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Research Article

Thermal Analysis of Forced Convective Heat Transfer on Tree like Branching Fins

K Prudhvi Ravi Kumar†*, S B Prasad Vejendla#, A Ravindra† and K. Vijay‡

†Department of Mechanical Engineering, Aditya Engineering College, Surampalem-533437, AP, India
#Department of Applied Mechanics, Indian Institute of Technology, Delhi-110016, India
‡Department of Mechanical Engineering, Aditya College of Engineering and Technology, Surampalem-533437, AP, India

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Abstract

In this paper we present the thermal analysis of forced convection on tree fins with Y-shaped branching. The temperature distribution of tree shaped fins is investigated by changing the bifurcation angle for different fin materials. The study results reveals that at 90⁰ angle is effective than the 60⁰ bifurcation angle. The work is carried out by the computational fluid dynamics by using Ansys workbench.

Keywords: *Tree fins, forced convection, cfd, thermal analysis, Y- fins*

Nomenclature and units

Q =heat flow from surface, (W)
h =heat transfer coefficient (W/m^2K)
As = Surface area where convection takes (m^2)
$\Delta T = T_s - T_\infty$ (K)
T_s = surface temperature (K)
T_∞ = Ambient temperature (K)
θ = bifurcation angle (dimensionless)
h = heat transfer co-efficient (W/m^2K)
v = velocity (m/s)

1. Introduction

Fins are extensively used for enhancement of heat transfer in different applications in as radiators in cars, computer CPU heat sinks, and in power plants as a heat exchangers. The basic mode of heat transfer in fin is convection. The governing equation for the convection is $Q=h\,A_s\,(T_s-T_\infty)$.From this equation it is clear that convection is depend upon the heat transfer co-efficient, surface area and temperature difference. In general we cannot vary the temperature difference between the surfaces and the convection coefficient is already stretched to its limit, the only alternative will be to increase the effective surface area by using fins or extended surfaces. Fins are extended surfaces from the base into the cooling fluid and in direct contact with the fluid. A. Aziz 1992 Ad Kraus (1999) are extensively studied on thermal performance and geometrical optimization of extended surfaces in natural convection (A. Aziz et al, 1992; A.D. Kraus et al, 1999). Leong et al experimentally studied rectangular fins and concluded that maximum heat transfer coefficients were located at positions between 22% and 45% of the fin height measured from the base. Temperature measurements along the fin were found to be in good agreement with one-dimensional solutions for convective fin tips.

Calamas and Baker inspired from a biological tree structure tested the performance of Mesoscale which have the flow network system just as in a tree and found that the performance of the tree-shaped fins can be characterized in a similar way to traditional compact heat exchanger. The performance of these fins which were designed by considering the biological aspects taken from the trees is also examined for conjugate heat transfer. When compared with the conventional rectangular fin structures, the fins which were manufactured with biologically inspired tree-like design, provides greater surface area for the higher rate of heat transfer. Plawsky found that the thermal analysis on contracting branch structures was higher than that of expanding structures.

M.A Almogbel presented a geometric optimization technique for tree-like fins based on fin volume and material and found that global thermal conductance can be maximized. Almogbel also concluded that optimized tree-like fins offer greater thermal performance when it is compared with longitudinal optimized T-shaped fins. Lorenzini and Rocha

*Corresponding author: **K Prudhvi Ravi Kumar** is a PG scholar, email: prudhviravikumar@gmail.com.
S B Prasad Vejendla is a Jr Technical Superintendent,
A Ravindra is an associate professor and **K Vijay** is an assistant professor.

presented a numerical optimization of Y-shaped fins based on fin volume and material and through a triple optimization found Y-shaped fin structures were found to offer higher thermal performance when compared to T-shaped structures. Bejan and Dan did the analysis by considering varying conditions to optimize the geometry of the branched fins. David Calamas et al. were found that the tree shaped fins are more effective than the regular rectangular fins.

2. Computational model

The tree shaped fin has been developed and computational fluid dynamics analysis were carried out in the commercially available software. The CFD model was developed based on the data available from the literature (D. Calamas et al) in a Mesoscale. For the analysis the input values the flow velocity of the fluid is taken as v = 50 m/s, the heat transfer co-efficient is taken as 25 w/m^2 k and the fin base temperature is taken as 600 K (T_s).

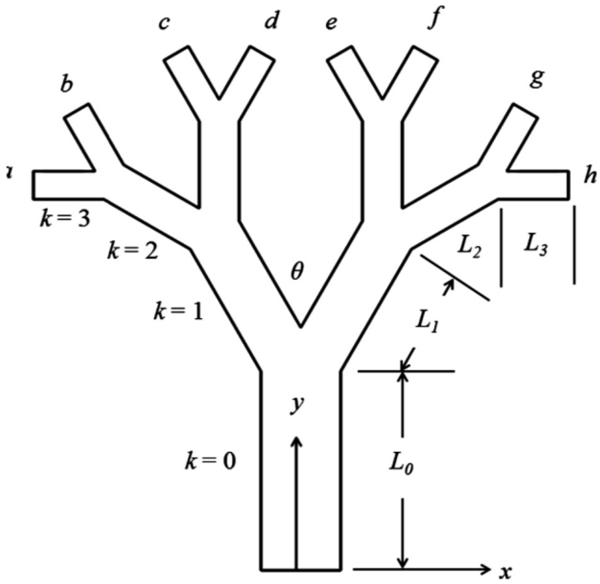


Fig.1 Tree shaped fin with bifurcation angles

Table 1 Dimensions of the Tree shaped fin

K	L (mm)	W (mm)
0	2.000	1.00
1	1.768	0.707
2	1.250	0.500
3	0.884	0.354

Tree shaped fin offer the more advantage due to the increased surface area for the forced convection heat transfer. The increased in surface areas for unit mass of the tree shaped fin offers the increased surface areas as compared to the traditionally employed fins.

3. Results and discussion

3.1 60⁰ Tree shaped fin

The **fig. 2.** Shows the temperature contour which indicates the temperature distribution through the fin. As the surface area increases by providing the bifurcation angle, the temperature at the fin tip gets decreases .The **fig. 2.** Shows that the variation of static temperature from the fin base to the fin tip.

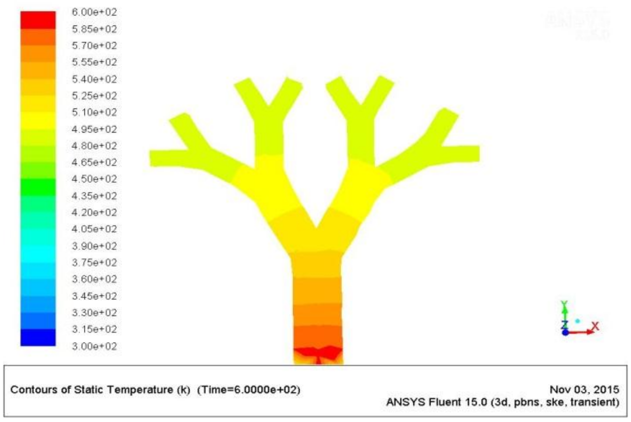


Fig.2 Static Temperature contour for 60⁰ Fin

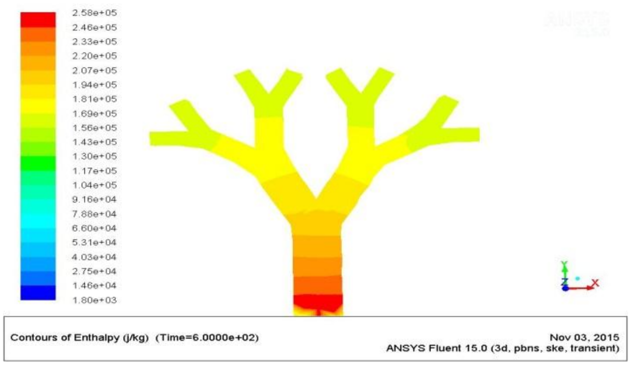


Fig. 3 Contours of Enthalpy for 60⁰ Tree shaped fin

As there is temperature variation in the fin, obviously there will be a variation in the enthalpy. If we observe the **fig. 3,** enthalpy varies from 2.58x10^5 to 1.69x10^5 J/kg.

3.2 90⁰ Tree shaped fin

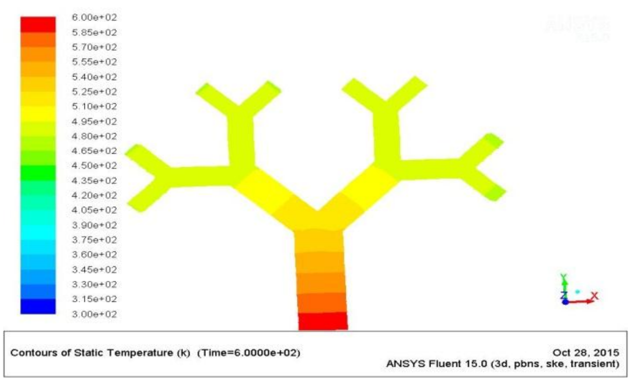


Fig.4 Static Temperature contour for 90⁰ Fin

The **fig 4.** Shows the temperature contour which indicates the temperature distribution through the fin. As the surface area increases by providing the bifurcation angle, the temperature at the fin tip gets decreases .The **fig. 4** shows that the variation of static temperature from the fin base to the fin tip.

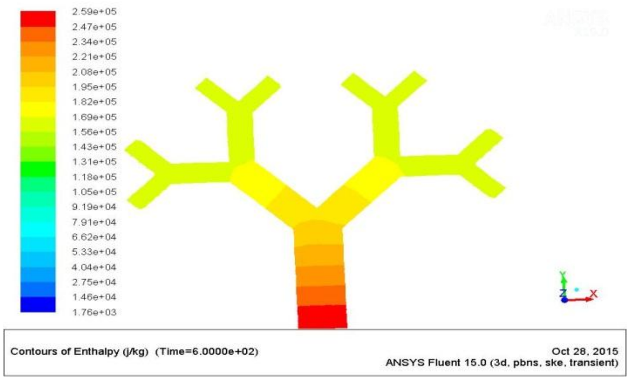
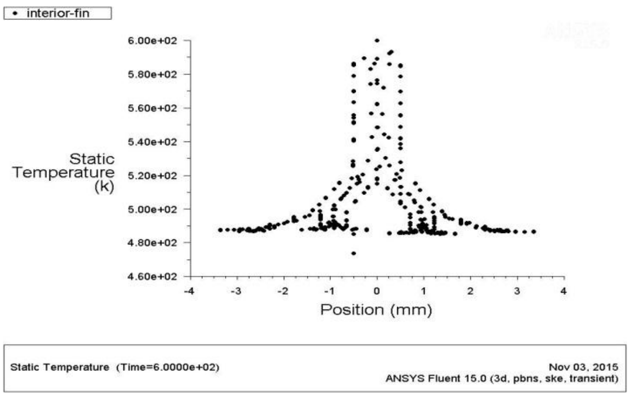


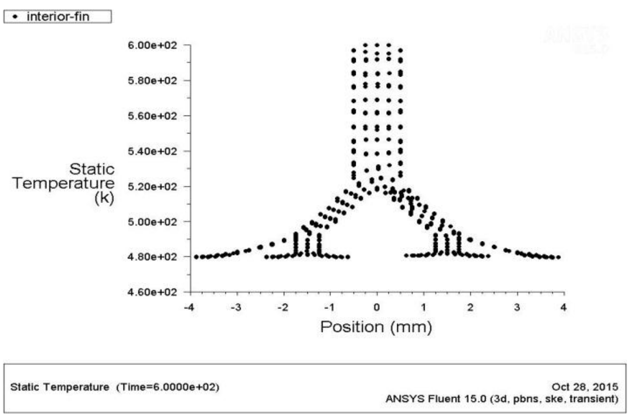
Fig.5 Contours of Enthalpy for 90^0 Tree shaped fin

As there is temperature variation in the fin, obviously there will be a variation in the enthalpy. If we observe the **fig. 5,** enthalpy varies from 2.59×10^5 to 1.69×10^5 J/kg.



Graph 1 60^0 Tree shaped fin

The **graph 1** shows that the Fin temperature drops from 600 K to 483 K.



Graph 2 90^0 Tree shaped fin

As we observe the **graph 2** the Fin temperature drops from 600 K to 478 K.

The materials also plays a major role in the temperature drop of a fin. So the analysis can also done by changing the fin materials .The analysis on fin materials aluminium, copper, carbon steel with the 1% carbon are done and the results shows carbon steel gives the better results that the other two, followed by aluminium. The detailed analysis for different materials are described in K. P. Ravi Kumar's M.Tech thesis.

Conclusion

A computational model has been developed to study the performance of Tree shaped fins for varying geometry, fin materials and the temperature distribution over the fin is noted. It was found the fallowing conclusions:

1) The surface area increases by varying the bifurcation angle of the fin which results in the temperature decrease at the fin tip.
2) The materials having the relatively high thermal conductivity will have the low temperature at the fin tip.

The investigation done on the fin materials as copper, aluminium and carbon steel with 1% carbon shows that the carbon steel gives the best results. As the cost of the carbon steel is high, aluminium which is next better material to carbon steel can be preferred as the fin material for the tree shaped fins.

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