Investigation and Utilization of Synthetic Rubber Materials for Thermal Insulation in Rocket Motor Systems

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Abstract -This study explores the properties and applications of synthetic rubber materials, particularly Rocket Case Insulation (ROCASIN), used in rocket motor casings. ROCASIN rubber, developed by ISRO, demonstrates exceptional thermal resistance, erosion protection, and mechanical properties, making it ideal for insulation in demanding aerospace environments. The research details the preparation, application, and curing processes of these rubber materials and discusses their performance under operational conditions. Key findings highlight ROCASIN's superior thermal stability and erosion resistance, which ensure the safety and reliability of rocket systems. These results underscore the importance of material innovation in advancing aerospace technology.

Keywords**:** ROCASIN, thermal resistance, erosion protection, aerospace materials

1. INTRODUCTION

Thermal insulation materials play a pivotal role in aerospace engineering, particularly in rocket motor casings, which face extreme heat and pressure during operation [1, 7, 10]. Synthetic rubbers like ROCASIN have emerged as key solutions due to their exceptional thermal, mechanical, and erosion-resistant properties. ROCASIN, an advanced insulation material developed by ISRO, provides specialized protection for rocket motor casings. The use of advanced adhesives, such as Chemlok, further enhances the bonding and durability of these materials. This paper investigates these materials' properties, preparation methods, and application processes, contributing to the broader understanding of their role in aerospace applications [4, 5, 6].

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2. RELATED WORK

Significant advancements have been made in the development and application of synthetic rubber materials for aerospace applications [2, 5, 8, 9]. Previous studies have highlighted the thermal and mechanical properties of elastomers and their role in enhancing the performance of rocket motor insulation systems. Research conducted by Kumar et al. (2021) examined the integration of heat-resistant fillers into elastomeric materials to improve thermal stability and erosion resistance. Additionally, studies on advanced adhesives, such as Chemlok, have provided insights into achieving superior bonding strength in multi-layer insulation systems. This section consolidates existing research and establishes the context for the methodologies and findings presented in this paper.

3. METHODOLOGY

3.1 Material Properties

Rocasin rubber is characterized by its density (1.17 ± 0.02 g/cm^3), excellent heat resistance, and flexibility, making it suitable for various industrial applications, including gaskets and automotive parts. ROCASIN, a copolymer of acrylonitrile and polybutadiene (NBR), incorporates heat-resistant fillers and additives to enhance its thermal and erosion resistance.

Thermal properties of ROCASIN include:

- Specific Heat: 1.4654 J/kg.K
- Coefficient of Linear Expansion: 3×10^{-4} mm/mm·°C
- Thermal Conductivity: 0.27196 W/m·K

Mechanical properties include tensile strength (100 kg/cm^2 minimum), elongation (600% minimum), and Shore A hardness (60–75). Erosion resistance, essential for withstanding combustion gases, is ensured by reinforcing agents and advanced formulations.

3.2 Application Processes

The preparation and application of ROCASIN rubber involve several steps:

- **Surface Preparation:** Visual inspection, degreasing, and grit blasting ensure the casing is free of defects and contaminants. TCE (Trichloroethylene) is used to clean the surface before applying adhesives.
- **Base Layer Application:** The ROCASIN rubber solution, prepared by dissolving rubber pieces in a toluene-EDC mixture, is applied as a base layer. This layer acts as a bonding medium for subsequent layers.
- **Cascading Layers:** Additional layers of carbon cloth and rubber are applied in a cascading manner to

achieve the desired thickness. Each layer undergoes TCE cleaning and adhesive application.

- **Top Layer and Loose Flaps:** A protective top layer covers the cascading layers, preventing direct exposure to combustion gases. Loose flaps at both ends enhance the overall integrity.

3.3 Curing Process

The assembled layers are vacuum-sealed and subjected to an autoclave curing cycle lasting 7.5 to 8.5 hours. The cycle involves incremental heating to 120°C under 5 bars of pressure, ensuring optimal bonding and material stability.

3.4 Day-Wise Preparations

To ensure proper implementation of the ROCASIN rubber insulation system, preparations should be carried out over multiple days. On the first day, ROCASIN rubber rolls should be cut into smaller sheets and dissolved in a mixture of toluene and EDC (1:1 ratio) to form a uniform rubber solution.The next day, the inner surface of the nozzle end segment (NES) must be coated with the first layer of the rubber solution, allowed to cure, and followed by the application of cleaned shell and dome section rubber sheets to complete the base lining. On the third day, rayon carbon fiber cloth should be dried in a hot oven at 120°C, coated with the rubber solution on both sides, and stored for later use.On the fourth day, ultrasonic testing (UT) must be conducted to ensure bonding integrity by marking grid lines on the NES calibrating the testing equipment. The fifth day involves bonding prepared carbon cloth sheets to the NES base layer, followed by a corresponding rubber layer to create the second coating. Subsequent layers, including the third and fourth, should be added in the following days using the same cascading process to ensure uniformity and alignment.On the seventh day, all sixteen cascading layers should be completed, with a protective top layer applied to shield the insulation. Finally, on the eighth day, the entire assembly must be vacuum-sealed and cured in an autoclave with incremental heating and pressurization to optimize bonding and material stability.

4. CONCLUSIONS

The findings underscore the critical role of advanced rubber materials like ROCASIN in ensuring the reliability and safety of rocket systems. Its superior thermal and erosion-resistant properties make it a cornerstone of modern aerospace insulation technology. Future research could explore further optimization of these materials to meet evolving industry demands.

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