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INVESTIGATION OF DYNAMIC CHARACTERISTICS ON GFRP COMPOSITES WITH EGG SHELL PARTICLES

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ABSTRACT

New engineering functional materials are required to the designers for many valid reasons which are stronger, lighter or less expensive compared with traditional materials. Polymer composite is the essential engineering material in the field aerospace, automobile and defense applications. In this research work, Glass fiber reinforced polymer composites with egg shell particles modified epoxy laminates were fabricated and dynamic mechanical characteristics were analyzed. Egg shell particles are dispersed with different volume fractions (0%, 5%, 7%, 9%) by mechanical stirring and ultra-sonication method. Laminates were prepared with hand layup method. Dynamic mechanical characteristics were examined by impulse excitation technique under fixed- free boundary conditions. In addition, mechanical properties such as impact strength and hardness of the composites were also determined.

Keywords: Functional materials, Egg-shell particles, GFRP laminates, Dynamic characteristics.

1. INTRODUCTION

The growth of composite materials began with glass fibers with tough epoxy resins. Recently developed composite materials are motivated by potential advantages of weight saving, organic raw materials, and ecological advantages. GFRP laminates are widely used as a light weight composite structure because of its high strength to weight ratio and better corrosion resistance. In common, unidirectional glass fiber reinforced composites are good in structural integrity and vibration damping characteristics. For using polymer composites as secondary structural components it is very much essential to predict the dynamic characteristics. It is difficult to assess the damping properties of laminates in the design and analysis stage.

Dispersion of inorganic fillers with organic epoxy resin has been identified as a new method to improve the electrical, mechanical and thermal properties of polymer composites[1-4]. The strength of polymer composites depends on type of fiber reinforced, type of filler materials incorporated, length of fiber and its orientation with respect to the stress direction [5-6]. In addition, response of the Nano composites could be further enhanced with increased nanoparticles volume / weight fraction, aspect ratio, arrangement of nanoparticles (orderly, randomly), uniform dispersion of nanoparticles [7-10], and size of interface zone where the discontinuity occurs [11]. Mechanical characterization of the fiber reinforced polymer matrix composites greatly affected by length to diameter ratio of the fiber, strength of the bond between fiber and matrix material and the amount of fiber. A particle may have any shape or size, but are generally spherical, ellipsoidal and polyhedral or irregular in shape and it has no long dimension. According to a study, eggshell waste generation in India is 190000 tonnes per annum. With this is mind, to utilize this waste material, in this work the egg shell powder is prepared and these particles are dispersed in epoxy and used to fabricate a glass fiber reinforced polymer laminates. Additions of egg shell particles in epoxy are mostly used to increase the strength and dynamic characteristics of the materials. However, the damping of composite materials can be several orders of magnitude higher than that of traditional engineering materials, making the mappealing also for components undergoing dynamic loading. Actually, the weight of the structures is reduced such that adding egg shell particles to a laminate has a significant effect on the natural frequencies and other characteristics of the structure without compromising the strength of the component.

2. FREQUENCY RESPONSE ANALYSIS

Fiber-reinforced laminates can be used similar to other structural components. In common, all the structural components subjected to vibrations. It is very much essential to reduce the vibration of such structures. Most common method to reduce the vibration of a structure is to move its natural frequencies away from frequency of excitation force[12]. There are different methods to modify the natural frequencies of beam structures. If a structure having natural frequency, the vibration amplitude grows rapidly with time, requiring a very low input energy results the structure fails by overstressing. For all the engineering components, to avoid resonances its natural frequencies must be determined in order to ensure that the loading frequencies imposed and the natural frequencies differ considerably. Crack like defects in a structural component also influence its dynamical behavior and change its stiffness and damping properties. Changes in the physical properties of the structures due to damage will alter the dynamic responses such as natural frequencies and damping characteristics.

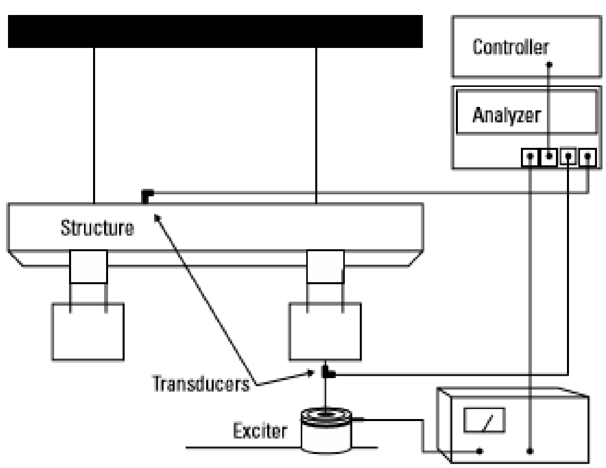


Figure 1: Vibration Exciter

In vibration excitation test (Figure.1), the excitation and response are measured and recorded in the form of time history. In this setup the time domain data is transformed into the frequency domain, and then the modal domain data can be further extracted from the frequency domain data. Main objective of this work is to determine the dynamic behavior of glass fiber reinforced laminates with egg shell modified epoxy resin.

3. Materials and Specimen Preparation

3.1 Glass / Epoxy Resin

Unidirectional glass fibers are as strong as any of the newer inorganic fibers but they lack rigidity on account of their molecular structure. The properties of glasses can be modified to a limited extent by changing the chemical composition of the glass, but the only glass used to any great extent in composite materials is ordinary borosilicate glass, known as E-glass. The largest volume usage of composite materials involves E-glass as the reinforcement. S-glass (called R-glass in France) has somewhat better properties than E-glass, including higher thermal stability, but its higher cost has limited the extent of its use. Thermo set epoxy resin DGEBA used as matrix material with Tri Ethylene Tetramine curing agent with specific gravity of 1.04 g / cm^3 is used as hardener. (Figure.2)

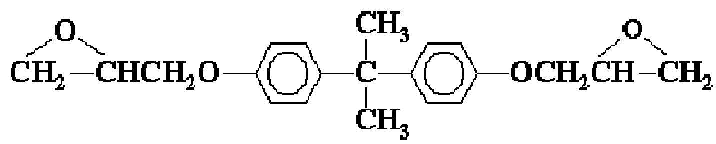
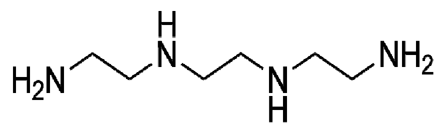
Name	Chemical structure
DGEBA	
Triethylenetetramine (TETA)	

Figure 2: Chemical structure of epoxy and hardener

3.2 Egg Shell Particles.

An eggshell is the outer covering of a hard-shelled egg it contains calcium carbonates. In this work, egg shell rinsed well in water and dried at a temperature of 60°C (Fig.3a) for 10 minutes. Then the shells are pulverized into a granular form (Fig. 3b) and the properties are summarised. Egg shell particles are generally in solid spherical shape.

Figure 3a: Dried Egg Shell

Figure 3b: Egg Shell powder

Egg shell powder contains:

- Water = 0.5g
- Protein = 2.1g
- Ashes = 96.9g
- Calcium = 38 mg
- Potassium = 41.6mg
- Sodium = 87mg
- Phosphorus = 99.3 mg
- Iron = 0.5 mg
- Magnesium = 375mg

4. FABRICATION OF GFRP LAMINATES

Composite laminates were prepared using hand layup technique in accordance with ASTM D5687 standard. Initially, a releasing agent is applied over a flat mould, then a thin layer of modified epoxy resin is applied and glass fibers are reinforced with the symmetric sequence of $(40/95/40)_{2S}$ as shown in Figure.4. This laminates consists of 6 layers and thickness of4 mm. four set of laminates are fabricated by different volume percentage (5%, 7%, and 9% & pristine epoxy) inclusion of egg shell particles. Test coupons are cut out using water-jet cutting process.

Fig. 4a: Specimen-1

Fig. 4b: Specimen-2

Fig.4c: Specimen-3

Fig 4d: specimen-4

Figure 4a-d: GFRP laminates specimens

5. EXPERIMENTAL RESULTS

5.1 Hardness Test

In this work, Brinell hardness number of the composite laminate is determined. Hardness values of the laminates are tabulated in Table.1. From the results, hardness values are increasing considerably with increasing percentage addition of egg shell particles. In this test of the specimen of 0%, 5%, 7% are the less hardness when comparing to the 9% of GFRP composites materials. In 9% GFRP composite has high hardness value is 85.489 BHN. The other percentage composites are low hardness values to comparing 9% GFRP. Maximum hardness values obtained for 9% egg shell particles added GFRP composites shown in Figure.5.

Table 1: Brinell Hardness Values of Laminates

Specimen	% of Egg shell in GFRP	BHN			
		1500 In Kg	2000 In Kg	2500 In Kg	3000 In Kg
Specimen-1	0	42.746	53.037	61.774	69.150
Specimen-2	5	44.333	54.969	63.985	71.587
Specimen-3	7	49.581	61.332	71.241	82.455
specimen-4	9	51.746	62.532	73.889	85.489

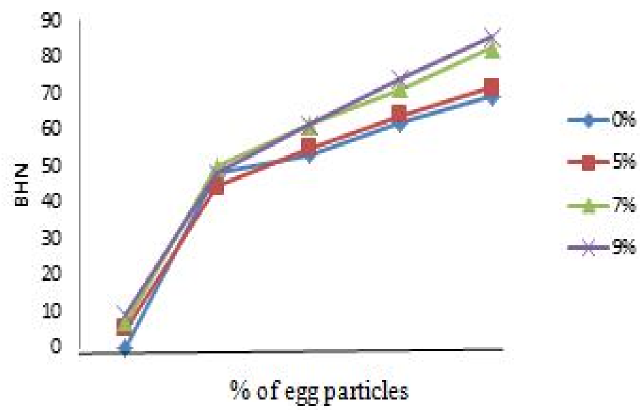


Figure 5: Hardness graph

5.2 Impact Test

Impact tests are performed for determining the fracture toughness of material using Charpy specimens with standard size of 55 × 10 × 5 mm^3 equipped with 45° V-shaped notches and 0.25 mm root radius at the tip of the notch. The specimen is impacted at velocities ranging from about 1 to 5.5 m/s. The total energy that is provided by the striking hammer accordingly ranges up to 300 J for a 20 kg hammer and a drop height of 1.55 m. In the original version of the test, the energy to break the specimen is simply determined from the difference of the heights of the striker before and after the test. Calculated the impact strength results are tabulated in Table.2

Table 2: Impact Strength for GFRP composites by adding of Egg shell powder

Sl. No	% of GFRP by adding of Egg shell Ceramics	Cross Section Area (CSA) In mm^2	Energy observed	Impact Strength In J/mm^2
1	0	275	32	0.1176
2	5	275	48	0.1745
3	7	275	28	0.1018
4	9	275	60	0.2181

To comparing the results (Figure.6) the 9% of GFRP composite material is given by better impact strength to comparing others in above graph. In this process the 0% has the impact strength of 0.13J/mm^2 and 5% has the impact strength of 0.17J/mm^2 and 7% has the impact strength of 0.1J/mm^2 and 9% has the impact strength of 0.23 J/mm^2. By the comparing of the range of impact strength of 7% is less strength when compared to other composites of 0%, 5%, 7% GFRP composites. But the 9% GFRP has the high impact strength to compare others 0.23 J/mm^2.

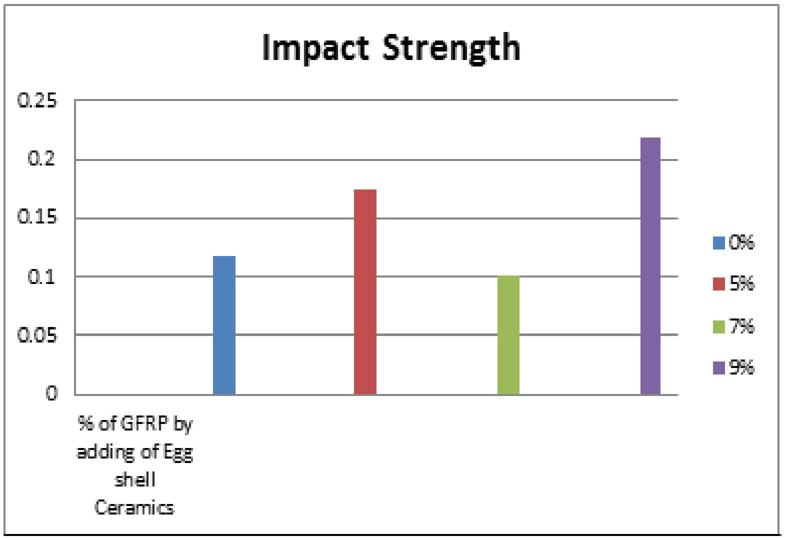


Figure 6: Impact strength

5.3 Frequency or Dynamic response test

To measure the dynamic characteristics of laminates, vibrations at a select point are measured by an accelerometer. The accelerometer is mounted by means of bees wax. The signal was then subsequently input to the second channel of the analyzer, where its frequency spectrum was also obtained. The response point was kept fixed at a particular point and the location of excitation was varied throughout the plate. Both input and output signals are investigated by means of FFT and resulting frequency response functions are transmitted to a computer for modal parameter extraction. The output from the analyzer was displayed on the analyzer screen by using DEWE Soft 7.0.6 software. Various forms of Frequency Response Functions (FRF) are directly measured as shown in Figure 7.

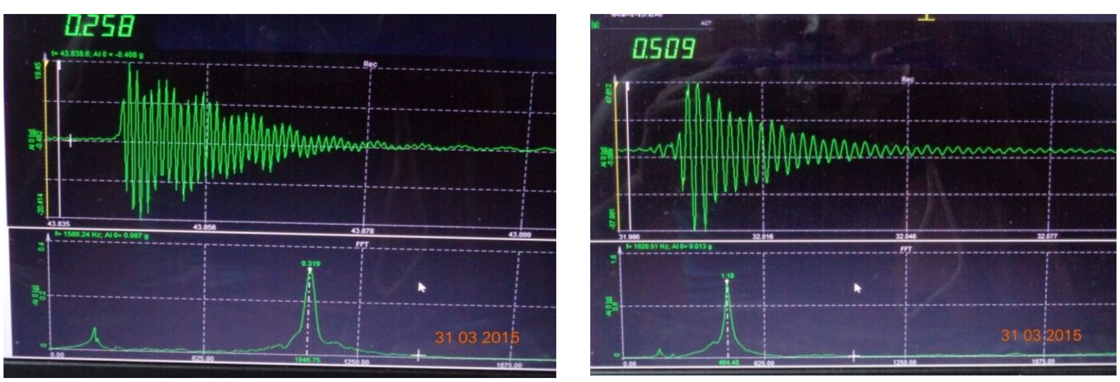


Figure 7: Natural Frequency response of GFRP composites

Experimental tests are performed to compare the natural frequencies of different structural materials like 0%, 5%, 7% & 9%.Data for the free vibration characteristics has been taken for first mode. (Table 3). The graphs have been plotted between excitation frequency and amplitude in terms of displacement. The natural frequencies are determined based on frequency response spectrum obtained by analyzing the acceleration signals from the beam as the response data. The natural frequencies (only for fundamental mode) of the specimens are identified as the frequencies corresponding to peaks present in the FFT spectrum.

Table 3: Natural Frequency for GFRP composites

Sl. No	% of GFRP by adding of Egg shell Ceramics	Natural Frequency In Hz				
		1	2	3	4	5
1	0	1077.27	1076.05	1075.44	1074.83	1073
2	5	466.92	465.70	465.09	467.53	466.31
3	7	1001.59	1002.20	999.76	1008.30	996.70
4	9	1044.31	1043.70	1046.75	1046.14	1050.4

To comparing the results the 5% of GFR**P** composite material is given by better frequency to comparing others. In this test of the specimen of 0%, 7%, 9% are the high frequency when comparing to the 5% of GFRP composites materials. In 5% GFRP composite has less frequency range in between 465-470 Hz. The natural frequencies of different compositions like 0%, 5%, 7% & 9%of different dimensions by varying their length and thickness which were calculated the natural frequency results are shown in the figure 8.

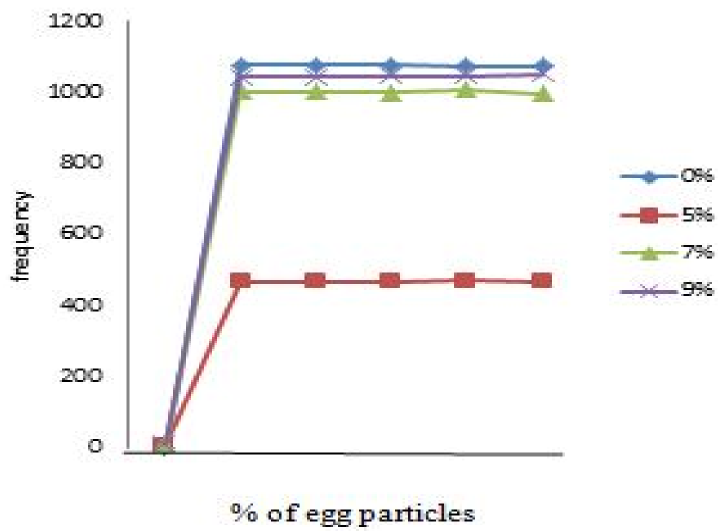


Figure 8: Natural Frequency of GFRP composites

6. CONCLUSION

The frequency response is a process of describing a structure performance under different loading conditions, in terms of its natural frequency and mode shapes. This project, aim with developing a new polymer matrix composite material and the developed material subjected to dynamic test with different loading conditions, based on the results it is concluded that

- Frequency response of specimen is based on constituent material proportions
- Percentage of ceramic particles inclusion in matrix material leads to higher frequency.
- Hardness of a material directly proportional to volume percentage of ceramic particles inclusion.
- Impact strength value is increases if the percentage of ceramic particles is increases.
- Further, the volume percentage of egg shell particles influences the resonance frequency set and not affecting material damping behavior under free vibration.

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