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Manufacturing and Thermal Analysis of Wind Turbine Blade

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Abstract

The project is about behavior of a domestic wind charger blade made from carbon composites at various temperatures. For a complete understanding the blade is tested against a metal plate. The composite blade is manufactured using carbon fiber prepegs. The blade is manufactured in two sections. Later the sections are joined together using adhesives. The blade is then tested for its behavior at various temperatures by placing the blade in an oven and a freezer at different temperatures. The Strain values at the respective temperatures are calculated and tabulated. These readings are compared against the metal plate which has undergone the same procedure to obtain its strain values. From the results, it is clear due to the high thermal expansion coefficient of the metal plate, the expansion is very high at higher temperatures and contraction at lower temperatures. On the contrary due to the negative thermal expansion coefficient of the carbon composite fibers, the composite blade contracts when heat is applied and expands when cooled to negative temperatures. This is mainly due to the negative thermal expansion coefficient. Since the value of the coefficient is also low, there is not a significant expansion or contraction at different temperatures for the carbon composite blade. As a result the use of carbon fibers in wind chargers which experience various temperatures will be an efficient way for increasing the life of the blades.

Keywords: Composite, Wind Turbine, Thermal coefficient, Temperature.

1. Introduction

Composite materials are made from two or more materials to form a different material which has a significant difference in its physical and chemical properties compared to its constituent materials. Carbon fibers contain a blend of amorphous carbon and graphite carbon. The structure and properties of carbon fibers are dependent on the raw materials used and the processing conditions of manufacture. Carbon fibers are commercially available in three basic forms namely, long, continuous tow, chopped and milled. Composites are manufactured using various techniques. The process we used is vacuum bag moulding.

2. Manufacture of the Blade

2.1 Preparation of the Mould

The mould for the manufacture of a composite blade is made by imprinting the RUTLAND 910-3 FM wind charger Blade made from polypropylene on a slightly heated wax. This is then allowed to settle for a prolonged period. The mould is filled of any gaps. It is then filed and polished to make the mould required for the manufacture of composite blade. The manufacture of the blade involves making two sides of the blade. This means that another mould for the other side of the blade is also made using the above said process.

The mould is coated with a mould sealant which fills any micro holes which was not filled before. The sealant used is CHEMLEASE 1366. The coating is allowed to dry for 15 minutes approximately and then coated again. After this process, another agent is coated called the mold release. This agent is coated for the easy removal of the carbon composite layers which are to be laid on the mould. The release agent is used is CHEMLEASE 1363. This is also coated twice to ensure a good release.

2.2 Vacuum Bag Molding

As stated before for this manufacture Vacuum bag molding process is used. Since this method is easier and efficient in this kind of manufacturing it is preferred when compared with other methods. The process is described as follows,

The mould which is completely covered is put inside a vacuum bag and the bag is sealed completely on all sides leaving no gaps. Two holes are made on either side of the vacuum bag. On one of the holes a vacuum pump is connected. On other side a pressure gauge is attached for measuring the vacuum in the bag.

The pump is switched on and the air inside the bag is sucked. This way vacuum is created inside the mould causing it to press down the layers of carbon composite prepegs. The pressure is maintained at -25bar for a short period of time. The pump is switched off after some time. The pressure gauge is checked for the pressure. The vacuum is maintained in the same way for about 24 hours. This allows the prepeg layers to squeeze tightly against one another resulting in thinner sections of the blade.

3. Joining the Two Sides of the Blade

In the same way as followed above the other side of the blade is manufactured. Now the sections are filed to ensure a good contact between them. The edges of the blades are freed of burrs. The adhesive used in the process is epoxy resin and hardener. The exact chemical used is "6004 Methacrylate". The working time of this is 10 to 12 minutes. Fixture time is 18-20 minutes. The mix ratio of this chemical is 1:1. The methacrylate is placed in two separate containers one has the resin and the other hardener. The resin and the hardener is mixed in the ratio of 2:1, this way the mixture is suitable for a quicker bonding process. This set up is allowed to settle for a period of 18-20 hours for a perfect bonding between the two sides of the blades. The blade is then filed using a high speed steel slitting saw for get a smooth finish. For the thermal analysis of the blade strain gauges are used to measure the thermal strains at different temperatures. The strain gauges used in the process are of rosette type. The strain gauge used is a 510-23 R.

4. Theoretical Analysis

The formula used for the calculation of the thermal strain is

$$\varepsilon = \alpha * \Delta T$$

Where

ε = thermal strain

α = linear coefficient of thermal expansion in K^{-1}

ΔT = Difference in temperatures in K

5. FEA Modeling Using ANSYS

The FEA model of the composite blade is done using a SHELL element type. The advantages of using this SHELL element are that it allows inputting the number of layers of fibers and specifying their thickness and other properties in an effective manner.

6. Result of Metal Plate

TEMPERATURE	STARIN (*10-6)		
	EXPERIMENTAL	ANSYS	THEORY
303 K	21.5	231.01	231.01
313 K	37.1	462	462
323 K	58.6	693	693
258.76 K	-138.8	-791	-790.9
256.58 K	-175.8	-840.1	-841
254.89 K	-212.66	-880	-880.3

7. Result of Composites

TEMPERATURE	STRAIN (* 10-6)		
	EXPERIMENTAL	ANSYS	THEORY
303 K	-18.5	-17.1	-17.1
313 K	-46.3	-34.2	-34.2
323 K	-92.5	-51.3	-51.3
258.76 K	37	58.6	58.5
256.58 K	64.8	45.81	45.78
254.89 K	148.1	65.23	65.168

8. Conclusion

Thus a domestic wind charger blade is manufactured using carbon fiber composite prepegs. The thermal analysis of the composite blade is performed under laboratory conditions. The analysis is also done using ANSYS ensuring the blade performance on a numerical basis. The blade is also analyzed theoretically. The carbon fiber performed well under all three analyses when compared to the metal plate. This analysis showed a property of the carbon fiber which is vital for temperature related applications .Owing to its negative thermal expansion coefficient, the carbon fiber gains a distinct ability to survive in various temperature conditions with less fatigue and strain.

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