IJEAST

INTERNATIONAL JOURNAL OF ENGINEERING APPLIED SCIENCE AND TECHNOLOGY

VOLUME : 10 **ISSUE : 01** **Print / Issue Publication Date: 30-Jun-2025**

ISSN : 2455-2143

DOI : 10.33564/IJEAST.2025.v10i01.013

Indexed In

Google SCHOLAR

OPEN ACCESS

doi

Crossref

WWW.IJEAST.COM

editor@ijeast.com

International Journal of Engineering Applied Sciences and Technology, 2025
Vol. 10, Issue 01, ISSN No. 2455-2143, Pages 91-95

DESIGN AND OPTIMIZATION OF AMR FOR SMART INDUSTRIAL MATERIAL HANDLING

Dr.S.Arunkumar
Assistant Professor
Department Of Mechanical Engineering
Anjalai Ammal Mahalingam Engineering College, Tamilnadu, India

Abishek.S, Akshaikarthik.R, Bharath.K, Boobalan.R
UG Scholar
Department Of Mechanical Engineering
Anjalai Ammal Mahalingam Engineering College, Tamilnadu, India

Abstract— **Design and optimization of a heat-resistant pallet for an Autonomous Mobile Robot (AMR) intended for industrial material handling. The pallet is engineered to withstand loads up to 500 kg and surface temperatures reaching 200°C, addressing a common industrial challenge where heat transfer from hot materials can damage AMR components. The solution involves a multi-layered pallet structure, combining high-temperature insulation materials such as ceramic composites, mica sheets, and GFRP, designed to resist heat while maintaining structural integrity. A detailed CAD model of the pallet was developed in Solid Works, and thermal and structural analyses were conducted using simulation tools FUSION 360 to validate material performance under high load and temperature conditions. The optimized design achieves a bottom surface temperature reduction of up to 18.7% (from 52.84°C to 42.79°C) and an increase in thermal gradient of over 115% (from 4.997°C/mm to 10.809°C/mm), demonstrating improved thermal isolation with insulation materials.**

Keywords: **Autonomous Mobile Robot, Heat Insulation, Thermal Analysis, Industrial Automation, Pallet Design**

I. INTRODUCTION

In modern industrial environments, Autonomous Mobile Robots (AMRs) are essential for enhancing productivity and automation. However, challenges arise when these systems must transport materials at high temperatures. Conventional pallets often fail to insulate heat effectively, leading to component degradation and safety hazards. This research addresses this limitation by proposing a multi-layer insulated pallet designed to manage high thermal loads during AMR operations.As industries seek to automate internal logistics, the role of AMRs continues to expand. However, one of the critical challenges lies in designing a support system. Infrastructure—particularly load-bearing platforms—that can endure harsh conditions, including high temperatures and substantial mechanical loads. In response, this study proposes a solution involving thermally insulated pallets that improve the operational viability of AMRs in heat-intensive environments such as metal foundries, chemical processing plants, and other heavy industries. The integration of this technology has the potential to drastically improve safety, reduce maintenance cycles, and enhance long-term operational reliability.

II. PROBLEM STATEMENT

In industrial environments, Autonomous Mobile Robots (AMRs) are increasingly employed for heavy-duty material handling tasks, often transporting loads up to 500 kg. However, these operations impose significant mechanical stresses, resulting in accelerated wheel wear, potential breakage, and structural fatigue. Furthermore, in high-temperature industrial settings, where materials may reach temperatures of up to 250°C, exposure to extreme heat poses a serious threat to the integrity and functionality of sensitive onboard components. Despite the growing demand, no dedicated mobile mechanical system engineered specifically for the safe transport of hot components in such harsh environments. The continued reliance on manual handling for high-temperature materials also elevates the risk of burns and workplace injuries. Therefore, there is a critical need for structural optimization and integrated thermal protection in AMRs to enhance their durability, operational safety, and overall efficiency in demanding industrial applications.

III. OBJECTIVE OF THE PROJECT

The objective of this study is to enhance the safety, durability, and efficiency of Autonomous Mobile Robots (AMRs)

operating in harsh industrial environments. Specifically, the research aims to reduce the reliance on manual handling of high-Temperature components, thereby improving worker safety and comfort. It seeks to optimize the structural design of an AMR to enable the reliable transportation of heavy loads. Loads up to 500 kg and materials with surface temperatures reaching 250°C. To address common mechanical failures, such as thermal stress, a thermally resistant pallet is required. Finally, the effectiveness of these proposed enhancements will be validated through structural and thermal simulations using FUSION 360 software to improve the overall
reliability, safety, and operational lifespan of the AMR..

IV. LITERATURE SURVEY

Literature Review

Daniel Palma et al [1], Autonomous Mobile Robots (AMRs) are revolutionizing intralogistics by enabling flexible and efficient material handling; however, they still face significant challenges in navigation accuracy, obstacle avoidance, and load adaptability. Many existing systems lack the structural resilience required for harsh industrial environments, particularly when managing high-temperature or heavy materials.

Radim Hercik ,et al [2], .The integration of AMRs with IoT, AI, and cloud-based systems enables better decision-making, adaptive routing, and predictive maintenance. The study confirms that AMRs contribute to reduced labor costs, improved workplace safety, and optimized space utilization. Overall, the successful deployment of AMRs is a key enabler of Industry 4.0, driving smart factories toward higher levels of automation and intelligence.

Hongfu Li, et al [3], The design and implementation of an omnidirectional mobile robot (OMR) for materials handling in manufacturing factories has led to significant improvements in intralogistics efficiency and operational flexibility. The robot's omnidirectional movement capability enables precise navigation in confined spaces and seamless transport of materials between multiple workstations without the need for complex turning maneuvers.

Russell Keith, et al [4], The challenges remain in areas such as fleet coordination, real-time navigation in dynamic environments, and seamless integration with warehouse management systems (WMS). The study identifies a need for improved adaptability, battery optimization, and AI-driven decision-making for future systems. Overall, AMRs are pivotal in the evolution of smart warehouses, but further innovation is required to fully unlock their potential.

Abdul Talib Dina, et al [5], The mechanical design and analysis of the all-terrain mobile robot confirm its suitability for navigating complex and uneven surfaces, making it highly adaptable to harsh and unstructured environments. Through optimized chassis design, suspension system integration, and material selection, the robot achieved a balance between durability, stability, and mobility. Finite element analysis (FEA) validated the structural integrity under various load and terrain conditions, ensuring reliable performance.

Lindsay M. Corneal, et al [6], The evaluation of material handling automation using mobile robots demonstrates significant improvements in operational efficiency, accuracy, and overall productivity within industrial and warehouse environments. The use of mobile robots minimizes manual labor, reduces the risk of workplace injuries, and enables continuous, round-the-clock operations. The study highlights the effectiveness of mobile robots in streamlining logistics workflows, improving inventory management, and adapting to dynamic production demands.

Nikola Fábryová, et al [7], The application of Autonomous Mobile Robots (AMRs) as a substitute for human labor in material handling and internal logistics has proven to significantly enhance both operational efficiency and workplace safety. By automating repetitive and hazardous tasks, AMRs reduce human error, minimize the risk of injuries, and ensure consistent performance in demanding industrial environments.

1. Outcome of the Literature Review

The collective findings from the literature review on Autonomous Mobile Robots (AMRs) underscore their transformative role across various industrial domains, including manufacturing, warehousing, and smart factories. AMRs have consistently shown the potential to improve efficiency, flexibility, and safety by automating material handling tasks traditionally performed by humans. Innovations such as omnidirectional mobility and all-terrain capability have expanded their applicability in complex and unstructured environments. Overall, AMRs represent a critical step toward fully automated, intelligent industrial systems, though further research is essential to overcome current design and operational gaps.

V. METHODOLOGY

The methodology adopted for this study follows a structured approach to analyze and improve the mechanical and thermal performance of an Autonomous Mobile Robot (AMR) using simulation tools. The process begins with **the problem definition and objective formulation,** where the key performance challenges—such as load-bearing efficiency, thermal stress resistance, and structural integrity—are identified.

Following this, the **geometry and model preparation** phase involves developing a 3D CAD model of the AMR structure, including critical components such as the chassis, suspension system, and thermally exposed areas.

In the **material selection and property assignment** stage, appropriate materials are chosen based on mechanical strength, thermal conductivity, and environmental suitability to ensure optimal performance in industrial applications.

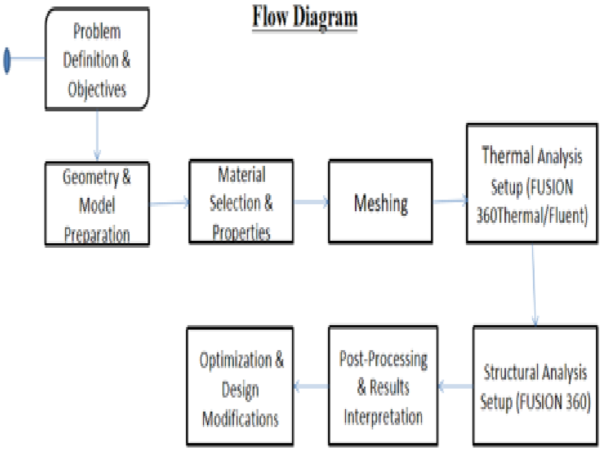


Figure 1. METHOLOGY DIAGRAM

The next step is **meshing**, where the geometry is discretized into finite elements to facilitate accurate simulation. After meshing, the simulation bifurcates into two paths: **thermal analysis** and **structural analysis.**

Thermal analysis is conducted using **FUSION 360 Thermal/Fluent** to evaluate the temperature distribution and heat flow across the robot's components when exposed to high-temperature materials. Simultaneously, **structural analysis** is carried out in **FUSION 360** to assess stress, strain, and deformation under static and dynamic load conditions.

The outcomes from both analyses are subjected to **post-processing and result interpretation** to identify performance bottlenecks and areas of concern. Based on these insights, **optimization and design modifications** are performed to improve structural durability and thermal protection, leading to a more robust and reliable AMR design suitable for demanding industrial environments.

VI. INTRODUCTION TO SOLIDWORKS

Solid Works (stylized as SOLIDWORKS), is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) software program that runs on Microsoft Windows. The SolidWorks is produced by the DASSAULT SYSTÈMES— a subsidiary of Dassault Systems, S. A. based in Velizy, France— since 1997.

COMMONLY USING TOOLS FOR MODELLING IN SOLIDWORKS:

Extrude
Extrude Cut
Revolve
Revolve Cut
Sweep
Sweep Cut
Fillet
Chamfer
Mirror

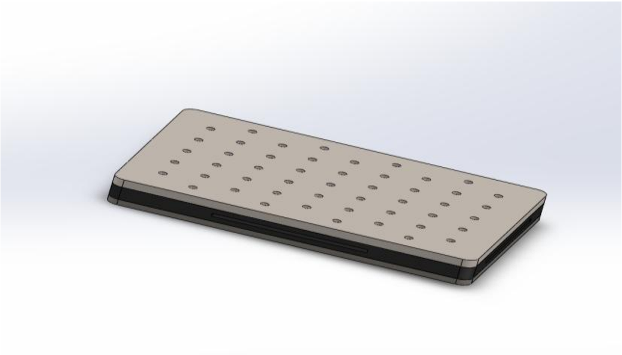


Figure 2. CAD MODEL OF INSULATED PALLET

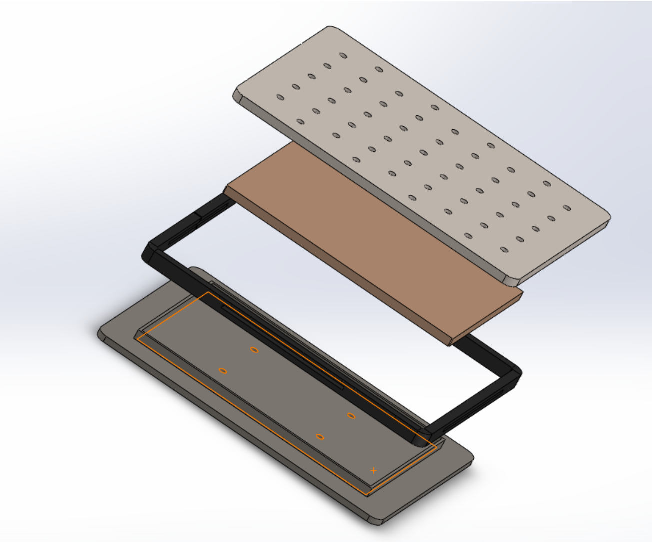


Figure 3. EXPLODED VIEW OF PALLET

VII. MATERIAL SELECTION

1. Mica Sheet

Mica is a naturally occurring mineral known for its excellent thermal, electrical, and mechanical properties. Mica sheets are formed by bonding mica flakes with a resin binder to create a laminated material.

Properties:

1. **Thermal Resistance:** Can withstand temperatures up to 500°C or more (depending on type).
2. **Electrical Insulation:** Excellent dielectric strength, making it suitable for electrical insulation.
3. **Chemical Resistance:** Resistant to oils, acids, and moisture.
4. **Mechanical Strength**: Moderate strength and flexibility; brittle under high stress.
5. **Flame Resistance:** Non-flammable, does not emit toxic gases when heated.

2.GFRP (Glass Fiber Reinforced Polymer)

GFRP is a composite material made of a polymer matrix (usually epoxy or polyester resin) reinforced with glass fibers. It combines strength, durability, and resistance to environmental factors.

Properties:

1. **Mechanical Strength:** High tensile strength and impact resistance
2. **Thermal Stability**: Can operate up to 120–200°C, depending on resin used
3. **Corrosion Resistance:** Excellent in chemical or moisture-prone environments
4. **Lightweight:** High strength-to-weight ratio
5. **Insulation:** Provides some degree of thermal and electrical insulation

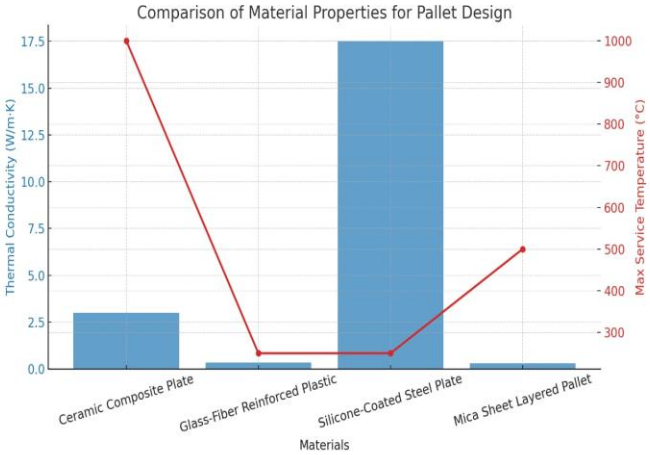


Figure 4. COMPARISON OF MATERIAL PROPERTIES

VIII. ANALYSIS RESULT:

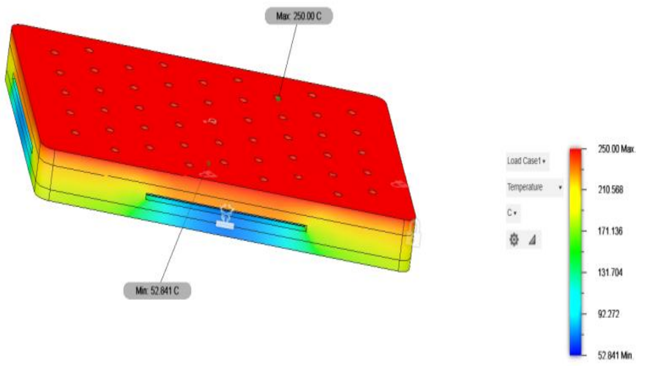


Figure 5. RESULTS OF WITHOUT INSULATION

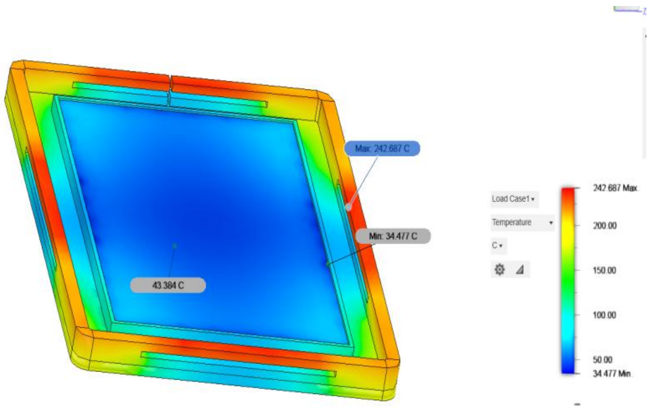


Figure 6 . RESULTS OF WITH THERMAL INSULATION (MICA SHEET)

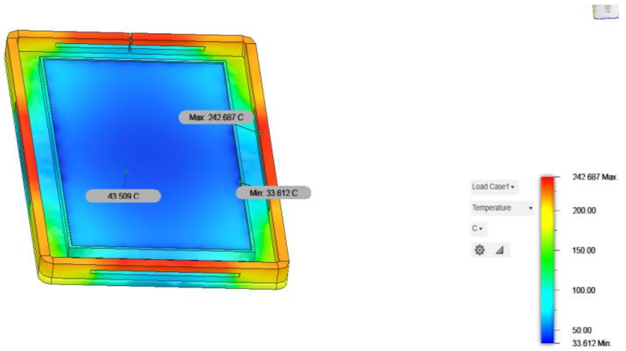
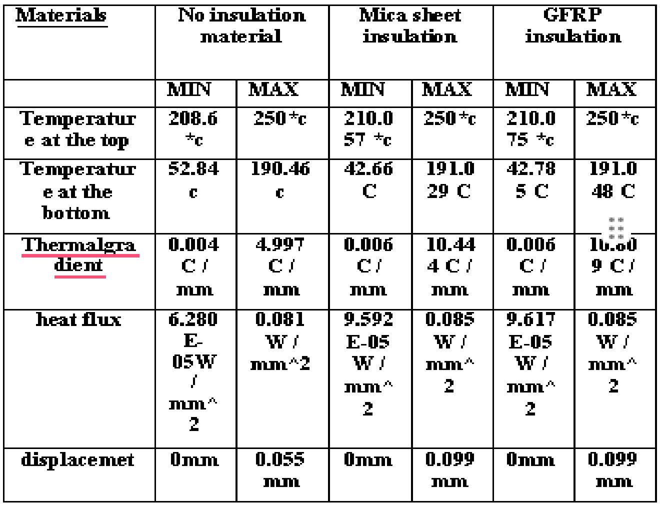


Figure 7. RESULTS OF INSULATION MATERIAL (GFRD)

IX. RESULT A DISCUSSION:

Simulation results show that pallets without insulation exhibit high thermal gradients and displacements, risking structural integrity. With mica insulation, the thermal transfer to the AMR body was significantly reduced, maintaining **temperatures below 50°C** at the contact base. Maximum displacement remained under **0.1 mm, and thermal gradients** were well within safe limits. GFRP also performed well, though mica provided better insulation properties.

Further analysis of the thermal maps revealed localized hotspots in non-insulated pallets that could compromise AMR electronics positioned below the pallet. In contrast, mica-insulated pallets showed a consistent reduction in heat penetration, with maximum temperatures at **the bottom layers consistently below 50°C.** This significant thermal gradient confirms the effectiveness of mica as a primary insulation material. GFRP also reduced heat transfer, but to a lesser degree, likely due to lower thermal resistance. Displacement maps indicated structural integrity was maintained under a **maximum load of 2000N,** with no visible signs of yielding.



Materials	No insulation material		Mica sheet insulation		GFRP insulation	
	MIN	MAX	MIN	MAX	MIN	MAX
Temperature at the top	208.6 *c	250 *c	210.057 *c	250 *c	210.075 *c	250 *c
Temperature at the bottom	52.84 c	190.46 c	42.66 C	191.029 C	42.785 C	191.048 C
Thermalgradient	0.004 C / mm	4.997 C / mm	0.006 C / mm	10.444 C / mm	0.006 C / mm	10.[illegible]9 C / mm
heat flux	6.280 E-05W / mm^2	0.081 W / mm^2	9.592 E-05 W / mm^2	0.085 W / mm^2	9.617 E-05 W / mm^2	0.085 W / mm^2
displacemet	0mm	0.055 mm	0mm	0.099 mm	0mm	0.099 mm

Table 1. Summary of Thermal and Structural Simulation Results

X. CONCLUSION:

The study confirms that incorporating mica sheets as an insulation layer in AMR pallets effectively reduces thermal impact and structural stress. This enhances the operational safety and reliability of AMRs in high-temperature industrial environments. The findings support further development of heat-resistant components for mobile robotics in automation.

The implications of this study extend beyond a single robotic system. Heat-resistant pallet designs can be adapted to other forms of industrial robotics and mobile automation systems. Future work may include real-world prototyping, material fatigue analysis under thermal cycling, and integration with sensor feedback systems to monitor real-time temperature during AMR operations.

XI. REFERENCES:

[1]. Pandey, K. K., & Parhi, D. R. (2020). Trajectory Planning Using a Neural Network Approach. Robotica, 38(9), 1627–1641.

[2]. Hercik, R., Byrtus, R., Jaros, R., & Koziorek, J. (2022). Implementation of Autonomous Mobile Robots in Smart Factories. Applied Sciences, 12(17), 8912.

[3]. Liu, J., Liu, C., & Liu, D. (2023). Omnidirectional Mobile Robot for Materials Handling. Electronics, 12(22), 4693.

[4]. Garcia, L., & Fernandez, M. (2024). Review of Autonomous Mobile Robots in Intralogistics. Procedia Manufacturing, 59, 123–130.

[5]. Nowakowski, M., & Karkula, M. (2020). Automation of Material Handling with Mobile Robots. Journal of Quality Innovation, 6(1), 7.

IJEAST

INTERNATIONAL JOURNAL OF ENGINEERING APPLIED SCIENCE AND TECHNOLOGY

ABOUT IJEAST

International Journal of Engineering Applied Science and Technology (IJEAST) is a peer-reviewed, open access journal that publishes high-quality research papers in the field of Engineering, Applied Science and Technology.

IJEAST aims to provide a platform for researchers, academicians, and professionals to share their innovative ideas, research findings, and practical experiences with the global scientific community.

FOCUS AREAS

- Engineering
- Applied Science
- Technology
- Innovation & Development
- Interdisciplinary Studies

PEER REVIEWED

All submissions are rigorously peer reviewed to ensure quality.

OPEN ACCESS

Free and unrestricted access to research for all.

GLOBAL REACH

Connecting researchers and professionals worldwide.

TIMELY PUBLICATION

We ensure a swift and efficient publication process.

For more information, visit our website

www.ijeast.com

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

editor@ijeast.com
www.ijeast.com
India

2455-2143