EXPERIMENTAL ANALYSIS OF EXCHANGER FIN TUBES TO INCREASE FURNACE PERFORMANCE

Vivek Bharat Khade

1Department of Mechanical Engineering, Pillai’s Institute of Information Technology, Engineering, Media Studies and Research New Panve

Abstract—In many process industries requirement of heating is achieved by most traditional means that is fired heating. Equipment set ups ranging from very small to gigantic are put in place for same. Cracker furnaces are one of them. Main task achieved by cracker furnace is heating process fluid to its cracking point. The equipment consists of various parts mainly furnace and convection modules. Furnace is lower part of the equipment and serves primary purpose of cracking process fluid. On the other hand convection modules are designed to absorb waste heat set free out of furnace after cracking process fluid. Other parts of the furnace are furnace coil and convection module coils which provide enclosed passage for fluid to be heated during heating. Further to this there are components like breaching and stack. These are passages for exit of flue gases at lower temperature to environment. Breaching and stack are designed such that they provide necessary suction for exit of the flue gas. In later stage requirement of preheated air for burners was observed. Burners are used to burn air gas mixture inside the furnace. This project deals with the experimental study and examination of heat transfer from extended pipe surfaces of different shapes. The finned pipes are to be used in an auxiliary unit where ambient air is preheated and supplied to mix with gaseous burner fuel. The process is to be done at lower temperature flue gases and flue gases are again deposited in main exit stream without affecting significantly on suction capacity of stack hence overall performance. There is generic option of designing circular fins on the pipe surface and achieve heat transfer. In this experiment fins of two more geometrical shapes have been designed equivalent in all respect to circular fin (except geometrical shape). The fabricated models are put under same conditions and observed for heat transfer from surface and fins to find out maximum heat transfer. The project investigates different shapes of fins in context of heat transfer considering natural convection. It is observed that the triangular fins have slightly higher tendency to transfer heat to surrounding than other two shapes. Scope of different fin shapes in applications other than auxiliary heat exchanger is discussed in short.

Keywords—finned tube, heat transfer, natural convection, furnace, auxiliary heater

I. INTRODUCTION

In the study of heat transfer, fins are surfaces that extend from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature gradient between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not feasible or economical to change the first two options. Thus, adding a fin to an object increases the surface area and can sometimes be an economical solution to heat transfer problems.

In thermal engineering, an annular fin is a specific type of fin used in heat transfer that varies, radially, in cross-sectional area. Adding an annular fin to an object increases the amount of surface area in contact with the surrounding fluid, which increases the convective heat transfer between the object and surrounding fluid. Because surface area increases as length from the object increases, an annular fin transfers more heat than a similar pin fin at any given length. Annular fins are often used to increase the heat exchange in liquid–gas heat exchanger systems. [7, 8]
1.1. Objectives:
- To design and develop solid model of finned tube
- Design and develop experimental setup
- Fabrication and assembly of components
- Record and compare observations
- Verify observations of simulation with experimental observation.

Figure 1: Schematic showing pre-heater position and flow directions of fluids

II. REVIEW OF LITERATURE

Heat is transferred from higher temperature system to a lower temperature system from higher temperature system boundaries. When system is put to raise its temperature its molecules increases kinetic energy. This increased kinetic energy is transferred to lower kinetic energy system which is surrounding the higher temperature system. Mainly there are three types of heat transfer occur in between two or more systems as: conduction, convection, and radiation. [7, 12, 13]

2.1. Types of fins

Heat is required to be transferred from one to another place in many engineering applications like exchangers, boilers, refrigerators etc. It is also generated as by product in many engineering applications. Most of the times it is required to be transferred to another medium to increase or decrease temperature of area of interest. [14] It controls excess heating in some cases and achieves heating in others. Heat transfer can be achieved by increasing temperature difference between the different temperature zones. But increasing temperature difference is not possible. Increasing surface area is one of the widely used techniques to achieve more heat transfer. It is done by use of fins.

Incropera F. P., DeWitt D. P mentioned that extended surface is commonly used for heat transfer. Same is achieved by by conduction inside solid and by convection from the surface of the solid. In fins there is use of both conduction and convection to increase rate of heat transfer in between solid and fluid/gas.

During research work done in past on single chimney pattern of lengthwise shorter fins it was observed that there is sideway entry of air. During natural convection the entering air is heated up due to contact with fins and becomes less dense. The low density and higher temperature air flows upward and comes in contact with upper fin surface but due to increased temperature it proves almost no effective in carrying away heat. Hence middle part of the fins remains no useful. Sane et al experimented on same phenomenon and confirmed that if the martial from middle portion of length of fin where the air temperature gets higher and is less useful for convection and added to the place where fresh air comes in contact with fins heat transfer coefficient increases. [6]

III. EXPERIMENTAL SET-UP

Assumptions for experimental analysis of heat transfer from fins:
1. The source temperature is steady throughout the length
2. Material of heating coil, pipe and fins is with uniform material properties
3. There is no/negligible heat generation inside the test piece
4. Heat is flowing from higher to lower temperature zones only i.e. one-dimensional only
5. All the thicknesses and surfaces are uniform throughout
6. There is uniform convection across the surface area of fins and pipe

In this experiment three fin shapes are considered for analysis as under

a) Circular Fin  
b) Rectangular Fin  
c) Triangular Fin

3.1. Specimen Dimension and Experimental set up

The specimen used for the experiment fabricated with one meter ½” (10S) pipe. The ID and OD of pipe specimen are 17.08 mm and 21.30 mm. Wall thickness of the selected tube is of 2.11 X 2 mm. As mentioned earlier in this experiment area of fin is to be kept constant. Hence calculations to maintain the area of the fins of all three types constant are as below:

Circular Fins:
- Tube ID: 17.08 mm
- Tube OD: 21.30 mm
- Tube Wall thickness X 2: 4.22 mm
- Circular Fin height: 40 mm
- Total OD of Fin: 101.3
- Surface Area of fin = Total area – Area of tube cross section

Now,
- Tube Area = πr² = 356.4707 mm²
- Area of one side face of fin = πr² = 7706.2857 mm²
- Fin thickness area = πDL = 477.5571 mm² (L is fin thickness)

Now let us take total fin surface area = (2 X Single surface area) + Fin thickness area
= 15890.12857 mm²

Square Fins:
- Tube ID: 17.08 mm
- Tube OD: 21.30 mm
- Tube Wall thickness X 2: 4.22 mm
- As surface area is to be kept constant in all the cases i.e. 15890.12857 mm²

Area = (2 X Area of square fin) + Fin thickness area
15890.12857 mm² = (2 X Area of square fin) + (4 X 1.5 X Length of one side of square)

Solving this we get, Square side length as 89.6251 mm

Triangular Fins:
- Tube ID: 17.08 mm
- Tube OD: 21.30 mm
- Tube Wall thickness X 2: 4.22 mm
- As surface area is to be kept constant in all the cases i.e. 15890.12857 mm²

Area = (2 X Area of triangular fin) + Fin thickness area
15890.12857 mm² = (2 X Area of triangular fin) + (3 X 1.5 X Length of one side of triangle)

Solving this we get, Triangle side length as 135.8897 mm
3.2. Experimental Test Apparatus and Experimental set up

![Figure 3.4: Photos of fabricated test pieces](image1)

![Figure 3.5: Photo of experimental setup](image2)

3.3. Experiment and procedure
- The experimental set up is as shown in Fig 3.5 above.
- Test Piece is placed in fabricated cover to lessen effect of any stray air field. This will ensure the heat flow is through natural convection only.
- Electric heating element made out of Nichrome is placed inside the test piece. End cap arrangement is made so that the heating element will not touch the pipe surface internally also the heating element is kept in metal enclosing to avoid any sagging of it inside the test piece due to heat.
- Room temperature is maintained at 26 degrees.
- Thermocouple attached to inner test tube surface to measure temperature of internal surface. Temperature cutoff set at 65 degrees is coupled to thermocouple.
- Current supplied to heating element and after completing first few cutoff cycles readings are taken.
- Further observations taken after achieving steady state with laser temperature measurement apparatus.
- Same procedure is done for all three specimens multiple times to avoid errors.
- All three specimens are solved in ABACUS and end results of three specimens are compared.

IV. OBSERVATIONS AND CONCLUSION

4.1. Methodology and boundary conditions
The analysis of the three models is done in following steps: Solid models are developed in Abacus by revolving and extruding plates. Material is created in material manager and properties defined for
same as conductivity at 20, 50 and 75 degrees as 60.4, 59.8 and 58.9 W/m K respectively. It is to be observed that at higher temperature the conductivity of the material reduces due to internal heat generation and increase in internal molecular collision. Room temperature maintained at 27 degrees in experiment. Similarly the temperature is set as 27 degrees as boundary condition. The convection type is free/natural convection hence surface film condition is set as convection coefficient as 0.2 for steel to air. The internal tube temperature is as per problem statement as 65 degrees by selecting internal surface and applying total surface 65 degrees temperature. Mesh type selected is 8 node brick element with global size 3 mm. There are total 100276, 103119 and 61104 number of nodes in circular, triangular and square finned pipes with total 75048, 73464 and 42456 elements each respectively. The final results obtained are saved and observed for temperature and heat distribution.

Figure 4.1: Temperature profiles

Summary of the experimental and software results is as below

**Experimental Results**

| Fin Shape | Tube Surface Temperature | Temperature at least distance from Pipe surface | Temperature at max distance from pipe surface |
|-----------|--------------------------|-----------------------------------------------|----------------------------------------------|
| Circular  | 62.96                    | 51.41                                         | 51.41                                         |
| Square    | 61.85                    | 51.63                                         | 50.49                                         |
| Triangular| 60.75                    | 51.91                                         | 50.10                                         |

**Simulation Results**

| Fin Shape | Tube Surface Temperature | Temperature at least distance from Pipe surface | Temperature at max distance from pipe surface |
|-----------|--------------------------|-----------------------------------------------|----------------------------------------------|
| Circular  | 64.79                    | 54.31                                         | 54.31                                         |
| Square    | 64.75                    | 54.21                                         | 53.23                                         |
| Triangular| 64.73                    | 52.24                                         | 51.08                                         |

From above results it can be concluded that though there is no significant difference in pipe surface temperature triangular shaped fin achieves lowest pipe surface temperature among the three. Hence for given shapes triangular shaped fins are most effective keeping all other operating and design parameters same.

1. From Fig 3.1 it is clear that the heat distribution is equal in all directions of circular fins while same in case of rectangular and triangular fins it varies with distance of peripheral point of fin from pipe surface.
2. Considering manufacturability and comparative results of the fins it is advisable to use circular fins in this case however in case of laboratory equipment where very specific temperatures are to be achieved mixture of fin shapes can be used.
3. In case of automobiles where circular and rectangular fins are very commonly used by casting triangular fins can be beneficial.

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