iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: II Month of publication: February 2020

DOI: http://doi.org/10.22214/ijraset.2020.2078

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 8 Issue II Feb 2020- Available at www.ijraset.com

CFD Analysis of Heat Transfer in Annular Fins of various Profiles having different Shapes of Perforation

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Abstract: Temperature Distribution in perforated annular fin with constant thermal conductivity, due to convective and radiative heat transfer, is presented in this paper. Perforating a fin is a common option for enhancing the heat transfer. Due to the perforation the Temperature Distribution and Heat Transfer can be affected. Steady-State Thermal analysis is performed for investigating temperature distribution in both non-perforated and perforated annular fins. The preparation of models and the analyses are carried out using ANSYS 19.2. The results have shown that Temperature Distribution is significantly lower in triangular profile and is affected after the perforation of elliptical shape .
Keywords: Finite element method, Annular fins, heat transfer, Temperature Distribution, Radius Ratio

I. INTRODUCTION

Heat Transfer has a vital role in numerous engineering fields. Fins are widely used for enhancing heat transfer in various thermal applications such as heat exchangers, super heaters, internal combustion engines, economizers etc. Reduction in cost and size of fins are the most important aim of fin industry. The heat transfer from the fin surface is caused in convection and radiation processes. These heat transfers are generally depend on effective surface area of the fin and the temperature difference between fin surface and surroundings. However, increasing the surface area causes increasing material size and cost. In this case, increasing the ratio of surface area to volume, by perforating the model, is the best option to enhance the heat transfer.

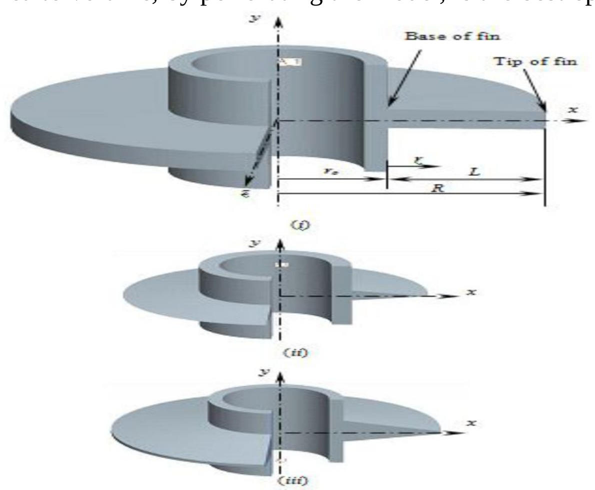


Fig 1. Circular fins with various profiles. (*i*) Rectangular section, (*ii*) triangular section and (*iii*) trapezoidal section

II. LITERATURE REVIEW

A comparative study of the distribution of temperature in circular fins of heat transfer equipment. The numerical analysis of this coupled field problem has been performed using the finite element method. The influence of various geometrical profiles viz., rectangular triangular and Trapezoidal, on the temperature and stress distribution are investigated. The results are obtained for Aluminium Nitride, Cupronickel and Inconel MA754 materials of heat transfer fins. The temperature and radial stress fields of circular fins of heat exchanger application are studied for 3 sorts of fin profiles and three materials. The temperature distribution along the radial direction has been found to be higher within the trapezoidal fin as compared to the triangular or rectangular fin whereas, radial stress distribution exhibited lowest in triangular fin for an equivalent material type. Fins having Aluminium nitride as material exhibited better heat transfer characteristics.[1]

According to Bayram, S. & Alparslan the wants of lightweight fins and economical, therefore the optimization of fin size is extremely important in fin's design. Therefore, fins must be designed to realize maximum heat removal with minimum material expenditure, taking under consideration, however, the convenience of producing of the fin shape.[2]

Metals are the most commonly used tube material in heat exchangers as they're good thermal conductors. These metals are limited to temperature application only, i.e., below 400°C. for prime temperature heat exchangers, operating with a process fluid above 1000°C, metals can't be used and hence ceramics are preferable[3]Increasing the number of nodes for an analysis requires prohibitive amount of computer memory and time, but it gives accurate results. Although, increased number of nodes gives better results for any problem, there will be certain number of nodes beyond which the accuracy of the result cannot be improved by significant amount [4].

A. Assumptions and Analysis

The finite element analysis is based on the following common assumptions:

1) Steady-state heat flow,
2) The materials are homogeneous and isotropic,
3) There is no heat source,
4) The convection heat transfer co-efficient is same all over the surface,
5) The temperature of the surrounding fluid is uniform,
6) The thermal conductivity of the material is constant.

The material property plays a very important role in determining the temperature distribution and the thermal stresses induced. The properties of the Al nitride are given in table 1.

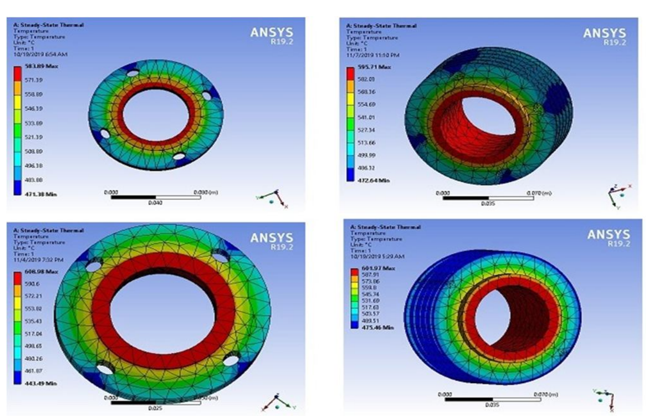
The tube of length 70 mm consisting of 6 annular fin at equal spacing .The inner (fluid and the tube) and outer (fin surface) convective heat transfer coefficient, *h*; are 1000 and 100 W/m^2 K. The heat flux was kept at zero at both tube edges. auto-meshing
.

TABLE I. Properties Of The Aluminum Nitride

Density, ρ (g/cm^3)	3.26
Young's modulus, E (GPa)	331
Poisson ratio, ν	0.22
Thermal conductivity, k (W/mK)	175
Thermal expansion coefficient,α ($^0C^{-1}$)	4.6
Density, ρ (g/cm^3)	3.26

III. ANSYS MODELING & MESHING

In geometry creation we have to create the annular fin of different profile. we used CATIA V5 to draw the profiles, first sketching is done and then specify the dimension for example its radius, and distance from XY-axis. Then go to revolve option to generate the profile then change the property of file to .stp format to three dimensional. Mesh generation create automatic grid. we have to modify the grid or make the grid finer so that accurate results will come. For generating fine mesh go for the sizing option then select the MESHING METHOD we can specify the type of mesh we want to create for example QUAD, TRI, QUAD/TR for making the division.



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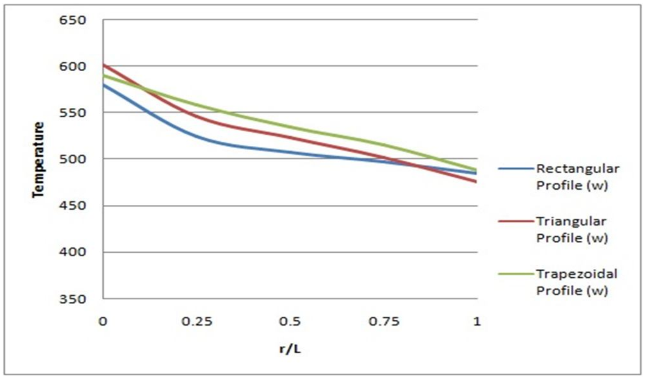
The modeled fins were subjected to convective boundary conditions on the inner and outer surface and the displacement boundary condition on the ends. Since only a small vertical section of the tube was considered for analysis the distribution of temperature in the radial direction along the mid plane of the fin was computed. A coordinate path was defined along the mid plane of the fin (y plane) from the base of the fin to its tip and the results extracted along this path. The radius ratio of the circular fin, R/ro has been considered 1.5.

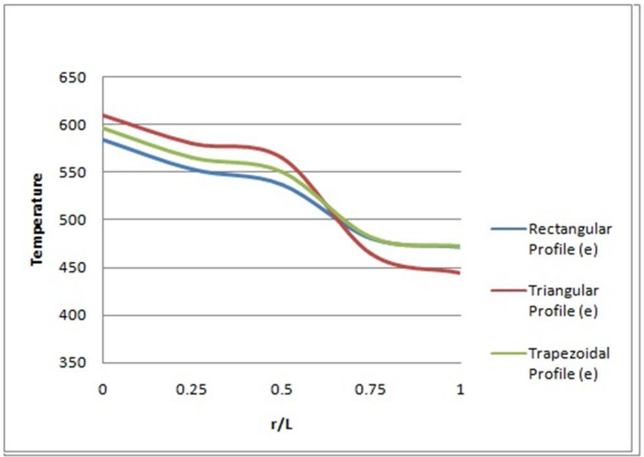
IV. RESULTS

The comparative results for selected parameters showed that the convective heat transfer characteristics of the annular fin is best for a triangular profile with R/ro = 1.5, the operating parameter. Fin with triangular profile is nearly as economic as the profile of minimum material requirement and the construction cost is also less compared with rectangular and trapezoidal profiles. Hence triangular profile is attractive because for equivalent heat transfer it requires much less volume than other profiles

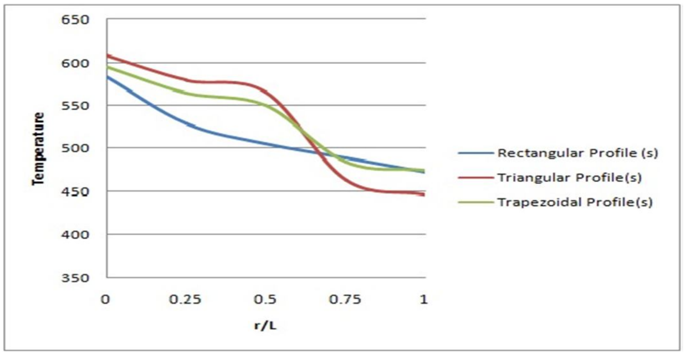
Temperature Variation without Perforation



Temperature Variation With Elliptical Perforation



Temperature Variation with Square Perforation



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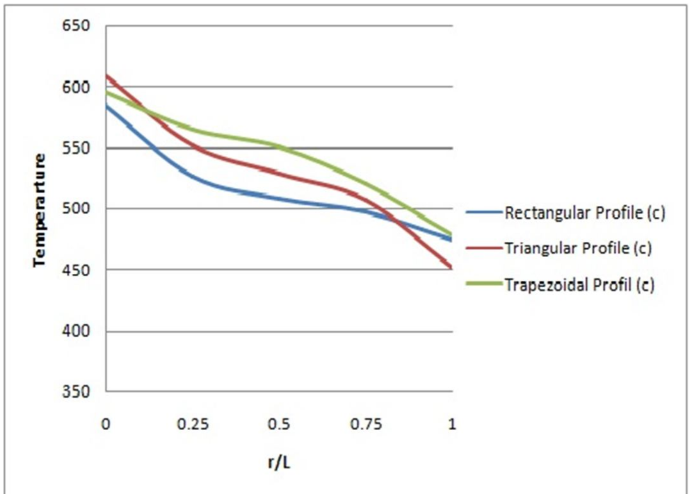
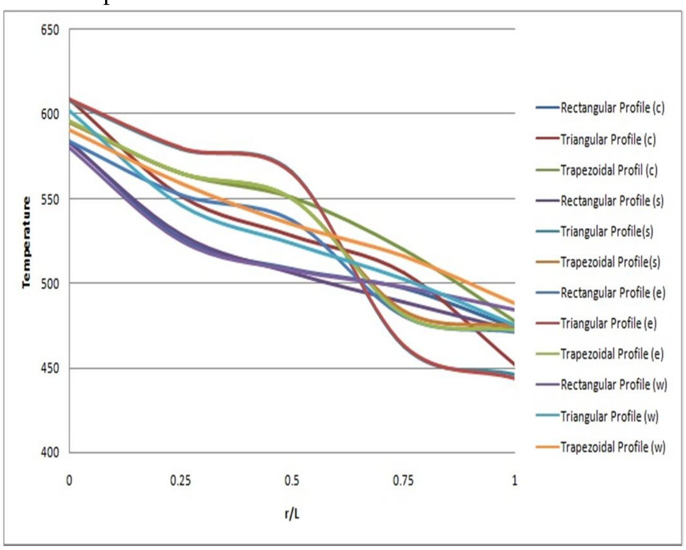
Temperature Variation with Circular Perforation



V. CONCLUSIONS

A thermal static analysis was carried out on Al Nitride annular finned-tube with different profiles to determine the temperature distribution along the length of the fin. Temperature distribution contours in case of radius ratio 1.5.



For the three different profiles are shown in Figures, and the effect of different fin profiles on the temperature distribution for various shapes of perforations are represented in the Figures.

The following conclusions can be made from analysis :

1) The temperature along the centerline is found to be maximum at the base of the fin and decreases along the length up to the tip of the fin for all the three profiles. The temperature distribution along the centerline is maximum in the case of triangular profile and minimum for rectangular profile, while that of the trapezoidal profile lies in between the triangular and rectangular profile.
2) The temperature distribution along the length of the fin for all three profiles of perforations decreases along the length up to the tip of the fin for all the three profiles and minimum temperature at tip is found to be in triangular profile with elliptical perforation.

VI. ACKNOWLEDGMENT

I wish to acknowledge the help provided by the technical and support staff in the Mechanical department of the SIRT Bhopal. I would also like to show my deep appreciation to my guide who helped me finalize my project..

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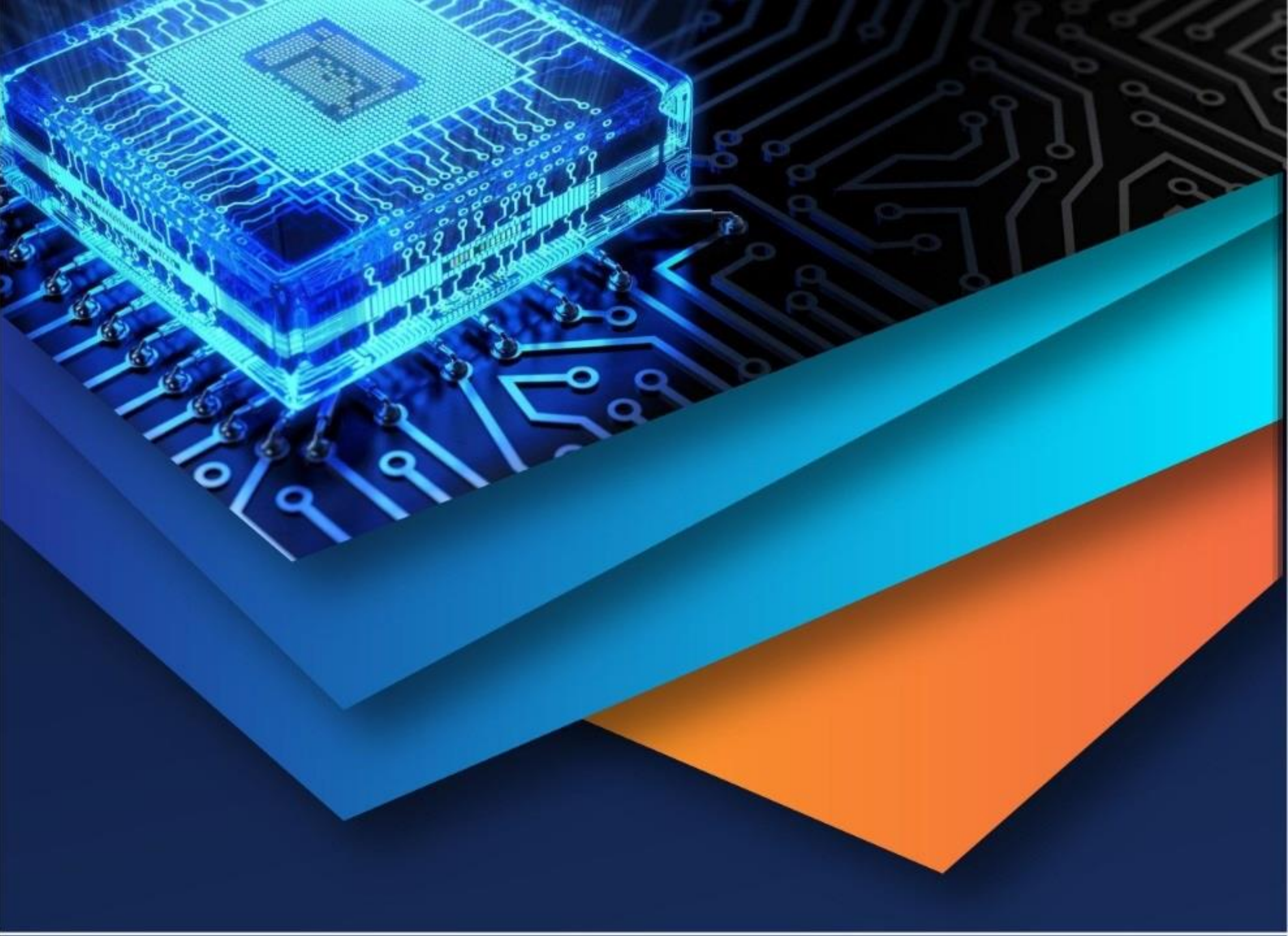

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