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Design and Fabrication of Micro-Scale Wind Turbine Blades Using Advanced Light Weight Materials Based on Rapid Prototyping Technique

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Abstract: -- A wind turbine is a device that converts kinetic energy from the wind to mechanical energy. Wind energy is one the most widely used renewable energy resources. Micro wind turbines need to be affordable, reliable and almost maintenance free for the average person to consider installing one. Micro - scale wind turbines produce more costly electricity than large and medium - scale wind turbines, especially in poor wind sites and in autonomous applications that require a high level of reliability. However, when designed properly with proper materials, micro - scale wind turbines could be a reliable energy source and produce valuable energy not only in developing countries but also in remote areas that are far away from the grid power in developed countries. Micro - scale wind turbines are in fact becoming an increasingly promising way to supply electricity in developing countries. The micro - scale wind turbines have quite different aerodynamic behavior than their large - scale counterparts. In this work the blades of the wind turbines are designed for low wind speeds of 3 m/s using NACA 2412 aerofoil. This paper elaborates the design of wind turbine blade using Q-Blade and 123D- Make software and fabrication using advanced light weight materials like Carbon fiber and PU foam.

Keywords: Carbon Fiber, NACA 2412 Foil, Rapid Prototyping, Wind turbine.

INTRODUCTION

Wind power is one of the major energy resource of future. Now a days there is huge scope for generation of electricity from wind energy due to the increased demand for electricity. The conventional energy resources such as coal, diesel and nuclear power etc., can also be used for the generation of electricity but these energy sources causes environmental pollution hence the non conventional energy sources such as solar, wind, geothermal energies are getting more importance now a days. The geothermal energy requires huge steps to extract the heat from earth and the drawback of solar energy is its intermittent availability. Hence the wind energy is most suitable source to produce electricity.

Although many power stations have setup in India still the demand for electricity is not being fulfilled so this motivates an engineer to develop a technology of generating electricity at low cost on site. This includes wind turbine technology also. Even though the wind turbine technology is older it is not being used widely for micro scale applications. In some cases micro wind turbines are used but are not efficient with respect to capacity and cost. So in this work we are going to develop a novel technology of manufacturing wind turbine blades for micro scale applications at low cost.

MATERIALS AND METHOD

Material selection for the wind turbine blades is difficult task for any engineer as there are many affecting parameters like tensile strength, flexibility, weight to strength ratio, cost, manufacturing feasibility etc., modern day domestic wind turbine blades are manufacturing either by using plastics or by polypropylene but the technological advancements led to the invention of carbon fiber and the manufacturing techniques of Rapid Prototyping. So in this work the blades are planned to fabricate using the

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advanced material like carbon fiber since the carbon fibers have high stiffness, low weight, high chemical resistance capacity and low tendency of expansion and the Rapid prototyping technique for manufacturing.

The carbon fiber selected for the present work is 2x2 woven twill type fibers.

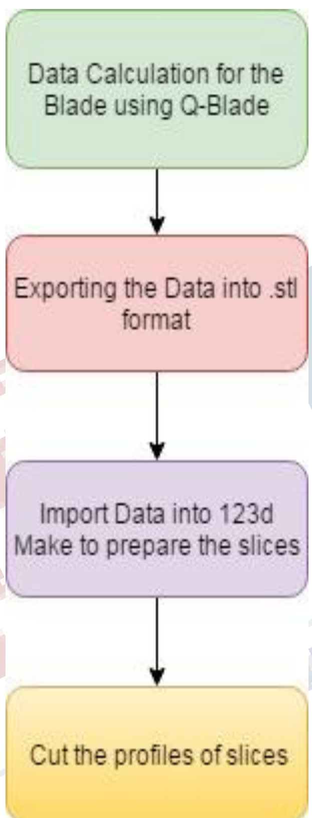

Fig 1: Process of designing the blade

Table 1: Properties of Carbon fiber

Property	Unit	Value
Young's modulus	GPa	70
In plane shear modulus	GPa	5
Poisons ratio	--	0.10
Ultimate tensile strength	MPa	600
Ultimate compressive strength	MPa	570
Thermal expansion coefficient	Strain/K	2.10

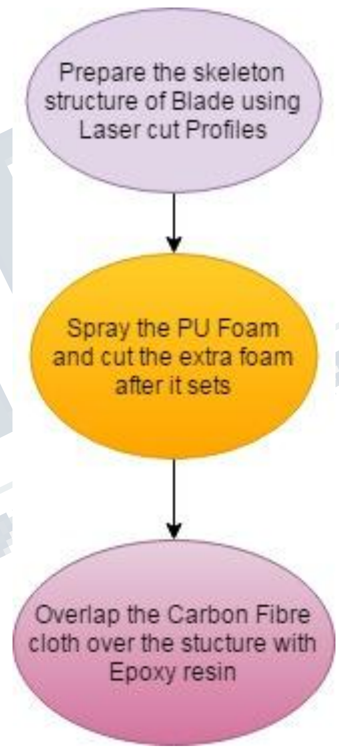

Fig 2: Process of fabricating the blade

DESIGNING THE TURBINE BLADE

The blades for the wind turbine were designed in the software Q-Blade in which the NACA 2412 foil was selected (fig 3). The selected length of the blade is 1 m and planned to fabricate using advanced materials like Carbon

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Fibers and PU Foam as they have high strength to weight ratio.

For the selected NACA foil the analysis was made based on Montgomery and Viterna extrapolation which consists of following basic steps,

- Blade design and optimization
- Rotor simulation
- Turbine definition and simulation.

Optimized performance and the data required for the blade calculations was obtained which included the variations of coefficient of lift and drag and also the optimized results of coefficient of lift for the angle of attack(fig 4 and fig 5).

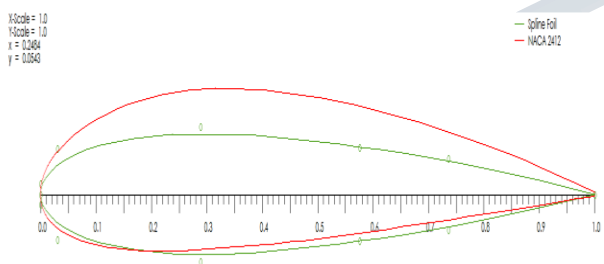

Fig 3: NACA Foil 2412 profile generated

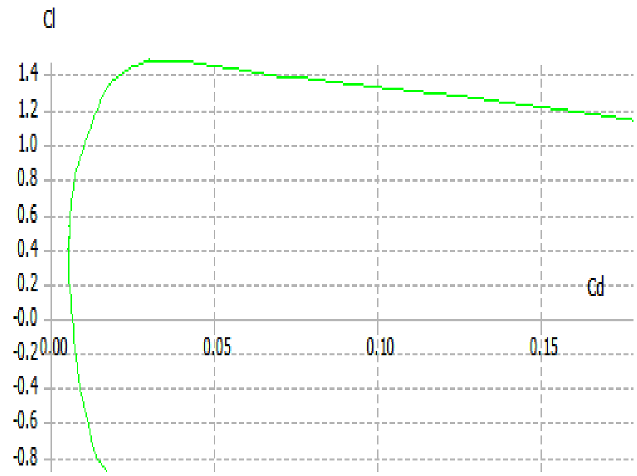

Fig 4: variation of C_l with C_d

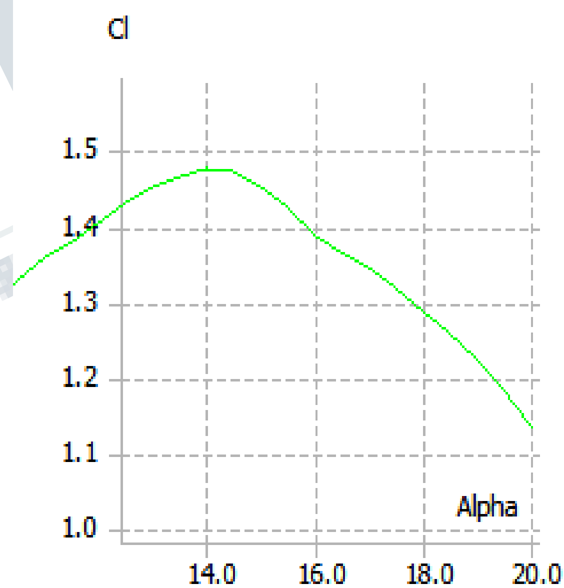

Fig 5: Variation of C_l with Angle of Attack

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Table 2: Blade data

Sl.No.	Position in 'm'	Chord length in 'm'	Twist in 'Degree'	Foil type
1	0.1	0.257	29.6	NACA2412
2	0.2	0.129	11.5	NACA2412
3	0.3	0.086	3.6	NACA2412
4	0.4	0.064	-0.6	NACA2412
5	0.5	0.051	-3.2	NACA2412
6	0.6	0.043	-5	NACA2412
7	0.7	0.037	-6.3	NACA2412
8	0.8	0.032	-7.2	NACA2412
9	0.9	0.029	-8	NACA2412
10	1	0.026	-8.6	NACA2412

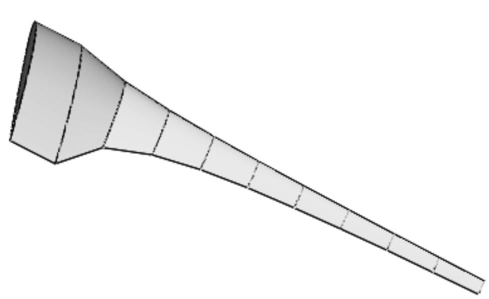

Fig 6: completed Blade design

Fig 7: Blade imported in 123D Make

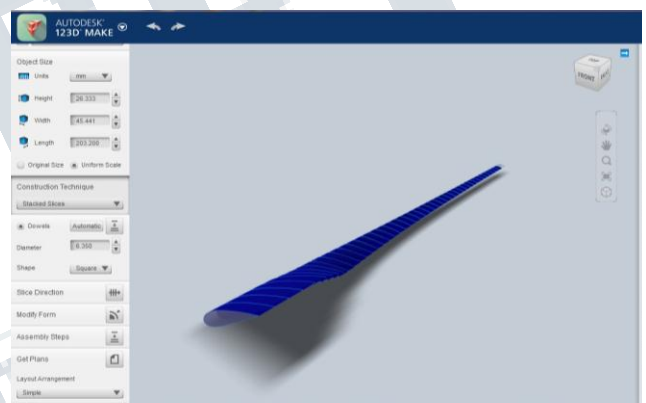

Fig 8: Blade sliced into 10 parts

By the optimized and available data (Table 2) the blade was developed and the blade model (fig 6) file was exported for the manufacturing using Rapid Prototyping Technique to .stl format.

The design of blade in .stl format was imported in 123d Make software developed by Autodesk (fig 7). In this the required manufacturing settings were made and the blade was sliced into 10 parts (fig 8). Finally these 10 parts files were converted to .dxf file and exported for further processing.

The sliced blade profiles were cut using Laser cutting machine and the material selected for cutting the slices was 1mm thick mild steel. After the laser cutting process blade's sliced profiles were assembled on the square bar to their positions to form the initial skeleton structure of the wind turbine blade.

FABRICATION PROCESS

The blade profiles cut in the laser cutting machine were assembled on the 5x5 mm square of 1 m and fixed with a help of metal bonding agent and is kept for 1 hour for settling. Once the profiles were joined to the bar the bar was sprayed with PU foam completely with the help of a foam sprayer. After spraying the foam the blades left as it is for about 4 hour till the PU foam expanded and hardened.

Fig 9: Blade profiles after laser cutting

Fig 10: Skeleton structure of blade

The extra PU foam in the surface of the blade was cut using hot wire foam cutter and it is sanded for the accurate dimensions of the blade. The carbon fiber cloth was cut into required size and is wrapped over the blade and the suitable resin and hardener mixture was used to set the carbon fiber cloth and after applying resin and hardener the blades were kept for about 24 hours till the resin is hardened as shown in (fig 11 and 12)

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Fig 11: Blade after spraying PU foam

Fig 12: Blade after wrapping to Carbon Fiber

CONCLUSION

The wind turbine was successfully designed for the wind speed of 3 m/s. The length of each blade manufactured was 1 m and the weight measured after the complete fabrication of blade was found 0.45 kg which is much lower for the length of 1m when compared to the blades manufactured by polypropylene material. In comparison with conventional domestic wind turbine blades the blades manufactured with carbon fibers were found to be slightly costlier but in comparison for the power and durability the presently manufactured blades are efficient and also can produce power up to 2.5 to 3 kW.

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