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A Review on Material Selection for Small Wind Turbine Blades Using the WASPAS Method

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Abstract: *The material selection for small wind turbine blades plays a crucial role in optimizing the performance, reliability, and cost-effectiveness of these renewable energy systems. With the growing demand for sustainable energy solutions, small wind turbines have gained prominence as a viable option for decentralized power generation. This paper focuses on the key factors that influence material selection for small wind turbine blades, including structural requirements, aerodynamic considerations, and environmental factors. Various materials commonly used for blade construction, such as fiberglass composites, carbon fiber composites, and wood, are explored in terms of their properties, advantages, and limitations. Furthermore, the impact of material selection on blade design, manufacturing processes, and maintenance is discussed, emphasizing the need for a holistic approach to ensure optimal performance and longevity of small wind turbine blades. By understanding the complexities of material selection, designers and engineers can make informed decisions that contribute to the overall efficiency and sustainability of small wind energy systems. The selection of materials for small wind turbine blades holds significant research importance due to its direct impact on the overall performance, durability, and cost-effectiveness of these renewable energy systems. Small wind turbines have emerged as a promising solution for decentralized power generation, especially in remote areas and off-grid applications. Efficient and reliable blade design is crucial for harnessing wind energy effectively, maximizing power output, and ensuring long-term operation. The research significance of material selection lies in its potential to address key challenges faced by small wind turbine systems In this research we will be using weighted-sum method. We have taken alternative parameters are, epoxy based Carbon FRP, epoxy based Glass FRP ($GFRP_{EP}$), polypropylene based Glass FRP with ($GFRP_{PP}$), polypropylene based Cotton-Glass FRP ($CGFRP_{PP}$), epoxy based Flax Glass FRP ($FGFRP_{EP}$), epoxy based Sisal-Glass FRP with ($SGFRP_{EP}$) have taken Evaluation parameters Attributes Alternatives, Tensile Strength, Production Rate(MPa), Flexural strength(MPa), Corrosion resistance, Blade Cost(USD), Setup Cost(USD),Density(kg/m^{3})}Out of all 10 materials aluminum gets first rank immaterial selection for small wind turbine blades .And($SGFRP_{EP}$) gets final rank With the WASPAS we are able to find the best material for small wind turbine blades which has been evaluated with various parameters and methodology.*

Keywords: *plastic, wood, aluminum, glass*

1. INTRODUCTION

The material selection for small wind turbine blades is a critical aspect of designing efficient and reliable renewable energy systems. With the increasing global demand for sustainable energy solutions, small wind turbines have emerged as a viable option for decentralized power generation, offering the potential for clean and renewable electricity in various applications. The selection of suitable materials for turbine blades is crucial in optimizing their performance, ensuring structural integrity, and minimizing maintenance costs. The design of small wind turbine blades involves a complex interplay of factors, including aerodynamics, structural requirements, and environmental considerations. These factors must be carefully balanced to maximize energy capture from the wind while ensuring the durability and longevity of the blades. The choice of materials plays a vital role in achieving these objectives.

Traditionally, small wind turbine blades were constructed using wood due to its availability and ease of manufacturing. However, advancements in materials science and engineering have led to the emergence of innovative materials that offer improved performance characteristics. Fiberglass composites and carbon fiber composites, for instance, have gained popularity due to their high strength-to-weight ratios, corrosion resistance, and enhanced aerodynamic properties. These materials offer the potential for lighter, more efficient blades capable of capturing more wind energy. The selection of materials for small wind turbine blades involves a careful consideration of their mechanical properties, such as stiffness, strength, and fatigue resistance, as well as their suitability for manufacturing processes. Additionally, environmental factors, such as the impact on the carbon footprint and recyclability, are increasingly becoming important criteria for material selection. Optimizing the material selection process for small wind turbine blades requires a multidisciplinary approach, involving expertise from materials science, engineering, aerodynamics, and sustainability. Researchers and engineers must evaluate the trade-offs between performance, cost, and environmental impact to make informed decisions that align with the specific requirements and constraints of each project. This paper explores the significance of material selection for all wind turbine blades, addressing the various factors influencing the decision-making process. It examines the properties, advantages, and limitations of different materials commonly used in blade construction. Furthermore, the impact of material selection on blade design, manufacturing processes, and maintenance is discussed, highlighting the need for a holistic approach to ensure optimal performance and sustainability.

2. MATERIALS AND METHOD

Weighted Aggregated Sum Product Assessment (WASPAS): Production Rate: Production rate indicates the speed or efficiency at which a particular material can be manufactured or produced. It measures the rate at which the material can be made available for use or distribution, reflecting the speed and effectiveness of the production process. Flexural Strength (MPa): Flexural strength, also referred to as bending strength, gauges a material's ability to resist deformation or fracture when subjected to bending or flexing forces. It is measured in megapascals (MPa) and assesses the material's capacity to endure applied loads without breaking. Blade Cost (USD): Blade cost refers to the monetary value associated with manufacturing or purchasing a blade made from the specific material being discussed. It represents the financial expense incurred in acquiring the blade. Setup Cost (USD): Setup cost refers to the initial expenses or investments required to establish the manufacturing process or equipment necessary for producing the blades. It includes costs associated with machinery, tooling, facilities, and any other requirements for setting up the production line. Aluminum is a lightweight metal with excellent strength-to-weight ratio and corrosion resistance. It is widely used in industries such as aerospace, transportation, and construction due to its durability and malleability. CFRP_{EP} stands for Carbon Fiber Reinforced Polymer with an Epoxy matrix. It is a composite material made of carbon fibers embedded in an epoxy resin matrix. CFRP_{EP} is known for its high strength-to-weight ratio, stiffness, and resistance to corrosion, making it suitable for applications in aerospace, automotive, and sports equipment. GFRP_{EP} refers to Glass Fiber Reinforced Polymer with an Epoxy matrix. It consists of glass fibers embedded in an epoxy resin matrix. GFRP_{EP} possesses good mechanical properties, high strength, and durability. It is commonly used in construction, marine, and automotive industries. GFRP_{PP} stands for Glass Fiber Reinforced Polymer with a Polypropylene matrix. Similar to GFRP_{EP}, it contains glass fibers, but the matrix material is polypropylene. GFRP_{PP} offers good chemical resistance, low cost, and ease of processing, and is often used in automotive parts, pipes, and consumer goods. CGFRP_{EP} refers to Carbon-Glass Fiber Reinforced Polymer with an Epoxy matrix. It is a hybrid composite material that combines carbon and glass fibers in an epoxy resin matrix. CGFRP_{EP} offers a balance of strength, stiffness, and cost-effectiveness, and finds applications in aerospace, automotive, and sporting goods. GFRP_{PP} stands for Carbon-Glass Fiber Reinforced Polymer with a Polypropylene matrix. It is a hybrid composite material similar to CGFRP_{EP}, but with a polypropylene matrix. CGFRP_{PP} provides a combination of lightweight, strength, and cost advantages, and is commonly used in automotive and consumer products. FGFRP_{EP} refers to Flax-Glass Fiber Reinforced Polymer with an Epoxy matrix. It is a composite material that incorporates both flax and glass fibers in an epoxy resin matrix. FGFRP_{EP} offers a renewable and environmentally friendly alternative, with good mechanical properties and impact resistance. It is often used in automotive, construction, and packaging applications. SGFRP_{EP} stands for Sisal-Glass Fiber Reinforced Polymer with an Epoxy matrix. It is a composite material that combines sisal fibers with glass fibers in an epoxy resin matrix. SGFRP_{EP} provides a lightweight and eco-friendly option, with good impact resistance and strength. It finds applications in automotive, construction, and packaging industries. Plastic refers to a wide range of synthetic materials that are moldable and can be shaped into various forms. Plastics are widely used in numerous industries due to their versatility, low cost, and durability. They can be found in products ranging from packaging and consumer goods to automotive parts and medical devices. The WASPAS method is a multi-criterion decision-making (MCDM) technique that is widely used in research and practical applications. Developed by Zavadskas and Turskis in 2011, WASPAS aims to facilitate decision-making processes by incorporating multiple criteria and assigning appropriate weights to each criterion. The WASPAS method provides a structured approach to evaluate and rank alternatives based on their performance across various criteria. It involves three main steps: normalization, weighted sum product, and ranking. In the normalization step, the criteria and alternatives are standardized to a common scale to facilitate meaningful comparisons. This step ensures that different criteria, which may have different units or scales, can be appropriately combined. The weighted sum product step involves giving weights to each criterion based on their relative importance in the decision-making process. These weights, which reflect the preferences of the decision-makers, can be determined using techniques like the analytical hierarchy process (AHP) or expert judgments. Once the weights are assigned, the weighted sum product for each alternative is computed by multiplying the normalized values of each criterion by their respective weights and adding them up. This step combines the performance of each alternative across all criteria into a single value. Finally, the alternatives are ranked based on their aggregated values, with the highest value indicating the most favorable option. It allows decision-makers to incorporate subjective judgments and expert opinions alongside objective measurements, enabling a comprehensive evaluation of alternatives. It has been used to evaluate and rank alternatives in areas such as project selection, supplier selection, site selection, and performance evaluation of systems or processes. In conclusion, the WASPAS method provides a systematic and effective approach for multi-criteria decision-making. By considering multiple criteria and assigning appropriate weights, it helps decision-makers make informed choices and rank alternatives based on their overall performance. Its versatility and practicality make it a valuable tool for researchers and practitioners in various disciplines.

3. RESULT AND DISCUSSION

TABLE 1. Material selection for small wind turbine blads

Attributes Alternatives	**Tensile Strength (MPa)**	**Production Rate**	**Flexural strength (MPa)**	**Corrosion resistance**	**Blade Cost (USD)**	**Setup Cost (USD)**	**Density (kg/m^{3})}**
Wood	70	0.3	147	0.3	90	7000	625
Aluminum	229	0.8	299	0.7	150	24000	2700
CFRP_{EP}	440	0.7	286	0.9	160	3000	1400
GFRP_{EP}	190	0.7	252	0.9	30	3000	1700
GFRP_{PP}	150	0.5	199	0.7	26	3000	1350
CGFRP_{EP}	165	0.7	218	0.8	22	3000	1300
CGFRP_{PP}	135	0.4	179	0.7	20	3000	1200
FGFRP_{EP}	88	0.3	122	0.5	30	3000	1320
SGFRP_{EP}	80	0.3	113	0.5	24	3000	1340
plastic	40	1	75	0.8	10	18000	1250

Table 1 shows the Material selection for small wind turbine blads using method of Weighted Aggregated Sum Product Assessment in Alternative parameters : epoxy based Carbon FRP, epoxy based Glass FRP (GFRPEP), polypropylene based Glass FRP with (GFRPPP), polypropylene based Cotton-Glass FRP (CGFRPPP), epoxy based Flax Glass FRP (FGFRPEP), epoxy based Sisal-Glass FRP with (SGFRPEP**)**and with Evaluation parameters : Attributes Alternatives**,** Tensile Strength, Production Rate(MPa), Flexural strength(MPa), Corrosion resistance, Blade Cost(USD), Setup Cost(USD),Density(kg/m^{3})}

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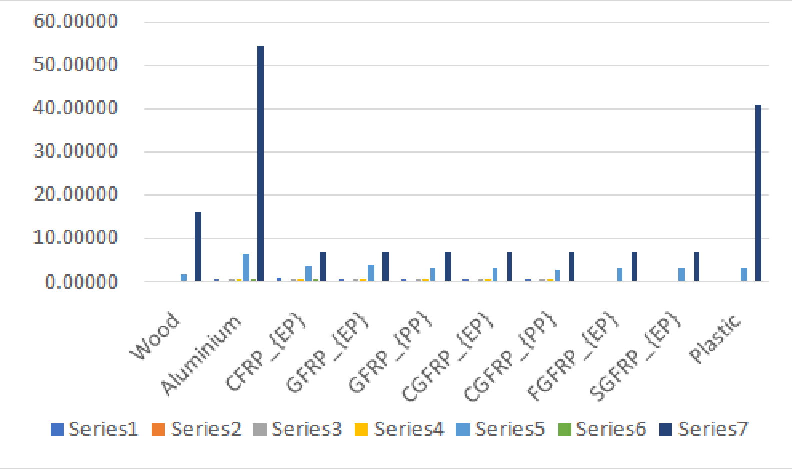

FIGURE 1 Material selection for small wind turbine blads

TABLE 2. Performance value

Performance value							
Wood	0.15909	0.00068	0.33409	0.33409	1.42045	0.20455	15.90909
Aluminum	0.52045	0.00182	0.67955	0.67955	6.13636	0.34091	54.54545
CFRP_{EP}	1.00000	0.00159	0.65000	0.65000	3.18182	0.36364	6.81818
GFRP_{EP}	0.43182	0.00159	0.57273	0.57273	3.86364	0.06818	6.81818
GFRP_{PP}	0.34091	0.00114	0.45227	0.45227	3.06818	0.05909	6.81818
CGFRP_{EP}	0.37500	0.00159	0.49545	0.49545	2.95455	0.05000	6.81818
CGFRP_{PP}	0.30682	0.00091	0.40682	0.40682	2.72727	0.04545	6.81818
FGFRP_{EP}	0.20000	0.00068	0.27727	0.27727	3.00000	0.06818	6.81818
SGFRP_{EP}	0.18182	0.00068	0.25682	0.25682	3.04545	0.05455	6.81818
Plastic	0.09091	0.00227	0.17045	0.17045	2.84091	0.02273	40.90909

Table 2shows the Performance value is divided by the maximum of the given value**.**

TABLE 3. Weightages

0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.14	0.14	0.14	0.14	0.14	0.14	0.14

Table 3 shows the weight of the Material selection, the weight is equal for all the value in the set of data in the table 1. The weight is multiplied with the previous table to get the next value.

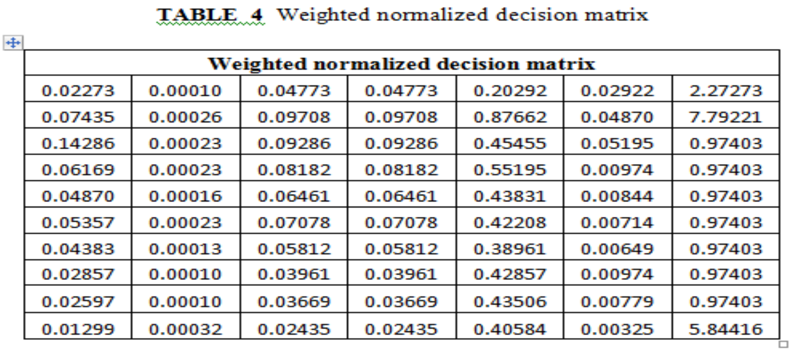

TABLE 4 Weighted normalized decision matrix

Weighted normalized decision matrix						
0.02273	0.00010	0.04773	0.04773	0.20292	0.02922	2.27273
0.07435	0.00026	0.09708	0.09708	0.87662	0.04870	7.79221
0.14286	0.00023	0.09286	0.09286	0.45455	0.05195	0.97403
0.06169	0.00023	0.08182	0.08182	0.55195	0.00974	0.97403
0.04870	0.00016	0.06461	0.06461	0.43831	0.00844	0.97403
0.05357	0.00023	0.07078	0.07078	0.42208	0.00714	0.97403
0.04383	0.00013	0.05812	0.05812	0.38961	0.00649	0.97403
0.02857	0.00010	0.03961	0.03961	0.42857	0.00974	0.97403
0.02597	0.00010	0.03669	0.03669	0.43506	0.00779	0.97403
0.01299	0.00032	0.02435	0.02435	0.40584	0.00325	5.84416

Table 4 shows the weighted normalization decision matrix it is calculated by multiplying the weight and performance value in table 2 and table 3

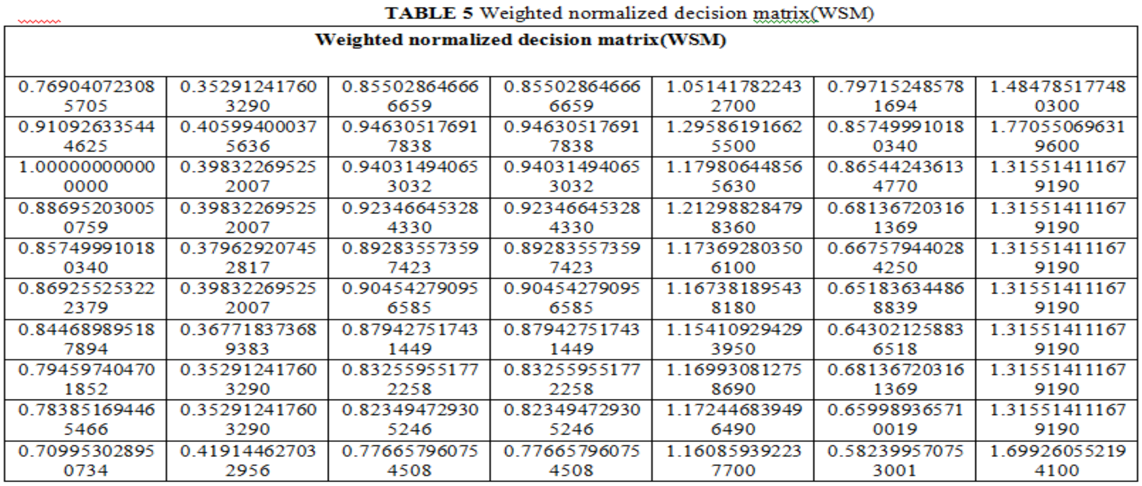

TABLE 5 Weighted normalized decision matrix(WSM)

Weighted normalized decision matrix(WSM)						
0.769040723085705	0.352912417603290	0.855028646666659	0.855028646666659	1.051417822432700	0.797152485781694	1.484785177480300
0.910926335444625	0.405994000375636	0.946305176917838	0.946305176917838	1.295861916625500	0.857499910180340	1.770550696319600
1.000000000000000	0.398322695252007	0.940314940653032	0.940314940653032	1.179806448565630	0.865442436134770	1.315514111679190
0.886952030050759	0.398322695252007	0.923466453284330	0.923466453284330	1.212988284798360	0.681367203161369	1.315514111679190
0.857499910180340	0.379629207452817	0.892835573597423	0.892835573597423	1.173692803506100	0.667579440284250	1.315514111679190
0.869255253222379	0.398322695252007	0.904542790956585	0.904542790956585	1.167381895438180	0.651836344868839	1.315514111679190
0.844689895187894	0.367718373689383	0.879427517431449	0.879427517431449	1.154109294293950	0.643021258836518	1.315514111679190
0.794597404701852	0.352912417603290	0.832559551772258	0.832559551772258	1.169930812758690	0.681367203161369	1.315514111679190
0.783851694465466	0.352912417603290	0.823494729305246	0.823494729305246	1.172446839496490	0.659989365710019	1.315514111679190
0.709953028950734	0.419144627032956	0.776657960754508	0.776657960754508	1.160859392237700	0.582399570753001	1.699260552194100

Table 5 Shows the weighted normalization decision matrix it is calculated by multiplying the weight and performance value.

TABLE 6. Preference Score (WSM) (WPM)

Preference Score		Preference Score	
2.623149	WSM Weighted Sum Model	0.246920968	WSM Weighted Sum Model
8.986299		0.651578105	
1.809318		0.47307085	
1.761266		0.327575018	
1.598864		0.267478931	
1.598604		0.283587867	
1.530325		0.234520338	
1.520227		0.20383634	
1.516331		0.190962503	
6.31526		0.206211916	

Table 6 shows the preference score of WSM Weighted Sum Model it is calculated by the sum of the value on the row of weighted normalized decision matrix. the preference score of WPM Weighted Product Model it is calculated by the product of the value on the row on weighted normalized decision matrix.

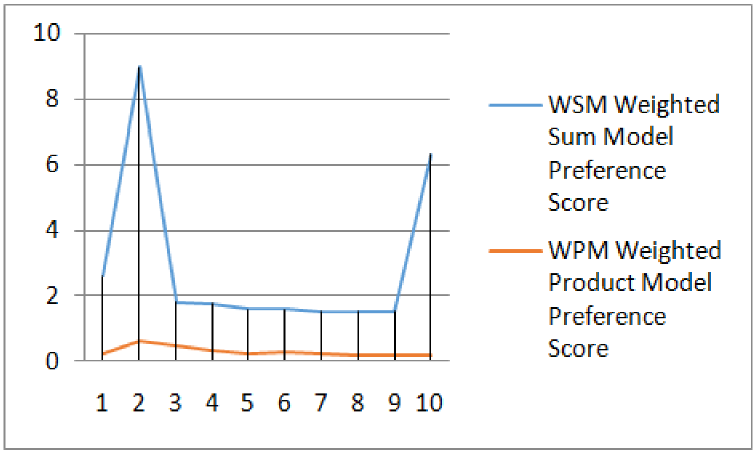

FIGURE 2. Preference Score (WSM) (WPM

Figure 2 shows the preference score of WSM Weighted Sum Model it is calculated by the sum of the value on the row on weighted normalized decision matrix. Government unity of leadership to plan (WSM) (WPM) is the highest and the value the calculation of the WPM Weighted Product Model and WSM Weighted Sum Model. WASPAS Coefficient.

TABLE 7. WASPAS Coefficient value lambda 0.5

lambda	**WASPAS Coefficient**
0.5	
	1.43504
	4.81894
	1.14119
	1.04442
	0.93317
	0.94110
	0.88242
	0.86203
	0.85365
	3.26074

Table 7. shows the WASPAS Coefficient value lambda 0.5

Table 8 shows the Material selection for small wind turbine blads the final result of this paper the wood performance is in 3rd rank, GFRP_{EP}is in 5rd rank, CFRP_{EP} is in 4th rank, the Aluminium is in 1st rank, the Plastic is in 2nd rank. The final result is done by using the WASPAS method.

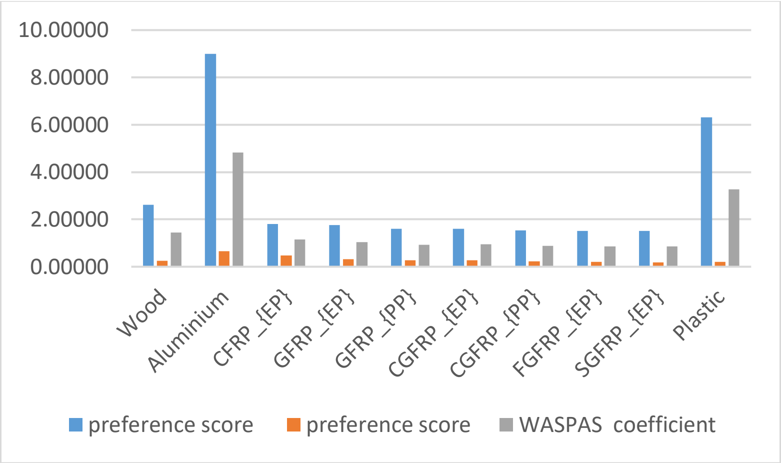

FIGURE 3. WASPAS Coefficient

TABLE 8. Rank

	RANK
Wood	3
Aluminium	1
CFRP_{EP}	4
GFRP_{EP}	5
GFRP_{PP}	7
CGFRP_{EP}	6
CGFRP_{PP}	8
FGFRP_{EP}	9
SGFRP_{EP}	10
Plastic	2

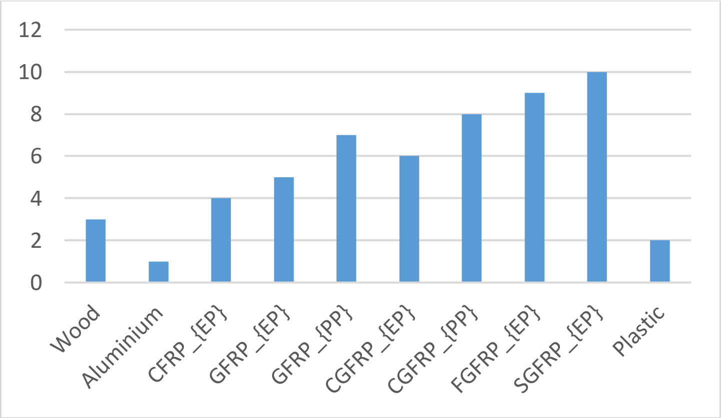

FIGURE 3. Rank

Figure 3 shows the Material selection for small wind turbine blads the final result of this paper the wood performance is in 3rd rank, GFRP_{EP}is in 5rd rank, CFRP_{EP} is in 4th rank, the Aluminium is in 1st rank, the Plastic is in 2nd rank. The final result is done by using the WASPAS method.

4. CONCLUSION

In conclusion, the material selection for small wind turbine blades plays a crucial role in optimizing the performance, reliability, and cost-effectiveness of these renewable energy systems. The choice of materials directly impacts the structural integrity, aerodynamic efficiency, and environmental sustainability of the blades. Through advancements in materials science and engineering, innovative materials such as fiberglass composites and carbon fiber composites have emerged as viable alternatives to traditional wood construction, offering improved strength-to-weight ratios and enhanced aerodynamic properties. The research significance of material selection lies in its ability to address key challenges faced by small wind turbine systems. By identifying and evaluating suitable materials, researchers and engineers can contribute to the development of lightweight and robust blade designs that can withstand varying wind conditions while minimizing maintenance and repair costs. Furthermore, the selection of eco-friendly and sustainable materials can significantly reduce the environmental impact associated with blade production, operation, and decommissioning, promoting the adoption of cleaner and greener energy sources. Optimizing material selection requires a multidisciplinary approach, considering factors such as mechanical properties, manufacturing processes, and economic feasibility. By understanding the complexities of material selection and considering the trade-offs between performance, cost, and environmental impact, designers and engineers can make informed decisions that contribute to the overall efficiency and sustainability of small wind energy systems. In summary, the research and development of materials for small wind turbine blades are vital in enhancing the overall performance, durability, and environmental sustainability of these renewable energy systems. Continued research in this field will lead to the advancement of blade design and manufacturing techniques, enabling the widespread adoption of small wind turbines as a viable solution for decentralized power generation.

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