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Experimental Investigation of Glass Powder Reinforcement Effect on Vibration Characteristic of Composite Beam

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ABSTRACT

In This paper an experimental studying for the influence of reinforcement powder on the mechanical properties and natural frequency of orthotropic composite beam and verification the results of this paper with other paper results presented by other researcher. The study evaluated the mechanical properties and natural frequency of composite beam reinforced with glass powder by experimental work and comparison the experimental results with numerical results evaluated by using finite element method (ANSYS program (Ver. 15)). The mechanical properties and natural frequency evaluated under the effect of different powder reinforcement volume fraction , as $\forall_p$= 15%, 20%, 25%, and 30%, with various beam boundary condition as simply supported and cantilever beam. The results evaluated shown that the powder reinforcement effect the increasing of mechanical properties of composite beam , therefore, increasing the natural frequency of beam, but, the influence ofunidirectional reinforcementfiber on natural frequency and mechanical propertiesof composite beam more than the influence of powder reinforcement. And, then, the reinforcement with powder materials cause increasing of matrix mechanical properties, therefore, increasing the mechanical properties of composite materials and natural frequency of composite beam. Finally, the comparison of experimental results show a good agreement with numerical results of other paper, where the maximum error is about (10.2%).

KEYWORDS: hyper composite beam, vibration composite beam, composite materials, mechanical properties of hyper composite, finite element, vibration ANSYS.

INTRODUCTION

Basically composite material can be defined as a mixture of materials that share among themselves to give new material has new properties better than the properties of the mixed materials, so that a chemical reaction does not happen between the mixed materials and each material retain the core of their properties that were owned by individual. In the past composite material used as (laminations) in the brick industry and consolidation of shields and swards. In the recent years the interest in composite material was increased due to its unique properties such as light weight and high stiffness.

Studies exhibited that fibre glass reinforced polypropylene can be obtained by easy manufacturing methods and the produced materials present high resistance to impact and moisture ingress, [1].

In the field of vibration the scientific research focuses on reducing the damage and problems caused by vibration such as structures failure, fatigue in mechanical components, noise transmission, defect in machines

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performance and many other problems. So was urgently needed to find material with lightweight and high stiffness to improve vibration damping technique, [2].

Alot of researches were implemented to test the "vibration" and dynamic of plate and beam, as, Muhannad Al-Waily [1], the influence of powder reinforcement on the natural frequency of unidirectional woven hyper composite material beam was studied. The study of natural frequency was evaluated with three methods, the first is theoretical method with driving of the general equation of beam motion with shear deformation and rotary inertia effects, the second is driving of the general equation of motion for single degree of freedom beam, and the third is the numerical method with finite element technique by using Ansys software (Ver. 14). The study included the powder reinforcement volume fraction effect for hyper composite material beams of the following types: unidirectional, woven hyper composite beams with various volume fractions of fiber. The results exhibited that the addition of reinforcement powder increases the strength of composite materials, and then, increases the natural frequency of beam.

Mohsin Abdullah Al-Shammari and *et al*. [3], examined composite plate manufactured from resin material, which was consolidated by two kindsof consolidations as powder consolidation and woven consolidation fiber to obtain an orthotropic triple composite materials compound of, resin as base material and two consolidations (powder consolidation and woven consolidation fiber). Theoretical and numerical techniques were used to estimate the composite plate natural frequency. The general equation of motion of the composite plate are solving by theoretical technique, whilethe evaluation of the plate natural frequency are done numerically by using Ansys software (Ver. 14).

Muhsin J. Jweeg and *et al*. [4], studied the bucklingcapacity of composite plate manufactured from resin as base material ,reinforced with powder and woven fiber with various volume fraction.Theoreticalmethod has been dependedto estimatethe bucklingcapacity of simply supported orthotropic triple material composite plate. The studyexhibited that increasing the powder reinforcement drive to increasebuckling capacity of the plate while the kind of reinforcement has light effect on the plate buckling capacity.

And,Muhannad Al-Waily and *et al* [5],studied the buckling capacity for isotropic triple material composite plate manufactured from resin as base material reinforced with powder and, mat or short reinforcement fiber. The buckling load of simply supported isotropic hyper composite plate has been estimated for three cases. First with various aspect ratio of plate, second with different volume fraction of powder and fiberreinforcement and third with variousmaterials of resin and reinforcement. The study exhibited that the increment of the mat or short reinforcement fiber has clear effect on the increment of the buckling loadthan that of the increment of powder reinforcement.

AbdulkareemAbdulrazzaqAlhumdany and *et al*. [6], studied the influence of the reinforcement material types on the mechanical properties and dynamic characteristics for composite plate by experimental ,theoretical and numerical methods. The general equation of motion of the composite plate was solved by theoretical method. The natural frequency of the plate was evaluated by using ANSYS. Program (Ver. 11). The study exhibit that, the mechanical properties and natural frequency improved when using the powder of date palm nuts.

Also, AbdulkareemAbdulrazzaqAlhumdany and *et al*. [7], this research presented isotropic hyper composite plates structures, which are made of (resin and fiber with powder as a reinforcement material). The basic item of this research is to improve the dynamical properties of the composite structure. This item has been verified by adding the powder as a reinforcement material. Square and rectangular hyper composite plates (AR=1 and 1.5) are made with different volume fractions for glass powder, resin and short fiber. Various boundary conditions are examined (SSSS, CCSS, CCCC, CFFF, SSFF and CCFF) to support these plates. The dynamical properties of hyper composite models are calculated numerically with considering these different parameters. The results showed that the natural frequency increases by increasing the volume fraction of powder or short fiber with decreasing the resin.

The presented research review studied the mechanical properties and natural frequency of hyper composite beam and plate with theoretical and numerical investigation and presented the experimental investigation of mechanical properties and natural frequency for hyper isotropic composite plate. But, in this research presented the experimental investigation I addition to numerical analysis of orthotropic hyper composite beam made of unidirectional and powder reinforcement with polyester resin material, with simply and cantilever beam.

Experimental Work:

The experimental work included manufacture the vibration beam sample combined from three materials are, polyester resin materials and two reinforcement as unidirectional reinforcement fiber and powder reinforcement with different volume fraction as shown in table I and Fig. 1 and the weight of resin and reinforcement powder and fiber required to manufacture vibration beam samples depended on the volume fraction are shown in table II.

The vibration beam sample made with dimensions, as shown in Fig. 2, as,

Length $(l) = 1$ meter

Width (w) = 0.25 meter

Hight (h) = 0.25 meter

and, the weight of resin and reinforcement powder and fiber materials can be evaluated with used of equation,

$$w_r = \rho_r * l * w * h * \forall_r = Resin\ Weight$$

$$w_p = \rho_r * l * w * h * \forall_r = Powder\ Reinforcment\ Weight$$

$$w_f = \rho_r * l * w * h * \forall_r = Unidirectional\ Fiber\ Weight \quad (1)$$

Where the density of materials used are, [5],

$\rho_r = 1200\ kg/m^3$,$\rho_p = 2400\ kg/m^3$,

And,[8], $\rho_f = 2750\ kg/m3.$

Fig. 1: Vibration Beam Sample With Different Volume Fraction.

Table 1: Volume Fraction Materials Of Vibration Beam Sample.

Sample No.	$\forall_r$ (%)	$\forall_f$ (%)	$\forall_p$ (%)
1	70	15	15
2		20	10
3		25	5
4		30	0
5	60	15	25
6		20	20
7		25	15
8		30	10

Table 2: Weight Of Vibration Beam Sample.

Sample No.	w_r (g)	w_f (g)	w_p (g)
1	52.5	25.8	22.5
2		34.4	15
3		43	7.5
4		51.6	0
5	45	25.8	37.5
6		34.4	30
7		43	22.5
8		51.6	15

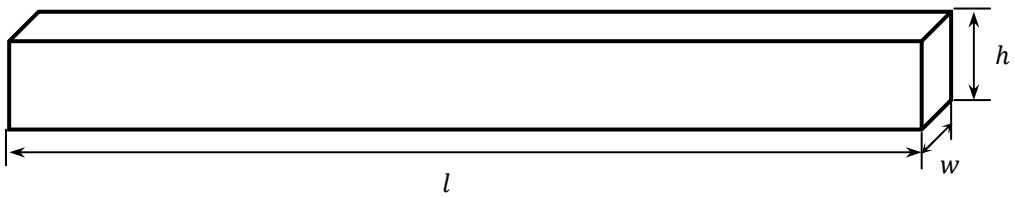

Fig. 2: Dimensions Vibration Beam Sample.

The vibration test of beam sample made for different beam supported as, simply supported beam, clamped supported beam, and, cantilever supported beam. And, the vibration test of beam made with using the vibration test machine shown in Fig. 3, where, it component from the following parts,

1. Structure rig.
2. Accelerometer, model (352C68), with sensitivity (10.2mV/(m/s2) measurement domain (491m/s2), mounted resonant frequency "(≥35KHZ), non-linearity "(≤ 1%)".
3. Amplifier, type480E09)"
4. Digital storage oscilloscope , model (ADS1202CL) and serial No.01020200300012., with max. frequency (200MHz), max. read of sample per second (500MSA/s), (F.F.T.) spectrum analysis and two input path.

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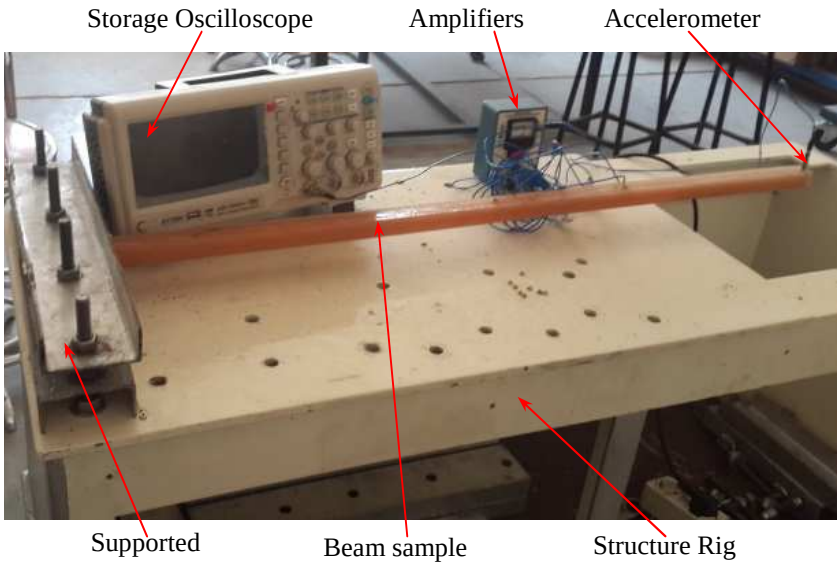

Fig. 3: Vibration Test Machine.

The natural frequency of the beam evaluated by supplying impact load on the beam and read the signal from storage oscilloscope by given from Accelerometer and Amplifiers, as shown in flow chart Fig. 4. And then, analysis the signal taken from the storage oscilloscope with FFT by using sig-view program and evaluated the natural frequency of beam, as shown in Fig 5.

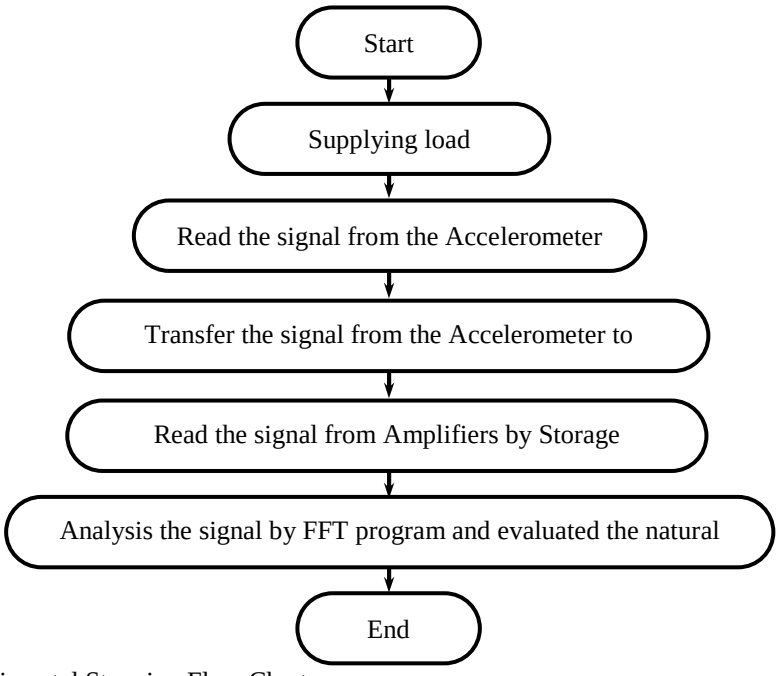

Fig. 4: Experimental Stepping Flow Chart.

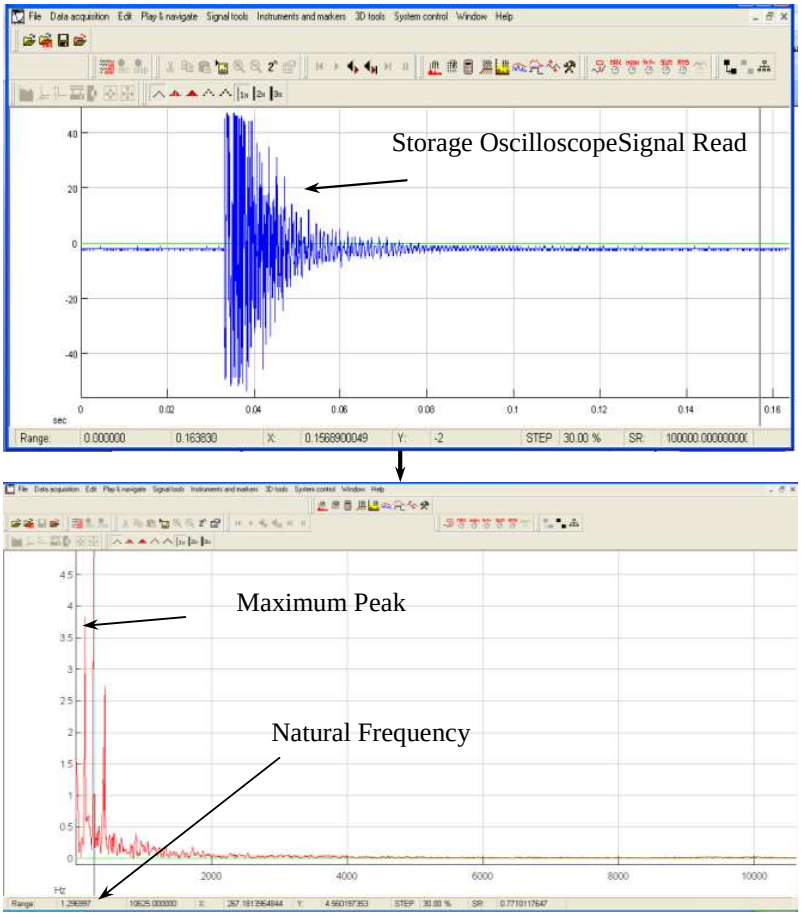

Fig. 5: Analysis Of Storage Oscilloscope Signal By Fft.

Numerical Investigation:

Wide range of engineering problems can be solved by using finite element method. the procedure used to solve any engineering problem is applying the essential physical laws of the system and then driving the differential equation covering the boundary condition and initial condition of the system, that what we called the mathematical model. Because of large number of boundary conditions, initial conditions and the difficulty of the differential equation itself, so obtaining exact solution impossible. Numerical solution is used to solve such problems via ANSYS program, which is successful engineering application gives the solution for wide range of engineering problem.[9].

The numerical study of vibration analysis for composite beam estimated by using the finite elements technique was executed by using the ANSYS software (ver.14). The three dimensional model were constructed and the element (Solid Tet 10 node 187) were used. Solid 187 elements is a higher order 3-D, 10-node element. Solid 187 has a quadratic displacement behavior and is well suited for modeling irregular meshes. The element is defined by 10 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyper-elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elasto-plastic materials, and fully incompressible hyper-elastic materials. The geometry, node locations, and the coordinate system for this element are shown in Fig. 6, [1].

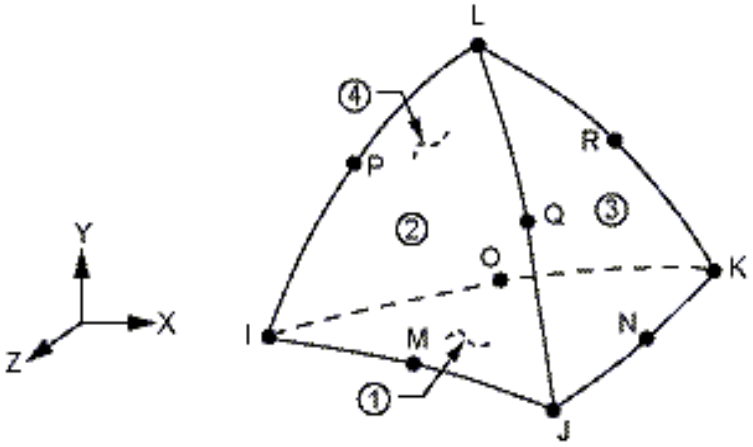

Fig. 6: geometry of Solid 187 Element.

RESULTS AND DISCUSSIONS

The mechanical properties of the material used in the manufacturing of the beams are listed in table III, [1]. The dimensions of the beam used are the same dimensions of the beam of [1] so as to compare the results with the published paper. The vibration test is done to estimate the fundamental natural frequency values (rad/sec). The results of three boundary conditions (simply supported , clamped and cantilever) are listed in the tables IV, V and VI respectively. These experimental results are shown in the figures 7, 8 ,9 and 10 for different values of fiber volume fraction (15%, 20%, 25% and 30%) respectively. It can be shown clearly that the increasing of powder in the composite beams leading to the increasing of the natural frequency of the beam for all boundary conditions. Also the results shows a good agreement with the theoretical results with the same properties [1]. The maximum error shown is 10.56% for the case of cantilever beam.Table IIIMechanical Properties of Unidirectional Hyper Composite Beam Compound of Glass Powder Fiber and Polyester Resin Matrix, [1].

Table III: Mechanical Properties of Unidirectional Hyper Composite Beam Compound of Glass Powder Fiber and Polyester Resin Matrix, [1].

$\forall_r$(%)	$\forall_f$ (%)	$\forall_p$(%)	E_1 (Gpa)	E_2 (Gpa)	G_{12} (Gpa)	ν_{12}	ρ (kg/m^3)
70	15	15	1.09	6.81	2.46	0.36	1620
	20	10	19.00	6.44	2.32	0.36	1620
	25	5	21.97	6.04	2.17	0.36	1620
	30	0	25.00	5.58	2.00	0.36	1620
65	15	20	16.77	7.73	2.80	0.36	1690
	20	15	19.61	7.36	2.66	0.36	1690
	25	10	22.51	6.95	2.51	0.35	1690
	30	5	25.47	6.50	2.34	0.35	1690
60	15	25	17.57	8.80	3.20	0.36	1760
	20	20	20.32	8.42	3.06	0.35	1760
	25	15	23.13	8.01	2.90	0.35	1760
	30	10	26.02	7.55	2.73	0.35	1760
55	15	30	18.52	10.06	3.67	0.35	1830
	20	25	21.16	9.67	3.53	0.35	1830
	25	20	23.87	9.25	3.37	0.35	1830
	30	15	26.66	8.78	3.19	0.34	1830
50	15	35	19.65	11.56	4.24	0.35	1900
	20	30	22.16	11.15	4.08	0.35	1900
	25	25	24.75	10.71	3.92	0.34	1900
	30	20	27.43	10.23	3.73	0.34	1900

Table 4: Comparison Between Numerical And Experimental Frequency Results Of Simply Supported Beam With Different Resin And Reinforcement Volume Fraction

$\forall_r$ (%)	$\forall_f$ (%)	$\forall_p$ (%)	Natural Frequency (rad/sec)		
			Nu	Ex	Error %
70	15	15	972.1	900.58	7.93
	20	10	1056.2	962.74	9.71
	25	5	1135.81	1053.42	7.82
	30	0	1211.61	1124.38	7.76
60	15	25	974.49	904.28	7.76
	20	20	1047.9	958.34	9.35
	25	15	1118.1	1028.47	8.72
	30	10	1185.9	1103.89	7.43

Table 5: Comparison Between Numerical And Experimental Frequency Results Of Clamped Supported Beam With Different Resin And Reinforcement Volume Fraction.

$\forall_r$(%)	$\forall_f$(%)	$\forall_p$(%)	Natural Frequency (rad/sec)		Error (%)
			Nu	Ex	
70	15	15	2203.44	2014.58	9.37
	20	10	2394.41	2233.37	7.21
	25	5	2574.76	2398.41	7.35
	30	0	2746.58	2534.19	8.38
60	15	25	2209.07	2016.87	9.53
	20	20	2357.67	2214.24	7.29
	25	15	2534.61	2349.48	7.88
	30	10	2688.3	2461.28	9.22

Table 6: Comparison Between Numerical And Experimental Frequency Results Of Cantilever Supported Beam With Different Resin And Reinforcement Volume Fraction.

$\forall_r$ (%)	$\forall_f$ (%)	$\forall_p$ (%)	Natural Frequency (rad/sec)		
			Nu	Ex	Error %
70	15	15	346.28	312.48	10.82
	20	10	376.29	349.26	7.74
	25	5	404.63	376.22	7.55
	30	0	431.63	401.23	7.58
60	15	25	346.12	322.14	7.44
	20	20	374.28	338.12	10.69
	25	15	401.0	370.87	8.12
	30	10	426.55	394.89	8.02

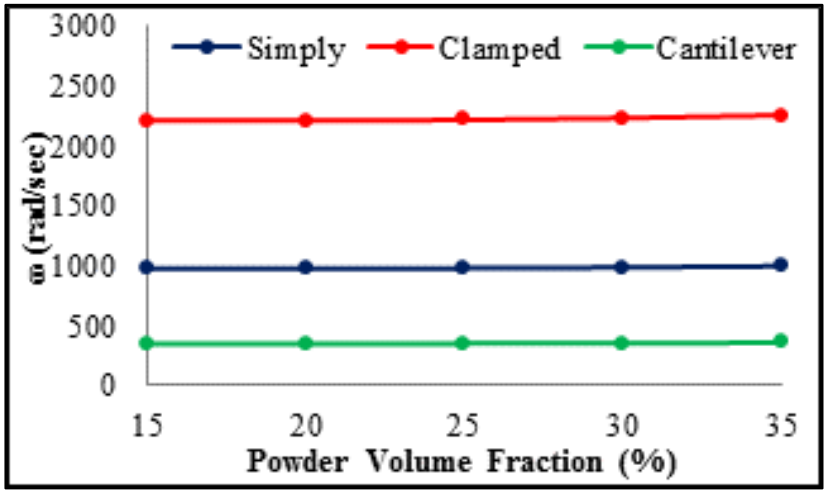

Fig. 7: Natural Frequency Of Composite Beam With Various Reinforcement Powder Volume Fraction And Different Beam Supported, FOR $\forall_f = 15\%$.

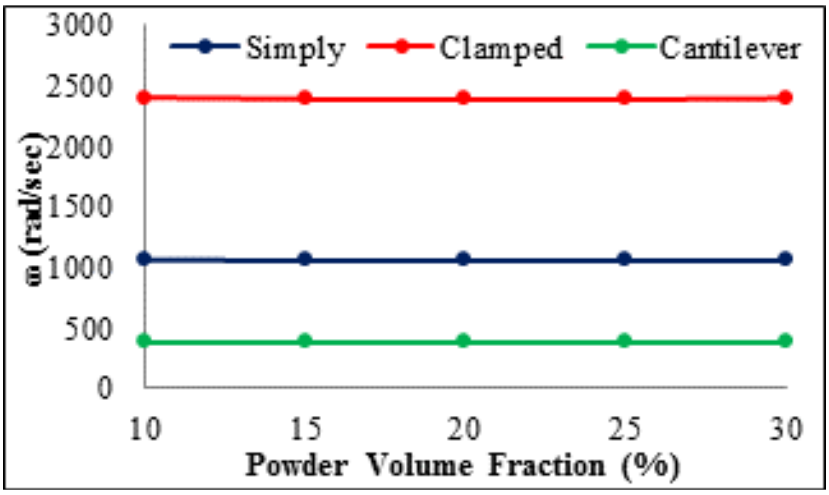

Fig. 8: Natural Frequency Of Composite Beam With Various Reinforcement Powder Volume Fraction And Different Beam Supported, FOR $\forall_f = 20\%$.

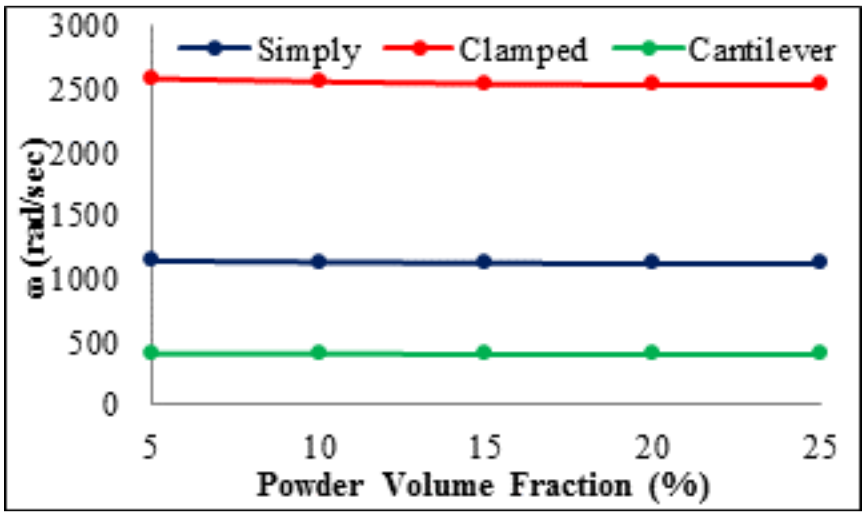

Fig. 9: Natural Frequency Of Composite Beam With Various Reinforcement Powder Volume Fraction And Different Beam Supported, FOR $\forall_f = 25\%$.

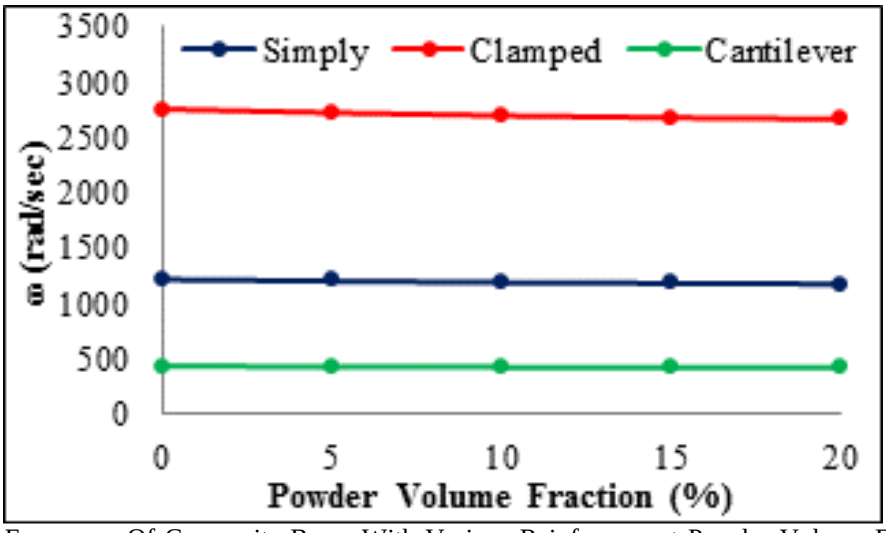

Fig. 10: Natural Frequency Of Composite Beam With Various Reinforcement Powder Volume Fraction And Different Beam Supported, FOR $\forall_f = 30\%$.

Conclusions:

From the investigation, some concluding observations are given below:

1. The experimental results showed good match with numerical results obtained, by using ANSYS software(Ver. 14), with maximum error between numerical and experimental results about (10.82%).
2. The reinforcement with powder increases the modulus of elasticity of hyper composite orthotropic unidirectional beams, then, the increasing of reinforcement powder causes increase of natural frequency of orthotropic hyper composite materials beam.
3. The increase of modulus of elasticity for resin materials causes increase in modulus of elasticity of matrix for hyper composite material, and then, increasing of modulus of elasticity for hyper composite materials beam, then, increasingof natural frequency of orthotropic" unidirectional hyper composite materials beams.
4. The natural frequency of hyper composite beam affected with unidirectional reinforcement fiber more than affected it with reinforcement with powder materials.
5. The recommendation of future work, studding the buckling behavior of hyper composite beam and studding the effect of powder reinforcement types and volume fraction on to buckling load. And, study the effect of powder reinforcement onto natural frequency of composite plate.

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