# "A REVIEW ON HEAT TRANSFER ENHANCEMENT BY PASSIVE METHODS"

**Mr. Tejas Sonawane[1], Mr. Prafulla Patil[1], Mr. Abhay Chavhan[1], Prof. B.M.Dusane[2]**

*[1]UG Student, Department of Mechanical Engineering,*

*[2]Assistant Professor, Department of Mechanical Engineering,*

*Department of Mechanical Engineering, Sandip Foundation's - Sandip Institute of Engineering & Management, Nashik.*

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**Abstract -** *The heat exchanger has the main role in the heat transfer processes such as energy storage and recovery. To increase the performance of the heat exchanger, the heat transfer enhancement methods are utilized in many industrial application. The heat transfer techniques are mostly used in areas such as thermal power plants, air conditioning equipment automobile, aerospace.*

*These methods are classified into three categories- 1.Active methods 2.Passive methods 3.Compound methods.*

*In recent days, the passive methods will be useful to designers to enhancement the heat transfer in heat exchanger.*

*Passive heat transfer augmentation method does not use any external power input. One of the ways to enhance heat transfer performance in passive method is to increase the effective surface area and residence time of the heat transfer fluid.*

***Key Words***: **Heat Exchanger, Effective Surface Area, Residence Time**

## 1. INTRODUCTION

The heat exchangers have an important role in the energy storage and recovery. Enhancement of heat transfer is of vital importance in many industrial applications. Due to the development of modern technology, the heat exchangers required in various industries for high heat-flux cooling to the level of megawatt per meter square. At this level, cooling with conventional fluids such as water and ethylene glycol are challenging. Hence, it is necessary to increase the heat transfer performance of working fluids in the heat transfer devices.

In the last decades, significant effort has been made to develop heat transfer enhancement techniques in order to improve the overall performance of heat exchangers. The interest in these techniques is closely tied to energy prices and, with the present increase in energy cost, it is expected that the heat transfer enhancement field will go through a new growth phase. Although there is need to develop novel technologies, experimental work on the older ones is still necessary. The knowledge of its performance shows a large degree of uncertainty which makes their industrial implementation difficult [9]. The efficiency of heat transfer equipment is essential in energy conservation. Also, a more efficient heat exchanger can reduce the size of the heat exchanger, thus reducing the costs associated with both material and manufacturing of the heat exchanger [8]. Improved heat transfer can make heat exchangers smaller and more energy efficient.

Heat transfer enhancement techniques have been extensively developed to improve the thermal performance of heat exchanger systems with a view to reducing the size and cost of the systems. Swirl flow is the one of the enhancement techniques widely applied to heating or cooling systems in many engineering applications.

Heat transfer enhancement techniques are classified as the - Passive Methods, Active Methods, and Compound Methods.

These methods are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc.

The rate of heat transfer can be increased passively by increasing the surface area, roughness, and by changing the boundary conditions. The active method involves addition of nano sized, high thermal conductivity, and metallic powder to the base fluid, to increase the heat transfer rate. Passive techniques, where inserts are used in the flow passage to enhance the heat transfer rate, are best suited compared to active techniques. Because the insert manufacturing process is simple and these techniques can be easily applied in an existing application.

Heat transfer enhancement techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Active methods involve some external power input for the enhancement of heat transfer.

Passive heat transfer augmentation method does not use any external power input. One of the ways to enhance heat transfer performance in passive method is to increase the effective surface area and residence time of the heat transfer fluid. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase surface area, given time and similarly heat transfer coefficient in existing system.

## 2. Literature Review

**Prabhakar Ray** et al. conclude that, wire coiled tube increases the pressure drop comparing to an empty tube. The pressure drop depends on the wire geometry and is always act a significant. Wire coil inserts perform better in transition and turbulent region flow. Within the transition region, if wire coils are fitted inside a smooth tube heat exchanger, heat transfer rate can be increased up to 200% keeping pumping power constant. In laminar flow wire coil insert is not very effective and results show that wire coils behave like as a smooth tube but accelerate transition to critical Reynolds numbers down to 700. In turbulent flow ,wire coils cause a high pressure drop increase which depends mainly on pitch to wire diameter ratio p/e. In the selection of the wire coil inserts, the shape of the insert is important. Wire coil gives better overall performance if the pressure drop penalty is considered. [1]

**G. D. Gosavi** et al. they experimentally investigated that, as far as the review is concerned, fins are the method of enhancing heat transfer. The perforated fin may dissipate about 50 to 60 % more heat. Heat transfer becomes more uniform by applying the perforations. The fin efficiency of perforated fin is greater than the solid fin. The perforated materials can have better strength. [2]

**Allan Harry Richard. T. L** et al. conclude that the experimental analysis in the project the enhancement of heat transfer of fin for different materials is analyzed and it can be improved. Fin efficiencies of materials are 66%, 91%, 94% are achieved. And among these materials from the analysis that copper has high thermal conductivity than brass and aluminum. [3]

**N. C. Kanojiya** et al. conclude that from this review, various ways of enhance the heat transfer rate by generating the swirl flow by passive method can be observed by using various types of inserts. In perforated twisted tape inserts, heat transfer rate increases hence, heat transfer coefficient increases with decreases in pressure drop. In a perforated twisted tape inserts, the friction factor increases in the laminar region and increase the heat transfer coefficient as compares to without perforated twisted tape inserts. In most of the review, nanofluid are not used for examine the heat transfer rate in heat exchanging device. The examination was done in perforated twisted tape insert either in thermal analyses, flow visualization, in heat exchangers, etc... The comprehensive study had been done on heat transfer in heat exchanger using various types of twisted tape inserts. They concluded the twisted tape inserts perform better in laminar flow than turbulent flow. The review shows that in future the inserts are most desirable function for heat transfer enhancement in various applications. We conclude that from the review if we use nanofluid for heat transfer enhancement with inserts heat transfer rate increases up to four times than that of without using nanofluid. [4]

**Nikhil S Shrikhande** et al. from this review conclude that, various ways of enhancing the heat transfer rate in automobile radiator by using different types of nanofluids, Reynolds number, fluid flow rate, and the volumetric or weight concentration. Addition of various nanoparticles or additives to a liquid slightly increases the viscosity and the thermal conductivity moderately. The suspension of nano particles in the base liquid increases the heat transfer area and ultimately it leads to the increase in the heat transfer because the heat transfer rate depend upon the total surface area available for transferring the heat. The thermal conductivity of aluminum oxide is lower than the copper oxide, silicon oxide and titanium oxide. From the above study it is seen that with increasing the fluid flow rate, particle concentration the heat transfer rate increases with little penalty of the pressure drop. [5]

**Dr. A. G. Matani** et al. conclude that, thermal characteristics in a tube fitted with twisted-tapes in co-swirl arrangement with wire coil are presented in the present study. Results shows that wire coil of pitch ratio 0.88 is more superior to all twisted tapes. In twisted tape double twisted tape act as counter swirl generator, which shows better performance than single twisted tape. The work has been conducted in the turbulent flow regime, Reynolds number from 5000 to 18,000 using air as the test fluid. The findings of the work can be drawn as follows:

1. For the inserted tube, the pressure drop tends to increase with the rise in mass flow rate while the friction factor and performance factor give the opposite trends.

2. The compound enhancement devices of the tube and the counter/co-swirl show a considerable improvement of heat transfer rate and thermal performance relative to the smooth tube acting alone, depending on twist ratios.

3. The counter/co-swirl tube yields higher friction factor and performance factor than the smooth tube at low Reynolds number. [6]

**C. Thianpong** et al. investigated that, augmentation of heat transfer rate in heat exchanger tubes by means of perforated twisted tapes (PTT) inserts is investigated experimentally. The results showed those heat transfer and friction factors were significantly influenced by the presences of wings and holes on PTTs. Both heat transfer and friction increased with the increase of wing depth ratio (w/W) and the decrease of perforation hole diameter ratio (d/W). Due to the dominant effect of increased heat transfer over that of increased friction factor, the thermal performance factor was found to be increased as wing depth ratio (w/W) increased and hole diameter ratio (d/W) decreased. [7]

### 3. Different Methods Of Heat Transfer Enhancement

Heat transfer enhancement, augmentation deals with the improvement of thermo hydraulic performance of heat exchangers. Different enhancements techniques have been broadly classified as passive, active and compound techniques.

### 3.1 Active method

The active method involves external power input for the enhancement in heat transfer; for examples it includes mechanical aids and the use of a magnetic field to disturb the light seeded particles in a flowing stream, etc.

### 3.2 Passive Method

The Passive heat transfer augmentation methods does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. By Using this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layers which increase effective surface area, residence time and simultaneously heat transfer coefficient increases in an existing system. Following methods are generally used as Inserts, Extended surfaces, Surface Modification, Use of Additives.

### 3.3 Compound Method

When any two or more techniques i.e. passive and active may be employed simultaneously to enhance the heat transfer of any device, which is greater than that of produced by any of those techniques separately, the term known as Compound enhancement technique.

### 4. Passive Methods To Be Study

- Using Treated Surfaces
- Using Inserts
- Using Extended Surfaces

### 4.1 Treated Surfaces

This technique involves using pits, cavities or scratches . They are primarily used for boiling and condensing duties.

### 4.2 Inserts

Inserts requires additional arrangements to make to fluid flow which enhance and augment the heat transfer. The type of inserts are: twisted tape, wire coils, ribs, baffles, plates, helical screw insert, mesh inserts, convergent – divergent conical rings, conical rings etc.

### 4.3 Extended Surfaces

Whenever the available surface is found inadequate to transfer the required quantity of heat with the available temperature drop, extended surfaces or fins are used.

### 5. Treated Surfaces

It consists of a variety of structured surfaces (continuous or discontinuous integral surface roughness or alterations) and coatings. The roughness created by this treatment do not causes any significant effect in the single phase heat transfer. These are applicable in cases of two phase heat transfer only.

### 5.1 Boiling:

Some of the treated surfaces are as follows:

- Machined or grooved surfaces
- Formed or modified low-fin surfaces
- Multilayered surfaces
- Coated surfaces

Boiling is a convective heat transfer process in which the liquid changes its phase into vapour at the liquid vapour interface. Such a process occurs when the heat is transferred from the solid surface to liquid in contact and surface temperature is maintained at a temperature higher than the saturation temperature of liquid.

Boiling process is used in boilers for steam formation, heat absorption in evaporators in refrigeration system, dehydration and drying of foods, distillation of liquids.

In enhanced boiling treated surfaces provide a large number of stable vapour traps or nucleation sites on the surface for bubble formation. In case of highly wetting fluids like refrigerants, organic liquids, cryogens and alkali liquid metals the normal cavities present on the heated surfaces tend to experience sub-cooled liquid flooding. For high surface tension fluids, coatings of non-wetting material (e.g. Teflon) on either the heated surface or its pits and cavities were found to be effective in nucleate boiling. Stainless steel surface along with Teflon can be spread to create spots of the no-wetting material on the heated surface which results in three to four times higher heat transfer coefficients.

### 5.2 Condensing:

Condensation is a process in which the vapour changes into a liquid at its saturation temperature corresponding to its vapour pressure. Such a process occurs when vapour comes in contact with solid surface which is at a temperature lower than the saturation temperature of vapour.

There are two types of condensation depending upon condition of surface. 1. Film wise Condensation 2. Dropwise Condensation

In case of film condensation, the film formed on surface offers thermal resistance of heat transfer. Due to low thermal conductivity of film the rate of heat transfer from vapour to surface are reduced.

In case of dropwise condensation, the vapour condenses in the form of droplets which grow in size and finally they roll of the surface under the influence of gravity. Thus, there is no such thermal resistance due to film in case of drop condensation and the vapour directly comes in contact with the surface.

In condensation of vapours, treated surfaces promote drop wise condensation which is ideal for preventing surface wetting and break up the condensate film into droplets. This process provides better drainage and more effective vapour removal at cold heat transfer interface. This technique increases heat transfer by a factor of 10 to 100 in drop wise condensation when compared with that in film wise condensation as proposed by Bergles. Non- wetting inorganic compound or a noble metals or an organic polymer can be used effectively for coating the heat transfer surfaces. Among these, organic coatings have been used considerably in steam systems.

## 6. Inserts

Inserts requires additional arrangements to make to fluid flow which enhance and augment the heat transfer.

The types of inserts are: twisted tape, wire coils, ribs, baffles, plates, helical screw insert, mesh inserts, convergent – divergent conical rings, conical rings etc. Tube insert devices including twisted tape, wire coil, extended surfaces and wire mesh inserts are considered as the most important techniques of Passive methods ; in which, twisted tape and wire coil inserts are widely applied than others.

Twisted tapes are the metallic strips twisted using some of the suitable techniques as per the required shape and dimension, which are inserted in the flow to enhance the heat transfer. The twisted tape inserts are most suitable and widely used in heat exchangers to enhance the heat transfer.

Wire coil inserts have been utilized as one of the passive enhancement techniques and are widely utilized in heat transfer equipments.

We study the following inserts - Twisted Tape, Wire Coils.

### 6.1 Twisted Tape

Twisted tapes are the metallic strips twisted using some of the suitable techniques as per the required shape and dimension, which are inserted in the flow to enhance the heat transfer. The twisted tape inserts are most suitable and widely used in heat exchangers to enhance the heat transfer.

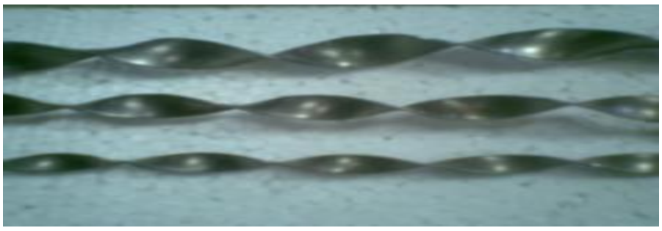


Fig 6.1 Twisted Tape

Twisted tape inserts increase heat transfer rates with less friction factor. The use of twisted tapes in a tube gives simple passive technique for enhancing the convective heat transfer by making swirl into the heavy flow which disrupting the boundary layer at the tube surface due to rapidly changes in the surface geometry. Which means to say that such type of tapes induce turbulence and swirl flow which induces inside the boundary layer and which gives better results of heat transfer coefficient and Nusselt number due to the changes in geometry of twisted tape inserts. Simultaneously, the pressure drop inside the tube will be increases when using twisted-tape as an insert. For this a many researchers have been done by experimentally and numerically to investigate the desired design to achieve the better thermal performance with less frictional losses. The heat transfer enhancement of twisted tapes inserts depends on the Pitch and Twist ratio.

### 6.2 Wire Coil

Wire coil inserts have been utilized as one of the passive enhancement techniques and are widely utilized in heat transfer equipments.

They show several advantages in relation to other enhancement techniques:

1) Easy installation and removal.

2) Simple manufacturing process with low cost.

3) Preservation of original plain tube from mechanical strength.

4) Possibility of installation in an existing smooth tube heat exchanger (retrofit).

5) Fouling mitigation (in refineries, chemical industries and marine applications).

Fig.6.2 shows a sketch of a wire coil inserted in close contact with the inner tube wall,

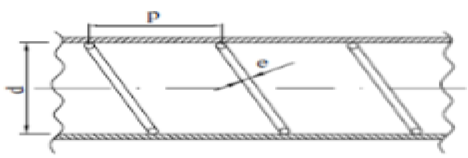



Fig 6.2 Helical Wire Coil Fitted Inside A Smooth Tube

where ,

p stands for helical pitch,

e for the wire-diameter

d is the tube inner diameter.

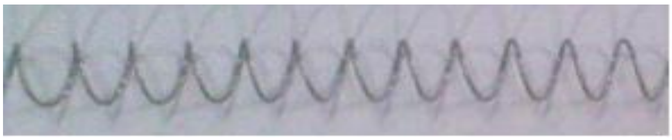


Fig. 6.3 Wire Coil

### 6.3 Experimental Section ( A )

The twisted tapes are made of mild steel and have tape width (w) of 10 mm, 15 mm & 20mm. Tape thickness (d) of 0.8 mm, and tape length (l) of 900 mm. Also a wire coil having pitch of 30 mm is used to generate co-swirl. All tapes were prepared with different twist ratios, y/w = 3.5, 2.66 and 2.25 respectively where twist ratio is defined as twist length (l) to tape width (w). Schematic view of twisted tape & wire coil is shown in Fig. 5. On the other hand, to avoid an additional friction in the system that might be caused the thicker tape. To produce the twisted tape, one end of a straight tape was clamped while another end was carefully twisted to ensure a desired twist length. As shown in Fig. 5, these twisted tapes are fixed one by one inside the pipe having wire coil to generate co-swirl.

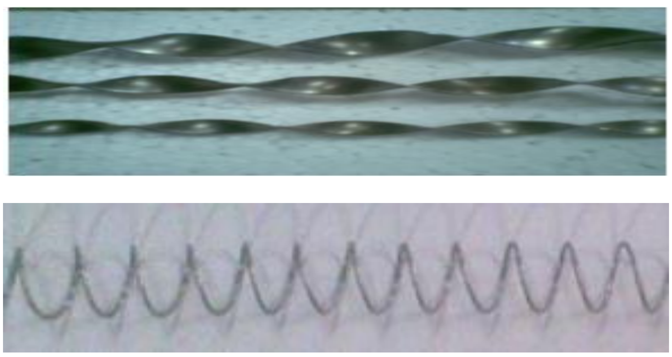


Fig. 6.5 Details Of Twisted Tape And Wire Coil

The test section is surrounded by nichrome heating wire, which is wrapped around the test section with a pitch distance of 5 mm. This pitch is good enough to provide a nearly uniform heating on the outer surface of the test section tube. The heating wire was powered by a variable AC power supply. The overall electrical power added to the heating section, Q, was calculated by measuring the voltage (0–200 V) and the electrical current (0–2 A). To control the convection losses from the test section and other components, foam insulation and glass wool used. Four thermocouples are to be embedded on the test section to measure surface temperature of pipe and two thermocouples are placed in air stream at entrance and exist of test section to measure air temperature.

To avoid floating voltage effects, the thermocouple bead is insulated from the electrically heated tube wall surface with a very thin sheet of mica between the thermocouple and the tube surface so as not to be effected from electricity. Fig. 6.6 shows the schematic view of experimental set-up.

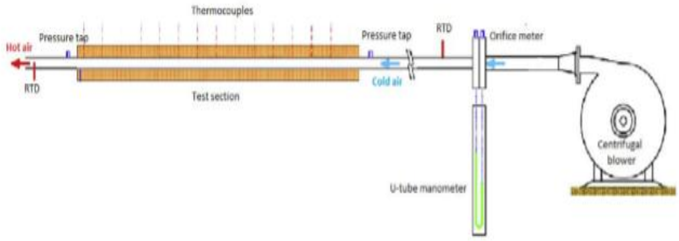
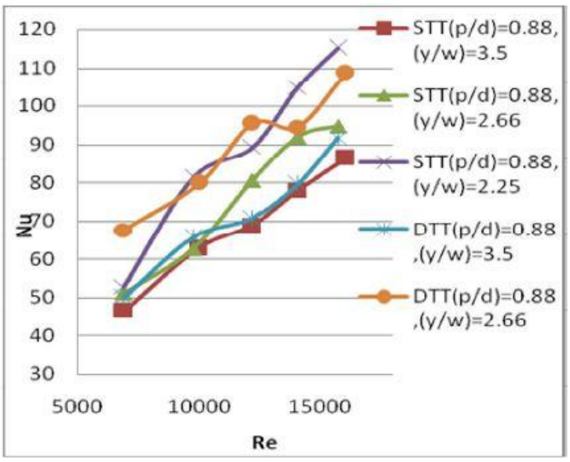


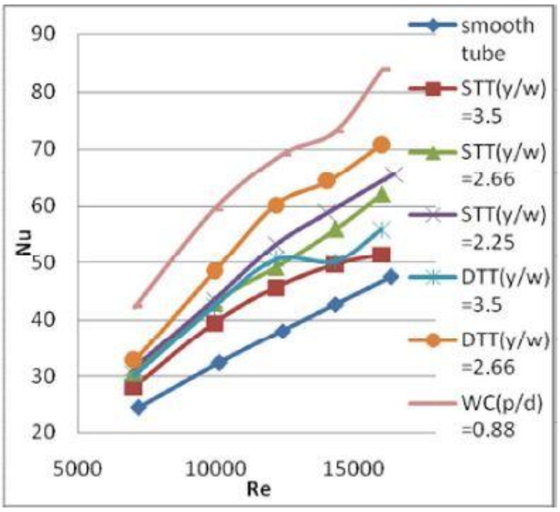

Fig. 6.6 Experimental Setup ( 1 )

Experimental results show that the Nusselt number (therefore, the heat transfer coefficient) increases with increasing Reynolds number for the conventional turbulent tube flow. This is the most likely caused by a stronger turbulence and better contact between fluid and heating wall.




Graph. 6.1 Variation of Nu for twisted tapes with wire coil

The variations of Nusselt number with Reynolds number for three different twist ratios (y/w = 3.5, 2.66, 2.25) with wire coil of pitch ratio (p/d = 0.88) shown in figure 6.1. Nusselt number increases with the decrease of twist ratio and the increase of Reynolds number. The highest Nusselt number is achieved for twist ratio (y/w = 2.25) and pitch ratio (p/d =0.88).




Graph. 6.2 Variation of Nu for different inserts

Experimental results of the friction factor (f) characteristics in plain tubes combined with a twisted tape (y/w = 3.5, 2.66, 2.25), double twisted tape (y/w = 3.5, 2.66) and wire coil (p/d = 1.17, 0.88) are presented in Figure 6.2. The friction factors of the plain tube acting alone are also plotted for comparison. Figure shows the influence of a plain tube combined with a twisted tape and wire coil on pressure loss, which indicates the friction in a heat exchanger.

## 7. Extended Surfaces

The heat conducted through solids, walls or boundaries has to be continuously dissipated to the surroundings or environment to maintain the system in steady state conduction. In many engineering applications large quantities of heat have to be dissipated from small areas. Heat transfer by convection between a surface and the fluid surroundings it can be increased by attaching to the surface thin strips of metals called fins. The fins increase the effective area of the surface thereby increasing the heat transfer by convection. The fins are also referred as “extended surfaces”. Extended surfaces (fins) are one of the heat exchanging devices that are employed extensively to increase heat transfer rates. The rate of heat transfer depends on the surface area of the fin. It increases the contact surface area, for example a heat sink with fins.

The heat transferred through the fins provides the problem of determination of heat flow through a fin requires the knowledge of temperature distribution through it. This can be obtained by regarding the fin as a metallic plate connected at its base to a heated wall and transferring heat to a fluid by convection. The heat flow through the fin is by conduction. Thus the temperature distribution in a fin will depend upon the properties of both the fin material and the surrounding fluid.

Most of the engineering problems require high performance heat transfer components with progressively less weights, volumes, accommodating shapes and costs. Extended surfaces (fins) are one of the heat exchanging devices that are employed extensively to increase heat transfer rates. The rate of heat transfer depends on the surface area of the fin. In this the heat transfer rate and efficiency for circular and elliptical annular fins were analyzed for different environmental conditions.

A fin is a surface that extends from an object to increase the rate of heat transfer to and from the environment by increasing convection. Different shape of cavity is used to increase the surface area of the fin with the fluid flowing around it.

Types of cavity provided on fin are

(a) Rectangular Cavity, (b) Triangular Cavity

(c) Trapezoidal Cavity, (d) Semicircular Cavity.

### 7.1 Experimental Section ( B )

Pin fin apparatus efficiency is being improved by adding different shape of fins and changing the geometric dimension of fin but they didn’t change any materials, in these thesis various material such as copper, aluminum, brass is analyzed, of those material copper had higher thermal efficiency as well as higher heat transfer rate.

### Experimental setup

A brass fin of circular cross section in fitted across a long rectangular duct. The other end of the duct is connected to the suction side of a blower and the air flows past the fin perpendicular to the axis. One end of the fin projects outside the duct and is heated by a heater. Temperature at five points along the length of the fin. The air flow rate is measured by an orifice meter fitted on the delivery side of the blower. The apparatus consists of a pin-fin placed inside an open duct the other end of the duct to connected to suction side of a blower the delivery side of a blower is taken on through on orifice meter to atmosphere ,the air flow rate can be varied by the blower speed regular and can be measured on the u tube manometer connected to one end of the pin fin. The panel of the apparatus consists of voltmeter ,ammeter and digital temperature indicator , heat regulator in it.

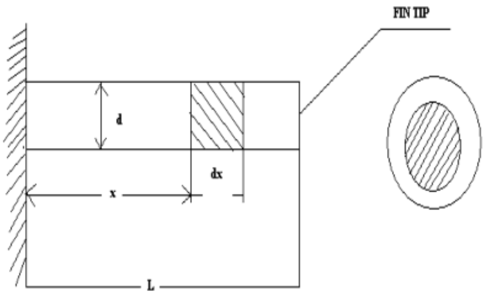



Fig.7.1 Schematic diagram of pin fin apparatus ( 1 )

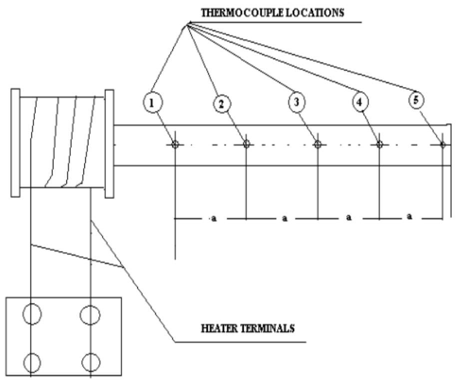



Fig. 7.2 Schematic diagram of pin fin apparatus ( 2 )

Extended surfaces of fins are used to increase the heat transfer rate from a surface to a fluid wherever it is not possible to increase the value of the surface heat transfer coefficient or the temperature difference between the surface and the fluid. Circumferential fins around the cylinder of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples.

It is obvious that a fin surface sticks out from the primary heat transfer surface. The temperature difference with surrounding fluid will steadily diminish as one move out along the fin. The design of the fins therefore required knowledge of the temperature distribution in the fin. The main objective of this experimental set up is to study temperature distribution in a simple pin fin.

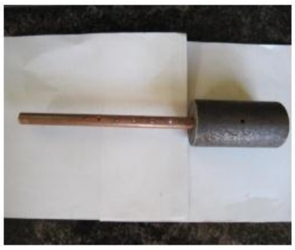
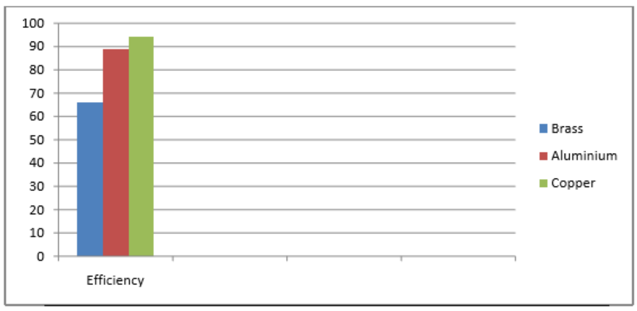


Fig. 7.3 Experimental setup ( 2 ) Fig.7.4 Brass Fin

Fig. 7.5 Copper Fin Fig.7.6 Aluminium Fin




Graph.7.1 Efficiency Graph

Efficiency of various materials are –

Brass – 66%

Aluminium – 91%

Copper – 94%

## 8 .Conclusion

We know the heat transfer enhancement can be done by using treated surfaces, using inserts, using extended surfaces which are the most important passive methods to enhance the heat transfer.

By using treated surfaces we enhance heat transfer rate which are applicable for boiling and condensing.

The twisted tape inserts are most suitable and widely used in heat exchanger to enhance the heat transfer. Twisted tape inserts increases heat transfer rate with less friction factor. The coiled circular wire should be applied instead of smooth one to obtain higher heat transfer.

The heat transfer can also done by extended surfaces which conclude that copper has higher thermal conductivity than brass and aluminium.

## 9. Future Scope

As we seen that the Passive heat transfer methods does not require need any external power input and the additional power needed to enhance the heat transfer is taken from the available power in the system.

In the convective heat transfer one of the way to enhance the heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. By using this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layers which increase effective surface area, residence time and simultaneously heat transfer coefficient increases in the existing system.

The main condition to enhance the heat transfer is to achieve the swirl in the bulk of fluids this can be done by the passive heat transfer enhancement methods.

The heat enhancement methods have the easy installation and removal as well as simple manufacturing process with low cost.

We know that the heat transfer enhancement can be done by inserts such as wire coils, twisted tube which are easily available and the process is simple.

Due to the above some reasons the passive heat transfer enhancement methods are widely used in the industrial applications. The passive heat transfer enhancement methods plays the very important role in increasing the overall performance of the heat exchanger.

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