



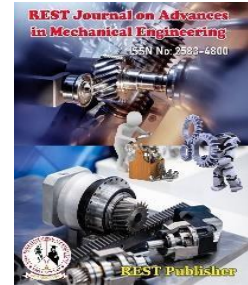
REST Journal on Advances in Mechanical Engineering Vol: 3(1), March 2024

REST Publisher; ISSN: 2583-4800 (Online)

Website:

<https://restpublisher.com/journals/jame/>

DOI: <https://doi.org/10.46632/jame/3/1/6>



Performance Evaluation of Coconut Shell Powder-Polymer Composites Using the TOPSIS Method

*P.Thirumalainayakkar, K.S.Arjun, S.Esvaran, K.Kabilan, S.Vishal

Arasu Polytechnic College, Kumbakonam, Tamil Nadu, India.

*Corresponding Author Email: thirumalainayar@gmail.com

Abstract: Coconut shell powder reinforced composite materials are materials made by mixing coconut shell powder with a binder material, like epoxy resin, to create a composite material. These materials have many potential applications, including in the construction industry, furniture, and electrical devices. This research highlights the effectiveness of using the TOPSIS method to evaluate and rank coconut shell powder-polymer composites. It identifies optimal materials for applications requiring high strength, durability, and water resistance, aiding material selection for sustainable engineering solutions while promoting the utilization of agricultural waste in advanced composite development. The TOPSIS analysis reveals that the Epoxy-Coconut Shell Powder composite ranks highest due to its superior tensile strength, water resistance, and low wear rate. Polyester and Polyurethane-Coconut Shell Powder composites follow with balanced performance, while Polypropylene and Polyethylene composites rank lower due to weaker tensile strength and higher wear rates. Epoxy-coconut bat powder composite is the best-performing material, offering excellent strength, water resistance, and durability. Polyester and Polyurethane composites provide balanced alternatives, while Polypropylene and Polyethylene composites exhibit lower performance. This analysis highlights the potential Coconut shell powder in eco-friendly ingredients development.

Keywords: TOPSIS method, Coconut shell powder, Polymer composites, Tensile strength, Sustainable materials, Wear resistance.

1. INTRODUCTION

Tensile strength was assessed using a composite made up of 80% Tamarind shell powder combined with 20% epoxy. A review of the existing literature revealed that Epoxy resin mixtures reinforced with coconut shell powder and tamarind shell powder exhibit significantly lower mechanical properties. Consequently, an attempt was made to develop and evaluate the mechanical properties of epoxy resin composites reinforced with coconut shell powder and tamarind shell powder. [1] Areca fiber and coconut husk powder are considered promising materials among natural fibers due to their abundance, affordability, and excellent performance. Areca fiber is sourced from the Areca Catechu L. [2] the global supply the volume of coconut shells is growing steadily every year, making them a valuable lignocellulosic waste resource. [3] The findings of this study indicate that the addition of coconut shell powder increases the brittleness of the material. As the fiber content in bamboo fibers (BF) increased from 10 to 30 wt. %, The addition of bamboo reduced the density of the mixture. Skin and coconut shell powder further contributed to this density reduction. Lightweight materials, such as PP/PCS PVC composites, offer benefits for easy handling and transportation. The observed decrease in density compared to the polymer matrix may be due to the lower density of the fibers used. [4] Coconut shell powder and ground polyethylene particles were mixed using a two-roll Rio mixer at 50°C with a rotor speed of 60 rpm. The filler content in the matrix ranged from 0% to 15% for six different coconut shell mixtures and from 15% to 30% for six tree apple shell mixtures. The mixtures were then compressed under gravity at 150°C. After compression, each sample was allowed to cool to room temperature under constant pressure before being extracted from the mold. [5] The assembly of the links was kept in a dry environment for 24 hours. After

curing for the same period, the product was removed from the mold and a polymer matrix composite (PMC) was prepared. Two types of laminates were prepared with the following compositions: 15% each of bamboo powder (BP) and coconut fiber by weight, combined with 70% polyester resin by weight. In the same manner, laminates containing 15% coconut fiber and 15% coconut batt powder by weight and 70% polyester resin were formed. The final laminates were cut into various shapes and sizes using a cutting machine, in accordance with the required test standards. [6] The positive DGS observed in this study indicates that the solubility of natural rubber filled with coconut shell powder is consistent regardless of the solvent used. [7] The compressive strength of coconut shell concrete is similar to that of regular concrete, making it a promising alternative to coarse aggregates in construction. [8] In this study, Coconut shell powder particles less than 150 μm were used. The particles were dried by heating in a pan to remove moisture. Tensile test specimens were fabricated following ASTM-D 3039/D3039M-00E02 standard, containing 20% coconut shell powder. [9] The content of other elements in the coconut shell powder was found to be less than 1.00%. The presence of silicon oxide, which is 0.98% in coconut shell powder, is noteworthy because it plays a key role when mixed with concrete. The particle size distribution analyzed using the sieving method shows that the particle diameter of coconut shell powder is 600 μm or smaller. To be used as a filler, the material must have very fine particles, a requirement that is met by coconut shell powder, with most particles being less than 150 μm . To gain a deeper understanding of the particle size and structure, scanning electron microscopic (SEM) testing was conducted. [10] The compressive strength of coconut shell concrete is comparable to that of traditional concrete, providing a promising alternative to traditional coarse aggregates. Adding coconut flakes creates environmentally friendly aggregates, which is particularly advantageous for applications such as underwater pipeline construction, which helps reduce the impact on marine life. This approach not only produces a lightweight aggregate but also increases the market value of coconut shell waste. Future research should aim to improve the properties exploring coconut shell concrete and its potential for use in other types of ceramic matrix composites. [11] Our results show that Coconut shell powder is composed of 13.6% Fe_2O_3 , 25.7% CaO , 46.1% K_2O , 2.8% CuO and 8.2% P_2O_5 . The Fe_2O_3 content increased significantly after grinding the sample for 20 h, while the percentages of CaO and K_2O decreased significantly. These findings suggest the chemical composition of coconut shell powder is greatly influenced by the grinding time, suggesting that the particle size plays a crucial role in determining the properties of the powder. [12] Most studies have focused on blending This study investigated the use of walnut shell powder, coconut shell powder, and wood apple shell powder to improve the mechanical properties of powder-reinforced polymer composites, rather than using each material individually. Specifically, the research examined the impact of particle reinforcement on the mechanical properties of composite samples where walnut shell powder and wood apple shell powder were added separately along with coconut shell powder. [13] The mixture is poured into the mold cavity after a release agent is applied to the mold walls to facilitate the removal process. Once the samples are dry, they are taken out of the mold. Initially, the samples are left to dry the mixture is left in the mold for 20 hours at room temperature. Then, it is taken out and dried in an oven at 50 degrees Celsius for 4 hours. This process is repeated using different particle sizes of coconut shell powder. [14] The variation of the coefficient of friction and the effect of sliding distance were studied for hybrid powder mixtures containing malic acid, unrefined rice husk, groundnut, coconut shell powder and steel with a surface roughness of 0.54 μm (Ra). Initially, the coefficient of friction for the mixture was measured at 0.25 when sliding at a speed of 1 m/s for 500 m. After this point, further increase in sliding distance beyond 500 m resulted in a constant coefficient of friction. [15] In this experimental study, an environmentally friendly composition was created by adding water hyacinth and coconut shell powder to an epoxy resin matrix. Materials were used in their untreated forms, with 15% by weight the findings indicated that the amount of coconut husk powder incorporated into the epoxy resin. The strength of the composite was improved the addition of water hyacinth and coconut husk powder resulted in an ultimate strength of 83.7 MPa. As a result, this eco-friendly composite has significant potential for future applications. And offers advantages for industrial use. [16] Solvent absorption properties of natural rubber v compounds were analyzed in aromatic solvents using both untreated and alkali-treated coconut shell powder (with particle sizes ranging from 0-45 μm and 45-90 μm). [17] A molding box with dimensions of 200 x 150 x 10 was constructed from wood. Five different types of panels were created, including hybrid glass/bamboo, pure bamboo and hybrid glass/bamboo composites, all of which were reinforced with nano- and micro-sized coconut coir powder in polyester resin.

2. MATERIALS AND METHODS

The findings of this study can be compared by replacing the weighted normalized matrix assess the sensitivity of the solution to these changes. Furthermore, this study can be extended using other Multiple Criteria Decision Making (MCDM) techniques such as AHP or TOPSIS Analytic Network Process (ANP). [19] CIFs are very useful in MCDM

methods because their properties significantly improve the accuracy of results in different MCDM techniques. The unique contribution of this paper lies in the novel development of CIF-TOPSIS and its application to address the challenge of selecting optimal locations for hospitals for epidemics. [20] Using the TOPSIS method, cities suitable for becoming smart cities can be identified. The results of this study indicate that Madden (Alternative 1) achieved the highest possible score of 0.8983, positioning it as the leading candidate among the evaluated alternatives. [21] TOPSIS method is a decision-making approach that incorporates multiple criteria tools designed to evaluate and select the optimal alternative from available software solutions in the medical information systems market. It is highly effective and user-friendly, as it considers both the ideal and the most antithetical solutions. A key advantage of TOPSIS is that the number of steps required for its application remains consistent, regardless of the number of alternatives or criteria involved. Unlike other methods, TOPSIS provides a numerical ranking of alternatives, making the results straightforward to interpret and particularly useful for ranking problems. While the ELECTRE method is often paired with TOPSIS, other ranking techniques such as PROMETHEE, SAW, MOORA, or VIKOR can also be employed. [22] This method enables experts to use unbalanced dual-level linguistic terms, which allows for the flexible expression of their complex cognition. Accordingly, the UDHL-TOPSIS method is used to tackle the engineering challenge of selecting a green mine. [23] The quality of travel website services can be viewed as a combination of various intangible attributes or criteria, making its evaluation a complex decision-making problem involving multiple criteria (MCDM). MCDM involves evaluating multiple criteria to decide. Among the widely used MCDM approaches, Technique for Ordered Preference by Similarity to Ideal Solution (TOPSIS) is a practical and an effective method for ranking and selecting alternatives on their Euclidean distance measures. [25] TOPSIS is a commonly used method for traditional MCDM problems, often used by researchers to address ranking and prioritization challenges. Essentially, TOPSIS is an efficient technique that evaluates alternatives by comparing their values for each criterion with the corresponding weights of those criteria. [26] TOPSIS is commonly used for decision making involving multiple attributes problems, but it differs from AHP in two important ways. AHP uses Comparisons between pairs of attributes. And options, not in TOPSIS have pairwise comparisons. In addition, AHP organizes attributes and alternatives in a hierarchical structure, whereas TOPSIS does not take this into account, and existing fuzzy TOPSIS methods also fail to address hierarchies in multi-attribute problems, giving AHP an edge. To fill this gap, the following section introduces a fuzzy hierarchical TOPSIS approach designed to handle multi-attribute hierarchical problems. [27] The findings of the study led to the development of TOPSIS for cardinal data by introducing new and unique reference points to improve its robustness against rank changes. Furthermore, the TOPSIS-MMD method is built on these innovative reference points and special normalization techniques. Importantly, a meaningful normalization approach is used for ordinal data. The TOPSIS-MMD method is intuitive, straightforward to implement, and highly reliable. [28] In traditional TOPSIS, the criteria score and weights are well defined. However, in many cases, accurate data alone does not adequately represent real-world scenarios because human judgments are often ambiguous, and decision makers may have difficulty expressing their preferences in precise numerical terms. [29] Tensile strength was evaluated using a composite containing 80% tamarind shell powder and 20% epoxy. A literature review indicated that epoxy resin composites reinforced with coconut shell powder and tamarind shell powder exhibit poor mechanical properties. [30] The main objective of the TOPSIS method is to find the solution (alternative) that is closest to the best solution, even if it is far from the ideal anti-ideal solution. The development of new techniques. Currently, the fuzzy TOPSIS method, which incorporates fuzzy set theory, is the most widely used version in practice.

3. ANALYSIS AND DISCUSSION

TABLE 1. Coconut Shell Powder-Reinforced Composite Materials

Composite Material	Tensile Strength (MPa)	Water Resistance (%)	Density (g/cm ³)	Wear Rate (mm ³ /Nm)
Polyester-Coconut Shell Powder	35	92	1.15	0.03
Epoxy-Coconut Shell Powder	42	95	1.2	0.025
Polypropylene-Coconut Shell Powder	28	85	0.95	0.045
Polyurethane-Coconut Shell Powder	38	88	1.1	0.035
Polyethylene-Coconut Shell Powder	30	90	0.97	0.04

Table 1 outlines the properties of various composite materials produced by combining coconut shell powder with different polymer matrices. The materials are compared in terms of tensile strength, water resistance, and density and

wear rate. The epoxy-coconut shell powder composite stands out with the highest tensile strength of 42 MPa, making it the strongest of the listed materials. It also has excellent water resistance (95%) and a relatively low wear rate of 0.025 mm³/Nm, indicating excellent durability. However, its density is slightly higher at 1.2 g/cm³, which may affect weight-sensitive applications. The polyester-coconut shell powder composite has a tensile strength of 35 MPa and excellent water resistance of 92%. Its density is moderate at 1.15 g/cm³, with a wear rate of 0.03 mm³/Nm, providing a well-rounded option for both strength and durability. The polyurethane-coconut shell powder blend combines a tensile strength of 38 MPa and a water resistance of 88%. Its density (1.1 g/cm³) and wear rate (0.035 mm³/Nm) are moderate, providing a consistent performance. At the lower end, polypropylene-coconut shell powder and polyethylene-coconut shell powder blends have lower tensile strengths of 28 MPa and 30 MPa, respectively. Although they are lighter, their high wear (0.045 and 0.04 mm³/Nm) may limit their suitability in high-friction environments.

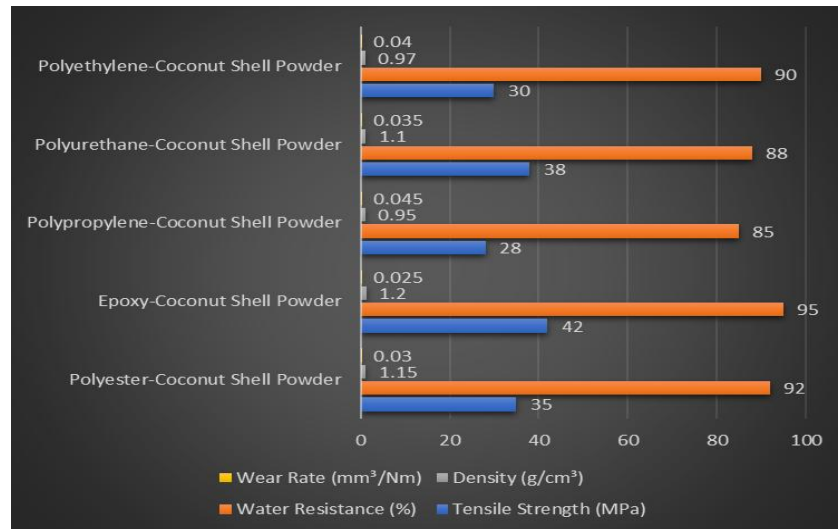


FIGURE 1. Coconut Shell Powder-Reinforced Composite Materials

Figure 1 illustrates the characteristics of various composite materials created by incorporating coconut shell powder into different polymer matrices. The comparison focuses on their tensile strength, water resistance, density, and wear rate. The Epoxy-Coconut Shell Powder composite stands out with the highest tensile strength of 42 MPa, making it the most robust material in the group. It also boasts the highest water resistance (95%) and a low wear rate of 0.025 mm³/Nm, highlighting its exceptional durability. However, its relatively higher density of 1.2 g/cm³ might be a consideration for weight-sensitive applications. The polyester-coconut shell powder blend offers a tensile strength of 35 MPa and a significant water resistance of 92%. With a moderate density of 1.15 g/cm³ and a wear rate of 0.03 mm³/Nm, it offers a balanced combination of strength and durability. The polyurethane-coconut shell powder blend has a tensile strength of 38 MPa and a water resistance of 88%. Its density (1.1 g/cm³) and wear rate (0.035 mm³/Nm) place it in the mid-range for performance. At the lower end, polypropylene-coconut shell powder and polyethylene-coconut shell powder blends have tensile strengths of 28 MPa and 30 MPa, respectively. Although lighter in density, their higher wear rates (0.045 and 0.04 mm³/Nm) make them less ideal for high-friction applications.

TABLE 2. Normalized Data using TOPSIS Method

0.448	0.457	0.477	0.376
0.537	0.472	0.498	0.313
0.358	0.422	0.394	0.564
0.486	0.437	0.456	0.438
0.384	0.447	0.402	0.501

Table 2 showcases the normalized data of composite materials analyzed using the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method. This approach evaluates the materials based on their relative performance in tensile strength, water resistance, density, and wear rate, enabling a more comprehensive comparison. The Epoxy-Coconut Shell Powder composite achieves the highest normalized values for tensile strength (0.537007128) and water resistance (0.47172114), indicating superior mechanical properties and durability. It also

exhibits a favorable normalized wear rate of 0.313112146, reflecting its resistance to wear and tear, though its normalized density is moderately high at 0.497591303. The Polyester-Coconut Shell Powder composite follows with respectable normalized values for tensile strength (0.44750594) and water resistance (0.456824683). Its normalized wear rate (0.375734575) and density (0.476858332) suggest balanced performance across all parameters. The Polyurethane-Coconut Shell Powder composite shows a good balance of properties, with moderate normalized values for tensile strength (0.485863592), water resistance (0.436962741), and density (0.456125361), and wear rate (0.438357004). On the lower end, Polypropylene and Polyethylene-Coconut Shell Powder composites have lower normalized tensile strengths (0.358004752 and 0.38357652, respectively) and higher wear rates (0.563601862 and 0.500979433), limiting their competitiveness.

TABLE 3. Weight Distribution

0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

Table 3 highlights the weight distribution assigned to each performance parameter—tensile strength, water resistance, density, and wear rate—for the composite materials under consideration. Notably, each parameter is given an equal weight of 0.25, reflecting a uniform prioritization of these attributes in the analysis. This equal weighting approach suggests that the evaluation does not favor any single property over the others. It underscores a balanced perspective, where tensile strength, water resistance, density, and wear rate are considered equally critical in determining the overall performance of the composite materials. For instance, the Epoxy-Coconut Shell Powder composite, which excels in tensile strength and water resistance, is evaluated on par with others that may perform better in wear rate or density. Similarly, Polypropylene-Coconut Shell Powder, which has lower tensile strength but lighter density, is not penalized disproportionately due to the uniform weighting. This methodology ensures an impartial assessment, particularly useful when no specific application dictates a preference for one property over another. However, in scenarios where certain attributes hold greater importance (e.g., tensile strength for structural applications or wear resistance for high-friction environments), the weight distribution might need adjustment to reflect those priorities.

TABLE 4. Weighted Normalized Decision Matrix using TOPSIS Method

0.111876485	0.114	0.119	0.094
0.134251782	0.118	0.124	0.078
0.089501188	0.106	0.098	0.141
0.121465898	0.109	0.114	0.11
0.09589413	0.112	0.101	0.125

Table 4 presents the weighted normalized decision matrix for composite materials, derived using the TOPSIS method. The matrix reflects the performance of each composite across four parameters—tensile strength, water resistance, density, and wear rate—factoring in equal weight distributions, as seen earlier. This step helps quantify the relative contribution of each property to the overall assessment. The Epoxy-Coconut Shell Powder composite achieves the highest weighted normalized values for tensile strength (0.134251782) and water resistance (0.117930285). Its lower wear rate value (0.078278036) further reinforces its position as a top performer, although its density contribution (0.124397826) is moderately high. The Polyester-Coconut Shell Powder composite shows a balanced performance with weighted normalized values of 0.111876485 for tensile strength and 0.114206171 for water resistance. Its density (0.119214583) and wear rate (0.093933644) contribute to its overall mid-range placement. The Polyurethane-Coconut Shell Powder composite demonstrates a well-rounded profile, with moderate values across all parameters, including tensile strength (0.121465898) and wear rate (0.109589251). On the lower end, Polypropylene and Polyethylene-Coconut Shell Powder composites exhibit lower contributions from tensile strength and water resistance. Their higher wear rate values (0.140900465 and 0.125244858, respectively) hinder their overall competitiveness.

Table 5. The Ideal Best (A+) and Ideal Worst Values (A-) Using TOPSIS Method

A+	0.134	0.118	0.098	0.078278
A-	0.09	0.106	0.124	0.1409

Table 5 provides the ideal best (A^+) and ideal worst (A^-) values determined using the TOPSIS method. These values represent the optimal and least favorable performance levels for each parameter—tensile strength, water resistance, density, and wear rate among the analyzed composites. The ideal best values (A^+) indicate the highest performance across parameters. For tensile strength, the best value is 0.134251782, signifying the strongest composite. Similarly, the optimal water resistance is 0.117930285, while the best density is 0.098481612, favoring lighter composites. The lowest wear rate, 0.078278036, represents minimal material degradation under friction. Composites closer to these values are considered highly efficient and desirable for applications. Conversely, the ideal worst values (A^-) reflect the lowest performance levels. The lowest tensile strength (0.089501188) and water resistance (0.105516571) indicate weak and less durable materials. The highest density (0.124397826) suggests heavier composites, while the worst wear rate (0.140900465) corresponds to materials more prone to wear and tear. The A^+ and A^- values serve as benchmarks for evaluating composite materials. Composites with attributes closer to A^+ and farther from A^- exhibit superior overall performance, making them better suited for diverse applications.

TABLE 6. Separation of Each Alternative from the Ideal Solution and Separation from the Negative-Ideal Solution Using TOPSIS Method

Composite Material	Si+	si-
Polyester-Coconut Shell Powder	0.034	0.052999
Epoxy-Coconut Shell Powder	0.026	0.077963
Polypropylene-Coconut Shell Powder	0.078	0.025916
Polyurethane-Coconut Shell Powder	0.038	0.046081
Polyethylene-Coconut Shell Powder	0.061	0.029883

Table 6 illustrates the separation values for each composite material from the ideal solution ($Si^+ - Si^+$) and the negative-ideal solution ($Si^- - Si^-$) using the TOPSIS method. These values represent the Euclidean distance of each composite's performance from the optimal and least favorable benchmarks, providing insights into their overall ranking. The Epoxy-Coconut Shell Powder composite has the smallest separation from the ideal solution ($Si^+ = 0.025916214$, $Si^- = 0.025916214$) and the largest separation from the negative-ideal solution ($Si^- = 0.077963354$, $Si^+ = 0.077963354$). This indicates that it is the closest to the ideal composite, making it the best-performing material among the alternatives. The Polyester-Coconut Shell Powder composite also performs well, with moderate values for $Si^+ = 0.034488796$ and $Si^- = 0.052999164$, suggesting a good balance of properties while remaining closer to the ideal than most other composites. The Polyurethane-Coconut Shell Powder composite shows a middle-ground performance with $Si^+ = 0.038225308$ and $Si^- = 0.046081101$, indicating moderate proximity to both ideal and negative-ideal solutions. On the lower end, the Polypropylene-Coconut Shell Powder composite has the largest $Si^+ = 0.077963354$ and smallest $Si^- = 0.025916214$, indicating it is farthest from the ideal and closest to the negative-ideal, making it the least desirable choice.

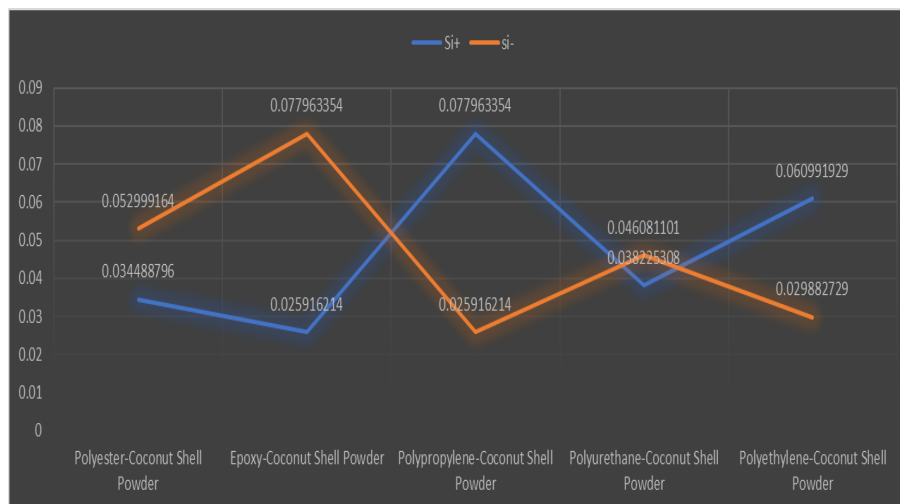


FIGURE 2. Separation of Each Alternative from the Ideal Solution and Separation from the Negative-Ideal Solution Using TOPSIS Method

Figure 2 depicts the separation values for each composite material from the ideal solution (S_i^+) and the negative-ideal solution (S_i^-) based on the TOPSIS method. These values represent the Euclidean distance of each material's performance from the best and worst benchmarks, offering insights into their relative rankings. The Epoxy-Coconut Shell Powder composite demonstrates the smallest separation from the ideal solution ($S_i^+ = 0.025916214$, $S_i^- = 0.025916214$) and the largest separation from the negative-ideal solution ($S_i^+ = 0.077963354$, $S_i^- = 0.077963354$). This makes it the closest to the ideal composite, establishing it as the top-performing material among the alternatives. The Polyester-Coconut Shell Powder composite also performs well, with moderate values of $S_i^+ = 0.034488796$, $S_i^- = 0.034488796$ and $S_i^+ = 0.052999164$, $S_i^- = 0.052999164$, indicating a good balance of properties while maintaining closer proximity to the ideal than most other composites. The Polyurethane-Coconut Shell Powder composite ranks in the middle, with $S_i^+ = 0.038225308$, $S_i^- = 0.038225308$ and $S_i^+ = 0.046081101$, $S_i^- = 0.046081101$, reflecting moderate proximity to both ideal and negative-ideal solutions. At the lower end, the Polypropylene-Coconut Shell Powder composite has the largest $S_i^+ = 0.077963354$, $S_i^- = 0.077963354$ and the smallest $S_i^+ = 0.025916214$, $S_i^- = 0.025916214$, making it the farthest from the ideal and closest to the negative-ideal, rendering it the least favorable option.

TABLE 7. Closeness Coefficient's Value and Rank

Composite Material	ci	rank
Polyester-Coconut Shell Powder	0.606	2
Epoxy-Coconut Shell Powder	0.751	1
Polypropylene-Coconut Shell Powder	0.249	5
Polyurethane-Coconut Shell Powder	0.547	3
Polyethylene-Coconut Shell Powder	0.329	4

Table 7 presents the Closeness Coefficient (C_i) values and corresponding rankings for the composite materials, calculated using the TOPSIS method. The Closeness Coefficient reflects how close each material is to the ideal solution, with higher values indicating better overall performance. The Epoxy-Coconut Shell Powder composite achieves the highest C_i value of 0.7505, earning the top rank (1). This result confirms its superior performance across all evaluated parameters, making it the most suitable choice for applications requiring high tensile strength, water resistance, and wear resistance. The Polyester-Coconut Shell Powder composite ranks second with a C_i of 0.6058. Its balanced performance in tensile strength, water resistance, and wear rate makes it a reliable alternative, though slightly less effective than epoxy-based composites. The Polyurethane-Coconut Shell Powder composite secures the third rank with a C_i of 0.5466, showcasing a moderate overall performance. It offers a good balance of properties, suitable for applications where neither strength nor wear resistance is critically dominant. On the lower end, the Polypropylene and Polyethylene-Coconut Shell Powder composites rank fourth ($C_i = 0.3288$, $C_i = 0.3288$) and fifth ($C_i = 0.2495$, $C_i = 0.2495$), respectively. Their lower scores reflect weaker overall performance, primarily due to higher wear rates and lower tensile strengths.

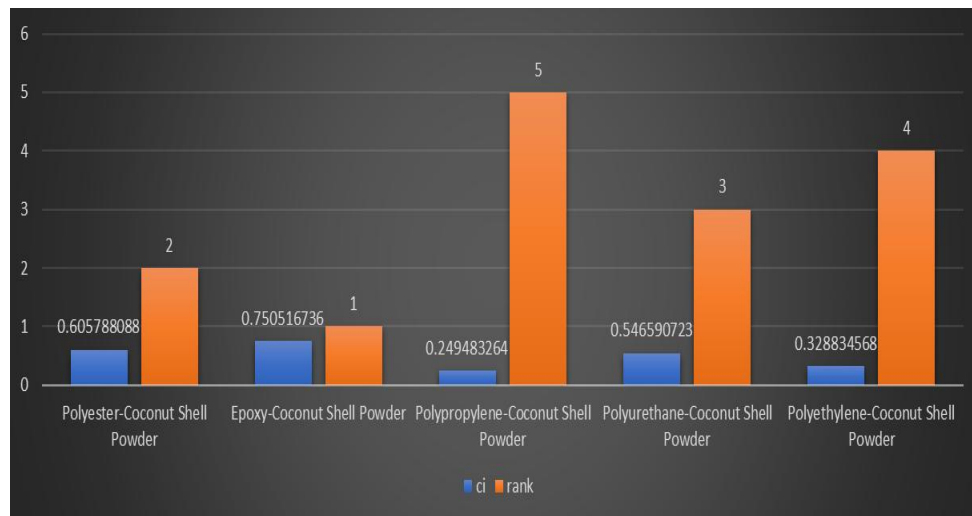


Figure 3. Closeness Coefficient's Value and Rank

Figure 3 illustrates the Closeness Coefficient values and rankings for the composite materials, determined using the TOPSIS method. The Closeness Coefficient indicates how near each material is to the ideal solution, with higher values representing superior overall performance. The Epoxy-Coconut Shell Powder composite has the highest Ci value of 0.7505, securing the first rank. This confirms its exceptional performance across all parameters, making it the best option for applications demanding high tensile strength, excellent water resistance, and low wear rates. The Polyester-Coconut Shell Powder composite follows in second place with a Ci value of 0.6058. Its well-rounded performance in tensile strength, water resistance, and wear rate makes it a dependable choice, although it is slightly outperformed by the epoxy-based composite. The Polyurethane-Coconut Shell Powder composite ranks third with a Ci of 0.5466, showcasing a moderate overall performance. It offers a good compromise between strength and wear resistance for applications that do not prioritize any single property. At the lower end, the Polypropylene and Polyethylene-Coconut Shell Powder composites rank fourth ($C_i=0.3288$) and fifth ($C_i=0.2495$), respectively. Their lower values reflect weaker performance, mainly due to higher wear rates and reduced tensile strength.

4. CONCLUSION

The use of coconut husk powder in various industries has created new opportunities for researchers and businesses to develop sustainable models for the future use of coconut fibers. Coconut and coconut coir powders have been used as reinforcements in polyethylene composites. Mechanical properties were evaluated through physical tests including Tensile and flexural tests, impact test, Young's modulus, hardness, density and water absorption were evaluated. Coconut shell powder and hybrid composites were used to investigate the wear properties of the composites. A total of 24 samples were fabricated, containing 10%, 20% and 30% treated and untreated natural filler mixtures. Thermal analysis was performed using TGA and DTG methods were used, and the Hybrid bamboo/glass fiber-reinforced coconut batt powder and other composites show low thermal degradation when compared to other composites. The TOPSIS method, a multi-criteria decision-making approach, combines circular intuitionistic fuzzy TOPSIS based on a novel theory. Unlike other extensions of fuzzy sets, circular intuitionistic fuzzy sets provide enhanced flexibility in representing the information of each decision maker, making it a more suitable method for collective decision-making. This approach effectively handles and Evaluates input from all decision makers. By using the TOPSIS method, the most suitable cities for designation as smart cities can be identified. The study concluded that Medan City has a maximum likelihood value of 0.8983, making it the most suitable candidate for a smart city compared to other alternatives. The proposed eigenvector-DEA-TOPSIS method uses the eigenvector technique to calculate the criterion weights, uses high, medium, and low linguistic terms to estimate the portfolio risks for each criterion, and uses a DEA model with equal weights to estimate these linguistic values. The TOPSIS method is used to combine portfolio risks from different criteria into an overall risk score for each portfolio. A numerical example is included to demonstrate the application of the proposed eigenvector-DEA-TOPSIS method. The Epoxy-Coconut Shell Powder composite ranks first demonstrating superior overall performance, particularly in tensile strength, water resistance, and wear resistance. The Polyester-Coconut Shell Powder composite follows in second place offering a balanced performance. The Polyurethane-Coconut Shell Powder composite ranks third with moderate overall results. The Polypropylene and Polyethylene-Coconut Shell Powder composites rank fourth and fifth, reflecting weaker performance due to higher wear rates and lower tensile strength.

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