) Electrostatic fields: It can be in the form of electric or magnetic fields or a combination of the two from dc or ac sources, which can be applied in heat exchange systems involving dielectric fluids. Depending on the application, it can also produce greater bulk mixing and induce forced convection or electromagnetic pumping to enhance heat transfer.

(v) Injection: Such a technique is used in single phase flow and pertains to the method of injecting the same or a different fluid into the main bulk fluid either through a porous heat transfer interface or upstream of the heat transfer section.

(vi) Suction: It involves either vapour removal through a porous heated surface in nucleate or film boiling, or fluid withdrawal through a porous heated surface in single-phase flow.

(vii) Jet impingement: It involves the direction of heating or cooling fluid perpendicularly or obliquely to the heat transfer surface.

iii. Compound Techniques: When any two or more of these techniques are employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually, is termed as compound enhancement. This technique involves complex design and hence has limited applications.

2. Performance Evaluation Criteria:

In most of the practical applications of enhancement techniques, the following performance objectives, along with a set of operating constraints and conditions, are usually considered for evaluating the thermo hydraulic performance of a heat exchanger:

- ➢ Increase in the heat duty of an existing heat exchanger without altering
- ➢ The pumping power or flow rate requirements.
- ➢ Reduction in the approach temperature difference between the two heat
- ➢ Exchanging fluid streams for a specified heat load and size of exchanger.
- ➢ Reduction in the size or heat transfer surface area requirements for a
- ➢ Specified heat duty and pressure drop.
- ➢ Reduction in the process stream's pumping power requirements for a
- ➢ Given heat load and exchanger surface area.

Different Criteria used for evaluating the performance of a single phase flow are:

A. Fixed Geometry (FG) Criteria: The area of flow cross-section (N and di) and tube length L are kept constant. They would typically be applicable for retrofitting the smooth tubes of an existing exchanger with enhanced tubes, thereby maintaining the same basic geometry and size (N, di, L). The objectives then could be to increase the heat load Q for the same approach temperature MTi and mass flow rate m or pumping power P; or decrease MTi or P for fixed Q and m or P; or reduce P for fixed Q

B.Fixed Number (FN) Criteria: The flow frontal area or cross-section (N and di) is kept constant and the heat exchanger length is allowed to vary. Here the objectives are to reduce either the heat transfer surface area (A→ L) or the pumping power P for a fixed heat load.

C.Variable Geometry (VN) Criteria: The number of tubes and their length (N and L) are kept constant, but their diameter can change. A heat exchanger is often sized to meet a specified heat duty Q for a fixed process fluid flow rate m. Because the tube side velocity reduces in such cases so as to accommodate the higher frictional losses in the enhanced surface tubes, it becomes necessary to increase the flow area to maintain constant m. this is usually accomplished by using a greater number of parallel flow circuits.

		Fixed				
Case	**Geometry**	**m**	**P**	**Q**	**ΔT_i**	**Objective**
FG-1a	N, L	X			X	Q↑
FG-1b	N, L	X		X		ΔT_i↓
FG-2a	N, L		X		X	Q↑
FG-2b	N, L		X	X		ΔT_i↓
FG-3	N, L			X	X	P↓
FN-1	N		X	X	X	L↓
FN-2	N	X		X	X	L↓
FN-3	N	X		X	X	P↓
VG-1	—	X	X	X	X	$(NL)^a$↓
VG-2a	$(NL)^a$	X	X		X	Q↑
VG-2b	$(NL)^a$	X	X	X		ΔT_i↓
VG-3	$(NL)^a$	X		X	X	P↓

Table 3.1. Performance Evaluation Criteria for Single Phase Forced Convection in Enhanced Tubes of Same Envelope Diameter (di) as the Plain Tube

3.Treated Surfaces:

These are primarily applicable in two phase heat transfer and they consist of a variety of structured surfaces (continuous or discontinuous integral surface roughness or alterations) and coatings. Though the treatment provides a roughness to the surface, it is not large enough to influence single phase heat transfer.

A. Boiling: Different types of treated surfaces used are

- Machined or grooved surfaces
- Formed or modified low-fin surfaces
- Multi-layered surfaces
- Coated surfaces

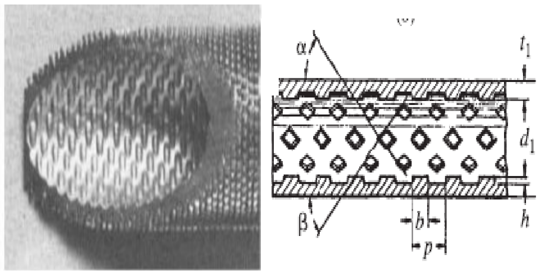
The principle of providing treated surfaces for enhanced boiling is to produce a large number of stable vapour traps or nucleation sites on the surface. This is applicable for highly wetting fluids like refrigerants, organic liquids, cryogens and alkali liquid metals where the normal cavities present on the heated surfaces tend to experience sub-cooled liquid flooding. For less wetting or relatively higher surface tension fluids, coatings of non-wetting material (eg.teflon) on either the heated surface or its pits and cavities have been found to improve stable nucleation and reduce the required wall super heat were proposed by Griffith and Wallis, Young and Hummel; Gaertner,Vachon. When the stainless steel surface along with Teflon is spread to create spots of the no-wetting material on the heated surface it was found to promote nucleate boiling in water with relatively low wall super heat and three to four times higher heat transfer coefficients, was proposed by Young and HummelIn a more recent study of boiling of alcohols (methanol, ethanol and isopropanol) at atmospheric and sub-atmospheric pressures on a horizontal brass tube coated with poly-tetra-fluoro-ethylene (PTFE), VijayaVittala et al. (2001), found a significant enhancement in heat transfer.

B. Condensing: Vapour space condensation heat transfer coefficients can be enhanced primarily by treated surfaces that promote drop wise condensation. The intent here is to prevent surface wetting and break up the condensate film into droplets which lends to better drainage and more effective vapour renewal at the cold heat transfer interface. This technique had been found to enhance the heat transfer by a factor of 10 to 100 in comparison with that in film wise condensation proposed by Bergles, (1998). Nonwetting coatings of an inorganic compound or a noble metals or an organic polymer have been used effectively. Among these, organic coatings have been used considerably in steam systems. Glicksman et al. (1973) have been found out that, by placing strips of Teflon or other non-wetting material in a helical or axial arrangement around the circumference of horizontal tubes, the average condensation heat transfer coefficients of steam on horizontal tubes can be improved by 20 to 50%. The application of hydrophobic coatings of self-assembled monolayer's, formed by chemisorption of alkylthiols on metallic surfaces; to promote drop wise condensation has been proposed by Das et al. (2000). It was found that steam condensation on coated corrugated tubes with gold and copper-nickel alloy surfaces under atmospheric and sub-atmospheric pressure conditions with wall sub-cooling of about 16°C and 6°C respectively showed that condensation heat transfer coefficients increased by factors of 2.3 to 3.6 compared to those for un-coated tubes.

4. Rough Surfaces:

Single Phase Flow:

The use of surface roughness in turbulent single phase flow is one of the simplest and highly effective techniques; small scale roughness has little effect in laminar flows. It essentially disturbs the viscous laminar sub-layer near the wall to promote higher momentum and heat transport. Surface roughness can be introduced in the form of wire-coiled type inserts or it may be integral to the surface. Rough surfaces have been employed to enhance heat transfer in single phase flows both inside tubes and outside tubes.



(a)(b)

Fig 3.1. Three-Dimensional Roughness

Dong et al. (2001) developed a new set of analogy based friction factor and Nusselt number correlations for turbulent flows of water and oil in spirally corrugated tubes. Adopting an empirical approach, combined with a statistical analysis of a fairly large database for heat transfer coefficients and friction factors for various roughness shown above, Ravigururajan and Bergles (1996) proposed correlations for Nusselt number and fanning factor as:

$$N_u = N_{uo}\left\{1+\left[2.64R_e^{0.036}\left(\frac{e}{d}\right)^{0.212}\left(\frac{p}{d}\right)^{-0.21}\left(\frac{\alpha}{90}\right)^{0.29}p_r^{-0.024}\right]^7\right\}^{\frac{1}{7}} \quad (3.4.1)$$

$$f = f_o\left\{1+\left[29.1\,R_e^{a1}\left(\frac{e}{d}\right)^{a2}\left(\frac{p}{d}\right)^{a3}\left(\frac{\alpha}{90}\right)^{a4}\left(1+2.94\,\sin\frac{\beta}{n}\right)\right]^{\frac{15}{16}}\right\}^{\frac{16}{15}} \quad (3.4.2)$$

Where, $a1 = 0.67 - 0.06\left(\frac{p}{d}\right) - 0.49\left(\frac{\alpha}{90}\right)$

$$a2 = 1.37 - 0.157\left(\frac{p}{d}\right)$$

$$a3 = -1.66\times10^{-6}R_e - 0.33\left(\frac{\alpha}{90}\right)$$

$$a4 = 4.59 + 4.11\times10^{-6}R_e^{-0.15}\left(\frac{p}{d}\right)$$

And the respective smooth tube, Nu_o and $f_o$performance are given by

$$Nu_o = \left(\frac{R_e.p_r\left(\frac{f_o}{2}\right)}{\left[1+12.7\left(\frac{f_o}{2}\right)^{0.5}\left(p_r^{\frac{2}{3}}-1\right)\right]}\right) \quad (3.4.3)$$

$$f_o = (1.5\,In\,R_e - 3.28)^{-2} \quad (3.4.4)$$

These above correlations have been shown very good compared with more than 1800 experimental data points. Tubes with grooves provide an external rough surface and have been used in double pipe and shell and tube bundles to enhance annulus or shell side heat transfer. Variable roughness can be obtained by using a wire-coil insert made of a shape memory alloy (SMA) that alters its geometry in response to change in temperature proposed by Bergles and Champagne, 1999. With a fixed roughness height (e/d), the wire coil inserts change from a compressed shape, which occupies a smaller fraction of the tube length, to an expanded shape that has the desired roughness pitch (p/d) and helix pitch (α/90) upon being heated. Champagne and Bergles (2001) have also shown that by using SMA (NiTi) wire coil inserts, heat transfer coefficients can be increased from 30 to 64% in single phase turbulent flow.

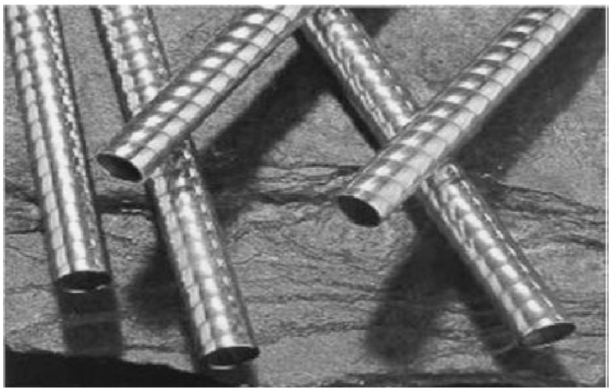


Fig.3.2. Two-Dimensional Roughness (Corrugated tubes)

5.Extended Surfaces:

Extended or finned surfaces are most widely used techniques which include finned tube for shell and tube exchangers, plate fins for compact heat exchanger and finned heat sinks for electronic cooling.

Single-Phase Flow: Enhanced heat transfer from finned surfaces for buoyancy driven natural or free convection has been considered primarily for cooling of electrical and electronic devices and for hot water base-board room heaters. The use of extended surfaces for cooling electronic devices is not restricted to the natural convection heat transfer regime but also can be used for forced convective heat transfer. By using segmented or interrupted longitudinal fins inside circular tubes, heat transfer can be increased by periodically disrupting and restarting the boundary layer on the finned surface and perturbing the bulk flow field. Plate fin or tube and plate fin type of compact heat exchangers , where the finned surfaces provide a very large surface area density, are used increasingly in many automotive, waste heat recovery, refrigeration and air conditioning , cryogenic, propulsion system and other heat recuperative applications. A variety of finned surfaces typically used, include offset strip fins, louvered fins, perforated fins and wavy fins. Watkinson et al. (1975) gave the expression for hydraulic diameter based isothermal fanning friction factor and Nusselt number for internally finned tubes with straight or spiral fins and laminar flows.

Fig 3.3.Tubes with Circumferential and strip fins on their outer surface [15]

$$f_h = \left(\frac{16.4}{R_{e_h}}\right) \times \left(\frac{d_h}{d}\right)^{1.4} \quad (3.5.1)$$

For straight fin tubes,

$$N_{u_h} = \frac{\left[\left(1.08 \log R_{e_h}\right)\right]}{\left[n^{0.5}\left(1+0.01 Gr_h\right)\right]} \cdot Re_h^{0.46} \cdot p_r^{\left(\frac{1}{3}\right)} \cdot \left(\frac{L}{d_h}\right)^{\left(\frac{1}{3}\right)} \cdot \left(\frac{\mu_w}{\mu_b}\right)^{1.4} \quad (3.5.2)$$

For spiral fin tubes,

$$N_{u_h} = \frac{\left[\left(8.533 \log R_{e_h}\right)\right]}{\left[\left(1+0.01 Gr_h\right)\right]} \cdot Re_h^{0.26} \cdot p_r^{\left(\frac{1}{3}\right)} \cdot \left(\frac{t}{p}\right)^{0.5} \cdot \left(\frac{L}{d_h}\right)^{\left(\frac{1}{3}\right)} \cdot \left(\frac{\mu_w}{\mu_b}\right)^{1.4} \quad (3.5.3)$$

Carnavo (1979) recommended following expressions form $f_h$and Nu_h in turbulent flows in tubes with straight and spiral fins.

$$f_h = 0.046 R_{e_h}^{-0.2} \cdot \left(\frac{A_f}{A_{fi}}\right)^{0.5} \cdot (\sec\alpha)^{0.75} \quad (3.5.4)$$

$$Nu_h = 0.023 R_{e_h}^{0.8} \cdot (P_r)^{0.4} \cdot \left(\frac{A_f}{A_{fi}}\right)^{0.5} \cdot (\sec\alpha)^{3} \quad (3.5.5)$$

Kelkar and Patankar (1990) considered in-line segmented fins which had half the fin surface area of staggered or continuous fins, were found to perform better with 6% higher Nusselt number and 22% lower friction factor.

6. Swirl Flow Devices:

Swirl flow devices generally consist of a variety of tube inserts, geometrically varied flow arrangements and duct geometry modifications that produce flows. These techniques include twisted tape inserts, periodic tangential fluid injection and helically twisted tubes.

A. Single-Phase flows: Twisted tape inserts are the most widely used swirl flow device for single-phase flows. These inserts increase the heat transfer coefficient significantly with a relatively small pressure drop penalty as reported by Smithberg and Landis (1964); Lopina and Bergles (1969); Date and Singham (1972); Manglik and Bergles (1992); Manglik and Yera (2002). Twisted tapes can be used in the existing shell and tube heat exchangers to upgrade their heat duties or when employed in a new exchanger for a specified heat duty, significant reduction in size can be achieved. The ease of fitting multiple bundles with tape inserts and their removal makes them useful in fouling situations, where frequent tube-side cleaning may be required. When swirl flow devices are placed inside a circular tube, the flow field gets altered in several ways like an increase in axial velocity and wetted perimeter due to the blockage and partitioning of the flow cross-section, longer effective flow length in the helically twisting partitioned duct and tape's helical curvature induces secondary fluid circulation or swirl. Swirl generation is the most dominant mechanism which effects transverse fluid transport across the tape partitioned duct, thereby promoting greater fluid mixing and higher heat transfer coefficients.

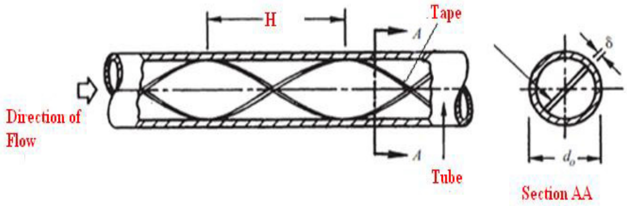
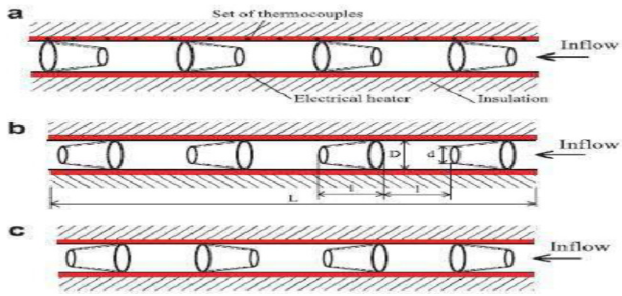


Fig. 3.4.Example of full-length twisted tape [15]

B. Boiling: The heat transfer enhancement due to the tape inserts is reflected in the reduced wall temperature along the tube length in a single phase liquid, sub-cooled boiling, bulk boiling and dispersed film boiling. The primary enhancement mechanism is the tape induced swirl, which tend to increase vapour removal and wetting of the heated surface.
C. Condensing: Steam condensation in tubes fitted with twisted tape inserts enhanced the heat transfer coefficients by 30% over the empty tube values.

7. Displaced Enhancement Devices:
Single-Phase Flow:
Several types of inserts which are categorized as displaced enhancement devices include static mixer elements (e.g. Kenics, Sulzer), metallic mesh, discs, wire matrix inserts, rings or balls which tend to displace the fluid from the core of the channel to its heated or cooled wall and vice versa, keeping the heat transfer surface unaltered. Rings and round balls have comparable heat transfer improvements, but the friction factors are exorbitantly high. Most of the devices are effective only in laminar flows, as in turbulent flows, the pressure drop penalties are extremely high as reported by Bergles (1998). The applications of static mixers are generally restricted to chemical processing with heat transfer, where fluid mixing is the primary need. Spiral brush inserts in short channels with turbulent flows and high wall heat flux have been shown by Megerlin et al. (1974) and found out that heat transfer coefficient can be improved as much as 8.5 times that in a smooth tube, but pressure drop was exorbitantly high; which restricted its use in practical applications.



a:- Diverging Ring, b:- Converging Ring, c:- Converging and Diverging Rings
Fig. 3.5. Conical Ring inserts in circular tubes [15]

8.Coiled Tubes:
A coiled or curved tube is a swirl producing geometry where the secondary fluid motion is generated by the continuous change in direction of the tangential vector to the bounding curve surface of the duct, which results in the local deflection of the bulk flow velocity vector. Applications of coiled tubes in domestic water heaters, chemical process reactors, industrial and marine boilers, kidney dialysis devices and blood oxygenators were found by Bergles et al. (1991); Nandakumar and masliyah, (1986).

A. Single-Phase Flow: The single phase flow behaviour, thermal-hydraulic performance and applications of curved and coiled tubes of circular as well as noncircular cross section have been proposed by Nandakumar and masliyah, 1986; Shah and Joshi, 1987; Bergles et al., 1991; Ebadian and Dong, 1998.The curvature induced swirl flow characteristics of curved or helically coiled tubes are strongly dependent on their geometrical attributes. The tube curvature acts to impose a centrifugal force on the fluid motion, thereby generating a secondary circulation in laminar flows which consist of two symmetrical counter-rotating helical vortices was proposed by Mori and Nakayama, 1965; Collin and Dennis, 1975; Nandakumar and masliyah, 1982; Prusa and Yao,1982;Cheng and Yuen,1987.The thermal entrance region for curved tubes is significantly smaller than that for straight tubes for the same flow conditions.

B. Boiling: Coiled tubes are commonly employed in commercial vapour generators, as they provide a substantial improvement in the evaporation heat transfer coefficient with a significantly smaller surface area to volume ratio. In forced convective evaporation of refrigerants, heat transfer coefficients were found to increase by 60% (Barskii and Chukhman, 1971).
9 Additives for Liquids:
A. Single-Phase flow: This technique for single-phase liquid flows has focused primarily on drag reducing consequences on the additives. The lowering of frictional losses has the indirect effect of providing heat transfer enhancement when evaluated on a fixed pressure drop or pumping power basis. In the case of soluble polymeric additives in water, where the solution has a shear thinning

rheology, the non-Newtonian effects lead to a significant reduction in frictional loss as well as a modest increase in the heat transfer coefficient as reported by Joshi and Bergles (1982), Prusa and Manglk (1995), Hartnett and Cho (1998), Chhabra and Richardson (1999), Manglik and Fang (2002). With polymeric additives that imparts a viscoelastic character to the solution, the heat transfer has been found to be further enhanced in rectangular ducts due to a visoelasticity driven secondary circulation that is imposed over the bulk flow (Hartnett and Kostic, 1985; Hartnett, 1992; Hartnett and Cho, 1998). Some of the additives used are polystyrene spheres suspension in oil and injection of gas bubbles. By injecting air bubbles at the base of a heated vertical wall, Tamari and Nishikawa (1976) found up to 400% higher free convection heat transfer coefficient in water and ethylene glycol. In a turbulent flow of water, Kenning and Kao (1972) obtained up to 50% increase in heat transfer by injecting nitrogen bubbles.

B. Boiling: The use of various additives like surfactants, polymers, etc. that lower the surface tension of the solution and binary mixtures of liquid (wetting agents, alcohols) have been found to enhance pool boiling substantially. Nucleate boiling heat transfer coefficient increases up to 20 to 160% in surfactant solutions depending on their concentrations (Tzan and Yang, 1990; Ammerman and You, 1996; Wu et al.,1998; Manglik, 1998; Hetsroni et al., 2000; Wasekar and Manglik, 2002) and 20 to 40% in binary liquid mixtures with wetting agents or alcohols. The improved thermal performance is strongly depended on the type and concentration of the surfactant additive, its chemistry (ionic nature, molecular and chemical composition and structure) and the diffusion kinetics at the dynamic liquid interface. The lowering of the solution's surface tension promotes nucleation of smaller bubbles, with a clustered activation of nucleation sites which depart at much higher frequencies than seen in pure water.

10. Active Techniques:

Rotating surfaces substantially enhance heat transfer coefficient up to 350% for laminar flows in straight tubes rotating around their own axis or a parallel axis (Mori and Nakayama, 1967; McElhiney and Preckshot, 1977; Bidyanidhi et al., 1977).Tang and McDonald, 1971 reported that, with high speed rotation of heated cylinders in saturated pools, the convective coefficients are so high that boiling can be suppressed. Depending on oscillation amplitude – to –tube diameter ratios and vibration Reynolds number, the heat transfer coefficients increase up to 20 times compared with those of stationary tubes (Bergles, 1998). In case of fluid vibrations, improvements of 100 to 200% over natural convection heat transfer coefficients in air were obtained by Sprott et al.,1960;Fand and Kaye,1961;and Lee and Richardson,1965;by generating intense sound fields and directing them transversely to a horizontal heated cylinder. Robinson et al.,(1958);Zhukauskas et al.,1961;Larson and London,1962;Fand ,1965;and Li and Parker,1967;reported 30 to 45% increase in free convection heat transfer by means of sonic and ultrasonic vibrations. As per Wong and Chon, 1969, ultrasonic vibrations do not promote any improvements in nucleate pool boiling; but they enhance vapour removal and tend to increase critical heat flux (CHF) by 50% as reported by Ornatskii and Shcherbakov, 1959. Mathewson and Smith (1963) investigated the effects of up to 176 dB acoustic field with frequencies in the range 50 to 330 Hz and found laminar film condensation coefficients for isopropanol to be enhanced by about 60% at low vapour flow rates

11.Compound Enhancement

Some examples of compound enhancement techniques are:

- Corrugated (rough) tube with a hydrophobic coating (treated surface) to promote dropwise condensation of steam.
- Single phase mass transfer enhancement in grooved (finned) channel with flow pulsations and heat transfer in an acoustically excited flow field over a rough cylinder.
- Gas-solid suspension flows in an electric field.
- Surfactant additives for sea water evaporation in spirally corrugated or doubly fluted (rough surface) tubes
- Application of Electro Hydro Dynamic (EHD) fields in pool boiling of refrigerants from micro finned and treated tubes

12. CONCLUSION

In This Paper We Study The Heat Transfer And Modes Of Heat Transfer. The Performance Evaluation Criteria And The Various Techniques Such As Using Treated Surfaces, Rough Surfaces, Extended Surfaces, Coiled Tubes, Delta-Winglet Twisted Tapes And Pipes With Internal Threads, Perforated Twisted Tape Are Study. In Paper We Study The Performance Of Enhancement Of Heat Transfer With Inserting The Various Geometry and From That We Conclude That the Effect of Inserting the Various Geometry Is Enhancingthe Heat Transfer Rate.

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