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# Heat transfer from different types of fins with notches with varying materials to enhance rate of heat transfer a Review

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**Abstract**

Fins are often used to act as an a betterment technique to give rise in heat transfer rate from the system to the environment which can be stated that it is an essential thermal working system which is being used for cooling purposes in various fields as per the need. So, for effective and efficient results the appropriate selection of fins on the basis of their material selection, designing and other parameters should take into consideration so that the main principle objective should be achieved. It has been noticed that fins with groves or notches gives the best results reducing in cost of the material so here in this paper we have discussed various designs of fins with detailed research papers to study the optimized heat transfer rate with different materials. Material also plays an important role so for dissipation of heat process

## Introduction

The convective heat transfer leans on heat transfer coefficient and surface area available for convection. Many researchers have studied heat transfer through fins with different geometries notched and UN notched geometries as well. This was done by both numerical and computational orientations and the maximum heat transfer by convection was usually obtained in trapezoidal or rectangular geometries according to the development of the geometry. The materials used for fins geometry was the purest form of aluminum. This paper will provide on the functions of notches with different shapes sizes with varying the materials to achieve the optimum increment in the heat transfer rate. Also the proper selection of extended surfaces depends on how the modifications in geometries of fins is done like groves dent marks and various notches which however results in enhancement of heat transfer.

As we know that of the two types of fins notched and un-notched and we know that the notched fins are delivers more heat transfer as that of un-notched fins. The notch is also further classified as inverted and out-averted notches. In convective heat transfer due to the single chimney pattern flow on horizontal array fins the stagnation zone is developed which leads to the inefficiency so to outcome this inefficiency the some part of the area of is removed to increase the heat transfer rate.

## Literature review

Fins may be consider as a form of heat exchanger that represents the flow of heat transfer from a medium to the atmosphere here several research have been done and the main motive of this paper is to attain the goal of particular study and then to examine in which field of operations is to be carried out. The object of this study is to analyze various studies and establish the best approaches of them so initially Jain and Aurangabadkar[1] analyzed heat transfer and optimization of fins by variation in geometry they examined heat transfer coefffient through fins through various geometries which were rectangular, circular and triangular with rectangular and trapezoidal extensions. The investigation was done computationally in following software's which was CREO parametric and ANSYS 14.5.The materials used for fins was Aluminum Alloy 6061 which is presently having highest thermal conductivity 160-170w/m$^2$. The analysis was performed by varying different base temperatures of fins which is shown below. which is shown below.

**Table 1** shows efficiency and effectiveness at different base temperature[1]

| Base temperature (ºC) | Temperature at the tip of fn (℃) | $Q_{fin}$ (W) | Efficiency η | Effectiveness ε |
|---|---|---|---|---|
| 100 | 93.979 | 11.04 | 79.47 | 17 |
| 80 | 75.527 | 8.016 | 77.55 | 17 |
| 60 | 57.148 | 4.99 | 78.62 | 17 |

Here in this table at three instinct base temperatures the variable in efficiency is seen with that of constant effectiveness as shown, further with different geometries the values are examined as shown in table 1.2

**Table 2** shows the rectangular fins with rectangular extensions and circular fins and heat dissipation rate.[1]

| Fin shape | Rectangular fin | Rectangular fin with rectangular notches | Circular fins |
|---|---|---|---|
| Temperature at base (°C) | 100 | 100 | 100 |
| $Q_{fin}$ (W) | 11.04 | 11.84 | 8.90 |
| Efficiency η | 79.47 | 94.4 | 68.87 |
| Effectiveness ε | 17 | 13 | 13 |

So here fins with triangular shaped has the more efficiency as compared to others. Now here in this paper the analysis done by using notched in fin geometries it is noticed that notches in fins also leads to effective results in heat transfer rate The enhancement of heat transfer rate is done vastly by creating numerous geometries by creating notches or grooves so with this aspect analysis done by , K.Sathishkumar et al**.**[2] Computational Analysis of Heat Transfer through fins with different types of notches in this paper they analyzed air as fluid medium used as an cooling purpose of fins with different notches of material aluminum. The idolizing of different notches is to get the differences in heat transfer rate at this notches by using ANSYS-CFD FLUENT SOFTWARE .They analyzed by taking fins with rectangular notches, v shaped notched and fins with holes. So the postulations stated that fin having rectangular notch has the highest heat transfer as compare to others which cease that the rectangular notch fins has the highest efficiency compared with the others.

As noticed that notches increases the heat dissipation rate to the fins and implements its operational work which is to be used so taking this into consideration experimental setup was done of inverted notches was done by S Dixit et al.[3] in this paper Numerical analysis of inverted notched fin array using natural convection they examined that in an rectangular array a new parameters arises which are how much area removed in the form of inverted notch, length of fin, height of fin are the parameters which is taken into considerations. This analysis was also done in CFD FLUENT .So the results after investigating enhanced that the fins with triangular notch has the maximum heat transfer coefficient followed by the trapezoidal and rectangular fins. Fins are most efficient with aluminum material so the experimental analysis has been set and different materials are used to analyses the results. The aluminum alloy has been taken vastly so contrary with these material brass with modifications is done by Chavan et al.[.4] in this paper Thermal analysis of Pin Fin using different materials and forms they performed analysis using brass and other two having modifications in brass that of knurling and holes in it and compared with normal aluminum alloy and the results obtained by using different materials of fin through experimental set up followed by experimenting a number of fins the results obtained were:

| Sr No | Material | $\Delta h_{w\,(cm)}$ | $R_e$ | ε | η |
|---|---|---|---|---|---|
| 1 | Brass | 80 | 207.143 | 32.643 | 79.726 |
| | | 60 | 177.737 | 33.035 | 80.683 |
| | | 40 | 144.62 | 33.592 | 82.043 |
| | | 20 | 102.024 | 34.485 | 84.223 |
| 2 | Brass with knurling | 80 | 207.351 | 32.646 | 79.733 |
| | | 60 | 179.006 | 33.056 | 80.732 |
| | | 40 | 145.337 | 33.605 | 82.075 |
| | | 20 | 102.262 | 34.492 | 84.242 |
| 3 | Brass with holes | 80 | 209.099 | 32.672 | 70.642 |
| | | 60 | 178.351 | 33.045 | 71.447 |
| | | 40 | 145.087 | 33.601 | 72.689 |
| | | 20 | 102.389 | 34.495 | 74.583 |
| 4 | Aluminium | 80 | 205.386 | 36.337 | 88.746 |
| | | 60 | 176.59 | 36.588 | 89.359 |
| | | 40 | 143.49 | 36.93 | 90.195 |
| | | 20 | 101.039 | 37.471 | 91.518 |

**Figure 1**: Results concluded [4]

Whereas it can be concluded that that as the Reynolds number increases the decreasing value of efficiency and effectiveness is observed. Also it has observed that using brass with various modifications does not affect much to the fins efficiency. The fins with groves,holes and notches has been seen many a time to the leading heat transfer increment so the finned tube with perforations is been performed by M .Zaidan et al [5] in this paper Assessment of heat transfer and fluid flow characteristics within finned flat tube they examined and estimated the flow characteristic of air over finned tube without and with perforations. The analysis done n ANSYS 15.2 with ring k-e turbulence model to analyses the heat transfer coefficient and pressure drop. Also the 3, 4,5,6,7 m/s free stream velocities and the figures used are shown below

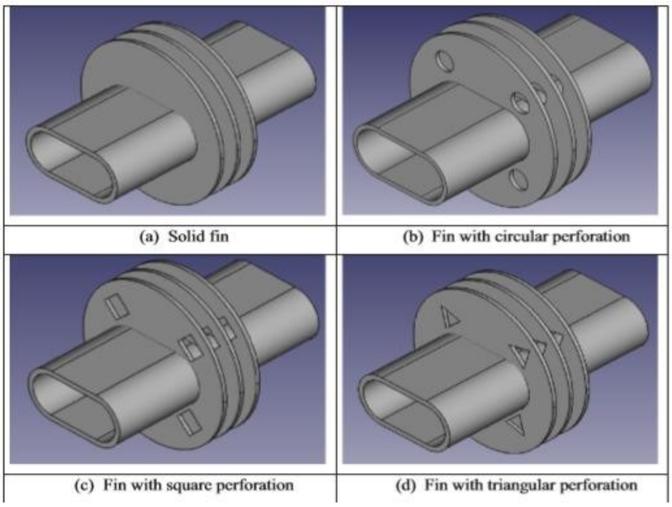
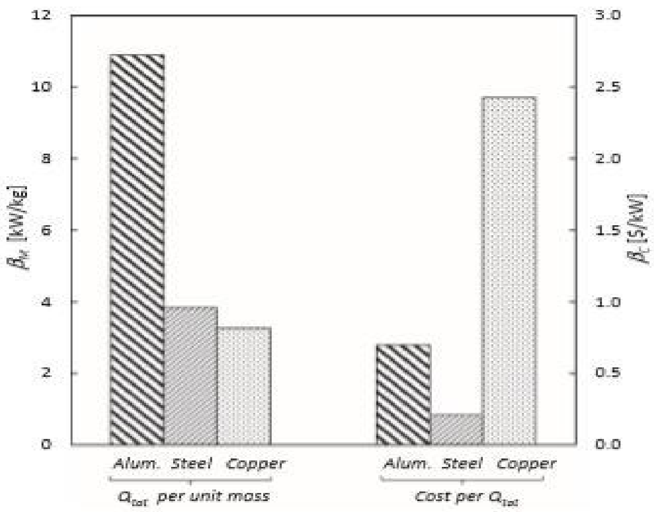



**Figure 2:** fins with different perforations [5]

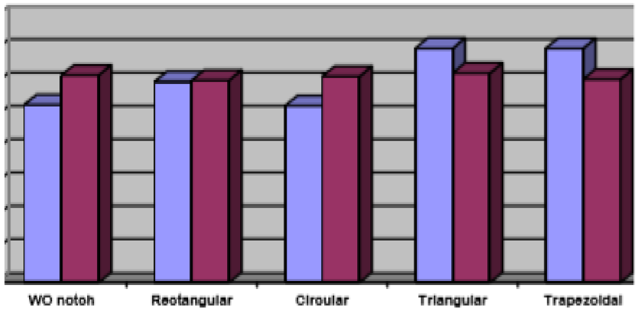
The results displayed that the flat finned perforations has more heat transfer than that of circular perforations and to that of triangular perforations also enhanced with greater heat transfer results. To further increase in the field of heat transfer research done by A.Hussein, et al.[6] in this paper on Numerical Investigation of heat transfer enhancement in plate-fin heat sinks: Effect of flow and fillet profile they examined the the thermal performance of rectangular fins with the fillet profile by CFD analysis. In the analysis it showed the development of flow direction and fillet profile on the thermal performance of plate fin i.e. rectangular fins. In a specific profile thaw parallel flow direction has been correlated with geometry design and the fair results has been obtained. For flat plate fins the thermal performance subjected to parallel flow with fillet profile and without profile carried through CFD analysis for non-fillet profile the experimental literature was done. So the maximum difference between the fillet profile and non-fillet profile were 8.8% and 12.4% for pressure drop and the thermal resistance for same conditions. The fillet profile were subjected to different conditions which gave the results that the effect of fillet profile by altering the flow direction had an eminent change in thermal performances of heat sink To improve above understandings experimentation done by N.A.Nawale et al.[7] in this paper On Heat Transfer through Fins Having Different Notches the experimental setup of vertical rectangular fins array without and with notch has been revieved. The notches are of different geometries for the purpose of comparison. By doing an experimental setup for obvious the heat transfer for triangular notched fin array attained the maximum value. The material selected for the fins was Aluminum. Also the fins with triangular notch were having several differential heights the notch with the maximum height had the highest heat transfer coefficient. For more accuracy and effective cost of the materials used for fins here more explicitly the fins are used with different materials and compared by. A.M .Gonzalez, et al.[8] here authors tells about a hybrid numerical-experimental analysis of heat transfer by forced convection in plate-finned heat exchangers here the fins materials are aluminum, carbon steel and copper. The airflow velocity i.e. Reynolds number is characterized depending upon the fins materials and heat transfer coefficient is analyzed.

**Table 3**: Graphical representation between mass and cost[8]




Here both experimental and numerical analysis is done to analyses the overall fin efficiency, η , and averaged convective heat transfer coefficient ,h by M Mashud et al.[9] in their paper Experimental Investigation of Heat Transfer of Cylindrical Fins with Different Grooves has examined experimentally the effect of pressure drop and heat transfer on cylindrical fins with various geometries. The uniform cylindrical fin withother two cylindrical fins with circular grooves and threads on the other side are examined experimentally. The results showed that the cylindrical grooved fins loses 1.23 times of heat loss compared to threaded fins and 2.17 times to that of solid pin fin at lower pressure. As the pressure losses the radiated heat transfer of the total heat transfer coefficient increases. Besides analysis performing the effect of geometries in increment of heat flux the extensions in fins also plays a vital role in heat dissipation rate which is shown by P Singh et al.[10] in this research paper heat transfer through fins with various extended geometries like rectangular, circular, triangular, trapezium. Also the heat transfer through this extensions and without extensions are compared thoroughly. As done the numerical analysis on Ansys the fins with rectangular extended surface has more transfer rate as compared to without extensions and other extended surfaces. This implies that the fins with rectangular extensions has higher effectiveness. For fins due to the pressure variance a chimney flow pattern is being developed in the base cross sectional area. This area generates an inactive zone over bottom area .this inactive generation due to the pressure difference does not contribute much for heat transfer so this much area are been extracted and the new geometry becomes the inverted notched fins. When the extracted area is removed from the fins with this problem a stagnant zone arises and at the base the fins are notched this analysis is done experimentally by .R Thakur et al.[11] here research carried out in Natural Convection Heat transfer by Heated Plate using Different types of Notched Fin arrays they experimentally analysed fins plate with inverted notched through four distinct area in by 10, 20, 30, 40% and carried out the heat transfer . The results they observed that as the area of notched increases the heat transfer rate also increases this factor depends on down and upside notches. Hence the maximum the area notched the heat transfer will increase and pressure drops. Furthermore research was done for performing best of the results so Mane et al.[12] did a review on Heat Transfer from Different Types of Notch Fin Arrays under forced convection to increase heat energy transfer in this paper they showed the importance of use of fins for heat transfer in present aspect becoming more advanced and that is done making fins with several geometries and through that the notched fins arrays will have more transfer coefficient than that of others fins geometries. So they concluded that fin with inverted notch will have the maximum heat transfer coefficient. Several studies showed the comparisons of fins with different notches here the comparison is done between experimentation and computational analysis S.H.Barhatte, et al.[13] carried an Experimental and Computational Analysis and Optimization for Heat transfer through fins with Different types of notches. Experimental analysis was compared with the computational analysis of three different fins arrays with notches. The results revealed that the rate of transfer can be increased with increasing the surrounding fluid. The heat transfer through triangular notch has the maximum value and reviewed by both experimentally and computationally.

**Table 4**: Comparison of heat transfer by CFD and that of by experiments [1]




Nakadi et al.[14] they experimentally investigated heat transfer from fins with various geometries and took fins material of Aluminum in purest form. The geometries were rectangular fin UN notched, circular notch, and triangular square and combined notch. After performing the experimental set up they concluded that the fins with combined geometry has the maximum value. Also the temperature distribution for fins with notches are steady as compared to without notched fins. Contrary to this to improve the above papers understandings for betterment of heat transfer the stagnant region is removed and inverted notch analysis is done by S M.Wange, R.M.Metkar[15] in this paper Computational analysis of inverted notched fin arrays dissipating heat by Natural Convection they examined the CFD analysis of inverted notch fins using pure Aluminum material for fins. Hence for fins laminar natural convection is the cause of heat transfer. By doing analysis in CFD model they also got the same results. The higher the notched area the higher is the heat transfer coefficients. Here for natural convection this paper tells about other parameters which rely on thermal performance of heat sinks so the orientation of heat sink here has changed and the analysis taken by More et al.[16] Performance Evaluation of Inverted Triangular Notch and Trapezoidal plate fins with Natural convection in this research they examined the cylindrical heat sink with vertical and horizontal orientation. The heat sink fins were notched and un-notched and trapezoidal plate fins and which can be of various geometries. Such arrangements of cylindrical heat sink are set up in LED light bulb. The heat sink for vertical and horizontal orientations with notched and UN notched and flat trapezoidal by varying set up the calculations and results are taken out. The results showed that for notched fins the overall increase in heat transfer for horizontal orientation is 11%. The heat transfer increment for vertical orientation between trapezoidal and UN notched is 29%. As we all know the effect of geometry of fins that leads to changes in the results at same context it matters a lot that of thickness to the calculations and results this analysis is shown in this paper by Devender.J et al.[17] Effect of geometry, material and thickness of fin on engine cylinder fins in this research work they examined different types of fins geometries which was rectangular and triangular for the purpose of heat flux and temperature distribution in two wheelers engine cylinders. They also used three different types of aluminum alloy, namely Alloy 2014, alloy 6061 and alloy 2024.

They also used different thickness for fins they was 2.5mm, 3mm and 3.5mm. So by varying all this parameters total 18 models were developed and executed in ANSYS 16.2. Then meshing was done to get the effective results for temperature distribution and heat flux. The results showed that temperature distribution for cylinder with rectangular fin of 3.5mm fin thickness for Aluminum Alloy 2014 is maximum and minimum for triangular fin of 2.5mm thickness. Also for alloy 2014 of rectangular fin of 2.5 mm thickness the heat flux was maximum and minimum for alloy 2024 of triangular fin with thickness 3.5mm. At the tips of both the fins the temperature increases with increasing thickness.

**Extended surface**

The term extended surface is used to characterize an essential special cause involving heat transfer by conduction within a solid and heat transfer by convection from the boundaries of solids. Extended surface are also needed just to increase the convection rate by increasing its Area. The rate of heat transfer from a surface at a temperature T so to the surrounding is given by Newton's law of cooling

$$Q=hAs(T_S-T_O)$$

**Fins**

Fins are used for enhancing the heat transfer rate by extending the surface area. The main aim is to provide the temperature distribution over the fins. Also to quantify the heat transfer taking place over it. They should have large thermal conductivity so as to minimize the temperature distributions from its base to its tips. Therefore fins are provided on the surface of the system to increase heat transfer. Some applications are as follows :

- Engine heads of motorcycles.,Condensers, evaporators &heat exchangers,Electrical supplies transformers

**Various geometries**

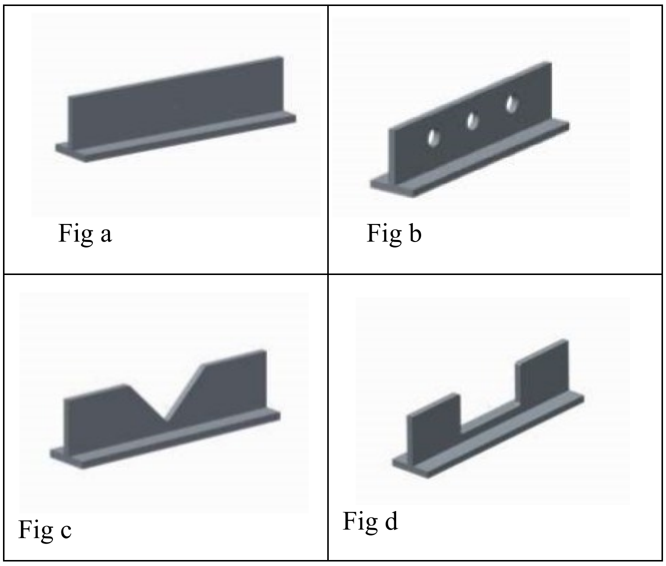



**Figure 3 :**The above figures represented by a,b,c,d shows different geometries which are generally used for analyzing and experimentations [2].

**Mathematical Methodology**

Mathematical analysis is also important to carry out an research with respect to analysis of heat transfer essential elements used for calculations are been shown by mathematical formulae which are given

- For calculating of whole body [12]

$$T\,(body) = \frac{Tb+Tf}{2}$$

- Temperature of whole body and surrounding temperature is given by [12]

$$\nabla T = T\ body - Tchamber\ ^{o}c$$

- Coefficient of expansion is given by [10]

$$\beta = \frac{1}{T_{mf}}$$

- The heat transfer coeffienct is given by

$$h = \frac{Nusselt\ number.\ k}{l_c}$$

**Material selection**

Here we will be using different materials for the analysis of fins heat transfer and the material are:

**Table 5**: The table represents the properties of two distinct materials shown which are generally been used for analysis and aluminum alloy is widely used for fins [2]

| MATERIAL PROPERTY | STRUCTURAL STEEL | ALUMINUM ALLOY |
|---|---|---|
| Density | 7850 kg / $m^3$ | 2714 kg / $m^3$ |
| Thermal conductivity | 60.5 W/m-k | 202.399 W/m-k |
| Specific heat | 434 J/kg-k | 871 J/kg-k |
| Young's modulus | 2e+11 Pa | 3.4e$^{+}$011 Pa |
| Poisson's ratio | 0.3 | 0.22 |
| Bulk modulus | 1.6667 e+011 Pa | 2.0238e$^{+}$011 Pa |
| Shear modulus | 7.6923e+011 Pa | 1.3934e$^{+}$011 Pa |

**Research gap**

All above authors have discussed about several study on fins regarding increment of heat transfer , K.Sathishkumar et al. [2] they have studied about different geometries of fins used in engine by taking aluminum alloy material and carried out heat transfer variations here we are going to take similar geometries but with material structural steel and the results will be comparing with aluminum alloy so with these will come to know about the material which will be suitable at cost effectiveness and various other parameters

**Conclusion**

It can be stated that numerous study has been done in fins with various designs shapes and materials that cause the heat transfer rate to an increasing factor in many operations for both experimental and computational analysis. In our knowledge very limited work has been done on fins having mixed notches with copper or cast iron as a material used for fins. Here then, the notches will of mixed in varieties of shapes that helps to raise heat transfer coefficient. This performance can also done by experimental setup also and finite element analysis and the results implies the thermal behavior of the different fins with various materials.

Results will represent that which of the fins geometry with materials would be utilized for the better optimization of heat transfer rate. This can be applied to the applications of fins and through this investigation it can be stated by implementing notches in the design of fins leads to the dissipation of heat from surface.

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