Selection of Material by weighted property method for Savonius Vertical Axis Wind Turbine Rotor blade

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Abstract - *Vertical Axis Wind Turbine (VAWT) rotors are getting more popularity for its easy manufacturing, working and economic when compare to Horizontal Axis Wind Turbine (HAWT), but less efficient than HAWT. In wind turbines, blades are the main important part, its performance dependence on the material, machinability and design of blade. In this paper materials considered for Savonius Vertical Axis Wind Turbine (SVAWT) blades are Aluminium (7020 Alloy), Mild Steel (grade 55), Stainless Steel (A580) and Polycarbonate sheet. The suitable material is selected by a technique Weighted Property Method (WPM). By computation the Polycarbonate sheet is optimized material for manufacturing of blade.*

Keywords: *material, SVAWT, HAWT, machinability, WPM, polycarbonate sheet.*

1. INTRODUCTION

Selection of material is very important procedure before detail design of product [1-2]. In this paper suitable material is selected for blades by Weighted Property Method, for manufacturing of small scale Savonius Vertical Axis Wind Turbine (SVAWT),material considered for manufacturing of SVAWT are Aluminium (7020 Alloy), Mild Steel (grade 55), Stainless Steel (A580) and Polycarbonate sheet, among these optimized material should be selected to increase performance of wind turbine , the selected materials for SVAWT must shows low density, corrosion resistant, economic, good machinability and good mechanical properties.

In wind turbine rotor consist about 10-14% weight of wind turbine and 20-30% of machine cost [3]. In older days wood is used in Savonius Vertical Axis Wind Turbine (SVAWT) blade , as research works carried out Aluminium alloys are used for SVAWT blades its shows low density, but it shows high corrosion rate, low mechanical property and costlier than the Stainless steel. Stain less steel shows high density, costlier than Aluminium alloy, now research work is going on composite material is used for manufacturing of blade to increase efficiency.

2. LITERATURE SURVEY

Selection of optimized materials or a machining in manufacturing of any product is first step; there are many methods for selecting optimized material and machining, are Fuzzy logic method, Multi-Criteria Decision Makin method, Cost analysis, Limits Property Method and Weighted Property Method. WPM method involve more attributes or requirements or property and also considers each property into account, but some selection methods like MCDM, Limits Property and Cost analysis method consider only some important material properties.

R. Hemanth, et.al [3]: has aimed to reduce the cost of two wheeler products by the cost analysis value. Considering data collection and analysis was reviled that by changing subsystems material may reduced cost of two wheeler priorities and by giving ranking to material used for subsystem like fuel tank, ignition coil mounting brackets, reduces the cost of two wheeler by 8%.

Kasim M. Daws, et.al [4]: Has studied about, an automated advisory casting process selection system is designed. Selection of material dependence on specified criteria or requirements weighted property index algorithm calculates relative importance of each property. Ranking or for rating of each requirements and alternative process was given by Fuzzy Logic method, which shows optimized alternative process.

M.A. Maleque, et.al [5]: has developed weighted property method for selection of optimum material for application of brake disc system, to use light weight material instead

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of cast iron. Two methods were used for the selection of materials, such as cost per unit property and digital logic methods. Cast iron, aluminium alloy, titanium alloy, ceramics and composites Material performance requirements were analyzed and alternative solutions were evaluated. Mechanical properties including compressive strength, friction coefficient, wear resistance, thermal conductivity and specific gravity as well as cost, were considered as the key parameters in the material selection stages. The analysis result shows that aluminium metal matrix composite as the most suitable material for brake disc system.

Dr. Mohammed Jasim Kadhim, et.al [6]: has made an attempt to show, there is no gap between materials and function oriented design. Concurrent qualitative selection of materials methodology (CQSM) was developed to know the importance of materials properties in the early design stages. The Weighted Property Method was modified from Quantitative method to Qualitative Method for selection of materials. Weighted factor index was calculated by Digital Logic (DL) and compared with the traditional method, Digital Logic (DL) method shows accurate results, because it does not eliminates least important properties.

Shankar Chakraborty, et.al [7]: has studied about the multi- criteria decision-making (MCDM) which is used to selection of suitable material , it also gives how the main material properties are considered and considered properties should be independent to each other, ranking was given according to which property has more priority.

Katica Simunovic, et.al [8]: has compared AHP (analytical hierarchy process) and Weighted property method by taking an example for selection of optimum stock material and manufacturing process.in method of AHP subjectivity was considered for giving ranking to the attributes,in WPM there is no consideration of subjectivity because it deals with transformed values of criteria, at the end both AHP and WPM shows same results.

3. DISCUSSION AND CALCULATION

Weighted property method is very useful when there are a lot of important requirements (properties) to compare and evaluate [1, 7]. Scaled values of the criteria (β) are multiplied by the weighting factor or index (α) (see the expression 1). The sum of multiplied scaled properties and weighting factors represents the performance index (γ), see the Eq. (1). The combination of stock material and matching manufacturing process with the highest performance index is the optimum solution.

The Table.1 shows material properties. In early days SVAWT blades are manufactured from wood, Cloths, now a day's Aluminium alloy is used because of it shows good corrosion resistant, low density, good mechanical properties but shows lower fatigue strength compare to steel, Stain less Steel shows good mechanical properties ,low corrosion rate and good fatigue strength but it shows high density and poor machinability and now days research is going on blade to manufacture by using composites, Polycarbonate sheet is one which shows low density, good corrosion resistant rate, low cost and good machinability but it shows slightly lower value of mechanical properties, due to this consequences, to choose suitable material for manufacturing of SVAWT blade Weighted Property Method (WPM) is used.

Table-1: Material and material properties, **source**: DOE and EWEA [9, 10]

Material	Material Properties							
	Density (gm/cm³)	Corrosion rate (µm/year)	Cost ($/Kg)	machinability	Yield strength (MPa)	Tensile Strength (MPa)	Specific modulus	Young's Modulus (GPa)
Aluminum (7020 Alloy)	2.78	25	3.5	3	280	400	26	69
Mild Steel (Grade 55)	7.8	5800	1.8	1	355	450	26	205
Stainless steel(A5 80)	7.8	2.5	4.9	1	275	800	25	200
Polycarbonate Sheet	1.2	1	1	3	60	75	2	2.4

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Table 2. Weighted factor

SL. No	Property	Weight Index (α)
1	Density	8
2	Corrosion rate	7
3	Cost	6
4	Machinability	5
5	Yield strength	4
6	Tensile strength	3
7	Specific modulus	2
8	Young's modulus	1

Table3. Scaled factor.

Material	Scaled factor index(β)							
	Density (gm/cm³)	Corrosion rate (µm/year)	Cost ($/Kg)	machinability	Yield strength (MPa)	Tensile Strength (MPa)	Specific modulus	Young's Modulus (GPa)
Aluminum (7020 Alloy)	43	4	29	100	79	50	100	34
Mild Steel (Grade 55)	15	0.0172	53	67	100	56.25	100	100
Stainless steel(A 580)	15	40	25	67	77	100	96	98
Polycarbonate Sheet	100	100	100	100	17	10	8	1

Performance Index, $\gamma = \sum (\beta * \alpha)$ (1)

Where, γ= Performance index,

β = scaled factor,

α = weighted factor.

Weighting factor (α) represents the relative priorities given to properties of material. This factor is calculated by using the experience or the digital-logic method. Digital-logic method calculates by the comparison of properties, WPM is used in combined properties with having different units. This method shows each material requirement (or property) is assigned to a certain weight (which depends on its importance to the performance of the design). Value for each weighing factor (α) should be given based on its importance in product; Table-2 shows the weighting factor or index value. Eq. (2) defines weighting factor for the property is the ratio of the number of positive decisions and the total number of decisions,

Total number of requirements, $N = \frac{n(n-1)}{2}$ (2)

It is desirable to quantify the relative importance of the property or attribute. One attribute may be very much more important than another, while others may be quite similar in importance. The relative importance is shown by using a point scale that does not exceed 100 points. Table.3 shows scaled values for different properties.

Scaled values of the properties are applied because of more reliable comparison of the properties with different units of measurements. Eq. (3) gives the dimensionless scaled property value for the property where a lower value is required (for example costs, mass loss, etc.).

$$\text{Scaled Property } (\beta) = \frac{\text{lowest value in the list}}{\text{Numerical Value of the Property}} X100$$
(3)

Equation (4) gives the dimensionless scaled property value for the property where a higher value is required (for example hardness, tensile strength, etc.).

$$\text{Scaled Property } (\beta) = \frac{\text{Numerical Value of Property}}{\text{Largest Value in the List}} X100$$
(4)

Table .4 gives performance values and ranking order of material to use in manufacture of Savonius VAWT blade. Polycarbonate sheet shows higher performance value.

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Table4. Performance value and ranking of material

Material	Performance Index (β*α)									
	Density(gm /cm³)	Corrosion rate (µm/ year)	Cost ($/ Kg)	Machinability	Yield strength (MPa)	Tensile Strength (MPa)	Specific modulus	Young's Modulus (GPa)	Performance Value (γ) (%)	Ranking
Aluminum (7020 Alloy)	9.4	0.76	4.6	14	8.6	4	6	1.0	48.57	3
Mild Steel (Grade 55)	3.3	3.6e-3	8.4	9.3	11	4.5	6	3	45.66	4
Stainless steel (A580)	3.3	7.6	4	9.3	8.4	8	5.7	2.9	49.54	2
Polycarbonate Sheet	22	19	16	14	1.8	0.8	0.4	0.03	74.18	1

4. CONCLUSION

Selection of material for Savonius Vertical Axis Wind Turbine blade is calculated by Weighted Property Method. Ranking of materials in Weighted factor computed by Digital logic method, among the Aluminium alloy (7020), Mild Steel (55 grade), Stainless Steel and Polycarbonate Sheet, Polycarbonate Sheet shows 74.18% performance value, which is higher than other material.

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BIOGRAPHY

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