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Aerodynamic Characteristic Material for Enhancing Efficiency of Wind Turbine

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Abstract—With the exhausting finite resources like crude oil, natural gas, coal, fossil-fuel etc.... the demand for non-renewable energy resources has increased over time. A wind turbine is one of the power generating devices which taps the wind energy and converts it into electrical energy and it is considered as a quality grade sustainable green energy. This paper proposes a framework to enhance the mass properties of the wind turbine blade, that increases the efficiency of the turbine. To avoid the damage caused by the stress concentration because of the axial load, aerogel a mechanically robust material having aerodynamic characteristic mainly contributes in minimizing the weight of the component while maintaining the required mechanical properties such as strength and durability. Parameters like inertia and torque have a major contribution to the working of the wind turbine; therefore, the mass of the wind turbine blades play a vital role. Heavier the turbine blades higher the chances of catastrophic failure. The enumerated results are analyzed and comparative study is made among the currently used turbine blade materials that are aluminum, glass fibre reinforced polymer, carbon fibre reinforced polymer where the density of these materials is considered as a key property.

Keywords- Aerodynamic characteristic; Catastrophic failure; Green energy; Inertia; Mechanically robust material; Torque

1. INTRODUCTION

Dependency on the non-renewable resource of energy to generate a quality grade sustainable green energy has increased over time. Tapping the kinetic energy from the wind that is abundant in nature is well known, but the output obtained must be reasonable. The wind turbine performance is dependent on the blade design related parameters that are the torque initiated, stress concentration due to axial load acting on the wind turbine blades, also, the self-weight of the blades is majorly dependent on the density of the material of the turbine blade. Lighter the turbine blade higher the response to the inertial force. Advanced and specialised models and material characterization methods are used in the effort to optimize the material used in the blade [1]

In this article, a theoretical approach is made to show that the performance of the wind turbine can be improved with the change in its currently used blade materials. The blade materials that are currently being used are carbon fibre reinforced polymer, glass fibre composites, aluminium. Although these materials are having suitable mechanical properties their mass to volume ratio add self-weight, which in turn affects the efficiency of the resultant output of the turbine. To overcome this problem the proposed framework aims at reducing the mass of the turbine blade, by replacing the it with a mechanically robust material called aerogel. Aerogel are the advance materials which exhibit an uncanny array of extreme material properties, they are synthetic porous ultralight materials and derived from a gel.

2. METHOD

Weight reduction in the turbine blades is one of the biggest challenges, this is one of the reasons for higher stress concentrations due to which catastrophic failure occurs. The wind turbine blades are the structure that are long and slender where the dominating loads are given by the aerodynamics and the gravitation. The 88.4m long weighing 33.7 tons is the longest blade noted from LM Wind Power [1] efforts are being made in order to optimize the blade materials used. In perspective of engineering aerogels are finding its application in various fields, due to which airloys are considered as one of the multifunctional materials. Airloys are 3 to 15 times lighter than plastics or other composites and yet they offer the durability and strength at the same time. Airloys are extremely lightweight and are porous solids that are composed of air by volume and has aerodynamic characteristics [2].

Comparison of mass related key material property that is density is made between the currently used turbine blade materials and the polyurea aerogel (aliphatic polyurea aerogel also known as airloy). Some of the currently used materials are glass fibre reinforced polymer, carbon fibre reinforced polymer and aluminium. A 30meter overall length wind turbine blade is developed with computer aided design (CAD) software as shown in the Fig.1. In order to obtain appropriate report, the centre of mass for the model is fixed as shown in the Fig. 2 and the respective coordinates are X = 30125.00 millimetres, Y = 3219.75 millimetres, Z = 0.00. The Volume = 1184800836.51 cubic millimetres (1.1848 cubic meters) and over all surface area= 1145639.57 square millimetres (1.1456-meter square). The thickness at the tip of the blade is 494.70 millimetres. Diameter of the blade at the hub side is 1964.95 millimetres and these parameters are constant for all the materials used for comparison. Fig. 3, Fig. 4, Fig. 5 and Fig. 6 depicts the analysis conducted by assigning different materials for the developed CAD model along with the mass properties.

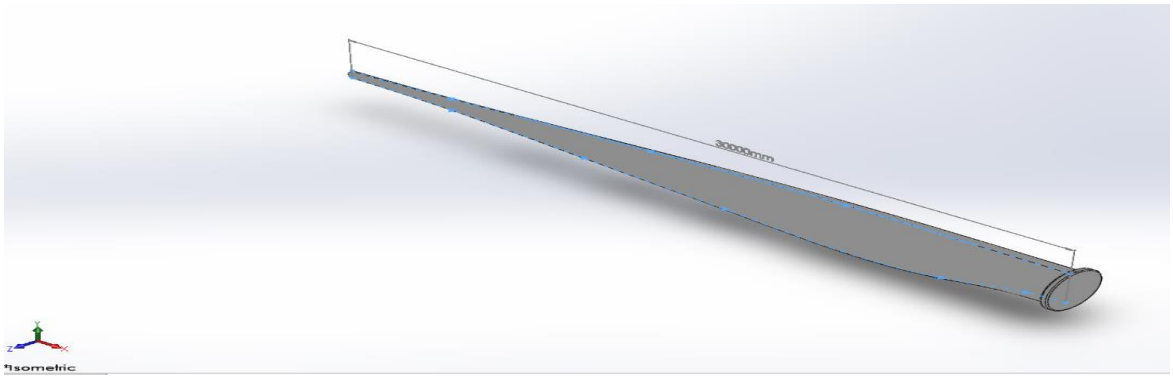

Figure 1. 3D CAD model of wind turbine blade of 30m overall length.

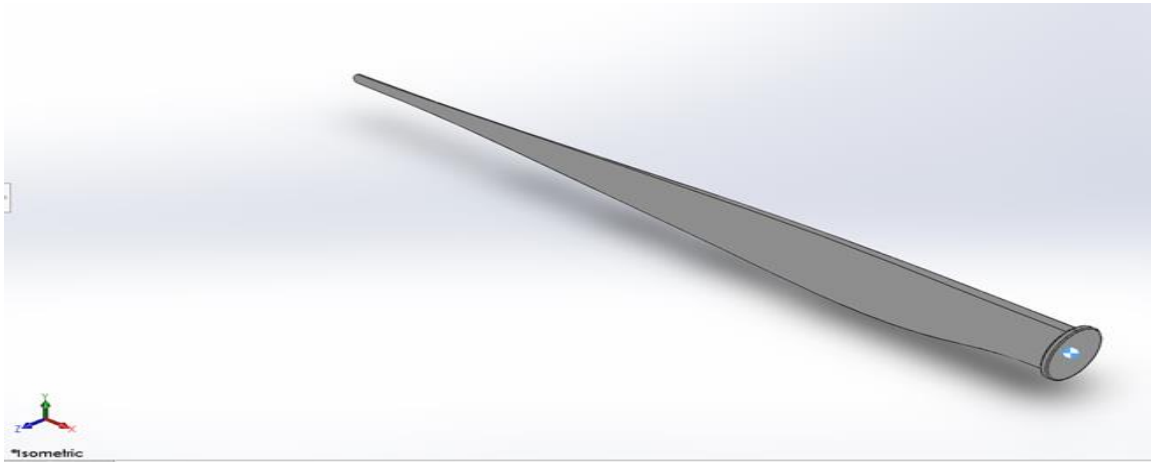

Figure 2. Showing centre of mass at X, Y and Z coordinates.

Material number 1
Mass properties of Wind Turbine Blade
Coordinate system: -- default --
Material – Glass fibre reinforced polymer (Fig. 3)
Density = 1.9 grams per cubic millimetre[1]
Mass = 2251121.59 grams

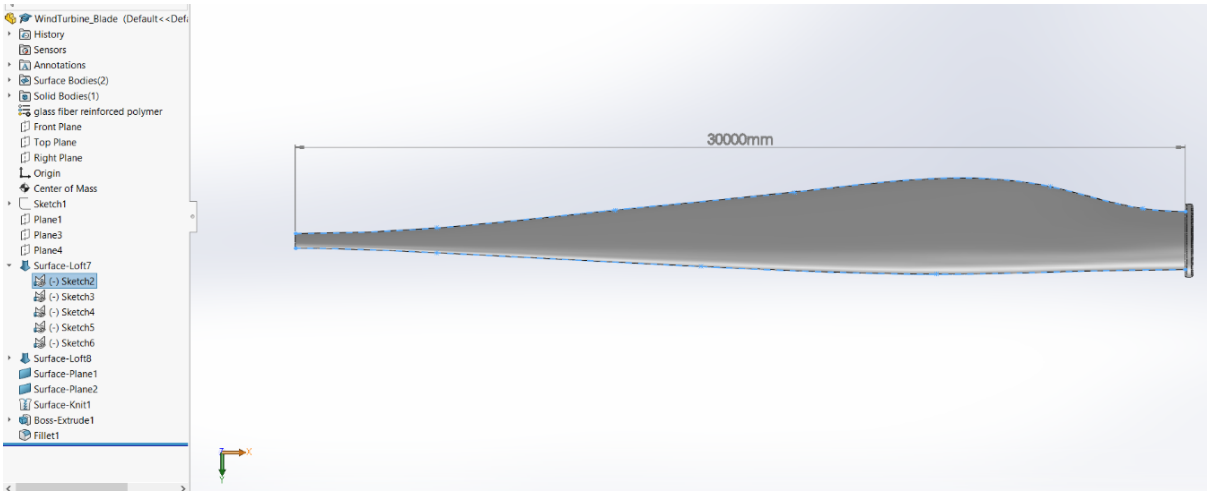

Figure 3. Material assigned- glass fibre reinforced polymer.

Material number 2
Mass properties of Wind Turbine Blade
Material – Aluminium (Fig. 4)
Coordinate system: -- default --
Density = 2.7 grams per cubic millimetre[1]
Mass = 3198962.26 grams

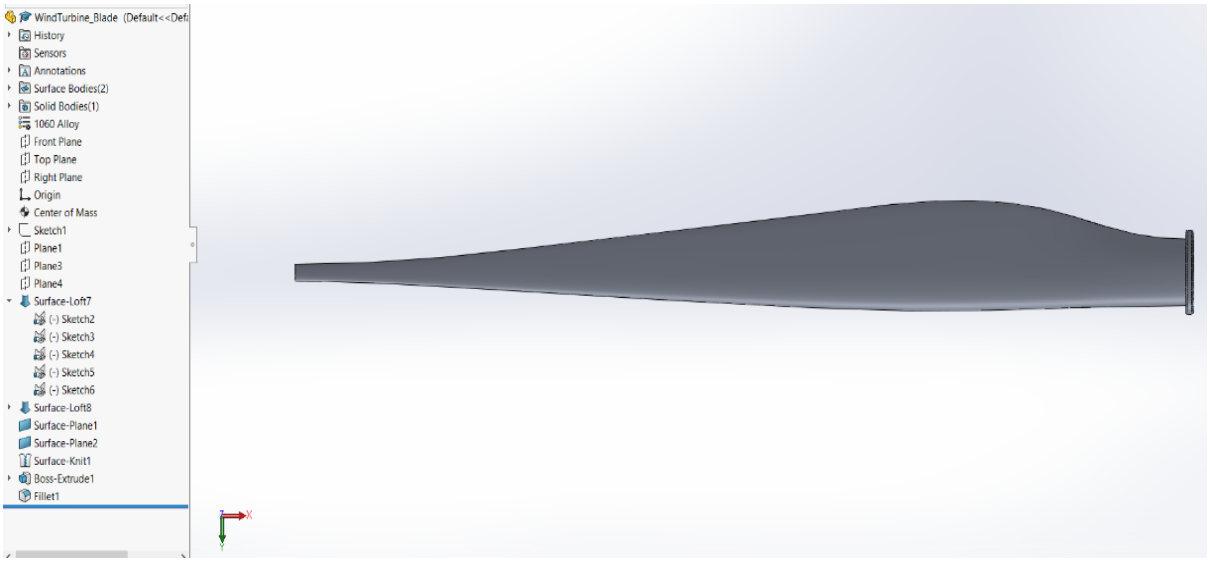

Figure 4. Material assigned- Aluminium.

Material number 3
Mass properties of Wind Turbine Blade
Material - Carbon fibre reinforced polymer (Fig. 5)
Coordinate system: -- default --
Density = 1.6 grams per cubic millimetre[1]

Mass = 1895681.34 grams

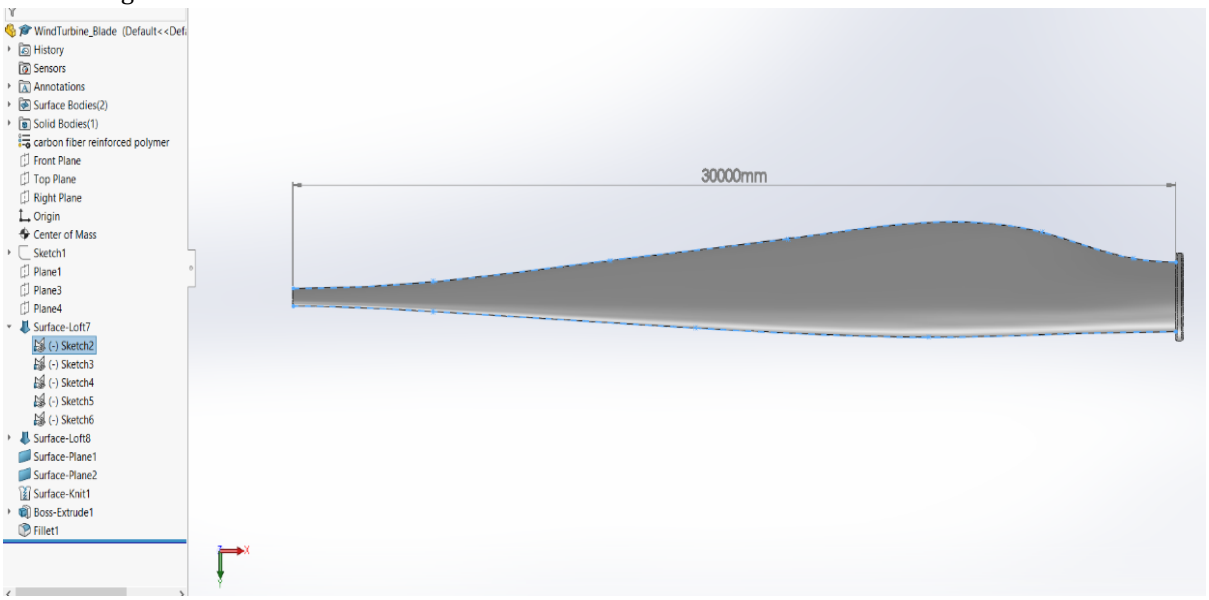

Figure 5. Material assigned- carbon fibre reinforced polymer.

Material number 4
Mass properties of Wind Turbine Blade (Fig. 6)
Coordinate system: -- default --
Material – Polyurea aerogel[3]
Density = 0.31 grams per cubic millimetre
Mass = 367288.26 grams

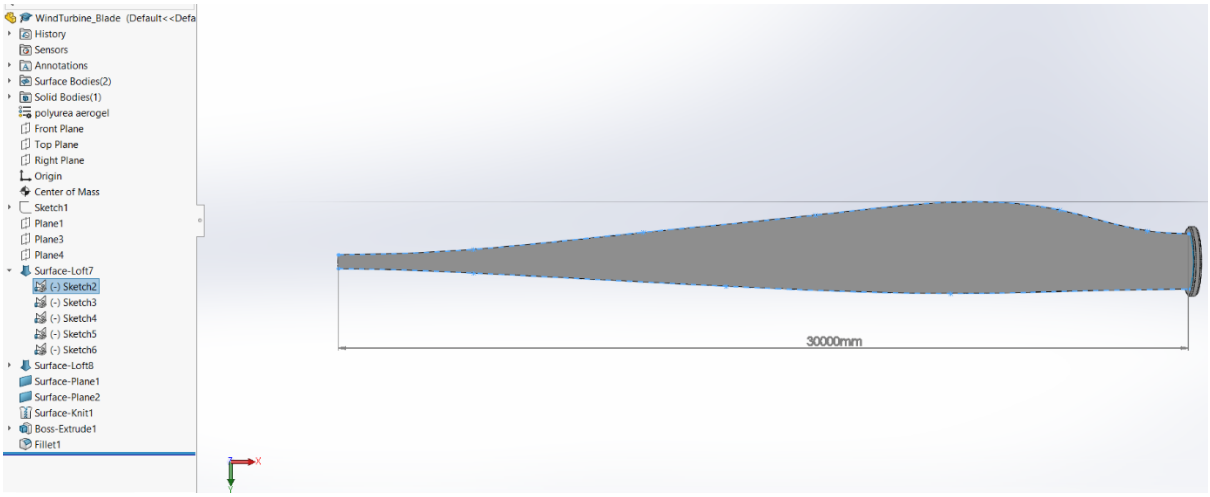

Figure 6. Material assigned- Polyurea aerogel.

3. RESULTS AND DISCUSSIONS

TABLE 1. COMPILED RESULTS

Material	Density in g/cc	Mass of the blade in kg
Aluminium	2.7	3198.96226
Glass fibre reinforced polymer	1.9	2251.12159
Carbon fibre reinforced polymer	1.6	1895.68134
Polyurea aerogel	0.31	367.28826

Upon comparison of the mass properties of the materials taken into consideration, the highest density material shows the highest mass of the wind turbine blade. The use of polyurea aerogel in the blade will drastically reduce its mass due to its low density thereby increasing the efficiency. With reduction in weight the torque required will also reduce. But the major disadvantage is that the cost remains high.

4. FUTURE SCOPE

Before the material can be incorporated to the real-world application it can be simulated for the best performing turbine blade design using various analysis software. Different grades of aerogels can be put to test in order to reveal its abilities.

5. REFERENCES

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