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Simulation by the finite element method of the wind turbine blade material under the influence of the variable wind force

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Abstract

Wind turbines are an essential source of renewable energy so we did this study to determine the appropriate material for blade where we worked on two materials CFRP and GFRP as one of the materials used where, we simulated by the program ansys as a professional program in the simulation process and choose the finite elements method FEM As a means of reaching the stress and strain and the deformation, This simulation was performed under the influence of variable winds according to weather, starting from 1500 to 4000 N as the maximum value of these materials. Through this process, any materials that were more resistant were extracted to give us a greater lifespan and more return to the wind turbine.

Keywords: wind turbine, CFRP, GFRP, FEM, blade, material.

1. Introduction

The rapid expansion of wind power is partly the result of increased turbine size and the addition of new wind farms[1]. For That all the research in wind energy seeks to develop as much as possible in the exploitation of this energy, through the development of the engineering structure of the shape, as well as the pursuit of developing the materials that make these turbines, and this is due to the large lengths used today where the size of wind turbine rotors increased in the decade The past from 40 m to more than 120[2].

In this study, we seek to compare between CFRP (Carbon Fiber Reinforced Plastics) and GFRP (glass-fiber reinforced plastic), for to compare these two materials we have to study the extent of their resistance to different forces that lead to distortions in the external form as well as we have to take into account the duration of operation of each material by studying fatigue For each of them, through which we get the coefficient of safety and the potential life that you will live, and all this after studying the vibrations of the wind turbine from the various conditions caused by the external pressures or forces caused by the change in the wind as well as the force of gravity.

2. Introduction to Fatigue

In Wind turbines, with their blades of several meters are elastic structures; in addition, they operate in transient and unstable environments at the top of a tower.

The wind is never really constant but rather pulsating and turbulent. For these reasons, wind turbines and their towers tend to be subject to vibration.

The vibrations generate a cyclic loading. That is to say that the applied forces increase and then decrease over time and this, repeatedly.

This type of load creates breakage by "fatigue" of the materials. In certain extreme cases, the vibrating system can enter into resonance that is to say that the imposed excitation frequency, leads to an increase in the range of motion which can contribute to the destruction of the system[3].

3. Finite element analysis and modeling

3.1 Mesh of the blade

The finite element method allows a mesh adapted to the problem dealt with. For explicit codes it is the same, and some additional stresses are added because of the wave paths in the structure. This paragraph presents the mesh used for the blade. During assembly, the connection is considered perfect and without friction between the different materials, so the contact is without interface[4].in this study we used 13520 nodes and 2790 element.

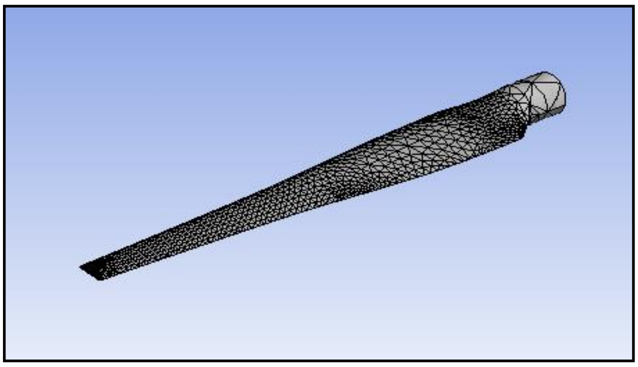

Fig.1. mesh of the blade

3.2 Materials for manufacturing a wind turbine blade:

3.2.1 Problem of how to choose the material

The choice of materials for the manufacture of a blade is a critical task as it directly affects the design and fabrication methods used. Again, for materials with good structural properties, the two main qualities of the ideal material are their ratios of high strength / density (S/ρ) and stiffness / density (E/ρ)[6]. In this study we will work on glass fiber reinforced plastic (GFRP) and Carbon Fiber Reinforced Plastics (CFRP).

Table 1. Properties of the materials[5]

Reinforcing Material	Yield Strength (MPa)	Tensile Strength (MPa)	Elastic Modulus (GPa)	Strain at Break percent
GFRP	N/A	480-1,600	35-51	1.2-3.1
CFRP	N/A	1,720-3,690	120-580	0.5-1.9

4. Modal analysis and identification of stresses and deformations

4.1 Modal deformities

Modal analysis is established. Some modes of vibration of the blade are presented in the table following:

Table 2. MODES IN terms of frequency of CFRP

Frequency [Hz]	Mode
12,425	1
36,802	2
67,711	3
83,566	4
138,84	5
174,69	6

Table 3. Modes according to deformation of CFRP

Deformation [mm]	mode
20,7599	1
18,1371	2
19,249	3
19,519	4
29,077	5
23,4938	6

TABLE 4. MODES IN terms of frequency of GFRP

Frequency [Hz]	Mode
11,659	1
34,082	2
59,968	3
75,893	4
105,49	5
126,28	6

Table 5. Modes according to deformation of GFRP

Deformation [mm]	mode
19,343	1
17,975	2
18,023	3
18,76	4
27,8	5
21,478	6

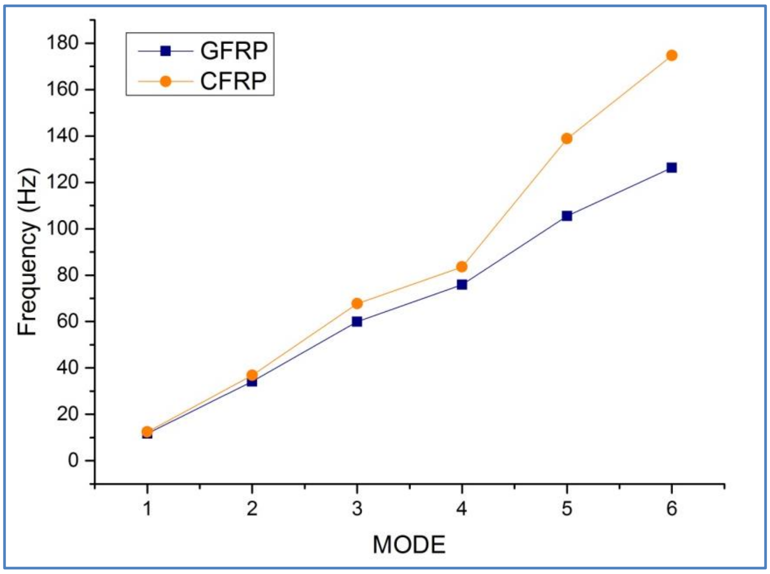

Fig.2. modes in terms the frequency for the GFRP and CFRP

Through the previous tables, which study both vibration as well as deformation in terms of modes, we noticed that GFRP is more resistant than CFRP, as it achieved a lower percentage in terms of vibration as well as in terms of deformation..

4.2 Analysis of stresses and deformations on the blade

To better understand the phenomena related to the analysis of structures[7], the relations between the stresses is the deformations are given by:

$$\{\sigma\} = [D]\{\varepsilon^{el}\} \tag{1}$$

Where

$\{\sigma\} = [\sigma_x\ \sigma_y\ \sigma_z\ \sigma_{xy}\ \sigma_{yz}\ \sigma_{xz}]^T$: Stress vector; $[D]$ Elasticity matrix; $\{\varepsilon\} = [\varepsilon_x\ \varepsilon_y\ \varepsilon_z\ \varepsilon_{xy}\ \varepsilon_{yz}\ \varepsilon_{xz}]^T$: Total deformation vector

$\{\varepsilon^{el}\} = \{\varepsilon\} - \{\varepsilon^{th}\}$ Elastic deformation vector.

From Equation (1) we can write:

$$\varepsilon_x = \frac{\sigma_x}{E_x} - \frac{\upsilon_{xy}\sigma_y}{E_y} - \frac{\upsilon_{xz}\sigma_z}{E_z}, \qquad \varepsilon_{xy} = \frac{\sigma_{xy}}{G_{xy}}$$

$$\varepsilon_y = -\frac{\upsilon_{xy}\sigma_x}{E_x} + \frac{\sigma_y}{E_y} - \frac{\upsilon_{yz}\sigma_z}{E_z}, \qquad \varepsilon_{yz} = \frac{\sigma_{yz}}{G_{yz}}$$

$$\varepsilon_z = -\frac{\upsilon_{xy}\sigma_x}{E_x} - \frac{\upsilon_{yz}\sigma_y}{E_y} + \frac{\sigma_z}{E_z}, \qquad \varepsilon_{xz} = \frac{\sigma_{xz}}{G_{xz}}$$

The three main stresses are denoted by σ_1, σ_2 andσ_3, and the three deformations byε_1, $\varepsilon_2$and ε_3 Maximum deformation ε_I is the maximum value of the absolute values of the differences,

$$\sigma_1 - \sigma_2, \sigma_2 - \sigma_3, \text{et } \sigma_3 - \sigma_1$$

$$\sigma_I = MAX(|\sigma_1 - \sigma_2|, |\sigma_2 - \sigma_3|, |\sigma_3 - \sigma_1|)$$

According to the Von Misses criterion, the equivalent deformation is given by:

$$\sigma_e = \frac{1}{1+\nu'}\left(\frac{1}{2}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]\right)^{\frac{1}{2}} \tag{2}$$

In the following table, we represent the Distributions of The equivalent stresses (Von Misses), and the equivalent strain on the blade and the displacement.

Table 6. LODE according to stress and strain and displacement of GFRP

lode	stress		displacement
1500	8,150E+06	4,075E-05	3,349E-03
2000	1,087E+07	5,433E-05	4,465E-03
2500	1,358E+07	6,792E-05	5,581E-03
3000	1,630E+07	8,150E-05	6,697E-03
3500	1,901E+07	9,508E-05	7,813E-03
4000	2,173E+07	1,087E-04	8,930E-03

Table 7. LODE according to stress and strain and displacement of CFRP

lode	stress	strain	displacement
1500	8,117E+06	2,585E-04	1,513E-02
2000	1,082E+07	3,446E-04	2,017E-02
2500	1,352E+07	4,300E-04	2,521E-02
3000	1,623E+07	5,100E-04	3,020E-02
3500	1,894E+07	6,030E-04	3,530E-02
4000	2,165E+07	6,892E-04	4,034E-01

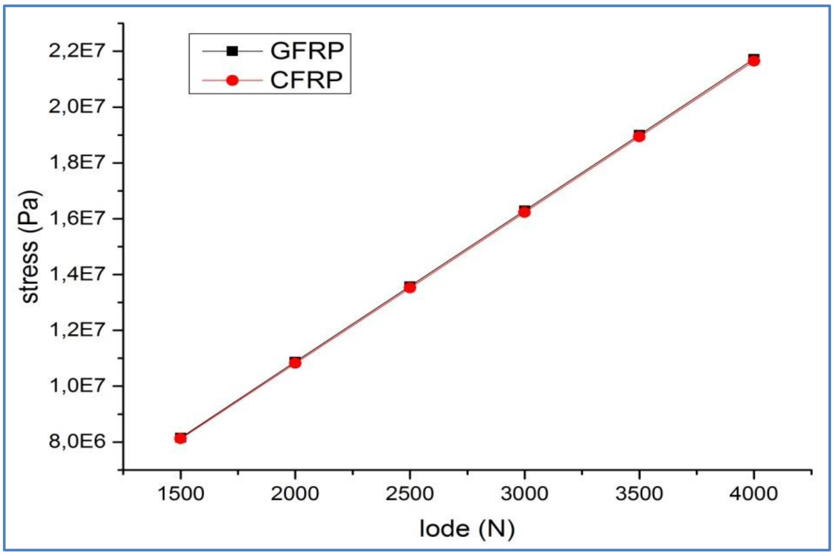

Fig.3. displacement in terms the lode for the CFRP and GFRP

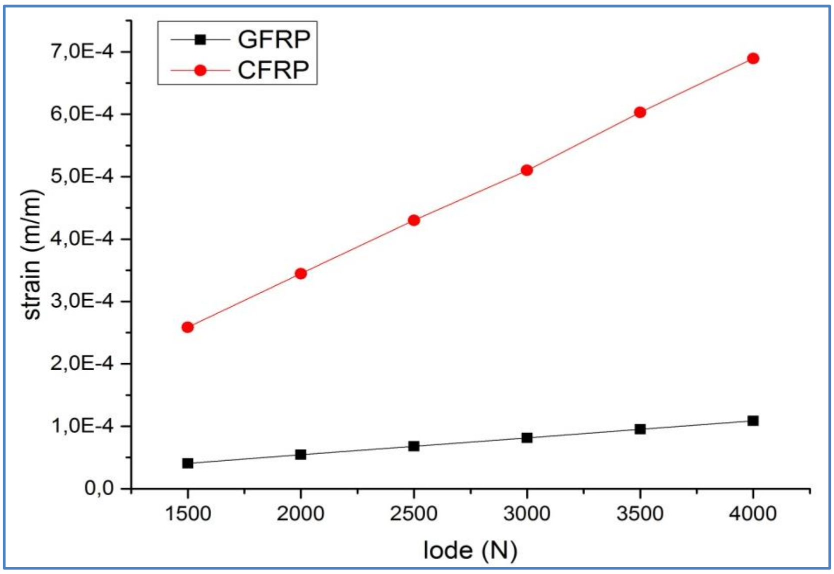

Fig.4. strain in terms the lode the CFRP and GFRP

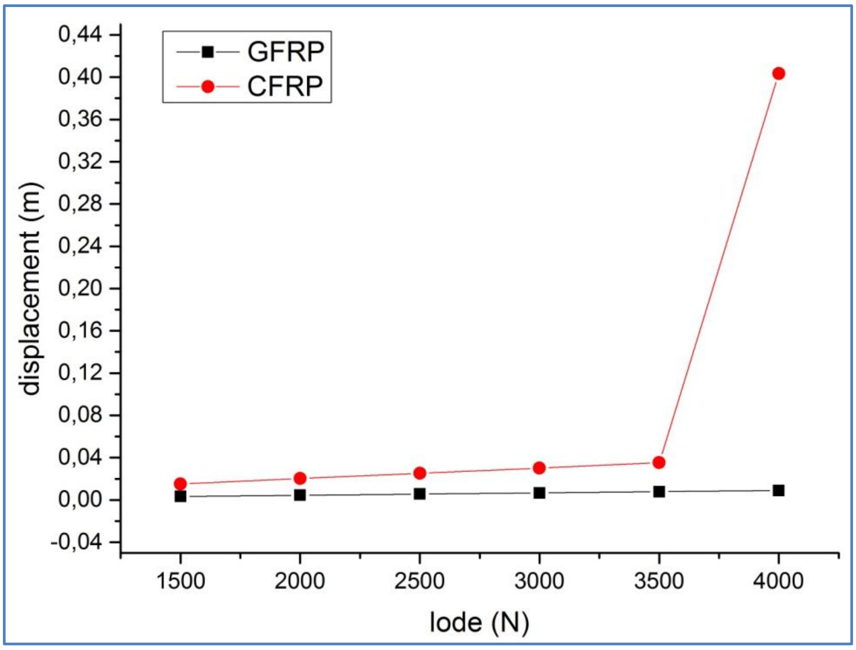

Fig.5. displacement in terms the lode the CFRP and GFRP

As is evident in each column of the table, which is the change in lode in terms of stresses and strain, as well as the displacement to Glass fiber reinforced plastic and Carbon fiber reinforced plastic as we note that the value of stresses is approximately equal in the first and second material while it was greater in CFRP and this makes the GFRP better than the first.

5. Conclusions

In this work we conducted a study on the material of making wind turbine and was the choice two materials for study the GFRP and the CFRP, where the results were as shown in the table. we get all the results using the method finite elements FEM and We applied a variable wind force, simulating what happens every day to blade by changing the wind force., where we observed that The maximum stress value was 2.1173E7 MPa, and the strain was the highest value 1,087E-4, the maximum vibration value in the mode 6 was 126.28 Hz and the deformation in the mode 5 was 27.8 mm for the GFRP and The maximum stress value was 2.165E7 MPa, and the strain was the highest value 6,892E-4, the maximum vibration value in the mode 6 was 174,69Hz and the deformation in the mode 5 was 29.077 mm for the CFRP. Where all previous results are at maximum wind strength or lode 4000N.

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