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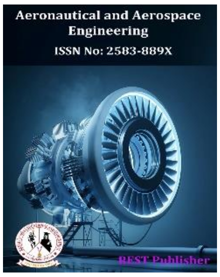

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Evaluation of Material Selection for Small Wind Turbine Blades Using the TOPSIS Method

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ABSTRACT: *When creating a wind turbine blade, the material choice is crucial. Small wind turbine blades can be made out of a variety of materials, including wood, metals, carbon fibre reinforced polymers, natural fibre reinforced polymers, glass fibre reinforced polymers, and nanocomposites. Low density, high strength, and a long fatigue life are three attributes that must be present in the material used to create turbine blades. The substance is additionally made to tolerate high aerodynamic drag, fatigue loads, and impacts from the environment including dust particulate collecting and humidity. The material used to make the turbine blades should have the aforementioned essential qualities, including low density, high strength, and long fatigue life. Additionally, the material is made to endure high aerodynamic drag, fatigue loads, and environmental effects including dust particle collection and moisture materials. In order to capture energy from moving air masses, rotor blade designs rely on the principles of lift or drag. The lift blade design generates a force that lifts the object perpendicular to the plane of motion using the same principle that allows aeroplanes, kites, and birds to fly. Low density, high strength, fatigue resistance, and damage tolerance are requirements for materials used to make wind turbine blades. Composite materials, or materials with an elevated component content, are used extensively in the construction of the blades. Top Rank by Similarity to the Ideal Solution (TOPSIS), a multi-criteria evaluation technique, makes use of numerous factors. The alternative must be the furthest away of the beneficial ideal solution (BIS) & the negative ideal solution (NIS) in order to be chosen. Topsis is built on this principle. The geometric gap between each choice and the most favourable option—that is, the option with the greatest score for each criterion—is calculated after a collection of alternatives is evaluated and the scores for all criteria are normalised. An analytical hierarchical process, the direct prioritisation approach, and other techniques can be utilised to calculate the value requirements according to the TOPSIS method. By using TOPSIS, parameters are thought to be steadily rising or decreasing. Alternate Parameters taken as Wood, Aluminium, epoxy based Carbon FRP (CFRPEP), epoxy based Glass FRP (GFRPEP), polypropylene based Glass FRP with (GFRPPP), epoxy based Cotton-Glass FRP (CGFRPEP), polypropylene based Cotton-Glass FRP (CGFRPPP), epoxy based FlaxGlass FRP (FGFRPEP), and epoxy based Sisal-Glass FRP with (SGFRPEP), plastic. Evaluation Parameters taken a Tensile Strength (MPa), Production Rate, Flexural Strength (MPa), Corrosion resistance, Blade Cost (USD), Setup Cost (USD), Density (kg/m^ {3}). From the result it is seen that epoxy based Carbon FRP (CFRPEP) got the first rank and Aluminium has the lowest rank. The first ranking epoxy based Carbon FRP (CFRPEP) is obtained with the lowest quality of Aluminium*

Keywords: *wind turbine blade, wood, tensile strength, density.*

1. INTRODUCTION

Wood hardness describes a wind turbine blades resistance to harm from insects, dust, rain, and hail. Impact resistance is also affected by the protective coating on the blades. The greatest maximum bending moment experienced by many tiny wind turbines requires that the material used to make the blades be rigid enough to resist bending and to keep them from colliding with the tower. The cheapest Brinell hardness ratings are as follows: pine (14.92; variation range: 11.31); laguri (15.28; variation range: 3.63); char (20.31; variation range: 5.38); ocher (26.36; variation range: 15.09); sisa (58.6; variation range: 17.94); and sal (65.78; variation range: 66.51). Laguri has a lowest value of while minimal hardness of pine has a somewhat greater average and highest point [1]. The wind turbine experiences several stress cycles that can cause fatigue throughout the course of its 20-year design life as well as highly turbulent aerodynamic loading. A big turbine that rotates at 30-70 rpm usually experiences 108-109 cycles throughout the course of its lifetime and operates for 4000 hours each year. In contrast, many manufactured objects are unlikely to go through a total of 106 cycles during the course of their entire lifespan. Significant gravitational, centrifugal, gyroscopic, inertial, and braking loads exist in addition to aerodynamic loading. The real-time loading scenario is significantly complicated by the way these loadings interact with the aerodynamic profile of the blades. The design community has studied a variety of material selection and optimisation techniques over the past few decades. Zhu et al. put forward a (KDSS) over optimal choice of materials of energy absorbers that utilised mould design principles, which included three functional criteria ('what we would like to achieve' factors) and related solutions for design ('how to achieve' factors) [2]. Given the rising demand for energy, the two main renewable energy sources are wind and solar. The need of the hour is reliable tiny wind power generation for a reasonable price. The amount of the materials used, the amount of operation and maintenance, and the cost of fuel all go into the price of energy generation. Energy cost and material amount are directly correlated. Every wind turbine design should consider the blade design. The long-awaited blade material decision is a crucial stage in the design of the blade. Small blades for wind turbines can be made out of a wide range of materials, including wood, fibreglass, carbon fibre, natural fibre, and sandwich composites. It is crucial to consider strength, durability, density, pricing, and availability while selecting a blade material. The material choice of wind turbine blades is a crucial aspect of blade design. In this study, a straightforward analytical hierarchy procedure for choosing the material for a small wind turbine blade is presented. One of the most straightforward and economical approaches for making decisions is AHP [3]. Wood is still frequently utilised in the wind power industry, particularly for tiny wind turbine blades, despite the usage of composite materials. Four Iranian-grown wood species—alder, ash, beech, and hornbeam—were examined for their usefulness as tiny blade materials. Since tiny turbines lack the pitch technique to optimise blade angles of attack during start-up, a solid blade's high stability can delay start-up. Solid blades are simple to build and intriguing from a structural perspective. In addition to common composite materials, wood is a choice for small blades for wind turbines. The four tree species examined in this study are ash, alder, beech, and hornbeam. All four tree species are native to Iran. Fixed blades must initially accelerate during the start-up time for traditional blades to reach a defined by users tip speed ratio. More so than their composition, the blades' form determines how much power they can produce. Nevertheless, the mechanical qualities of wood are significant since blades must withstand aerodynamics and centrifugal forces. Since prior research indicated that small turbine blades constructed of wood have extremely long fatigue lifetimes, fatigue behaviour was not taken into consideration [4]. The goal of technological advancements in wind turbine blades continues to be improved designs, materials, production, analysis, and testing. These previous advances are succinctly outlined. The presentation includes manufacturing trends, design drivers, and changes to these design factorsSmall blades for wind turbines can be made of wood in addition to the widely used composite materials. The four tree species studied in this study—alder, ash, beech, and hornbeam—are all found in Iran. Fixed blades have to accelerate for an amount of time referred to as start-up time before traditional blades may reach a customised tip speed ratio [5]. Small blades for wind turbines can be made of wood in addition to the widely used composite materials. The four tree species studied in this study—alder, ash, beech, and hornbeam—are all found in Iran. Fixed blades have to accelerate for an amount of time referred to as start-up time before traditional blades may reach a customised tip speed ratio [6]. Although there is a market for small wind turbines in applications for distributed energy generation, they will continue to be more expensive than solar photovoltaic systems in the future. When evaluating the fatigue stresses of important structural components like blades, design conservatism might be blamed for high unit prices. Each material has unique fatigue characteristics that depend on its geometrical shape, manufacturing process, and environmental factors [7]. The major structural components of a wind turbine, which has numerous parts and may produce a lot of electricity, are the turbine blades. It is expensive to produce wind turbines because of their size, and since they must last a long time—20–25 years—it is crucial provided the turbine blades be well-designed using accepted blade design principles. In order to develop future wind turbine blade structures, the wind industry must expand its business for onshore and offshore applications that show off novel blade designs and specify the outstanding performance of alternative material systems. In order to take advantages of new material systems, blade designers are continuously looking for fresh, inventive design idea [8]. Use of readily available components and natural resources is one of the main ways to lower the cost of a turbine for wind power. Utilising locally accessible materials lowers material, transportation, and manufacturing expenses. One of the greatest materials for making miniature wind turbine blades is wood. This section of the article focuses on the choice of woods available in Nepal for blades for small wind turbines for rural applications as the use of carbon fibre reinforced material has gained in favour for small blade for wind turbine construction [9]. A shell with a consistent thickness and unidirectional reinforcement make up the blade structure. Aerodynamic factors determine the shell's exterior geometry. For shell and reinforcement, many different lay-ups are taken into account. Finite element analysis is used to perform structural analysis. The results were entered into a database and subject selection software was used to analyse the data. Finding a light blade that adheres to the necessary design limitations is done through a graphical selection stage [10]. Danish three-bladed rotor designs form the basis for the majority of contemporary wind turbines. Over time, this design has shown to be the best one in terms of performance and balance. The blades of a turbine are bolted to the rotor hub, which frequently has dynamic blade pitch control, which is coupled to the shaft that drives the that reaches the nacelle. The nacelle housing houses the bed plate, engine, gearbox, shaft, control box, and other gear necessary for passing power from the spinning rotor to the generator. The nacelle/rotor assembly is supported by a steel tower resting on a concrete foundation. A yaw management system connects the rotor/nacelle assembly to the tower, enabling it to face the predominant wind direction for improved power production [11]. The materials used to construct big wind turbine blades have evolved over time in response to technological advancements, higher loads placed on the blades as a result of longer blades, and demands to lower production costs without compromising performance. With some carbon fibre reinforced composites utilised for very long blades, glass fibre reinforced composites are currently the primary building material. Fibreglass skin bonded to a foam core, carbon fibre, shredded fibreglass, and very little timber are used as building materials. All materials used to make knives share at least one trait, namely a long fatigue life. Because during operation, static and cyclic loads are both applied to wind turbine blades. Hoop pine is a sensible option for compact wind turbines because it has been used to create propellers for ultra-light aeroplanes [12]. Production of tiny blades has a lot of possibilities for rapid prototyping. When creating the blades for the horizontal axis wind turbine, they optimised the aerodynamic shape using electrical glass and polyester resin. They improve the blade form and match the torques produced by the connected generator and rotor. They discovered that the performance that was measured and estimated agreed well. A horizontal-axis wind turbine (HAWT) blade was optimised using blade element momentum theory. They showed the great potential of this approach to forecast wind turbine performance by using Viterna formulas for extrapolating airfoil information in the post-stall regime. It is possible to create an airfoil system to improve the dependability of wind turbine blades [13]. Materials with certain desired attributes are examined and analysed, including those with low weight to lessen the effects of gravity, strong strength to survive wind and gravity, high fatigue resistance to endure cyclic loads, and high stiffness to provide the best possible shape stability. Carbon nanotubes are carbon allotropes that have a nanostructure ratio of aspect to aspect greater than 1,000,000. Composites reinforced by nonmaterial display good mechanical characteristics. These spherical carbon molecules are advantageous for wind turbine blades because of their unique characteristics. In this work, various types of resins with various qualities that can be utilised to reinforce carbon nanotubes are researched and compared to materials utilised for wind turbine blade [14]. Blades are crucial structural elements of wind turbines since they influence performance depending on things like material, shape, turning angle, etc. First, a method for choosing materials is suggested. For a load-bearing box girder of a blade with a specified airfoil form, size, and type and position of internal load-bearing longitudinal beams, a more thorough computer study based on finite element methods was created. Using plane and shell elements, nonlinear and linear analysis produces results for displacements and stresses [15].

2. METHODOLOGY

The value of R is used to process the TOPSIS multi-criteria procedure, which involves minimising the separation from the linear solution that is positive and maximising the range from the ideal solution that is negative. On the contrary hand, the R distance is determined using the M-TOPSIS approach. As a result, we can more accurately estimate the ranking order of each alternative. The synthetic estimate method is regarded as a multi-criteria (MCDM) method for synthetic estimation using multiple variables. In a synthetic evaluation, all the relevant historical information is gathered, the information is processed based on the internal relationships between the factors, the correct evaluation model is designed using mathematical statistics or a bio mathematical method, and finally the evaluated subjects are identified using the proper sequence [16]. The TOPSIS technique seeks to identify a compromise solution that is located closest to the PIS and farthest from the NIS. These two distances are used in the ranking index calculation, but their respective weights or importance is not taken into account. The link between the criteria is another issue with TOPSIS or a drawback. Since the TOPSIS technique relies on Euclidean distance, relatedness is not taken into account, and findings are impacted by overlapping data. employing a simulation technique, experimentally demonstrates the basic causes of the traditional TOPSIS method's drawbacks. The theoretical underpinnings of the TOPSIS approach are better understood and contributed to by thorough practical investigation utilising simulation with an application [17]. The TOPSIS (Technique for Ordered Selection Analogous to Optimal Solution) approach is discussed in Chen and Hwang, referencing Hwang and Yoon. The most advantageous options are chosen from a constrained collection of options using a multi-criteria approach known as TOPSIS. The fundamental principle is that the final choice should be closer to the positive optimal solution and farthest from the adverse optimal result. The chosen alternative needs to be "far" from the undesirable best solution and "close" to the advantageous best answer. The foundational idea behind TOPSIS method is this. The TOPSIS technique introduces two "reference" sites; however, the relative significance of travel from these points is not considered [18]. The TOPSIS approach is frequently employed in academic writing. The proposed technique should only undergo modest and initial TOPSIS method modifications. Literature-based TOPSIS technique 90 RR criteria, practise decision-making exercises, and actual cases are all available. Seven RR instances from the literature were used to evaluate the TOPSIS approach based on these characteristics for every one of 4,800 randomly generated decision issues [19]. There are some issues with the TOPSIS approach. One issue with TOPSIS is the fact that it can lead to a phenomena known as rank reversal. In this situation, adding or removing one option from the choice issue alters the preference order of the alternatives. This can occasionally result in total ranking tilting, where the sequence of preferences is fully reversed, with the greatest alternative becoming the worst after adding or deleting an alternative in the process. Such a phenomenon could be inappropriate in many instances. The TOPSIS method's rank reversal problem is still an open issue. It may be questioned whether the TOPSIS technique is valid because such rank reversals go against the utility theory's invariance postulate [20]. The Fuzzy TOPSIS approach to robot selection evaluates linguistically the evaluations of numerous possibilities, various subjective criteria, and the relative importance of each need. The values of the objective requirements are transformed into dimensionless indices in order to ensure consistency between the standards of the objective criteria and the linguistic judgements of the subjective criteria. Each weighted estimator's membership function is produced using fuzzy interval arithmetic. To prevent the complicated aggregation of fuzzy numbers, these weighted estimates are subsequently divided into smooth values using the average ranking approach of eliminations. The distance between the ideal and non-ideal solutions is used to calculate a proximity coefficient, which is then used to rank the options in that order. An example using numbers demonstrates how the calculations of the proposed method work [21]. The TOPSIS method uses comparing the best solution to establish order preference. For 15 tenants, this method among multi-criteria decision-making (MCTM) is currently one of the most used ones. The TOPSIS 16 technique was created particularly to handle data with real values. Since it is frequently challenging to effectively offer 17 exact estimations of options with respect to regional standards, these estimations are frequently regarded as 18 gaps. The TOPSIS technique has interval expansions, but these modifications are based on various heuristic methods for defining positive and negative optimal solutions. Real numbers or intervals that are beyond 21 in the decision matrix provide these optimal solutions. This is due to the fact that it goes against the fundamentals. This is due to the fact that it is in disagreement with the foundations of the traditional TOPSIS technique [22]. Entropy Method (EM) & OP by Similarities to (TOPSIS) are two frequently used normalisation techniques. When these two techniques are combined, information entropy (IE) is employed as a measurement indicator. Given the variety of attribute data (DAD), entropy-based TOPSIS technique analyses the impacts of normalisation. While DAD influences the contribution of characteristics to each alternative's position relative to the ideal outcome and the adverse effects of the ideal solution, normalisation can affect decision-making by changing DAD. Contribute an attribute [23]. An approach to solving non-linear programming (NLP) problems is provided via the Fuzzy Topsys method based on alpha levels. The proposed Fuzzy TOPSIS approach is studied using several numerical instances, including an application for bridging risk assessment, to show its uses and distinctions from previous techniques. It is demonstrated that the suggested fuzzy TOPSIS method outperforms previous fuzzy methods. An strategy to order preference that comes close to the perfect result is the TOPSIS method. The expense criterion/attribute is maximised and minimised in a negative ideal solution (also known as an anti-ideal solution), whereas the benefit criterion/attribute is maximised and minimised in an ideal solution (also known as a positive ideal solution). The stated benefit criteria/attributes are minimised while the cost criteria/attributes are maximised [24]. Hwang and Yoon's TOPSIS (Technique for Order Preference Similar to Optimal Solution) is a well-known MADM (multi-attribute decision making) technique. The fundamental tenet of TOPSIS is the notion that the choice to be selected should, on the positive side, be closest to the ideal answer and, on the negative side, be the farthest away. The literature goes into great length about TOPSIS's theory and applications. We design a strategy for solving MADM problems using the TOPSIS idea, and then we analyse distance functions and provide a numerical example to demonstrate the suggested approach. Large-scale multi objective nonlinear programming problems require the use of extended TOPSIS approaches. Additionally, we use t-test analysis to compare the preference rankings derived by various distance metrics [25].

3. ALTERNATE PARAMETERS

Wood: Wood is still frequently utilised in the wind energy industry, particularly for tiny wind turbine blades, despite the usage of composite materials. Four Iranian-grown wood species—alder, ash, beech, and hornbeam—were examined for their usefulness as tiny blade materials.

Epoxy Based Carbon FRP (CFRPEP): Epoxy-based Carbon FRP (CFRPEP) refers to a composite material composed of carbon fibres embedded in an epoxy resin matrix. CFRPEP combines the high-strength properties of carbon fibres with the excellent bonding and structural characteristics of epoxy resin.

Epoxy Based Glass FRP (GFRPEP): Glass fibre reinforcement and epoxy resin are combined to create the composite material known as glass fibre reinforced polymer (GFRP/GFRPEP). Due to its advantageous mechanical characteristics and resistance to corrosion, GFRP is widely employed in a variety of industries.

Polypropylene Based Glass FRP with (GFRPPP): Glass fibre reinforcement and polypropylene (PP) resin are combined to create the composite material known as polypropylene-based glass fibre reinforced polymer (GFRPP/GFRPPP). GFRPP is appropriate for a wide range of applications because it combines the mechanical benefits of glass fibres with those of polypropylene.

Epoxy Based Cotton-Glass FRP (CGFRPEP): Epoxy-based Cotton-Glass FRP (CGFRPEP) is a composite material that combines cotton fibres and glass fibers embedded in an epoxy resin matrix. CGFRPEP harnesses the unique properties of both cotton and glass fibers to create a versatile and high-performance composite material.

Polypropylene Based Cotton-Glass FRP (CGFRPPP): PP resin, cotton fibres, and glass fibres are all components of the composite material known as polypropylene-based Cotton-Glass Fibre Reinforced Polymer (CGFRPP/CGFRPPP). CGFRPPP is ideal for a variety of applications since it delivers a special blend of characteristics from each component.

Epoxy Based Flaxglass FRP (FGFRPEP): Epoxy resin, flax fibres, and glass fibres are all components of the composite material known as epoxy-based flax-glass fibre reinforced polymer (FGFRP/FGFRPEP). FGFRPEP is suitable for a number of applications because it delivers distinctive features from each component.

Epoxy Based Sisal-Glass FRP WITH (SGFRPEP): Sisal fibres, glass fibres, and epoxy resin are all components of the composite material known as sisal-based sisal-glass fibre reinforced polymer (SGFRP/SGFRPEP). SGFRPEP is excellent for a number of applications since it delivers a special blend of characteristics from each component.

PLASTIC: Plastic is a material that is frequently used to make wind turbine blades. The exact kind of plastics utilised in wind turbine blades is typically a composite material made of a polymer matrix and a number of reinforcing fibres.

4. EVALUATION PARAMETERS

Tensile Strength (MPA): A material's ability to endure tension or pulling force without fracturing or deforming is referred to as its tensile strength.

Production Rate: Production rate refers to the quantity or volume of a product that can be manufactured or produced within a given time period. It is a measure of the efficiency and capacity of a production system or process. The production rate can be expressed in various units depending on the nature of the product and the industry, such as units per hour, units per day, or units per month.

Flexural Strength (MPA): Flexural strength, measured in megapascals (MPa), is a mechanical property that characterizes the ability of a material to withstand bending or flexural loads without breaking or fracturing. It represents the maximum stress or force that a material can withstand before it experiences failure in a bending or flexural mode.

Corrosion Resistance: Corrosion resistance refers to the ability of a material or substance to resist or withstand the detrimental effects of corrosion when exposed to corrosive environments. Corrosion is a natural process that occurs when metals or materials react with their surrounding environment, leading to degradation, deterioration, or loss of functionality.

Blade Cost (USD): Blade cost refers to the monetary value associated with the manufacturing or procurement of wind turbine blades. It represents the expenses incurred in the production, materials, labor, and other factors involved in the manufacturing or purchase of wind turbine blades.

Setup Cost (USD): Setup cost, also known as start-up cost or initial investment, refers to the expenses incurred in establishing or initiating a business, project, or operation. It represents the upfront financial investment required to set up the necessary infrastructure, equipment, resources, and systems to begin operations.

Density (kg/m^ {3}): Density is a basic physical property that represents the mass of a substance per unit volume.

5. RESULT AND DICUSSION

TABLE 1. Material selection for Small Wind Turbine Blades

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
Aluminium	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 Tensile strength, Production rate, Flexural strength, Corrosion resistance, Blade cost, Setup cost, Density for the attributes alternatives.

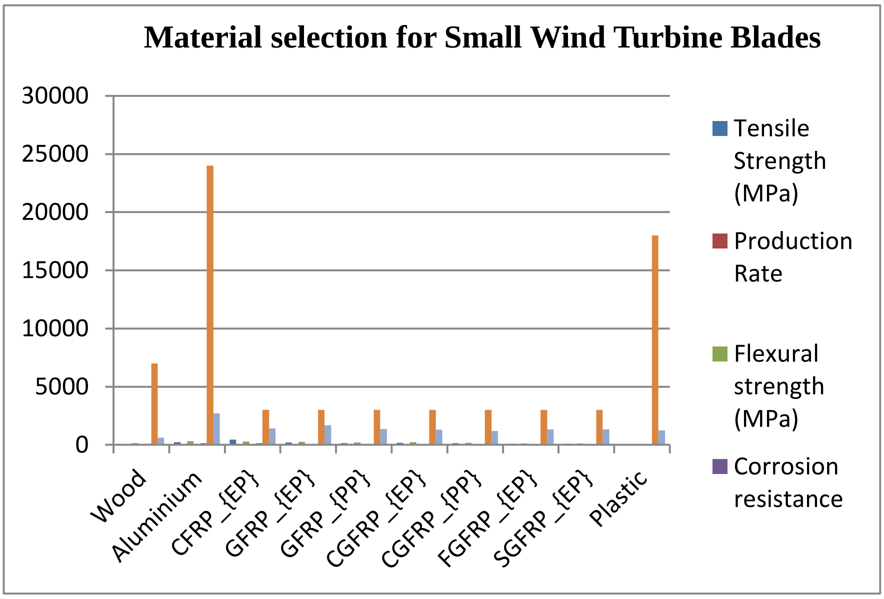

FIGURE 1. Material selection for Small Wind Turbine Blades

Figure 1 shows in Tensile Strength (MPa), CFRP_ {EP} has the highest value and Plastic has the lowest value. In Production Rate Plastic} has the highest value and SGFRP_ {EP}, FGFRP_ {EP}, Wood has the lowest value. In Flexural strength CFRP_ {EP} has the highest value and Plastic has the lowest value. In Corrosion resistance, GFRP_{EP}, CFRP_{EP} the highest value and Wood has the lowest value.

TABLE 2. Normalized matrix

Normalized matrix						
8.047561	0.04623	33.79899	0.040411	33.00327	1540.302	82.19837
86.12697	0.328746	139.8335	0.220016	91.67575	18106.4	1534.019
317.9608	0.251696	127.9384	0.363701	104.3066	282.9126	412.4385
59.28918	0.251696	99.32763	0.363701	3.66703	282.9126	608.1364
36.95309	0.128416	61.94056	0.220016	2.754347	282.9126	383.5047
44.71324	0.251696	74.33305	0.287368	1.972047	282.9126	355.623
29.932	0.082186	50.11584	0.220016	1.629791	282.9126	303.0161
12.71843	0.04623	23.2803	0.112253	3.66703	282.9126	366.6494
10.5111	0.04623	19.9722	0.112253	2.346899	282.9126	377.8442
2.627775	0.513665	8.798153	0.287368	0.407448	10184.85	328.7935

This table shows the normalized data for the Attributes Alternatives.

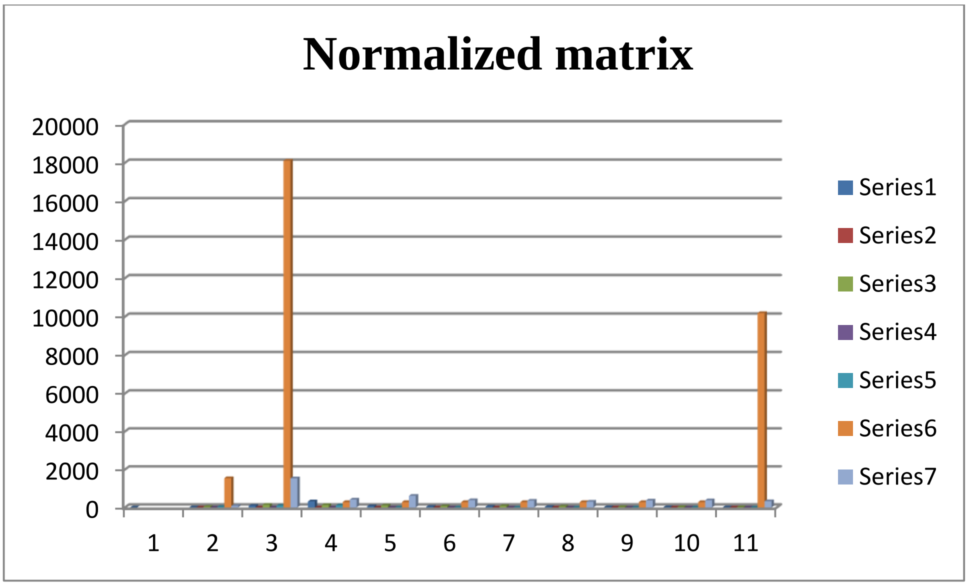

FIGURE 2. Normalized matrix

Figure 2 shows the schematic representation for the Attributes Alternatives like Wood.

TABLE 3. Weighted matrix

Weight matrix						
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1
0.142857	0.142857	0.1	0.1	0.1	0.1	0.1

Table 3 shows the weighted matrix for the Wood.

TABLE 4. Weighted normalized matrix

Weighted normalized matrix						
1.149652	0.006604	4.82842647	0.005773	4.714753	220.0431	11.74262
12.30385	0.046964	19.9762208	0.031431	13.09654	2586.629	219.1456
45.42297	0.035957	18.2769203	0.051957	14.90095	40.41608	58.91979
8.469882	0.035957	14.1896614	0.051957	0.523861	40.41608	86.87663
5.279012	0.018345	8.84865179	0.031431	0.393478	40.41608	54.78639
6.387605	0.035957	10.6190078	0.041053	0.281721	40.41608	50.80329
4.276	0.011741	7.15940638	0.031431	0.232827	40.41608	43.28801
1.816919	0.006604	3.32575776	0.016036	0.523861	40.41608	52.37849
1.501586	0.006604	2.85317125	0.016036	0.335271	40.41608	53.97774
0.375396	0.073381	1.25687903	0.041053	0.058207	1454.979	46.9705

Table 4 shows the weighted normalized matrix for the Wood. In this matrix we have to multiply weight to the normalized matrix.

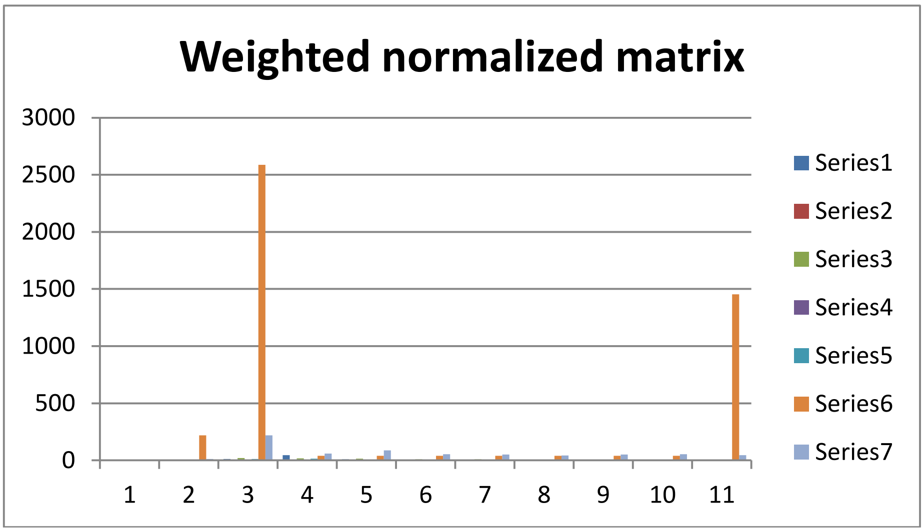

FIGURE 3. Weighted normalized matrix

Figure 3 shows the graph of weighted normalized matrix.

TABLE 5. Positive matrix

Positive matrix						
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262
45.42297	0.073381	19.97622	0.051957	0.058207	40.41608	11.74262

Table 5 shows the positive matrix for the Attributes Alternatives

TABLE 6. Negative matrix

Negative matrix						
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456
0.375396	0.006604	1.256879	0.005773	14.90095	2586.629	219.1456

Table 6 shows the negative matrix for the Attributes Alternatives.

TABLE 7. Material selection for Small Wind Turbine Blades

Alternatives	Si+	Si-	CCI
Wood	185.6802	2375.682	0.927507
Aluminium	2554.894	22.27016	0.008641
CFRP_{EP}	49.48617	2551.704	0.980976
GFRP_{EP}	83.93064	2549.733	0.968132
GFRP_{PP}	59.90193	2551.57	0.977062
CGFRP_{EP}	56.00986	2551.838	0.978523
CGFRP_{PP}	53.40871	2552.331	0.979503
FGFRP_{EP}	61.88879	2551.71	0.97632
SGFRP_{EP}	63.29435	2551.607	0.975795
Plastic	1415.842	1144.769	0.447069

Table 7 shows the value of Si plus, Si minus, CCI for the Attributes Alternatives like Wood, Aluminum, epoxy based Carbon FRP (CFRPEP), epoxy based Glass FRP (GFRPEP), polypropylene based Glass FRP with (GFRPPP), epoxy based Cotton-Glass FRP (CGFRPEP), polypropylene based Cotton-Glass FRP (CGFRPPP), epoxy based FlaxGlass FRP (FGFRPEP), epoxy based Sisal-Glass FRP with (SGFRPEP), Plastic.

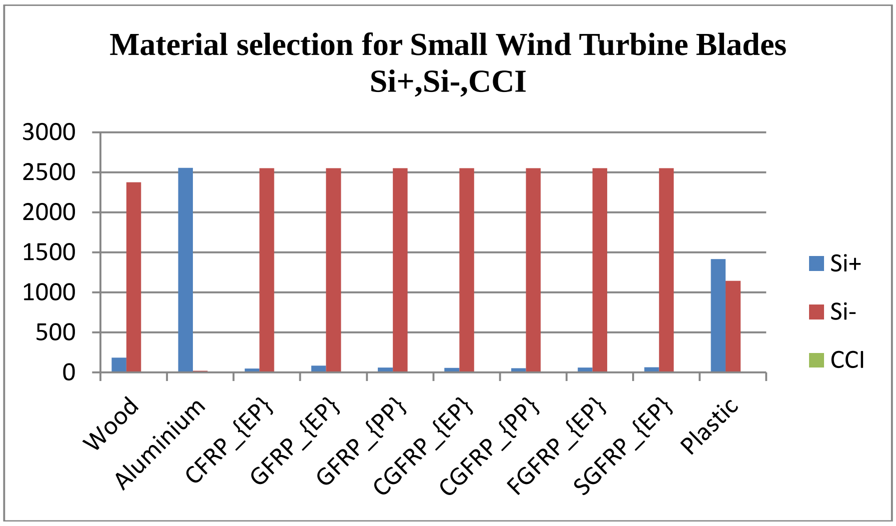

FIGURE 4. Material selection for Small Wind Turbine Blades Si+, Si-, CCI

Figure 4 shows the schematic view of Si plus, Si minus, CCI for the Attributes Alternatives like Wood, Aluminum, epoxy based Carbon FRP (CFRPEP), epoxy based Glass FRP (GFRPEP), polypropylene based Glass FRP with (GFRPPP), epoxy based Cotton-Glass FRP (CGFRPEP), polypropylene based Cotton-Glass FRP (CGFRPPP), epoxy based FlaxGlass FRP (FGFRPEP), epoxy based Sisal-Glass FRP with (SGFRPEP), Plastic.

TABLE 8. Rank

Alternatives	CCI	Rank
Wood	0.927507	8
Aluminium	0.008641	10
CFRP_{EP}	0.980976	1
GFRP_{EP}	0.968132	7
GFRP_{PP}	0.977062	4
CGFRP_{EP}	0.978523	3
CGFRP_{PP}	0.979503	2
FGFRP_{EP}	0.97632	5
SGFRP_{EP}	0.975795	6
Plastic	0.447069	9

Table 8 shows the rank for the Attributes Alternatives. Here we get the ci, si+, si-.

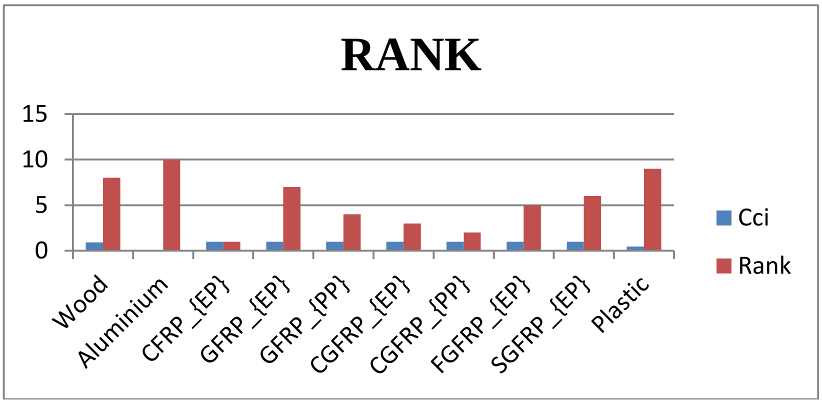

FIGURE 5. Rank

Figure 5 shows the rank for Attributes Alternatives, CFRP_{EP} is in position 1, CGFRP_{PP} is in position 2, CGFRP_{EP} is in position 3, GFRP_{PP} is in position 4, FGFRP_{EP} is in position 5, SGFRP_{EP} is in position 6, GFRP_{EP} is in position 7, Wood is in position 8, Plastic is in position 9, Aluminum is in position 10.

6. CONCLUSION

Wood hardness is the term used to describe a windmill blade's capacity to withstand the effects of insects, dust, rain, and hail. Impact resistance is also impacted by the blades' coating. Small wind turbine blades must be made of a material that is rigid enough to prevent bending and tower collision, which is often the largest ultimate bending moment. Throughout a wind turbines 20-year design life and extremely turbulent aerodynamic loading, numerous stress cycles that result in fatigue are experienced. Over the course of its lifespan, a big turbine operating at 30-70 rpm typically experiences 108-109 cycles and works for 4000 hours annually. No more than 106 cycles are anticipated for their entire life cycle, in contrast to many manufactured products. In addition to aerodynamic loading, there are significant gravitational, centrifugal, gyroscopic, inertial, and braking stresses. These loadings' interactions with the blades' aerodynamic profile greatly exacerbate the real-time load condition. The two primary renewable energy sources are wind and solar energy because of the rising demand for electricity. The necessity of the hour is reliable tiny wind power generation at a fair price. The cost of producing energy includes the cost of the raw materials utilised, the cost of operation and maintenance, and the cost of fuel. Cost of materials and energy are closely related. Blade design must be taken into account in every wind turbine design. An essential step in the design of the blade is the long-awaited selection of the blade material. Small wind turbine blades can be made out of a wide range of materials, including wood, fibreglass, carbon fibre, natural fibre, and sandwich composites. It is crucial to consider strength, durability, density, pricing, and availability while selecting a blade material. Despite the introduction of composite materials, wood is still extensively utilised in the wind energy sector, especially for tiny wind turbine blades. Alder, Ash, Beech, and Hornbeam are four Iranian wood species that were looked into for potential usage in making tiny knives. A sturdy blade is simple to construct and structurally clever, but small turbines lack a pitch mechanism to optimize blade angles of attack during startup, therefore its high stability causes startup to take longer. The TOPSIS multi-criteria approach, which involves minimizing the separation from the positive ideal solution and maximizing the distance from the negative ideal solution, is implemented using the value of R. On the other hand, the M-TOPSIS method is used to calculate the distance R. As a result, it is possible to predict each alternative's ranking order with more accuracy. The synthetic estimate approach, which employs many variables, is regarded as a multi-criteria synthetic estimating (MCTM) method. The TOPSIS method looks for a compromise solution that is both farthest from and closest to the PIS. The ranking index is calculated using both of these distances, but their weights or relevance are not taken into consideration. Another issue or flaw in TOPSIS is the linking of criteria. The TOPSIS approach determines order preference by using optimal solution matching. This multi-criteria decision-making method (MCTM) is currently one of the most popular ones for 15 tenants.

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