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COMPARATIVE ANALYSIS OF TUBULAR HEAT EXCHANGER FOR VARYING TUBES & TEMPERATURE PROFILES USING HYPERWORKV-13.0

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ABSTRACT:
Heat exchanger keeps an important place in the industries like electric power generation, oil refining, chemical engineering etc. The study presents the linear static-steady thermal analysis of simple tubular type heat exchanger for different no of tubes with varying temperatures ranges. The thermal stress and heat transfer induced is studied using Altair HYPERMESH HyperworkV13.0 simulating software at steady state boundary conditions. Heat exchanger is designed for analyzing heat transfer rate using air as a working medium for parallel flow justifying the phenomenon of convection within the shell and pipes used. In this paper an attempt is made to model and analyze the comparatives study for three temperature profiles: Grid & Gradient temperature and element flux. This paper concludes that as the no. of pipes are increased the linearity increases for different temperature profiles. Whereas the rise percentage in the heat flow with respect to lesser no of pipes is negligible (4 to 10 degree Celsius).With respect to fewer pipes, geometrical area is increased as no of pipes are increased thereby increasing cost of manufacturing. The pictorial representations of simulated results reveals towards the higher level of linearity in case of more no of pipes for the steady state linear-thermal analysis.

Keywords: HYPER-MESH, Shell & Tube type heat exchanger, Thermal stress, Tubular exchanger

I. INTRODUCTION

Heat exchangers are the most common device for transferring the heat from between two process streams at different temperatures. They find a widespread application in power generation, chemical processing, electronic cooling, air-conditioning, refrigeration and automotives. The design of a new heat exchanger is referred to the (i) sizing problem, means it includes construction type, flow arrangement, tube and shell material, and physical size which has to meet the specified heat transfer and pressure drop.(ii) rating of existing heat exchanger. In this paper, transfer of thermal energy is focused to be carried out using convection between the geometry of the heat exchanger design. The basic component of heat exchanger involves tubes with one fluid or gas running through it and another fluid or gas circulating on outer surface. Thus three heat transfer operations are needed to be described:

1. Convective heat transfer from fluid to the inner wall of the tube,
2. Conductive heat transfer through the tube wall, and
3. Convective heat transfer from the outer tube wall to the outside fluid.

Convection is generally the dominant form of heat transfer in liquids and gas. Convective heat transfer involves the combined processes of conduction (heat diffusion) and advection (heat transfer by bulk fluid flow). The design of a heat exchanger requires a balanced approach between the thermal design and pressure drop. The performance parameters include heat transfer, pressure drop, effectiveness etc. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distil, concentrate, crystallize, or control a process fluid [13].

In present due to large no. of heat exchangers configurations, classification has been generalized on the basis of operation, construction, and heat transfer and flow arrangements. Heat exchangers can transfer heat through direct contact with the fluid or through indirect ways. They can also be classified on the basis of shell and tube passes, types of baffles, arrangement of tubes (Triangular, square etc.) and smooth or baffled surfaces. The selection of a particular heat exchanger configuration depends on several factors which may include the area requirements, maintenance, flow rates, and fluid phase [3]. In order to meet these widely varying applications, several types of heat exchanger have been developed and classified. A classification by Kakac and Liu (1998) is outlined as under:

a. Recuperators and regenerators
b. Transfer processes: direct contact or indirect contact
c. Geometry of construction: tubes, plates, and extended surfaces
d. Heat transfer mechanisms: single phase or two phase flow
e. Flow Arrangement: parallel flow, counter flow, or cross flow

II. DESIGN ASPECTS

In this paper, a simple novel tubular heat exchanger is selected to view the details of model and to make solid observation regards the flow inside the heat exchanger. Table has been made below to represent the design parameter and geometric parameter [4]. The model with nine numbers of pipes is inserted inside the heat exchanger with air as the working fluid at various temperature profiles.

In this paper, heat exchanger with nine numbers of pipes placed inside in order to produce the uniform flow of air across the exchanger. The geometric model is being optimized by varying the temperature ranges from 100 to 500 degree Celsius. The computational modeling involves pre-processing solving and post-processing [2]. The geometric modeling, boundary conditions & grid generation for tubular heat exchanger is discussed below:

a) Geometric Model:

The geometric model of simple novel heat exchanger was made on Altair hyperworksV13.0. Design parameter is fixed geometric parameter. The heat exchanger specifications are as follows:

Length of heat Exchanger	500mm
Outer diameter of tubular heat exchanger	100mm
Inner diameter of tubular heat exchanger	80mm
Outer diameter of tubes of heat exchanger	10mm
Inner diameter of tubes of heat exchanger	8mm
Length of the tubes of heat exchanger	500
Number of pipes	5
Number of pipes	9
Material of the heat exchanger	Aluminium

Table 1: Geometric dimension of tubular heat exchanger

The material of the tubular heat exchanger is Aluminum. The longitudinal arrangement of the tube pipes inside the heat exchanger has been adopted [1].

b) Boundary condition:

The working fluid in the shell side, constant wall temperature assigned to the tube walls, slip condition assigned to the entire surface, heat flux boundary condition assigned to the outer shell wall and also assuming the shell is completely insulated [12].

S. No.	Quantities	Valve/ Condition
1	Working fluid	Air
2	Shell temperature	100℃ to 500℃
3	Gauge pressure	Zero Pascal
4	Inlet velocity profile	Uniform m/sec
5	Heat flux	Zero W/m²
6	Slip	No slip

Table 2: Boundary condition used for heat exchanger analysis.

c) Grid Generation:

The process of meshing and grid selection is obtained through simulation too Altair HYPERMESH. The shell volumes are meshed using quadra-hedral element. The three dimensional model is then discritized in hyper mesh. In order to capture the thermal and velocity boundary layers the entire model is descritized using Quadra-hedral mesh element along with the grid generation of 2mm, which are accurate and involve less computation effort. Fine control of the quadra-hedral mesh near the wall surface allows capturing the boundary layer gradient accurately. The heat exchanger is discretized into solid in order to have better to control over the number of nodes. The mesh is made finer for simulating conjugate heat exchanger phenomenon, so as to get the better results [5] [7].

III. RESULT: THERMAL STATIC ANALYSIS

For the steady static thermal analysis between different no. of pipes (for N = 05 & N = 09) is carried out by simulation with setting all the boundary conditions using Altair Hyper-mesh (as a simulation tool). The simulation results are obtained for different temperature ranges and different iterations are placed for inlet air into the shell containing group of arranged pipes which from range 100 to 500 degree Celsius. Under considering, three temperature profiles the comparative results are summarized for five & nine no. of pipes.

a) Comparative results for Element Flux:

For the element flux analysis, simulation for both no. of pipes is obtained with varying the temperature ranges. The contour plot is viewed as figure below, followed by the comparison table for maximum and minimum element fluxes.

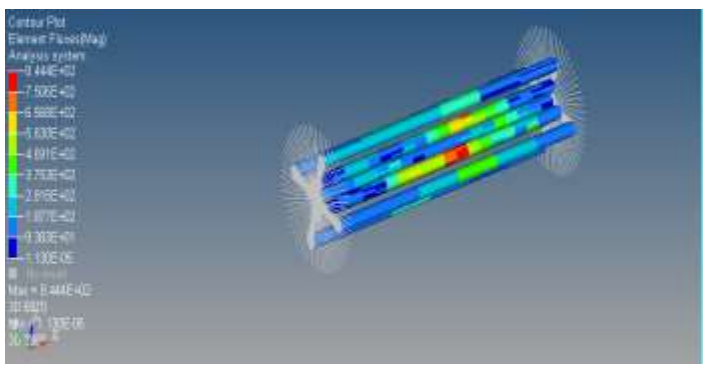
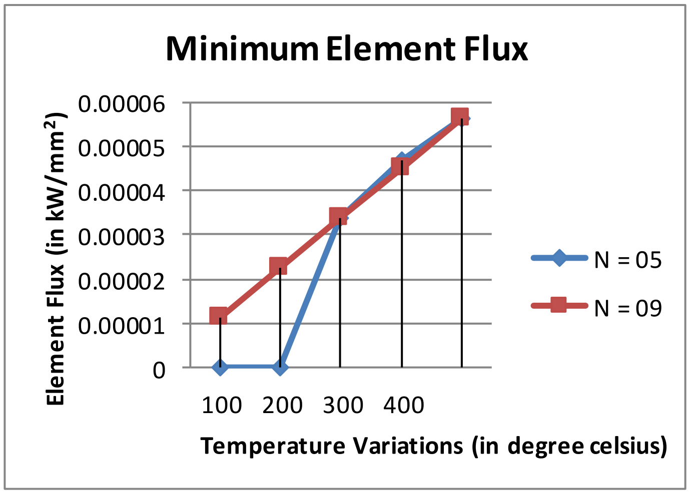


Figure 1: Contour plot of Element Flux for N= 09

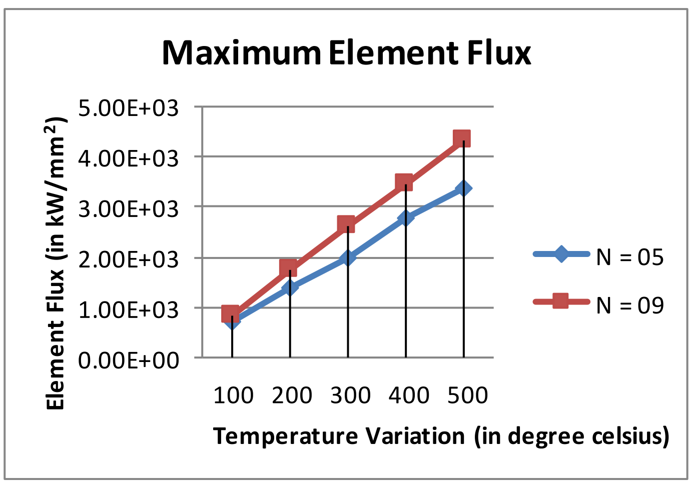
S. No	**Temp. Variation (in degree Celsius)**	**Maximum Element Flux (in kW/mm²)**		**Minimum Element Flux (in kW/mm²)**	
		For N = 05	**For N = 09**	**For N = 05**	**For N = 09**
1	100	6.947 x 10^2	8.444 x 10^2	0.00	1.130 x 10^{-5}
2	200	13.89 x 10^2	17.27 x 10^2	0.00	2.260 x 10^{-5}

3	300	19.95 x 10^2	26.31 x 10^2	3.390 x 10^{-5}	3.390 x 10^{-5}
4	400	27.70 x 10^2	34.55 x 10^2	4.679 x 10^{-5}	4.521 x 10^{-5}
5	500	33.72 x 10^2	43.11 x 10^2	5.651 x 10^{-5}	5.651 x 10^{-5}

Table 3: Comparison table for Element Flux



Graph 1: Minimum Element Flux (N = 09 & 05)



Graph 2: Maximum Element Flux (N = 09 & 05)

b) Comparative result for Grid Temperature:

The contour plot for the Grid Temperature is obtained while taking the pipes under consideration. The maximum & minimum temperatures are observed for the iterative temperature of air blown. The comparisons in corresponding pipes are summarized as under which is followed by graphs.

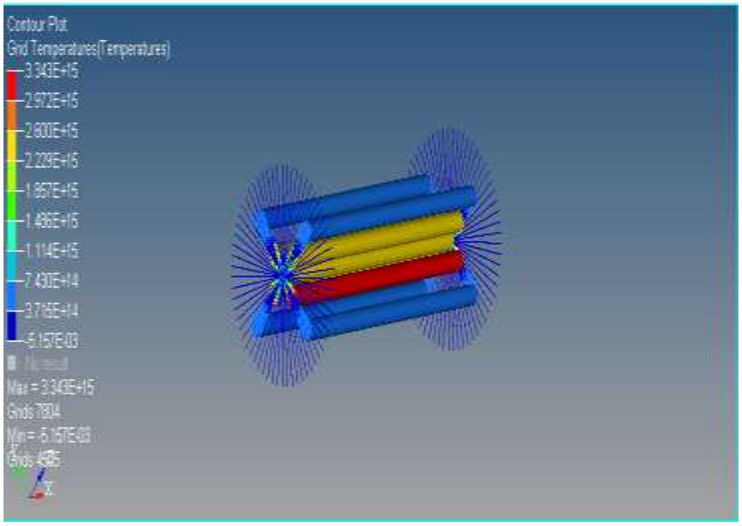
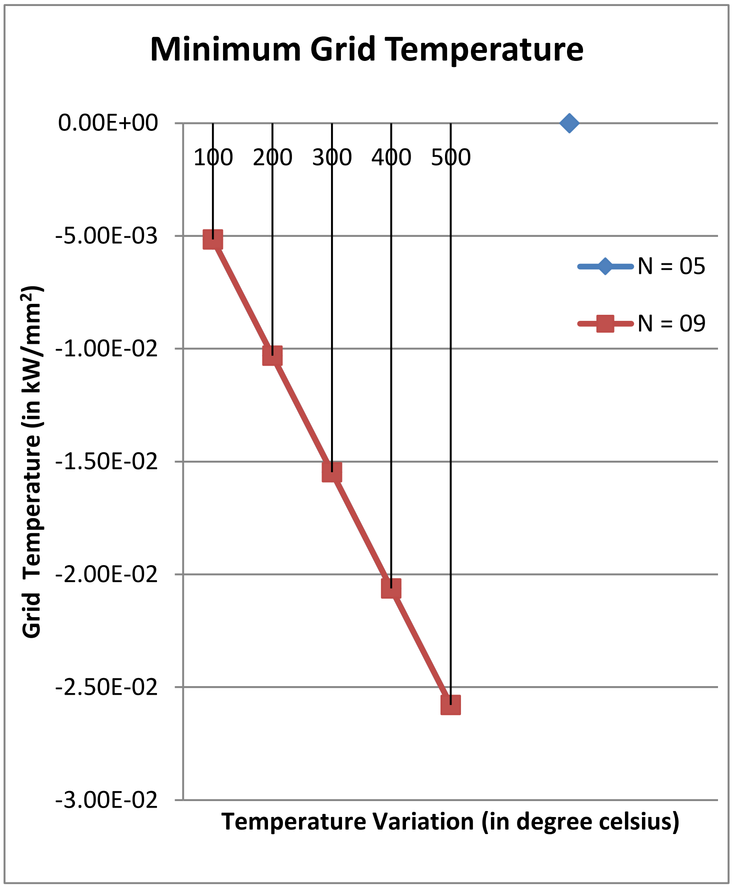


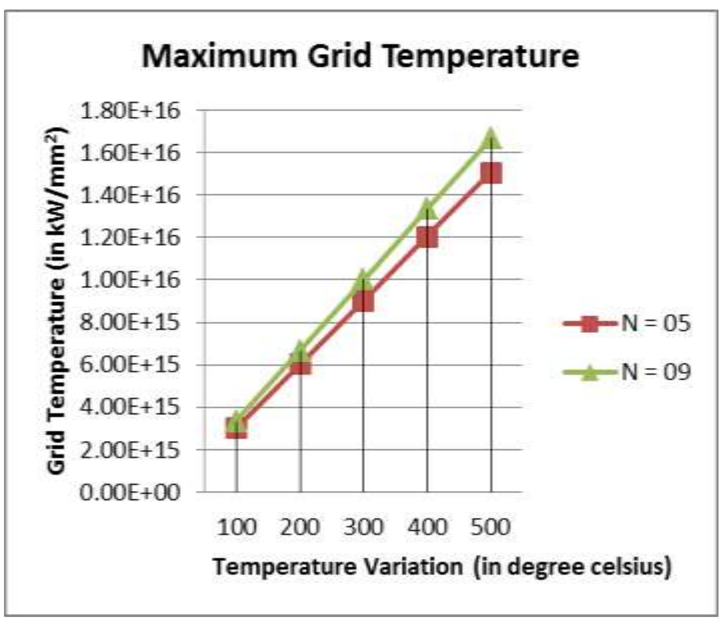
Figure 2: Contour plot of Grid Temperature for N = 09

S. No	Temp. Variation (in degree Celsius)	Maximum Grid Temperature (in kW/mm²)		Minimum Grid Temperature (in kW/mm²)	
		For N = 05	For N = 09	For N = 05	For N = 09
1	100	3.008×10^{15}	3.343×10^{15}	-0.5157×10^{-2}	-0.5157×10^{-2}
2	200	6.016×10^{15}	6.667×10^{15}	-1.031×10^{-2}	-1.031×10^{-2}
3	300	9.024×10^{15}	10.00×10^{15}	-1.547×10^{-2}	-1.547×10^{-2}
4	400	12.03×10^{15}	13.33×10^{15}	-2.063×10^{-2}	-2.063×10^{-2}
5	500	15.04×10^{15}	16.67×10^{15}	-2.579×10^{-2}	-2.579×10^{-2}

Table 3: Comparison table for Grid Temperature



Graph 3: Minimum Grid Temperature (N = 09 & 05)



Graph 4: Maximum Grid Temperature (N = 09 & 05)

c) Comparative results for gradient temperature

The temperature Contours plot for element temperature gradient can be observed, having thermal analysis in the HYPERMESH. The maximum & minimum temperature as observed are noted as in table 3 and also compared with increase no. of pipes. The pictorial representation of results obtained for element gradient temperature is viewed to be in linear state.

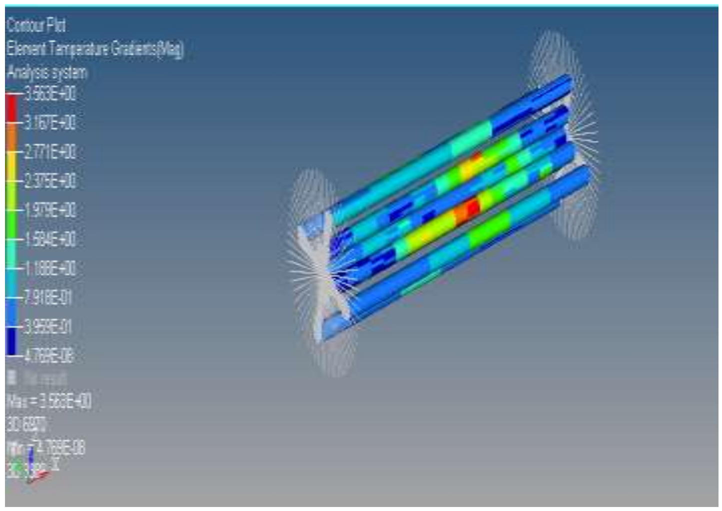
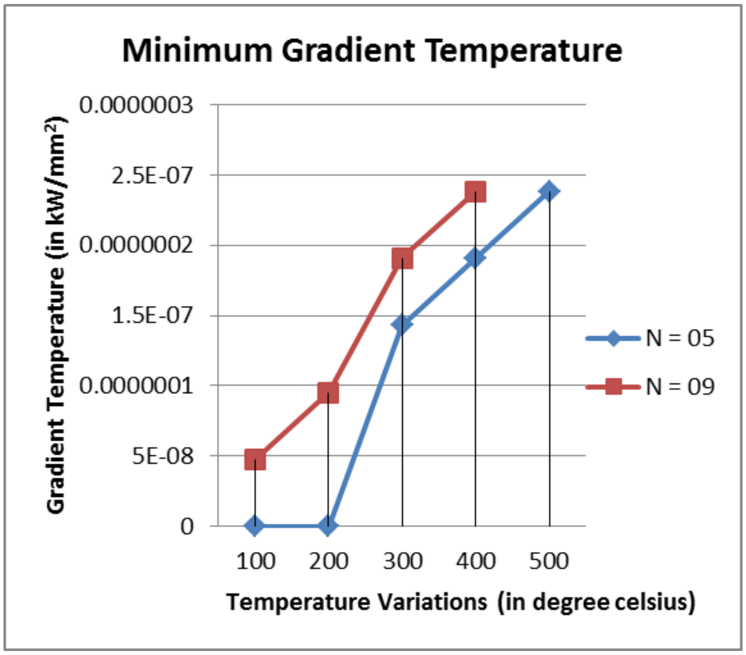


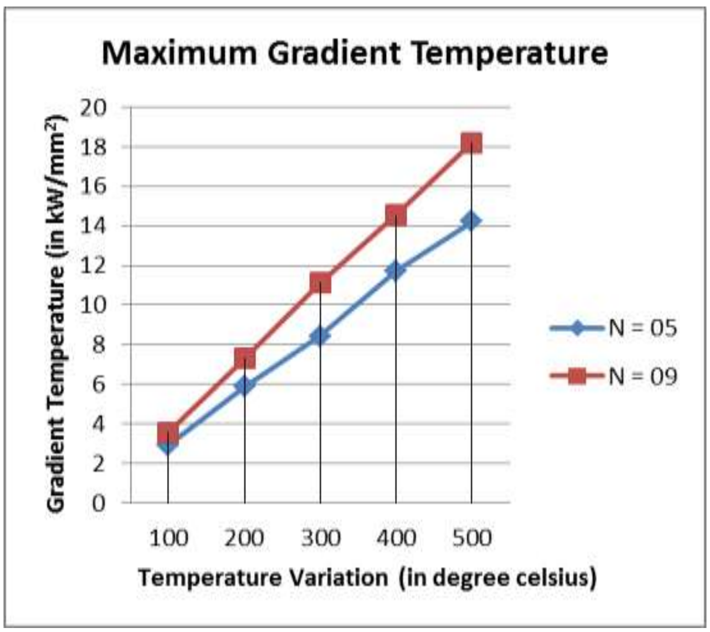
Figure 3: Contour plot for Gradient Temperature (for N = 09 & 05)

S. No	Temp. Variation (in degree Celsius)	Maximum Element Gradient Temperature (in kW/mm^2)		Minimum Element Gradient Temperature (in kW/mm^2)	
		For N = 05	For N = 09	For N = 05	For N = 09
1	100	2.931	3.563	0.00	0.4769 x 10^{-7}
2	200	5.862	7.289	0.00	0.9537 x 10^{-7}
3	300	8.419	11.10	1.431 x 10^{-7}	1.431 x 10^{-7}
4	400	11.72	14.58	1.908 x 10^{-7}	1.907 x 10^{-7}
5	500	14.23	18.19	2.384x 10^{-7}	2.384 x 10^{-7}

Table 3: Comparative Table comparison table for Gradient Temperature



Graph 5: Minimum Gradient temperature



Graph 5: Minimum Gradient temperature

IV. CONCLUSION

The heat transfer and flow distribution is discussed in details and proposed model is compared with increasing no of pipes (from N = 05 to N = 09) so as to have an optimum heat transfer rate in case of a tubular type heat exchanger. A CFD package HyperworkV13.0 was used for the simulation study of heat transfer characteristics of a tubular type heat exchanger for parallel flow and the results were then compared with less no. of pipes (N = 05) to find out the better heat transfer rate. The study showed that there is not much difference in the heat transfer performances of the parallel-flow configuration with five no of inner tube and that by increasing the no of inner tube to nine in number. The graphical study reveals that as compare to less no. of pipes the linearity in the heat transfer rate of nine no. of pipes is increased. The heat transfer rate is poor because of less no of pipes used inside the shell. Thus the design can be modified for better heat transfer flow but the rate of increment is very less with increase in geometric area thereby increasing cost.

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