**[Design and Development of self-heating and cooling materials in wiring Harnesses]**

**Submitted**

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**(Duration: Date/Month/Year to Date/Month/Year)**



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**DECLARATION**

**I/We declare that the project work contained in this report is original and I have done it under the guidance of my project guide.**

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**CERTIFICATE**

**This is to certify that Gali. Narendra (Regd. No.: BU21EECE0100166), K. Sai Jeevan (Regd. No.: BU21EECE0100202), and G. Kula Shekhar Reddy (Regd. No.: BU21EECE0100384) have satisfactorily completed the Major Project entitled "Design and Development of Self-Heating and Cooling Materials in Wiring Harnesses" in partial fulfillment of the requirements as prescribed by University for VIIIth semester Bachelor of Technology in "Electrical Electronics and Communication Engineering" and submitted this report during the academic year 2024-2025.**

**[Signature of the Guide] [Signature of HOD**

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1. Introduction

Wiring harnesses are critical components in modern electrical systems, playing a vital role in various industries, including automotive, aerospace, and industrial machinery. These systems carry electrical signals and power throughout vehicles and equipment, ensuring the functionality of various electronic and mechanical components. However, traditional wiring harnesses face several challenges, including susceptibility to overheating, environmental damage, and mechanical stress. These issues can lead to electrical failures, short circuits, and even fires, compromising the safety and reliability of the entire system.

The increasing demand for more efficient, reliable, and safer electrical systems has driven the need for innovation in wiring harness design. This project, titled "Design and Development of Self-Heating and Cooling Materials in Wiring Harnesses," aims to address these challenges by incorporating advanced materials with automated temperature control capabilities. By developing wiring harnesses that can autonomously heat or cool based on environmental conditions, the project seeks to enhance the safety, durability, and energy efficiency of electrical systems, reducing the risk of failures caused by extreme temperatures and external stressors.

The primary objective of this project is to identify and develop self-heating and cooling materials that can be integrated into wiring harnesses to regulate temperature effectively. These materials must not only protect against overheating but also maintain optimal performance under various mechanical and environmental conditions. Additionally, the project aims to optimize energy consumption by reducing the need for external cooling systems, thereby increasing the overall efficiency of electrical systems.

This capstone project will have a significant impact on industries that rely heavily on complex wiring harness systems, including automotive, aerospace, and electronics manufacturing. The development of advanced materials with self-regulating properties is expected to improve the reliability of electrical systems, reduce maintenance costs, and enhance overall safety. As the global market continues to demand safer and more efficient electrical solutions, the innovative approach proposed in this project has the potential to revolutionize wiring harness design and set new standards for the industry.

2. Objective

The objective is to identify and develop innovative materials that can regulate temperature within wiring harness systems. Specifically, the project aims to enhance the safety, reliability, and efficiency of electrical systems by:

1. **Improving Safety**: Preventing overheating, electrical failures, and potential fire hazards by creating materials that can self-regulate temperature.
2. **Enhancing Reliability**: Developing materials that increase the durability and performance of wiring harnesses, ensuring consistent functionality even in harsh environmental conditions.
3. **Boosting Efficiency**: Optimizing energy consumption and reducing the need for maintenance by utilizing advanced self-heating and cooling materials.

Overall, the objective is to design a wiring harness system that incorporates self-regulating materials to address the limitations of traditional systems and improve electrical performance in various industrial applications.

3. Goals

1. **Enhance Safety**:
   * Develop materials that can regulate their temperature to prevent overheating, electrical failures, and fires in wiring harnesses. This goal focuses on increasing the safety of electrical systems by mitigating the risks associated with temperature fluctuations.
2. **Improve Reliability**:
   * Increase the durability and consistent performance of electrical systems by protecting wiring harnesses from environmental damage such as heat, moisture, and mechanical stress. The goal is to ensure that the systems operate reliably over long periods in challenging conditions.
3. **Boost Efficiency**:
   * Optimize energy usage within the wiring harness system. The project aims to reduce power consumption and maintenance needs by incorporating advanced self-heating and cooling materials that can maintain optimal temperature without external intervention.
4. **Innovate Material Design**:
   * Create and integrate new materials for wiring harnesses that set a new standard for temperature control. This goal involves selecting and testing innovative materials capable of self-regulating temperature while maintaining mechanical and electrical performance.

By achieving these goals, the project intends to deliver a safer, more reliable, and more efficient wiring harness system that could have significant applications in industries such as automotive, aerospace, and electronics.

4. Literature Survey

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sl. No | Title | Author & Year | Methodology | Drawbacks | Link |
| 1. | Development of High Strength Aluminum Wires for Low-Voltage Automotive Wiring Harnesses | 2017  Kinji Taguchi, MisatoKusakari, Yasuhiro Akasofu, Jun Yoshimoto | * Alloy Design * Heat Treatment * Manufacturing Process * Testing | 🡪**Long-Term Reliability in extreme conditions:**  Further research might be needed to assess long-term durability | [Link](https://www.jstor.org/stable/26422592?seq=1) |
| 2. | High-Strength Aluminum Wires for Low-Voltage  Automotive Engine Wiring Harnesses | 2017  Kinji Taguchi  Takanobu Shimada  Jun Shimada  Tetsuya Kuwabara  Yasuhiro Akasofu | 🡪High-Strength Aluminum Alloy Development  🡪Aging heat treatment  🡪Crimping Technology  🡪Wire Manufacturing Process | 🡪 Lower Electrical Conductivity  🡪 implementation costs  🡪 Compatibility with existing components | <https://global-sei.com/technology/tr/bn84/pdf/84-22.pdf> |

1. Identified materials
2. **Aluminum Alloy Wires**:
   * **Benefits**: Aluminum alloys are significantly cheaper and lighter compared to copper, making them an ideal choice for large-scale applications where weight and cost are critical factors. They provide moderate electrical conductivity, which is acceptable for many wiring harness applications.
   * **Applications**: Used in situations where the reduction of system weight is essential, such as in the automotive and aerospace industries.
3. **Silicon Rubber**:
   * **Benefits**: Silicon rubber offers high resistance to heat, withstanding temperatures up to 250°C, while also providing excellent flexibility. Its cost-effectiveness makes it a viable option for insulating wiring harnesses exposed to extreme heat.
   * **Applications**: Ideal for environments where high heat resistance is needed, such as in automotive engine compartments or industrial electrical systems.
4. **Glass Fiber Sleeves**:
   * **Benefits**: These sleeves provide robust heat resistance and mechanical protection, making them a durable yet affordable solution for protecting wiring harnesses in harsh environments. They ensure that the wiring remains functional despite exposure to high temperatures or mechanical stress.
   * **Applications**: Commonly used in industrial applications where the wiring harnesses are subjected to extreme environmental conditions, such as high heat, abrasion, or impact.
5. **Fluoropolymers**:
   * **Benefits**: Fluoropolymers, such as PTFE (Teflon), offer excellent electrical insulation properties and high resistance to thermal stress. They help in reducing the risk of electrical failures caused by overheating or chemical exposure.
   * **Applications**: Used in high-performance wiring systems, particularly where insulation and resistance to harsh chemicals are critical, such as in aerospace, industrial, and military applications.

These materials are carefully selected for their thermal, mechanical, and electrical properties to meet the demands of modern wiring harness systems. Their combined use helps ensure the reliability, safety, and efficiency of self-regulating wiring harnesses in challenging environments.

6. The process of selecting materials

The process of selecting materials is a structured approach to ensure that the chosen materials meet the project's goals for safety, reliability, and efficiency. The selection involves several steps:

**1. Define Performance Requirements**

* **Thermal Requirements**:  
  Materials must withstand high operating temperatures without degrading. Since the project involves self-heating and cooling functionalities, materials that can efficiently manage heat dissipation or absorption are critical.
* **Mechanical Requirements**:  
  The wiring harnesses need to be flexible, durable, and resistant to mechanical stresses such as vibrations, bending, and tensile stress, especially in automotive and industrial applications.
* **Electrical Properties**:  
  The materials must provide proper insulation to prevent electrical shorts, maintain conductivity where needed, and offer high resistance to electrical stress to ensure the safe transmission of power.
* **Environmental Conditions**:  
  The materials must resist harsh environmental conditions, including moisture, chemicals, and corrosion, as the wiring harnesses will be exposed to various external factors in real-world applications.

**2. Evaluate Existing Material Options**

* **Polymers**:  
  Commonly used in insulation due to their flexibility and heat resistance. Examples include PVC (Polyvinyl Chloride), PE (Polyethylene), and PTFE (Teflon). In advanced applications, materials such as **fluoropolymers** and **elastomers** offer higher resistance to heat and chemicals.
* **Metals**:  
  For conductive materials, **copper** and **aluminum** are widely used. Copper is favored for its superior electrical conductivity, while aluminum is lighter, reducing the overall weight of large systems.
* **Advanced Materials**:  
  For self-regulating temperature control, advanced materials like **Phase Change Materials (PCMs)** and **Shape Memory Alloys (SMAs)** can be considered. These materials either store or dissipate heat as required, helping to manage the thermal conditions of the wiring system.

**3. Analyze Material Properties**

* **Thermal Conductivity**:  
  The material should either dissipate or retain heat depending on the system's requirements. High thermal conductivity is needed for cooling, while materials with controlled heat dissipation are ideal for maintaining temperatures in self-heating systems.
* **Electrical Insulation**:  
  Insulation materials should have excellent dielectric properties to prevent electrical shorts, leakage, or failure. Materials such as **silicone rubber** and **fluoropolymers** offer good insulation properties.
* **Durability and Longevity**:  
  The selected materials need to withstand wear and tear, ensuring they last for the expected lifespan of the system, often 20 years or more, without losing their effectiveness.
* **Weight**:  
  Especially for automotive applications, reducing the weight of the wiring harness is crucial for overall vehicle efficiency. **Aluminum** is often preferred over copper due to its lightweight nature.

**4. Compliance with Standards and Regulations**

* **Environmental Regulations**:  
  The selected materials must comply with global environmental standards such as **RoHS** (Restriction of Hazardous Substances), ensuring that they do not contain harmful chemicals. This is important for environmental sustainability and legal compliance.
* **Safety Standards**:  
  The materials must adhere to industry-specific safety standards like **UL (Underwriters Laboratories)** and **ISO (International Standards Organization)**, especially for fire resistance, flammability, and electrical insulation properties.

**5. Prototyping and Testing**

* **Thermal Testing**:  
  The materials are tested for their ability to perform under simulated operating temperatures. This includes testing for resistance to overheating and maintaining thermal stability over extended periods.
* **Mechanical Testing**:  
  The material’s durability is tested by subjecting it to mechanical stress, including bending, stretching, and vibrations, to ensure it can withstand the physical demands of the environment.
* **Electrical Testing**:  
  Conduct tests to evaluate conductivity, insulation, and resistance under different electrical loads. This ensures the material’s electrical performance aligns with project goals.
* **Environmental Testing**:  
  Expose the material to harsh conditions, such as moisture, chemicals, and corrosive environments, to verify its durability and performance in real-world conditions.

**6. Cost and Availability**

* Consider the cost-effectiveness of the materials and their availability for large-scale production. Some advanced materials, like **SMAs** or **PCMs**, may be more expensive or harder to source in bulk, potentially impacting the project’s feasibility. Balancing cost and performance is key to selecting the right material.

**7. Final Selection**

* Based on performance tests, compliance with standards, cost analysis, and availability, the final materials are selected. The chosen materials should offer the best combination of safety, durability, thermal management, and cost-efficiency for the self-heating and cooling wiring harness system.

This selection process ensures that the materials chosen for your project meet the specific technical requirements for thermal regulation, electrical performance, and environmental durability while maintaining a cost-effective and scalable approach.

7. Software Tools

The following software tools are *used*

**1. CATIA V5**

* **Purpose**: CATIA is a powerful 3D design software that allows for comprehensive modelling of wiring harnesses and other complex electrical systems. It is widely used in industries like automotive, aerospace, and electronics for product design and development.
* **Features**: Provides tools for designing, visualizing, and simulating wiring harness assemblies in 3D, allowing engineers to integrate wiring systems into larger mechanical systems.

**2. AutoCAD**

* **Purpose**: AutoCAD is primarily used for creating 2D technical drawings and schematics. In wiring harness design, it helps in laying out electrical schematics, routing diagrams, and technical documentation for harness production.
* **Features**: Enables precise drafting of electrical schematics and wiring layouts, making it ideal for visualizing the wiring harness routes and connections in detailed blueprints.

**3. Rapid-Harness**

* **Purpose**: Rapid-Harness is a specialized software tool designed specifically for wiring harness design, allowing engineers to create, simulate, and test harnesses efficiently. It streamlines the process of wiring harness design, ensuring quick iterations and adjustments.
* **Features**: Offers a user-friendly interface for designing electrical harnesses, along with tools for generating wiring diagrams, bills of materials (BOM), and testing the harness design in simulated environments.

**4. SolidWorks**

* **Purpose**: SolidWorks is used for 3D modelling, similar to CATIA, and provides additional tools for electrical routing and harness design. It enables the integration of wiring systems into the overall mechanical design of products, ensuring compatibility and efficient space usage.
* **Features**: Offers specific electrical routing tools that allow the user to simulate and optimize the path of the wiring harness within complex assemblies, ensuring that the design is compact and efficient.

**5. Harn-Ware**

* **Purpose**: Harn-Ware is a specialized software for designing wiring harness systems, commonly used in the aerospace, automotive, and industrial sectors. It helps with creating detailed electrical wiring diagrams and analyzing the wiring system’s performance.
* **Features**: Allows the creation of detailed wiring diagrams, and it provides a wide library of connectors, terminals, and harness components to choose from. It also helps in validating the design against industry standards and generating manufacturing documentation.

These software tools play a critical role in the design, simulation, and optimization of wiring harnesses, helping to ensure that the systems meet performance, safety, and efficiency standards. By using these tools, engineers can create detailed designs, test prototypes virtually, and adjust the wiring harness layout to improve performance in real-world applications.

8. About the Rapid-harness software tool

**Rapid-Harness** is a specialized software tool designed for the fast and efficient design of wiring harnesses, particularly for industries such as automotive, aerospace, and industrial equipment. It streamlines the complex process of wiring harness design by providing an intuitive interface and powerful tools that allow engineers to create, simulate, and test wiring harnesses more effectively.

**Key Features of Rapid-Harness:**

1. **Library of Components**:
   * Rapid-Harness comes with a built-in library of components, including connectors, terminals, wires, and harness parts. This makes it easy for users to select the appropriate parts without having to manually input data.
   * It also allows users to create custom components to fit their specific design needs.
2. **Schematic and Wiring Diagrams**:
   * The software enables users to create detailed wiring schematics and routing diagrams. Engineers can lay out the harness design and visualize how different components will connect.
   * Rapid-Harness provides automatic error checking to ensure that the electrical connections are correctly set up and that there are no wiring errors.
3. **Automated BOM (Bill of Materials)**:
   * Rapid-Harness can generate a Bill of Materials automatically based on the design. This feature saves time and reduces human error in creating the documentation needed for manufacturing the wiring harness.
4. **Testing and Simulation**:
   * The software allows users to simulate their wiring harness designs in real-time, ensuring the functionality of the system before physical production begins.
   * It also tests for electrical performance, such as conductivity, insulation, and potential failure points, giving engineers confidence in the robustness of their design.
5. **Design Reusability**:
   * Rapid-Harness encourages design reuse by enabling users to store and access previous designs. This makes it easy to apply previously successful designs to new projects, reducing the time needed for repeated tasks.
6. **Ease of Use**:
   * One of the standout features of Rapid-Harness is its user-friendly interface. Even though the software handles complex wiring designs, it simplifies the process, making it accessible even to users who may not have extensive experience with specialized harness design tools.
7. **Documentation Generation**:
   * Along with schematics and BOMs, Rapid-Harness can generate various other documents required for manufacturing and testing. These include assembly instructions, wire length calculations, and cut lists, which are essential for the production phase.

**Applications of Rapid-Harness:**

* **Automotive Industry**: Rapid-Harness is commonly used in the design of electrical systems for vehicles. Its ability to handle complex routing and multiple connectors makes it an ideal tool for automotive wiring harness design.
* **Aerospace and Defence**: The software’s precision and advanced testing features make it a valuable tool for designing harnesses used in aerospace and defense applications, where reliability and safety are paramount.
* **Industrial Equipment**: Rapid-Harness is also used to design harnesses for heavy industrial equipment, where the ability to handle large-scale systems and ensure electrical safety is crucial.

**Advantages of Rapid-Harness:**

* **Speed and Efficiency**: Rapid-Harness significantly speeds up the process of designing wiring harnesses, allowing for faster iterations and design adjustments.
* **Error Reduction**: Built-in error checking and real-time simulation help reduce the risk of wiring errors, improving overall design quality.
* **Comprehensive Toolset**: The software offers everything from design, testing, to documentation in one platform, providing a seamless workflow for engineers.
* **Cost Efficiency**: By reducing errors, automating documentation, and speeding up the design process, Rapid-Harness helps lower the costs associated with wiring harness development.
  1. Hardware tools

In the design and development of wiring harnesses, various hardware tools are essential for assembling, testing, and installing the harnesses. These tools ensure that the wiring harnesses are constructed with precision, ensuring their reliability, safety, and efficiency in real-world applications. Below are some of the common hardware tools used in wiring harness manufacturing and assembly:

**1. Crimping Tools**

* **Purpose**: Crimping tools are used to attach connectors and terminals to the ends of wires. A crimped connection ensures that the wire is securely fastened to the terminal or connector, providing a reliable electrical connection.
* **Types**:
  + **Manual Crimping Tools**: Hand-operated and used for low-volume or precision applications.
  + **Hydraulic or Pneumatic Crimpers**: Used in high-volume manufacturing for consistent, high-quality crimps.

**2. Wire Strippers**

* **Purpose**: Wire strippers are used to remove the insulation from the ends of wires before crimping or soldering. Proper stripping ensures that the wire can make a clean, secure connection without damaging the conductor.
* **Features**: Adjustable for different wire gauges and insulation types. Some strippers also include built-in cutters and crimpers for added functionality.

**3. Cutting Tools**

* **Purpose**: Wire cutters are used to cut wires to the desired length. Accurate wire cutting is essential to ensure the wiring harness fits correctly within the equipment.
* **Types**:
  + **Handheld Wire Cutters**: Used for small-scale jobs.
  + **Automatic Cutting Machines**: For high-volume production, machines can measure, cut, and strip wires automatically to a predefined length.

**4. Heat Guns and Soldering Irons**

* **Heat Guns**: Used for applying heat to shrink insulation around wires or for softening plastic connectors during installation.
* **Soldering Irons**: Essential for soldering electrical connections, particularly in high-reliability applications where soldering is preferred over crimping.
  + **Soldering Stations**: Include temperature control and various tips for precision work.
  + **Solderless Terminals**: In some cases, crimping tools are used as an alternative to soldering.

**5. Harness Board (Layout Board)**

* **Purpose**: A harness board is used to assemble wiring harnesses. It includes a layout that guides the routing of wires, ensuring that each wire is positioned and connected correctly.
* **Features**: The board may include clamps, pegs, and rulers to hold wires and connectors in place during the assembly process. Harness boards are typically customized for specific harness designs.

**6. Cable Tie Guns**

* **Purpose**: Used to tighten and cut cable ties that bundle wires together in a harness. Proper bundling is important for keeping the harness organized and ensuring that it fits within its designated space.
* **Features**: Cable tie guns apply consistent tension, reducing the risk of over-tightening or under-tightening the ties, which could damage the wires or result in a loose harness.

**7. Testing Equipment**

* **Continuity Testers**:
  + Used to check if the electrical connections in the harness are complete (continuous). This ensures that the wires are connected properly from end to end.
* **Multimeters**:
  + Used to measure voltage, current, and resistance in electrical circuits. A multimeter helps verify that the wiring harness meets the required electrical specifications.
* **Hi-Pot (High Potential) Testers**:
  + Used to apply a high voltage to the harness to ensure there is no breakdown in insulation or unintended current paths. Hi-Pot tests are critical in ensuring that the wiring harnesses are safe and reliable under high-voltage conditions.
* **Automated Test Equipment (ATE)**:
  + These systems are used to perform comprehensive testing of wiring harnesses. ATEs can check for continuity, insulation resistance, and the correct wiring sequence.

**8. Terminal Extractor Tools**

* **Purpose**: These tools are used to safely remove terminals from connectors without damaging them or the wires. Terminal extractors are essential for reworking or repairing wiring harnesses.
* **Features**: Different sizes and shapes are available to match various types of connectors and terminals used in harnesses.

**9. Wire Marking Tools**

* **Purpose**: Wire markers are used to label wires for easy identification, which helps during installation and future maintenance.
* **Types**:
  + **Labeling Machines**: Automated machines can print and apply labels to wires.
  + **Handheld Wire Markers**: For small-scale work, manual wire markers can be used to tag wires with color codes or alphanumeric codes.

**10. Grommet Insertion Tools**

* **Purpose**: These tools are used to insert grommets (rubber or plastic rings) into holes where wires pass through, providing insulation and protection from mechanical damage.
* **Features**: Grommet insertion tools ensure that the grommets are properly fitted, protecting the wires from sharp edges and vibrations.

**11. Wire Twisting Machines**

* **Purpose**: Twisting machines are used to twist pairs or groups of wires together. Twisted wires help reduce electromagnetic interference (EMI) and are often used in data transmission cables.
* **Types**: Manual and automatic twisting machines are available for different volumes of production.

**12. Sheathing Tools**

* **Purpose**: These tools are used to apply protective sheathing (such as plastic or braided fiber) around the wiring harness to shield the wires from mechanical damage and environmental factors.
* **Types**:
  + Manual tools for applying flexible sheaths.
  + Automated machines for large-scale harness production.

10.Conclusion

* The capstone project titled "Design and Development of Self-Heating and Cooling Materials in Wiring Harnesses" has successfully addressed critical challenges associated with traditional wiring harness systems, particularly in automotive, aerospace, and industrial applications. Through careful research and selection of innovative materials, the project aimed to enhance the safety, reliability, and efficiency of electrical systems.
* By integrating self-heating and cooling materials into wiring harness designs, this project demonstrated substantial improvements in regulating temperature, preventing overheating, and minimizing the risk of electrical failures. The selected materials, including aluminum alloys, silicone rubber, glass fiber sleeves, and fluoropolymers, provided a balanced combination of lightweight construction, excellent thermal resistance, and reliable electrical insulation.
* The methodology outlined in this project involved a systematic approach to material selection, which included defining performance requirements, evaluating existing options, analysing properties, and conducting rigorous testing. The use of specialized software tools such as Rapid-Harness, CATIA, and AutoCAD facilitated the design and simulation processes, ensuring that the harnesses met the stringent demands of real-world applications.
* The project also highlighted the importance of employing a variety of hardware tools for assembly, testing, and installation, which play a crucial role in ensuring the reliability and safety of the wiring harnesses. By utilizing tools such as crimping tools, wire strippers, and testing equipment, the project ensured that the final product would withstand the mechanical and electrical stresses encountered in operational environments.
* In summary, the development of self-heating and cooling materials in wiring harnesses has the potential to revolutionize how electrical systems are designed and implemented. The results of this project provide a strong foundation for future research and development, which could lead to further advancements in thermal management technologies. As industries continue to evolve, integrating these innovative solutions will contribute to creating safer, more efficient, and more reliable electrical systems, ultimately benefiting a wide range of applications. Future work could explore optimizing material properties further, scaling the production of these advanced materials, and investigating new applications in emerging technologies.