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Study on the Rubber Powder Composite for Rubber Car Mats Application

Muhammad Syahrul Azhar Mohd Sangit[1], Norhasikin Ismail[1]*

[1] *Department of Mechanical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 86400, Pagoh, Muar, Johor, MALAYSIA*

*Corresponding Author: nhasikin@uthm.edu.my
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Abstract

This research focuses on developing rubber car mats using waste rubber powder as a sustainable alternative to traditional raw rubber, motivated by the rising cost of raw rubber due to reduced natural rubber production by the Organization of the Rubber Exporting Countries (OPEC). The research aims to provide an environmentally friendly and cost-effective solution for automotive applications while maintaining mechanical performance. Rubber composites were prepared by mixing waste rubber powder with epoxy resin and hardener in varying weight ratios (20%, 30%, 40%, and 50%). 120g of each sample was fabricated and tested according to ASTM standards: tensile strength (ASTM D638 Type 4), bending strength (ASTM D790), and impact resistance (ASTM D256). The mechanical testing revealed that 20% exhibited the highest tensile strength (15.7 MPa) and bending strength (62.58 MPa), while 50% showed the highest impact strength (6.66 MPa) with energy absorption of 1.34%. However, composite analysis determined that percentages did not provide the best mechanical properties for car mat applications. The result analysis is not in the range of actual impact strength for a rubber car mat. Generally, not all percentages of rubber car mats are as elastic as a common rubber car mat. at the market. This study can be used for other suitable applications such as car bumpers, car spoilers and car skirting.

1. Introduction

The automotive industry seeks sustainable alternatives for robust materials, focusing on rubber car mats. Traditional materials meet durability needs but harm the environment through resource depletion and waste [1]. Rubber powder waste composite, derived from tyre production waste, offers a greener option with strength and longevity. This study evaluates its mechanical properties and eco-friendly production to determine its suitability for car mats, aligning with industry goals for reduced environmental impact and sustainability.

Research on the use of waste rubber powder in automotive production emphasises its potential as an eco-friendly and cost-effective alternative to raw rubber. Rubber powder composites address environmental concerns by repurposing industrial tyre waste while offering functional and durable solutions for automotive applications, such as rubber car mats [2]. Studies have shown that combining rubber powder with binders like epoxy resin enhances mechanical properties, including durability, flexibility, and impact resistance. Mechanical tests such as tensile strength, bending strength, and impact resistance are commonly used to evaluate the performance of rubber composites.

Existing research often concludes that an intermediate rubber powder ratio, typically around 30%, achieves the best balance between strength and flexibility, making it ideal for heavy wear and tear products, like car mats. Previous research on common rubber car mats has 10-30% rubber powder, typically ideal with 12-20 Mpa of tensile strength, 32-43 MPa bending strength and 8.5-9.2 kJ/m^2 impact strength [3]. These findings align with the current study, which identified 30% rubber powder as the optimal composition for car mat applications. Previous research suggested that optimising rubber-to-resin ratios is critical for improving composite performance [4]. Additionally, focusing on sustainable production methods, such as recycling waste materials and minimising energy use, aligns with industry goals of reducing environmental impact. These studies underscore the importance of developing processes that lower manufacturing costs while ensuring that rubber powder composites meet automotive products' durability and performance requirements. Rubber powder composites provide a practical solution for reducing waste and a sustainable pathway for advancing automotive materials.

We hypothesise that rubber powder composites, specifically with a 30% rubber powder ratio, offer an eco-friendly and cost-effective alternative to traditional materials for automotive applications, such as car mats. We predict these composites balance strength, flexibility, and durability while addressing environmental concerns by repurposing tyre production waste. By optimising the rubber-to-resin ratio and incorporating sustainable production methods, such as recycling and minimising energy consumption, rubber powder composites can meet the automotive industry's performance requirements while contributing to reduced environmental impact and waste reduction [5].

2. Methodology

The methodology outlines the systematic process of producing and testing rubber powder composite car mats. This section details the steps involved in preparing the samples, ensuring safety during handling, and conducting mechanical tests to evaluate their performance. It begins with preparing raw materials, including measuring and mixing epoxy resin, hardener, and rubber powder in varying compositions.

2.1 Material

Rubber powder waste was used as a raw material, and two types of chemicals, epoxy resin and hardener, were used to produce samples. Rubber waste from enterprises was blended into a powder shape. Rubber powder waste obtained from rubber factory. Rubber powder waste has the flexibility to modify its mechanical properties, such as elasticity. Its various mechanical properties can be used for various applications. Epoxy resin and hardener work together to create durable, strong test samples by forming a solid material through a chemical reaction, allowing for accurate mechanical testing of properties like strength and durability. Epoxy resin and hardener obtained from a chemical factory.

2.2 Preparing Mould

The production process involved several steps. First, the epoxy resin, hardener, and rubber powder were measured using the 3:1 ratio [6]. Table 1 shows the number of masses of material ratios for one sample. Figure 1 shows that the mixture was placed into a moulding container, and the resin and hardener were thoroughly mixed using a stirrer until the mixture was smooth and free of streaks or lumps. Resin-hardener mixture while stirring continuously to ensure the rubber additive was evenly distributed. This procedure was repeated for 30%, 40%, and 50% rubber powder compositions. All prepared mixtures were left to dry in a smoke chamber for 24 hours.

***Table 1*: Number of masses material ratios for one sample**

Rubber Powder Percentages (%)	Rubber Powder Weight (g)	Resin Weight (g)	Hardener Weight (g)	Total Weight (g)
20%	24	72	24	120
30%	36	63	21	120
40%	48	54	18	120
50%	60	45	15	120

***Fig. 1*: Mixture Preparation**

2.3 Preparing Sample

After drying, the moulds were removed from the smoke chamber for cutting. Before starting, additional safety measures were taken by wearing a workshop coat, safety shoes, safety gloves, safety glasses, and a mask to protect against dust, strong odours, moving machinery, sharp tools, and cutting disc debris. Each mould was carefully removed from the moulding container and marked using a marking pencil and elbow L based on ASTM measurement standards shown in Figure 2. Further shaping was done with a cutter and saw to meet the specified measurements. Figure 3 shows the samples were finished by trimming or sanding rough edges and applying additional coatings or finishes if necessary.

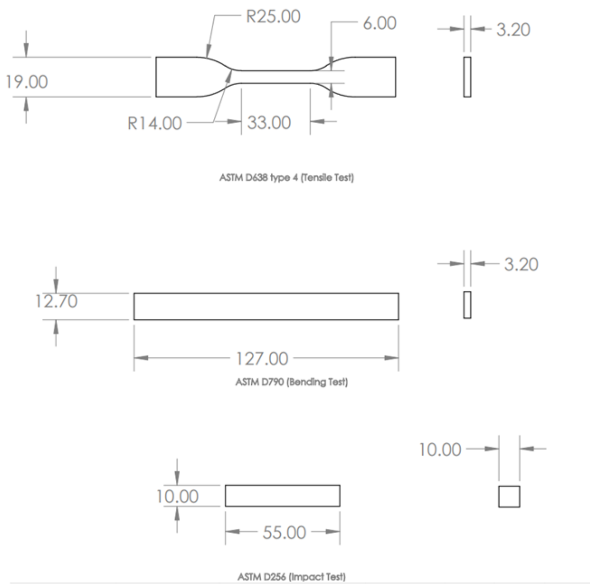

***Fig. 2*: Dimensions for all specimens.**

(a) **(b)** **(c)**

***Fig. 3*: Samples (a) Tensile Test ; (b) Bending Test ; (c) Impact Test**

2.4 Mechanical Testing

All specimens underwent mechanical testing, including the tensile test (ASTM D638 Type 4), to determine tensile strength, a maximum pulling stress that can act on samples before they break. The bending test (ASTM D790) was included to define its flexural strength, a maximum stress that can samples bend before its break. Impact tests (ASTM D256) were conducted to determine the impact strength, which is the maximum energy that the sample absorbed. The finishing process was repeated for all compositions, including the 20%, 30%, 40%, and 50% rubber powder samples. The resulting specimens were prepared for testing to evaluate their mechanical properties and performance for car mat applications. Characterisation refers to the comprehensive analysis of the rubber powder composite car mats produced in this study. It includes evaluating the key physical, mechanical, and environmental properties to determine the suitability of different rubber powder compositions for automotive applications. The primary properties characterised were tensile strength, bending strength, impact resistance, surface quality, and the uniformity of rubber powder distribution in the resin matrix [7].

3. Result and Discussion

The results and discussion section presents and analyses the findings from the production and testing of rubber powder composite car mats. This section includes the mechanical properties of the samples, such as tensile strength, bending strength, and impact resistance, for varying compositions of rubber powder (20%, 30%, 40%, and 50%). The results are compared to industry standards and previous research to evaluate the performance and suitability of the composites for automotive applications.

3.1 Tensile Test

Figure 4 shows the stress-strain differences between the 20%, 30%, 40% and 50% percentages of rubber powder. Based on Figure 1, the highest tensile stress was obtained at 30% rubber powder with a reading of 11.86 MPa. The strain (%) was obtained at 30% rubber powder, with a reading of 10.09%. From the data shown, the ratio of 30% of rubber powder has an optimum interaction between the rubber powder and the matrix. Previous research said 10-30% rubber powder is typically ideal with 12-20 MPa [8]. A balance between tensile strength and elongation ensures the mats can endure stretching or pulling forces during use without tearing. This means that the rubber is well spread throughout the matrix, which could have been a factor in its effective stress transfer, as the stress transfer plays a crucial role in allowing the rubber powder to absorb and distribute the mechanical loads.

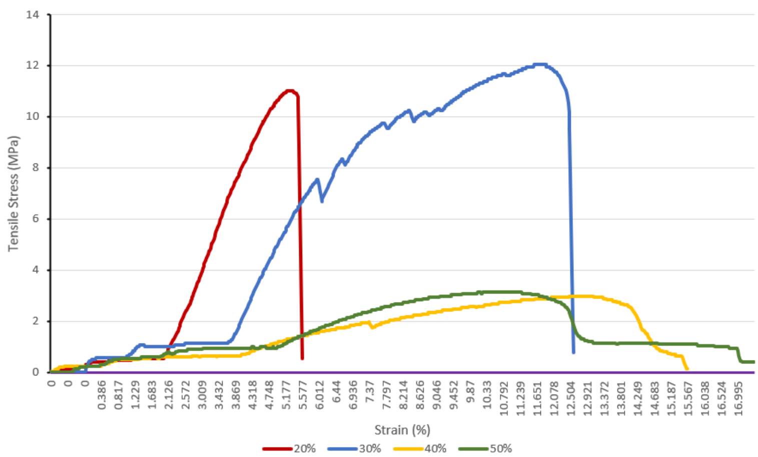

Fig. 4 *Graph Tensile Stress against Strain of Percentages*

3.2 Bending Test

Based on Figure 5, the results show that at the flexural strength of 51.55 MPa, the 30% and 26.81 MPa for 40% rubber powder. Both percentages are in the range of actual bending strength for common rubber car mats. Previous research analysed that 10-30% rubber powder has balanced strength and flexibility with 32-43 MPa bending strength [9]. This is because rubber car mats are subjected to frequent bending, folding, and deformation under foot traffic and pressure from shoes. Flexural strength evaluates the material resistance towards bending or flexural stresses. The tensile strength measures how a material can withstand pulling force.

Rubber powder optimum interaction between rubber powder and the matrix is still considered, but increasing the rubber powder content often increases the load-bearing capacity and structural integrity.

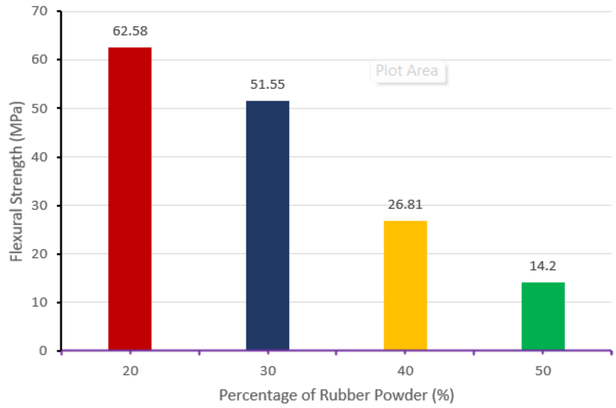

Fig. 5: Bar Chart of Flexural Strength

3.3 Impact Test

Figure 6 illustrates the average impact strength in the unit of kJ/m2 and its percentage for energy absorption. The percentage with the highest impact strength was 50%, with a 6.66 kJ/m2 value. For the percentage of energy absorption, the 50% ratio is the highest, with a value of 1.34%. The percentage of rubber powder in a composite affects its ability to absorb energy and resist impact because rubber is good at deforming and absorbing energy. Adding more rubber powder makes the material more flexible, absorbing more energy during impact without breaking. However, too much rubber can reduce the material's strength, making it less resistant to forces like bending or stretching. Due to experimental error, this test did not achieve a common rubber car mat impact strength of 8.5-9.2 kJ/m^2 for 20-30% rubber powder [10]. Rubber materials absorb energy efficiently due to their elasticity, which is critical for withstanding sudden forces, such as dropping heavy objects on the mat

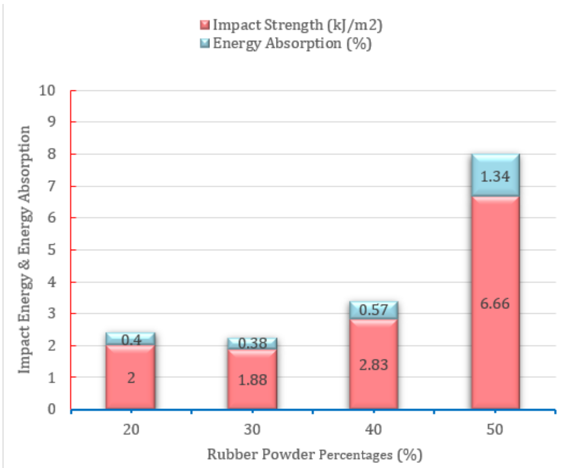

Fig. 6: Bar Chart of Energy Absorbtion and Impact Strength

4. Conclusion

The analysis results indicate that the measured impact strength falls outside the expected range for common rubber car mats. All rubber car mat samples exhibit the same elasticity level as commercially available products. Reduced elasticity compromises flexibility, increasing the risk of breakage and making the material unsuitable for rubber car mat applications [11]. The findings of this study suggest that research is more appropriate for alternative automotive applications, such as car bumpers, spoilers, and skirting, where higher rigidity and impact resistance are desirable. Due to several potential factors, the study could not determine the optimal rubber composition for car mat applications. These include inaccuracies in the formulation percentages or procedural inconsistencies during sample preparation. To enhance the suitability of the material for rubber car mats, future research should explore optimised rubber content ratios, such as 35%, 45%, 55%, and 65%. alternative manufacturing techniques, such as the hot stamping method, may improve elasticity and overall performance. Further investigations and refinements are necessary to develop a rubber composition that meets industry flexibility, durability, and impact resistance standards.

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