

# Investigation of Heat Transfer Performance of Metallic and Composite PIN Fins With Circular PIN Fin

**Gauravkumar Tandel**

Department of Mechanical Engineering  
SAL Institute of Technology & Engineering Research  
Ahmedabad, Gujarat.

**Dr. Harshit Bhavsar**

Department of Mechanical Engineering  
SAL Institute of Technology & Engineering Research  
Ahmedabad, Gujarat.

**Mr. Manish Patel**

Department of Mechanical Engineering  
SAL Institute of Technology & Engineering Research  
Ahmedabad, Gujarat.

**Mr. Rakesh Prajapati**

Department of Mechanical Engineering  
SAL Institute of Technology & Engineering Research  
Ahmedabad, Gujarat.

**Abstract**-Efficient thermal management plays a crucial role in enhancing the performance and reliability of modern engineering systems, engineering systems, particularly in electronics, automotive applications, and industrial equipment where excessive heat generation can lead to failure and reduced efficiency. This study investigates the heat transfer performance of metallic and composite pin fins with geometrical variations, focusing on Aluminum (Al) and Aluminum Silicon Carbide (AlSiC) materials combined with circular shape pin fin. Experimental analysis was conducted using a pin fin apparatus under controlled natural convection conditions by maintaining uniform electrical input, while numerical simulations were performed using ANSYS to validate and analyse thermal behaviour, key parameters such as temperature distribution, heat transfer rate, heat flux, and fin efficiency were evaluated and compared for all configurations. The results reveal that material properties and geometry significantly influence thermal performance, where Aluminum demonstrates higher heat transfer rates due to its superior thermal conductivity, making it suitable for applications requiring rapid heat dissipation. In contrast, AlSiC exhibits slightly higher fin efficiency, indicating better utilization of surface area despite lower heat transfer rates. Geometrically, circular pin fins show better efficiency and more uniform temperature distribution. Overall Aluminum circular pin fin offers most balanced performance in terms and both heat transfer and efficiency, while AlSiC serves as a promising lightweight and cost-effective alternative for specific applications. This study Highlights the importance of combined optimization of material and geometry in designing efficient thermal management systems and provides useful insights for improving heat sink performance in practical applications.

**Keywords**- Thermal performance, Heat transfer, Fin materials, Circular pin fin.

## I. INTRODUCTION

### A. Introduction:

The rapid advancement of modern engineering systems, particularly in electronics, automotive, and industrial applications, has significantly increased the demand for efficient thermal management solutions. [1] As devices become more compact and powerful, the rate of heat generation rises considerably, which can adversely affect performance, reliability, and lifespan. Excessive temperature can lead to system failure, reduced efficiency, and material

degradation, making effective heat dissipation a critical design requirement in engineering systems. [2] To achieve long-term durability and reliable operation, it is essential to keep temperatures within safe operating limits.

Heat transfer is a fundamental physical process that governs the movement of thermal energy due to temperature differences, occurring through conduction, convection, and radiation. In most practical applications, convection plays a dominant role in removing heat from surfaces exposed to fluids such as air. However, when the available surface or fins are commonly used to enhance heat transfer performance. Fins increase the effective surface area, thereby improving the rate of heat dissipation without significantly increasing the size of the system. [3] Among different fin types, pin fins have gained considerable importance due to their compact geometry, uniform heat dissipation capability, and suitability for both natural and forced convection conditions. Pin fins are widely used in electronic cooling systems, heat exchangers, and automotive applications due to their ability to enhance airflow mixing and increase heat transfer efficiency. [4], [5]

Material selection is one of the most important factors affecting the thermal performance of pin fins. Materials with high thermal conductivity facilitate efficient heat transfer from the base to the tip of the fin. Copper exhibits excellent thermal performance; due to its high cost and weight, aluminum is more commonly used in practical applications. Aluminum offers a good balance between thermal conductivity, weight, cost, and manufacturability. [6]

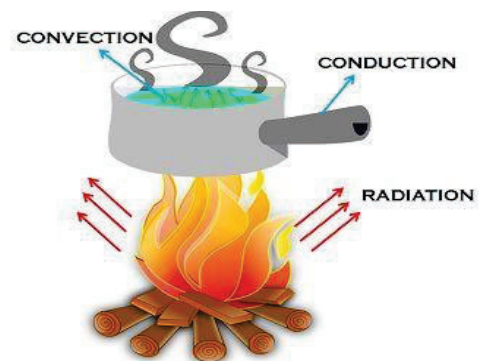


Fig- 1. Conduction, convection & radiation

Recent studies have explored the use of composite materials such as Aluminum Silicon Carbide (AlSiC), which provide improved mechanical strength, reduced thermal expansion, and acceptable thermal conductivity, making them suitable for advanced thermal applications.[7] In addition to material properties, the geometry of pin fins plays a crucial role in determining heat transfer performance. Various geometries such as circular, square, rectangular, and elliptical fins have been investigated in previous studies. It has been observed that geometry affects both surface area and airflow characteristics, which directly influence heat transfer rates. Increasing surface area generally improves heat dissipation, but may also increase pressure drop and flow resistance. [8], [9] Several researchers have studied advanced geometric modifications such as grooved, helical, and splayed pin fins, which enhance turbulence and improve airflow interaction, leading to better thermal performance. [10], [11] Studies also indicate that square fins may provide higher heat transfer rates due to larger surface area, while circular fins offer better efficiency and uniform temperature distribution. [12], [13] Additionally, fin spacing and arrangement significantly affect performance, as closely spaced fins improve heat transfer but restrict airflow, whereas wider spacing enhances airflow but reduces effective surface area. [14], [15]

The mode of convection is another key parameter influencing thermal performance. Natural convection is widely used due to its simplicity and low cost, but it provides lower heat transfer rates compared to forced convection enhances cooling by increasing airflow velocity and turbulence, resulting in improved heat dissipation, although it may increase energy consumption and system complexity. [16],[17] Various enhancement techniques have been proposed to improve pin fin performance, including surface roughness modification, coating, and hybrid material usage. Surface roughness increases turbulence and improves heat transfer efficiency. [18] Similarly, coating fins with high thermal conductivity materials has been shown to enhance fin efficiency and thermal performance without altering geometry. [19] With the advancement of computational tools, numerical methods such as Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) have become essential for analysing pin fin performance. These methods allow accurate prediction of temperature distribution, heat transfer rates, and flow characteristics under different conditions. Numerical simulations also optimization of design parameters before experimental validation, reducing time and cost. [20], [21]

Despite extensive research, several gaps remain in the existing literature. Most studies focus on individual parameters such as material, geometry, or surface treatment, rather than their combined effects. Additionally, experimental validation of composite materials under real operating conditions is limited. The interaction between geometry and material properties also requires further investigation to achieve optimal thermal performance. [22], [23]

In this context, the present study investigates the heat transfer performance of metallic and composite pin fins with geometrical variations. Aluminium (Al) and Aluminium Silicon Carbide (AlSiC) are selected as the materials of study, while circular and square geometries are considered for analysis. The research combines experimental investigation using a pin fin apparatus with numerical analysis through

ANSYS simulation. Key parameters such as temperature distribution, heat transfer rate, heat flux, and fin efficiency are evaluated to determine the most effective combination of material and geometry. This study aims to contribute to the development of efficient, compact, and cost-effective thermal management systems for practical engineering applications.

## II. Material selection & Design

### A. Material selection:

- The selection of material for pin fins is a key factor that governs the effectiveness and durability of thermal systems, particularly in applications where continuous heat dissipation is required. Unlike purely design-based considerations, material selection focuses on the intrinsic physical and thermal properties that influence how efficiently heat energy is transported and released into the surrounding environment. An ideal fin material should possess high thermal conductivity to facilitate rapid heat flow, along with sufficient mechanical strength to withstand thermal stresses during operation. Additionally, factors such as resistance to oxidation, long-term stability, and compatibility with operating conditions must also be considered, especially when the system is subjected to repeated heating and cooling cycles.
- In this investigation, Aluminium (Al) is chosen as the primary material due to its widespread use and proven reliability in heat transfer applications. Aluminium provides an excellent combination of thermal conductivity and low density, allowing efficient heat removal without adding significant weight to the system. Its natural resistance to corrosion and ease of processing further enhance its suitability for experimental and industrial use. These characteristics make aluminium a practical benchmark material for evaluating the thermal behaviour of pin fins under controlled conditions.
- To broaden the scope of analysis, Aluminium Silicon Carbide (AlSiC) is selected as an alternative material representing advanced composite technology. This material is formed by reinforcing aluminium with silicon carbide particles, resulting in a structure that exhibits enhanced stiffness, improved wear resistance, and reduced thermal expansion. Such properties are particularly beneficial in environments where dimensional accuracy and structural integrity are critical. Although the presence of ceramic particles may slightly reduce thermal conductivity compared to pure aluminium, the overall performance of AlSiC can be advantageous in applications requiring a balance between thermal efficiency and mechanical robustness. The inclusion of both materials in this study enables a more comprehensive understanding of how different material characteristics influence heat transfer performance in pin fin systems.

### B. Design of pin fin model:

The design of pin fins plays a critical role in determining the overall thermal performance and efficiency of pin fin. Proper selection of pin fin diameter, height, spacing, and convective heat transfer coefficient. A well optimized pin fin design maximizes heat dissipation while minimizing pressure drop and fan power consumption, leading to lower operating temperatures and improved reliability of electronic components. Poor design can result in hotspots, reduced fin

efficiency, and higher thermal resistance. Ultimately, effective pin fin design enables compact, lightweight, and cost-efficient cooling solutions designed for electronics with high power density requirements, automotive, and aerospace systems.

- Material selection is a critical factor, as it directly affects the conduction of heat from the base of the fin to its tip. In this work, Aluminium (Al) and Aluminium Silicon Carbide (AlSiC) are selected for comparative analysis. Aluminium is widely used due to its high thermal conductivity, low weight, corrosion resistance, and ease of manufacturing, making it suitable for efficient heat dissipation. On the other hand, AlSiC, a metal matrix composite, offers improved mechanical strength, better dimensional stability, and reduced thermal expansion, although it possesses slightly lower thermal conductivity compared to pure aluminium. The inclusion of these two materials enables a meaningful comparison between a conventional metal and an advanced composite material in thermal applications. In this research design has been carried out SolidWorks software and analysis had been done by ANSYS software simulation.

➤ Design of circular pin fin:

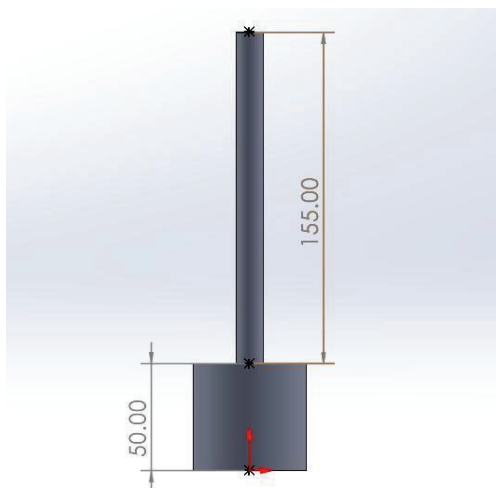


Fig - 2. Front view of circular pin fin

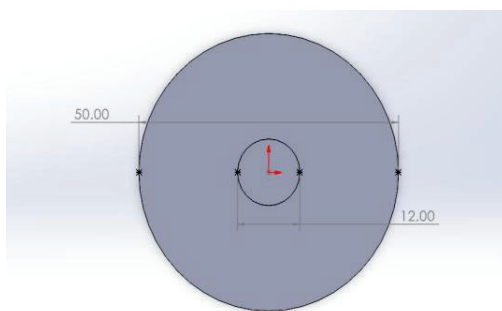


Fig – 3. Top view of circular pin fin

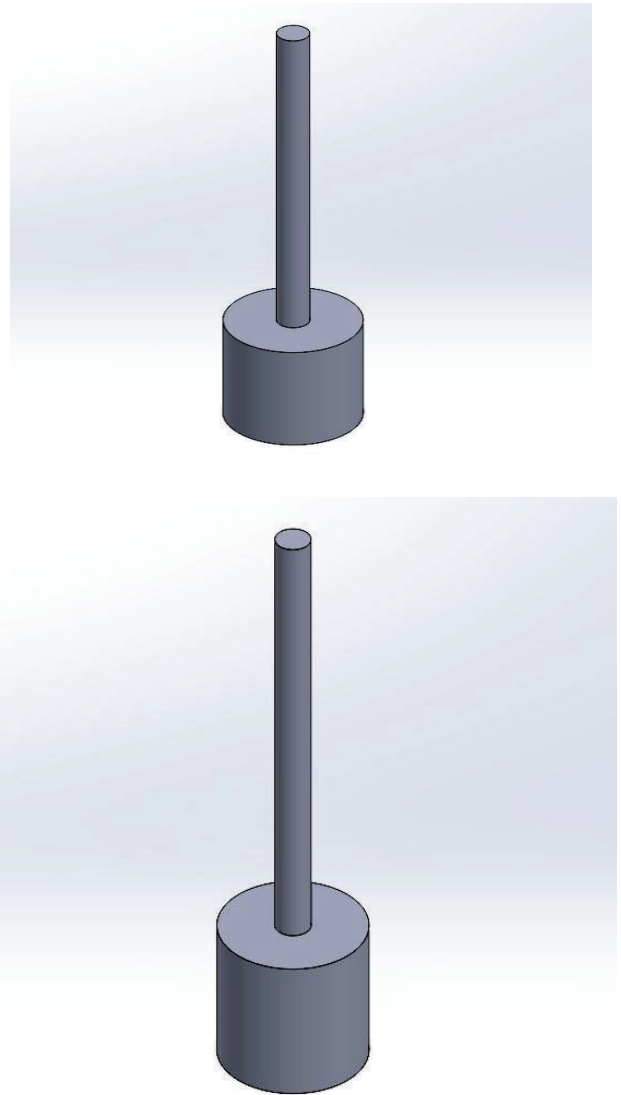


Fig – 4 Isometric view of circular pin fin

Table - 1 Geometry of pin fin and their specification

GEOMETRY OF PIN FIN	SPECIFICATIONS
Circular pin fin	Diameter- 12mm, Length- 155mm

In addition to material selection, the geometry of the pin fin significantly influences heat transfer characteristics. The circular pin fin is chosen due to its uniform shape, smooth airflow interaction, and lower resistance to fluid motion, which contributes to stable and efficient heat transfer. The dimensions of circular pin fins are selected carefully to ensure consistency. The circular pin fin has a diameter of 12 mm and a length of 155 mm. These dimensions are chosen to represent practical applications and to maintain a similar scale for performance evaluation.

- The operating conditions are defined to simulate realistic thermal environments. Air is considered as the working fluid, and the system operates at an ambient temperature

of approximately 30°C. Heat is supplied at the base of the fin using an electrical heater, and the heat is conducted along the fin length and dissipated into the surrounding air through convection. Both natural and forced convection conditions are considered to study the variation in heat transfer performance under different airflow scenarios. The experimental setup consists of a base plate, heater, thermocouples for temperature measurement, and a power supply unit to control the heat input. Temperature readings are recorded at different points along the fin to analyse the temperature distribution and evaluate thermal performance.

- To further support the experimental investigation, numerical modelling is also carried out using simulation techniques. A three-dimensional model of the pin fin is developed based on the actual dimensions, and appropriate material properties and boundary conditions are applied. The simulation helps in visualizing temperature distribution, heat flow, and thermal gradients within the fin, providing deeper insight into the heat transfer mechanism. The combined use of experimental and numerical approaches ensures accurate analysis and validation of results.
- The overall design of the pin fin system is aimed at understanding the influence of material properties and geometric variations on heat transfer performance. By maintaining consistent operating conditions and comparing different configurations, the study seeks to identify the most efficient combination for enhanced thermal management. This design approach provides a comprehensive framework for analysing pin fin

behaviour and contributes to the development of optimized and cost-effective cooling solutions for various engineering applications.

### III. METHODOLOGY

- Graphical comparison provides a clear understanding of how different pin fin configurations perform under similar conditions. The temperature distribution graphs show a consistent decline in temperature from the base to the tip for all cases, indicating effective heat transfer. Aluminium fins display a more gradual temperature drop, reflecting better heat conduction, while Aluminium Silicon Carbide (AlSiC) fins show a slightly sharper gradient. In terms of geometry, circular fins exhibit a smoother and more uniform temperature profile.
- The heat transfer and heat flux graphs further highlight the performance differences. Aluminium fins demonstrate higher heat transfer rates and heat flux values compared to AlSiC, mainly due to superior thermal conductivity.
- Efficiency graphs reveal that while Aluminium fins provide higher heat transfer, AlSiC fins offer comparable efficiency in utilizing the available surface area. Circular fins generally show better efficiency due to more uniform heat distribution and reduced thermal resistance. Overall, the graphical analysis suggests that Aluminium circular pin fins provide a balanced performance, combining effective heat transfer with good efficiency, making them suitable for practical thermal management applications.

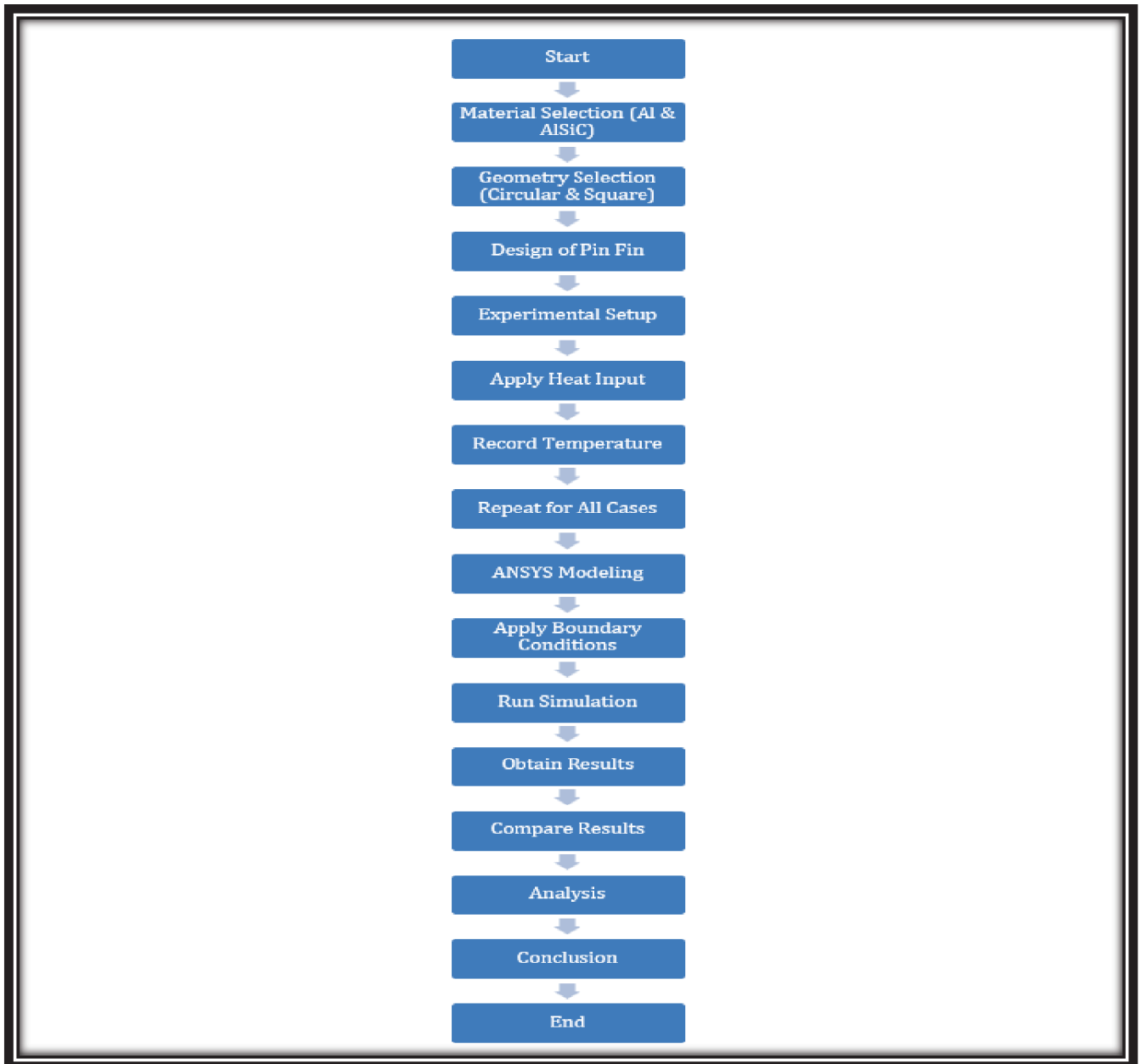


Fig – 5 Flowchart of methodology

#### A. Experimental Analysis:

The experimental investigation is carried out to evaluate the heat transfer performance of pin fins made from different materials and geometries under controlled conditions. The setup consists of a pin fin apparatus where the test specimen is mounted vertically on a heated base plate. Heat is supplied at the base using an electric heater, and it is conducted along the length of the fin while being dissipated to the surrounding air through convection. Air is considered as the working fluid, and experiments are performed under both natural and forced convection conditions to study their influence on thermal behaviour.



Fig – 6 Pin Fin apparatus

Temperature measurements are taken at multiple locations along the length of the pin fin using thermocouples, which are connected to a temperature indicator for accurate readings. Before conducting the experiment, the system is allowed to reach steady-state conditions to ensure consistent and reliable data. The electrical input is maintained constant throughout each test to provide uniform heat supply. Readings of voltage and current are recorded to calculate the heat input, while temperature data is used to determine temperature distribution along the fin. The experiment is repeated for all combinations of materials (Aluminium and Aluminium Silicon Carbide) and circular geometry to enable a comparative analysis. The collected data is further used to calculate key performance parameters such as heat transfer rate, heat flux, and fin efficiency. Here are the calculations for collected data are mentioned below,

- Step 1: Total heat input (Q)  
 From Electric heating:  $Q=V \times I$   
 $\Rightarrow Q = 21\text{ W}$
- Step 2: Surface area calculation  
 For circular  $A=\pi dl$   
 $\Rightarrow A=0.00584\text{ m}^2$
- Step 3: heat flux Heat flux  
 $q = Q/A$   
 For circular  $q \sim 3595\text{ W/m}^2$

These values are for ideal or theoretical heat flux with no heat loss at bottom by heater if we go with experimental analysis (Report) we can get results below:

- For circular fin  $Q= 7.057\text{ W}$
- For circular fin area is  
 $A= 0.00584\text{ m}^2$
- For circular fin heat flux is  
 $q=1208\text{ W/m}^2$
- For circular pin fin  
 Voltage  $V= 28\text{ V}$   
 Current  $I= 0.75\text{ A}$   
 Base temp =  $84^\circ\text{C}$   
 Ambient temp =  $29^\circ\text{C}$   
 Length (L)=  $0.155\text{ m}$   
 Diameter (d) =  $0.012\text{ m}$   
 Calculation of Heat input  
 $Q = V \times I = 28 \times 0.75 = 21\text{ W}$   
 Surface area  $A=\pi dL$   
 $A= \pi \times 0.012 \times 0.15, A = 0.00565\text{ m}^2$
- Mean temperature,  
 $T_m = \frac{T_s + T_\infty}{2}, T_m = 329.5\text{ K}$
- Properties of air at  $\sim 330\text{ k}$ ,  
 Thermal conductivity of air (k)=  $0.028\text{ W/m}\cdot\text{K}$   
 $\nu = 0.00019\text{ m}^2/\text{s}$
- Prandtl No (Pr)= $0.7 \beta=1/T_m \Rightarrow \beta= 0.00303$
- Grashoff no (Gr)  
 $Gr = \frac{B(T_s - T_\infty)}{\nu^2} g$

$$\Rightarrow Gr \sim 1.53 \times 10^7$$

- Nusselt no (Nu)  
 $Nu = 0.53 [Gr \cdot Pr]^{1/4}$   
 $\Rightarrow Nu \sim 30.05$
- Heat transfer coefficient (h)  $h = (Nu \cdot k)/L$   
 $\Rightarrow h \sim 5.61\text{ W/m}^2 \cdot \text{K}$
- Calculation of Heat Transfer  $Q = h \cdot A (T_s - T_\infty)$   
 $\Rightarrow Q \sim 1.74\text{ W}$
- Heat flux (q)  $q = Q/A$   
 $\Rightarrow q \sim 308\text{ W/m}^2$

- Fin efficiency  

$$\eta = \frac{\tanh(mL)}{mL}$$

$$\text{Where } m = \sqrt{\frac{hp}{kA}} \Rightarrow m = 36.56$$

$$\Rightarrow \eta = \frac{\tanh(mL)}{mL}$$

$$\Rightarrow \eta = 0.91$$

Table – 2 Calculated data table for Al & AlSiC with circular geometry

Material	Geometry	h (W/m <sup>2</sup> . K)	η	Q (W)
Al	Circular	5.6	0.91	1.74
AlSiC	Circular	5.4	0.89	1.78

- Aluminium circular fins show better performance compared to AlSiC circular fins. Aluminium has a higher heat transfer coefficient ( $5.6\text{ W/m}^2 \cdot \text{K}$ ) and heat transfer rate ( $1.74\text{ W}$ ) than AlSiC ( $5.2\text{ W/m}^2 \cdot \text{K}$  and  $1.62\text{ W}$ ). It also has slightly higher fin efficiency ( $0.91$  vs  $0.90$ ). This means Aluminium circular fins transfer heat more effectively and utilize their surface area more efficiently.
- Overall, Aluminium demonstrates better heat dissipation performance than Aluminium Silicon Carbide (AlSiC), as it consistently provides higher heat transfer rates in both circular ( $7.057\text{ W}$ ) and AlSiC achieves slightly higher efficiencies. In terms of geometry, circular fins make more effective use of their surface area, resulting in better efficiency with aluminum pin fin. Considering these factors, Aluminium with circular geometry offers the most balanced performance between heat transfer and efficiency, whereas AlSiC represents the least effective combination among the cases studied.

#### B. Simulation Analysis:

To complement the experimental study, numerical simulation is performed to analyse the thermal performance of pin fins under similar conditions. A three-dimensional model of the pin fin is developed using simulation software based on the actual dimensions of the specimens. The geometry is carefully created for circular configurations, and material properties corresponding to Aluminium and Aluminium Silicon Carbide are assigned accordingly.

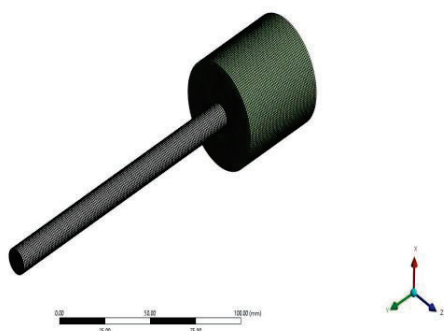
Appropriate boundary conditions are applied to replicate the experimental setup. A constant heat input is specified at the base of the fin, while convective heat transfer conditions are applied to the exposed surfaces. The surrounding environment is defined based on ambient temperature, and air properties are considered for convection analysis. The computational domain is discretized using a fine mesh to ensure accuracy in results, particularly near the surface where heat transfer gradients are significant.

Steady-state thermal analysis is performed to obtain temperature distribution, heat flux, and overall thermal performance of the pin fins. The simulation results are then compared with experimental data to validate the model and ensure consistency. This combined approach of experimental and numerical analysis provides a comprehensive understanding of heat transfer behaviour and helps in identifying the most efficient configuration for thermal management applications.

The modelling and analysis of pin fin in ANSYS is performed using a combination of ANSYS Space Claim/Design Modeler for geometry creation and ANSYS Mechanical or ANSYS Fluent for thermal and fluid flow analysis. The 3D CAD model of the pin fin is first created with precise dimensions of pin diameter, pin height, and pin arrangement.

Appropriate material characteristics including thermal conductivity, density, and specific heat are specified to the model (e.g., Aluminium alloy or Al-SiC composite). For thermal analysis, steady-state thermal or transient thermal modules are used by applying a heat flux or temperature load at the base and convective heat transfer coefficient on the pin surfaces. When fluid flow is considered, conjugate heat transfer analysis is carried out in ANSYS by coupling the solid domain (pin fin) with the fluid domain (air), applying inlet velocity, post-processing includes evaluation of temperature distribution, heat transfer rate, thermal resistance, fin efficiency. Validation is performed by comparing simulation results with theoretical calculations or experimental data to ensure accuracy.

This ANSYS-based approach enables parametric optimization of pin geometry for maximum thermal performance with minimum pressure drop. The computational domain is discretized with finer mesh refinements in the regions surrounding the fins. Grid independence is ensured by comparing output across three mesh density.



Statistics	
Nodes	807615
Elements	194056
Show Detailed St...	No

Fig – 7 Meshing of Circular pin fin

The 3D model of the single cylindrical pin fin was developed for numerical simulation in ANSYS. It consists of a circular base with a long-extended pin measuring approximately 100 mm in length. A fine surface mesh was applied to the entire geometry to accurately capture the heat transfer and airflow behaviour around the pin.

The mesh statistics show a total of 807,615 nodes and 194,056 elements. This high mesh density ensures good resolution of the boundary layers and provides reliable results for both conduction inside the pin and convection in the surrounding air. With this level of refinement, important parameters such as temperature distribution, fin efficiency, pressure drop, and overall thermal performance can be predicted with good accuracy. Here are the results for circular geometry with different materials mentioned below,

**Circular Aluminium pin fin:** Heat is entering the system near the large cylinder and flowing strongly into the rod at the connection point. As it travels down the rod, the heat flux drops because the heat is being lost to the surrounding air along the way. The rod is effectively cooling down as we move away from the base.

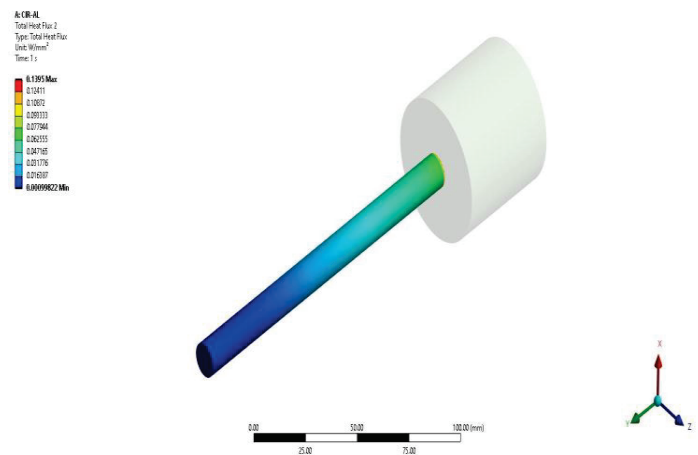


Fig – 8 Thermal simulation of circular Al Pin fin

**Circular Aluminium silicon carbide pin fin:** Hot spot at the connection point with heat flowing along the rod, creating a smooth temperature gradient after just second. The end of the rod has not heated up much because only second has passed heat has not had enough time to conduct all the way to the end.

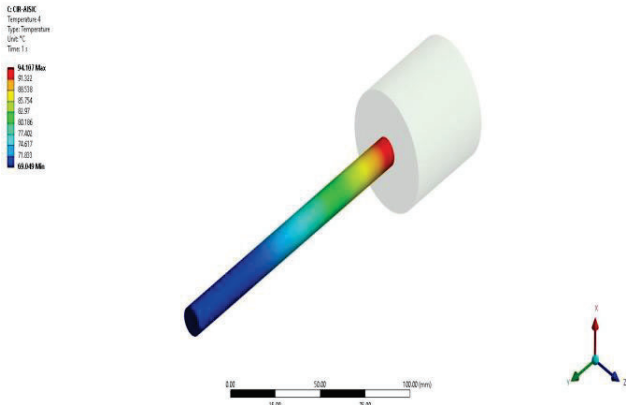


Fig - 12 Thermal simulation of Circular AlSiC pin fin

➤ Experimental calculation:

- For circular Aluminium pin fin:

Given:

Heat transfer coefficient ( $h$ ) = 25 W/m<sup>2</sup>K  
 Perimeter ( $P$ ) = 0.037699 m  
 Thermal conductivity ( $k$ ) = 205 W/m. K  
 Area ( $A$ ) = 0.000113 m<sup>2</sup>,  
 Length ( $L$ ) = 0.155 m  
 Temperature at base ( $T_b$ ) = 93.11 °C  
 Ambient Temperature ( $T_\infty$ ) = 30 °C

- Step 1: Temperature difference

$$\theta_b = T_b - T_\infty$$

$$\theta_b = 93.11 - 30$$

$$\theta_b = 63.11 \text{ } ^\circ\text{C}$$

- Step 2: Fin parameter ( $m$ )  $\Rightarrow m = \sqrt{\frac{hp}{kA}}$

$$mL = 6.379 \times 0.155 = 0.989$$

- Step 3: mL value

$$mL = 6.379 \times 0.155 = 0.989$$

- Step 4: Heat transfer rate

$$Q = \sqrt{\frac{hp}{kA}} \times \theta_b \times \tanh(mL)$$

$$Q = 7.057 \text{ W}$$

- Step 5: Fin efficiency

$$\eta = \frac{\tanh(mL)}{mL}$$

$$\eta = 0.765$$

Table – 3 Calculated data table for Al & AlSiC with circular geometry

Material	Geometry	$h$ (W/m <sup>2</sup> . K)	$Q$ (W)	$\eta$
Al	Circular	25	7.057	0.765
AlSiC	Circular	25	6,65	0.790

- For circular geometry, Aluminium (Al) exhibits a higher heat transfer rate of 7.057 W compared to Aluminium Silicon Carbide (AlSiC) at 6.65 W, indicating better heat dissipation capability. However, AlSiC shows superior fin efficiency (0.790) compared to Al (0.765), suggesting more effective utilization of the fin surface despite slightly lower heat transfer.

- Overall, Aluminium (Al) provides consistently higher heat transfer rates for both circular and square pin fins, making it preferable when maximum heat dissipation is the primary objective. Conversely, Aluminium Silicon Carbide (AlSiC) offers higher fin efficiency, indicating better thermal effectiveness and material utilization.

IV. COMPARATIVE RESULTS BY GRAPH

- Graphical comparison provides a clear understanding of how different pin fin materials perform under similar conditions. Aluminium fins display a more gradual temperature drop, reflecting better heat conduction, while Aluminium Silicon Carbide (AlSiC) fins show a slightly sharper gradient. In terms of geometry, circular fins exhibit a smoother and more uniform temperature profile.
- Aluminium fins demonstrate higher heat transfer rates and heat flux values compared to AlSiC, mainly due to superior thermal conductivity.

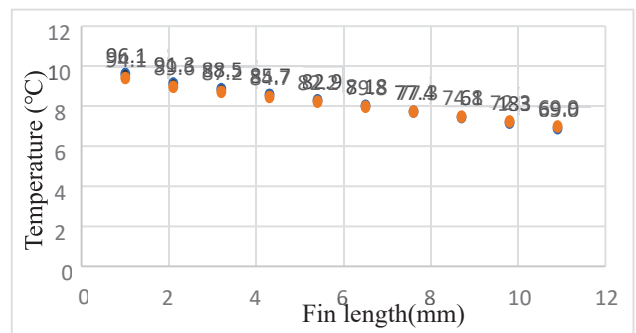


Fig – 15 Temperature distribution along length of Al & AlSiC circular pin fin

- The fig – 15 illustrates how the temperature changes as the length of the pin fin increases for both aluminium and AlSiC materials. It can be clearly seen that the temperature decreases steadily with increasing fin length for both materials. At shorter fin lengths (around 10–20 mm), the temperature is highest (close to 95–98 °C), while at longer lengths (100–110 mm), it drops to approximately 70 °C.
- The performance of pure aluminium and AlSiC is quite similar across the entire range, with AlSiC showing a slightly lower temperature at most fin lengths. This trend confirms that longer pin fins provide better heat dissipation, and the AlSiC composite offers a small but noticeable improvement in thermal performance compared to conventional aluminium.
- It can also be observed that AlSiC consistently shows slightly lower temperatures compared to pure aluminium across all fin lengths, highlighting its marginal but better thermal performance. The difference between the two materials becomes more noticeable at longer fins lengths. Overall, the graph demonstrates that increasing the pin fin length is an effective way to improve cooling performance, with AlSiC offering a small advantage over conventional aluminium.

- Efficiency graphs reveal that while Aluminium fins provide higher heat transfer, AlSiC fins offer comparable efficiency in utilizing the available surface area. Circular fins generally show better efficiency due to more uniform heat distribution and reduced thermal resistance. Overall, the graphical analysis suggests that Aluminium circular pin fins provide a balanced performance, combining effective heat transfer with good efficiency, making them suitable for practical thermal management applications.

#### V. RESULTS

- Both Experimental and analytical results consistently show that aluminum outperforms aluminum silicon carbide in heat transfer rates for circular pin fin, indicating aluminium's superior ability to dissipate heat.
- AlSiC demonstrates slightly higher fin efficiency in analytical results, suggesting better surface utilization, while experimental efficiencies for both materials are very close, with Aluminium sometimes having a slight advantage.
- Despite differences in absolute values between experimental and analytical data, the relative performance trends remain the same: Aluminium excels in heat transfer capacity, while AlSiC offers competitive or better efficiency, highlighting a balance between maximizing heat dissipation and fin effectiveness.

#### IV. CONCLUSION

- This study demonstrates that both material choice and fin geometry play a crucial role in enhancing the thermal performance of pin fins.
- Aluminium proves to be highly effective in maximizing heat transfer due to its superior thermal conductivity, making it suitable for applications where rapid cooling is required. In contrast, AlSiC offers a balanced performance with slightly lower heat transfer but better efficiency and improved mechanical stability, making it ideal for more demanding or high-reliability environments.
- By Increasing fin length improves cooling performance, but only up to an optimal point, after which the effectiveness reduces. Overall, the results confirm that the optimal design depends on the specific application requirements. For maximum heat removal, aluminium fins are a strong choice, while AlSiC fins are better suited for applications requiring durability and consistent thermal performance.

#### REFERENCES

1. Heat Transfer-A Practical Approach by Y. A. Cengel – 2<sup>nd</sup> Edition.
2. Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, David P. DeWitt - Fundamentals of Heat and Mass Transfer-Wiley- 2017.
3. I. Lakshmi Anusha, S. Murali, P. Srinivas Rao, P. Padmavathi," CFD analysis of splayed pin fin heat sink using advanced composite materials" International journal of current engineering and technology-2014.
4. I T Nazzal, T K Salem, R R J Al Doury, "Theoretical investigation of a pin fin heat sink performance for electronic cooling using different alloys materials" IOP publishing-2020.
5. Mr. Pankaj Kumar, Naresh Prasad Choudhry, "Experimental investigation of heat transfer by using in fin of different materials in forced convection" International Journal of advanced research and development-2017.
6. Venkateswara Reddy Kolagotla, Sai babu Kolahalam, Emmanuel Buradagunta, Naresh Babu Nelakuditi, Pichi Reddy Seelam, Dhana Raju Valla Pudi, Mallikarjuna Rao Dandu, "Comparative thermal analysis by using simulation of circular fin manufactured with several materials" Nano World Journal-2023.
7. Fang Wang, Yuding Li, Mengwei Liu, Dongqing Pang, Weifeng Du, Yichi Zhang, Xiaoqian Cheng, Tangtang Gu, Wenliang Guo, "Comprehensive evaluation of the performance of heat exchangers with aluminium and copper finned tubes" Hindawi International journal of chemical engineering-2023.
8. Arun Eldhose, Dr. Benny Paul, Jelvin Tom Sebastian, "Numerical analysis of pin fin by varying shape and materials" International Research journal of engineering and technology-2018.
9. Prabhakar Bhandari, Kamal S. Rawat, Yogesh K. Prajapati, Diwakar Padalia, Lalit Ranakoti, Tej Singh, "Design modifications in micro pin fin configuration of microchannel heat sink for single phase liquid flow: A review" Journal of Energy Storage-2023.
10. Prem Chandra, Kanishk Sharma," Comparison of a pin fin and straight fin heat sink" International research journal on advanced science hub-2025.
11. Md. Abdul Raheem Junaidi, Raghavendra Rao, S. Irfan Sadaq, Mohd Moinuddin Ansari," Thermal analysis of splayed pin fin heat sink" International journal of modern communication technologies & research-2014.
12. Vaishnav Madhavdas, Dibya Rup Das, Kaustubh Anand Mohta, S. Senthur Prabu "Comparative analysis on heat transfer of various fin profile using solid works: A systematic review" IOP Publishing -2021.
13. Harshita Pant, Divyanshi Shukla, Shriya Rathor, S. Senthur Prabu," Heat transfer analysis on different pin fin types using SolidWorks" IOP Conf. Series: Earth and Environmental Science -2022.
14. A Dewan, P Patro, I Khan, P Mahanta, "The effect of fin spacing and materials on the performance of a heat sink with circular pin fins" Sage Journals -2009.

15. Mohammad Sarairoh, "Computational Fluid Dynamics Simulation of Plate Fin and Circular Pin Fin Heat Sinks," Jordan Journal of Mechanical and Industrial Engineering, -2016.
16. Ruby Haldar, Abhimanyu Kumar, Trishit Janah, Prabir Biswas, "Experimental investigation of heat transfer by forced and natural convection in a pin fin for different materials" International journal for research in applied science & engineering technology-2022.
17. Laxmi Narayan Pidida, Umesh Kumar Suryawanshi "Experimental Investigation and Thermal Analysis on Electroplating Coated Pin -Fins under Natural Convection" International Research Journal of Engineering and Technology-2023.
18. P. Kaviyarasu, C. Saravanan. "Experimental investigation of convective heat transfer through rough and smooth surfaced aluminium 6063 pin fin apparatus" International research journal of advanced engineering and science-2017.
19. Sreedhar Vullo Ju, P.S. Kishore, Mukul Shrivastava, "Enhancement of heat transfer characteristics of plain fin coated with brass and aluminium" International journal of recent technology and engineering-2019.
20. K. Subahan, E. Siva Reddy, R. Meenakshi Reddy, "CFD Analysis of pin fin heat sink used in electronic devices" International journal of scientific & technology research-2019.
21. Darshan J V, Pavan D," CFD analysis and optimization of pin fin heat sink" International journal of scientific & engineering research-2020.
22. Tao Yang, Xiaoming Zhang, Zhenyuan Chang, Ran Xu, Jiao jiao Ma, Liang Xu, Lei Xi, Energies- 2024.
23. Mohankumar D, Shashank, Pazhaniappan Y, Nithesh Kumar RA, Ragul R, Manoj Kumar P, Nikhil Babu P, "Computational study of heat-transfer in extended surfaces with various geometries," IOP Conf. Series: Materials Science and Engineering- 2021.
24. Yogesh Sharama, "Analysis of heat transfer through Conduction, Convection, and radiation" International Journal of all research education and scientific methods (2016).