DESIGN AND ANALYSIS OF VERTICAL AXIS WIND TURBINE BLADES (VAWT)

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Abstract

Due to the scarcity of fossil fuels, alternative energy has become necessary to meet the world's growing energy demands. A wind turbine is a rotary device that extracts wind energy and converts it to mechanical energy. The behavior and performance of wind turbines subjected to aerodynamic and ambient conditions must be studied in order to maximize the use of available wind energy. The NACA 0018 aero foil wind turbine blade is used to model vertical axis wind turbine rotors in this study. To improve rotor performance, the straight three bladed vertical axis wind turbine rotor is twisted to 45 degrees and 90 degrees. The weight of the rotor is significantly increased by twisting the rotor while maintaining the height and diameter of the rotors. Fiber reinforced composite materials are used to reduce the weight of the rotor without compromising its performance. To increase the strength-to-weight ratio, carbon, glass fibers, and epoxy resin were used in the fabrication. A straight and twisted three bladed vertical axis wind turbine rotor was CFD-analyzed in ANSYS-FLUENT and structurally analyzed in ANSYS for this purpose. Because of the limitations of experimentation, the wind loads on the blades were calculated using a computational fluid approach. The structural behavior of the rotor is obtained for a predetermined set of operating conditions after further application of these loads. The analysis' results are validated by comparing them to previously collected data.

IndexTerms: Vertical Axis Wind Turbine (VAWT), ANSYS, NACA 0018, Carbon, Glass Fibre

I. Introduction

Wind turbines are wind power devices that are used to generate electricity. The classification of wind turbines is determined by the orientation of the shaft and rotational axis. A horizontal axis wind turbine, also known as a horizontal axis wind turbine, is a wind turbine with a shaft that is horizontally parallel to the ground (HAWT). The shaft of a vertical axis wind turbine (VAWT) is parallel to the ground.

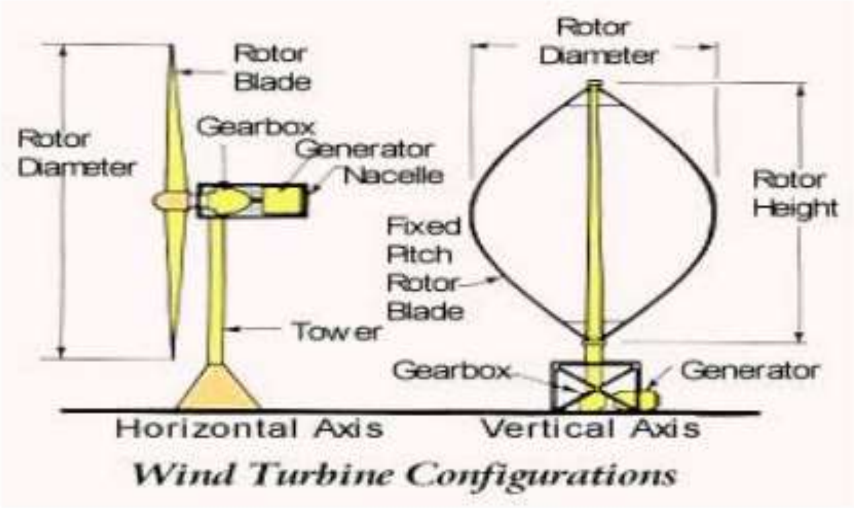

Fig.1 Wind Turbine Configurations

The rotor designs of the two configurations are instantly distinguishable, and each has its own set of advantages. Vertical-axis wind turbines (VAWT) are divided into two types: those that extract power from the wind using aerodynamic drag and those that use lift. The VAWTs have the advantage of being able to accept wind from any direction. This simplifies their design and eliminates the problem of gyroscopic forces on a convectional machine's rotor as the turbine tracks the wind. The generator and drive train can also be mounted at ground level due to the vertical axis of rotation. The disadvantages of this type of rotor are that pitching the rotor blades is difficult to control power output, they are not self-starting, and they have a low tip-speed ratio. HAWTs (horizontal axis wind turbines) are convectional wind turbines, and VAWTs are unlikely to be omnidirectional. HAWTs must change direction as the wind changes direction. They'll need some way of orienting the rotor in relation to the wind.

1.1Types of Wind Turbines

1.1.1 Horizontal Axis Wind Turbines

Horizontal axis wind turbines, as previously stated, are the most mature and widely used wind turbines on the planet. In this section, we'll take a quick look at the main features, benefits, and challenges of this type of turbine. The design of a horizontal wind turbine is influenced by a number of factors, including blade material selection and stress distribution, as well as turbulence effects and vibrations. We will only give a brief overview of HAWTs because this project is primarily focused on Savonius vertical wind turbines.

1. 1.1.2 Principle

A horizontal axis wind turbine is one whose rotor is connected to a horizontal shaft. The blades of the rotor rely on lift to rotate the turbine. The HAWTs' blades have an aerofoil shape, which causes this. The aerofoil blade design functions similarly to that of an airplane wing. The pressure difference between the blade's two sides produces a lift force that is perpendicular to the blade, causing it to rotate. The effect of lift and drag is depicted in the diagram.

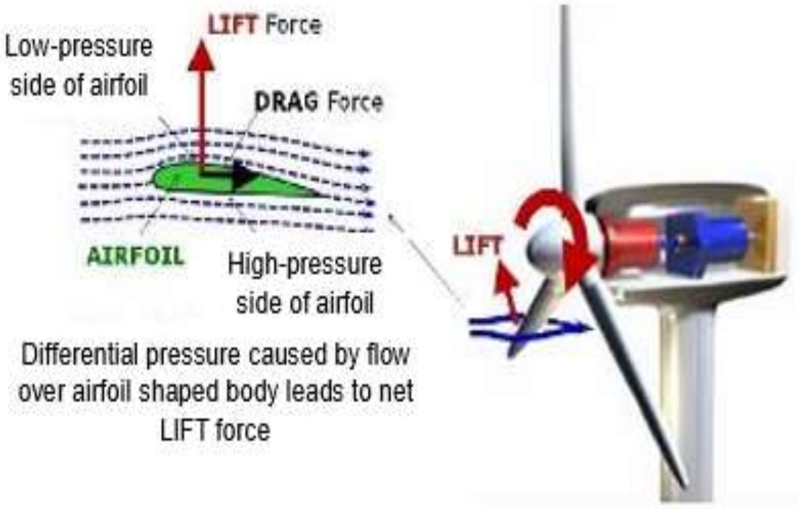

Fig.2 The effect of lift and drag

They usually have two or three blades, with the diameter and height varying according to the power output required. The larger the swept area and the more power output, the higher the tower, the faster the wind, and the longer the blades, the larger the swept area and the more power output. Before reaching the generator, the rotor is connected to a shaft that passes through a gearbox. A good wind turbine blade design has a high lift to drag ratio, which maximizes the turbine's power output. Because the blade is designed to maximize lift and minimize drag, the majority of the wind energy will turn the rotor, producing more power.

1.1.3 Advantages

HAWTs, like all renewable energy sources, are a clean, long-term energy source with a lot of promise. The advantages of HAWTs include "high generating capacity, improved efficiency, variable pitch blade capability, and tall tower base structure to capture large amounts of wind energy." Their massive sizes allow for large-scale generation, and their variable pitch angle allows them to use the most efficient angle of attack. HAWTs are based on proven technology, and their high efficiencies make them a cost-effective energy source for both onshore and offshore applications. They do, however, have a number of drawbacks, which are discussed in the following section.

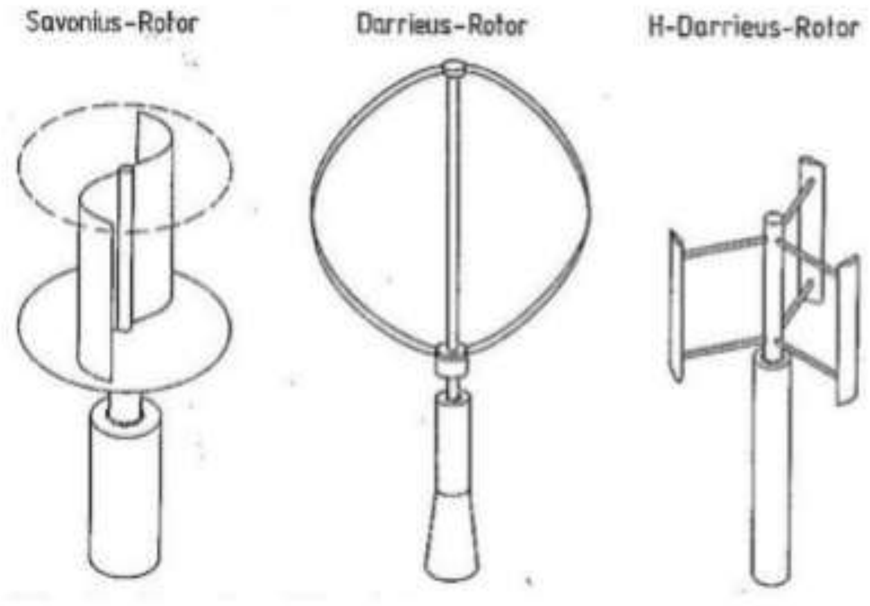

Fig.3 Types of VAWT

1.2.2 Darrieus Rotor

Vertical turbines with aerofoil blades that turn the rotor and generate electricity using lift force are known as Darrieus turbines. The first ones were designed and built in the 1920s by Georges Jean Marie Darrieus, a French aeronautical engineer. Despite the fact that they both rely on lift forces, their operation differs significantly from horizontal axis turbines. Once the turbine starts rotating, the motion of the blades through the air creates an apparent wind that is relative to the rotating blades. A force combination is created when this relative airflow is combined with the wind. This causes the rotor to rotate in the same direction due to a net positive torque. Because the motion is sustained by a combination of the airflow created by the blades' motion and the wind, rather than just the wind, if the Darrieus turbine is stationary, the wind will not usually cause it to move. The Darrieus rotor must be spun until the desired operating speed is reached, which is a significant disadvantage. The diagram depicts the operation's principle.

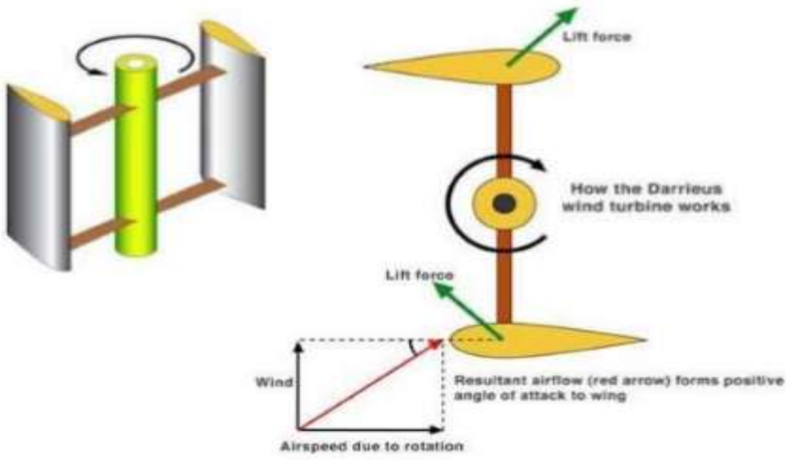

Fig.4 Working principle of a Darrieus rotor

Darrieus' rotor is shaped like an eggbeater. The bending moments caused by the centrifugal forces acting on the rotating blade are reduced by this curved shape. Figure depicts a Darrieus eggbeater turbine in action.

The blades in these designs are difficult and expensive to make because of their shape (aerofoil, curvature). As a result, a second type of Darrieus turbine was developed, which will be discussed in the next section.

Fig 5.Darrieus "eggbeater" turbin

1.2.3 H-Darrieus Rotor

The Giromill rotor, or H-Darrieus rotor, is a more efficient version of the Darrieus rotor. Its blades are easier to manufacture and more efficient, making it more appealing from both a technical and economic standpoint. Straight blades take the place of curved blades and operate on the same principle. The Giromill's two-blade version takes the shape of the letter H, hence the name. Depending on the needs, the blades can be fixed or variable pitch, with some variable pitch designs being able to self-start. Other experimental variations of the Darrieus rotor are less common, but the ones discussed are the most common.

Fig.6 H-Darrieus rotor

1.2.4 Savonius Vertical Axis Wind Turbines

Sigurd Savonius, a Finnish engineer, invented the Savonius wind turbine in 1922. The simplest design is an S-shaped blade with two blades. The curved blades of the Savonius turbine are pushed by drag to generate a torque that turns the rotor. It is the simplest wind turbine to design and build in terms of aerodynamics, which reduces its cost significantly when compared to other VAWTs and HAWTs that use aerofoil blade designs. It operates on a very basic principle. The difference in drag forces acting on the concave and convex parts of the turbine's blades causes it to rotate. This principle is illustrated in the following diagram:

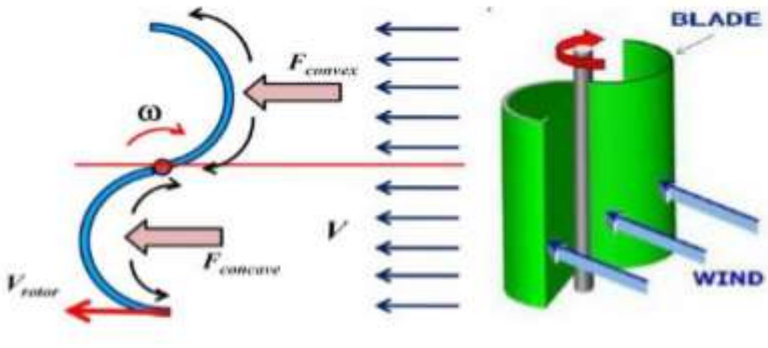

Fig.7 Working principle of a Savonius rotor

The air is trapped in the concave part of the turbine, which propels it forward. The drag created by the flow on the convex part is lower than the drag created by the flow on the concave part. The difference in drag force is what causes this turbine to spin. This reduces the turbine's efficiency because some of the wind's energy is used to push the convex part, and thus "wasted." More blades can be added to the S shape design, which spins using the same principle as shown in Figure :

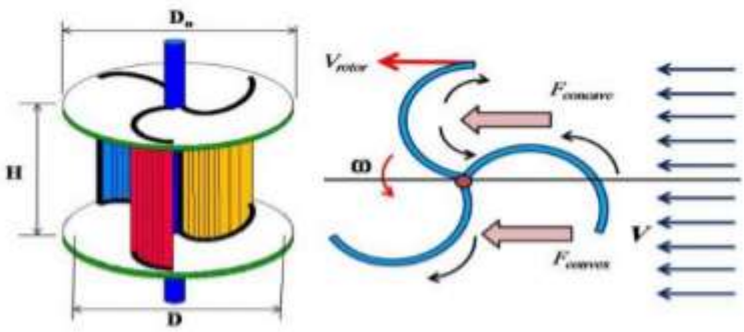

Fig.8 Three blades Savonius turbine

II. CREO

One of the most popular and powerful design tools on the market is CREO. The demand for CREO certification has risen in tandem with the popularity of CREO. CREO comes in a variety of forms. CREO 4.0 is the most recent version, and CREO certifications with this version are in high demand. Despite the increased demand, many design engineers still lack a thorough understanding of this tool. As a result, the focus of this blog will be on providing basic information about CREO. Pro-Esoftware has been updated to CREO.

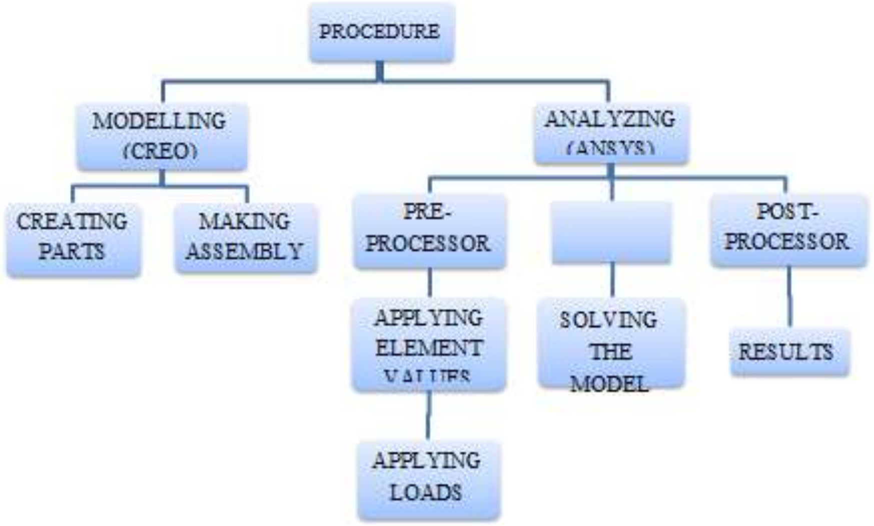

Fig. 9 Design flow of Vertical Axis Wind Turbine

2.1 Operating On Multi-CAD Data

CREO can work with any CAD data source with ease. As a result, designers can save a lot of time and effort when using CREO and working on different platforms. While redesigning the same design, it also eliminates the minor possibility of human error. As a result, it is beneficial to both designers and organizations.

CATIA, Siemens NX/Solidedge, and SolidWorks all compete directly with Creo Elements/Pro and Creo Parametric. The Creosuite of apps replaces and supersedes PTC's Pro/ENGINEER, CoCreate, and ProductView products. Creo offers a wide range of software package options and features.

2.2 Modeling Of Vertical Windmill Using CAD System:

There are some good reasons for using a CAD system to support the mechanical design function:

- To increase in the productivity.
- To get better the quality of the mechanical design.
- To uniform design standards. To create a manufacturing data base.
- To remove inaccuracies due to hand-copying of drawings and irregularity between Drawings.

It is a document that contains the production specifications for a part. Part drawings are typically drawn to get a clear idea of the model that will be produced. In CREO 4.0 PARAMETRIC, the entire frame's part drawing is drawn with all views. The components created in the part module are imported into the assembly module using the ‘insert components' command, and then mated together to form the required assembly. As shown below, the different views of the assembly and the drawing generated in CREO 4.0 PARAMETRICare.

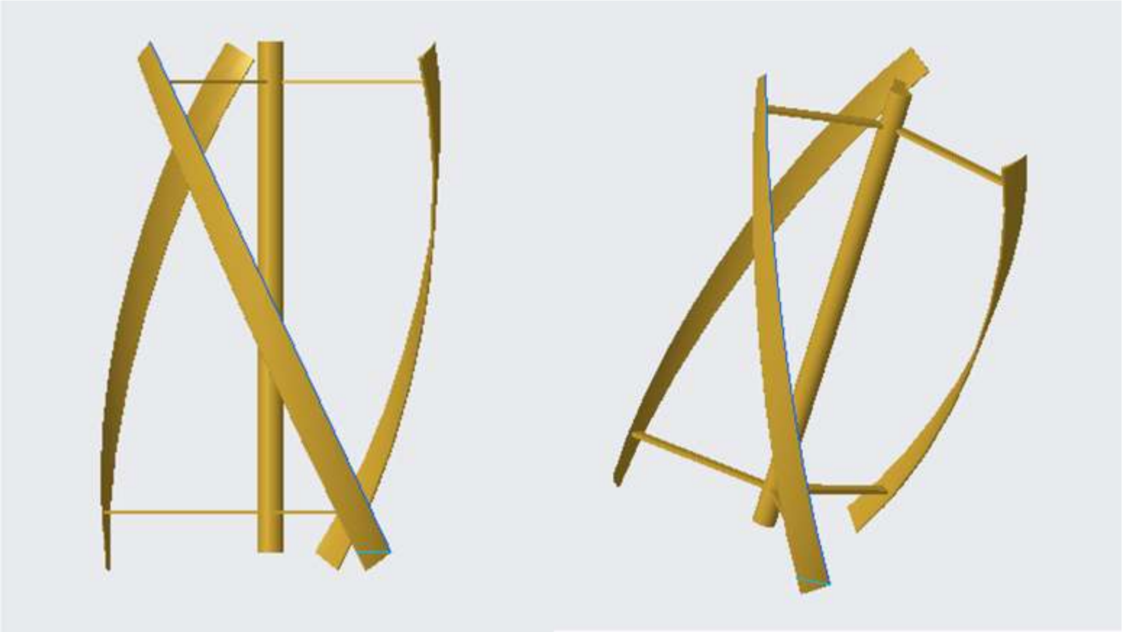

Fig.9 VERTICAL WINDMILL BLADE WITH 90 DEGREE ANGLE

III. RESULTS AND DISCUSSION

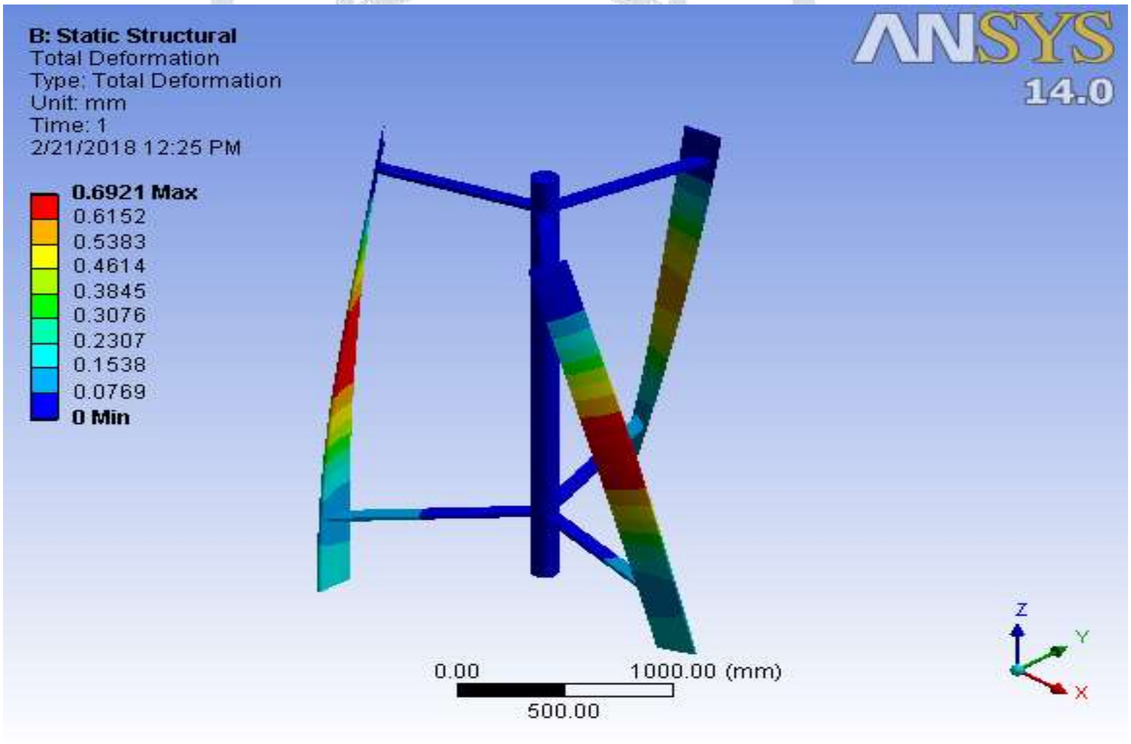

Fig. 10**Aluminium Alloy for 45 deg**

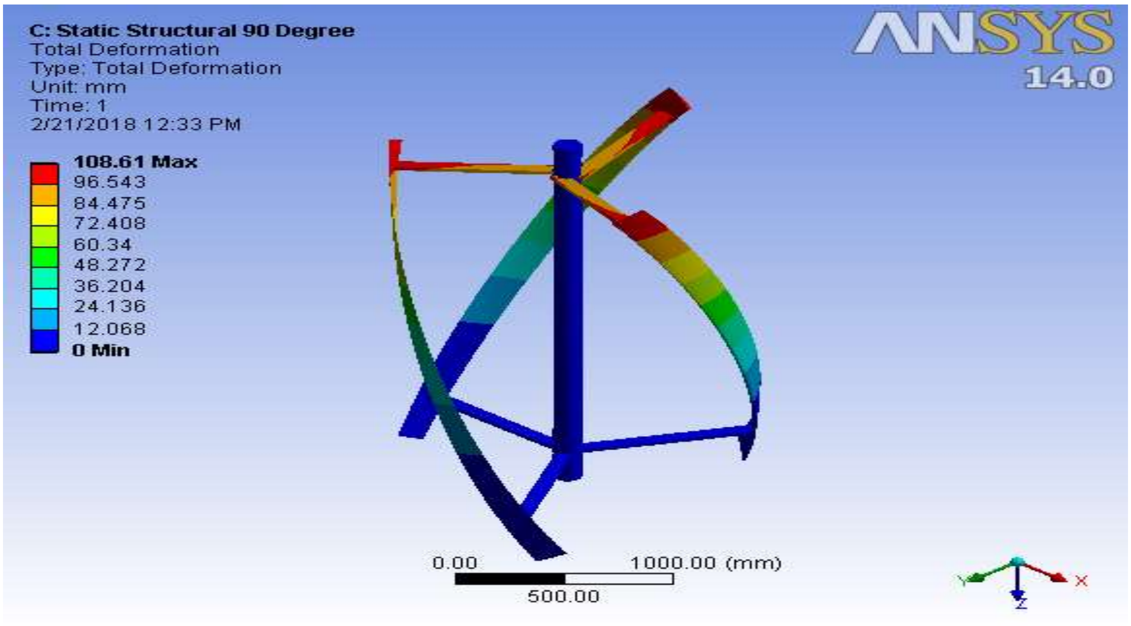

Fig.11 **Aluminium Alloy for 90 deg**

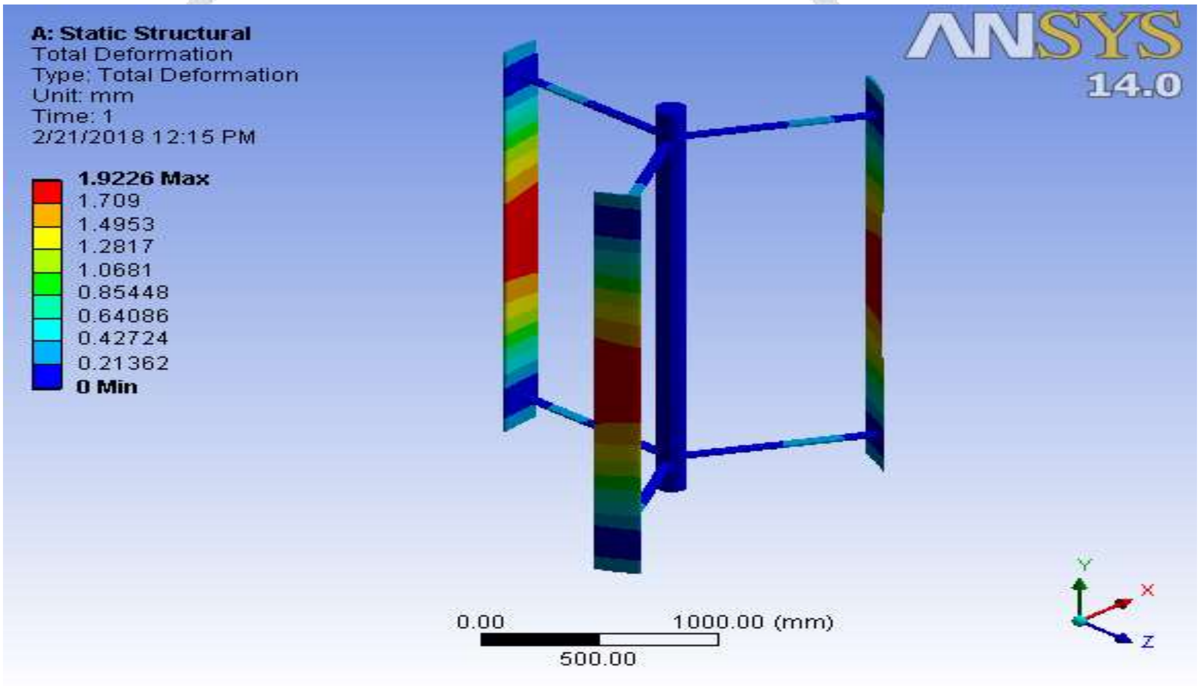

Fig. 12 **Aluminium Alloy for 0 deg**

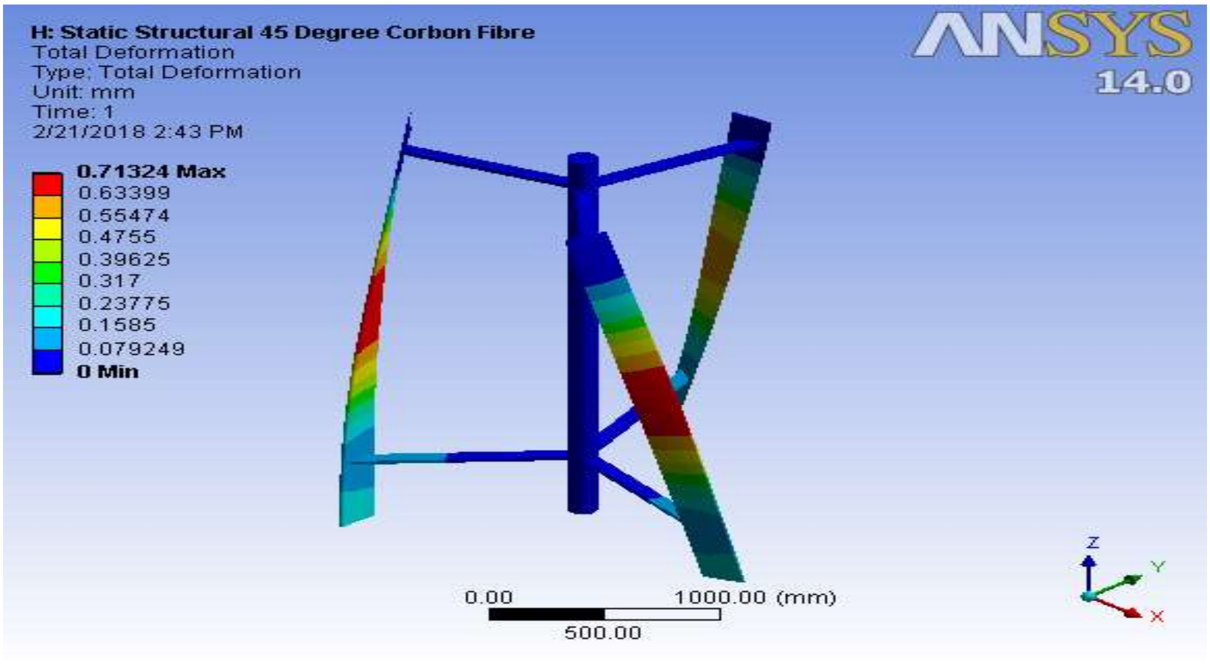

Fig. 13 **Carbon fibre for 45 deg :**

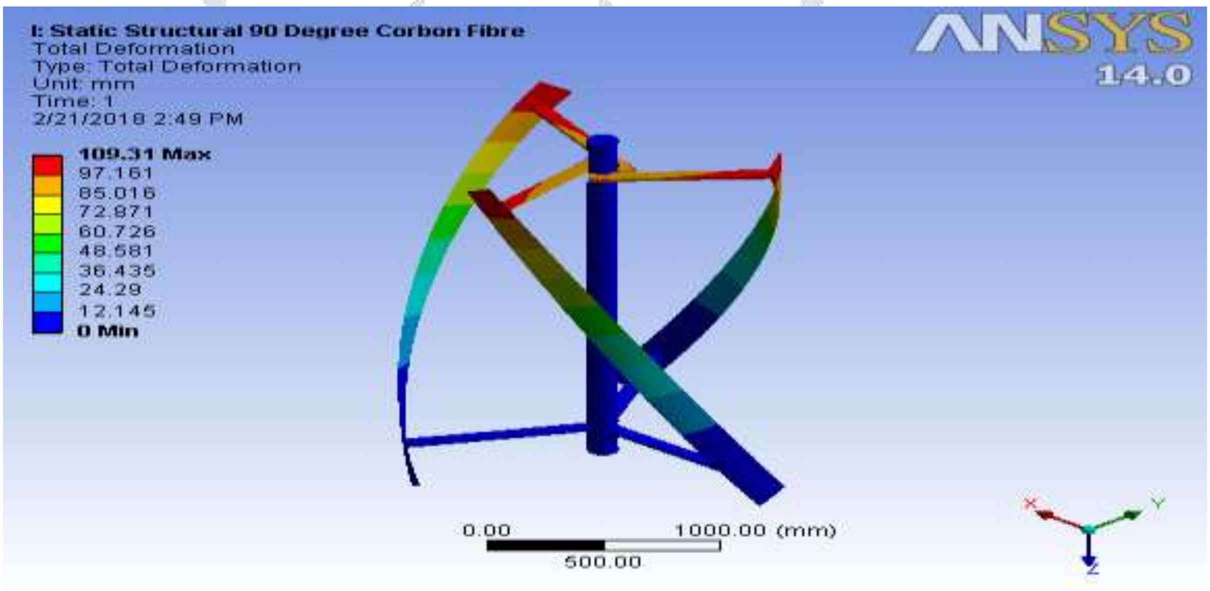

Fig. 14 **Carbon fibre for 90 deg**

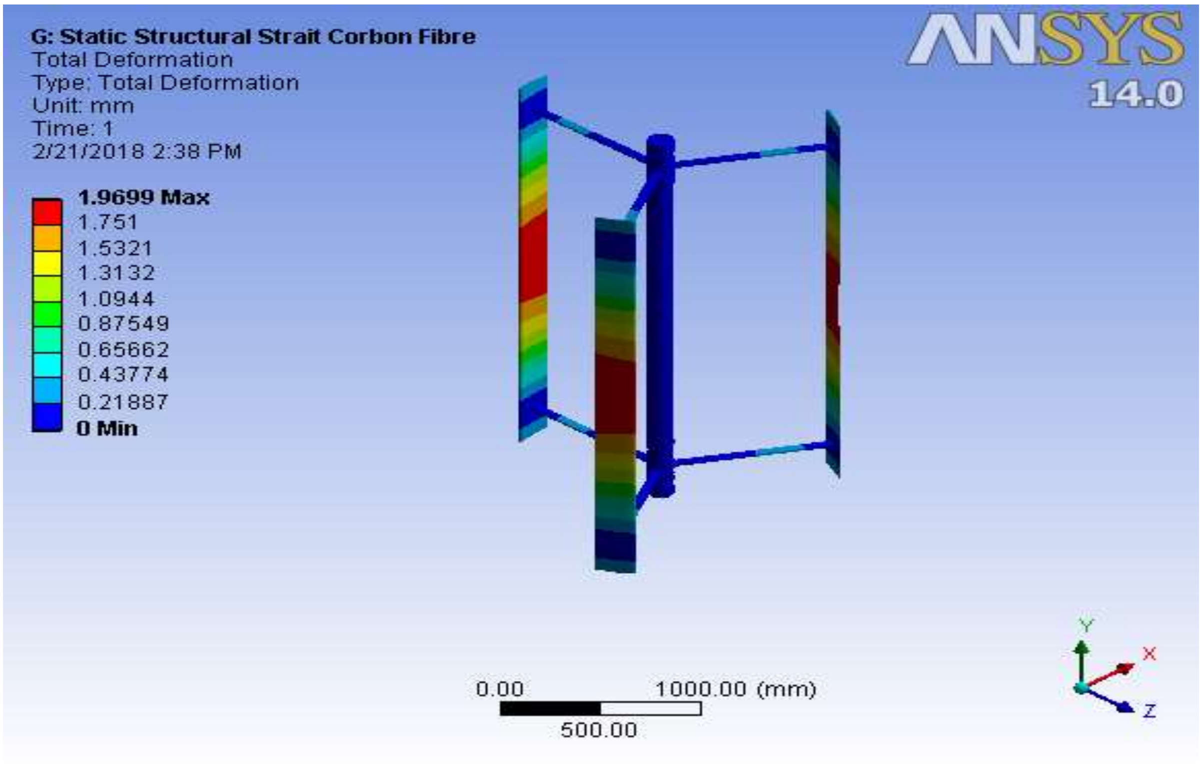

Fig. 15 **Carbon fibre for 0 deg**

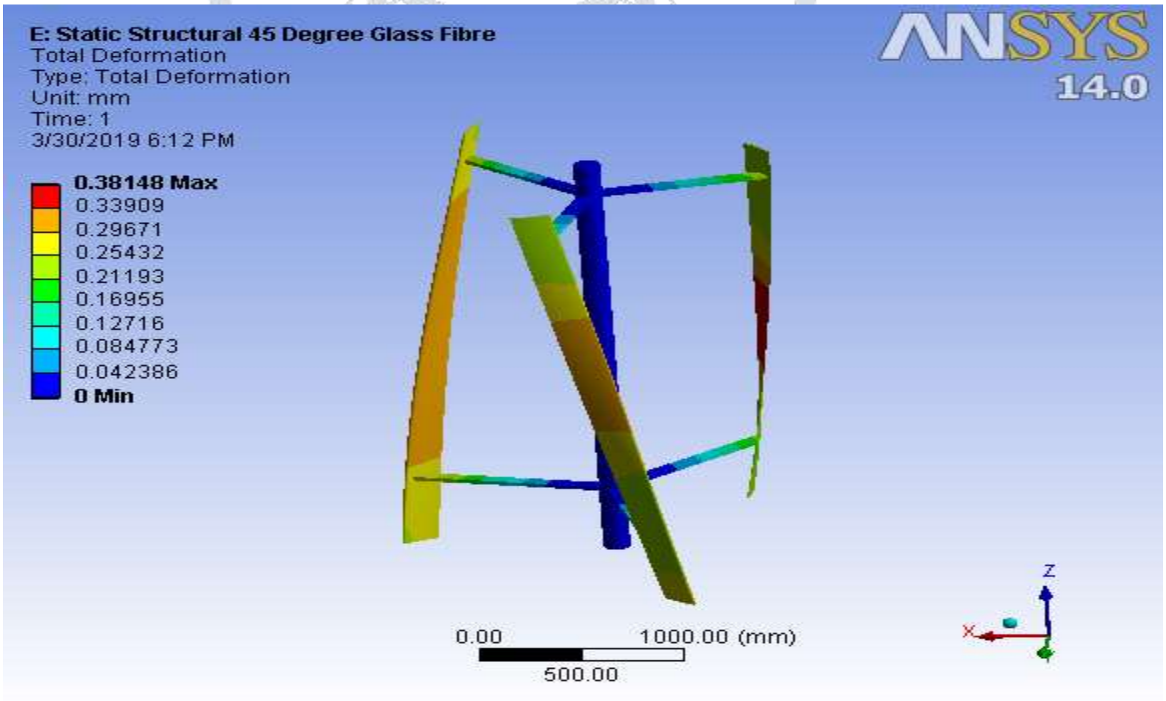

Fig.16 **Glass fibre for 45 deg**

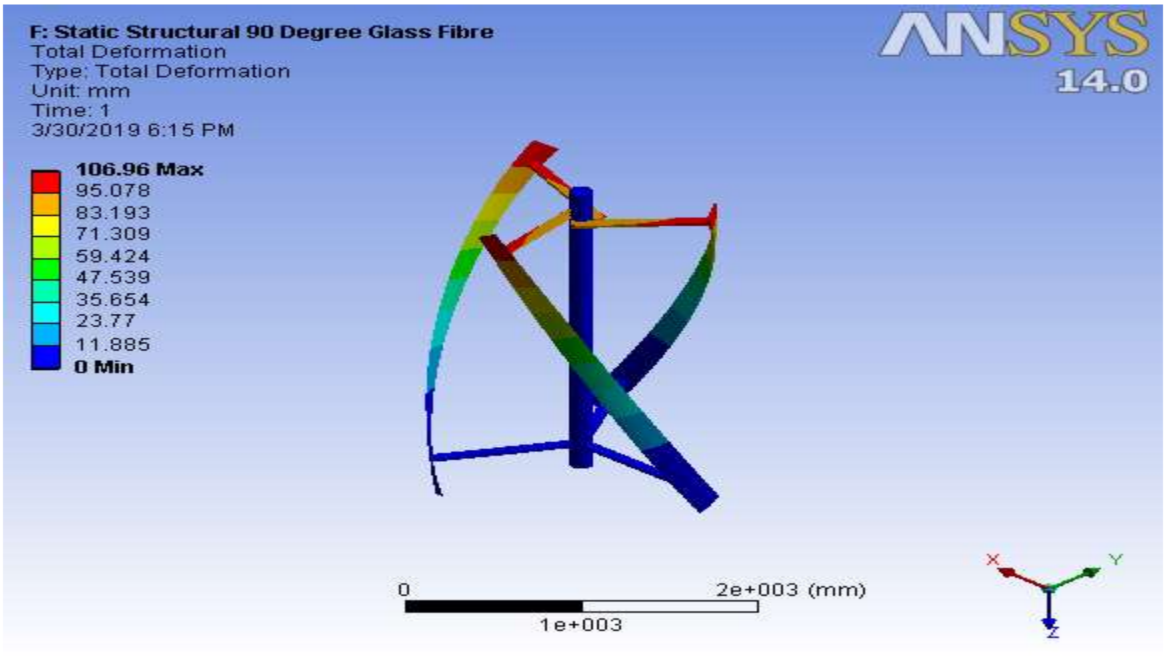

Fig. 17 Glass fibre for 90 deg

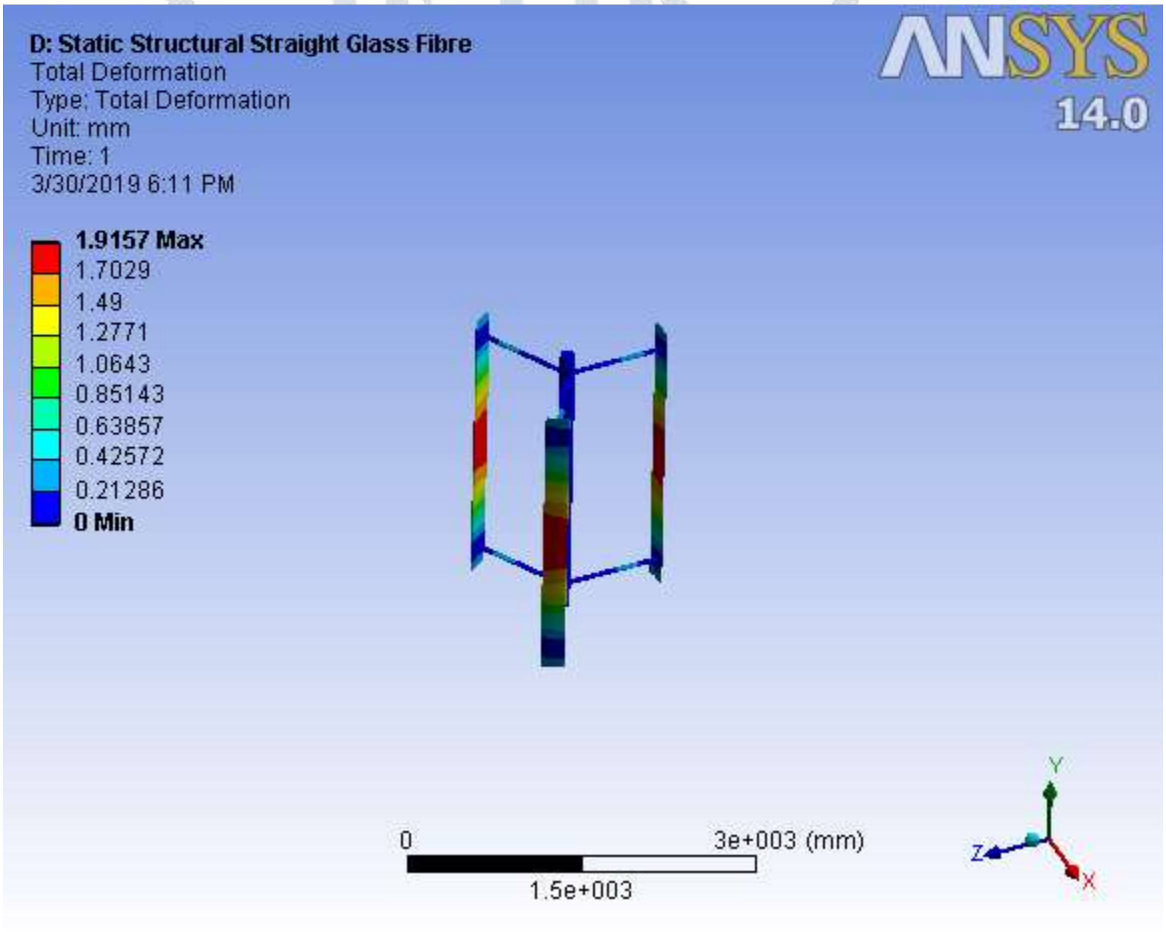

Fig.18 Glass fibre for 0 deg

IV. CONCLUSION

Based on this work, some iterations we have considered for aligning material properties for **VAWT (Density,Youngsmodulus,Tensile yield strength &Tensile ultimate strength)**

1.Aluminium: Total deformation value takes maximum of **1.927Mpa**

Maximum pressure ranges upto**0.1Mpa**

Tensile yield strength ranges for **280Mpa**

Compressive yield strength ranges for **530Mpa**

Density of Aluminium**2.7*10^3** kg/m3

Two basic composite materials which have been used in 0ur project followed by their constituents are displayed.

1.Glassfibre: Glass fibre is a material consists of numerous extremely fine fibre of glass. Density = **2.58*10^3** kg/m3

Youngs modulus **= 7.2*10^10** pascals

Poisson ratio = **0.21**

Total deformation = **0.3** Max

2.Carbonfibre: Carbon fibres are fibres about **5-10**micrometres in diameter and composed mostly of carbon atoms.

Density = **1.6*10^3** kg/m3

Youngs modulus = **7*10^10**pascals

poisson ratio = **0.1** & Total deformation = **0.713** Max.

By comparing above all materials based on the test results Carbon fibre is most suitable for our process due to its **atomic structure**, **low density**, **high strength&lightweight.**

REFERENCES

[1] Miracle, D.B., and Donaldson, S.L., “Introduction to composites” Journal of Composite Materials , Vol. 34, pp. 200-215, 1995.

[2] Farley, G.L., and Jones, R.M., “Crushing Characteristics of Continuous Fiber Reinforced Composite Tubes,” Journal of Composite Materials, Vol.26, No.1, pp. 37-50, 1992.

[3] Matzen miller, A., and Schweizerhof, K., “Crashworthiness Simulations of Composite Structures-A First Step with Explicit Time Integration,” Nonlinear Computational Mechanics- a State of the Art, Springer Verlag, New York, 1991.

[4] Han.J., and Yamazaki. K., “Crashworthiness Optimization of S-shape square tubes”. International Journal of Vehicle Design, Vol 31, No.1, pp 72-85, 2003.

[5] Reid, J.D., “Crashworthiness of Automotive Steel Mid rails: Thickness and Material Sensitivity”. Thin-Walled structures Vol. 26, No. 2, pp. 83-103, 1996.

[6] Philipps, M., Patberg, L., Dittmann, R., Henrik, A., “Structural analysis and testing of composites in automotive crashworthiness application”, SAE Special publications, Vol 1320, 981140, Safety and Material Test Methodologies, pp 97- 101, Feb, 1998.

[7] Jacob, C.G., Fellers, F.J, Simunovic, S., and Starbuck, J.M., "Energy Absorption in polymer composites for automotive crashworthiness", 1996.

[8] Fleming, D.C., “The Energy Absorption of Graphite/Epoxy Truncated Cones,” M.S. Thesis, Department of Aerospace Engineering, University of Maryland, College Park, 1991.

[9] "Federal Motor Vehicle Safety Standards And Related Regulations”, U.S department of Transportation. 1995.

[10] Farely, G.L., “Energy Absorption of Composite Materials”, Journal of composite Materials, Vol. 17, pp. 267-279, 1983.

[11] Mamalis, A.G., Robinson, M., Manolakos, D.E., Demosthenous, G.A., Ioannidis, M.B., and Carruthers, J.Crashworthy capability of composite material structures”. 1996.

[12] KumCheol Shin, Jung Ju Lee, Ku Hyun Kim, Min Cheol Song, JeungSoo Huh, "Axial crush and bending of an aluminum/GFRP hybrid square tube and its energy absorption capability", Vol 57, pp. 279-287, 2002

[13] B.Maheswaran, S. Senthil, R.Sathiyamoorthi ‘Comprehensive design and FEM analysis of Piston and Connecting rod using ANSYS for two wheeler engines’, Journal of Innovation in Mechanical Engineering, Vol. 2(1), pp. 10-16 (2019), Guru Nanak Publications.

[14] M.D. Mohan Gift, C. Karthikeyan, M. Dinesh Babu, R. Sathiyamoorthi, 2020 “Analysis and Optimization of Vehicle Rim Cooling Criteria with Air Knife”, International Journal of Research and Analytical Reviews (IJRAR), Vol. 7 (2), pp. 31-35.