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Cooling Effect Improvement by Dimensional Modification of Annular Fins in Two Stage Reciprocating Compressor

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Abstract
The Reciprocating Compressor fins are made from Aluminum alloy and it is provided for increase in contact area in convective heat transfer. Air cooling is a method of dissipating heat It works by making the object to be cooled have a larger surface area or have an increased flow of air over its surface. a fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection.
The aim of present work study is to prepare a finite element model of fin. The result of finite element model will be verified with experimental work with thermocouple. After comparing results of FEA model we can modify boundary condition, material shape & size for improvement in efficiency & cooling rate. It is possible to find optimum solution with FEA package ANSYS 14 used for modeling and analysis.
Effectiveness of fin can be improved by changing geometry of fin. So after increase effectiveness it can increase cooling rate and minimize the time for cooling process of Reciprocating compressor. Aim of this work is increase effectiveness of the fin for best performance.
Keywords: Reciprocating air compressor, Annular fin, Thermocouples, finite element analysis.

I. INTRODUCTION

In the study of heat transfer, a fin is a surface that extends 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 difference 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 economical or it is not feasible to change the first two options. Adding a fin to an object, however, increases the surface area and can sometimes be an economical solution to heat transfer problems.

The fins are commonly used for increasing the heat transfer rates from the surfaces whenever it is not to possible to increase the rate of heat transfer either by increasing the heat transfer coefficient on the surface or by increasing the temperature difference between the surface and surrounding fluids. The term extended surface is commonly used to depict an important special care involving heat transfer by conduction within a solid and heat transfer by convection from the boundaries of the solid. For an extended surface, the direction of heat transfer from the boundaries is perpendicular to the principal direction of heat transfer in the solid. The fms are commonly used on small power developing machines as engines used for scooters and motor cycles as well as small capacity compressors. They are also used in many refrigerating systems (either in evaporator or condenser) for increasing the heat transfer rates.

II. LITERATURE REVIEW

N.Nagarani[1], have study about Most of the engineering problems require high performance heat transfer components with progressively less weights, volumes, accommodating shapes and costs. In this paper the heat transfer rate and efficiency for circular and elliptical annular fins were analyzed for different environmental conditions. Elliptical fin efficiency is more than circular fin. If space restriction is there along one particular direction while the perpendicular direction is relatively unrestricted elliptical fins could be a good choice.
Now a days compact heat exchanger with less weight, cost and space are required in food processing industries, chemical industries and refrigeration units.

RUPALI V. DHANADHYA[1], **ABHAY S. NILAWAR**[2]**& YOGESH L. YENARKAR**[3] have study about examines the heat transfer augmentation from horizontal rectangular fins with circular perforations under natural convection compared with solid fins. Fins with different thickness keeping length constant are also examined. The parameters considered were geometrical dimension and thermal properties of fin such as material properties, convective heat transfer coefficient. Finite element analysis has been done using ANSYS 11. Study showed that as perforations increases heat transfer rate also increases. Heat transfer enhancement of the perforated fin increases with increase in fin thickness. The removal of excess heat from system components is essential to avoid damaging effects of overheating.Therefore, the enhancement of heat transfer is an important subject of thermal engineering. Heat transfer between a surface(To) and the fluid surrounding it (Ts) is given by Q = h A (To-Ts). Heat transfer rate may be increased by increasing the heat transfer coefficient between a surface and its surrounding, or by increasing the heat transfer area of the surface. In most cases, the area of heat transfer is increased by extending surfaces. These extended surfaces are called as fins. Fins are used to enhance convective heat transfer in a wide range of engineering applications and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation transformers. Other applications include engine cooling, condensers in refrigeration and air conditioning Fins as heat transfer enhancement devices have been quite common. The different materials like Mild steel, Stainless Steel, Aluminum, Silver, Copper etc are used for making fins. As the extended surface technology continues to grow, new design ideas have been emerged including fins made of anisotropic composites, porous media, interrupted and perforated plates.

Due to the high demand for lightweight, compact, and economical fins, the optimization of fin size is of great importance. Therefore, fins must be designed to achieve maximum heat removal with minimum material expenditure taking into account the ease of the fin manufacturing. The improvement in heat transfer coefficient is attributed to therestarting of the thermal boundary layer after each interruption. Thus perforated plates and fins represent an example of surface interruption.

M. Sudheer[1], G. Vignesh Shanbhag[1], Prashanth Kumar[1] and Shashiraj Somayaji[2] have study about The selection of a particular fin configuration in any heat transfer application depends on the space, weight, manufacturing technique and cost considerations as well as the thermal characteristics it exhibits. Radial or annular fins are one of the most popular choices for enhancing the heat transfer rate from the primary surface of cylindrical shape.

Different profiles have profound influence on the thermal characteristics of annular fins. In the present study, a detailed work has been carried out to develop a finite element methodology to estimate the temperature distribution for steady-state heat transfer and thermal stresses induced by temperature difference in a silicon carbide (SiC) ceramic finned-tube of the heat transfer equipment. Finite element method (FEM) was used to compute the temperature and the stress fields. An extensive study was carried out using ANSYS, a powerful platform for finite element analysis. Results obtained were presented in a series of temperature and thermal stress distribution curves for annular fins with rectangular, trapezoidal and triangular profiles for a wide range of radius ratios. It was found that the radius ratio and fin profiles are the significant parameters affecting the temperature and thermal stress distribution in annular fins.

III. PREPROCESSING OF FEA USING ANSYS

The concept of FEA can be explained with a small example of measuring the perimeter of a circle. To measure the perimeter of a circle without using conventional formula, divide the circle into equal segments. Then, join the start point and endpoint of each of these segments by straight line. Now, the length of straight line can be measured easily and thus, the perimeter of the circle. If the circle is divided into four segments only, the result will not be accurate. For accuracy circle should be divided into more number of parts. However with increase in number of parts the effort required will be more. The same concept applies to FEA also, therefore there is always a compromise between accuracy and speed while using this method. This makes it an approximate method.

3.1 ANALYSIS MODEL

The Reciprocating Compressor fins are made from Aluminium alloy and it is provided for increase in contact area in convective heat transfer. By the using of fins the contact area of engine to air is increased therefore the heat transfers rate increase. That's why fins are used for cooling of the compressor. I had measured dimensions of extended surface or fin provided in Two Stage Reciprocating Compressor. Figure 4.1 shows the fins provided on the Compressor

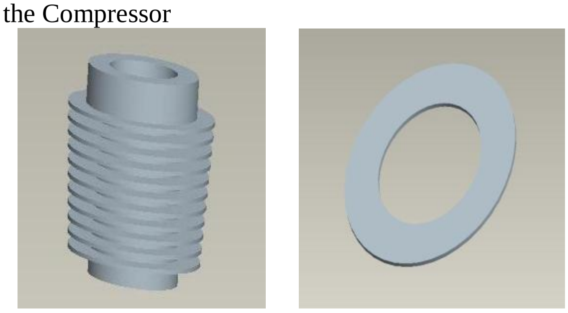


Figure 3.1 fin provided in Two Stage Reciprocating Compressor

3.2 INITIAL AND BOUNDARY CONDITIONS, MATERIAL PROPERTIES AND BASIC ASSUMPTIONS

To create a simplified equation for the heat transfer of a fin, many assumptions need to be made:

1. Steady state
2. Constant material properties (independent of temperature)
3. No internal heat generation
4. One-dimensional conduction
5. Uniform cross-sectional area
6. Uniform convection across the surface area

PRE PROCESSING DETAILS

- Element type- solid87
- Analysis Type- Thermal
- Material Properties
- Thermal Conductivity= 190 watt/m°C
- Density= 2650Kg/m^3
- Specific Heat= 900J/Kg.K

SOLID87 ELEMENT DESCRIPTION

- SOLID87 is well suited to model irregular meshes (such as produced from various CAD/CAM systems). The element has one degree of freedom, temperature, at each node.
- The element is applicable to a 3-D, steady-state or transient thermal analysis

BOUNDARY CONDITIONS FOR NATURAL CONVECTION

Conduction and convection will occurred in fins during heat transfer. Heat transfer process starts when engine stops. 3 sides of fins are in contact of air and one side is contact of cylinder. So in 3 sides there will heat convection will done and in bottom side heat conduction process done. So applying boundary condition in 3 sides which are in contact of air.

By the taking data for boundary condition

Initial Temperature =122°C
Film Co- efficient =11w/m^{2}K
Bulk Temperature = 33°C

IV. FEA ANALYSIS OF EXISTING FIN GRAPH OF TEMP. V/S TIME. OF EXISTING FIN

The graph of result is shown in figure 4.1 it is temperature v/s time which is for one selected node. It shows that it initial temperature is taken 122 °C then it will come at bulk temperature in approximate 30 minutes

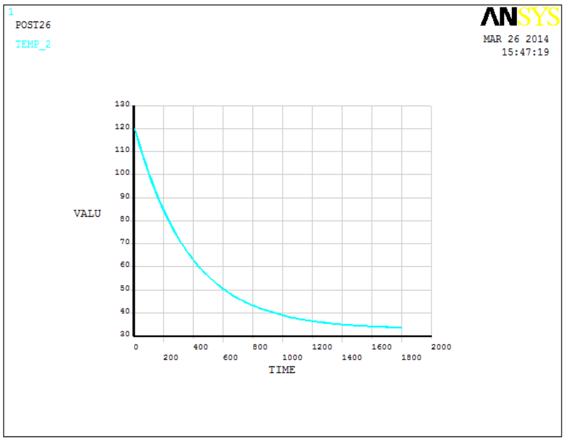
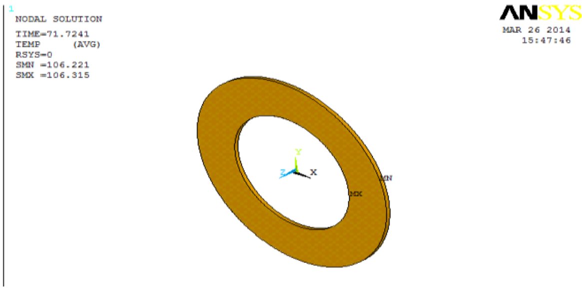
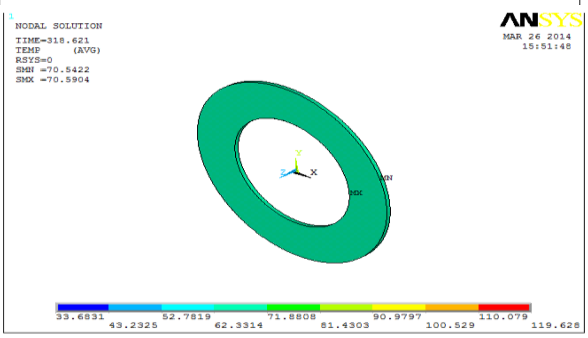


Figure 4.1 graph of temp. v/s time for one selected node

RESULTS OF TEMPERATURE IN TIME INTERVAL





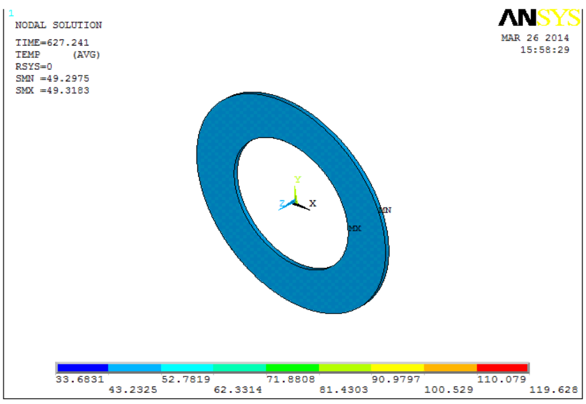


Figure 4.4 result after 10 minutes

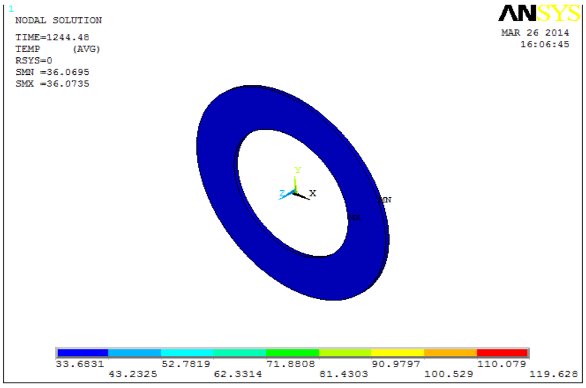


Figure 4.5 result after 20 minutes

V. FEA ANALYSIS OF MODIFIED FIN GRAPH OF TEMP. V/S TIME. OF EXISTING FIN

The graph of result is shown in figure 5.1 it is temperature v/s time which is for one selected node. It shows that it initial temperature is taken 122 ^{0}C then it will come at bulk temperature in approximate 22 minutes.

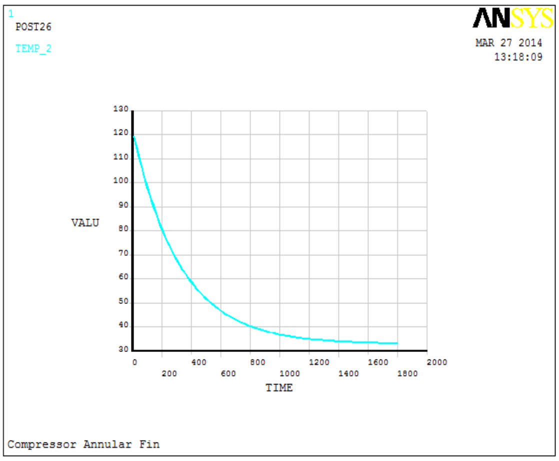


Figure 5.1 graph of temp. v/s time for one selected node

RESULTS OF TEMPERATURE IN TIME INTERVAL

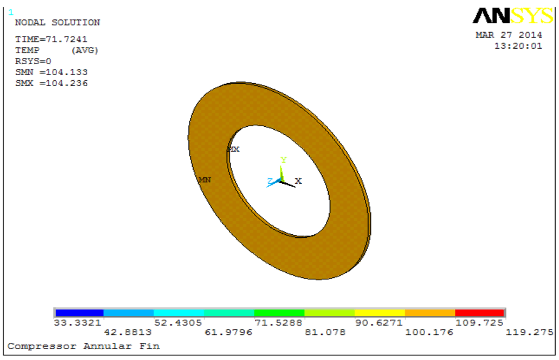


Figure 5.2 result after 1 minutes

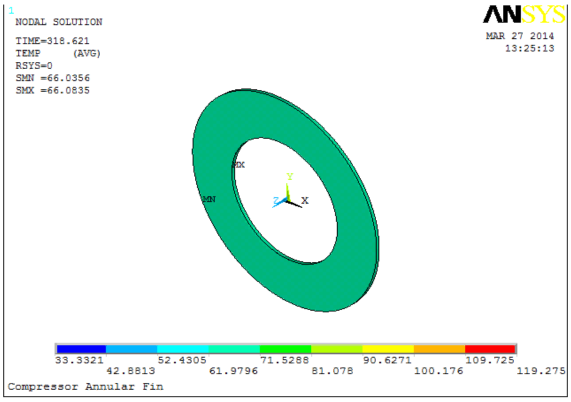


Figure 5.3 result after 5 minutes

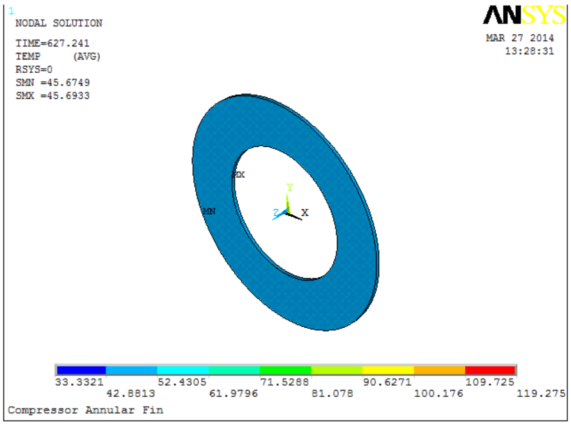


Figure 5.4 result after 10 minutes

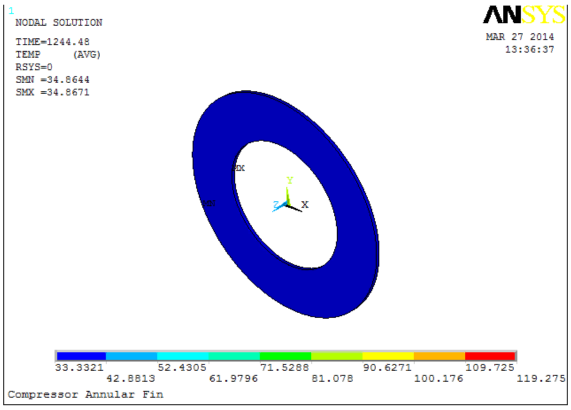


Figure 5.5 result after 20 minutes

VI. COMPARISON OF FEA ANALYSIS OF MODIFIED FIN WITH EXISTING FIN READINGS

Time (after stop compressor)	FEA result of existing fin	FEA result of Modified fin
Initial temp.	**119.628 °C**	**119.628 °C**
1 minute	**106.316 °C**	**104.236°C**
2 minute	**95.041 °C**	**91.8094 °C**
3 minute	**85.4994 °C**	**81.5491 °C**
4 minute	**77.4243 °C**	**73.0777 °C**
5 minute	**70.5904 °C**	**66.0835 °C**
7 minute	**59.921 °C**	**55.5508 °C**
10 minute	**49.3183 °C**	**45.6933 °C**
14 minute	**41.3687 °C**	**38.8968 °C**
20 minute	**36.0735 °C**	**34.8671 °C**

Table 6.1 Comparison of fea analysis of modified fin with existing fin.

As shown in table 6.1 existing fin comes at room temperature in 30 minutes. After modification the cooling rate increases and it comes at room temperature in 22 minutes.

TOTAL EFFECT OF MODELING FIN

- In existing fine there are 11 fins are available having with 3.5mm thickness and space between two fins is 8 mm
- Total width of cylinder is 116.5mm
- Gap remains constant between two fins.
- After modification of fin there will taken 13 fins on width of cylinder and space between two fins remain constant

VII. CONCLUSION

In this work I select the fin of TWO STAGE RECIPROCATING COMPRESSOR for increase effectiveness of fins. After that the measured dimensions and material properties. Then FEA model created for analysis. After FEA analysis of that fin it was validated by experimental reading. Thermocouple was used of experimental reading. And it was validated by experimental readings. And both results are found same.

After validation evolution of fin performance was carried out. In the evolution efficiency and effectiveness was calculated for existing fin. After that modification was carried out. After modification effectiveness was increased with minor change in efficiency.

FEA of modified fin was carried out and go result that the cooling time was reduce. So in this work I modified fin for best cooling rate.

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