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MODELLING AND ANALYSIS OF CYLINDRICAL COOLING FIN (HEAT LOSS)

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Abstract - *The project titled Modeling and Analysis of Cylindrical Cooling Fin focuses on enhancing heat dissipation efficiency in Permanent Magnet Synchronous Motors (PMSM) by optimizing cooling fin designs. This study examines the thermal performance of three fin geometries—pin fin, flat fin, and trapezoidal fin—using aluminum as the material due to its high thermal conductivity and lightweight properties. A 3D model of the motor was developed in SolidWorks, which was then used for simulation and thermal analysis in ANSYS. The primary objective is to determine the most efficient fin geometry for maximizing heat flux and improving the thermal management system of the motor. Each fin type is analyzed under identical operating conditions to evaluate heat flux and performance. The results of this study will help identify the optimal fin configuration for enhancing motor efficiency, increasing operational lifespan, and improving overall thermal management.*

Key Words: Heat Transfer, Cylindrical Cooling Fin, Thermal Analysis, Permanent Magnet Synchronous Motor, ANSYS, SolidWorks, Aluminum, Heat Flux.

1. INTRODUCTION

Cooling systems are essential for maintaining optimal performance and efficiency in various mechanical systems, especially in electric motors like Permanent Magnet Synchronous Motors (PMSM). Overheating in PMSM can significantly reduce motor performance and longevity, making effective thermal management crucial. One of the key components of a thermal management system is the cooling fin, which dissipates excess heat through conduction and convection.

The design of cooling fins has a significant impact on their ability to manage heat. In this study, we investigate three different cooling fin geometries: pin fin, flat fin, and trapezoidal fin, each of which offers distinct thermal performance advantages. Aluminum has been selected as the fin material due to its high thermal conductivity, low weight, and cost-effectiveness. The performance of each fin type is evaluated in terms of heat flux, thermal resistance, and material usage.

1.1 Background of the Work

Efficient thermal management is critical for Permanent Magnet Synchronous Motors (PMSM), widely used in electric vehicles and industrial applications, to prevent overheating and ensure optimal performance. Cooling fins play a key role in dissipating heat, with their geometry and material significantly influencing thermal efficiency. Commonly used fin types include pin fins, flat fins, and trapezoidal fins, each offering unique advantages. Aluminum, known for its high thermal conductivity and lightweight properties, is a preferred material for fins. This study compares the thermal performance of these fin geometries to optimize heat dissipation, improve motor efficiency, and extend operational lifespan.

1.2 Motivation and Scope of the Proposed Work

Permanent Magnet Synchronous Motors (PMSM) are increasingly employed in industries such as automotive, robotics, and renewable energy due to their efficiency and performance. However, overheating remains a critical challenge, leading to reduced efficiency, performance degradation, and shorter lifespans. Effective thermal management is essential to address these issues and ensure reliable operation. Cooling fins, as integral components of heat dissipation systems, play a vital role in maintaining optimal motor temperatures.

This study is motivated by the need to enhance the heat dissipation capabilities of PMSM by analysing and optimizing cooling fin designs. The research focuses on three fin geometries—pin fin, flat fin, and trapezoidal fin—using aluminium, chosen for its high thermal conductivity and lightweight properties. By leveraging advanced design tools like SolidWorks for 3D modelling and ANSYS for thermal simulation, the study evaluates the thermal performance of these fin geometries under identical operating conditions.

The scope of the work extends to identifying the optimal fin configuration for maximum heat flux, minimal material usage, and enhanced cooling efficiency. The findings aim to improve the efficiency, durability, and sustainability of PMSM, contributing to advancements in thermal

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management systems for modern electric motors across various industries.

2. METHODOLOGY

The methodology outlines the approach adopted for the modeling, simulation, and analysis of cooling fins to optimize thermal management in Permanent Magnet Synchronous Motors (PMSM). The process is structured into three main stages: **3D Modeling**, **Thermal Analysis**, and **Performance Evaluation**.

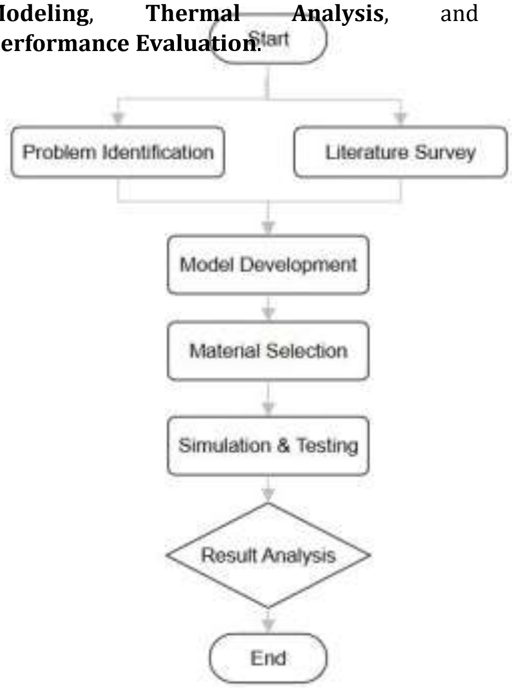

Fig-1: Flowchart

2.1 3D Modelling

The 3D geometry of the PMSM and cooling fins was designed using SolidWorks. Three fin geometries pin fin, flat fin, and trapezoidal fin were created with identical base dimensions to ensure a fair comparison. Aluminum was chosen as the fin material due to its excellent thermal properties and lightweight characteristics. The motor housing and fins were integrated into a single assembly to maintain accuracy during simulations.

2.2 Thermal Analysis

Thermal simulations were conducted in ANSYS to evaluate the heat dissipation performance of each fin geometry. The analysis involved applying identical thermal and boundary conditions to all models, including a fixed heat source representing motor heat generation and convection conditions for heat transfer to the surroundings. Heat flux, temperature distribution, and thermal resistance were recorded for each configuration.

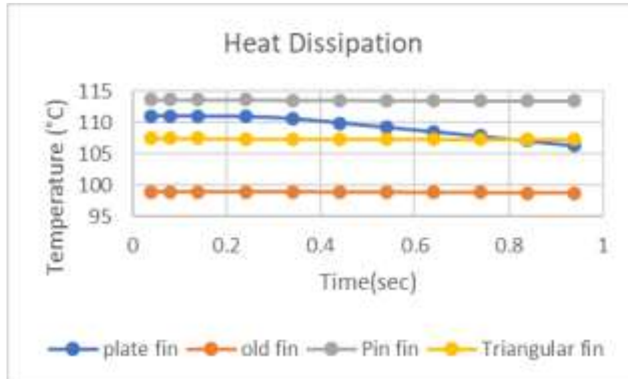

Chart -1: Heat Analysis

2.3 Performance Analysis

The results from the thermal analysis were compared to identify the optimal fin geometry. Key performance metrics included maximum heat flux, even temperature distribution, and material efficiency. The findings were analyzed to determine the most effective fin design for improving the thermal performance and reliability of PMSMs.

3. CONCLUSIONS

This study analyzed the thermal performance of pin, flat, and trapezoidal fin geometries to enhance the cooling efficiency of Permanent Magnet Synchronous Motors (PMSM). Using aluminum as the fin material, 3D modeling in SolidWorks and simulations in ANSYS revealed that pin fins offered superior heat flux and temperature distribution due to their higher surface area. This makes pin fins the optimal choice for improved thermal management. The findings contribute to the development of efficient cooling systems, ensuring better performance, reliability, and longevity of PMSM. These insights are applicable across industries like automotive, robotics, and renewable energy.

Suggestions for Future Work

1. **Optimization of Fin Geometries**: Further refine pin fin designs by exploring advanced shapes, sizes, and arrangements to maximize heat dissipation while minimizing material usage.
2. **Experimental Validation**: Conduct real-world experiments to validate simulation results, ensuring the reliability and practicality of the proposed designs under operational conditions.
3. **Integration with Advanced Cooling Systems**: Combine cooling fins with hybrid systems, such as liquid cooling or phase-change mechanisms, to enhance thermal management for high-performance applications.

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