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Experimental investigation for powder reinforcement effect on mechanical properties and natural frequency of isotropic hyper composite plate with various boundary conditions

Abdulkareem Abdulrazzaq Alhumdany[1], Muhannad Al-Waily[2], Mohammed Hussein Kadhim[1]

[1] Mechanical Engineering Department, College of Engineering, Karbala University, Ministry of Higher Education & Scientific Research, Karbala, Iraq.
[2] Mechanical Engineering Department, Faculty of Engineering, Al-Kufa University, Ministry of Higher Education & Scientific Research, Najaf, Iraq.

Abstract
In this research eleven samples of composite plate materials was made with different volume fraction of the components to produce an isotropic hyper composite materials composed of three materials, epoxy resin and two reinforcements: short glass fiber and glass powder. The composite structure was studied to estimate the mechanical properties (modulus of elasticity E, modulus of rigidity G, and Poisson's ratio υ) and the natural frequency experimentally. The experimental procedure includes the tensile test machine with the load capacity (0-540KN) and vibration test machine. The effect of volume fraction for different aspect ratios of plate were studied with six boundary conditions (Simply supported along all edges (SSSS), Simply-Free Support Edges (SSFF), Clamped-Free Support Three Edges (CFFF), Simply-Clamped Supported Edges (SSCC), Clamped-Free Supported Edges (CCFF), and Clamped Support along all edges (CCCC). The results showed that the modulus of elasticity of hyper composite of short glass fiber and glass powder reinforcement and epoxy resin material was increased with the increase of short fiber volume fraction ($\forall_{sf}$%). But the yield stress was decreased with the increase of powder volume fraction ($\forall_{p}$%) of hyper composite material. The natural frequency of isotropic hyper composite materials plate was increased with the increase of short fiber volume fraction were the volume fraction of short fiber ($\forall_{sf}$= 40%) at samples 4 and 8, maximum natural frequency had occur. It was observed that the natural frequency for aspect ratio (AR=1) was higher than that for aspect ratio (AR=1.5). The Experimental mechanical properties and natural frequency of composite plate with various volume fraction results are compare with results of other researcher and the comparison shown the good agreement between presented results and results of research, Muhannad Al-Waily [7], where, the maximum error of mechanical properties compared about (8.77%) and maximum error for natural frequency compared about (10.48%).

Keywords: Hyper composite materials; Isotropic composite plate; Natural frequency; Mechanical properties, Experimental vibration, Powder effect.

1. Introduction

The first attribute of composite materials that has been encouraged in the engineering applications was their light-weight because of the positive effects on efficiency, noise and vibrations. Composite materials are attaining both high strength and high stiffness when compared with metallic materials, especially in the weight sensitive aerospace and aircraft engineering .

The last few decades witness a major effort to develop composite material systems and analyze and design structural components made from them [1]. At present composite materials refer to materials having strong fibers (continuous or discontinuous) surrounded by a weaker matrix material. The matrix works to distribute the fibers and also to transmit the load to the fibers. The bonding between fibers and matrix is created in the manufacturing phase of the composite material. This has essential influence on the mechanical properties of the composite material (elastic properties: modulus of elasticity E, modulus of rigidity G, and Poisson's ratio υ), [2].

The analysis of natural frequency of composite plate/shell plays an important role in the design of structure in mechanical, civil, and aerospace engineering applications [1]. Composite materials consist of two or more materials which together produce desirable properties that cannot be achieved with any of the components alone, [3]. The desirable characteristics of most fibers are high strength, high stiffness, and comparatively low density. Glass fibers are the mostly used ones in medium performance composites because of their high tensile strength and low cost .

Many studies were performed to examine the Analysis of natural frequency and properties of composite plate, as,

Parsuram Nayak, [4], presents a combined experimental and numerical study of free vibration of woven fiber Glass/Epoxy composite plates. He determined experimentally Elastic parameters and natural frequencies of woven fiber Glass/Epoxy cantilevered composite plates and compared with the developed computer program based on FEM, and determined the natural frequency and mode shape of the plate using ANSYS package. The present experimental value and program result compared with ANSYS package. The experimental frequency data is in fair agreement with the program computation. The Percentage of error between experimental value and ANSYS package is within 15%.

Itishree Mishra andShishir Kumar Sahu, [5], presented a study involves extensive experimental works to investigate the free vibration of woven fiber Glass/Epoxy composite plates in free-free boundary conditions. the specimens of woven glass fiber and epoxy matrix composite plates were manufactured by the hand-layup technique and determined Elastic parameters of the plate experimentally by tensile testing of specimens using Instron 1195. An experimental investigation is carried out using modal analysis technique with Fast Fourier Transform Analyzer, PULSE lab shop, impact hammer and contact accelerometer to obtain the Frequency Response Functions. Also, this experiment is used to validate the results obtained from the FEM numerical analysis based on a first order shear deformation theory. The effects of different geometrical parameters including number of layers, aspect ratio, and fiber orientation of woven fiber composite plates are studied in free-free boundary conditions in details .

Muhsin J. Jweeget. Al, [6], presented an experimental and theoretical study of composite materials reinforcement fiber types . The experimental work and the theoretical investigation covered the study of modulus of elasticity for long, short, woven, powder, and particle reinforcement of composite materials types with difference volume fraction of fiber. They study of effect of fiber and resin types and the effect of volume fraction of fiber and matrix materials on modulus of elasticity for composite materials. Their results showed good agreement between experimental and theoretical study for different types of composite materials. They showed that the best modulus of elasticity for reinforcement composite is unidirectional fiber types in longitudinal direction and the woven reinforcement fiber types for transverse direction.

Muhannad Al-Waily, [7], suggested analytical solution for dynamic analysis of hyper composite plate combined from two reinforcement fiber, mat and powder or short and powder, with polyester or epoxy resin matrix. The theoretical study of hyper composite plate evaluated the effect of the volume fraction and types of reinforcement fiber and matrix resin. The suggested analytical solution include evaluation of the mechanical properties of isotropic hyper composite material plate, as modulus of elasticity and modulus of rigidity in addition to Poisson's ratio. The results show the natural frequency increasing with the increasing of reinforcement fiber and with the increasing of strength reinforcement fiber or resin matrix. A comparison made between analytical results from theoretical solution of general equation of motion of hyper composite plate, with numerical solution, by ANSYS program Ver. 14, results, given good agreement with maximum error about 1.8% and minimum error about 0.75%.

This work presents an experimental study of modal testing of different volume fractions of short reinforcement fiber, reinforcement powder, and resin matrix hyper composite plates. A program based on FEM is developed. The experimental results of the program have been compared with that obtained from the finite element analysis and theoretical Analysis results. Elastic properties of the plates determined from tensile test method. Variation of natural frequency with different parameter is studied as different aspect ratios and boundary conditions supports.

2. Experimental study

The experimental study of composite materials included study of mechanical properties of different types of composite materials with different volume fractions short reinforcement glass fiber, glass reinforcement powder, and epoxy resin.

2.1 The density evaluation

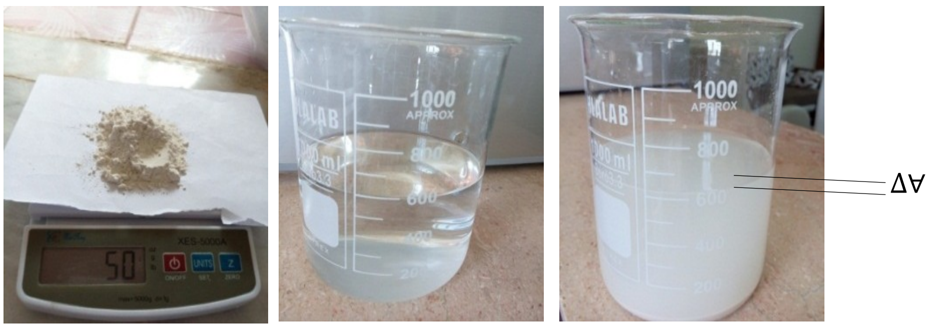
To predict the weight of composite components, the density of each component (reinforcement glass fiber, glass powder, and polyester resin materials) must be known. The tools used are,

- Dial Phials
- Sensitive Libras.

The density can be calculated by divide the material weight on the difference in water volume. As follows:

$$density = \rho = \frac{Material\ \ Weight}{(\nabla\forall) Water} \quad (1)$$

where, $\nabla\forall$ change of water volume after adding the material to water. and ρ is density of short fiber, powder, or resin materials, (Kg/m^3). As shown in Figure 1. And, The weight used fiber and resin materials are show in Table 1.



Weight of the powder   Volume of water   Water with powder

Figure 1. Steps to evaluate density of glass powder used

Table 1. Density of glass fiber and polyester resin materials

Materials	Weight of Fiber (g)	Δ∀ (mL)	Density (kg/m^3)
Short Fibers	150	75	2000
Glass powder	50	20.8	2400
epoxy	240	200	1200

2.2 Composite plates manufacturing processes

To test the mechanical properties of Composite Materials the samples are manufactured with the dimensions: $32cm$ width, 44 cm length, 5 mm thickness, in the laboratory with the standard conditions. The following steps composite materials manufacturing as shows in Figure 2. And the produced composite plates were shown in Figure 3.


1- Upper wood block painted with insulated layer


2- Frame of glass on lower wood block


3- Fixing the glass frame on the lower wood block


4- Painting the insulated layer on the wood block and glass frame


5- Weighting of resin, powder and fibers


6- Mixing of resin and powder


7- Putting the resin mixture on fibers


8- Another layer of fibers


9- Putting the upper wood block


10- Pressing upper block on lowers by a heavy weights fibers

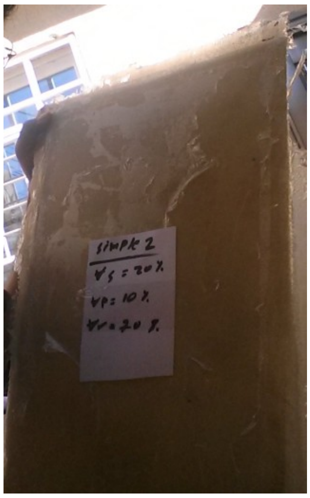

11- Resulting composite plate

Figure 2. Steps of manufacturing the composite plates

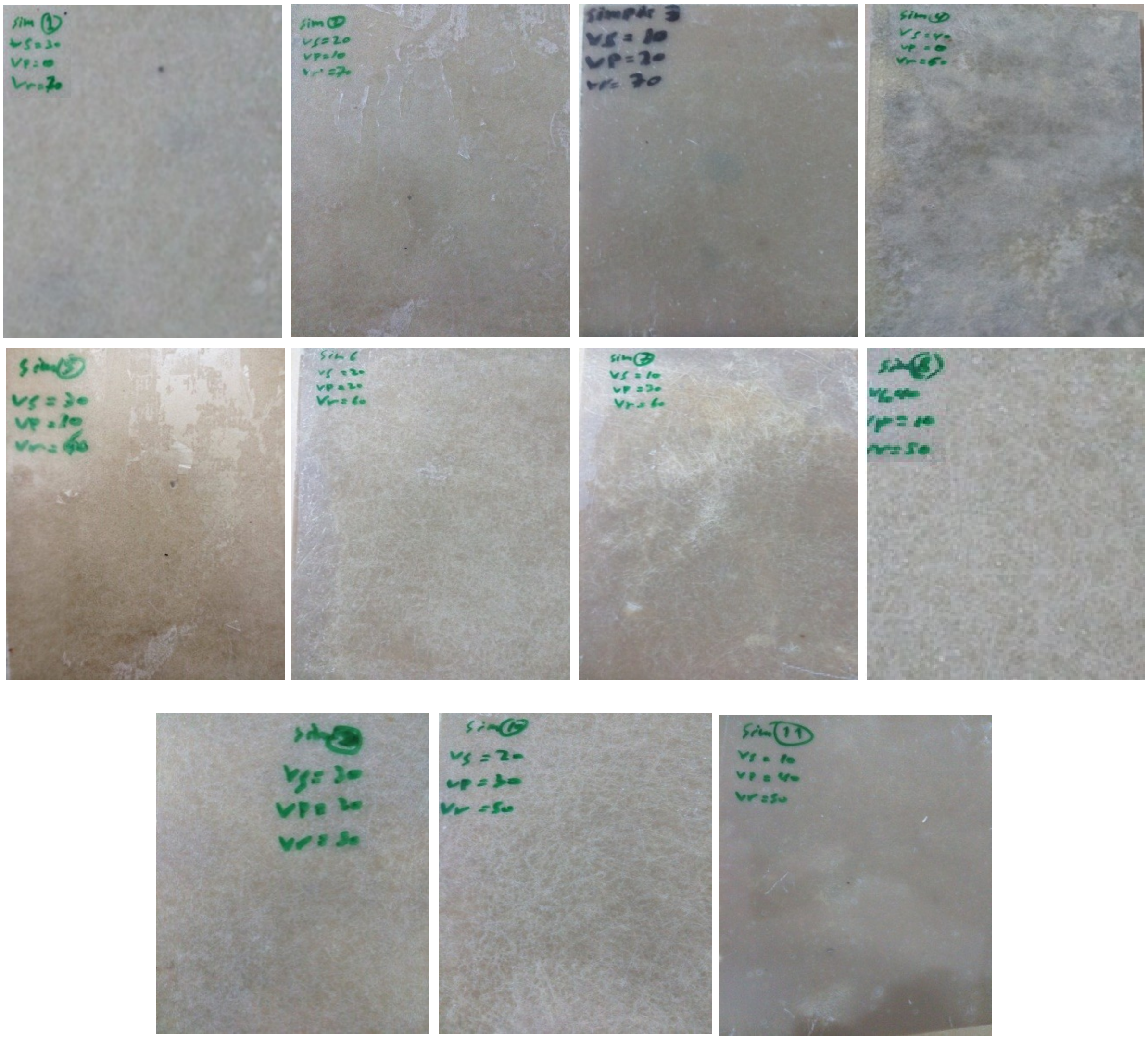


Figure 3. The final composite plates

2.3 Tensile test samples of composite materials

The tensile experimental test of composite materials includes the determination of the modulus of elasticity for composite materials of short, and powder reinforcement fiber and polyester resin in various volume fractions of fiber and resin materials.

as ASTM Number (D3039/D03039M) [8], the shape and dimensions of tensile test sample selected as shown in Figure 4, as, Length of sample = 20cm, Width of sample = 3cm, Thickness of sample = 5mm. Three samples are divided to test it for each type of composite plate. As shown in Figure 5.

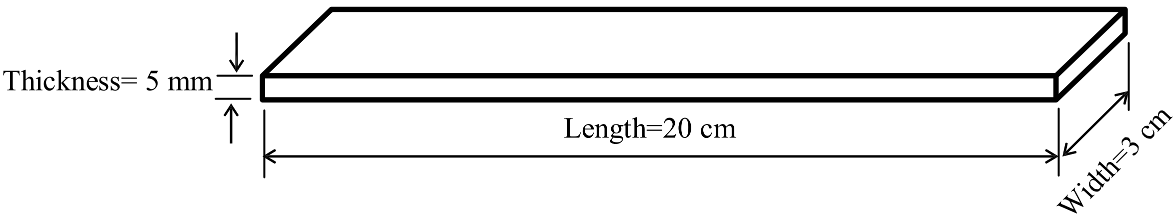


Figure 4. Shape and dimensions of tensile test sample

Then, the tensile test properties of composite materials are defined by testing the samples by tensile machine shown in Figure 6. The tensile test machine used to evaluate modules of elasticity and yield stress for different reinforcement composite types with the load capacity (0-540KN). The resulting sample after tensile test is shown in Figure 7.

The environmental conditions of the laboratory that the tensile test done in it are (Temperature = 25 C^0 and Moisture = 40%). The results that obtained from the tensile test for the specimens are shown in Figure 8.

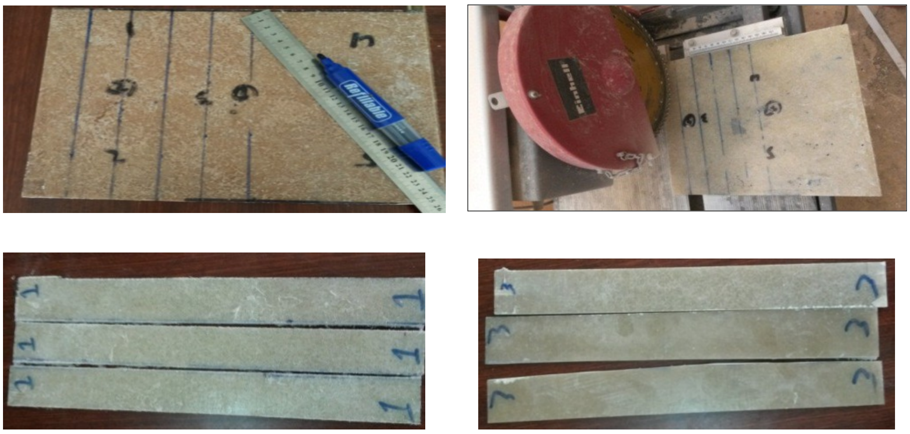


Figure 5. Tensile test samples preparing

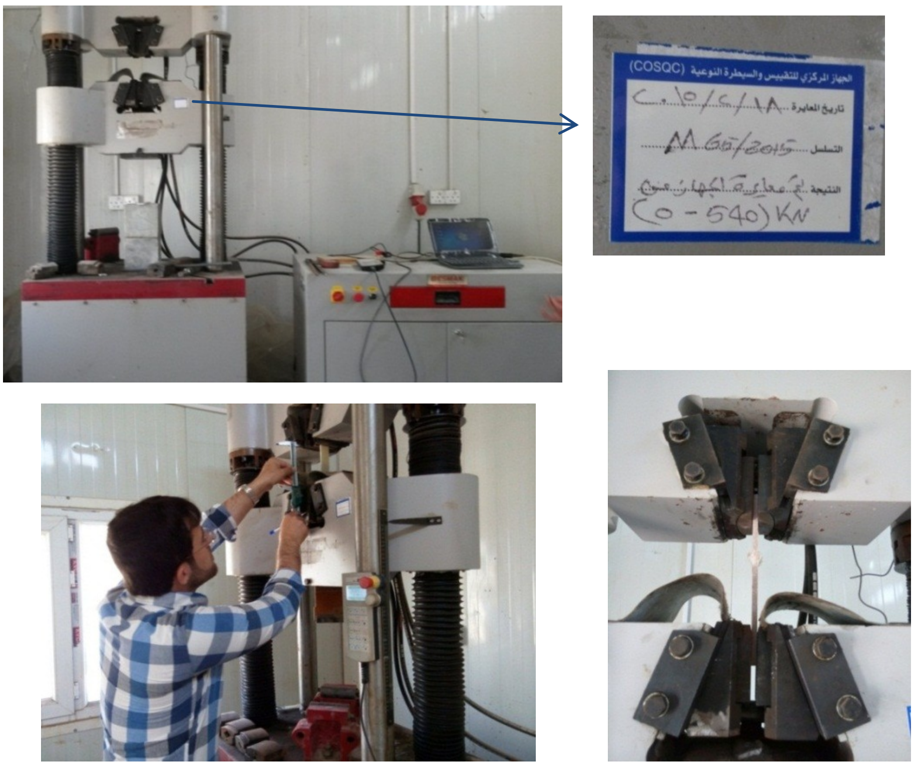


Figure 6. Tensile test machine and processes of test

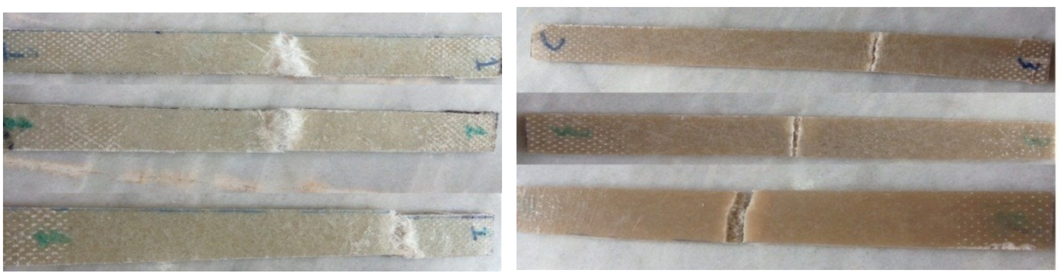


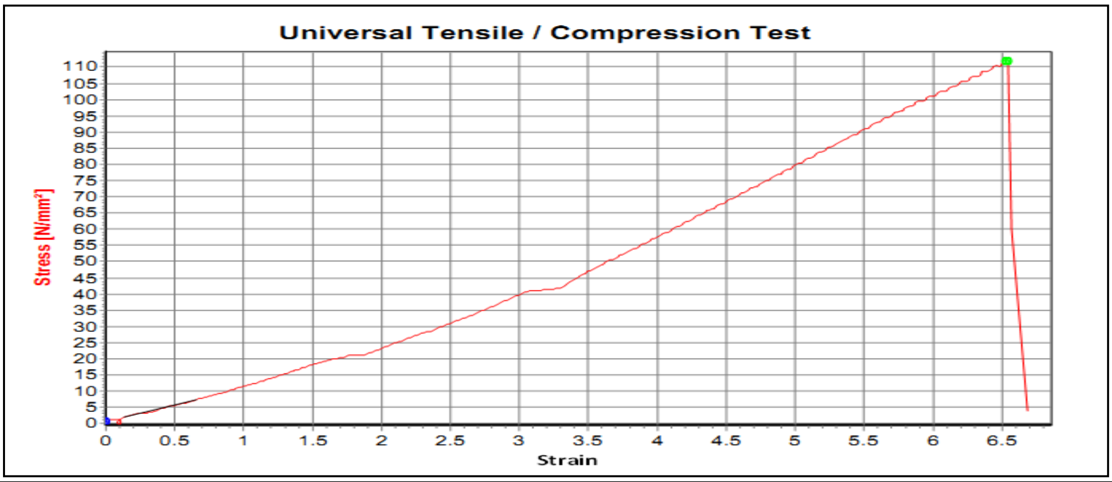
Figure 7. Tensile test samples after testing

Operator: Jafar
Material: 12mm rebar
File name: 1.MVL

Date: 25.04.2015
Time: 11:22

Test parameters

Test:	Universal Tensile / Compression Test
UTM type:	Machine
Load cell:	Force
Extensometer:	XHead
Clamping device:	-- 3 --
Test area:	Lower test area
Sample dimensions:	
Length data:	Le = 50 mm; Lc = 100 mm
Test rates:	V0 = 5 mm/min; V1 = 50 mm/min; V2 = 50 mm/min
Rate switch points:	F0 = 0.5 MPa; U12 = 8 MPa
End of test criterions:	Force = 150 kN; dF = 70 %



Test results

	OK	Date	Time	Comm.1	Comm.2	Max. Force kN	Max. Stress MPa	Peak Disp. mm	Breaking Force kN
2	x	25.04.15	11:22			15.39	111.94	6.52	15.39

		Breaking Stress MPa	Breaking Disp. mm	M N/mm²
2		111.94	6.54	518.14

Statistics n = 2

	Max. Force kN	Max. Stress MPa	Peak Disp. mm	Breaking Force kN	Breaking Stress MPa	Breaking Disp. mm
Average	7.70	61.07	6.52	7.69	57.77	6.54
Standard deviation	10.87	71.94	0.00	10.88	76.61	0.00
Variation coeff.	141.23	117.80	0.00	141.36	132.61	0.00

Test&Motion Page 1 of 2

Operator: Jafar
Material: 12mm rebar
File name: 1.MVL

Date: 25.04.2015
Time: 11:22

	M N/mm²
Average	518.14
Standard deviation	0.00
Variation coeff.	0.00

Figure 8. Tensile test result of short reinforcement glass fiber, glass reinforcement powder, and epoxy resin composite (sample 5)

2.4 Vibration test of plate samples

The vibration test involves studying the fundamental natural frequency of the composite plate samples. The made of vibration plate sample are shown in Figure 2. The dimensions of vibration plate samples used are, as shown in Figure 9,

$$a_t = a + 5\ cm\ (edges), b_t = b + 5\ cm\ (edges) \quad (2)$$

For, $a = 25\ , a_t = 25 + 5\ cm\ (supported) = 30$

$$h = 5\ mm, \text{ and different aspect ratio, } (b/a) = 1,1.5 \quad (3)$$

Then,

$$b_t = b + 5\ cm\ (supported) = 37.5 + 5\ cm\ (supported) = 42.5\ cm \quad (4)$$

where, a, b, h are length and width, thickness of plate, respectively.
And, a_t, b_t are the total experimental length, width of plate respectively.

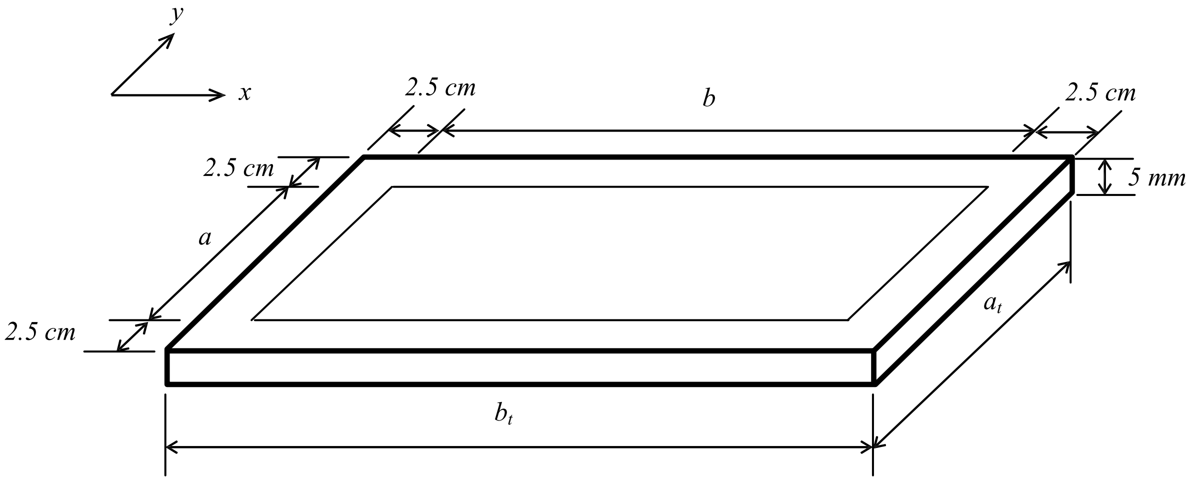


Figure 9. Shape and dimensions of vibration test sample

The vibration plate samples studied are supported with different boundary conditions SSSS, SSCC, SSFF, CCFF, CFFF,CCCC as shows in the Figure 10, of different aspect ratios, (b/a=1, 1.5)

1. Simply supported along all edges (SSSS)
2. Simply-Free Support Edges (SSFF)
3. Clamped-Free Support Three Edges (CFFF)
4. Simply-Clamped Supported Edges (SSCC)
5. Clamped-Free Supported Edges (CCFF)
6. Clamped supported along all edges (CCCC)

The flowchart in Figure 11, shows the sketch of the structure rig test. Vibration structure rig shown in Figure 12, is used to evaluate the fundamental natural frequency with different parameters and boundary condition.

The machine and other parts used in the vibration structure rig are shows in Figure 13 (a, b, c, d, e) . The fixed plate sample and accelerometer part and make impact location point on the plate shown in Figure 14, and the vibration test composite Plates with different boundary conditions are shown in Figures 15.

The vibration test machine and rig involved the following parts:

1. Structure to support the plate sample, made of steel plate with (10 mm) thickness, and other dimensions as shown in Figure 13 (a).
2. Digital storage oscilloscope, model (ADS 1202CL+) and serial No.01020200300012 as shown in Figure13 (b), with the information; maximum frequency (200 MHz), maximum read of sample per second (500 MSa/s), FFT spectrum analysis and two input channels.
3. Amplifier, type (480E09), as shown in Figure 13 (c). The amplifier measures the response signal from accelerometer and gives output signal to the digital storage oscilloscope.
4. Impact hammer tool, model (086C03) (PCB Piezotronics vibration division), as shown in Figure 13 (d), with the information about measurement range (2224 N), resonant frequency (≥ 22 KHz), excitation voltage (20 to 30 VDC), constant current excitation (2 to 20 mA), output bias voltage (8 to 14 VDC), discharge time constant (2000 sec), hammer mass (0.16 kg), head diameter (1.57cm), tip diameter (0.63 cm), and hammer length (21.6 cm).
5. Accelerometer, model (352C68), as shown in Figure 13 (e), with The information regarding this accelerometer are: sensitivity (10.2 mV/(m/s^2)), measurement range (491 m/s^2), mounted resonant frequency (≥ 35 kHz), non-linearity (≤ 1%).
6. Two positions indicated on the tested plates: central and lateral to apply five impulses to excite the plate on each position by an impact hammer. As shown in Figure 16.

Impulse force test hammer is adapted for adapts FFT analysis of structure behavior testing. Impulse testing of the dynamic behavior of mechanical structure involves striking the test object with the force-instrumented hammer, and measuring the resultant motion with an accelerometer. Then analysis of response signal is read from digital storage oscilloscope to FFT function by using sig-view program to transform from t-domain into ω-domain and get the fundamental natural frequency of the plate Figure 17.

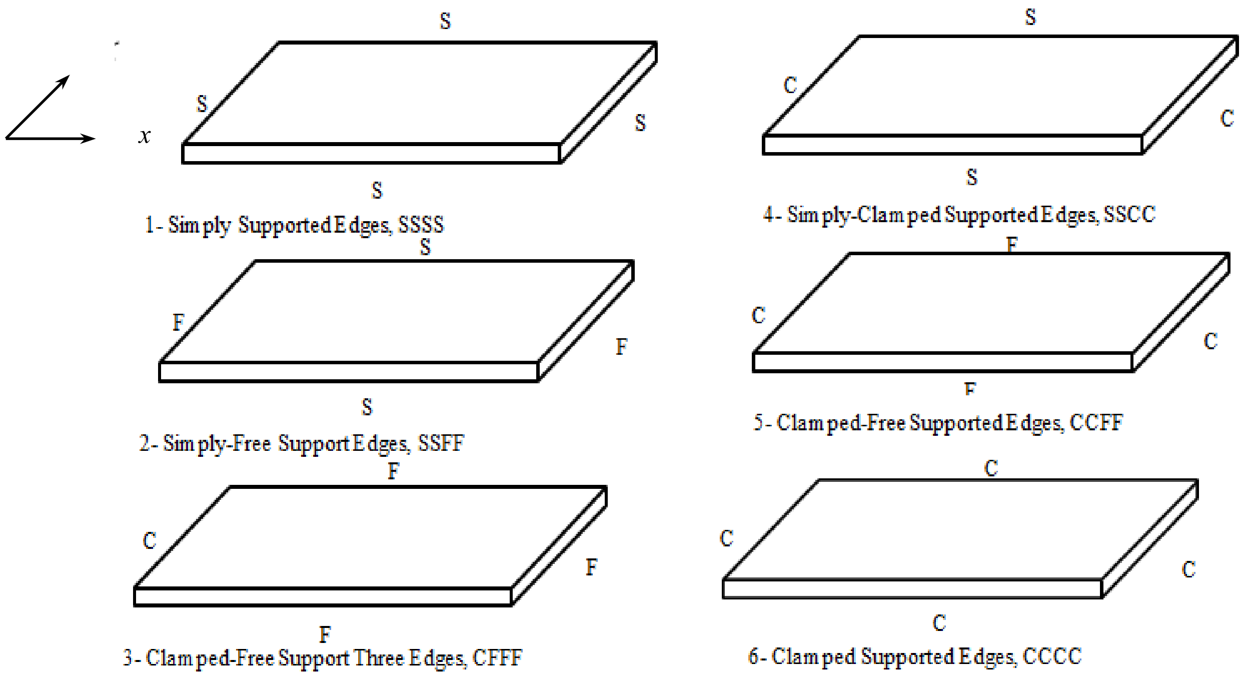


Figure 10. Different boundary conditions of vibration test plate

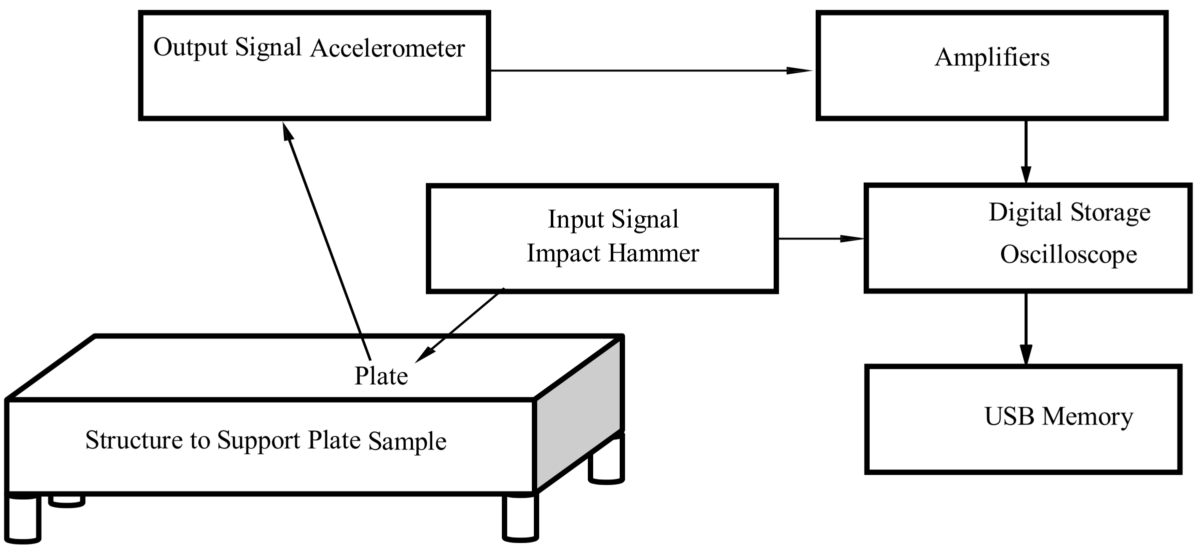


Figure 11. Flowchart of vibration structure rig

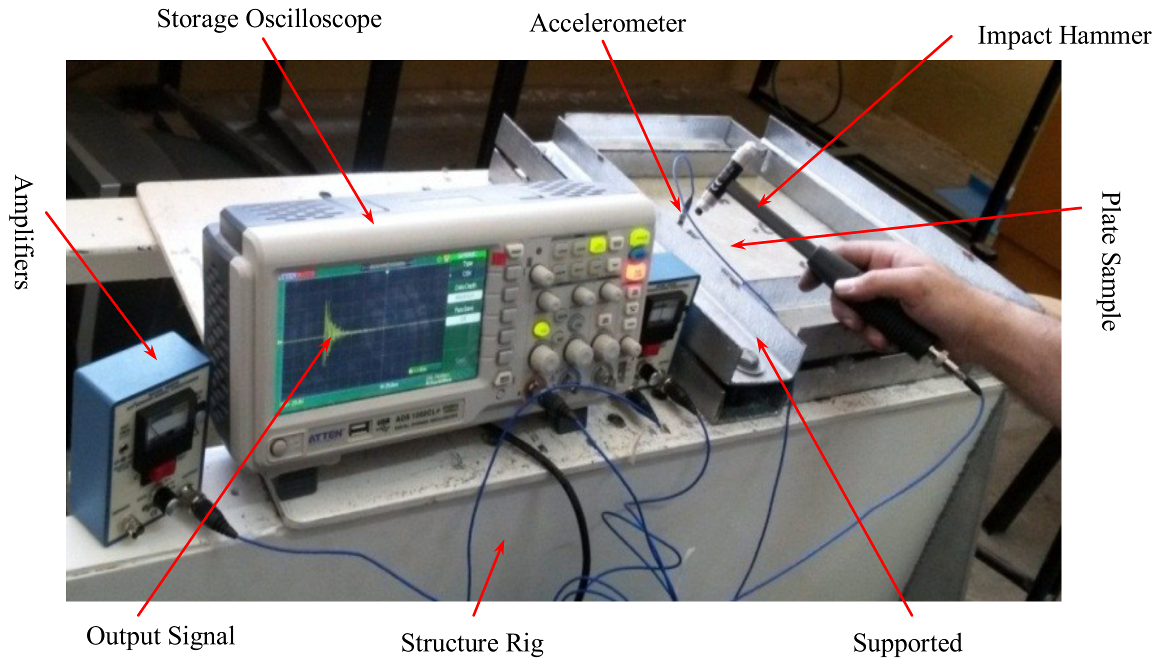


Figure 12. Rig and vibration test machine of composite plate structure

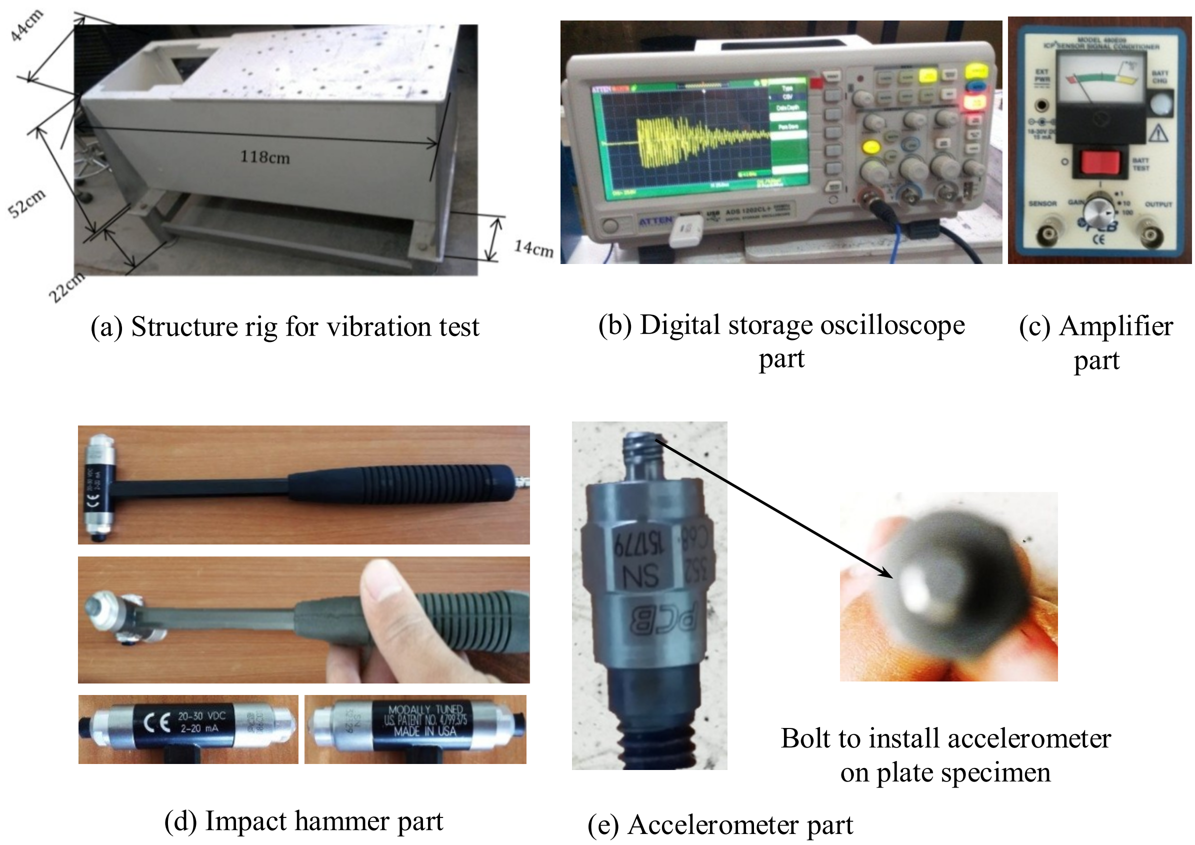
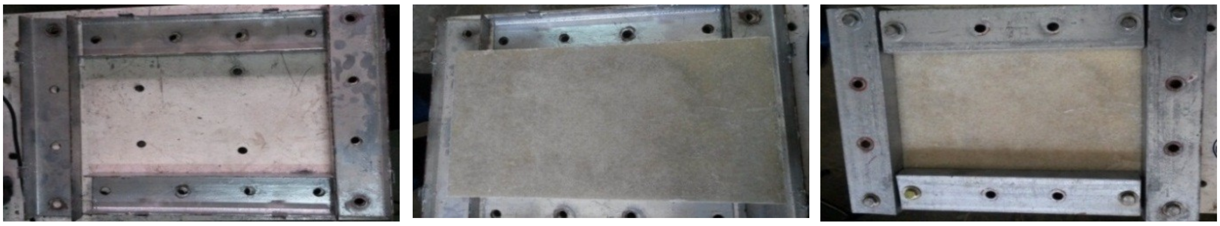
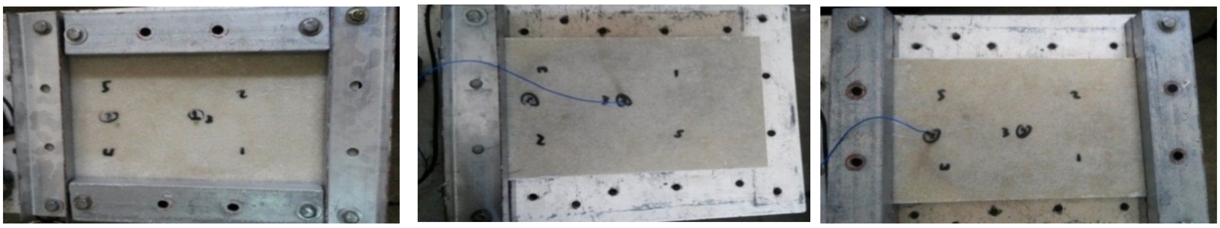


Figure 13. Vibration test machine parts

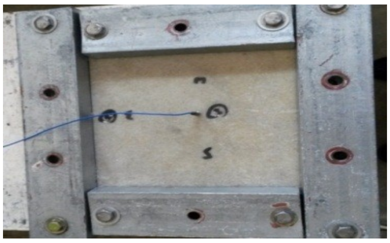


(a) Fixed the plate sample

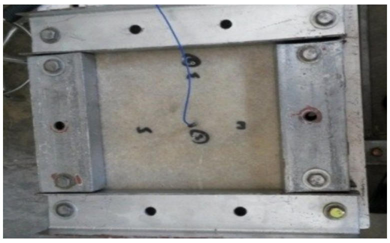


(b) Fixed the Accelerometer Part and impact location point for various boundary conditions of plate sample

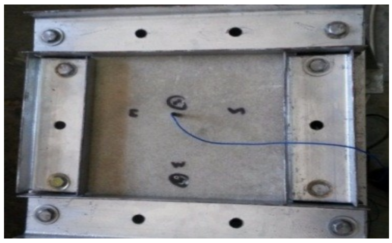
Figure 14. Fixed plate sample and accelerometer part and impact location point for vibration test



SSSS



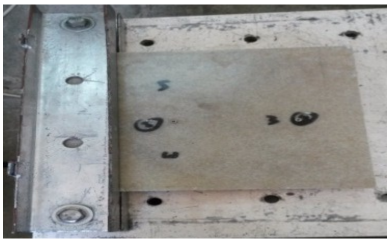
SSCC



CCCC

CCFF

SSFF



CFFF

Figure 15. The vibration test composite plates with different boundary conditions

Figure 16. The central and lateral positions of e- accelerometer part on the vibration tested plat

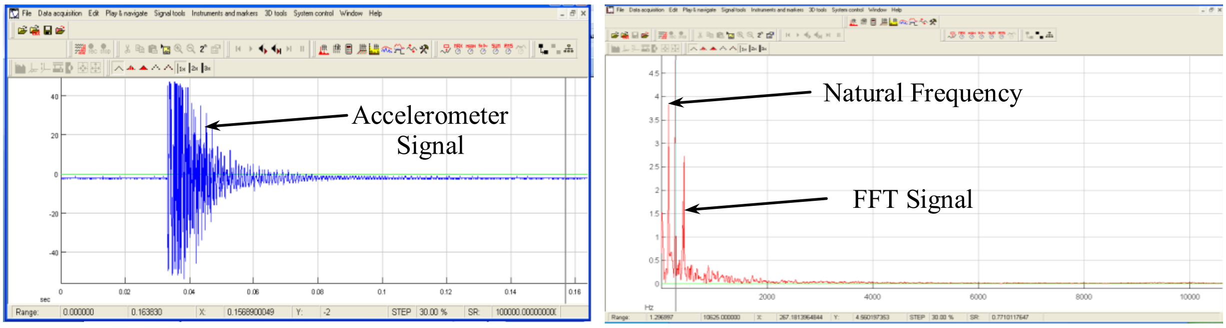


Figure 17. Sig-view program for FFT analysis function

3. Results and discussions

The results of isotropic hyper composite plate included the experimental values of the mechanical properties and natural frequency of short reinforcement composite plate combined from reinforcement(short glass fiber , glass powder reinforcement) and epoxy resin matrix material with different volume fraction and two aspect ratios (AR=1 and 1.5), for different boundary conditions. In addition to, compare the results evaluated with experimental test of natural frequency and mechanical properties of simple supported plate with theoretical results for other research, Muhannad Al-Waily [7].

3.1 Verification case study

The comparison of mechanical properties and natural frequency for isotropic hyper composite plate studied between experimental presented results and theoretical results presented by Muhannad Al-Waily, [7], for simply supported plate with aspect ratio (AR=1, ($a = b = 25\ cm$) and ($h = 5\ mm$)) and different volume fraction of resin, powder and short fiber, as shown in Tables 2 and 3.

Table 2. Comparison of experimental mechanical properties results with theoretical mechanical properties results of Muhannad Al-Waily, [7]

Short fiber volume fraction $\forall_{sf}\%$	Powder volume fraction $\forall_p\%$	Risen volume fraction $\forall_r\%$	E (Gpa) experimentally	E (Gpa) theoretically, [7]	Error %
30	0	70	15.352	14.005	8.77
20	10		12.325	12.058	2.17
30	10	60	16.869	16.107	4.52
20	20		14.865	14.075	5.32
30	20	50	19.232	18.786	2.32
20	30		17.286	16.741	3.15

Table 3. Comparison of experimental natural frequency results, of simply supported plate and aspect ratio (AR=1), with theoretical natural frequency results of Muhannad Al-Waily, [7]

Short fiber volume Fraction $\forall_{sf}\%$	Powder volume fraction $\forall_p\%$	Risen volume fraction $\forall_r\%$	ω (rad/sec) experimentally	ω (rad/sec) theoretically, [7]	Error %
30	0	70	1478.7	1347.014	8.91
20	10		1327.05	1236.749	6.81
30	10	60	1523.84	1374.748	9.78
20	20		1394.7	1274.106	8.65
30	20	50	1584.3	1418.263	10.48
20	30		1431.4	1329.897	7.09

From Table 2; the maximum error, between experimental presented mechanical properties results and theoretical results; [7], about 8.77% (with 30% short reinforcement fiber, 0% powder reinforcement and 70% resin materials) and the minimum error about 2.17% (with 20% short reinforcement fiber, 10% powder reinforcement and 70% resin materials). Also, Table 3 shown the maximum error between experimental presented natural frequency of simply supported plate results and theoretical results; [7], about 10.48% (with 30% short reinforcement fiber, 20% powder reinforcement and 50% resin materials) and the minimum error about 6.81% (with 20% short reinforcement fiber, 10% powder reinforcement and 70% resin materials).The tables had shown the good agreement of the mechanical properties and natural frequency results between presented work and other research.

3.2 The mechanical properties of composite plates

The experimental values of mechanical properties of hyper composite plate studied are shown in Table 4. Were the modulus of elasticity and the yield stress measured.

Table 4. Mechanical properties of short hyper composite materials combined of different reinforcement powders and fiber and epoxy resin matrix

Sample No.	Volume fraction of short fiber $\forall_{sf}$%	Volume fraction of powder fiber $\forall_{p}$%	Volume fraction of risen $\forall_{r}$%	E (Gpa)	Y (Mpa)
1	30	0	70	15.352	152.603
2	20	10		12.325	104.38
3	10	20		10.41	50.1
4	40	0	60	17.218	215.64
5	30	10		16.869	117.28
6	20	20		14.865	95.07
7	10	30		12.573	41.96
8	40	10	50	19.984	134.96
9	30	20		19.232	108.45
10	20	30		17.286	65.43
11	10	40		14.128	34.8

The experimental values of tensile test results showed that the modulus of elasticity of samples 8 and 9 were the maximum at volume fraction of short fiber $\forall_{sf}$ = 40,30% respectively and the yield stress of sample 4 was more than that of other samples, were three samples of composite plates tested and the experimental values of tensile test results average to get the modulus of elasticity and the yield stress values.

3.3 Vibration results

The experimental vibration test results of isotropic hyper composite plate measured, the evaluation the natural frequency of composite plate structure with different aspect ratios (AR=1 and 1.5), and six different boundary conditions (SSSS, SSFF, CFFF, SSCC, CCFF,CCCC), Included reading the signal to FFT function by using sig-view program to get the fundamental natural frequency, as shown in Tables 5 to 7. The experimental values of fundamental natural frequency were averaged by indicating two positions: central and lateral on the tested plates and applying five impulses to excite the plate on each position by an impact hammer.

Table 5 shown the volume fraction of resin, powder and short fiber reinforcement of samples studied in experimental investigation to evaluate the natural frequency. And, Tables 6 and 7 shows the natural frequency of plate samples studied with experimental investigation with various volume fraction of resin and reinforcement and different boundary conditions (SSSS, SSFF, CFFF, SSCC, CCFF,CCCC) of plate, for aspect ratio of plate AR=1 and 1.5, respectively.

Figures 18 to 22, shows the effect of reinforcement powder and short fiber on the natural frequency of different boundary conditions plate with different aspect ratio of composite plate. When, the dimensions of composite plate as in eqs. 2 to 4 and the mechanical properties and volume fraction of resin and reinforcements powder and short powder as in Table 4.

It can concluded that when the volume fraction of short fiber ($\forall_{sf}$ = 40%) at sample 8, maximum natural frequency was occur (due to the maximum modulus of elasticity (stiffness) occur with sample 8), and, the natural frequency increasing with increase the reinforcement powder or short fiber (since the increasing of short fiber causes increase of the modulus of elasticity (stiffness) of plate), also, the natural frequency increasing with increase the short fiber more than the increasing of natural frequency when increase the powder reinforcement, since the effect of short fiber more than the effect of powder reinforcement. All figures showed that the natural frequency for plate with aspect ratio (AR=1) was higher than that natural frequency for plate with aspect ratio (AR=1.5), since the stiffness/weight for plate with AR=1 more than stiffness/weight of plate with AR=1.5.The Clamped-Supported along all Edges (CCCC) boundary condition showed the highest values of the natural frequency, but the Clamped-Free Supported (CFFF) boundary condition showed the lowest values.

Table 5. The Sample number, sample name , volume fraction of components

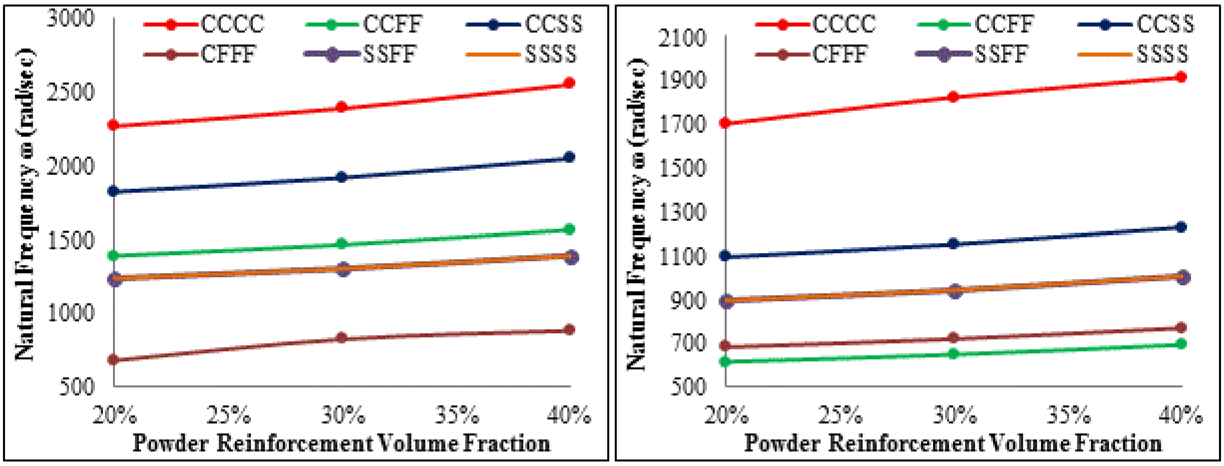
Sample Number	Sample Name	Volume Fraction of Short Fiber $\forall_{sf}\%$	Volume Fraction of powder fiber $\forall_{p}\%$	Reinforcement Volume Fraction $(\forall_{p}\% + \forall_{sf})\%$	Volume Fraction of Risen $\forall_{r}\%$
1	Sample 1	30	0	30	70
2	Sample 2	20	10		
3	Sample 3	10	20		
4	Sample 4	40	0	40	60
5	Sample 5	30	10		
6	Sample 6	20	20		
7	Sample 7	10	30		
8	Sample 8	40	10	50	50
9	Sample 9	30	20		
10	Sample 10	20	30		
11	Sample 11	10	40		

Table 6. Experimental natural frequency results for isotropic hyper composite plate with different reinforcements short fiber and powder effect for various boundary conditions plate, with AR=1.

Sample Number	Sample Name	Natural Frequency ω (rad/sec)					
		CCCC	CCFF	CCSS	CFFF	SSFF	SSSS
1	Sample 1	2742.12	1654.81	2215.36	941.38	1489.45	1478.7
2	Sample 2	2500.2	1520.69	2103.41	826.41	1412.34	1327.05
3	Sample 3	2154.31	1310.24	1790.87	712.55	1203.14	1176.3
4	Sample 4	2856.64	1920.58	2602.35	1021.35	1623.24	1604.8
5	Sample 5	2787.9	1636.27	2102.54	924.96	1540.28	1523.84
6	Sample 6	2605.14	1580.22	2086.32	867.35	1480.38	1394.7
7	Sample 7	2354.28	1485.39	1858.64	872.46	1335.27	1263
8	Sample 8	3145.2	1978.24	2517.32	1025.36	1779.35	1680.1
9	Sample 9	3025.68	1921.3	2344.24	984.24	1542.21	1584.3
10	Sample 10	2601.86	1635.27	2284.27	920.37	1448.37	1431.4
11	Sample 11	2500.35	1518..32	1987.35	931.24	1356.23	1316.2

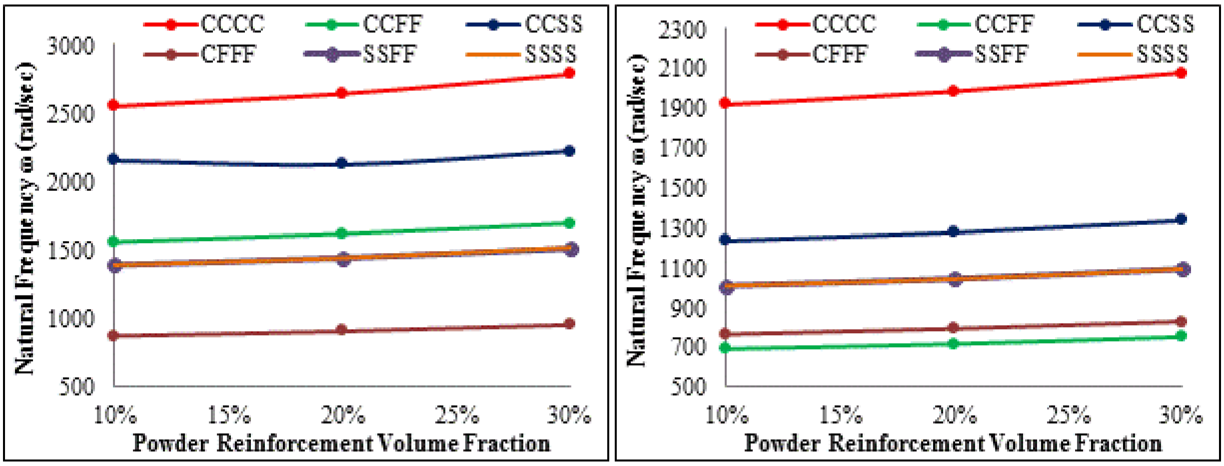
Table 7. Experimental natural frequency results for isotropic hyper composite plate with different reinforcements short fiber and powder effect for various boundary conditions plate, with AR=1.5

Sample Number	Sample Name	Natural Frequency ω (rad/sec)					
		CCCC	CCFF	CCSS	CFFF	SSFF	SSSS
1	Sample 1	1986.34	739.64	1324.17	864.87	1096.21	1091.2
2	Sample 2	1940.23	643.86	1203.16	745.22	985.14	987.6
3	Sample 3	1730.36	587.42	1028.39	670.38	826.84	850.02
4	Sample 4	2235.23	846.49	1399.35	875.99	1256.201	1247.2
5	Sample 5	2125.34	784.87	1267.14	813.62	1130.17	1146.67
6	Sample 6	1850.15	745.21	1201.39	815.76	988.34	986.4
7	Sample 7	1598.36	698.22	1107.36	684.82	896.18	921.9
8	Sample 8	2310.32	892.34	1482.14	976.43	1176.32	1229
9	Sample 9	2211.86	789.66	1350.24	853.69	1116.34	1206.96
10	Sample 10	2101.98	725.14	1305.1	786.74	1023.37	1177.3
11	Sample 11	1872.47	675.14	1201.23	746.48	986.01	948.07



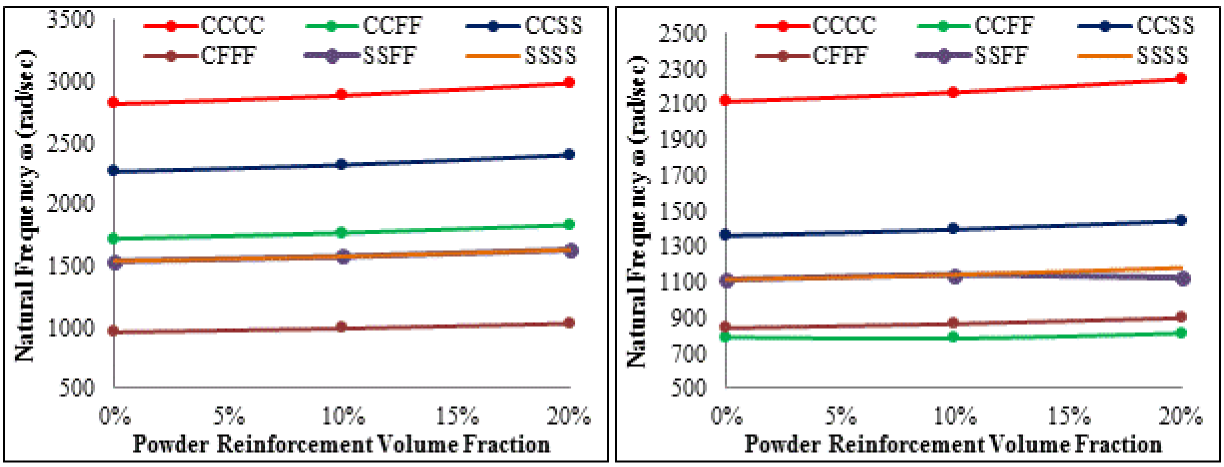
AR=1 AR=1.5

Figure 18. Experimental natural frequency with powder reinforcement effect and various plate boundary condition, for short fiber volume fraction $\forall_{sf} = 10\%$ and various plate aspect ratio



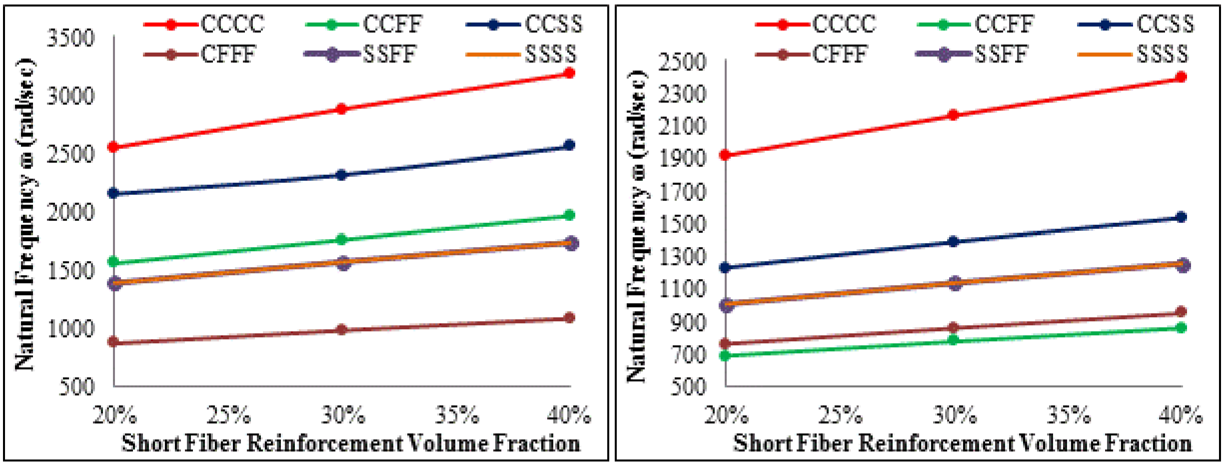
AR=1 AR=1.5

Figure 19. Experimental natural frequency with powder reinforcement effect and various plate boundary condition, for short fiber volume fraction $\forall_{sf} = 20\%$ and various plate aspect ratio



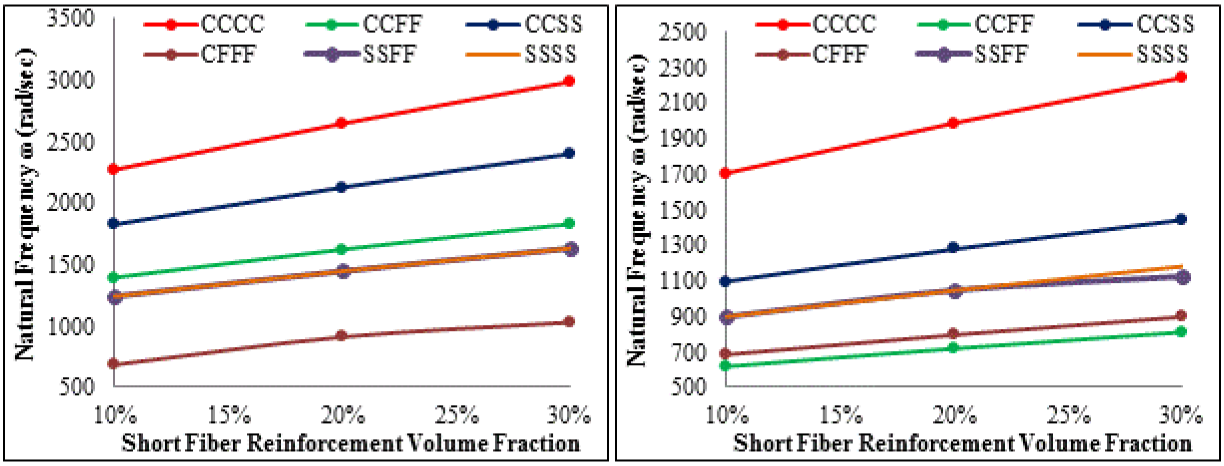
AR=1 AR=1.5

Figure 20. Experimental natural frequency with powder reinforcement effect and various plate boundary condition, for short fiber volume fraction $\forall_{sf} = 30\%$ and various plate aspect ratio



AR=1 AR=1.5

Figure 21. Experimental natural frequency with reinforcement short fiber effect and various plate boundary condition, for powder reinforcement volume fraction $\forall_{pf} = 10\%$ and various aspect ratio



AR=1 AR=1.5

Figure 22. Experimental natural frequency with reinforcement short fiber effect and various plate boundary condition, for powder reinforcement volume fraction $\forall_{pf} = 20\%$ and various aspect ratio

4. Conclusions

The main conclusions of this work are,

1. The comparison between the presented work and other research had shown the good agreement of mechanical properties and natural frequency results. And, the increasing of reinforcement powder cause increases the modulus of elasticity of hyper plate and increasing the natural frequency of plate.
2. The modulus of elasticity of hyper composite plate was increased with the increase of short fiber volume fraction ($\forall_{sf}$%).
3. The yield stress decreased with the increase of powder volume fraction ($\forall_{pf}$%) of hyper composite material.
4. The natural frequency of isotropic hyper composite materials plate was increased with the increase of short fiber volume fraction were the volume fraction of short fiber ($\forall_{sf}$= 40%) at samples 8, maximum natural frequency had occur.
5. The clamped-supported along all edges (CCCC) boundary condition showed the highest values of the natural frequency for both aspect ratios, but the Clamped-Free Support Three Edges (CFFF) boundary condition showed the lowest values for aspect ratio(AR=1) and Clamped-Free Supported (CCFF) for aspect ratio(AR=1.5).

6. It was observed that the natural frequency for aspect ratio (AR=1) was higher than that for aspect ratio (AR=1.5).

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Abdulkareem Abdulrazzaq Alhumdany, Ph.D. In Mechanical Engineering, Mechanical Engineering Department, University of Technology, Iraq. Specialization: Applied Mechanics, Ph.D. thesis title, "Analysis of spur gear set performance under el as to hydrodynamic lubrication", Graduation Date: 2006. M.Sc. In Mechanical Engineering, College of Engineering/University of Baghdad, Iraq. Specialization: Applied Mechanics, M.Sc. thesis title "Closed form solutions for the free vibrational characteristics of open profile circular cylindrical shells", Graduation Date: 1985.B.Sc. In Mechanical Engineering, College of Engineering/University of Baghdad, Iraq. Specialization: General Mechanics, Graduation Date: 1981.Research Interests, Vibration Analysis, Stress Analysis under Static and Dynamic Loading.
E-mail address: alhumdany@yahoo.com

Muhannad Al-Waily, Ph.D. in Mechanical Engineering, College of Engineering, Alnahrain University, Iraq. Specialization: Applied Mechanics- Vibration Analysis Study, Composite Material Study-Crack Study, Health Monitoring, Graduation Date: 2012. M.Sc. In Mechanical Engineering, College of Engineering/University of Kufa/Iraq. Specialization: Applied Mechanics- Vibration Analysis Study, Composite Material Study-Stress Analysis Study, Graduation Date: 2005. B.Sc. In Mechanical Engineering/ College of Engineering/University of Kufa, Iraq. Specialization: General Mechanics, Graduation Date: 2002.Research Interests, Vibration Analysis, Stress Analysis under Static and Dynamic Loading, Composite Materials, Fatigue and Creep Analysis of Engineering Materials, Mechanical Properties of Engineering Materials, Control and Stability of Mechanical Application, Damage (Crack and Delamination Analysis), Buckling Analysis, and other mechanical researches.
E-mail address: muhanedl.alwaeli@uokufa.edu.iq

Mohammed Hussein Kadhim, B.Sc. In Mechanical Engineering/ College of Engineering, University of Kufa, Iraq. Specialization: General Mechanics, Graduation Date: 2013. He is pursuing M.SC. Degree in Mechanical Engineering from Karbala University. Research Interests: Vibration Analysis, Composite Materials, and Mechanical Properties of Engineering Materials.
E-mail address: 91engmohammed@gmail.com