Numerical Analysis and Performance Evaluation of Fin (ALHE30) Material by using Pin Fin Apparatus

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***Abstract* - As we know that fins are basically extended surface, which is used to increase the heat transfer rate, this is basically a secondary surface mounted on primary surface to augment heat transfer from it. This study presents the result of computational numerical analysis of air flow and heat transfer. Pin fin become helpful to enhance heat transfer with in a suitable performance. By above chosen analyzed material AlHE30, the scope of present work is comparing numerical analysis and performance evolution of rectangular (ALHE30) fins under natural and forced convection conditions.**

***Keyword*: Heat transfer, fin, cfd tool, temperature flow.**

I. INTRODUCTION

In the study of heat transfer, Fin is an extended surface (also known as combined conduction, convection system) is a solid within which heat transfer by conduction is assumed to be one dimensional, while it is also transferred by convection(and or radiation)from the surface in the direction transverse to that of conduction .Extended surfaces may exist in many situations but are commonly used as fins to enhance heat transfer by increasing the surface area available for convection(and or radiation).They are particularly beneficial when available area is small and for natural convection.

TYPES OF FIN

1. Straight Fins 2. Annular Fins 3. Longitudinal Fins 4. Rectangular Fins 5. Conical Fins 6. Trapezoidal Fins 7. Parabolic Fins 8. Cylindrical Fins 9. Triangular Fins.

ADVANTAGES

By using the fins, heat transfer rate can be increased without any preventive maintenance. It is the cheapest way to increase heat transferring rate from the hot bodies. Round pin formations produce outstanding cooling power.

APPLICATIONS

Common applications of finned surfaces are with, Cooling electronic component, Condenser and Economizers of Thermal power plant, Drying type cooling towers, Air cooled cylinders of compressor IC engines, Evaporators and Condensers of Refrigerator and Air conditioning

II. LITERATURE REVIEW

Md.Shamim Hossain , J. U. Ahamed, Farazana Akter, Debdatta Das, Santoshi Saha [2]were investigated " heat transfer analysis pin fin array" .Heat transfer by convection between a surface and the surrounding fluid can be increased by attaching and extended thin strips of metal called fin. When heat transfer takes place by convection from both interior and exterior surfaces of plates , generally fins are used on the surface were the heat transfer coefficient is low. The selection of fin depends on different parameters like geometrical shape, fins spacing, fin height, base thickness, kind of material, surface fins etc. There have been many investigations on heat transfer and pressure dropping channels with Pin –Fins of circular cross section. Is observing that it is heat transfer is increased rapidly with the fan speed. With the increase of fan speed the heat transfer coefficient is increase if velocity of fan is increased because increase in fan velocity occurs less time of contact between fin and air as a result decreased actual heat transfer from fin and consequently decreased fin efficiency in forced convection.

Sanjay Kumar Sharma and Vikas Sharma [3]were investigated "maximizing the heat transfer through fins using cfd as a tool". This study presents the results of computational numerical analysis of air flow and heat transfer in a light weight automobile engine ,considering three different morphology pin fins. On numerical study using Ansys fluid(Version 6.3.26)was conducted to find the optimum fin shape based on minimum pressure drop and maximizing the heat transfer across the Automobile engine body. The recent behind the improvement in heat transfer by drop shape pin fin was increased wetted surfaced areas and delay in thermal flow separation from drop shape pin fin. By compilation of all the test run runs in Fluent ,several key performance indicators were studied to understand heat transfer characteristics and trends for each pin-fin configurations. To understand the results we studied Temperature based results in graphical mode, Velocity results and pressure based results.

Objective

Experimental conduction of Aluminum HE30 material rod with specific dimension by pin fin apparatus for both natural and forced convection. Computational analysis of same material by using ANSYS 13.0 software for conduction convection boundary condition.

III. PERFORMANCE EVALUATION OF RECTANGULAR FIN BY PIN FIN APPARATUS

Natural convection and forced convection

Convection is defined as, when a fluid flows inside a duct or over a solid body and the temperature of the fluid and the solid surfaces are different, heat transfer between the fluid and the solid surface will takes place. This type of heat transfer is called as convection.

Convection heat transfer is divided into two types on basis of fluid motion. They are

1. Free or Natural Convection
2. Forced Convection

Free or Natural convection is defined as, if the fluid motion is setup by Buoyancy effect resulting from density variation caused by temperature difference in the fluid, the heat transfer said to free or natural convection.

Forced convection is defined as if the fluid motion is artificially created by means of an external agency like blower or a pump, the heat transfer is said to forced convection.

Heat transfer by convection between a surface and the surrounding fluid can be increased by attaching an extended thin strip of metal called fin. When heat transfer takes place by convection from both interior and exterior surfaces of a plate, generally fins are used on the surface where the heat transfer coefficient is low. The selection of fin depends on different parameters like geometrical shape, fin spacing, fin height, base thickness, kind of material, surface finish etc. There have been many investigations restricted on the heat transfer and pressure drop in channels with pin-fins of circular cross-section Sparrow were among the first to investigate the heat transfer performance of inline and staggered wall attached arrays of cylindrical fins. Metzger investigated the heat transfer characteristics of staggered arrays of cylindrical pin-fins.

IV. EXPERIMENTAL PROCEDURE

Experimental Set up

Fig. 1 Pin Fin Apparatus

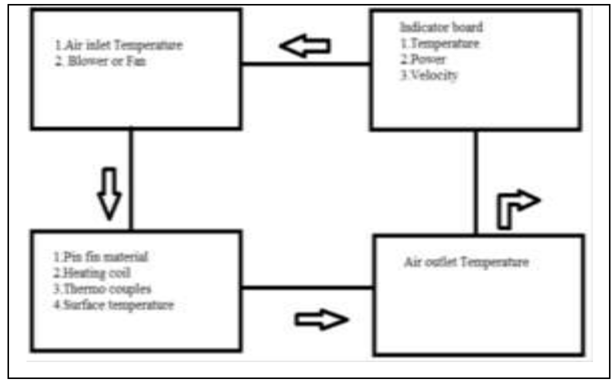

Fig. 2 Pin Fin Apparatus

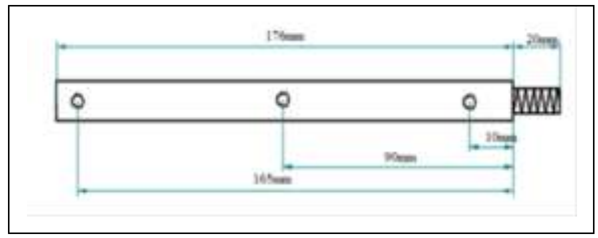

Fig. 3 Pin Fin Specimen Dimension (ALHE30)

Fig.4 Aluminum (AlHE30) Specimen

In this experiment the material used for pin fin rod is Commercial Aluminum rod (AlHE30) with an thermal conductivity of 204w/m°k. The pin fin array used is in circular rod with diameter of 20mm and length of 198mm.After various machining process like, Facing, Drilling, Thread cutting and Grooving on circular rod it have an diameter of 14mm and length of 196mm.

In above diagram circular rod contains 20mm length of 12 V-Threads on it for purpose of fitting to heating coil to heat the Commercial Aluminum rod. It also contains 3circular concentric holes which is having 5mm diameter and 10mm depth for an attachment of 3 thermo couples to find out surface temperature.

Procedure for Natural Convection

1. Switch on the mains and console after ensuring the given model has fitted in duct.
2. Open the windows provided on the top and bottom of the duct for conducting expert in natural convection.
3. Switch on the heater and adjust the power input for various conductions in watts.
4. Wait for sufficient long time till the given Aluminum rod (AlHE30) till it become steady state reached.

Table 1: Natural convection

SL	VOLT	TEMPERATURE° C					
		T1	T2	T3	T4	T5	T6
1	80	174.8	149.8	136.3	30.2	-	34.9
2	90	186.7	160	145.4	33.1	-	36.9
3	100	181.1	173.3	158.4	29.3	-	35.7
4	110	184	185.2	169.5	30.7	-	37.9
5	120	196.2	183.2	178.1	29.8	-	37.1

Free Convection Formula

- Cross sectional Area $AC=\pi r2$
- Beta Value $\beta=1Tavg+273$
- Prandtl Number $Pr=Cp\ \mu k$
- Grashof Number $Gr=g\beta\Delta TC3\int2\mu2$
- Reynolds Number $Re=GrPr$
- Nusselts Number $Nu=0.54(GrPr)0.25$
- Heat transfer coefficient $Nu=hdk$
- Mass flow rate $m=\sqrt{4}hk\times d$
- Effectiveness $\mathcal{E}=\sqrt{4}kfinh\times d\times\tanh(ml)$
- Efficiency $\eta fin=\tanh(ml)m\times l$
- Flow of discharge $Q=\sqrt{hpkA}\tanh(ml)$

Table 2: Variation of $\boldsymbol{Gr}$, $\boldsymbol{Pr}$, $\boldsymbol{Nu}$, h, Ɛ, $\boldsymbol{in}$, Q at 80, 90,100,110 and 120 voltage respectively

SL	Grx10^6	Pr	Nu	h	Ɛ	ηfin	Q
1	48.70	0.694	41.1	92	24	43.8	0.34
2	47.87	0.687	40.9	94	24	43.5	0.35
3	51.04	0.687	43.1	98	23	42.5	0.36
4	52.62	0.681	43.3	98	23	42.4	0.34
5	50.19	0.688	42.9	100	23	42.2	0.36

Procedure for Forced Convection

1. Note down the following readings Power in watts and temperature reading in degree Celsius.
2. After conducting experiment in natural convection made to allow the fin to cool say toroom temperature before starting to conduct experiment for forced convection.
3. Once the fin has reached the ambient temperature, start the blower and adjust the flow gas required for the forced convection.
4. Increase the power supplied to the heater as to maintain the sum temperature before starting the blower
5. Wait for sufficient long time till the given Aluminum rod (AlHE30) till it become steady state reached and note down the temperature readings Power, Velocity of air flow.

Table 3: Forced Convection

	voltage	Velocity	TEMPERATURE° C					
SL	VOLTs	m/s	T1	T2	T3	T4	T5	T7
1	80	1.25	175	150	136	30	34	35
2	90	1.25	186	160	145	33	35	37
3	100	1.25	181	173	158	29	35	36
4	110	1.4	184	185	169	31	36	38
5	120	1.0	196	183	178	30	36	38

Forced Convection Formula

- Cross sectional Area $AC=\pi r2$
- Beta value $\beta=1Tavg+273$
- Prandllt Number $Pr=Cp\ \mu k$
- Reynolds Number $Re=\int Ud\mu$
- Nusselts number $Nu=(0.615Re)0.466$
- Heat Transfer Coefficient $Nu=hdk$
- Mass flow rate $m=\sqrt{4}hkfin\times d$
- Effectiveness $\mathcal{E}=\sqrt{4}kfinh\times d\times\tanh(ml)$
- Efficiency $\eta fin=\tanh(ml)m\times l$
- Flow of Discharge $Q=\sqrt{hpkA}\tanh(ml)$

Table 4:Variation of velocity u, $\boldsymbol{Re}$, $\boldsymbol{Nu}$, h,Ɛ, $\boldsymbol{\eta fin}$, Q at 80,90,100,110 and 120 voltage respectively

SL	Re	Nu	H	Ɛ	ηfin	Q
1	923	14.8	30.6	37.4	66	0.17
2	930	15.9	34.1	38.4	67	0.18
3	996	19.9	30.6	37.3	66	0.18
4	979	19.7	41.8	33.7	60	0.21
5	699	16.78	35.7	35.6	63	0.26

V. COMPUTATIONAL METHOD – CFD TOOL

CFD is numerical technique used for the solution of the equations governing fluid flow and heat transfer problems inside a defined flow geometry (Scott,1994).CFD has wide applications in the areas of fluid and transfer within the aerospace and nuclear industries backed by the availability of powerful supercomputers. It has expanded into other industries such as the chemical and petrol chemical industries. It is only in recent years that it has been applied to food industry, with a limited variety of food-related problem being investigated (Scott and Richardson, 1997). CFD offers a powerful design and investigative tool to the process engineer in many applications. However, at the present little use of this technology as been reported in the food industry. Its application in such areas would be beneficial for the better understanding of the complex interaction occurring in the food systems. The development of CFD packages came from the need to solve complex fluid flow problems of the general nature of wide range of geometry and boundary conditions (Hatton and Carpenter, 1976).CFD work by dividing the physical environment of interest into a two or three-dimensional (3-D) grid harness. It consist a number of discrete cells and can evaluated fluid velocities, temperatures, and pressure inside every one of the cells where fluid flows. This is done by the simultaneous solution of the equations describe fluid flow, heat, mass transfer

Work Carried Out Using CFD

Working in Computational fluid dynamics (CFD) is done by writing down the CFD codes. CFD codes are structured around the numerical algorithms that can be tackle fluid problems. In order to provide easy access to their solving power all commercial CFD packages include sophisticated user interface input problem parameters and to examine the results. Hence all codes contains three main elements;

- Pre-processing
- Solver
- Post-processing

Pre-processing

Preprocessor consist of input of a flow problem by means of an operator friendly interface and subsequent transformation of this input form of suitable for the use by the solver

The user activities at the Pre-processing stages involves

1. Definition of the geometry of the region: The computational domain. Grid generation is the subdivision of the domain into a number of smaller, no overlapping sub domains (or control volume or element selection of physical or chemical phenomena that need to be modeled).
2. Definition of fluid properties: Specification of appropriate boundary conditions at cells, which coincide with or touch the boundary. The solution of a flow problem (velocity, pressure, temperature etc.) is defined at nodes inside each cell. The accuracy of CFD solution is governed by number of cells in the grid. In general the larger numbers of cells better the solution accuracy. Both the accuracy of the solution and its cost in the terms of necessary computer hardware and calculation time are dependent on the finesse of the grid. Efforts are underway to develop CFD codes with a (self) adaptive meshing capability. Ultimately such programs will automatically refine the grid in areas of rapid variation.

Solver

These are three distinct streams of numerical solutions techniques: finite difference, finite volume and finite element methods. In outline the numerical methods that form the basis of solver performs the following steps

1. Approximation of unknown flow variables are by means of simple functions
2. Discretization by substitution of the approximation into the governing flow equations and subsequent mathematical manipulations.

Post-processing

As in the pre-processing huge amount of development work has recently has taken place in the post processing field. Owing to increased popularity of engineering work stations, many of which has outstanding graphics capabilities, the leading CFD are now equipped with versatile data visualization tools.

These includes:

- Domain geometry and Grid display
- Vector plots
- Line and shaded contour plots
- 2D and 3D surface plots
- Particle tracking

VI. CONTOURS AND MESHED MODEL

General steps for solving problems using ANSYS- 13.0

Step1: Ansys Utility Menu

File-clear and start new – do not read file-ok

File-change job name-enter new job name-XXX ok

File-change title-enter new title-YYY ok

Step2: Ansys Main Menu-Preferences

Select-Thermal-Ok

Step3: Preprocessor

Element type-Select type of element from the table and the required options.

Real Constant-Give the detail such as thickness, areas, moment of inertia, etc. required defending on the nature of the problem.

Material Properties-Select units-Choose one of the following type of units.

USER - User defined system(default)

SI -International system (SI or MKS; m, kg,°K)

CGS -CGS system (cm, g, s, ℃)

MPA - MPA system (mm, Mg, s℃,)

BFT - British system using feet (ft, slug, s, °F)

Modelling

Creating the required geometry such as nodes, elements, area, and volume by using the appropriate options.

Generate

Element/nodes using mesh tool if necessary.

Apply the boundary conditions

Lodes Such as DOF constraints, force momentum, pressure etc.

Solution- solve the problem

General post processor- plot/list the required results.

Plot ctrls- animate-deformed shape-def+undeformed- ok.

To save the solution/geometry etc:

Ansys tool bar-save-DB-file-save as-zzz.db-ok.

To open the solution / geometry etc:

Ansys tool bar- resume-DB-file-resume from-zzz.db-ok. Plot-volume / area / elements / nodes to see the geometry.

Meshed Model of Pin Fin Rod

The geometrical model of Pin fin rod is import to FEM to discretization model for required element size in present case used as element size 10 mm. The finite element model is the input data for the analysis , the FEM model consist of element , nodes, depends upon the quality of this we get accurate results.

Without the quality of mesh we not get accurate results, for the present requirement we are considering 3D quadratic tetrahedral elements to whole structure. Tetrahedron element is the 3D elements are used to mesh for complicated structure or big structure it contains 5 nodes quadratic structure.

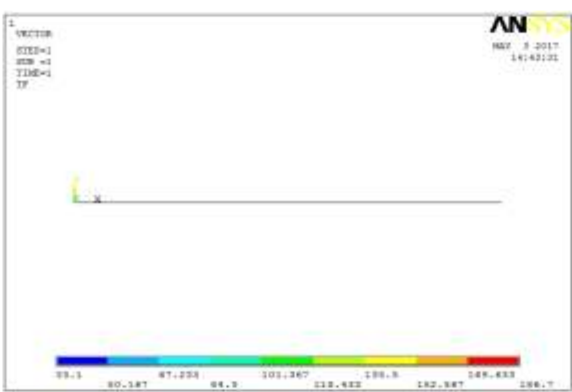

Fig. 4 Vector plot for Temperature on different nodes

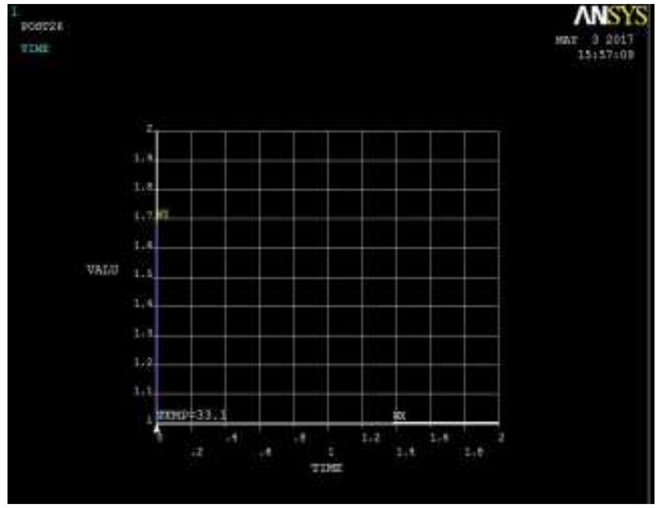

Fig. 5 Time v/s Value

Fig. 6 Temperature Contour for Natural Convection

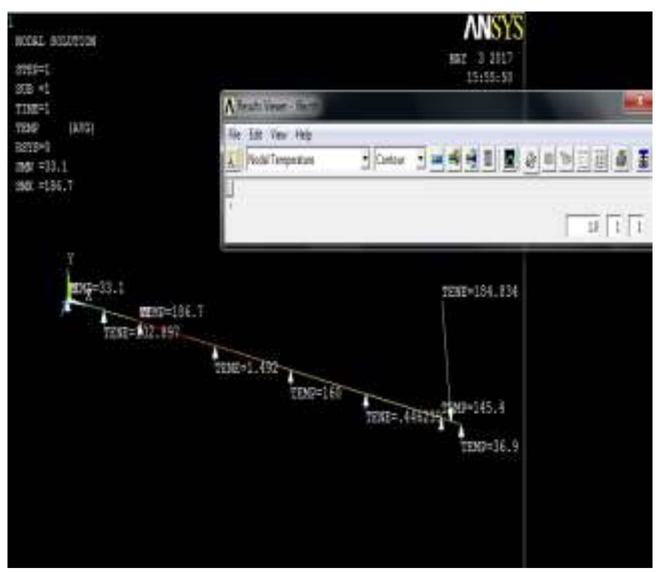

Fig . 7 Nodal Solution

VII. RESULT & DISSUCUSSIONS

The results are obtained from all three methods discussed earlier are presented here with forcomparison. Thermal analyses are carried out on atmospheric temperature conditions andexperiments were conducted at laboratory conditions. CFD analysis are carried out by usingANSYS 13.0 version software for computational method.

Discussion On The Result Obtained By Fin Material (ALHE30) By Pin Fin Apparatus

Experimental conduction by pin fin apparatus is carried out over a fin material (Al HE30)from different voltages (80volts To 120volts) at different temperature are obtained at respective temperature points for natural convection and forcedconvection voltages (80volts To 120volts) and velocities of (1m/s To 4m/s) .

Form above experimental conduction for natural convection, variation in $Gr$from 48.70×106 to 50.19× 106, $Pr$is 0.6946 to 0.688, $Nu$is 41.1834 to 11.855, h is 92.280 to 100.36, Ɛ is24.55 to 23.64, ηfin is 43.84% to 42.20%, and Q of 0.3489 to 0.3652 .

It evident that Q (Heat transfer) is gradually increases from 0.3489watts to 0.3652watt

For forced convection variation in $Re$from 9223.88 to 699.66, $Nu$is 14.816 to 16.780, h is 30.64 to 35.74, $m$is 6.55 to 7.07, Ɛ is 37.40 to 35.74, ηfinis66.78% to 63.63%,Q of 0.1764to 0.2080Watt

It evident that Q (Heat transfer) is gradually increases from 0.3489watts to 0.3652watt.

Discussion on the Result Obtained by Computational Method

CFD analysis has been carried out over aluminum (AlHE30) rod for different temperature atdifferent nodes for both natural convection and forced convection. Different temperaturecontours are shown in Figure 5.01 and Figure 5.02, meshed model of AlHE30 rod is shownin Figure 5.5.From temperature nodal solution it evident that at node 2 maximum value oftemperature of 186.70℃ is obtain.

VIII. CONCLUSION

In the present work AlHE30 were used as a test surface variation of effectiveness and efficiency is investigated with various parameters. The experimental results gives heat transfer coefficient and efficiency were good agreement. With numerical analysis by the study of heat transfer characteristics and trend for pin fin configuration.

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