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Thermal and Structural Analysis of Tree Shaped Fin Array

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ABSTRACT
The effective heat disbursal from surfaces using fins of various shapes and sizes has been a constant research interest. In the field of electronics, increasing the heat dissipation capacity of the fins used has been a continuous challenge for engineers. With the evolution of various structures and materials for the manufacture of fins has provided impetus to the research and experimentation. The present paper discusses the possibility of using a variant of tree fin array as a heat sink for a processor in a computer terminal. An array of Tree fins with and without slots were modelled and tested for different materials. By observing the structural deformation and temperature distribution the probable Tree fin and its material is suggested and discussed.
Keywords: Heat sink, Tree fin, fin array, slotted fins

I. INTRODUCTION
With the advent of electronic age and the miniaturisation of mother boards and processors and the sudden spurt in their usage has intensified the search for the right kind of heat dissipation mechanisms from electronic chips. The heat transfer can be increased by the three different augmentation techniques such as Passive techniques, Active techniques and Compound techniques. The active heat transfer enhancement techniques have not found commercial interest because of the capital and operating cost of the enhancement devices. A compound technique involves complex design. The majority of passive techniques employ special surface geometry or fluid additives for enhancement. Passive techniques are the best augmented techniques. Extended surfaces are widely used passive techniques to enhance heat transfer.

I. LITERATURE SURVEY
The tree shaped flow paths are the most common and visible way of distribution in the engineering as well as the real world entity propagation. The tree shaped flow paths have been put in place on the principle of global optimisation of system performance subject to global constraints [1]. The system is the volume that is covered at every point by the volume-point flow. The objective of optimisation is the minimisation of overall resistance offered by the volume-point flow. The global constraints being, the fixed system volume and the fixed volume fraction occupied by the channels.

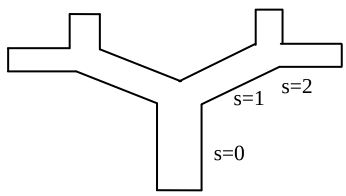
Thermal performance and mass minimisation of extended surfaces was studied for rectangular, pin and triangular shaped arrays for effective heat dissipation from various surfaces by different convection models natural and forced[3,4,5,6,]. With the availability of various advanced materials and methodologies of transport and thermal media deposition, the landscape of heat dissipation has changed.

A systematic theoretical investigation of the effects of fin spacing, fin height, fin length and temperature difference between fin and surroundings on the free convection heat transfer from horizontal fin arrays was carried out with a parametric study to ascertain optimum performance, this performance was analysed and shown that it cannot be obtained from one or two parameters[10]. Experimental investigations on pin-fin arrays subjected to forced convection environments to find the dependencies of nusselt number on Reynolds number yielded good results [11].

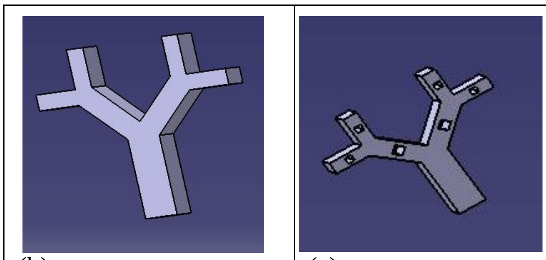
The effect of free convective heat transfer from fins and fin arrays attached to a heated horizontal base was experimentally studied [9]. The technique of differential interferometry has been utilised and experiments have been carried out under steady state conditions. Local values of heat flux, temperature, heat transfer coefficients, and local, overall Nusselt numbers have been estimated.

The utilisation of tree shaped fins for effective heat dissipation in space environment was studied [7]. This paper discusses variations in a tree shaped fin and for various materials keeping volume constant. The usages of rectangular fins in the heat sink used for the processor were proved to be of lower heat conducting capability than the tree fins.

II. DESIGN AND MODELLING



(a)



(b) (c)

Figure 1: (a)Sketch of the proposed tree fin (b)Tree fin without slots (c)Tree fin with slots

Table 1: Dimensions of given to the tree fin

Stem Number(s)	Length (cm)	Width (cm)	Depth (cm)	Slot dimensions (cmx cm)
0	2.50	1.0	0.50	None
1	1.77	0.71	0.50	0.355x 0.355
2	1.25	0.50	0.50	0.25x0. 25

The selection of tree fins with three stems is selected with the angle between the stems taken as 90^0 as has been reported to be the best when considering other angles of 30 and 60[7]. The usage of fins with the above said angle and structure is considered for heat dissipation from the electronic devices and other heat generating components. A plate of 10 cm X 10 cm X 1 cm is created with a heat source on one of the 10 cm X 10cm surface and two sets of five fins each were placed on the other side of plate. The fins were placed equidistant from the edges on two sides of the surface. This placement of the fins provides a place for the locking of the plate onto the heat generating chip. An analysis of the fins attached to the surface was done for varying temperatures being generated by the heat generating chip at 75^0 C, 85^0 C and 95^0 C. These temperatures were selected according to the amount of heat being generated by the electronic equipment (processor) in a computer.

The usage of slots in the fins generated is also analysed by placing slots on all the stems except the main one so as to enhance the heat reliving capability of the fins. The structural stability of the fins thus generated was also done to show that the fins are viable for usage. The analysis of the slotted fins is also done for the above mentioned three different temperatures.

Further the usage of different metals in the manufacture of these fins is also analysed for presenting a usable material for the fins. The different materials used in the analysis of the fins are aluminium alloy, copper alloy and stainless steel. These materials were selected on the cost of procurement and manufacture of the fins.

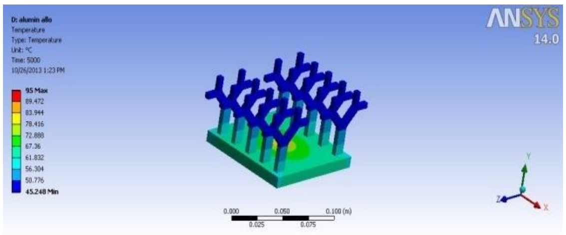
The structural deformation was done for the condition of highest temperature as that would be the maximum temperature to which the setup will be exposed and the findings will help in designing.

Each fin stands at a height of 5.5 cm above the base of 1 cm and the temperatures in the range of 75^0 to 95^0 are chosen keeping in mind the processor a computer terminal.

III. RESULTS AND DISCUSSION

4.1 Thermal Analysis

The modelling and analysis of an array of ten fins placed on a slab is done for natural convection. Different materials like aluminium alloy, copper alloy and structural steel were chosen as fin materials and respective base temperatures are varied from 75^0C to 95^0C with an increment of 10^0C.



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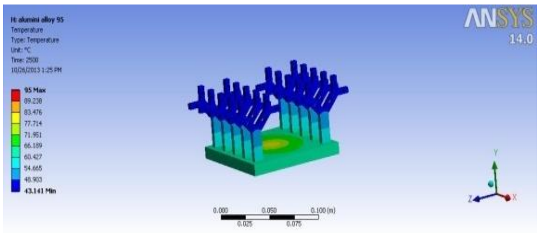
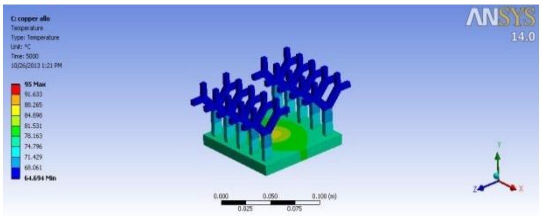


(b)

Figure 5: Aluminium alloy fin array (a)without and (b)with slots at 95^0 C



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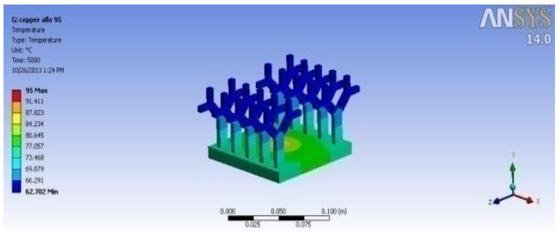
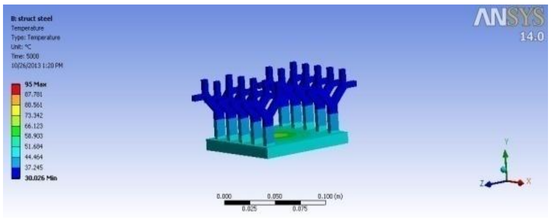


(b)

Figure 6: Copper alloy fin array (a)without and (b)with slots at 95^0 C



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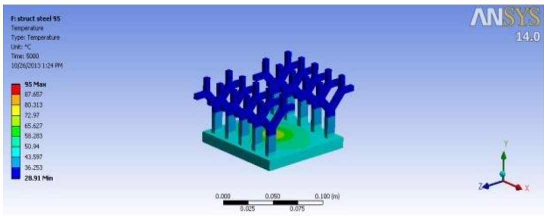

(b)

Figure 7: Structural steel fin array (a)without and (b)with slots at 95^{0}C

The figures 2, 3 and 4 represents temperature distribution of different materials (copper alloy, structural steel and aluminium alloy) for the Tree fins with and without slots at a chip temperature of 95^{0}C.

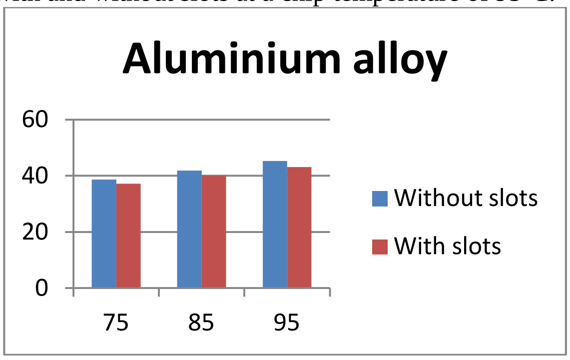

Figure 5: Graph illustrating the minimum temperatures attained by fins without slots and with slots at various chip temperatures for Aluminium alloy

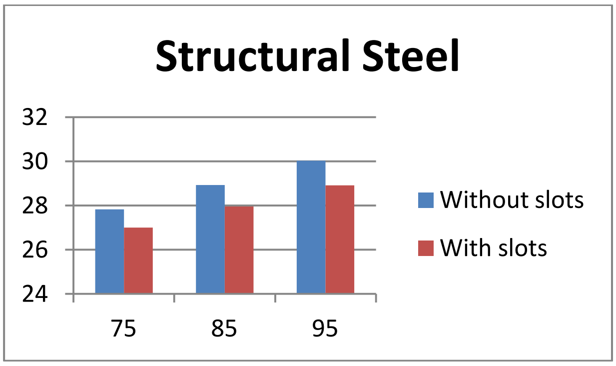

Figure 6: Graph illustrating the minimum temperatures attained by fins without slots and with slots at various chip temperatures for Structural Steel

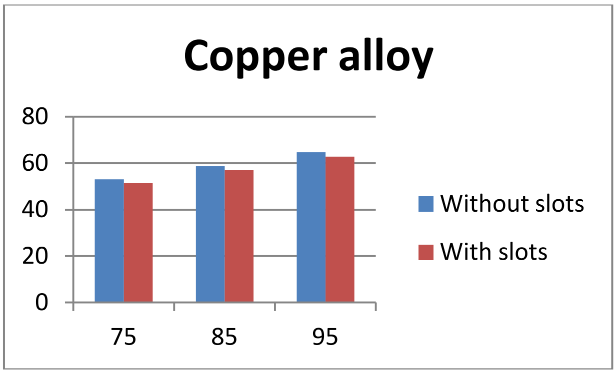

Figure 7: Graph illustrating the minimum temperatures attained by fins without slots and with slots at various chip temperatures for Copper alloy

Minimum temperatures attained by different fin materials in the shape of tree at different chip temperatures are plotted (figure 5, 6 and 7). It is illustrative from the graphs that fins with slots were having minimum temperatures compared to fins without slots due to increase in effective heat transfer surface area (64.694^{0}C without slots and 62.702^{0}C when slots are present on the stems of the tree fin made of copper alloy at a chip temperature of 95^{0}C).

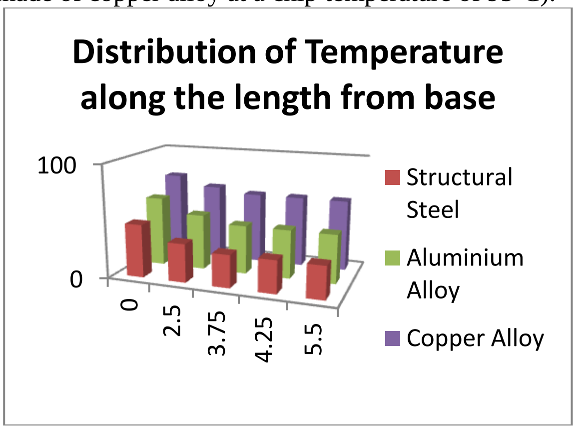

Figure 8: Temperatures attained by the fin along the length from base

Fig. 8 shows temperatures variations along the fin length for different materials. Copper alloy attains maximum temperature at different lengths due to high thermal conductivity (k = 410 w/mK) compared to aluminium alloy (k=156 w/mK) and structural steel (k= 56 w/mK). Due to this high thermal conductivity copper alloy has a better capability to dissipate heat from surface.

4.2 STRUCTURAL ANALYSIS

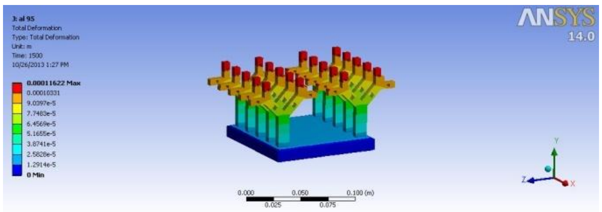

Figure 9: Aluminium alloy fin array deformation with slots at 95^{0}C

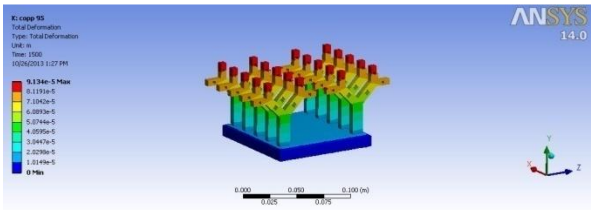

Figure 10: Copper alloy fin array deformation with slots at 95^0 C

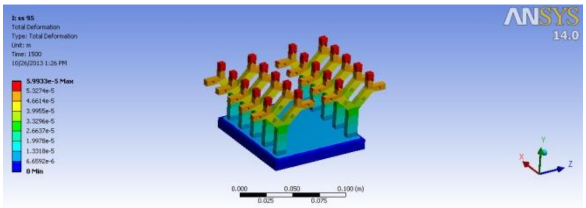

Figure 11: Structural steel fin array deformation with slots at 95^0 C

The above figures show the structural analysis performed on array of fins for different kinds of materials at a temperature of 95^0C keeping the base locked. The deformation obtained was in the acceptable range (<0.1 mm) at the free end.

IV. CONCLUSIONS

The array of tree fins with slots has a better heat transfer capability when compared to a tree fin without slots. Copper alloy is best among the analysed materials, but owing to the cost, weight, availability and other factors aluminium alloy is recommended.

The deformations of the various materials compared, have shown that slotted tree fins are in acceptable range to the given heat inputs (a maximum of 95^0C being the upper limit for a processor).

Aluminium alloy can be used in the shape of tree fins with slots as a heat sink for an effective transfer of heat being generated and will not deform much at the given temperatures.

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