IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 2, February 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
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Natural Convective Heat Transfer from Inclined Narrow Plates

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Abstract

Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source (like a pump, fan, suction device, etc.) but only by density Differences in the fluid occurring due to temperature gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process continues, forming convection current; this process transfers heat energy from the bottom of the convection cell to top. The driving force for natural convection is buoyancy, a result of differences in fluid density. Steady state natural convection from heat sink with narrow plate-fins having parallel arrangement mounted on inclined base was experimentally investigated. Aluminium heat sink with two different lengths viz. 200mm width 140 modelled. Fin thickness was kept constant at 5mm. Fin height was selected 20mm and 30mm for 200mm length of fin while it was Effect of fin height, fin length, inclination of base was determined. And also checking these results with different material properties.Finally we can conclude how the temperature and heat flux is varying while changing fins height and also which material is most suitable for these thermal boundary conditions.

Keywords: Temperature, Stress, Strain, Thermal barrier etc…

1.Introduction

Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source(like a pump, fan, suction device, etc.) but only by density Differences in the fluid occurring due to temperature gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process continues, forming convection current; this process transfers heat energy from the bottom of the convection cell to top. The driving force for natural convection is buoyancy, a result of differences in fluid density. Because of this, the presence of a proper acceleration such as arises from resistance to gravity, or an equivalent force (arising from acceleration, centrifugal force or Coriolis effect), is essential for natural convection. For example, natural convection Essentially does not operate in free-fall (inertial) environments, such as that of the orbiting International Space Station, where other heat transfer mechanisms are required to prevent electronic components from overheating. Convective heat transfer, often referred to simply as convection, is the transfer of heat from one place to another by the movement of fluids.

1.1 two types of convective heat:

Free or natural convection: when fluid motion is caused by buoyancy forces that result from the density variations due to variations of thermal temperature in the fluid. in the absence of an external source, when the fluid is in contact with a hot surface, its molecules separate and scatter, causing the fluid to be less dense. As a consequence, the fluid is displaced while the cooler fluid gets denser and the fluid sinks. Thus, the hotter volume transfers heat towards the cooler volume of that fluid.[2] Familiar examples are the upward flow of air due to a fire or hot object and the circulation of water in a pot that is heated from below.

Forced convection: when a fluid is forced to flow over the surface by an external source such as fans, by stirring, and pumps, creating an artificially induced convection current.

2. Literature Survey

W.Elenbass [1] investigated experimentally, the heat transfer performance of rectangular fins on a vertical base in free convection heat transfer. The effects of geometrical parameters and base-to-ambient temperature difference on the heat transfer performance of fin arrays were observed and the optimum fin separation values were determined.

E.M Sparro [2] investigated the heat transfer performance of rectangular fins on a vertical base in free convection heat transfer. The effects of geometric parameters and base-to-ambient temperature difference on the heat transfer performance of fin arrays were observed and the optimum fin separation values were determined.30 fin configurations were tested.

J.R Bodoia [3] investigated steady state natural convection from heat sink of rectangular fins on a vertical base. The effects of geometric parameters and base-to-ambient temperature difference on the heat transfer performance of fin arrays were observed and the optimum fin separation values were determined. 30 fin configurations were tested.

A.De Lieto Vollaro [4] tested heat sink for wide range of angle of inclination with upward and downward orientations. By modifying Grashoff number with cosine of inclination angle, they suggested the modified correlation, which is best suited for inclination angle interval of -60° ≤ θ ≤ +80°. It was also observed that the flow separation inside the fin channels of the heat sink is an important .

Design of final layout :

Solid modelling in general is useful because the program is often able to calculate the dimensions of the object it is creating. Many sub-types of this exist. Constructive Solid Geometry (CSG) CAD uses the same basic logic as 2D CAD, that is, it uses prepared solid geometric objects to create an object.

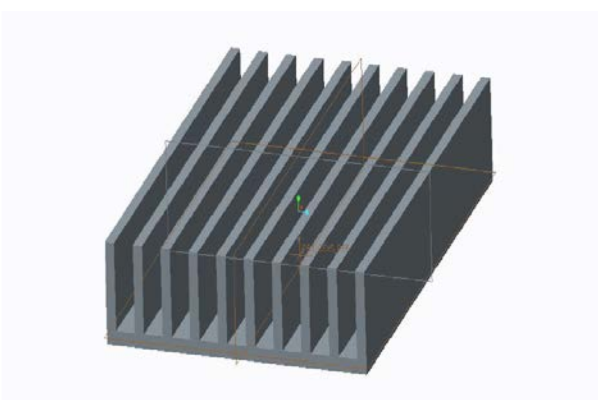

Fig:2.1 Final layout of fins with walls

The figure is our required final model with dimensions 200mm*140mm*30mm.

3. Methods for Design and Analysis to Develop the Work

3.1 CAD

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provide the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations.

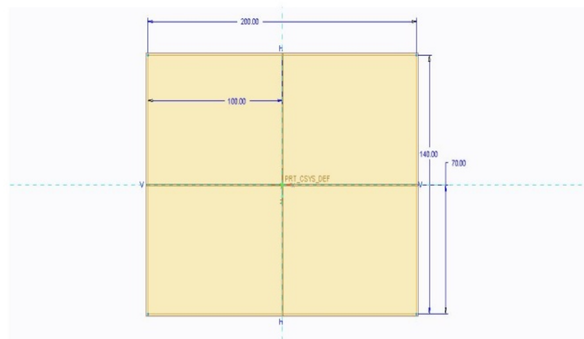

Fig:3.1 Design Parameters

3.2 ANSYS:

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures". By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters. FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to

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the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

4.Analysis:

Creo is a family or suite of design software supporting for discrete manufacturers and is developed by PTC. PTC Creo is a scalable, interoperable suite of product design software that delivers fast time to value. It helps teams create, analyze, view and leverage product designs downstream utilizing 2D CAD, 3D CAD, parametric & direct modeling. PTC Creo Parametric provides the broadest range of powerful yet flexible 3D CAD capabilities to accelerate the product development process.

4.1 Thermal Analysis

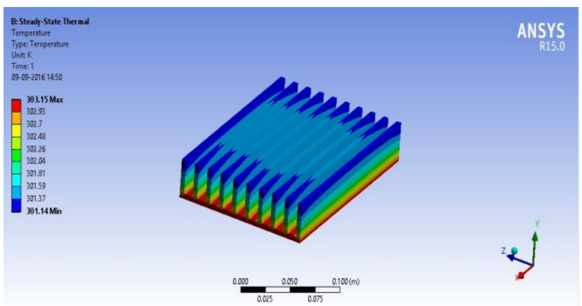

Fig 4.1: Total Temperature

the figure shows the results of steel fins total temperature distribution.And here we have we have maximum temperature 303.15Tk which is red colour and minimum 301.98k which is shown in blue colour

Heat flux

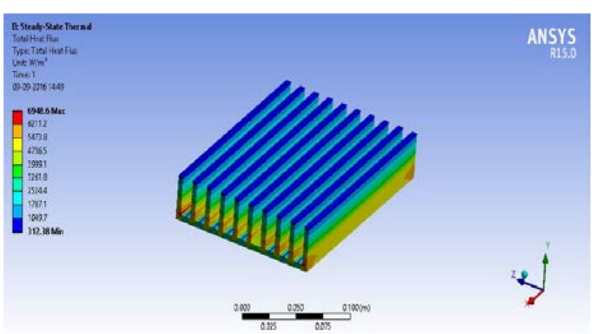

Fig 4.2: Heat Flux

The above figure shows the results of steel fins total heat flux. And here we have maximum heat flux 4889w/m^2 which is shown in red colour and minimum 85.266w/m^2 which is shown in blue colour.

Heat flux in x-direction

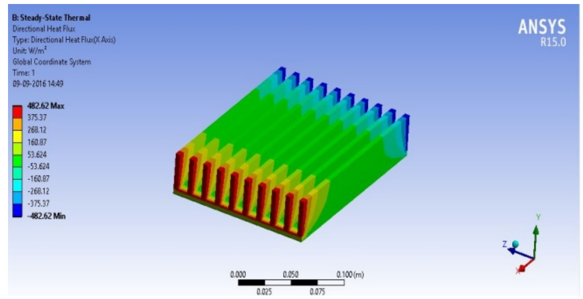

Fig:4.3: Heat flux in x-direction

The above figure shows the results of steel fins heat flux in x-direction. And here we have maximum heat flux 482.62w/m^2

Heat flux in y-direction

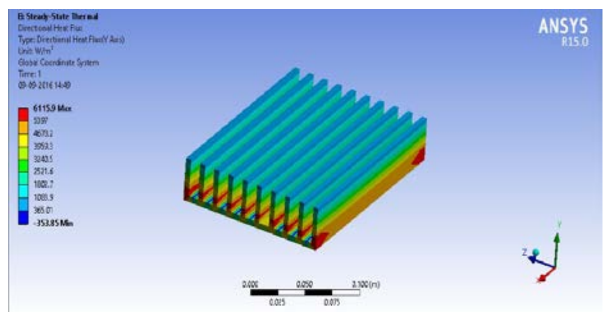

Fig:4.4: Heat flux in y-direction

The above figure shows the results of steel fins heat flux in y-direction. And here we have maximum heat flux 6115.9w/m^2

Heat flux in z-direction

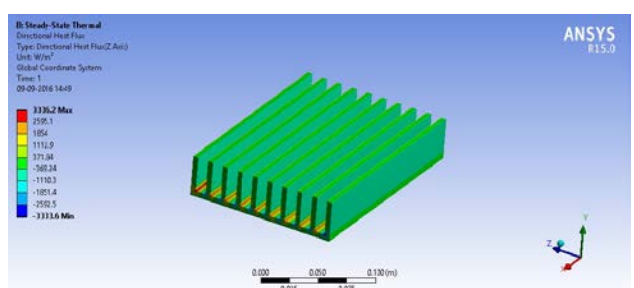

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Fig:4.5: Heat flux in z-direction

The above figure shows the results of steel fins heat flux in z-direction. And here we have maximum heat flux 3336.2w/m^2

4.2 Dynamic Analysis:
Steel Alloy:

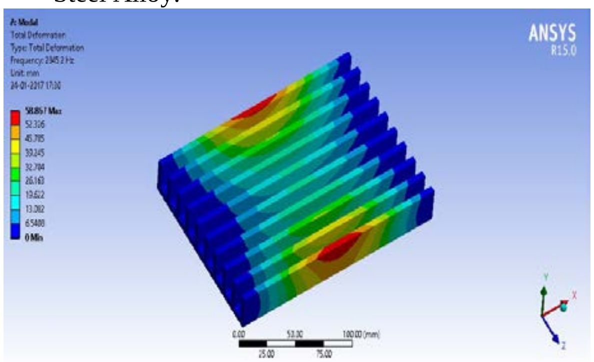

Fig 4.6: Dynamic Analysis Mode1

The above figure shows natural frequency results of steel fins for mode1 here we have 2845.2HZ

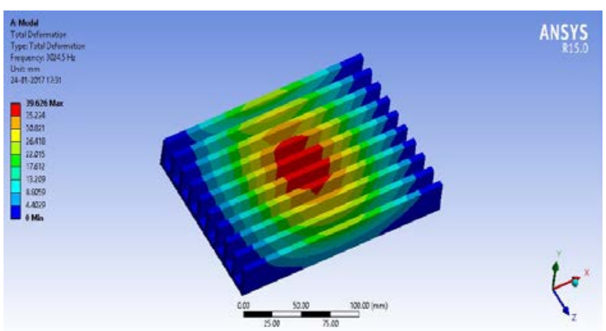

Fig 4.7: Dynamic Analysis Mode2

The above figure shows natural frequency results of steel fins for mode2 here we have 3024.5HZ.

5. Results and Discussion

Table 5.1 Thermal Analysis between Steel and Al

Material	Total Heat flux(w/mm²)	Temperature
Steel	4889.2	5143.3
al-alloy	5052.4	4723.9

Above table shows the variation between the materials steel and aluminium when we applied700c ambient temperature and 7e-4 film coefficient on the top surface of the piston crown.

Thermal analysis between steel and aluminium piston we can say the heat flux of existing model has been increased by material change but by changing material steel to aluminium .we may not increase the temperature distribution and it has been decreased from 303.15 to 268.2 but the heat flux is increased from 4889 to 5143.from this we can say steel material is good.

Table 5.2 Thermal Analysis between Steel and Al

Material	Total Heat flux(w/mm²)	Temperature
Steel	6374.5	6948.6
al-alloy	5052.4	4723.9

Above table shows the variation between the materials steel and aluminium when we applied700c ambient temperature and 7e-4 film coefficient on the top surface of the piston crown.Thermal analysis between steel and aluminium piston we can say the heat flux of existing model has been increased by material change but by changing material steel to aluminium .we may not increase the temperature distribution and it has been decreased from 303.15 to 268.2 but the heat flux is increased from 4889 to 5143.from this we can say steel material is good.

Conclusion

- Fin geometry model has been created by using cad tool (creo-2) and analyses with cae tool (Ansys work bench) in this process we analysed our model with real time boundary conditions with two materials.
- And here we taken model dimensions (L(200mm)),(W(140mm)),height is 20 mm and for another model 30 mm and for these models we applied same boundary conditions for all. And calculated results like total temperature and heat flux and heat flux in x,y,z directions respectively.
- By increasing the fin length here absorb that the temperature is constant for both models but the total heat flux has been increased for 30mm fin length.
- From the results al-alloy and steel both materials maintain same amount of total temperature distribution and here heat flux is high for al-alloy. And when we increases fins

length the temperature distribution is same for both material but the total heat flux has been increased compare to existing model.

- Generally one cannot decide one material/object is good by only single analysis so that here we also checking natural frequency ranges of our objects and finding their natural frequency for each material and each model. By these results here we can avoid resonance.
- From the results we observe that al-alloy material has good frequency values than steel material. And when we increases fin height the frequency range will decreases.
- Finally we can conclude that from the entire thermal and dynamic analysis results al-alloy can also suit for this object.

Scope of Future Work

- In this project we created heat fins with the help of cad tool (creo-2) and in this process we changing heat fins height and analysing both models with same boundary conditions with two materials and calculating their thermal and dynamic results. From all these we came to know what will happen if we increases fins height and which material can suitable for this object.
- Till now we did analysis only on steel and al-alloy and calculated their thermal and dynamic results. We can also use different al-alloy series like (al-6061, al-7075, etc) and also for steel we can also use monel-400, en-9. In this project we did analysis on different fins height only and remaining all are maintain constant we can also change the thickness of the fins.

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