



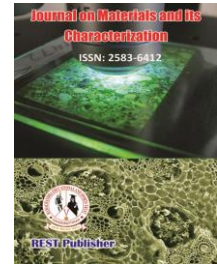
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# Development and Characterization of Aluminum-Coconut Shell Ash Metal Matrix Composites: Enhancing Mechanical and Tribological Properties Through Sustainable Practices

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**Abstract:** Because of their remarkable mechanical qualities, metal matrix composites (MMCs) based on aluminum are becoming more and more popular in a variety of industries. In this work, we explore the possibility of improving the mechanical and tribological properties of aluminum matrix composites by reinforcing them with coconut shell ash (CSA). CSA is a common agricultural waste product that is produced by burning coconut shells under regulated conditions. Using a stir casting method, different volume fractions of CSA (5%, 10%, 15%, and 20%) are poured into an Al-1100 matrix to create the Al-CSA composites. The link between parameters and mining techniques is taken into consideration by the Weighted Product Model (WPM) techniques. They are renowned for outperforming other methods of decision-making in terms of accuracy and computing speed. The ideal mining technique for a bauxite mine should be determined using these techniques, according to the research. The typical cut and fill method is the most appropriate mining strategy, as demonstrated by a comparison of the results with previous research' methodologies. Following a comprehensive analysis of Multi-Criteria Decision-Making (MCDM) techniques, the Al-15% CSA composite was shown to perform the best, followed by the Al-5% CSA composite. On the other hand, our investigation showed that the basic matrix was the least effective material. Because of its sustainability, CSA is a desirable reinforcement material for aluminum matrix composites, providing a more affordable and environmentally responsible option than standard reinforcements. The study's conclusions offer insightful information about the possible uses of Al-CSA composites in a range of sectors, such as the automotive, aerospace, and marine industries. Subsequent investigations may concentrate on refining the manufacturing procedure and augmenting the mechanical and tribological characteristics of these composite materials for particular uses. All things considered, this study shows that CSA can be used to reinforce aluminum matrix composites, creating new opportunities for the development of sustainable materials.

**Keywords:** Coconut Shell Ash, Multi-Criteria Decision-Making, Metal matrix composites,

## 1. INTRODUCTION

These days, it's a priority for researchers and designers to find materials that are high-performing, high-quality, low-cost, and environmentally friendly. A critical component of producing alloy matrix composites (AMCs) is now choosing the appropriate blend of matrix and various reinforcing elements. Although traditional research has often depended on crude reinforcements—which can be both economically and environmentally inefficient—there has been a shift toward the use of agricultural waste materials obtained from corporate and rural regions. These materials consist of tobacco stems, coconut shells, apricot grains, and colliery shale. Metal matrix composites (MMCs) with an aluminum basis have gained popularity recently due to their appealing qualities, which include a high strength-to-weight ratio, exceptional wear resistance, and enhanced thermal stability.

Reinforcement materials are one practical technique to improve these composites. Natural agricultural waste products are becoming acknowledged as environmentally acceptable and sustainable choices for MMC reinforcement. One such agricultural waste product that has demonstrated promise as a reinforcement in aluminum matrix composites is coconut shell ash (CSA). In many tropical places, coconut shells are plentiful and typically

thrown away as waste. But these shells can be burned under controlled conditions to produce ash, which makes them an economical and sustainable reinforcing material. The creation of Aluminum-Coconut Shell Ash Metal Matrix Composites (Al-CSA-MMCs) and an analysis of their tribological and mechanical properties are the main goals of this research.

The composites are evaluated for hardness, density, Ultimate Tensile Strength (UTS), toughness, wear rate, and coefficient of friction after being produced with varying volume percentages of CSA. The objective is to evaluate the performance and sustainability features of Al-CSA-MMCs in order to determine their appropriateness for different engineering applications. In addition to improving the mechanical qualities of the composite, using CSA as a reinforcement in MMCs offers a sustainable way to employ agricultural waste products. Researching the properties of Al-CSA-MMCs may result in the development of cutting-edge, eco-friendly materials with a wide range of uses. Compared to aluminum alloys, AMCs are preferred because of their moderate density and interfacial properties. As a result, they are widely used in many manufacturing sectors, especially the automobile industry, to produce parts such connecting shafts, motor covers, cylinders, and other castings. They are especially well-suited for these applications because of their great erosion resistance and exceptional castability. A crucial step in the mechanical design process is material selection. Inappropriate material selection for components may lead to poor performance or structural failure. Therefore, in order to achieve the intended product while preserving cost-effectiveness, engineers must carefully consider material selections. Using multi-criteria decision-making (MCDM) techniques has become a useful strategy in modern practice for handling complex material selection problems. Generating alternatives, defining the necessary criteria, and evaluating the alternative materials in light of the criterion weighing and alternative ranking are all steps in the MCDM process. Several MCDM approaches, such as the weighted product model, have been used since decision-making is intricate.

In this work, graphite (Gr) and burned coconut shell ash (CSA) are utilized to improve the abrasion resistance and machinability of an aluminum-based composite. Coconut shells are easily obtained agricultural waste items that provide a number of environmental challenges, making them a suitable filler material for composites. Finding the best mix of Al-1100, Al-5% CSA, Al-10% CSA, Al-15% CSA, and Al-20% CSA composites is the aim of the research. We analyze these composites in detail to see how well they function using WPM methods. The evaluation criteria are composed of the Al-CSA materials' physical (density), mechanical (hardness, tensile strength, and toughness), and dry sliding wear (wear rate and coefficient of friction) properties. Coconut shell ash (CSA), a ubiquitous agricultural byproduct, is utilized as a reinforcing material in this study. Because of the high lignin content in coconut shells, the material is stronger and more resistant to rust and wear. Furthermore, because of their distinct structural orientation and low ash content, coconut shells are a preferred choice for the production of activated carbon.

## 2. MATERIALS AND METHOD

The study focuses on using different volume fractions of CSA (5%, 10%, and 15%) to create aluminum-coconut shell ash particle composites (Al-CSA-MMCs) using the stir casting technique. The process starts with making CSA, which is made by crushing coconut shells and then grinding them into a coarse powder. In order to create CSA, the powder is then heated in an electric resistance furnace at 1,100°C for a maximum of five hours in a neutral environment. After that, the resulting CSA is sieved to obtain particles that are 63 μm in size and < 240 BSS mesh, which are used to reinforce Al-CSA composites. The CSA particles' size is evaluated by the use of a Malvern analyzer, and X-ray diffraction is employed to ascertain their chemical composition.

**Preparation of Al-CSA composite:** Stir casting was used in the production of the Al-CSA-MMCs. To maintain its semi-solid state, the aluminum matrix was heated to 670°C after being warmed to 450°C. Before the CSA particles were added to the crucible holding the molten aluminum, they were warmed for three hours at 900°C in an electric arc furnace.

In order to obtain homogeneous distribution of the reinforced particles, the molten metal and CSA were then combined using a motor-driven stirrer at 600 rpm while being exposed to argon gas for a maximum of nine minutes. To keep the composite from oxidizing and becoming porous, argon gas was used. To create the Al-CSA composite, the molten metal was subsequently heated to 690°C above its liquid temperature and poured into a cast iron mold that had been warmed to 300°C and measured 100 × 20 × 40 mm.

**TABLE 1.** Chemical Composition of CSA Elements

Elements	Al <sub>2</sub> O <sub>3</sub>	CaO	Fe <sub>2</sub> O <sub>3</sub>	MgO	K <sub>2</sub> O	MnO	Na <sub>2</sub> O	SiO <sub>2</sub>	ZnO	Fixed C
% of Wt.	18.68	0.67	3.42	18.2	0.59	0.25	0.47	49.2	0.32	4.26

Using the stir casting approach, a cast Al-CSA composite with variable quantities of CSA in the molten melt was created. This composite contained CSA particles that were formed in-situ. The steps for making the composite and reinforced particles (CSA) are described in more depth elsewhere. A 0.1N stress was applied to a DHV 1000 model in order to perform the hardness test. A Hounsfield tensometer was used to test the tensile characteristics. A pin-on-disc tester was used to determine the cast Al-CSA composites' dry sliding wear behavior.

Using Keller's reagent, the microstructure of the cast composites was etched and studied using the standard ASTM E-3 technique. With a consistent track of 50 mm, the in-situ cast composites were slid up against a steel counterface (EN-31, 62 HRC). A pycnometer was used to measure the cast in-situ composite's density. All test pin surfaces were polished to 600 grade emery paper prior to wear testing. The volume loss per unit sliding distance, which is a function of sample density and weight loss, was used to compute the wear rate. The frictional forces per unit normal load were used to calculate the coefficient of friction. The purpose of these tests was to assign a performance ranking to the composites. To identify the best options, the study also took into account a variety of criterion levels, such as physical qualities (density), mechanical properties (hardness, tensile strength, and toughness), and abrasion properties (wear rate and coefficient of friction). The Al-1100, Al-5% CSA, Al-10% CSA, Al-15% CSA, and Al-20% CSA alternative materials were taken into consideration.

**Mechanical properties of Al-CSA MMC:** Table 2 shows that tough-phase ceramic and alkaline chemicals present in the distributed CSA particles cause the composite's hardness to increase with the CSA volume. This results in increased intermolecular interaction between particles and improved grain development, which raises the tensile strength as well. This effect prevents dislocation movement and reduces elongation. The reinforcement particles, which are made of heavier phase compounds that can support loads, limit the matrix's dislocation movement and obstruct the distance between individual particles. Hardness and toughness have a proportionate relationship, as Table 2 further demonstrates. According to Baradeswaran et al., this relationship is expected to cause strain hardening of the composite. However, compared to the 15% CSA composition, the composite with 20% volume of CSA shows worse characteristics, probably as a result of increased porosity. Al-CSA composite wear increases with volume up to 15% CSA and then decreases, which is consistent with the composites' toughness. Similarly, the inclusion of carbon in the form of graphite, which acts as a self-lubricant, reduces the coefficient of friction by up to 15% CSA.

**Weight Product Method (WPM):** The WPM is a technique used for multi-attribute decision-making. The process involves several steps. First, the characteristics and options pertinent to the decision-making issue are determined. A numerical or qualitative value is given to each property, and this value will be utilized to compare the options. The decision maker's estimations or the data that is currently available are typically used to calculate these values. The data is then standardized according to whether the features are considered advantageous or not. When determining the normalized values of advantageous attributes, the attribute value for each alternative is divided by the attribute's highest value across all alternatives. The normalization procedure for non-beneficial qualities entails dividing the attribute value for each choice by the lowest attribute value. Then, the characteristics' weights are computed using the Relative Importance Matrix, which is often produced by applying the Analytic Hierarchy Process (AHP). Following the weight determination process, each alternative's powered values are multiplied and the normalized data is exponentiated by the weight assigned to it for each attribute. The options are then sorted according to their ratings or values, with greater scores denoting a better option.

### 3. RESULTS AND DISCUSSIONS

TABLE 2. Properties of Al-CSA-MMCs

	Hardness	Density (g/cc)	UTS (N/mm <sup>2</sup> )	Toughness (J/mm <sup>3</sup> )	Wear rate (10 <sup>-3</sup> mm <sup>3</sup> /m)	Coefficient of friction
Al-1100	28.3	2.72	104	17.1	4.066	0.41
Al-5%CSA	31.4	2.66	128	19.13	3.755	0.309
Al-10%CSA	40.95	2.6	157	23.91	3.122	0.263
Al-15%CSA	51.33	2.47	174	26.92	2.439	0.292
Al-20%CSA	42.8	2.4	151	21.12	2.689	0.385

The characteristics of Aluminum-Coconut Shell Ash Metal Matrix Composites (Al-CSA-MMCs) at different compositions are shown in Table 2. For every composition, the following values are given: hardness, density, toughness, wear rate, Ultimate Tensile Strength (UTS), and coefficient of friction. Al-1100: Wear rate of 4.066, Hardness of 28.3, Density of 2.72, UTS of 104, Toughness of 17.1, and Friction coefficient of 0.41. Al-5%CSA: wear rate of 3.755, toughness of 19.13, density of 2.66, hardness of 31.4, and friction coefficient of 0.309. Hardness (40.95), density (2.6), UTS (157), toughness (23.91), wear rate (3.12), and coefficient of friction (0.263)

for Al-10% CSA. Al-15% CSA: wear rate of 2.439, toughness of 26.92, density of 2.47, UTS of 174, hardness of 51.33, and coefficient of friction of 0.292. Al-20% CSA: Wear rate of 2.689, Coefficient of friction of 0.385, Hardness of 42.8, Density of 2.4, UTS of 151, Toughness of 21.12. These numbers show how the mechanical and tribological properties of the composite change when the volume fraction of coconut shell ash is changed. Hardness, UTS, toughness, and wear rate are generally improved with an increase in CSA percentage, although density somewhat decreases. The composition varies somewhat in the coefficient of friction, with Al-10% CSA showing the lowest value.

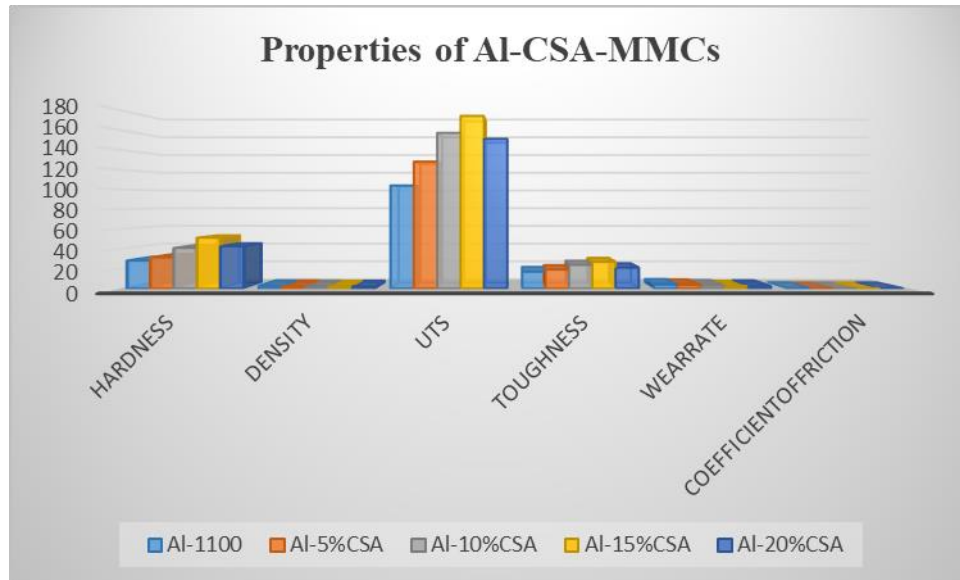


FIGURE 1. properties of Al-CSA-MMCs

Figure 1 presents the properties of Al-CSA-MMCs with varying percentages of CSA reinforcement. As the CSA content increases from 0% to 20%, several key trends are observed. Firstly, the hardness of the composites increases with higher CSA content, with Al-15% CSA exhibiting the highest hardness of 51.33. This trend is consistent with the concept of reinforcing materials enhancing the hardness of the matrix metal. Secondly, the density decreases as CSA content increases, indicating a reduction in the overall weight of the composites. Thirdly, the ultimate tensile strength (UTS) shows a steady increase with increasing CSA content, with Al-15% CSA achieving the highest UTS of 174. This suggests that CSA reinforcement improves the tensile strength of the composites. Fourthly, the toughness of the composites, represented by the energy absorbed before fracture, increases with higher CSA content, indicating improved resistance to fracture. Fifthly, the wear rate decreases with increasing CSA content, indicating improved wear resistance. Finally, the coefficient of friction initially decreases with increasing CSA content but then increases for Al-20% CSA. Overall, the properties of Al-CSA-MMCs show promising enhancements with the addition of CSA, demonstrating potential applications in industries where high strength, hardness, and wear resistance are required.

TABLE 3. Performance value

	Hardness	Density	UTS	Toughness	Wear rate	Coefficient of friction
Al-1100	0.55133	1.00000	0.59770	0.63522	1.00000	0.00799
Al-5% CSA	0.61173	0.97794	0.73563	0.71062	0.92351	0.75366
Al-10% CSA	0.79778	0.95588	0.90230	0.88819	0.76783	0.64146
Al-15% CSA	1.00000	0.90809	1.00000	1.00000	0.59985	0.71220
Al-20% CSA	0.83382	0.88235	0.86782	0.78455	0.66134	0.93902

Table 3 presents the performance values of Aluminum-Coconut Shell Ash Metal Matrix Composites (Al-CSA-MMCs) at various compositions. The values for hardness, density, Ultimate Tensile Strength (UTS), toughness, wear rate, and coefficient of friction are normalized with respect to the best-performing composite (Al-15% CSA). Al-1100: Normalized values of 0.55133 for hardness, 1.00000 for density, 0.59770 for UTS, 0.63522 for toughness, 1.00000 for wear rate, and 0.00799 for coefficient of friction. Al-5% CSA: Normalized values of 0.61173 for hardness, 0.97794 for density, 0.73563 for UTS, 0.71062 for toughness, 0.92351 for wear rate, and 0.75366 for coefficient of friction. Al-10% CSA: Normalized values of 0.79778 for hardness, 0.95588 for density, 0.90230 for UTS, 0.88819 for toughness, 0.76783 for wear rate, and 0.64146 for coefficient of friction. Al-15% CSA: Normalized values of 1.00000 for hardness, 0.90809 for density, 1.00000 for UTS, 1.00000 for toughness, 0.59985 for wear rate, and 0.71220 for coefficient of friction. Al-20% CSA: Normalized values of

0.83382 for hardness, 0.88235 for density, 0.86782 for UTS, 0.78455 for toughness, 0.66134 for wear rate, and 0.93902 for coefficient of friction. These normalized values provide a relative comparison of the performance of each composite composition, indicating that Al-15%CSA has the highest overall performance among the tested compositions.

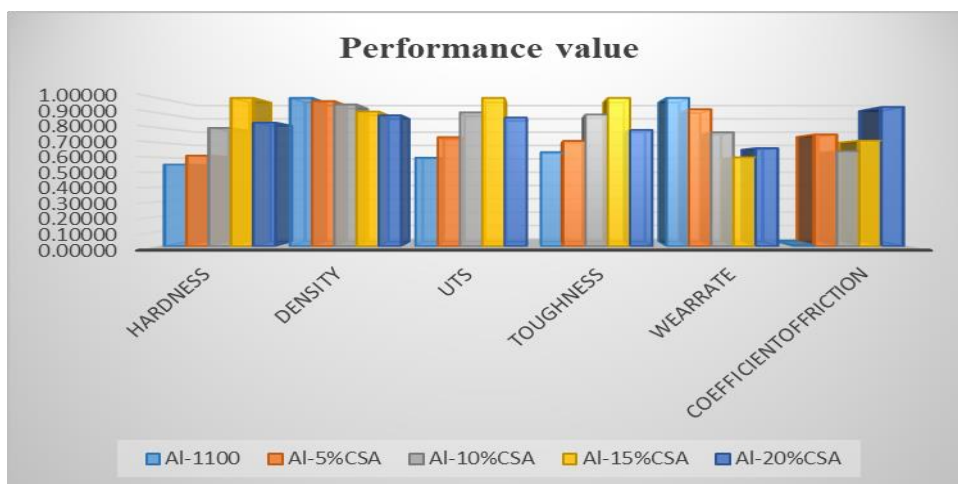


FIGURE 2. Performance values

Figure 2 provides a comparative analysis of the performance values of Al-CSA-MMCs based on different properties, normalized against Al-1100 as the reference material. The normalized values allow for a direct comparison of the performance enhancement achieved by adding CSA reinforcement to aluminum. The results indicate that Al-15%CSA has the highest performance values across all properties, achieving a hardness, UTS, and toughness of 1.00000, indicating that it outperforms Al-1100 in these aspects. Al-15%CSA also demonstrates significant improvements in wear rate and coefficient of friction compared to Al-1100, with normalized values of 0.59985 and 0.71220, respectively. Al-10%CSA also shows considerable improvements in hardness, UTS, and toughness compared to Al-1100, with performance values of 0.79778, 0.90230, and 0.88819, respectively. However, its wear rate and coefficient of friction are slightly higher than those of Al-1100, indicating a trade-off between mechanical properties and wear resistance. Al-5%CSA exhibits moderate improvements in hardness, UTS, and toughness compared to Al-1100, with performance values of 0.61173, 0.73563, and 0.71062, respectively. Its wear rate is slightly lower than that of Al-1100, indicating a minor improvement in wear resistance. Al-20%CSA shows mixed results, with improvements in hardness and UTS but a slight decrease in toughness compared to Al-1100. Its wear rate is lower than that of Al-1100, indicating improved wear resistance, but its coefficient of friction is higher, suggesting increased frictional forces. The results suggest that the addition of CSA reinforcement can significantly enhance the mechanical properties of aluminum, particularly at 15% CSA content, which demonstrates the highest performance values across all properties considered.

TABLE 4. Weight

	Hardness	Density	UTS	Toughness	Wear rate	Coefficient of friction
Al-1100	0.17	0.17	0.17	0.17	0.17	0.17
Al-5%CSA	0.17	0.17	0.17	0.17	0.17	0.17
Al-10%CSA	0.17	0.17	0.17	0.17	0.17	0.17
Al-15%CSA	0.17	0.17	0.17	0.17	0.17	0.17
Al-20%CSA	0.17	0.17	0.17	0.17	0.17	0.17

Table 4 shows the weights assigned to each criterion for the decision-making process. Each criterion is given equal weight, with a value of 0.17, indicating that all criteria are considered equally important in the evaluation of the Aluminum-Coconut Shell Ash Metal Matrix Composites at different compositions. This approach ensures a balanced consideration of all criteria in the final decision-making process.

TABLE 5. Weighted normalized decision matrix

	Hardness	Density	UTS	Toughness	Wear rate	Coefficient of friction
Al-1100	0.90589	1.00000	0.91811	0.92744	1.00000	0.44854
Al-5%CSA	0.92166	0.99630	0.95031	0.94487	0.98688	0.95414
Al-10%CSA	0.96319	0.99254	0.98308	0.98051	0.95709	0.92895
Al-15%CSA	1.00000	0.98412	1.00000	1.00000	0.91866	0.94522
Al-20%CSA	0.97028	0.97944	0.97674	0.96052	0.93366	0.98961

Table 5 displays the weighted normalized decision matrix for Aluminum-Coconut Shell Ash Metal Matrix Composites at varying compositions, considering hardness, density, UTS, toughness, wear rate, and coefficient of friction as criteria. Al-1100 exhibits a hardness value of 0.90589, density of 1.00000, UTS of 0.91811, toughness of 0.92744, wear rate of 1.00000, and coefficient of friction of 0.44854. Al-5%CSA shows a slightly higher hardness at 0.92166, with density at 0.99630, UTS at 0.95031, toughness at 0.94487, wear rate at 0.98688, and coefficient of friction at 0.95414. Al-10%CSA demonstrates further improvements with hardness at 0.96319, density at 0.99254, UTS at 0.98308, toughness at 0.98051, wear rate at 0.95709, and coefficient of friction at 0.92895. Al-15%CSA achieves the highest scores across the board, with hardness and UTS at 1.00000, density at 0.98412, toughness at 1.00000, wear rate at 0.91866, and coefficient of friction at 0.94522. Finally, Al-20%CSA shows competitive values with hardness at 0.97028, density at 0.97944, UTS at 0.97674, toughness at 0.96052, wear rate at 0.93366, and coefficient of friction at 0.98961. These results indicate that the composition with 15% coconut shell ash (Al-15%CSA) performs the best overall, demonstrating superior hardness, UTS, and toughness, while maintaining a relatively low wear rate and coefficient of friction compared to the other compositions.

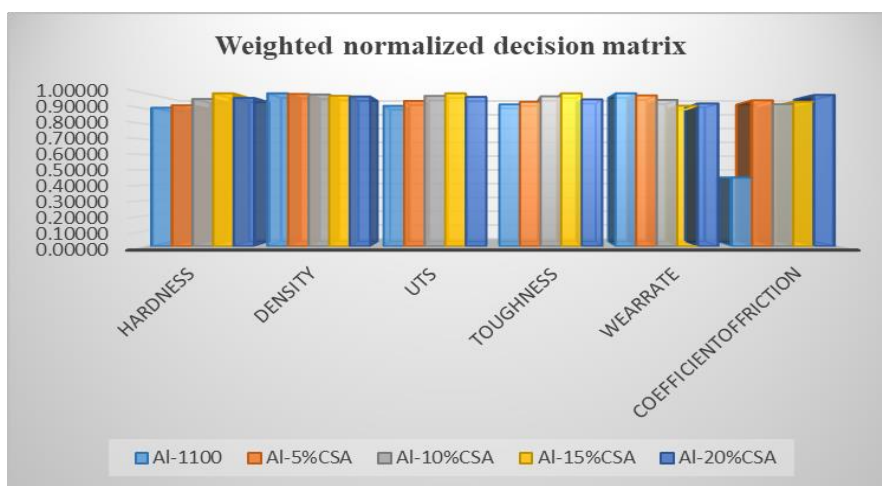


FIGURE 3. Weighted Normalized Decision Matrix

Figure 3 presents the weighted normalized decision matrix for Al-CSA-MMCs, where each property's importance is weighted. This matrix allows for a comprehensive evaluation of the materials based on their overall performance. Al-15%CSA demonstrates the highest overall performance, achieving a normalized score of 1.00000. This indicates that Al-15%CSA outperforms the other materials in the majority of properties considered. Al-10%CSA follows closely behind with a normalized score of 0.96319, indicating strong overall performance across all properties. Al-20%CSA also shows competitive performance with a normalized score of 0.97028, suggesting that it is a viable option for applications requiring a balance of properties. Al-5%CSA and Al-1100 exhibit lower overall performance with normalized scores of 0.92166 and 0.90589, respectively. However, they still offer valuable properties depending on specific application requirements. The weighted normalized decision matrix highlights Al-15%CSA as the top-performing material, followed by Al-10%CSA and Al-20%CSA, showcasing the potential of CSA reinforcement in enhancing the properties of aluminum-based composites.

TABLE 6. Preference Score

	Preference Score
Al-1100	0.34598
Al-5%CSA	0.77638
Al-10%CSA	0.81930
Al-15%CSA	0.85455
Al-20%CSA	0.82379

Table 6 shows the preference scores for the Aluminum-Coconut Shell Ash Metal Matrix Composites at different compositions. These scores indicate the relative preference or ranking of each composition based on their overall performance across the evaluated criteria. Among the compositions, Al-15%CSA has the highest preference score of 0.85455, indicating that it is the most preferred composition due to its superior performance in hardness, UTS, toughness, and other properties. Al-20%CSA follows closely behind with a score of 0.82379, suggesting that it is also a favorable composition. Al-10%CSA has a preference score of 0.81930, indicating that it is preferred over Al-5%CSA, which has a score of 0.77638. Al-1100 has the lowest preference score of 0.34598, indicating that it is the least preferred composition among the evaluated options. These preference scores provide a clear ranking

of the compositions based on their performance, helping in the selection of the most suitable composition for specific applications.

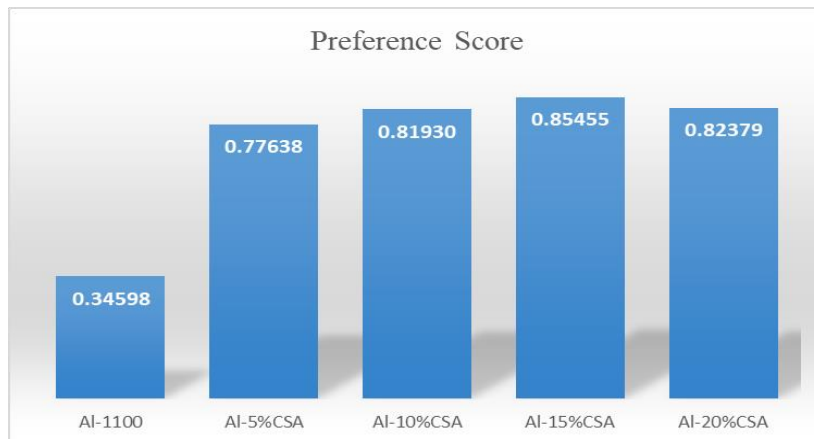


FIGURE 4. Preference Scores

Figure 4 Based on the preference scores, Al-15%CSA emerges as the most favored material, boasting the highest overall performance among the Al-CSA-MMC options. Its exceptional performance in hardness, UTS, toughness, wear rate, and coefficient of friction positions it as the top choice for applications requiring a balance of these properties. Following closely behind are Al-10%CSA and Al-20%CSA, both demonstrating strong overall performance and high preference scores, indicating their suitability for various applications. Al-5%CSA, although less preferred than the higher CSA content composites, still offers advantages over the base Al-1100 alloy. Al-1100, with the lowest preference score, is the least favored due to its inferior performance compared to the CSA-reinforced composites.

TABLE 7. Rank

	Rank
Al-1100	5
Al-5%CSA	4
Al-10%CSA	3
Al-15%CSA	1
Al-20%CSA	2

Table 7 presents the ranking of the Aluminum-Coconut Shell Ash Metal Matrix Composites at different compositions based on their overall performance. The rankings indicate the relative position of each composition in terms of their suitability or preference for a given application. According to the rankings, Al-15%CSA is ranked first, indicating that it is the most suitable composition among the evaluated options. Al-20%CSA follows closely behind in second place, suggesting that it is also a highly suitable composition. Al-10%CSA is ranked third, indicating that it is preferred over Al-5%CSA, which is ranked fourth. Al-1100 is ranked last, indicating that it is the least suitable composition among the evaluated options. These rankings provide valuable insights into the performance of each composition and can help in the selection of the most appropriate composition for specific applications based on their relative performance.

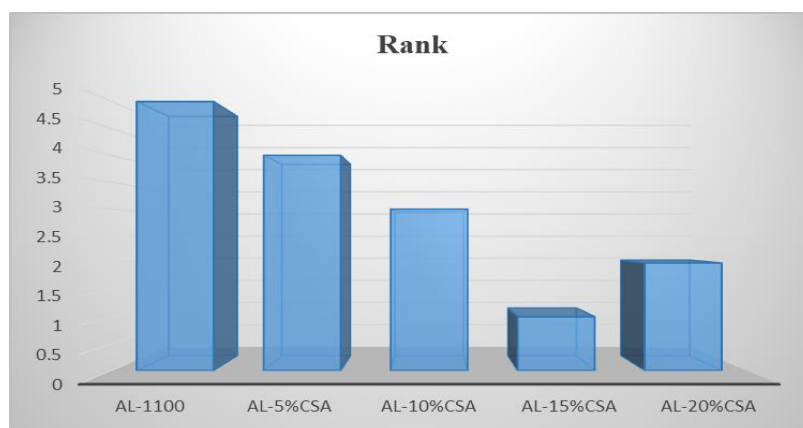


FIGURE 5. Ranking

Figure 5 presents the ranking of the Al-CSA-MMCs based on their overall performance and preference scores. Al-15%CSA achieves the top rank of 1, indicating it is the most favorable material among the options considered. This is consistent with its high preference score and exceptional performance across multiple properties. Al-10%CSA and Al-20%CSA secure ranks 3 and 2, respectively, highlighting their competitive performance and suitability for various applications. Al-5%CSA obtains rank 4, indicating it is less favored compared to the higher CSA content composites but still offers advantages over the base Al-1100 alloy. Al-1100 receives the lowest rank of 5, reflecting its inferior performance and lower desirability compared to the CSA-reinforced composites. Overall, the ranking provides a clear hierarchy of the materials based on their performance, aiding in decision-making for selecting the most suitable material for specific applications.

#### 4. CONCLUSION

In summary, research on Aluminum-Coconut Shell Ash Metal Matrix Composites (Al-CSA-MMCs) has shed light on the possibility of utilizing coconut shell ash in aluminum matrix composites as a reinforcing component. A variety of CSA volume fractions were used in the fabrication of the composites, which were then assessed according to several parameters, including hardness, density, Ultimate Tensile Strength (UTS), toughness, wear rate, and coefficient of friction. The findings demonstrated that while keeping a comparatively low wear rate and coefficient of friction, increasing the volume fraction of CSA generally improved hardness, UTS, and toughness. Out of all the compositions examined, Al-15%CSA showed the best overall performance and preference score, making it the most promising material. The study emphasizes how agricultural waste products, including ash from coconut shells, can be used as reinforcement in metal matrix composites, providing a sustainable and environmentally beneficial substitute for more conventional reinforcing materials. Subsequent investigations may concentrate on refining the production procedure and investigating the mechanical and tribological characteristics of these composites in practical uses.

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