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CFD Analysis of temperature dissipation from a hollow metallic pipe through circular fins using Ansys 14.5

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ABSTRACT

The aim of this paper is to identify the advantages of low-finned tube Heat Exchangers over Plain tube (Bare Tube) units. To use finned tubes to advantage in this application, several technical issues were to be addressed. (1) Shell side and tube side Pressure, (2) Cost, (3) Weight and (4) Size of Heat Exchanger, Enhanced tubular heat exchangers results in a much more compact design than conventional plain tube units, obtaining not only thermal, mechanical and economical advantages for the heat exchanger, but also for the associated support structure, piping and skid package unit, and also notably reduce cost for shipping and installation of all these components. A more realistic comparison is made on the basis of respective cost per meter of tubing divided by the overall heat transfer coefficient for the optimized units, which gives a cost to performance ratio. This approach includes the entire Temperature control of the shell and tube heat exchanger is characteristics of nonlinear, time varying and time lag. Since the temperature control with conventional PID controller cannot meet a wide range of precision temperature control requirement, the temperature control system of the shell and tube heat exchanger by combining fuzzy and PID control methods was designed in this paper. The simulation and experiments are carried out; making a comparison with conventional PID control showing that fuzzy PID strategy can efficiently improve the performance of the shell and tube heat exchanger.

Key-words: *heat pipe heat exchanger, HPHE, simulation, CFD analysis of temperature*

INTRODUCTION

The technology of heating and cooling of systems is one of the most basic areas of Mechanical engineering. Wherever steam is used, or wherever hot or cold fluids are required we will find a heat exchanger. They are used to heat and cool homes, offices, markets, shopping malls, cars, trucks, trailers, aero-planes, and other transportation systems. They are used to process foods, paper, petroleum, and in many other industrial processes. They are found in superconductors, fusion power labs, spacecrafts, and advanced computer systems. The list of applications, in both low and high tech industries, is practically endless. In our basic study of thermodynamics and heat transfer, we studied the form of the control volume energy balance and its application too many engineering problems, including to a basic heat exchanger problem. In this module, we will extend heat exchanger analysis to include the convection rate equation, and demonstrate the methodology for predicting heat exchanger performance that include both design and performance rating problems. If the true design flows, heat load, and temperatures cannot be achieved in testing, the test data must be extrapolated (taking into account tube plugging) to compute the overall heat transfer coefficient and compare it to the design value. But any calculation

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must also consider uncertainty and error in the experimental measurements of temperature and flow. Furthermore, even before an overall coefficient is computed, the test data must be assessed to have sufficient accuracy. This may be done as a pretest where experimental parameters are estimated, and it is judged whether the overall heat transfer coefficient can be meaningfully found. For power plant personnel such analysis is challenging due to the fact that information must be drawn from instrument design and operation, heat transfer applications, and statistical theory. Certainly a great amount of published work already deals with these topics. Although statistical methods are numerous, many techniques are cumber some and difficult to apply to actual power plant heat exchangers as measurements from operating units are often limited in sample size and quality; plant personnel must have a relatively simple and practical, but effective, method to judge the data. However, a simplified methodology specific to power plant coolers is not readily available in the common literature. Knowledge of instrument sensor accuracy, impact of number of sensors, data sampling intervals, and a reasonable statistical confidence level are some of the factors to be considered, especially in the case of temperature measurement. To address this, the present work, drawing from industry standards, presents a centralized, practical statistical approach and quantifies these factors so that heat exchanger temperature data may be easily and quickly assessed. Furthermore, sample calculations are presented to facilitate the use of the proposed methodology. Although the concentration is on temperature measurement, the procedure can be easily extended to flow measurement or any other parameter.

STRUCTURE AND OPERATION OF HEAT PIPES

The main regions of the standard heat pipe are shown in Fig. 1. In the longitudinal direction (see Fig. 1a), the heat pipe is made up of an evaporator section and a condenser section. Should external geometrical requirements make this necessary; a further, adiabatic, section can be included to separate the evaporator and condenser. The cross-section of the heat pipe, Fig. 1b, consists of the container wall, the wick structure and the vapour space.

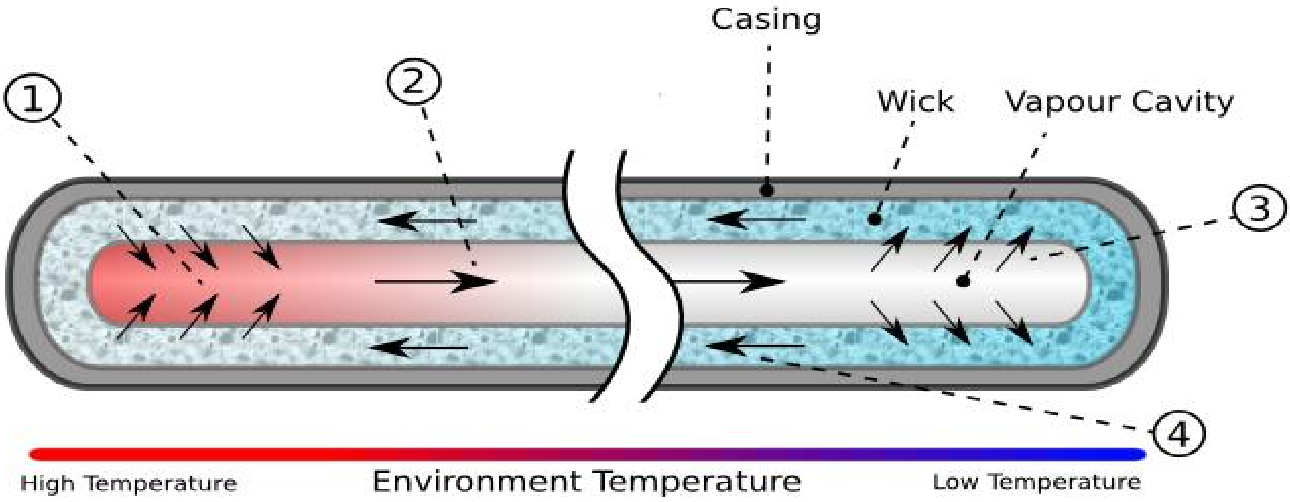

Fig.1 main regions of the heat pipe

The heat pipe is characterized by the following:

(i) Very high effective thermal conductance.

(ii) The ability to act as a thermal flux transformer.

(iii) An isothermal surface of low thermal impedance. The condenser surface of a heat pipe will tend to operate at uniform temperature. If a local heat load is applied, more vapour will

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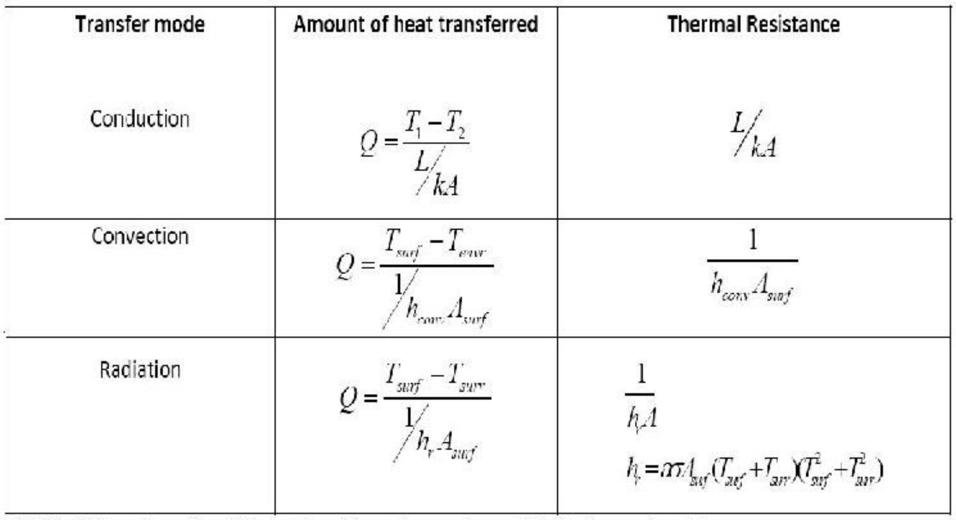
condense at this point, tending to maintain the temperature at the original level. The overall thermal resistance of a heat pipe, defined by equation (1), should be low, providing that it Functions correctly. The operating limits for a wicked heat pipe are illustrated in diagram.



Transfer mode	Amount of heat transferred	Thermal Resistance
Conduction	$Q = \frac{T_1 - T_2}{L/kA}$	L/kA
Convection	$Q = \frac{T_{surf} - T_{env}}{1/h_{conv}A_{surf}}$	$\frac{1}{h_{conv}A_{surf}}$
Radiation	$Q = \frac{T_{surf} - T_{surr}}{1/h_r A_{surf}}$	$\frac{1}{h_r A}$ $h_r = \varepsilon\sigma A_{surf}(T_{surf}+T_{surr})(T_{surf}^2+T_{surr}^2)$

Table 1 Equations for different heat transfer modes and their thermal resistances

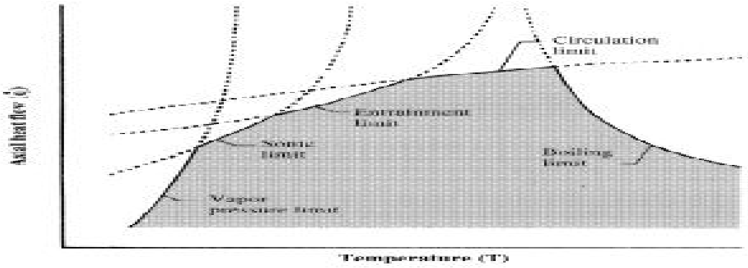


Fig.2 Limitations to heat transport in a heat pipe

Each of these limits may be considered in isolation. In order for the heat pipe to operate the maximum capillary pumping pressure, ΔPc, max must be greater than the total pressure drop in the pipe. This pressure drop is made up of three components.

(i) The pressure drop ΔPl required to return the liquid from the condenser to the evaporator.

(ii) The pressure drop ΔPv necessary to cause the vapour to flow from the evaporator to the condenser.

(iii) The pressure due to the gravitational head, ΔPg which may be zero, positive or negative, depending on the inclination of the heat pipe. If this condition is not met, the wick will dry out in the evaporator region and the heat pipe will not operate.

CFD MODELING

CFD methods consist of numerical solutions of mass, Momentum and energy conservation with other equations like species transport. Two main stages comprise the solution of CFD problems. First, whole of fluid field divides to small elements that their names are mesh, and then partial differential equations that explain transport phenomena in fluid flow are used for these elements. Consequently, many non-linear equations appear which have to solve simultaneously. The solution of these equations accomplish with numerical algorithm and methods. Conservation equations for compressible flow are

CONTINUITY EQUATION

$$\rho_2 A_2 v_2 = \rho_2 A_1 v_1$$

REYNOLDS EQUATIONS

$$\mathrm{Re} = \frac{\rho w d_o}{\eta}$$

in which	Re	Reynolds number
	ρ	density of the liquid
	w	flow velocity of the liquid
	d_o	orifice diameter,
	η	viscosity

$$\mathrm{Re} = \frac{\rho v l}{\mu} = \frac{v l}{\nu}$$

Where:

v = Velocity of the fluid

l = The characteritics length, the chord width of an airfoil

ρ = The density of the fluid

μ = The dynamic viscosity of the fluid

ν = The kinematic viscosity of the fluid

HEAT PIPE HEAT EXCHANGER CFD

Modeling It was made a specific geometry for the HPHE in in dimensions of 150*180*150 (cm*cm*cm) that is based on the basic design and with attention to needs and process constraints in the operation unit of gas field. After making geometry of HPHE in Gambit (the CAD program), meshing of HPHE's evaporator drew a volume which has relatively 1500000 cells. Then, this model entered in Fluent (CFD solver program) to solve. In fluent user interface 3D double precision (3dd), segregated solution method turbulence model are used to simulate this CFD Problem. The schematic of HPHE geometry for this case study is shown Fig. 3

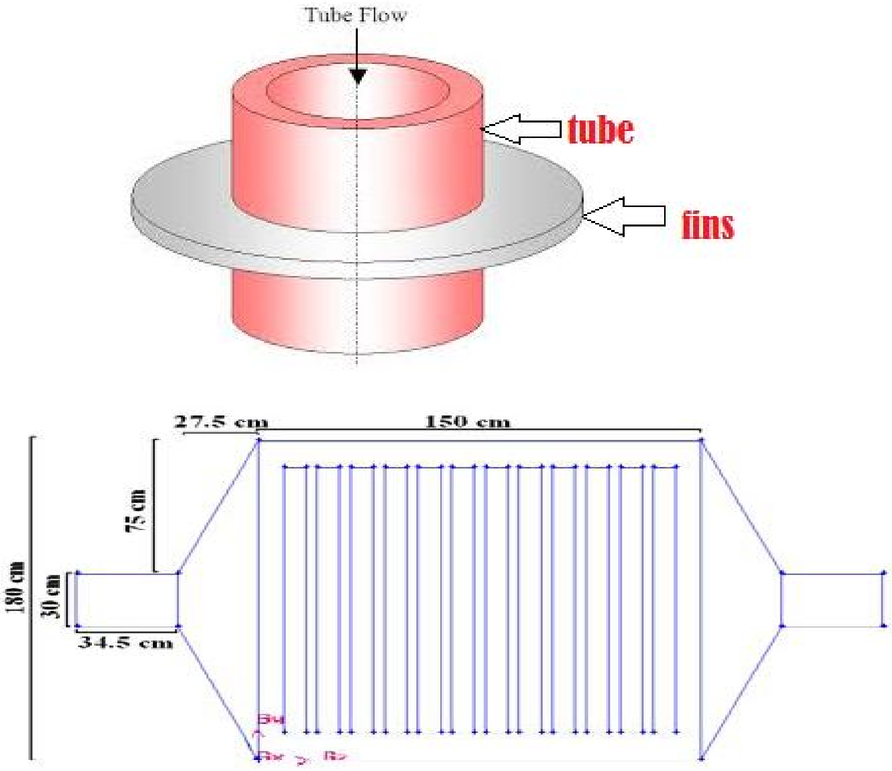


Fig. 3 case1: Model of HPHE (basic design)

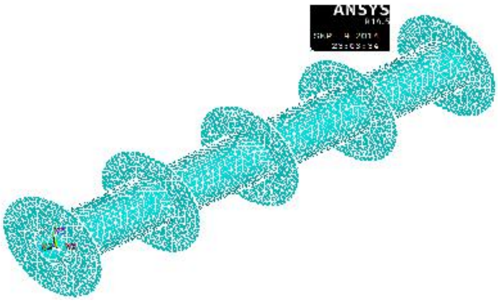
There are 72 tubes in this heat exchanger that have been placed in 6 rows with 12 tubes in any row. Inlet flow conditions (physical specifications) which come from basic design condition are given in table 1 and they are same for all of cases. **Table 1** physical specification of combustion gases for CFD modeling

Table 1 physical specification of combustion gases for CFD modeling

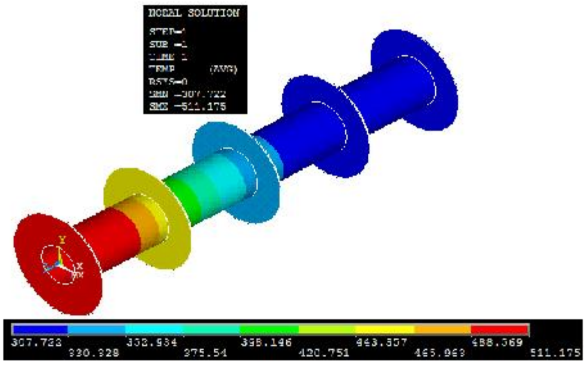
Physical parameters	**Value**
Temperature (K)	793
Mass rate (kg/sec)	3.75
Viscosity (kg/m.s)	2×10^{-5}

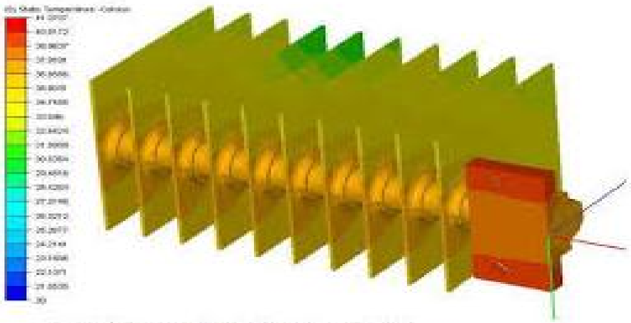
Density (kg /m3)	0.88
Heat conduction (W/m.K)	95

So that is shown in Fig. 3, entry's dimensions of HPHE is 30*30 (cm*cm) and flow enters in center of tubes bundle. For simulation of evaporator where hot fluid (combustion gases) accompanies pressure drop, heat flux is supposed constant value. In Fig. 2 to 5 are shown geometry of four different cases that this paper Purposes to compare with them. is introduced as basic condition and its geometry specifications presented in Fig. 1. In the second case, dimensions of cross area of entry have been double size. In the case (3) with same dimensions to basic design, is used one horizontal plate after entry. Finally, in 4th case one Imperfect cone is used in entry of HPHE to analyze the distributed flow. In the assessment of this article; analysis of outlet temperature of combustion gases as well as flow distribution on the tubes bundle is presented.



HEAT PIPE HEAT EXCHANGER CFD MODELING





CFD analysis was used to select the optimum fin pitch.

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PRINT TEMP NODAL SOLUTION PER NODE

 ***** POST1 NODAL DEGREE OF FREEDOM
LISTING *****

 LOAD STEP=     1  SUBSTEP=     9
  TIME=    20.000      LOAD CASE=   0

   NODE      TEMP
     1   419.99
     2   419.97
     3   419.99
     4   420.00
     5   419.99
     6   419.99
     7   419.99
     8   419.99
     9   419.99
    10   420.00
    11   420.00
    12   420.00
    13   419.99
    14   419.99
    15   419.99
    16   419.99
    17   419.99
    18   419.99
    19   419.99
    20   419.99
    21   419.99
    22   419.99
    23   419.99
    24   420.00
    25   420.00
    26   419.99
    27   419.99
    28   419.99
    29   419.99
    30   419.99
    31   420.00
    32   419.97
    33   419.99
    34   419.97
    35   419.97
    36   419.97
    37   419.97
    38   419.97
    39   419.98
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***** POST1 NODAL DEGREE OF FREEDOM
LISTING *****

LOAD STEP=     1  SUBSTEP=     9
TIME=    20.000      LOAD CASE=   0

NODE      TEMP
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80   419.98
81   419.98
82   419.98
83   419.99
84   419.99
85   419.99
86   419.99
87   419.98
88   419.99
89   419.98
90   419.99
91   419.99
92   419.99
93   419.48
94   419.48
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95   419.48
96   419.48
97   419.48
98   419.48
99   419.48
100   419.48
101   419.48
102   419.48
103   419.48
104   419.48
105   419.48
106   419.48
107   419.48
108   419.48
109   419.48
110   419.48
111   419.48
112   419.48
113   419.48
114   419.48
115   419.48
116   419.48
117   419.48

 MAXIMUM ABSOLUTE VALUES
 NODE       4036
 VALUE    420.27
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RESULTS AND DISCUSSIONS

1. The finned tube heat exchanger is more economical than Conventional Bare tube Exchanger

2. The tube side pressure drop and fluid velocity is higher than the conventional bare tube exchanger, which prevent fouling inside the tubes,

3. The shell side pressure drop is some lesser but fluid velocity is higher than the conventional heat exchanger. Which safe the outer surface of tubes from fouling creation and fluid transfer time,

4. The shell diameter of finned tube Exchanger is lesser than Conventional bare tube heat exchanger, which saves sheet material and reduces the size of the shell, which helps to easily installation in the plant,

5. There using fewer tubes than conventional heat exchanger to achieve same heat transfer rate, which benefit to save cost as well as total weight of Heat exchanger, to easy transfer here and there.

6. There is small inner diameter and less No. of tubes than conventional Heat exchanger to achieve same heat transfer rate so there using less amount of water to transfer heat from hot

CONCLUSION

From this paper it can be seen that the use of finned tube can contribute greatly in the development of compact shell and tube heat exchanger designs. The benefits of compact shell and tube heat exchanger designs is that they lead to cost saving either in original equipment and installation cost due to reduced size, or in increased production economics due to increase capacity. The augmentation may not only reduce the cost of the tubing, but also those of the heads, shell, baffles and tube sheets (smaller diameters, smaller wall thicknesses, fewer tube holes to drill, less alloy cladding material, etc). Even for conventional Heat exchangers, if the entire cost of the heat exchanger is included as it should be its total cost to plant, a more compact, lighter weight enhanced shell-and-tube unit can greatly reduce the cost of shipping and installation.

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