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Thermal Analysis of Fin and Tube Heat Exchanger

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ABSTRACT
This paper studied experimentally the effect of heat transfer of fin and tube type heat exchanger for different mass flow rate of fluid. The thermal stresses induced on fin and tube is also studied by ansys software at steady state condition by changing the width of fin and diameter of tube. Readings were taken experimentally by changing mass flow rate of fluid at respective temperatures. Comparison was done on theoretically and experimentally obtained results. It is observed that as the width of fin increases thermal stresses on fin also increases. Likewise for tube, by varying diameter of tube different values of stress are obtained. It is also observed at full valve position maximum thermal stresses are induced on fin as well as tube.

Keywords: Fin and tube Heat Exchanger, Aluminum Fin, Copper Tube, Experimentation, Mass flow rate, Steady State thermal Stress.

I. INTRODUCTION

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. One of the important processes in engineering is the heat exchange between flowing fluids. Fin-tube heat exchanger with two rows of round tubes is widely used in air-conditioning and refrigeration systems to meet such demands as fan power saving and quietness. The fin and tube heat exchanger are usually constructed from a bank of copper tubes expanded into a stack of aluminium fins, 0.12 to 2 mm thick. Copper tube of 7 mm, 9.5 mm (3/8"), 12.7 mm (½ ") or 15.9 mm (5/8") is commonly used for small, medium and large-sized coils. Multiple tubes are assembled into a stack of fins, which have holes pre-punched in a fin press. The holes in the fins have collars extruded on to them during the fin punching operation, which prevent telescoping of the fins during the coil expansion and provide the desired fin spacing (which usually varies from 2.5 to 8 fins / cm).

In this work fin and tube heat exchanger model is fabricated, which consist of fin and tube arrangement, fan with motor, temperature indicator, valve, pump, thermostat. Hot water flows through copper tube which is then cooled by air flowing through fan this is how heat transfer takes place between two different fluids. And likewise rate of heat transfer and efficiency of heat exchanger is calculated. In this experiment by changing the mass flow rate of hot fluid that is water outlet temperatures are obtained and hence various results such as temperature difference, rate of heat transfer and effectiveness are obtained.

Modeling of fin, tube is done on Prov-e software and then stresses of respective part are calculated using Ansys software. Then again by varying width of fin and also diameter of tube further comparison is done.

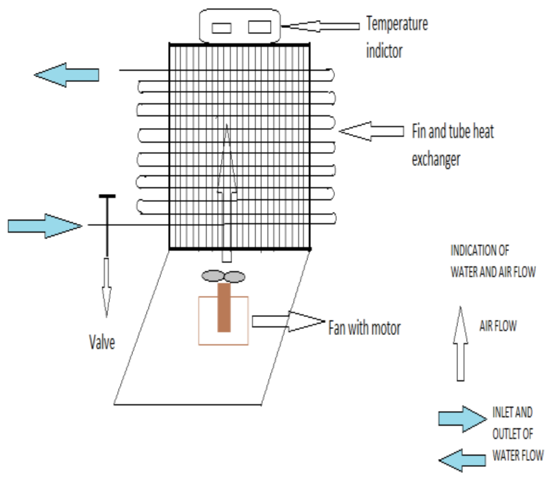

Fig .1 Line diagram of experimental fin and tube heat exchanger

II. NOTATION

d_o	Outer Diameter of tube
d_i	Inner Diameter of tube
l	Length of tube
t	Thickness of fin
L	Length of fin
W	Width of fin
$\dot{m}h$	Mass flow rate of hot fluid (water)
$\dot{m}c$	Mass flow rate of cold fluid (air)

Th1 Inlet temperature of hot fluid (water)
Th2 Outlet temperature of hot fluid (water)
Tc1 Inlet temperature of cold fluid (air)
Tc2 Outlet temperature of cold fluid (air)
Q Rate of heat transfer
E Young's Modulus
α Co-efficient of expansion
ΔT Temperature difference

Fig.2, 3 shows fin and tube. Referring to this figure, the fin and tube data is considered in this study are,

Outer diameter of tube = 10mm
Inner diameter of tube = 8mm
Length of one tube = 284mm
Length of fin = 260mm
Width of fin = 50mm
Thickness of fin = 0.12mm

The width of fin is varied as 50mm, 60mm, 70mm, 80mm and diameter of tube is varied as 10mm, 12mm, 14mm, 16mm. Fin is made up of aluminium, and tube is made up of copper.

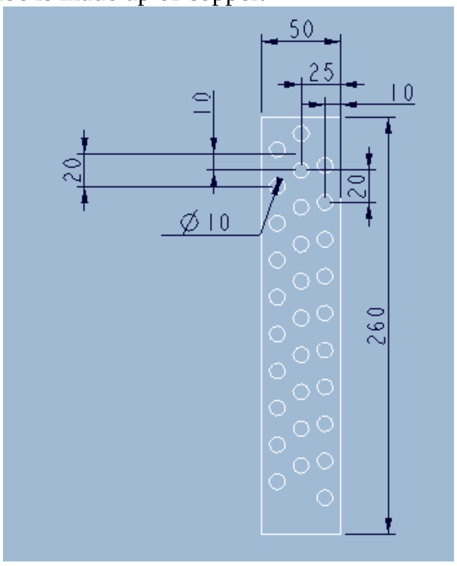

Fig.2 Geometry of fin

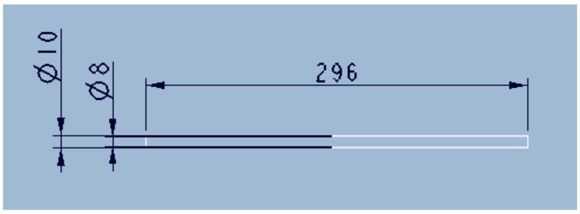

Fig.3 Geometry of tube

III. ANALYTICAL STRESS CALCULATIONS

Analytical stresses are carried out using the equation,

Thermal stress (σ) = EαΔT

IV. MODELLING AND ANALYSIS OF FIN AND TUBE

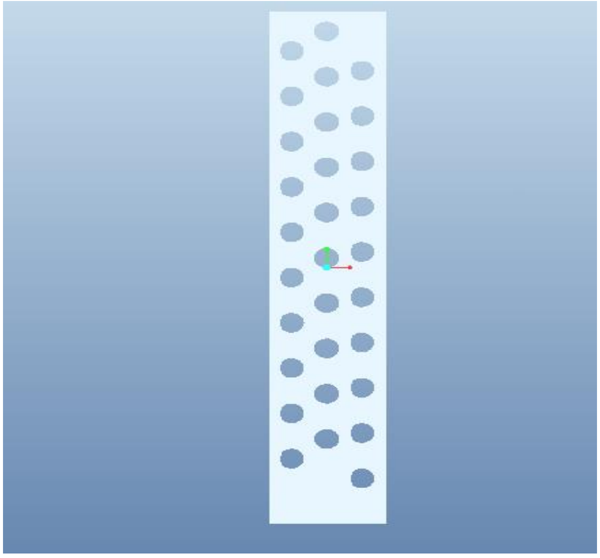

Fig.3 shows model of fin

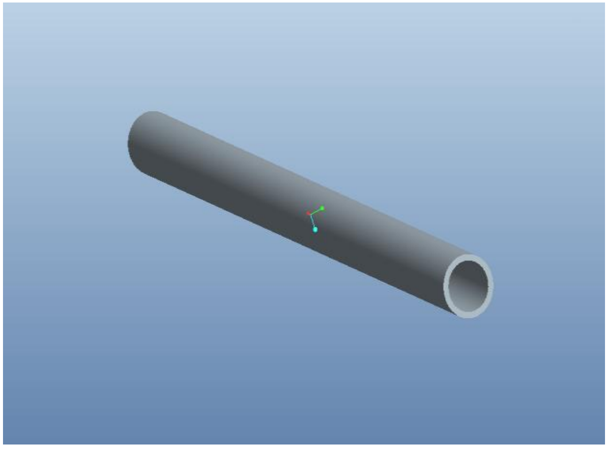

Fig.4 shows the model of tube

COMPARISION OF THEORETICAL AND EXPERIMENTAL RESULTS

After performing experimentation, the results were compared with theoretical calculation which is shown below.

Theoretical Results	**Experimental Results**
Th1=80^{0}C	Th1=80^{0}C
Tc1=33^{0}C	Tc1=33^{0}C
m·h=0.0133kg/s	m·h=0.0133kg/s
m·c =0.052kg/s	m·c=0.052kg/s
Th2=57.46^{0}C	Th2=59^{0}C
Tc2=59.96^{0}C	Tc2=55^{0}C
Q=1252.67W	Q=879.9W
∑=51%	∑=44.6%

Table 1: Comparison between theoretical and experimental results at full valve position

Theoretical Results	Experimental Results
Th1=77^{0}C	Th1=77^{0}C
Tc1=33^{0}C	Tc1=33^{0}C
m·h =0.008kg/s	m·h=0.008kg/s
m·c =0.024kg/s	m·c =0.024kg/s
Th2=60.18^{0}C	Th2=57^{0}C
Tc2=56.32^{0}C	Tc2=60^{0}C
Q=562.47W	Q=668.8W
∑=53%	∑=45%

Table 2:Comparison between theoretical and experimental results at half valve position

V. STRESS IN FIN

Stress induced in fin at full valve position

Case 1: At full valve position varying width of fin

In this case position of valve is full that is 100% open (maximum mass flow rate=0.0133 kg/s) and varying width of fin is considered. The finite element analysis of fin at steady state condition as per loading and boundary conditions reveled the thermal stress distributation in the form of stress contour. The representative Von mises thermal stress contours are shown in fig. 5 and stresses are shown in table 3.

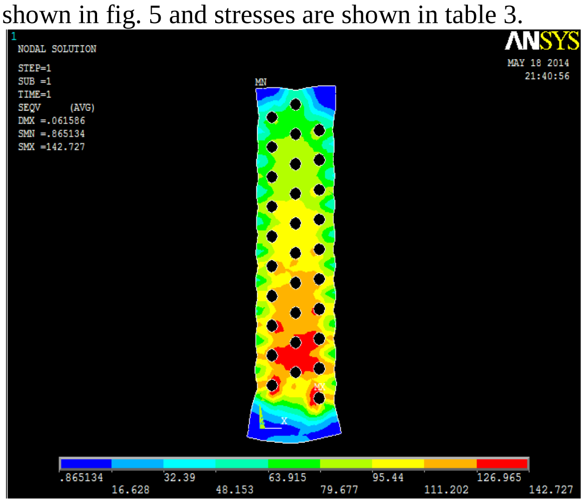

Fig. 5: Von mises thermal stress contour of fin of 60mm width at full valve position

Width of fin in (mm)	Valve position	Von mises thermal stress on fin in (N/mm^2)
50	Full	140.236
60	Full	142.727
70	Full	153.809
80	Full	163.535

Table 3. Von mises thermal stresses on fin at full valve position by varying width of fin

Case 2: At half valve position varying fin width

In this case position of valve is half that is 50% open (minimum mass flow rate=0.008 kg/s) and varying width of fin is considered. The finite element analysis of fin at steady state condition as per loading and boundary conditions reveled the thermal stress distributation in the form of stress contour. The representative Von mises thermal stress contours are shown in fig. 6 and stresses are shown in table 4.

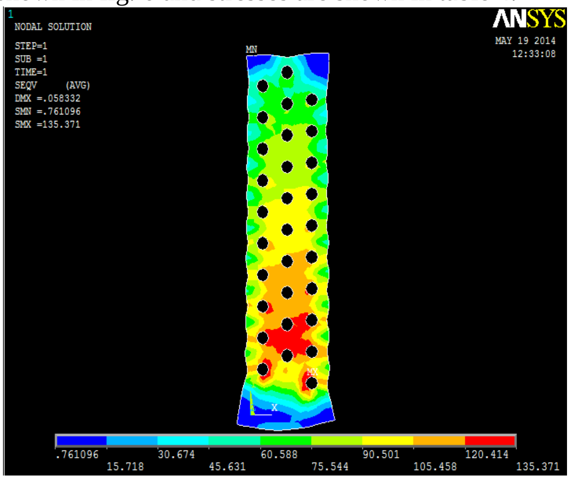

Fig.6 Von mises thermal stress contour of fin 60 mm width at half valve position

Width of fin in (mm)	Valve position	Von mises thermal stress on fin in (N/mm^2)
50	Half	132.811
60	Half	135.371
70	Half	145.833
80	Half	155.012

Table 4. Von mises thermal stresses on fin at half valve position by varying width of fin

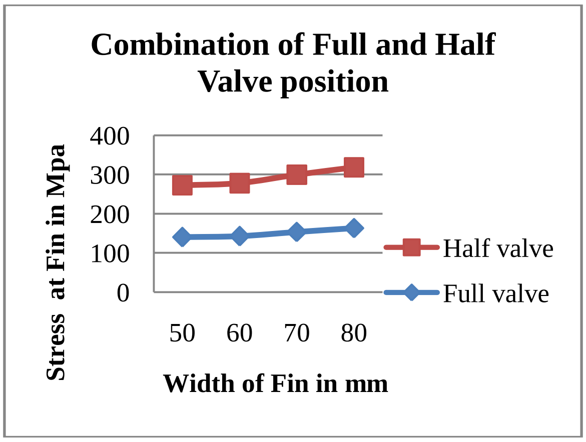

Fig.7 Variation of stress with width in full and half valve position

VI. STRESS IN TUBE

Stress induced in tube at full valve position

Case 1: At full valve position varying diameter of tube

In this case position of valve is full that is 100% open (maximum mass flow rate=0.0133 kg/s) and varying diameter of tube is considered. The finite element analysis of fin at steady state condition as per loading and boundary conditions reveled the thermal stress distribution in the form of stress contour. The representative Von mises thermal stress contours are shown in fig. 8 and stresses are shown in table 5.

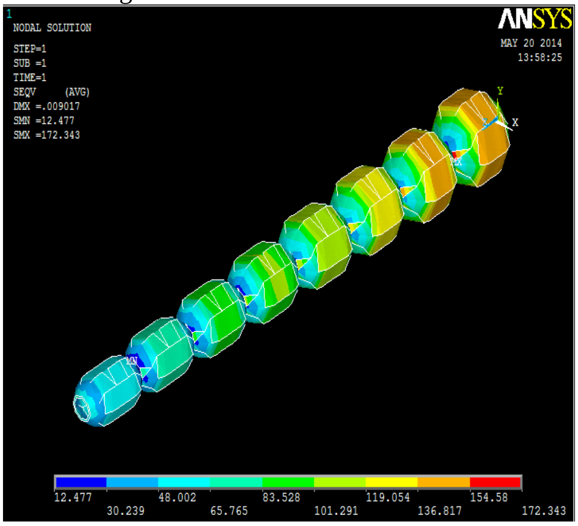

Fig. 8 Von mises thermal stress contour for tube 12mm diameter at full valve position

Diameter of tube in (mm)	Valve position	Von mises thermal stress on tube in (N/mm^2)
10	Full	161.772
12	Full	168.088
14	Full	172.343
16	Full	181.8

Table 5. Von mises thermal stresses on tube at full valve position by varying diameter of tube

Case 2: At half valve position varying tube diameter

In this case position of valve is half that is 50% open (minimum mass flow rate=0.008 kg/s) and varying width of fin is considered. The finite element analysis of fin at steady state condition as per loading and boundary conditions reveled the thermal stress distribution in the form of stress contour. The representative Von mises thermal stress contours are shown in fig.9 and stresses are shown in table 6.

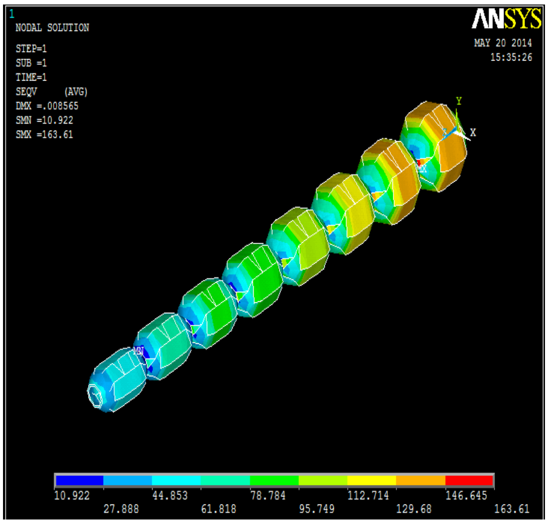

Fig.9 Von mises thermal stress contour for tube 12mm diameter at half valve position

Diameter of tube in (mm)	Valve position	Von mises thermal stress on tube in (N/mm^2)
10	Half	153.583
12	Half	159.684
14	Half	163.61
16	Half	172.707

Table 6. Von mises thermal stresses on tube at half valve position by varying diameter of tube

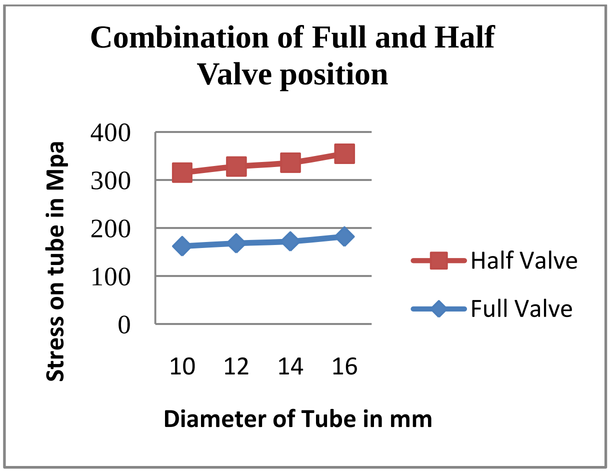

Fig.10 Variation of stress with diameter of tube at full and half valve position

VII. CONCLUSION

It is observed that after performing experimentation and comparing it with theoretical part results are matched hence accuracy of heat exchanger is examined and we come to know about efficiency of heat exchanger. It is also observed that at full valve position maximum thermal stresses are induced on fin as well as tube. The maximum thermal stress is on tube with magnitude 161.772 N/mm^2 and fin with magnitude 140.236 N/mm^2. Tube has maximum thermal stress because tube is in direct contact with hot water so tube persist more stress than fin. It is also observed that at full valve position maximum thermal stresses are induced than at half valve position. This condition is same for fin as well as tube.

The analysis is also carried out by varying width of fin; it was observed that by increasing width of fin thermal stresses also increases. Likewise by varying diameter of tube as the diameter increases thermal stresses in tube also increases.

The final conclusion can be made that the experimental model of specified dimension is a safe design and also gives appropriate results of heat transfer which is our prime importance.

REFERENCES

[1] **Stewart,S.W.,Shelton,S.V.,and Aspelund, K.A**.DepartmentofMechanical Engineering, Georgia Institute of Technology, 771 Ferst Drive, Atlanta, GA 30324, U.S. (2003), "**FINNED TUBE HEAT EXCHANGER OPTIMIZATION**", *2nd International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics*

[2] **Manish Mishra, Prasanta Kumar Das*,** Mechanical Engineering Department, Indian Institute of Technology, Kharagpur, India – 721302, "**OPTIMUM DESIGN OF CROSSFLOW PLATE-FIN HEAT EXCHANGERS THROUGH GENETIC ALGORITHM**", *International Journal of Heat Exchangers, (2004), Vol 5, Iss 2, Pg. 379-401*

[3] **N.Nagarani, Professor,** Mechanical Engineering Department, Anna university of technology, Coimbatore, K.S.R College ofTechnology,Tiruchengode-637215,Tamilnadu,India" **EXPERIMENTAL HEAT TRANSFER ANALYSIS ON ANNULAR CIRCULAR AND ELLIPTICAL FINS**", *International Journal of Engineering Science and TechnologyVol. 2(7), (2010), Pg. 2839-2845*

[4] **Dr.M.Thirumarimurugan1*Dr.T.Kannadasan2 Prof.S.Gopalakrishnan3,** 1* Selection Grade Lecturer, Department of Chemical Engineering, Coimbatore Institute of Technology, Coimbatore- ,,2 Professor in Chemical Engineering, Coimbatore Institute of Technology, Coimbatore and on other duty as Vice Chancellor i/c, Anna University Coimbatore, Coimbatore ,,3 Head of the Department, Department of Chemical Engineering, Coimbatore Institute of Technology, Coimbatore-"**Performance analysis of cross flow plate fin heat exchanger for Immiscible system using ANN**", *International Journal of Chemical and Environmental Engineering, July 2010, Volume 1, No. 1.*

[5] **Ahmed F. Khudheyer and Mahmoud Sh. Mahmoud,** Department of Mechanical Engineering, Nahrain University, Baghdad, Iraq, " **NUMERICAL ANALYSIS OF FIN-TUBE PLATE HEAT EXCHANGER BY USING CFD TECHNIQUE**", *ARPN Journal of Engineering and Applied Sciences, VOL. 6, NO. 7, JULY 2011*

[6] **J.A.Livingston1, P.Selvakumar2,** Department Of Mechanical Engineering, Kongu Engineering College, Perundurai, "**Effective Heat Transfer Enhancement in Finned Tube Heat Exchanger with Different Fin Profiles**", *International Journal of Engineering Research (2013)VolumeNo.2,Issue No.2, Pg : 83-87*