Comparative analysis on heat transfer of various fin profile using solid works: A systematic review

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Abstract. Fins are widely used to enhance the amount of heat transfer by improving the rate of convection heat transfer. Fins are also known as extended surfaces, i.e., extrusions from the object surface. There are numerous kinds of fins, and based on the shape and size, the amount of heat transfer through the fins will differ. Heat transfer depends upon the geometry of the fin and depends upon a number of factors such as the nature of the fin surface, the ambient temperature; the velocity of the air, etc. In this present study, the systematic review is carried out by critically analyzing the different types of fin profile such as plain rectangular fin, wavy fin, circular pin fin, and rectangular pin fin to increase the fins efficiency. The outcome from this study reveals that the heat transferred by the fins is mainly dependent on the fins profile (type and shape), length, angle, and surface area. Alongside the orientation of the fins, porosity, thermo-geometry also affects the fins' efficiency.

Keywords: Heat transfer analysis; Fin efficiency; Fin configuration; Solid Works

1. Introduction
Fins also called extended surfaces (substances) that are mainly used in enhancing heat transfer (HT). Fins are used in many different industries to control the heat in the industry. Fins are also mainly used in electrical appliances such as power stations, computers, and substation transformers. Additionally, it is also used in cooling systems in IC engines such as car radiators. To get a proper Fin geometry that will control/transfer the heat generated by the system, one must arrive at the approximate temperature distribution. The geometry of the fin which offers maximum effectiveness and economy is of best use. With the help of the Runge-Kutta method, it was found that Si3N4 material with exponentially shaped fins performs better HT among other three metals, Cu, Al, and SiC. Fins are generally made up of copper and aluminum due to their higher and efficient heat absorption rate as well thermal conductivity. HT analysis is affected by the fin's thermo-geometric parameters, which was proved by Hatami et al., who worked with porous fins made of Si3N4 and AL. The total weight of the fin is supposed to be proportional to the ratio of material density to thermal conductivity. Cast iron is also seen as a material used to create fins axis possesses high fluidity, and hence it is easily cast into any thin sections and also in complex shapes. Rectangular fins are extended surfaces from a cylinder that is used for heat removal.

The HT (conduction) from the wall surface (inner) to fin tip surface is given as (equation (1)): 
\[ q = \frac{k(T_w - T_{fin})}{L} \]  

(1)

The convection HT from the surface of the fin to atmospheric air is given as (equation (2)):

\[ q_f = h(T_w - T_{fin}) \]  

(2)

The HT rate for rectangular profile fin geometry is given by (equation (3)):

\[ q_f = m\left(\frac{\sin hml + \frac{h}{mk}\cosh ml}{\cosh ml + \frac{h}{mk}\sinh ml}\right) \]  

(3)

Where \( m^2 = \frac{hP}{kA} \).

On the other hand, Triangular HT is also an extended surface from the cylinder but is used for heat distribution (equation (4)):

\[ q_f = \frac{w\sqrt{2ht}(t_0 - t_{\infty})\left(I_1(2\beta\sqrt{t})\right)}{(I_0(2\beta\sqrt{t}))} \]  

(4)

Where \( \beta^2 = \frac{2hl}{kt} \)

L = Fin length (m); w = Fin Width (m); h = Convective HT coefficient (W/m²K); k = Thermal conductivity (W/mK); P = Fin perimeter (m); q = Rate of heat loss from fin (W); T(fin) = Surface temperature of fin (K); A = Area of cross-sectional the fin (m²); b = Bessel Function; t (0) = Fin’s basal temperature (C); t (a) = Ambient temperature of fin (C); t = Thickness fin (m); T(w) = cylinder wall temperature (K); A = Area of cross-sectional the fin (m²).

2. SR Research Methodology:

The SR study, also known as the systematic review study, deals with systematic identification, classification, and work to find new evidence from all the research papers or publications. By conducting this SR study, with the use of the guidelines provided by the SR study, we have an aim to discuss the effect of fins in HT and how the thermal properties change based on the length of the fins, angle of the fins, the area covered by the fins, where it is used (i.e., the application it is used for) and the shape or type of the fins used.

The SR research method comprises of the following steps:

1) Planning for the Systematic Review study:

Given below are the protocols that have to be followed while doing a systematic review:

a) To properly define the research goals and find the different research questions that had to be answered.

b) Explanation of the methods used for searching and selecting the data and explaining how the data extraction is done.

c) Finding the potential validity threats.

d) Allocating tasks amongst the authors

2) Conducting the Systematic Review:
These are the steps taken during the execution of the systematic review protocol:

a) Meticulously searching for the main studies (primary)
b) Selecting the main studies by checking the validity and the coherence of the given content with the selected title.
c) Extracting data and adequately analysing the selected primary studies.

3) Reporting the Systematic Review results:

In the systematic review, we have adequately evaluated all the findings regarding the research questions put forward. Subsequently, the essential findings and limitations are reported and discussed the open opportunity for future researchers. The following subsections give extensive information regarding the principal undertaking of the Systematic Review protocol used.

2.1. Goal and Research Questions

2.1.1. Search Strategy. There are many different forms of research papers, and to find those, some steps are involved for identifying, collecting, and summarization of all the existing evidence. To find those research papers which were related to our systematic review, we have used four different electronic data sources (EDS), which are as follows: Mendeley, Scopus, and Google scholar. These different EDS platforms are where we specifically found the details in the field of (OUR TOPIC NAME). We then started our project by searching for specific keywords we took from our defined research questions; as a result, we found many different research papers.

In those electronic data sources (EDS) mentioned above, we conducted several searches until we found the papers which had the most accurate answers to our research questions. A top-down sequential process was used so that only the relevant or appropriate research studies are considered. The method mentioned above was also applied to include only the relevant research papers.

The data extraction process was carried out to ensure the relevance of the papers identified and to check the papers' validity. This was to ensure that the research questions that are put forward are answered correctly without any complications.

Two authors were dedicated to research, and one author was dedicated to the drafting of the paper. One of the authors was mainly involved in searching for the research papers, and the other author reviewed the papers given to him by the first author. Then the paper was further reviewed by the third author and was drafted.

Criteria followed during the selection of the Research Paper (Inclusion and Exclusion Criteria):

The selection process of the research papers begins with two tasks which are:

1. To search for the review papers irrespective of any inclusion or exclusion criteria
2. Then to add the inclusion and extrusion criteria as required.

The exclusion criteria used in this research study were:

a) 1st Exclusion criterion: Was to reject all the research papers unrelated to engineering.

b) 2nd Exclusion criterion: Was to reject all the research papers which were not related to Fins (heat exchanger)

c) 3rd Exclusion criterion: Was to reject all the research articles not written in English.
d) 4th Exclusion criterion: Was to reject those research papers that were not in the final publication stage.

e) 5th Exclusion criterion: Was to reject papers that were not journals.

f) 6th Exclusion criterion: Was to reject those papers that were not released in 2021.

g) 7th Exclusion criterion: Was to reject papers that were not related to efficiency.

Proper predefined protocols were applied to minimize the threat of creating biases in the systematic review paper. Following all these protocols it helped us in further reduction of the number of research papers. The authors further used a top-down method to refine the search even more to get more accurate answers to our question. Figure 1 shows the number of papers obtained when each of the exclusion criteria was used. Figure 2 shows the graph between the number of papers taken for literature review VS the source of the paper. From the graph it is observed that most of the papers are taken from Scopus database and the rest of the papers are taken from google scholar.

Figure 1. No of papers obtained based on exclusion criteria
The method which was used for refining is as under:

1. First stage: The titles, abstracts, and keywords of the research article were considered.
2. Second stage: If the first stage wasn’t enough to exclude the research article, then the authors’ full text was reviewed by the authors, which was mainly focused on the sections like introductions, results, and conclusions of the research work.
3. Third stage: After the first two steps, if the paper lacked good content, then the references of the specific research paper were reviewed.

The following three steps were used to refine the papers. Every research paper reviewed had to go through all the above steps to be used as a reference. Figure 3 shows the flowchart of the above-mentioned process of refining the papers.

![Flow chart represents how to refine the research papers](image_url)
2.1.2. Data Extraction Process: All the research papers reviewed by the first and second authors were saved in Mendeley, which was later used to extract and store all the reviewed research papers. Mendeley was the software that was used for proper referencing of the research papers reviewed in our paper. The proper use of Mendeley helps in getting a systematic, detailed, and consistent approach to carry out the data extraction process of a Systematic Review study.

To carry the data extraction process extensively, the authors were divided into three different categories as stated A1 (the first author), A2 (the second author), and A3 (the third author), respectively. Author one and author two thoroughly went through all the research questions and papers independently, and the first review was done by the author who found the paper. The other author did the second review; after finishing those studies, the results would be passed on to the third author for drafting, where the final checking of the selected review paper was done and to draft all the details found by our two authors (A1 and A2).

3. Literature Review
Hashem Shatnaw et al. [1] aimed to develop a solar thermal power generation mechanism which was comparable to the conventional power generation methods. It was found that better efficiency can be provided by building short-finned tubes that will minimize thermal losses and also by allowing the solar tower receiver to work well in high temperatures. JTI (Jubail Technical Institute) built the experimental model to investigate the HT properties of solar receivers. After doing the tests, the author concluded that the pressure drop is directly proportional to the Reynolds number and inversely proportional to hydraulic diameter. The author also came to a conclusion that there is a positive correlation between the Nusselt number and the Reynolds number which means that when Reynolds number rises, the Nusselt number rises with it. B. J. Gireesha & G. Sowmya [2] in their work, HT Analysis of an Inclined Porous Fin using Differential Transform Method. In this the author used the Darcy model to solve the problem and derive its conclusion. The second-order nonlinear ordinary differential equation has been consequent as the governing equation. A crucial analytical approach known as the Differential Transform Method has been used to solve the dimensionless problem. The conclusions they got after the experiments were: An ascending value of the thermo-geometric parameter and radiative parameter decreases the temperature profile; the greater values of the porosity parameter, results, in a rise in HT rate. The angle of inclination has a significant impact on the fin thermal performance, furthermore, the fin efficiency is also affected by the porosity parameter, thermo-geometric parameter as well as radiative parameter and to solve fin problem with greater accuracy Differential Transform Method is one of the effective methods.

Yeongtaek Oh, Kuisoon Kim et al. [3] in their work, studied the performance characteristics of geometry and effects of the position of curved vortex generators on fin-tube heat exchangers (HE). In their research, three types of curved winglet VGs were placed in HE (fin tube) and investigation happened using 3-dimensional numerical calculations. A polar coordinate-centered based system of each tube was used to describe the position of the curved winglet VGs. The conclusions he got from the experiments are that the position angle: (a) is a critical parameter in determining the performance of HT of a HE with CVGs. (b) The effect of R on Nu/Nu0 varied based on the angle and (c) the structure of the CVGs. When an angle of 30° was set for all CVGs, Nu/Nu0 value increased and so did the value of R. The tube vortices generated and CVGs mixed at $\alpha = 30$, significantly improved the overall performance on HT of the fin-tube HE. Flow guidance and secondary flow effects were varied on the shape of the CVGs when they were positioned at the back of the tube. It has been confirmed that CVGs can improve the performance of HT of a fin-tube HE. Abdullah Mansur Aldosr et al. [4] studied using a new type of liquid coolant, G13 ethylene glycol, to cool oblique fins. Within the LCP, the oblique fin structures were found to be in line. Experimentally, the effects of systems and three different flow speeds were investigated. Ethylene glycol and purified water are used as coolants in all cases. The current experiment revealed that using 75 percent purified water and 25 percent G13 ethylene glycol at a flow rate of 0.7 GPM is the best way to run the cold pad.
To obtain a better understanding of the influence of the internal fins on the melting process, the researcher Dinggen Li et al. [5] utilized a two-relaxation time lattice to study natural convection melting in a cubic cavity with internal fins, taking into consideration the instances of double fins and tree-shaped fins in addition, all simulations are run in parallel to increase computing efficiency. NVIDIA’s CUDA was used to create simulations. The numerical findings showed that the fin arrangement had a substantial impact on the melting efficiency in the cubic cavity. When equal length fins with different angles are employed, it is shown that the design has the most influence on the first half of the melting process, while the uneven melting produced by convection in the second half cannot be effectively prevented. Furthermore, \( u = 0 \) and \( d = 15 \) are the optimal angles for melting performance when compared to other circumstances. Furthermore, it is observed that the impact of a single tree-shaped fin is spread across the cavity, and there is no large continuous zone of an inclined interface generated by natural convection. As a result, it was discovered that adding the thinner and longer tree-shaped fins to the LHTES unit greatly enhanced the absorption of latent heat energy, increasing the rate of sensible heat storage. Mohamed et al. [6] studied the numerical investigation of the thermal and hydraulic performance of fin and flat tube HE with various aspect ratios (AR). The author provided a comprehensive three-dimensional numerical analysis of hydraulic and thermal efficiency. This research looks at a wide range of fin and tube HE configurations and operating circumstances. The results of these tests are as follows: The HE with a flat tube provides improved hydraulic performance compared to the circular tube due to the decreased pressure drop. For inlet air velocity less than 1.4 m/s, the HE with a lower flat-tube aspect ratio produced a higher HT coefficient; for inlet air velocity of more than 1.4 m/s, the HE with a higher flat-tube AR produced a higher HT coefficient. When a flat tube with an AR of 0.33 was used in place of a circular tube (AR = 1), the value of goodness factor \((j/f)\) increased by 28.52 percent and 42 percent and value of Re became 75 and 525 respectively. The HT per unit fan power \((Q/Pf)\) was higher in the HE with a lower flat-tube AR. Based on the \(j/f\) area and the HT per unit fan power \((Q/Pf)\) it was found that flat tube should have a minimum AR equal to 0.33 which is the ideal tube shape with the highest thermal-hydraulic efficiency and the ability to decrease the size of the fin and tube HE.

Dnyaneshwar et al. [7] investigated the effects of pin fin arrangement and its HT characteristics on heat sink performance. This research used conjugate HT physics to analyze the stability and flow regimes (unsteady) in a 3-D environment. A heated plate was used to compare a method of a vertical fins 3-dimensional model with and without perforations mounted on a hexahedron for examining the degree of HT enhancement under natural convection, as well as a comparison of various shapes of perforations such as circular, rectangle, triangular, and hexagonal. It saves money by sacrificing a small amount of heat transmission rate and reducing the system’s weight. The author concludes that hybrid pin fins are less effective than splayed pin fins. Samer H. Atawneh et al. [8] used metaheuristic algorithms to LaHood to optimize the thermal performance of longitudinal porous fins with a square cross-section using the entropy generation model. Mathematical models were developed for HT and the optimization of a longitudinal fin square profile. The values of the governing parameters were optimized using FFA, PSO, and hybrid algorithms for the lowest average entropy generation rate. According to the results of these studies, the hybrid FFA-PSO was found to be more efficient than either FFA or PSO algorithms in terms of convergence speed and computational efforts. The worldwide best values for both fin tip conditions are observed to be very close.

Soleymani et al. [9] Performance analysis of hotspots using geometrical and operational parameters of a microchannel pin-fin hybrid heat sink. After doing numerical studies and Ansys analysis, the authors concluded that the HT increases when the angle of the NACA 0024 airfoil pin fin is increased or if the geometry is changed from a NACA 0024 airfoil pin fin to a rounded pin fin (rectangle). It is also noticed that the thermal resistance decreases when the angle of the NACA 0024 airfoil pin fin is increased or if the geometry is changed from a NACA 0024 airfoil pin fin to a rounded rectangle pin fin. When there is an increase in NACA 0024 airfoil pin fin angle, the drop in pressure increases. The required pumping power increases when the NACA 0024 airfoil pin fin angle is increased or if the geometry is changed
from a NACA 0024 airfoil pin fin to a rounded rectangle pin fin. The thermal performance of the micro pin fin has been studied experimentally by Singh et al. [10]. The observations made by the author were that the increase in the height of the fin or decrease in the spacing between the fins leads to a decrease in the thermal resistance and higher pressure drop. An increase in the height of the fin or decrease in the spacing between the fins increased the thermal performance and the temperature-reducing capacity of the heat sinks. The temperature reducing capacity and thermal management of the micro heat sink are more dependent on the height of the pin fin compared to the spacing between the fins. An increase in the height of the fin or decrease in the spacing between the fins increases the Nusselt number. It was also found that micro square pin-fin heat sinks more effectively reduced the temperature of high-density power chips.

The study of the HT by fins was done by Tong et al. [11] using fluent software to methodically investigate the effect of the HT fins’ length and angle on heat distribution and water flow in PEMFCs. It was observed that fins could efficiently improve the HE effect of the TMS of PEMFC. It was also found that the performance of the TMS was significantly impacted by the fin angle and the length of the fin. The influence of fin angle on TMS performance was significantly more than that of fin length. The TMS's performance was directly related to the fin angle and fin length. Wright et al. [12] experimentally investigated the different types of fins based on geometry and found that the HT increased when using airfoil-shaped fins. It was also observed that the HT was directly proportional to the area covered by the airfoil-shaped fins. Densely packing of the fins increased the convective HT significantly, but there was also a considerable pressure drop. The airfoil-shaped fins are much more efficient compared to the conventional round pin fins. Padmanabhan et al. [13] in their work, investigated the temperature distribution of fin profiles using analytical and CFD analysis. In the article, the authors have used two different types of fins to check which of the one is more suitable under the given circumstances where CFD analysis took place in four-engine stroke temperature where the compression stroke temperature is 867.42 K, expansion stroke temperature is 1387.34 K, and exhaust stroke temperature is 610.212 K. With the CFD and analytical analysis the authors compared both the values and found out that both the values were comparable and were close to each other. They were also able to figure out the advantage of using triangular geometry, which is, the amount of material it utilizes is significantly less, which makes it even more economical when compared with rectangular fin. The HT rate was also found more in rectangular fin than in triangular fin. When the temperature drop was taken into accord, it was found that the rectangular fin was higher than that of triangular fin geometry.

Sanjay Gupta et al. [14] in their work, the authors have discussed the water-cooling system with the help of hydrogen fuel. For this study, the authors decided to use copper as fin material rather than aluminium which is generally used as copper has twice the thermal conductivity than aluminium. The authors found out that if the number of fins is increased, the MH bed thickness will get reduced, resulting in faster kinetics; they came to this conclusion as they could see that the alloy quantity present between the fins decreases. The same effect was also found in fins thickness. The authors also found out that there is not much change in kinetics reaction and storage amount after a limit for fin numbers and fin thickness. The internal fins of the reactor can be placed parallel but perpendicular to its axis. The authors also discovered that cylindrical reactors with fins placed transverse to the cylinder's axis had enhanced heat and mass transfer compared with the fins placed parallel to the cylinder's axis. This happens as fins placed transverse to the fin's axis increase the area of HT, which then significantly increases the margin. Mohan Kumar et al. [15] in their work, performed a study for fins based on many different geometries to identify the HT rate. The authors used the bar fins, stepped fins, stepped fins with indentations and made modifications to have a perfect study. After the numerical analysis of those fins, the authors found out if the surface area of the fins is increased, and so does the HT (i.e., increased). The authors also defined what factors fins depend upon: (i) the volume or the mass of the body and (ii) the body's surface area. Rectangular fins are not expensive concerning other types of fins and are mainly used because of this nature. The authors came to many different conclusions, some of them being that diamond-shaped
fins provide the best HT compared with different fins. The less the number of materials and resources used to make fins, the better is the efficiency. While using the Fins with indentation the time of contact between the surrounding air and the heated surface of the fin improves as Fins with indentations have increased drag and reduced wake zone, and this results in an improved overall efficiency of the fin. By increasing the surface area of the fin, we can eventually reduce the weight and volume of the material required, which can also help us reduce the number of fins required for a fixed HT rate whenever required. The authors also concluded that aluminium 6061 being the best material for steeped fins with circular indentation. The authors also concluded that the average velocity of air around the rectangular steeped fin is higher than that of the other three types of fins, and coming to least is the rectangular fin with indentations. Air's velocity is highest towards the surface of the rectangular fin because there is an increased amount of drag, and when there is more drag in the rectangular fin, the contact between fin and air is more which will then improve the overall rate of HT in the system.

Sivalakshmi et al. [16] in their work, the authors have discussed the use of helical fins as helical fins can enhance HT due to the impact produced by many vortices present in the flow region. To test the heat, transfer the experimental setup comprises a hot and cold air loop. The author concluded that HT rates had been increased for almost all the different mass flow rates, and the percentage increase for higher mass flow rates was 38.46%. The effectiveness of the HE was found to be 35% higher helical finned exchanger-based inner tube than to the use of the smooth inner pipe. The authors concluded that using helical fins in a water-air exchanger will increase the HT rate from all the statements.

Hemant Naik et al. [17] in their work, found that gas flowing between the fins and liquid will have less flow rate if the gas has a higher flow of thermal resistance. With the help of longitudinal vortices, HT and fluid mixing are enhanced. As longitudinal vortices and horseshoe have higher strength, the rate of mixing and transfer fluid are enhanced. When the rectangular winglet pairs are attached far from the upstream and downstream flow of fluid on the tube, the authors found that these RWP's were more promising than the RWP's connected near the tube, and the RWP's which were placed near were also counterproductive.

4. Results and Discussions
After reviewing multiple research papers of various authors, it is found that the amount of heat transferred by the fins is dependent on the length of the fins, angle of the fins, the area covered by the fins [18], where it is used (i.e., the application it is used for) and the shape or type of the fins used—the HT increases when the airfoil-shaped fin angle increases whereas the thermal resistance decrease. Similarly, when the airfoil-shaped fin is changed to a rounded rectangle pin fin, the HT increases, whereas the thermal resistance decreases. An increase in the height of the fin or decrease in the spacing between the fins increased the thermal performance and temperature, reducing the capacity of the heat sinks. An increase in the height of the fin or the fin angle increased the TMS. The temperature reducing capacity and thermal management of the micro heat sink are more dependent on the height of the pin fin compared to the spacing between the fins [19]. The impact of fin angle was found to be much higher than the impact of the fin length on the performance of the TMS. It was also found that the HT depended greatly on the area covered by the fins. The airfoil-shaped fins are more efficient in comparison to that of the conventional rounded ones. When rectangular and triangular fins were compared, the triangular fin has a better transfer rate and gives out much more heat. It also came to light that high fin will have optimum HT's, where the spacing between the fins are less. When shallow fins are compared, it is found that the optimum HT occurs when there is a certain amount of gap between the fins. The temperature drop was found to be higher in perforated fins than in non-perforated fins. To increase the heat dissipation rate and surface area, fins should be arranged with notch and holes in the extended surfaces. Diamond-shaped fins provide the best HT characteristics when compared with the other types. Fins are much more efficient when arranged longitudinally than circular or annular as it has improved HT and lower backpressure. To increase the fluid temperature, we should increase the number of vertical pins;
we can also have increased convective and radiative HTs when the number of fins is less than seven, and it stabilizes when the number of pins is more than or equal to 9.

The temperature at the tip of the stepped fins with indentations was found to be lower than the temperature at the normal and stepped fins, with the greatest temperature differential. The fin's efficiency is affected by or depends on the porosity parameter, thermo-geometric parameter, and radiative parameter. It was also found that the Differential Transform Method is one of the best methods to solve fins, based on accuracy. There is a decrease in temperature with ascending values of thermo-geometric and radiative parameters. The melting efficiency in the cubic activity affects the arrangement of fins. The oblique fins enhance the flow rate, which then enhances the HT performance [20]. When the geometry of the fins is changed, the rate of HT is increased, and the energy storage capacity is also increased, with which we will not have to increase the number of fins. When thinner and longer tree shape fins are added, there is the absorption of latent heat energy in the LHTES but there is also an increase in the sensible heat storage rate.

**Figure 4. Different types of Fins**
Figure 5. Thermal analysis of baseplate

Figure 6. Thermal analysis of plain rectangular fin
Figure 7. Thermal analysis of Wavy fin

Figure 8. Thermal analysis of circular pin fin
Figure 9. Thermal analysis of rectangular pin fin

Figure 10. Thermal analysis of Circular pin fin (with small diameter and more number)
Figure 4 shows a few different types of fins which were used to do the analysis. A Solid works analysis was used to do the thermal analysis of the different types of fins. In the analysis, a base plate made of aluminium was used. Keeping all the constraints needed for the thermal analysis such as the base thermal load and the convection coefficient constant the analysis was done. Only the type of fins used and the area covered by the fins are changed. Even the height of the fins was kept constant. Table 1 shows the result that was obtained from the analysis. Figure 5-10 shows the result of the analysis that was obtained by using a fine mesh of the fins. The maximum and minimum temperature of the baseplate are displayed in the analysis result. The greater the temperature gap between the maximum and minimum temperature, the greater the quantity of HT, since heat flows from higher to lower temperatures.

Table 1 Results obtained from Simulation of different types of fins

| Fin pattern                        | Maximum temperature (K) | Minimum temperature (K) | Temperature difference (K) |
|------------------------------------|-------------------------|-------------------------|---------------------------|
| No fin                             | 3.273e+03               | 3.267e+03               | 0.006e+03                 |
| plain rectangular fin              | 3.273e+03               | 2.694e+03               | 0.579e+03                 |
| Wavy fin                           | 3.273e+03               | 2.892e+03               | 0.381e+03                 |
| circular pin fin                   | 3.273e+03               | 2.968e+03               | 0.305e+03                 |
| rectangular pin fin                | 3.273e+03               | 2.739e+03               | 0.534e+03                 |
| Circular pin fin (with less diameter and more number) | 3.273e+03               | 2.740e+03               | 0.533e+03                 |

From table 1 it is found that the temperature difference is maximum for the plain rectangular fin as it covers more area. Therefore, the plain rectangular fin has the highest heat transfer. The rectangular pin fins have a higher transfer in comparison to the cylindrical fins due to the shape as the rectangular pin fin covers more surface area. The cylindrical pin fin with a smaller diameter and a greater number of fins has higher HT compared to the cylindrical pin fin with bigger diameter and lesser number of fins as it covers more surface area. The above results found using the thermal analysis are in coherence with the results found from the literature review.

5. Conclusions
Based on the literature survey and the Solidworks analysis the various influencing factors affecting the fin's thermal performance are found. The main conclusions drawn from the literature survey and the solidworks analysis are given below

1. Heat transferred by the fins is dependent on the length of the fins, angle of the fins, the area covered by the fins, and the shape or type of the fins used.
2. The HT increases when the airfoil-shaped fin angle increases, whereas the thermal resistance decreases.
3. An increase in the height of the fin or decrease in the spacing between the fins increased the thermal performance and temperature, reducing the heat sink's capacity.
4. The influence of fin angle on the TMS’s performance was significantly greater than that of fin length. It was also found that the HT depended greatly on the area covered by the fins.
5. Fins, when arranged longitudinally than circular or annular, are much more efficient as it has improved HT and lower back pressure.
6. The fin's efficiency is affected by or depends on the porosity parameter, thermo-geometric parameter, and radiative parameter.

6. Availability of the Data:
The data that was utilized to back up the study's conclusions is given in the paper.

7. Conflicts of Interest
All authors declared that they have no conflicts of interest relevant to this article.

8. Annexure
ODE - One Dimensional Differential Equation
R - Radial Distance
He - Heat Exchanger
AR - Aspect Ratio
HT - Heat Transfer
CFD - Computational Dynamics Fluid
TMS - Thermal Management System

9. References
[1] Shatnawi H, Lim C W, Ismail F B and Aldossary A 2021 Comput. Mater. Contin. 68 (2) 1693–1711 doi: 10.32604/cmc.2021.016741
[2] Gireesha B J and Sowmya G 2020 Int. J. Ambient Energy 1–18 doi: 10.1080/10430750.2020.1818619
[3] Oh Y and Kim K 2021 Appl. Therm. Eng. 189 116736 doi: 10.1016/j.apt.2021.116736
[4] Aldosry A M, Zulkifli R and Ghopa W A W 2021 World Electr. Veh. J. 12 (2) doi: 10.3390/wevj12020055
[5] Li D and Yu Z 2021 Case Stud. Therm. Eng. 25 100919 doi: 10.1016/j.csit.2021.100919.
[6] Alnakeeb M A, Saad M A and Hassab M A 2021 Alexandria Eng. J. 60 (5) 4255–4265, doi: 10.1016/j.aej.2021.03.036
[7] Mate D M and Tale V T 2020 Mater. Today Proc. 43 2377–2382 doi: 10.1016/j.matpr.2021.01.940
[8] Atawneh S H, Khan W A, Hamadneh N N and Alhomoud A M 2021 Comput. Mater. Contin. 67 (1) 73–87 doi: 10.32604/cmc.2021.012351
[9] Soleymani Z, Rahimi M, Gorzin M and Pahamli Y 2020 Int. J. Heat Mass Transf. 159 doi: 10.1016/j.ijheatmasstransfer.2020.120141
[10] Singh N R, Onkar S and Ramkumar J 2021 Int. J. Heat Technol. 39 (1) 170–178 doi: 10.18280/ijht.390118
[11] Tong G, Xu X, Yuan Q,Yang Y, Tang W and Sun X 2021 Ionics (Kiel). 27 (2) 743–757 doi: 10.1007/s11581-020-03841-w
[12] Wright L M 2021 J. Therm. Sci. Eng. Appl. 13 (4) doi: 10.1115/1.4049424
[13] Padmanabhan S, Thiagarajan S, Deepan Raj Kumar A, Prabhakaran D and Raju M 2021 Mater. Today Proc. 44 (5) 3550–3556 doi: 10.1016/j.matpr.2020.09.404
[14] Gupta S and Sharma V K 2021 Int. J. Energy Res. 45 (2) 1836–1856 doi: 10.1002/er.5859
[15] Mohankumar D, Shashank, Pazhaniappan Y, Nithesh Kumar R A, Ragul R, Manoj Kumar P and Nikhil Babu P 2021 IOP Conf. Ser.: Mater. Sci. Eng. 1059 012055 doi: 10.1088/1757-899X/1059/1/012055
[16] Sivalakshmi S, Raja M and Gowtham G 2021 Mater. Today Proc. 43 (2) 1128-1131 doi: 10.1016/j.matpr.2020.08.563

[17] Naik H and Tiwari S 2021 Int. J. Therm. Sci. 161 106723 doi: 10.1016/j.ijthermalsci.2020.106723

[18] Desai K, Lakra G, Rajesh R and Senthur Prabu S 2021 Mater. Today Proc. 46 (17) 8473-8479 doi.org/10.1016/j.matpr.2021.03.491

[19] Thakar S S, Nambiar S, Chandavarkar G A and Senthur Prabu S 2021 Mater. Today Proc. 46 (17) 8753-8760 doi: 10.1016/j.matpr.2021.04.066

[20] Daniel Abishai L, Surejilal M. E, Sri Harish S and Senthur Prabu S 2021 Mater. Today Proc. 45 (2) 2671-2677 doi: 10.1016/j.matpr.2020.11.520