Influences of Glass and Carbon Powder Reinforcement on the Vibration Response and Characterization of an Isotropic Hyper Composite Materials Plate Structure

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***Abstract*— The effects of variable powder reinforcement on the natural frequency and response (under transit loading) of a isotropic hyper composite plate structure are studied for different boundary conditions (simply supported composite plate at all edges and clamped supported composite plate at all edges). The powders investigated are glass and carbon powder, and short fiber serves as the reinforcement; the composite plate is a combination of powder, short fiber reinforcement, and polyester-resin materials. The effects of powder reinforcement on vibration characterization and response are investigated by experimental and numerical work. The experimental work included the evaluation of mechanical properties and natural frequency of the plate with variable fraction and reinforcement type, whereas the numerical work included the evaluation of natural frequency and response of composite plate with various volume fractions and reinforcement-powder type. The experimentally obtained natural-frequency results are compared with the numerically obtained ones, and good agreement is observed. The maximum error is approximately 9.78%. We also find that increasing the powder volume fraction or using stronger powders causes stiffness of the plate and elevated frequency value. Additionally, the responses of the composite plate decrease with increased powder-reinforcement volume.**

***Index Term*-- Hyper Composite, Vibration Composite, Powder Reinforcement, Natural Frequency, Response Plate, Composite Mechanical Properties, Vibration Isotropic Composite Plate.**

I. INTRODUCTION

Many engineering applications use composite material structures. Given that the composite materials have unique properties, they are considered as proper substitute for metals, [1]. Therefore, a number of properties are considered to be important for the application of composite material, such as mechanical properties and dynamic and static behaviors. Thus, the response of composite plate needs to be studied because most applications are exposed to dynamic loads.

Therefore, different parameters affect the response of the plate under impact or transient loading. Decreasing the load subjected on a plate should increase the strength of the plate. Therefore, one technique used to improve the strength, mechanical properties, dynamic characterizations and behavior, and static behavior is reinforcing composite materials with powder reinforcement. Using powders with high strength leads to the improvement of the properties and other behaviors of composite materials.

The response of composite materials plate has been investigated in general by a number of researchers.

Mallikarjuna et al. (1998), [2], presented a model of dynamic analysis of a laminated composite plate by using iso-parametric finite element on a model of higher-order displacement. Also, the wave propagation was described by using Kirchhoff plate theory. The dynamic response load is presented in the paper by using the first-order shear deformation theory. The dynamic transient response evaluated with different parameters affected the mesh of finite element, time step, orthotropy, and scheme of lamination.

Makhecha et al. (2001), [3], presented the response analysis by using higher-order shear deformation theory of thick laminated composite plate. The finite element model is used to simulate the mechanical and thermal load of the composite plate. The different parameters affecting the response of the plate are presented, such as aspect ratio of plate, ply angle, layers numbers, and thermal coefficients.

Heimbs et al. (2008), [4], presented different techniques to evaluate the dynamic behavior of CRP composite plate under low-velocity impact loading using the LS-Dyna to simulate the finite element model of composite plate under impact load. The main objective of their work is to present the different simulation approaches and the effect of various simulation parameters, in addition to comparing the numerical results with the experimental results.

Ansari et al. (2015), [5], presented an investigation of the FRP composite-laminated plate under different range of velocity impact load. The investigation included studying a variation of residual velocity and ballistic limit with different masses and h/a ratio impactor. The model is used to simplify the composite material plate and the impactor with 3D finite element is a Lagrangian mesh. The stress/strain failure criteria with shock effect under ballistic impact were presented for studying the stage-wise damage evolution in fiber reinforcement polymer composite plate.

Basturk et al. (2016), [6], presented an investigation of nonlinear response for composite plate under blast loading.

The models used for investigating composite plate are the homogenous laminated model and power law model. Also, the large deflection for thin plate theory was used to investigate the nonlinear effect of geometry. In addition, the approximate solution-to-space domain was used and substituted into the equations of motion.

Al-Waily et al. presented different investigations during different years demonstrating the effect of powder reinforcement on the dynamic and static characterization of composite plate. In 2013, Al-Waily et al. [7] presented a theoretical investigation of the effect of powder reinforcement on the natural frequency of isotropic composite plate. Also, in 2014, Al-Waily et al. [8] presented a theoretical solution for the effect of powder reinforcement on the natural frequency of the orthotropic composite plate. In 2015, Al-Waily et al. [9, 10] presented theoretical investigation of buckling behavior of isotropic, [9], and orthotropic, [10], hyper composite plate with various reinforcement powder effects. Also during the same year, Al-Waily et al. [11] presented the experimental work of powder reinforcement influence on the natural frequency of isotropic composite plate with different boundary condition effect. Then, in 2016, Al-Waily et al. [12] presented the effect of date palm powder reinforcement on the vibration characterization of isotropic composite plate with experimental technique. Finally, in 2017, Al-Waily et al. [13] presented the investigation of carbon nanotube powder reinforcement on the mechanical properties and natural frequency of isotropic composite plate. Therefore, the papers presented show that adding of powder as reinforcement improves the mechanical properties and dynamic and static behaviors of the composite plate structure.

The presented researchers investigated the powder volume fraction of the mechanical properties and the natural frequency of the composite plate. However, this research presents the effect of powder reinforcement types and volume fraction on mechanical properties, vibration response, and characterization of isotropic hyper composite plate structure reinforced with various supports, comprising short reinforcement fiber and polyester-resin materials, in addition to reinforcement powder.

II. EXPERIMENTAL WORK

The experimental work included the manufacture of plate combined with three different materials—powder reinforcement, short fiber reinforcement, and polyester-resin materials. First, the mechanical properties (modulus of elasticity) of composite materials plate with different volume fraction and reinforcement powder types were evaluated, wherein the powder types used were glass and carbon powder. Second, the composite plate natural frequency with different powder parameter effects and various boundary conditions of the plate were evaluated.

The mechanical properties of composite materials are evaluated by using the tensile test of manufactured composite material samples. The sample is manufactured based on ASTM standard (D 3039 M-E122), [14, 15] as shown in Fig. 1. Thus, to evaluate the modulus of elasticity, we must test three samples for each volume fraction, and then calculate the average of its values. Table I shows the modulus of elasticity for composite materials with different values of volume fraction and different types of powder reinforcement. The tensile test machine shown in Fig. 2 is the composite material test sample with tensile length specimen $= 20\ cm$, width of specimen $= 3\ cm$, and specimen $= 5\ mm$.

a. Tensile Sample Reinforcement with Glass Powder.

b. Tensile Sample Reinforcement with Carbon Powder.

Fig. 1. Tensile test Samples with Different Powder Reinforcement Types.

Table I
Experimental Modulus of Elasticity for Isotropic Hyper Composite Materials.

$\forall_{sh}$ (%)	$\forall_p$ (%)	$\forall_r$ (%)	Modulus of Elasticity (GPa)	
			Glass Powder	Carbon Powder
15	15	70	10.34	11.86
15	25	60	12.16	13.43
15	35	50	13.87	15.84
20	10	70	12.38	13.53
20	20	60	14.38	15.37
20	30	50	15.83	16.89
25	5	70	13.56	14.24
25	15	60	14.83	16.31
25	25	50	16.82	18.96
30	0	70	14.86	15.86
30	10	60	16.23	17.32
30	20	50	18.62	19.37

$\forall_{sh}$: Volume Fraction of Short Reinforcement Fiber.
$\forall_p$: Volume Fraction of powder Reinforcement.
$\forall_r$: Volume Fraction of Polyester Resin Material.

The second part of the experimental work included the manufacture of the composite plate samples with different powder volume fractions and types of reinforcement powder (as shown in Fig. 3), and then, testing the samples using a vibration test machine (as shown in Fig. 4) to evaluate the natural frequency of the plate. The powder reinforcement used are glass and carbon reinforcement powders, the short reinforcement fiber used glass fiber, while the polyester-resin materials used composite plate structure as matrix. The composite plate samples are supported with different boundary conditions:

1. Simply supported composite plate at all edges (SSSS)
2. Clamped supported composite plate at all edges, (CCCC).

And, the plate dimensions are,

1. Length $= L = 20\ cm$,
2. Width $= w = 20\ cm$,
3. Thickness $= h = 5\ mm$.

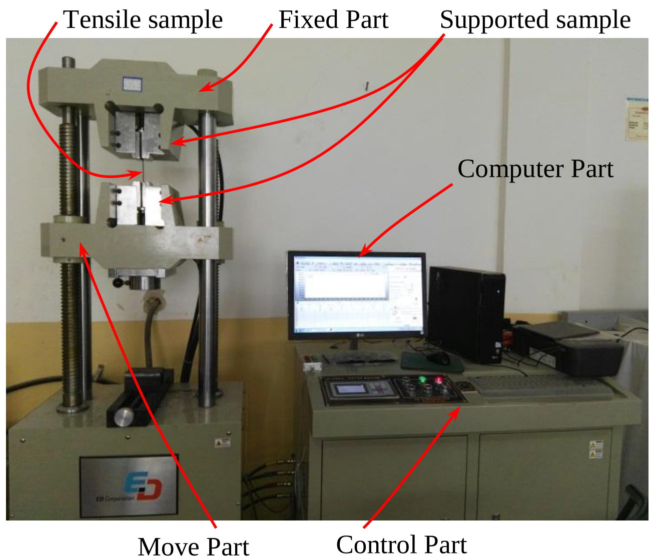
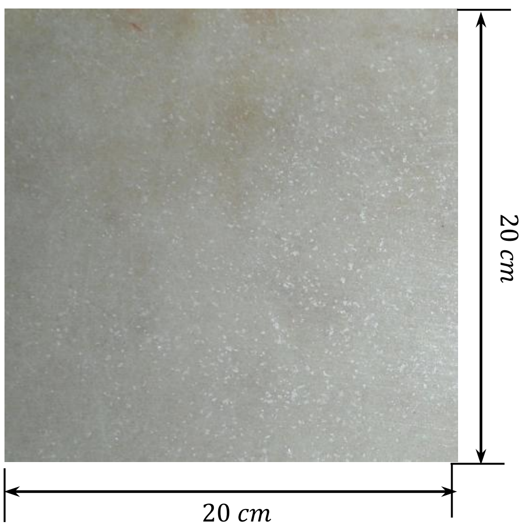


Fig. 2. Compound of Tensile Test Machine.



a. Vibration plate sample reinforcement with glass powder.

b. Vibration plate sample reinforcement with carbon powder.

Fig. 3. Composite Plate Vibration Samples.

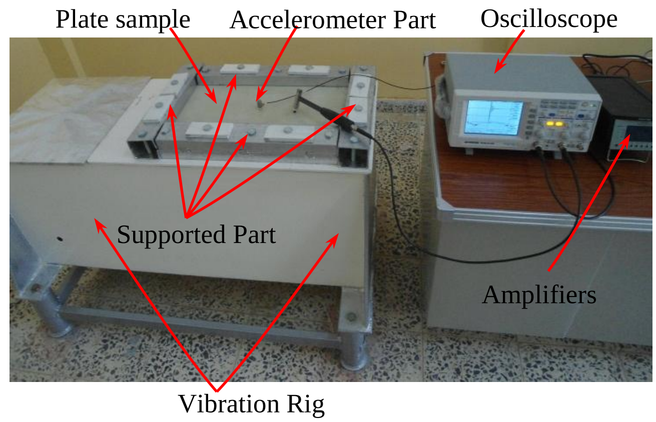
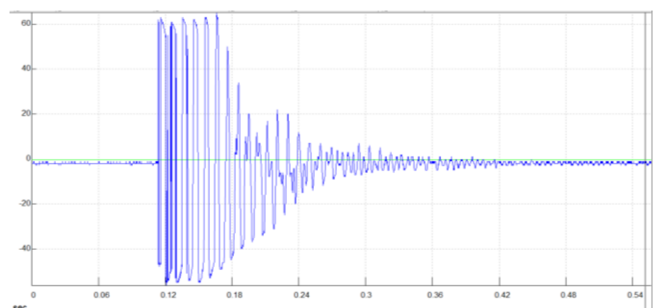
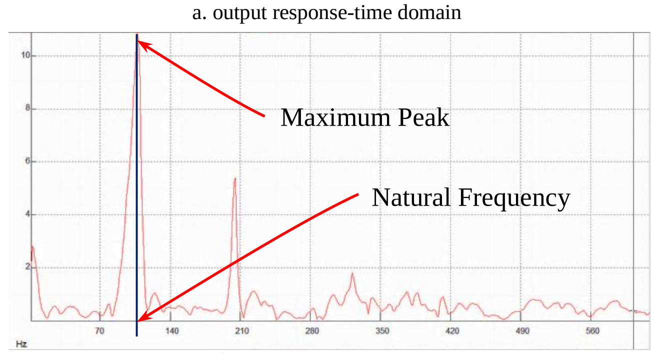


Fig. 4. Vibration Test Machine Compounds.

Therefore, the natural frequency of the composite plate was evaluated by analyzing the output signal of the vibration test with sig-view program, as shown in Fig. 5, by fast Fourier transformation (FFT) technique [16]. The FFT transfers the time–response domain to the frequency–response domain; therefore, the value of frequency is given the maximum amplitude in frequency–response domain, representing the natural frequency value of the composite plate.



a. output response-time domain



b. frequency-response domain.

Fig. 5. Fast Fourier Transformation for output vibration signal.

The output signal of the vibration test is analyzed by evaluating the natural frequency of the isotropic plate with variable volume fraction powder reinforcement and different powder (glass and carbon powder). Then, using the mechanical properties, it is evaluated by using the experimental part of the numerical investigation to evaluate the natural frequency of the composite plate and the results of natural frequency are compared with the experimental results.

Finally, the experimental work included evaluating the density of hyper composite materials by using the equation,

$$\rho_c = \rho_p \forall_p + \rho_{sh} \forall_{sh} + \rho_r \forall_r. \qquad (1)$$

Where $\rho_p, \rho_{sh}, \rho_r$ are the density for powder, short fiber, and polyester-resin materials, respectively. $\rho_p, \rho_{sh}, \rho_r$ are calculated experimentally. Therefore, the density of the combined composite materials can be calculated by using Archimedes' Law. The experiment gave the following values of density of powder, short fiber, and polyester materials, as,

ρ_p: density of glass powder $= 2400\ kg/m^3$
ρ_p: density of carbon powder $= 1600\ kg/m^3$
ρ_p: density of glass short fiber $= 2000\ kg/m^3$
ρ_p: density of polyester-resin material $= 1100\ kg/m^3$ (2)

Then, by substituting the values of density, as shown in Eq. (2), the density of the composite materials is evaluated as shown in Table II.

Table II
Density of Isotropic Composite Materials with Various Volume Fractions.

$\forall_{sh}$ (%)	$\forall_p$ (%)	$\forall_r$ (%)	Density (kg/m^3)	
			Glass Powder	Carbon Powder
15	15	70	1430	1310
15	25	60	1560	1360
15	35	50	1690	1410
20	10	70	1410	1330
20	20	60	1540	1380
20	30	50	1670	1430
25	5	70	1390	1350
25	15	60	1520	1400
25	25	50	1650	1450
30	0	70	1370	1370
30	10	60	1500	1420
30	20	50	1630	1470

III. NUMERICAL INVESTIGATION

The numerical investigation included using the finite element technique to evaluate the natural frequency and vibration response of isotropic hyper composite plate. Therefore, the first part evaluated by numerical work determines the natural frequency of the isotropic plate with different volume fractions and types of reinforcement powder and various plate-supported conditions. Moreover, the results of natural frequency are compared with the results of the experimental work to evaluate the agreement between the two techniques. Finite element technique is used to calculate the response of composite plate with various powder parameters on the effect of composite plate structure. Also, the natural frequency and response of the plate are evaluated for various plate boundary conditions—CCCC and SSSS.

To evaluate the natural frequency and response of plate by finite element using Ansys program package, we must first select the types of elements that can be used. The best element used with Ansys program is the shell element [8, 17]. Thus, shell 8-node-281 [8, 18] is used to evaluated the best values of natural frequency and response of plate.

The characterizations of shell 281 are,

1. Analyzing the thick structure of the shell .
2. The element has eight nodes and six dots at each node.
3. The element is well suited for linear, large rotation, and/or large-strain nonlinear application.
4. The element is used for layered applications for modeling composite shell or sandwich construction.
5. The element formulation is based on logarithmic strain and true stress measures.
6. The element kinematics allow for finite membrane strain.

Fig. 6,shows the node location, and the coordinate of element shell 8-node-281. Also, the mesh of the composite plate using shell 281 element is shown in Fig. 7, where the number of mesh are given the best results for natural frequency and response in presented work are approximately 1600 elements with 12,800 nodes. The number of elements can be selected by calculating the variable required with a different number of elements. When the value of its variable is stable, the number of the element that gives stable results is selected.

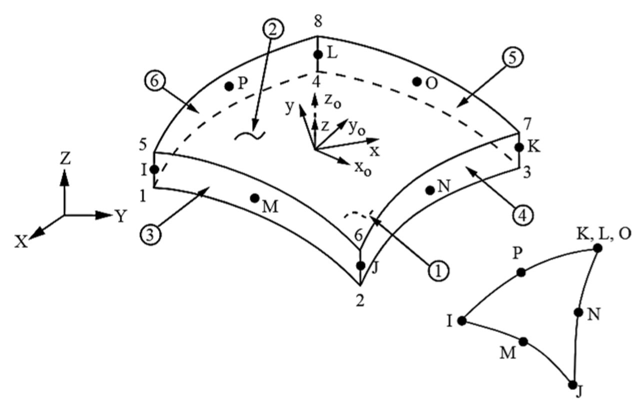


Fig. 6. Shell 281 Geometry.

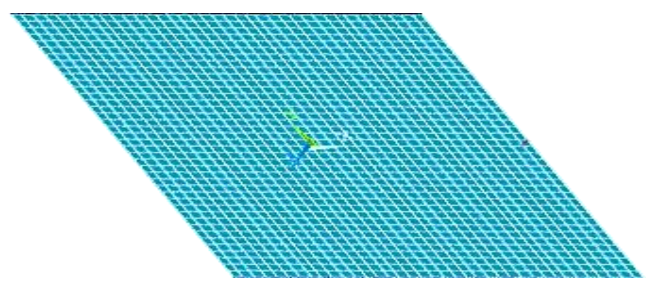


Fig. 7. Mesh of Plate by shell element 281.

Evaluation of the natural frequency of composite plate by ANSYS program required the input data as the mechanical properties. Then, the mechanical properties and modulus of elasticity, used in the numerical part, are evaluated by experimental part, as shown in Table I. Other mechanical properties are required, as Poisson's ratio can be obtained from Table III [9]. Moreover, the rigid modulus of elasticity calculated from the equation of isotropic materials is

$$G = \frac{E}{2(1+\nu)} \qquad (3)$$

Where,
E: modulus of elasticity of composite materials.
ν: Poisson's ratio of composite materials.

Therefore, the value of the modulus of elasticity is presented as in Table I and Poisson's ratio as in Table III. The results of Eq. 3 can be listed in Table IV. In addition, the dimensions of plate investigation are the same dimensions used in the experimental part. Also, evaluating the response of composite plate can be performed by using mechanical properties and density of hyper composite plate, as shown in Tables I, II, III, IV, with various volume fractions of powder and short fiber reinforcement. Also, the load subjected on the plate structure is impulse 20 N load with 0.1 s where the load is subjected at the central location for composite plate.

Finally, the output of the Ansys program included the natural frequency and response of isotropic hyper composite plate with various powder-reinforcement volume fractions and type effect and different plate boundary conditions. The boundary conditions for the plate used are SSSS and CCCC.

After this, comparing the results of natural frequency evaluated by numerical technique with the results of natural frequency calculated by experimental technique prove that numerical technique can be used to investigate the effect of powder reinforcement on the dynamic behaviors (response) of isotropic hyper composite plate structure.

Table III

Poisson's Ratio for Isotropic Hyper Campsite Materials, [9].

$\forall_{sh}$ (%)	$\forall_{p}$ (%)	$\forall_{r}$ (%)	Poisson's Ratio	
			Glass Powder	Carbon Powder
15	15	70	0.372	0.372
15	25	60	0.363	0.363
15	35	50	0.355	0.355
20	10	70	0.381	0.381
20	20	60	0.371	0.371
20	30	50	0.361	0.361
25	5	70	0.390	0.390
25	15	60	0.378	0.378
25	25	50	0.367	0.367
30	0	70	0.400	0.400
30	10	60	0.385	0.385
30	20	50	0.373	0.373

Table IV

Rigid Modulus of Elasticity for Isotropic Composite Materials.

$\forall_{sh}$ (%)	$\forall_{p}$ (%)	$\forall_{r}$ (%)	Rigid Modulus (GPa)	
			Glass Powder	Carbon Powder
15	15	70	3.768	4.322
15	25	60	4.461	4.927
15	35	50	5.118	5.845
20	10	70	4.482	4.899
20	20	60	5.244	5.605
20	30	50	5.816	6.205
25	5	70	4.878	5.122
25	15	60	5.381	5.918
25	25	50	6.152	6.935
30	0	70	5.307	5.664
30	10	60	5.859	6.253
30	20	50	6.781	7.054

IV. RESULTS AND DISCUSSION

The investigation of an isotropic hyper composite plate studied in this paper included calculating the natural frequency of the plate by using experimental and numerical techniques, comparing the results, and evaluating the dynamic response of the plate with the numerical technique. The plate investigation is uses mechanical properties, calculated by experimental and theoretical techniques, are shown in Tables I to IV, and the dimensions of the plates are:

1. Length of plate = L = 20 cm,
2. Width of plate = w = 20 cm,
3. Thickness of plate = h = 5 mm.

The plate is supported by two support types, as,

1. Simply supported at all edges, SSSS.
2. Clamped supported at all edges, CCCC.

Moreover, the plate studied was composed of various volume fractions of glass reinforcement fiber and polyester-resin materials in addition to various volume fractions of reinforcement powder for two types of powder (glass and carbon powder).

Therefore, the results included evaluating the natural frequency of isotopic hyper composite plate by experimental and numerical work, and then, comparing the results together to show the agreement of the experimental work result. The results of natural frequency are shown in Tables V to VIII, where the results presented are for simply supported and clamped plate reinforcement with glass and carbon powder, respectively. From the results shown in the tables, we observe that the natural frequency of the plate is increased by increasing the volume fraction of the reinforcement powder with the same volume fraction of the short fiber. Also, the natural frequency increases with reinforcement of powder of greater strength and larger modulus of elasticity. Therefore, the natural frequency of plate reinforcement with carbon powder is greater than the natural frequency of plate reinforcement with glass powder due to the high strength of carbon powder. Given that the natural frequency of plate is dependent on the mechanical properties of the composite plate materials, therefore, the natural frequency is increased with the reinforcement of the powder due to the increase in the mechanical properties of the matrix material, resulting in the increase of the mechanical properties of the composite plate materials.

Also, from Tables V to VIII the error between experimental and numerical work for dynamic behavior of composite plate is shown. The tables show that the error between its techniques used is from 5% to 10%. Given that its percentage error is acceptable between the experimental and numerical work, the numerical technique can be used to evaluate the other characterizations of isotropic hyper composite plate.

Therefore, by using numerical technique combined with finite element technique, the dynamic response of composite plate can be calculated, as shown in Figs. 8 to 21, for various plate supported and different reinforcement volume fraction and powder materials. The plate is subjected to impulse dynamic load with maximum pulse load (20 N) and through time (0.1s).

Tale V

Comparison for Experimental and Numerical Frequency Results, for CCCC Supported Plate Reinforcement with Various Glass Powder Volume Fraction.

$\forall_{sh}$ (%)	$\forall_p$ (%)	$\forall_r$ (%)	Natural Frequency ω (rad/sec)		Error (%)
			Experimental Results	Numerical Results	
15	15	70	1918.45	2063.39	7.02
15	25	60	1957.38	2134.22	8.29
15	35	50	2008.64	2182.70	7.97
20	10	70	2087.54	2282.73	8.55
20	20	60	2169.48	2343.80	7.44
20	30	50	2193.48	2351.57	6.72
25	5	70	2238.17	2416.04	7.36
25	15	60	2281.38	2433.14	6.24
25	25	50	2312.16	2446.74	5.50
30	0	70	2392.82	2559.51	6.51
30	10	60	2434.81	2578.62	5.58
30	20	50	2463.39	2594.65	5.06

Tale VI

Comparison for Experimental and Numerical Frequency Results, for CCCC Supported Plate Reinforcement by Various Carbon Powder Volume Fraction.

$\forall_{sh}$ (%)	$\forall_p$ (%)	$\forall_r$ (%)	Natural Frequency ω (rad/sec)		Error (%)
			Experimental Results	Numerical Results	
15	15	70	2137.69	2308.85	7.41
15	25	60	2248.37	2402.18	6.40
15	35	50	2367.14	2553.69	7.30
20	10	70	2289.76	2457.17	6.81
20	20	60	2374.92	2559.75	7.22
20	30	50	2463.28	2624.92	6.16
25	5	70	2349.21	2512.24	6.49
25	15	60	2468.12	2625.99	6.01
25	25	50	2573.87	2768.85	7.04
30	0	70	2498.31	2644.22	5.52
30	10	60	2553.28	2695.38	5.27
30	20	50	2618.32	2786.68	6.04

Tale VII

Comparison for Experimental and Numerical Frequency Results, for SSSS Supported Plate Reinforcement with Various Glass Powder Volume Fraction.

$\forall_{sh}$ (%)	$\forall_p$ (%)	$\forall_r$ (%)	Natural Frequency ω (rad/sec)		Error (%)
			Experimental Results	Numerical Results	
15	15	70	1726.54	1877.68	8.05
15	25	60	1793.27	1942.14	7.67
15	35	50	1854.29	1986.25	6.64
20	10	70	1918.24	2077.28	7.66
20	20	60	1972.37	2132.85	7.52
20	30	50	2004.87	2139.92	6.31
25	5	70	2053.17	2198.59	6.61
25	15	60	2071.86	2214.15	6.43
25	25	50	2091.12	2224.71	6.00
30	0	70	2137.24	2329.15	8.24
30	10	60	2187.36	2346.55	6.78
30	20	50	2203.18	2361.13	6.69

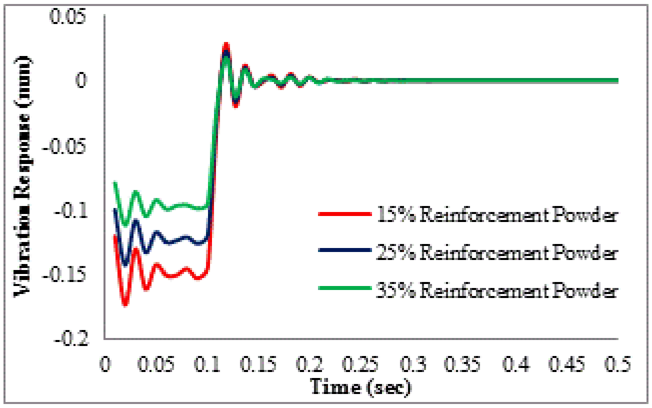
Tale VIII

Comparison for Experimental and Numerical Frequency Results, for SSSS Supported Plate Reinforcement by Various Carbon Powder Volume Fraction.

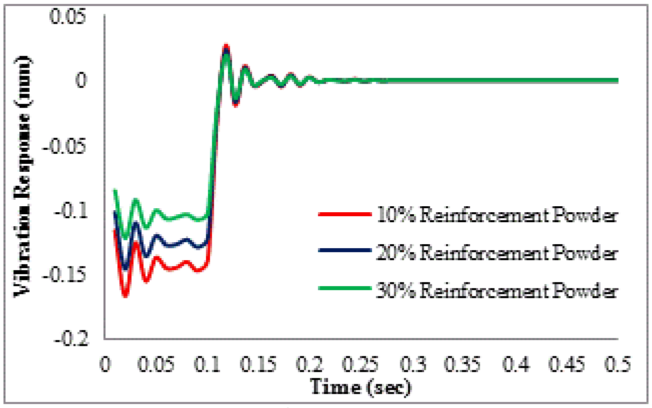
$\forall_{sh}$ (%)	$\forall_p$ (%)	$\forall_r$ (%)	Natural Frequency ω (rad/sec)		Error (%)
			Experimental Results	Numerical Results	
15	15	70	1895.57	2101.06	9.78
15	25	60	2012.28	2185.98	7.95
15	35	50	2118.34	2323.85	8.84
20	10	70	2043.57	2236.03	8.61
20	20	60	2138.34	2329.37	8.20
20	30	50	2192.37	2388.68	8.22
25	5	70	2084.37	2286.14	8.83
25	15	60	2213.68	2389.65	7.36
25	25	50	2338.72	2519.65	7.18
30	0	70	2261.14	2406.24	6.03
30	10	60	2291.37	2452.79	6.58
30	20	50	2351.35	2535.88	7.28

Therefore, the effect of different reinforcement volume fractions and powder types on the response of plate with time is shown in Figs. 8 to 11. The figures show the response for simply supported and clamped plate supported, respectively. The figures show that the response of the plate is decreased with increased volume fraction of powder reinforcement, at the same volume fraction of short fiber. Also, the effect of reinforcement short fiber volume fraction is shown in Figs. 12 and 13, where the figures show the response of plate with time for various short fiber volume fraction for simply supported and clamped plate. The figures show that the response of the plate also decreases with increasing volume fraction of short fiber. However, the percentage decrease of response occurring in reinforcement composite materials by short fiber is more than the percentage decrease of response occurring in reinforcement composite materials by powder materials. Also, the effect of powder reinforcement types on the response of the plate is shown in Figs. 14 to 21. The figures show that the response of plate reinforcement by carbon powder less than the response of plate reinforcement by glass powder.

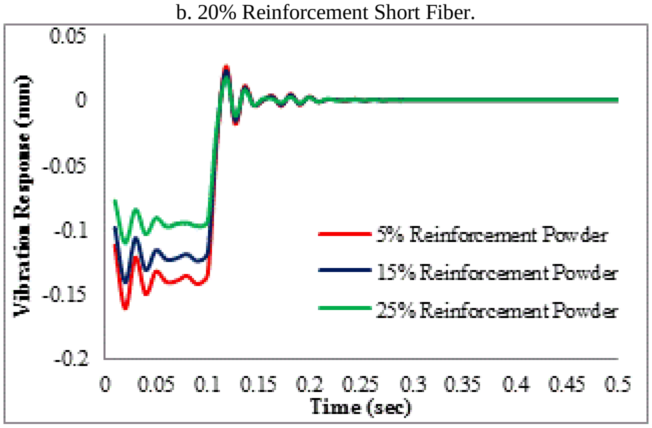
Figs. 8 to 21 show that increasing the composite materials strength leads to the decrease of the response of the plate. Therefore, given that the increase of powder or short fiber volume fraction leads to the increase of the strength of composite material plates, the response of the plate decreases. Also, given that carbon powder is stronger than glass powder, the reinforcement of carbon powder results in stronger composite materials compared with composite materials reinforced by glass power. The response of composite plate reinforcement with carbon powder less is than the response of plate reinforcement with glass powder. Moreover, given that the effect of short fiber on the mechanical properties is greater than the effect of powder reinforcement at the same volume fraction, the decrease of response due to reinforcement by short fiber is greater than the decrease of response plate reinforcement by powder materials.



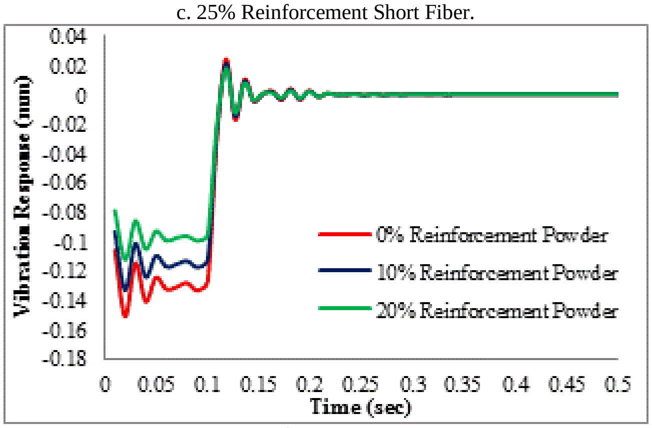
a. 15% Reinforcement Short Fiber.



b. 20% Reinforcement Short Fiber.

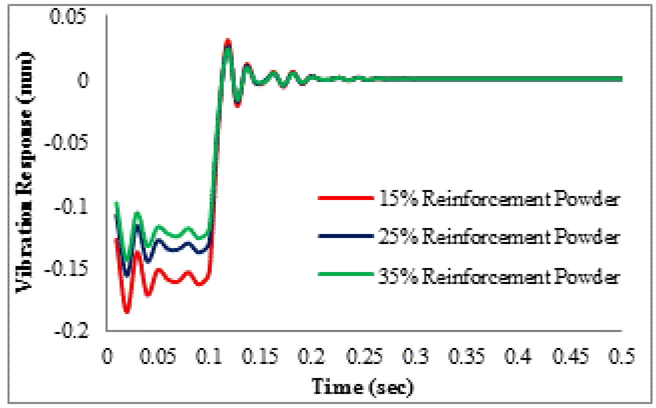


c. 25% Reinforcement Short Fiber.

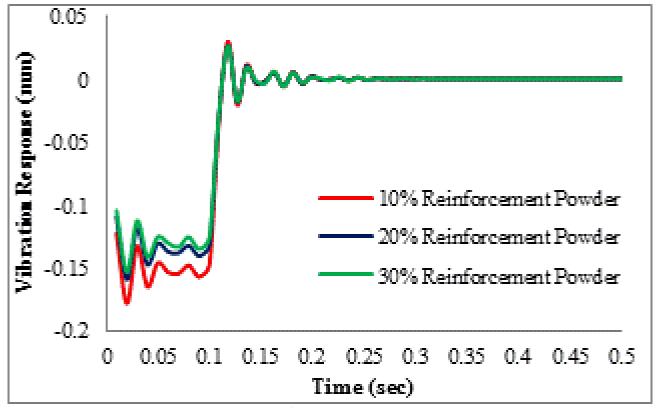


d. 30% Reinforcement Short Fiber.

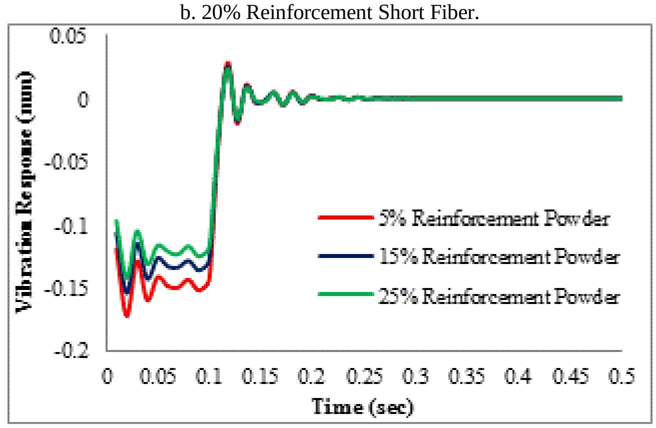
Fig. 8. Vibration Response for Clamped Supported Plate with Various Reinforcement Short Fiber and Glass Powder, with Variable Powder Reinforcement Volume Fraction at Same Short Reinforcement Fiber.



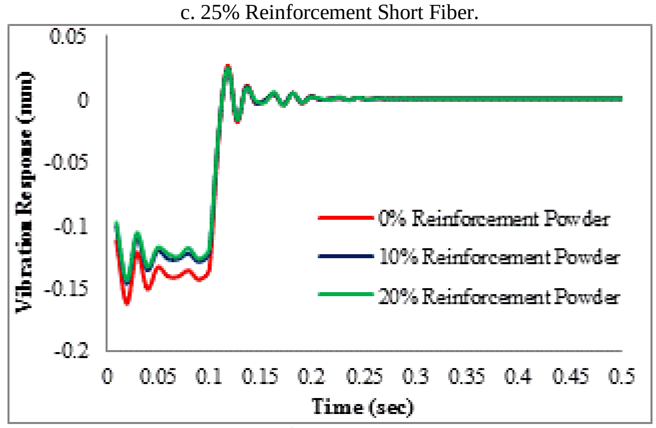
a. 15% Reinforcement Short Fiber.



b. 20% Reinforcement Short Fiber.

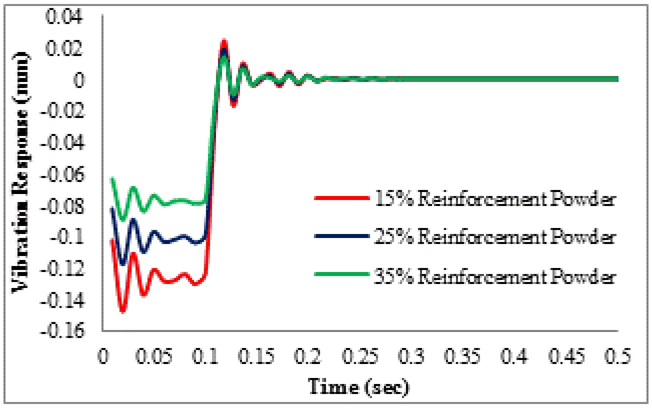


c. 25% Reinforcement Short Fiber.

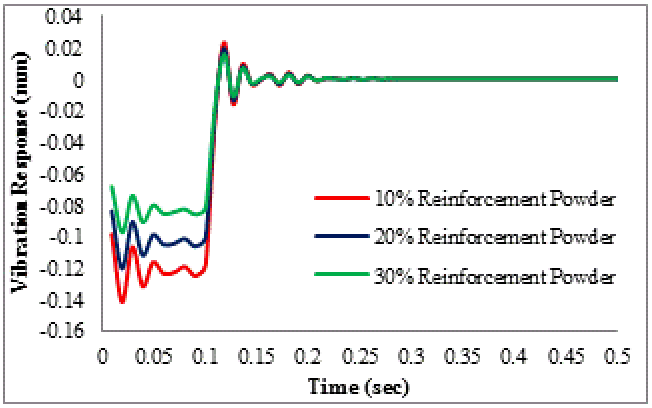


d. 30% Reinforcement Short Fiber.

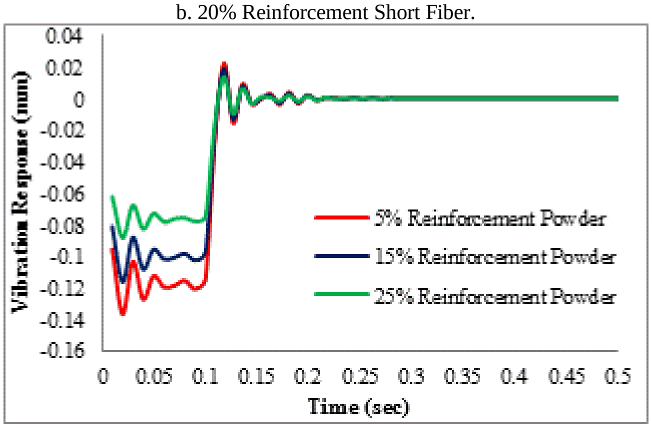
Fig. 9. Vibration Response for Simply Supported Plate with Various Reinforcement Short Fiber and Glass Powder, with Variable Powder Reinforcement Volume Fraction at Same Short Reinforcement Fiber.



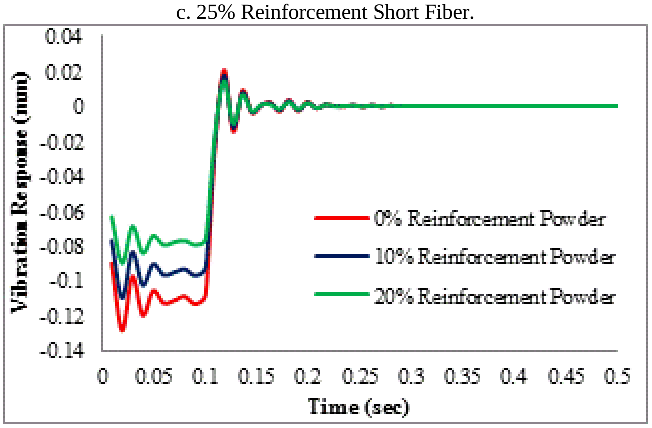
a. 15% Reinforcement Short Fiber.



b. 20% Reinforcement Short Fiber.

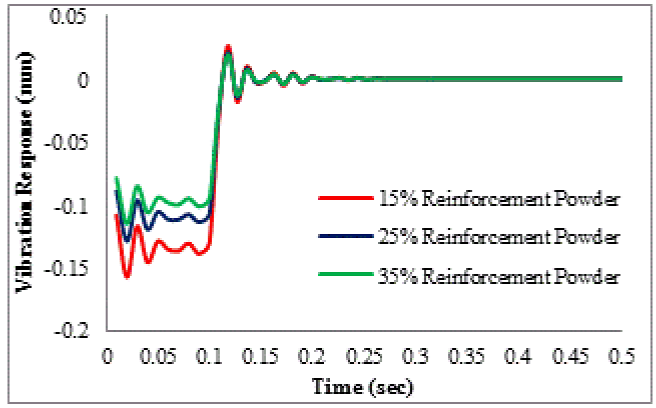


c. 25% Reinforcement Short Fiber.

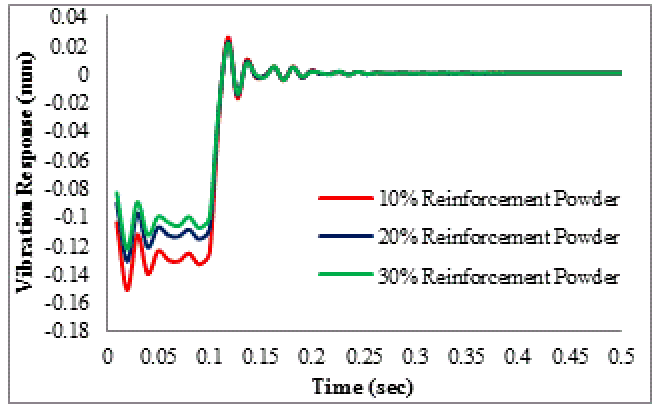


d. 30% Reinforcement Short Fiber.

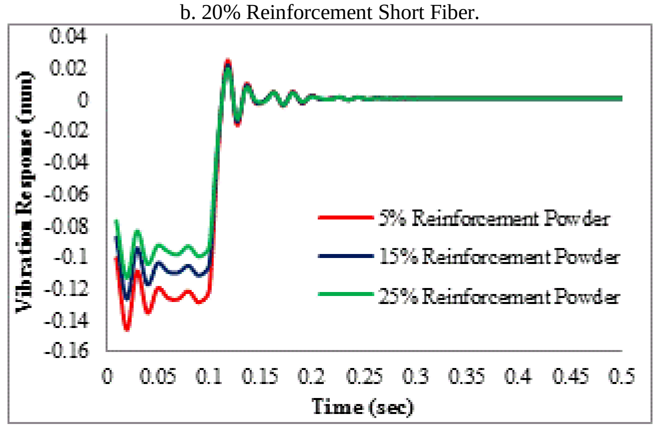
Fig. 10. Vibration Response for Clamped Supported Plate with Various Reinforcement Short Fiber and Carbon Powder, with Variable Powder Reinforcement Volume Fraction at Same Short Reinforcement Fiber.



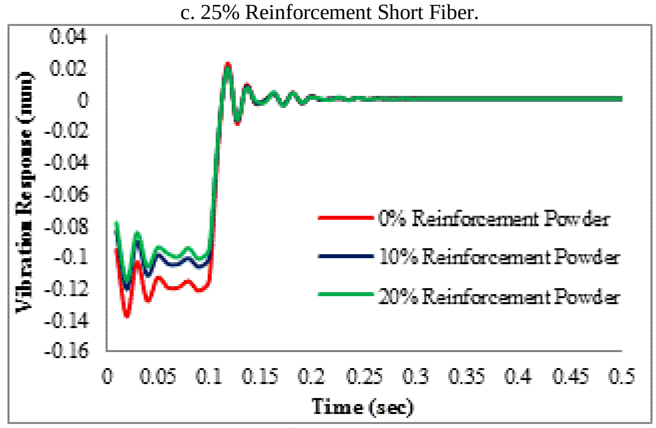
a. 15% Reinforcement Short Fiber.



b. 20% Reinforcement Short Fiber.

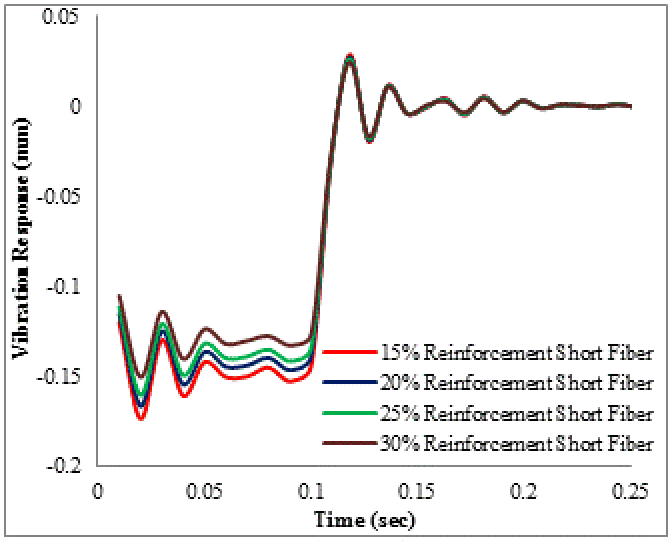


c. 25% Reinforcement Short Fiber.

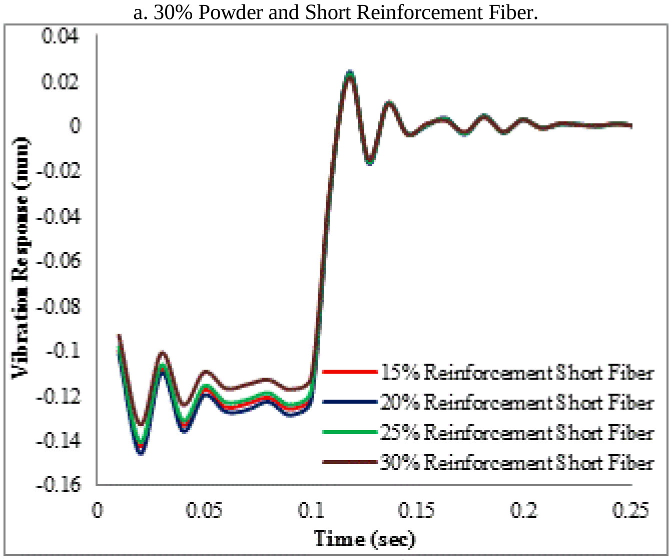


d. 30% Reinforcement Short Fiber.

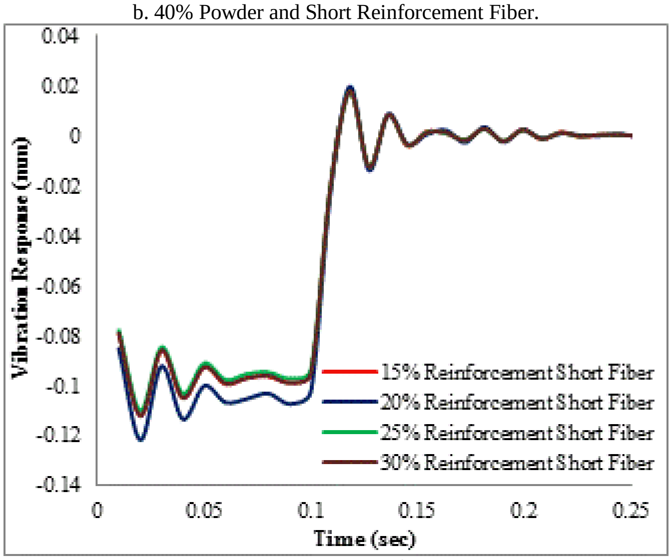
Fig. 11. Vibration Response for Simply Supported Plate with Various Reinforcement Short Fiber and Carbon Powder, with Variable Powder Reinforcement Volume Fraction at Same Short Reinforcement Fiber.



a. 30% Powder and Short Reinforcement Fiber.

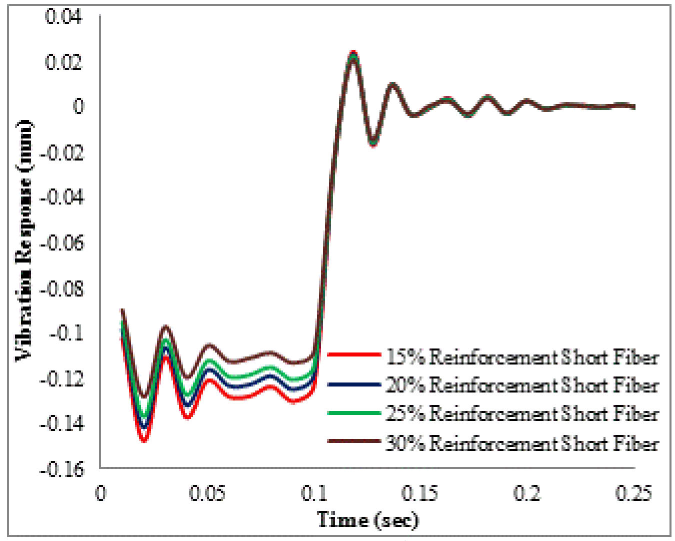


b. 40% Powder and Short Reinforcement Fiber.

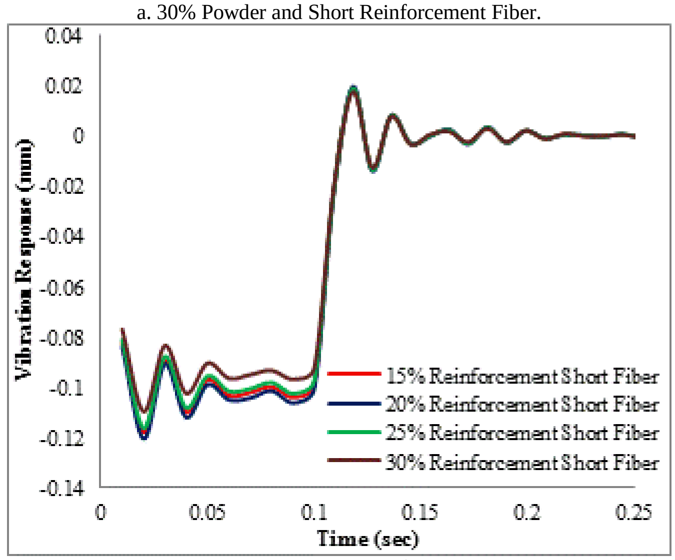


c. 50% Powder and Short Reinforcement Fiber.

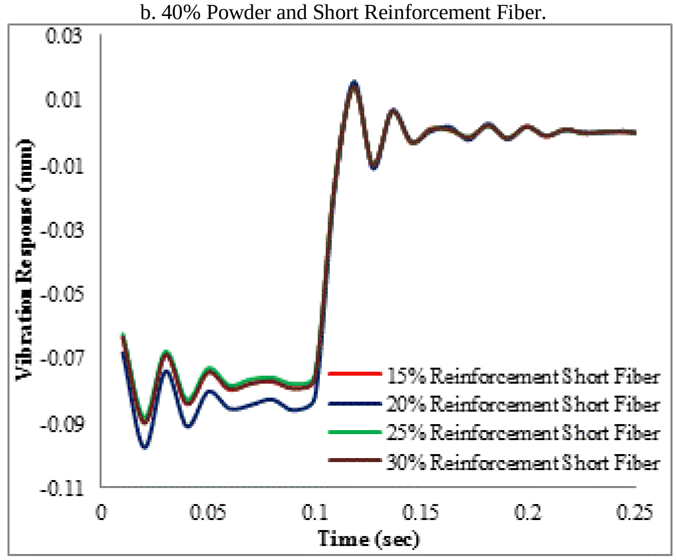
Fig. 12. Vibration Response for Clamped Supported Composite Plate with Various Volume Fraction of Glass Powder and Short Reinforcement Fiber, with Variable Volume Fraction of Powder and Short Fiber Together.



a. 30% Powder and Short Reinforcement Fiber.

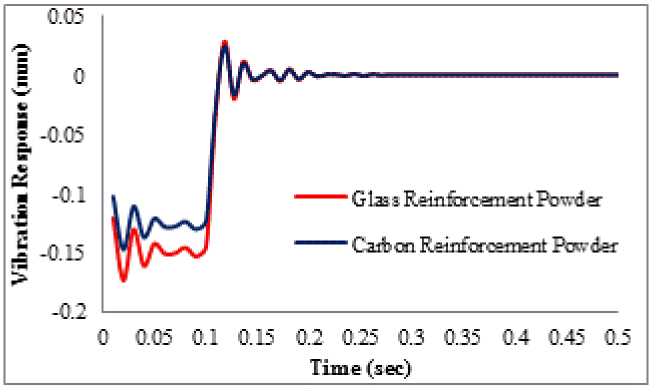


b. 40% Powder and Short Reinforcement Fiber.

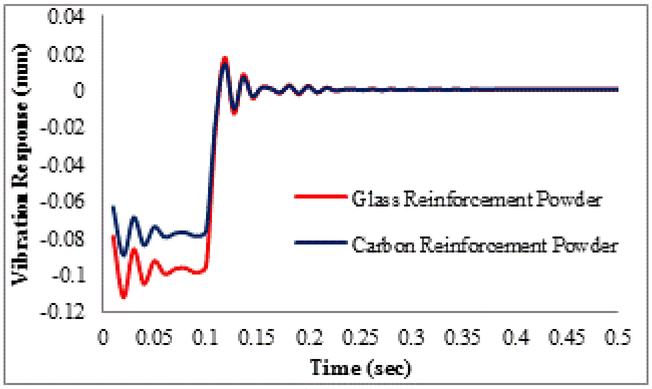


c. 50% Powder and Short Reinforcement Fiber.

Fig. 13. Vibration Response for Clamped Supported Composite Plate with Various Volume Fraction of Carbon Powder and Short Reinforcement Fiber, with Variable Volume Fraction of Powder and Short Fiber Together.

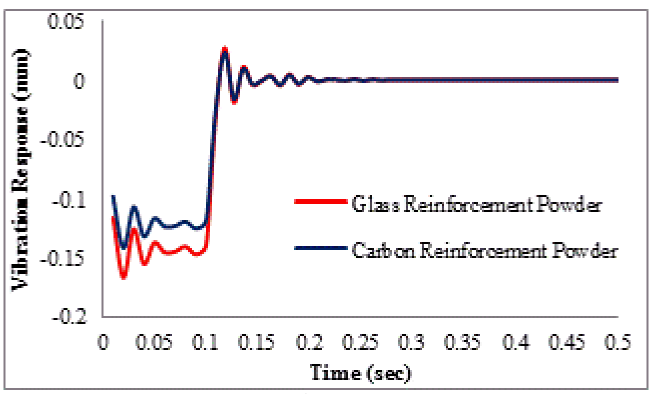


a. 15% Reinforcement Powder

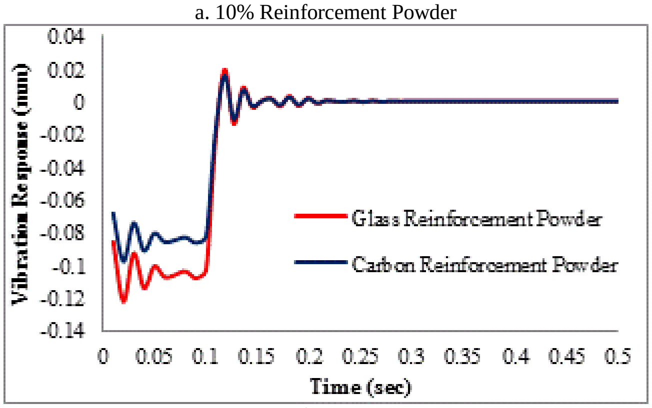


b. 35% Reinforcement Powder

Fig. 14. Comparison of Response for CCCC Plate with Glass or Carbon Reinforcement Powder and 15% Short Fiber.

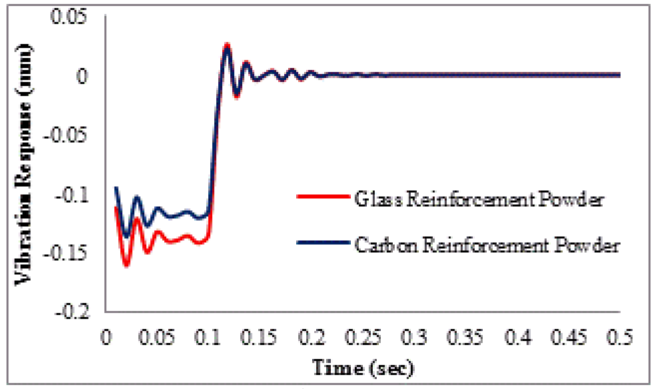


a. 10% Reinforcement Powder

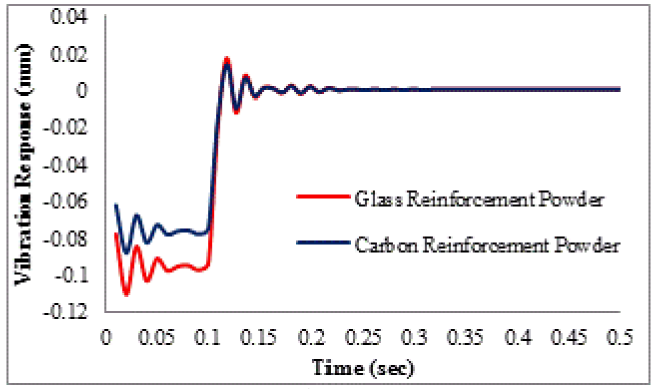


b. 30% Reinforcement Powder

Fig. 15. Comparison of Response for CCCC Plate with Glass or Carbon Reinforcement Powder and 20% Short Fiber.

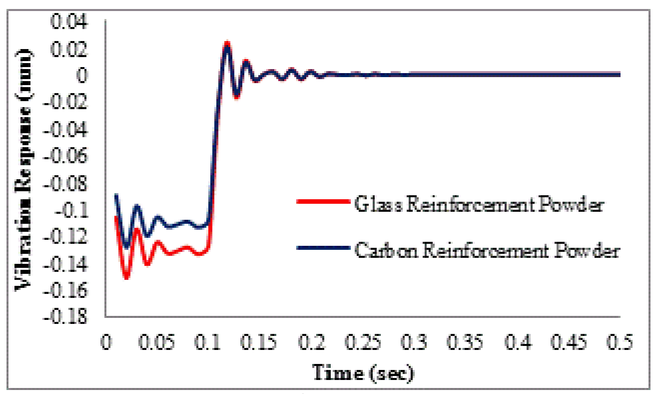


a. 5% Reinforcement Powder

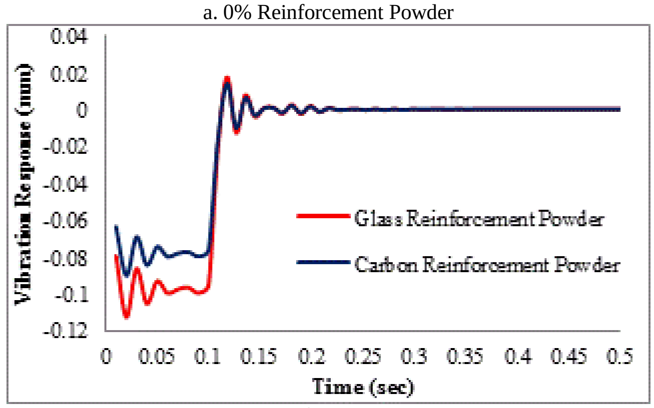


b. 25% Reinforcement Powder

Fig. 16. Comparison of Response for CCCC Plate with Glass or Carbon Reinforcement Powder and 25% Short Fiber.

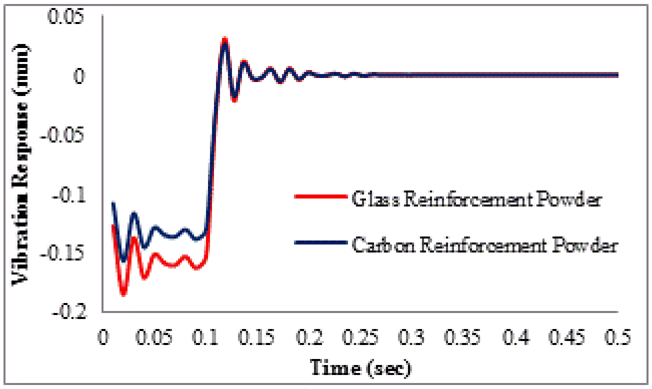


a. 0% Reinforcement Powder

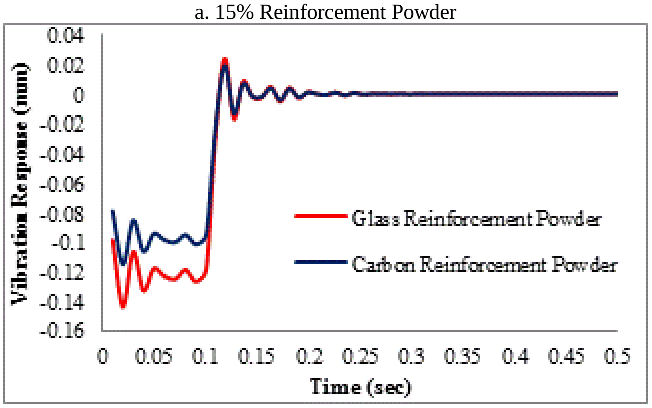


b. 20% Reinforcement Powder

Fig. 17. Comparison of Response for CCCC Plate with Glass or Carbon Reinforcement Powder and 30% Short Fiber.

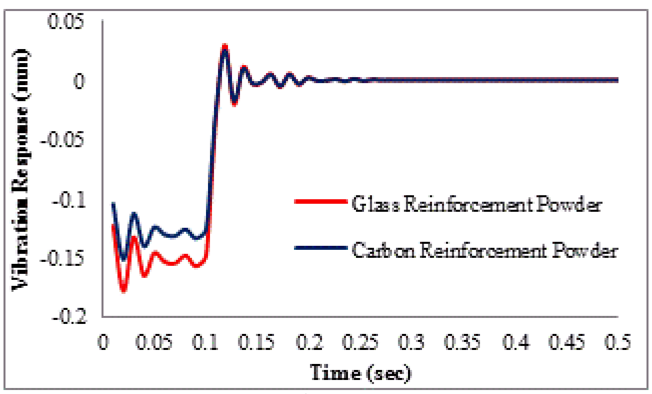


a. 15% Reinforcement Powder

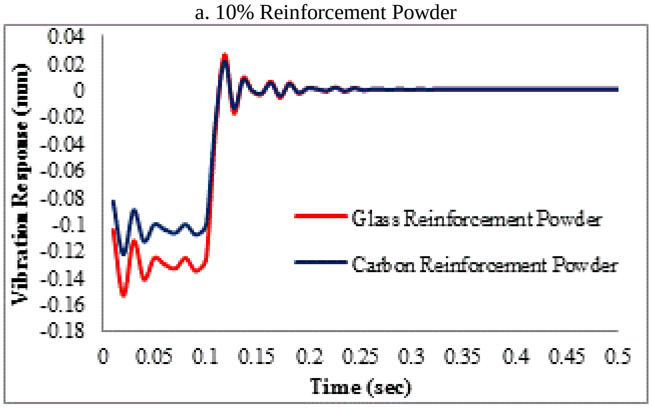


b. 35% Reinforcement Powder

Fig. 18. Comparison of Response for SSSS Plate with Glass or Carbon Reinforcement Powder and 15% Short Fiber.

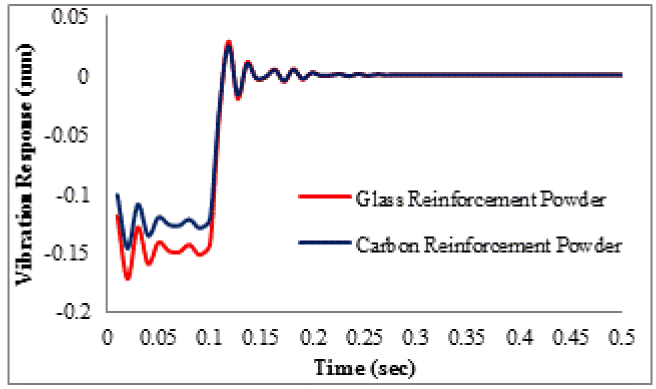


a. 10% Reinforcement Powder

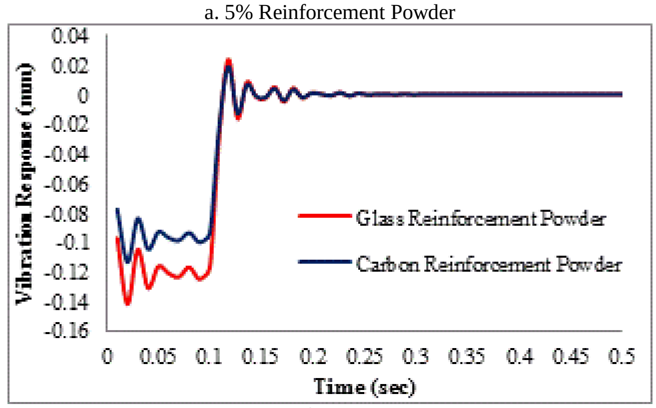


b. 30% Reinforcement Powder

Fig. 19. Comparison of Response for SSSS Plate with Glass or Carbon Reinforcement Powder and 20% Short Fiber.

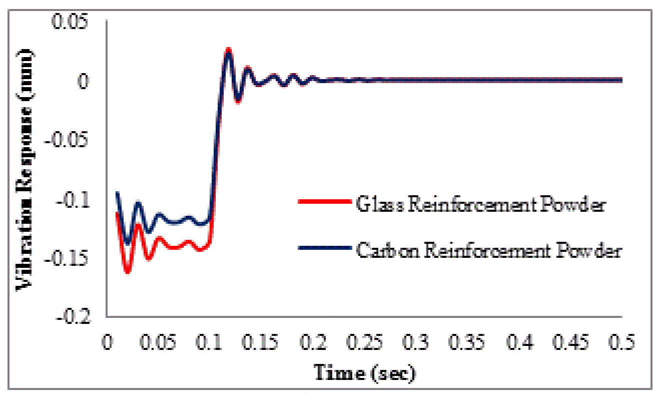


a. 5% Reinforcement Powder

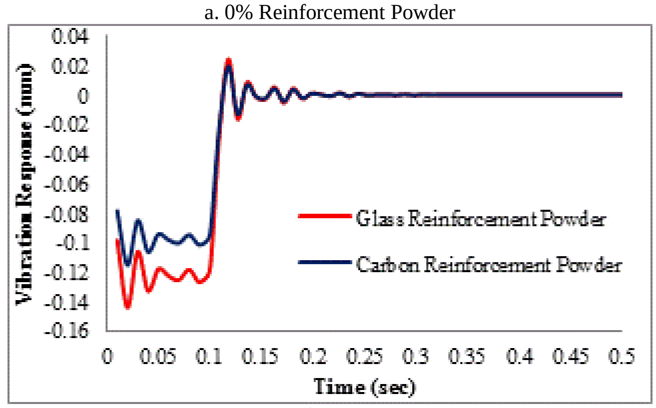


b. 25% Reinforcement Powder

Fig. 20. Comparison of Response for SSSS Plate with Glass or Carbon Reinforcement Powder and 25% Short Fiber.



a. 0% Reinforcement Powder



b. 20% Reinforcement Powder

Fig. 21. Comparison of Response for SSSS Plate with Glass or Carbon Reinforcement Powder and 30% Short Fiber.

V. CONCLUSION

The following conclusions are listed from the presented experimental and numerical work of mechanical properties and dynamic characterizations of hyper composite materials plate:

1. The experimental work is a good tool to investigate the effect of powder reinforcement types and volume fracture on mechanical properties of hyper composite materials.
2. The experimental work is a good tool to investigate the dynamic characterization as a natural frequency of hyper composite plate, with various powder parameters effect, compared with numerical work of natural frequency.
3. The numerical work is a good tool to investigate the dynamic behavior and dynamic response under transient loading of isotropic hyper composite plate with various powder reinforcement parameter influences and different boundary conditions of the plate.
4. The comparison between experimental and numerical investigation of natural frequency with different powder parameter effects give a good agreement between the two techniques used, with a maximum error of approximately 9.78.
5. Increasing the volume fraction for reinforcement powder with same volume fraction of reinforcement short fiber results in the increase of the mechanical properties, strength, and stiffness of isotropic hyper composite materials. Therefore, the increase of powder volume fraction causes the decrease of response of isotropic hyper composite plate.
6. The effect of short reinforcement fiber is greater than the effect of powder reinforcement. Therefore, increasing the short reinforcement powder content improves the mechanical and dynamic characterization more than increasing the powder reinforcement.
7. Using high-strength powders improves the mechanical properties and dynamic behaviors, such as natural frequency and response of composite plate. Therefore, the modulus of elasticity and natural frequency of composite plate reinforced with carbon powder is better than the composite plate reinforced with glass powder.
8. The increase in the fixed boundary for the plate increases the stiffness of the composite plate; therefore, the clamped boundary conditions plate is best for supported plate, and the natural frequency of the plate is greater than the natural frequency for plate with other support. Moreover, the response of the plate with clamped support is less than the response of the plate with other supports.

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