EXPERIMENTAL VERIFICATION OF MODAL TEST ANALYSIS OF CIRCULAR PLATE USING EMA

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Abstract:-The present analysis aims to propose a technique for confirmative atomic number 26 model of circular plate by comparison experimental modal analysis (EMA) knowledge, measured with the mode shapes calculated by the finite component analysis software system. A Resonance Frequency take a look at was conducted to excite the plate structure and LMS take a look at software system used for mensuration the response of the output acceleration in 3 axes. This was accomplished by making finite component models victimisation the software system ABAQUS, finishing the in depth model of circular plate and modifying the ratio of the model to alter the mesh density of the circular plate. Resonance frequency of the circular plate was with success foreseen at corresponding frequencies victimisation the updated model. in order that its modal parameters a lot of closely match those obtained from experiment. Comparison of the experimental and theoretical knowledge unconcealed that the natural frequencies and corresponding mode shapes correlate between the atomic number 26 model.

Keywords: **Vibration, Finite component Analysis, Resonance Frequency activity take a look at, Experimental Modal Analysis**

Introduction:

At present, the analysis of dynamic structures carried extensively victimisation Finite component technique that it's helpful for modeling complicated structures [1]. usually inaccuracies square measure arising at boundary conditions, variation in material properties and whereas simplifying the model. These uncertainties within the modeling method as a result of the expected dynamics of a structure to diverge from the measured dynamics of the important structure [2]. So, the measured knowledge could also be within the style of frequency response operate (FRF) knowledge or natural frequencies and mode shapes. FRF results square measure obtained by conducting modal testing. Modal testing [3] could be a formalized technique for identification of natural frequencies and mode shapes of structures.

Due to a general lack of confidence in atomic number 26 models, the dynamic testing of structures has become a customary procedure for model validation and change. Over the past thirty years, modal testing and analysis became a fast-developing technique for the experimental analysis of the dynamic properties of structures (Ewins, 2001). one in all the earliest researchers World Health Organization tried to include the complicated eigenvalue analysis with an outsized finite component model and used modal analysis to match natural frequencies and its mode shapes for hydraulic brakes parts was (Liles, 1989).

Kung et al (2000) valid the foremost brake parts. most distinction between experimental and atomic number 26 modal for the rotor is seven-membered, the brake pad is 4WD and also the caliper is five-hitter whereas alternative brake parts and assembly weren't thought of. Abu Baker (2005) conducted atomic number 26 modal analysis and compared the expected result with experimental results that got by James (2003). He found that the most relative error for brake assembly is five.2% and also the rotor is eighteen whereas the opposite parts were valid by Associate in Nursing trade supply.

Hassan et al (2009) used a simplified atomic number 26 model (rotor and brake pads). He found that the most distinction between atomic number 26 and experimental results of the brake pad at five.2 kHz is 7.47% and also the rotor at three.5 kHz is 2.57%.

Hooper et al conducted a experimental assessment of the frequency response of Li particle pouch cell and assessed mode shapes victimisation impulse excitation. Correlation carried for the cell's frequency response with road iatrogenic vibration profiles.

Banwell developed a atomic number 26 model for confirmative by comparison Experimental modal analysis. They terminated that comparison of the experimental and theoretical knowledge of natural frequencies and corresponding mode shapes related well and may be accustomed construct the model.

This project are going to be centered on numerical modeling and experimental validation for the needs of investigation circular plate.Relevant FRF theory:

While the workpiece is in steady state ie., hanging in free-free condition, which is presented whenever the body subjected to action of force, can be given by

$$G(\omega) = \frac{X(\omega)}{F(\omega)} ---------(1)$$

Where, G(ω) = The Frequency Response Function (FRF) of the system

X(ω) = Output Response

F(ω)=Input Excitation

So, FRF can be expressed as the amplitude of vibration X(ω) produced by magnitude of the forcing function for F(ω)applied using Roving Impact Hammer at frequency ω. The FRF is also called the magnification factor or transfer function in metal cutting. This function for real and imaginary parts is given by

$$\mathrm{Re}[G(\omega)] = \frac{k - m\omega^2}{(k - m\omega^2)^2 + (c\omega)^2} = \frac{1}{k}\frac{1 - r^2}{(1-r^2)^2 + (2\xi r)^2} \text{--------}(2)$$

$$\mathrm{Im}[G(\omega)] = \frac{-c\omega}{(k - m\omega^2)^2 + (c\omega)^2} = \frac{1}{k}\frac{-2\xi r}{(1-r^2)^2 + (2\xi r)^2} \text{--------}(3)$$

Where,

$$r = \frac{\omega}{\omega_n}$$

The real part represents the mobility of the system, while the imaginary part represents the interance.

The magnitude of FRF is given by

$$G(\omega) = \sqrt{\frac{X(\omega)}{F(\omega)}}$$

$$= \frac{1}{k\sqrt{(1-r^2)^2 + (2\xi r)^2}} \text{--------}(4)$$

This represents the dynamic compliance of the system [2]

Experimental set-up and procedure:

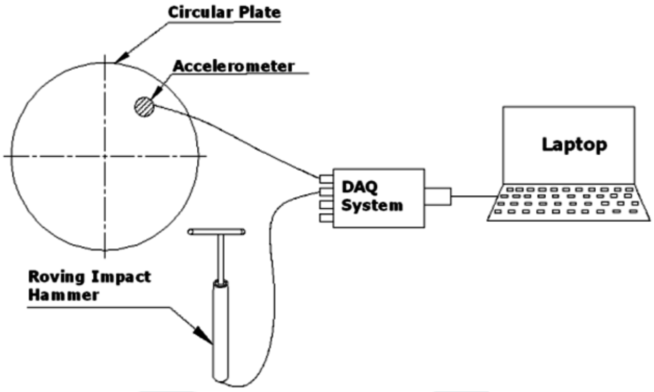
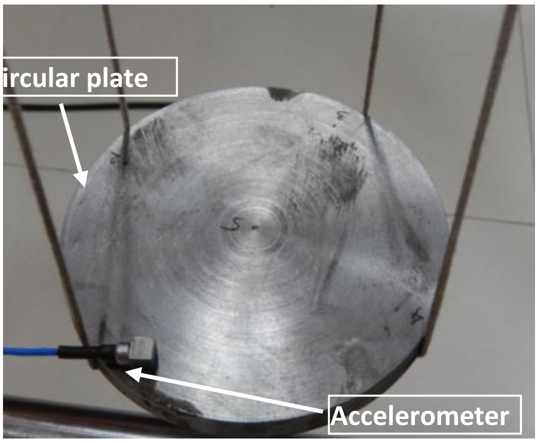
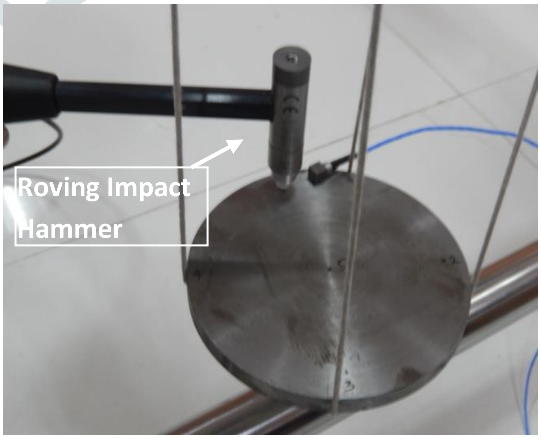


Fig.1. Schematic diagram of an experimental set-up for modal testing in a laboratory



(a)



(b)

Fig.2. Actual experimental setup of a) Circular plate under "Free-Free" condition with accelerometer b) Roving Impact Hammer during excitation

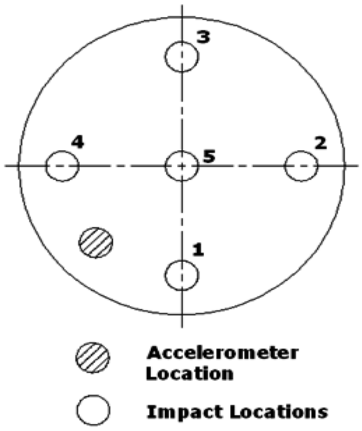


Fig.3 Layout used for SISO impulse excitation tests

As illustrated in figure 1, measuring system, Roving impact hammer and dynamic signal analyzer were used for conducting experimental modal analysis. onerous tipped Roving impact hammer was accustomed build energy within the structure and marked cell on the circular plate was compact 3 times that is shown in figure three as grid layout. Figure two (a) shows the experimental set-up with the position of measuring system on circular plate of free-free condition and Figure two (b) shows that the impact developed by roving impact hammer. The 3 axis measuring system with sensitivity of 10mV/g was used and was connected to the circular plate victimisation beeswax. the situation of the measuring system was selected at a least disturbance by the excitation and to allow high response to the acceleration. Specifications of the measuring system and Roving impact hammer got in table one &2 severally.

The results of every measuring averaged to get a way of single input single output (SISO) response of the take a look at section. The response of the given impulse was received victimisation associate degree measuring system throughout excitation of the circular plate. Frequency response perform (FRF) of experimental knowledge was noninheritable by the excitation and response signals for the hammer and acceleration through a four channel knowledge acquisition system unit (model: NI9233) and LMS take a look at model software system that is additionally known as Dynamic signal analyzer (DSA). The DSA conjointly performs the transformation to convert the measured time domain signals in to FRFs.

Table 1: Impact Hammer Model: PCB 086C03 specifications

Sl.No	Specifications	Measurement range
1	Hammer mass	0.16 kg
2	Sensing element	Quartz
3	Sensitivity	±15%
4	Measurement range	±2224 N pk

Table 2: Specifications of Accelerometer Model: PCB 352B10

Sl.No	Specifications	Measurement range
1	Weight	0.7 gm
2	Sensing element	Ceramic
3	Sensitivity	±10%
4	Measurement range	±4905 m/s^2pk

Results and Discussions:

1. Methodology adopted for validation:

FE models of the circular plate square measure developed mistreatment metal software system (ABAQUS 6-10). so as to make sure that accuracy of the metal model trust those of the physical elements, ratio of the model was hand-picked and improved at the elements level. First, metal modal analysis at the element level is administrated and simulated up to frequencies of eight kilohertz. Then, the mesh sensitivity of the element is taken into account. so as to correct the expected frequencies with the experimental results, a metal modification or improvement is employed to scale back the errors between the results by standardisation the ratio throughout meshing. The methodology used for validation of metal model are going to be mentioned within the following sections, as shown in figure four.

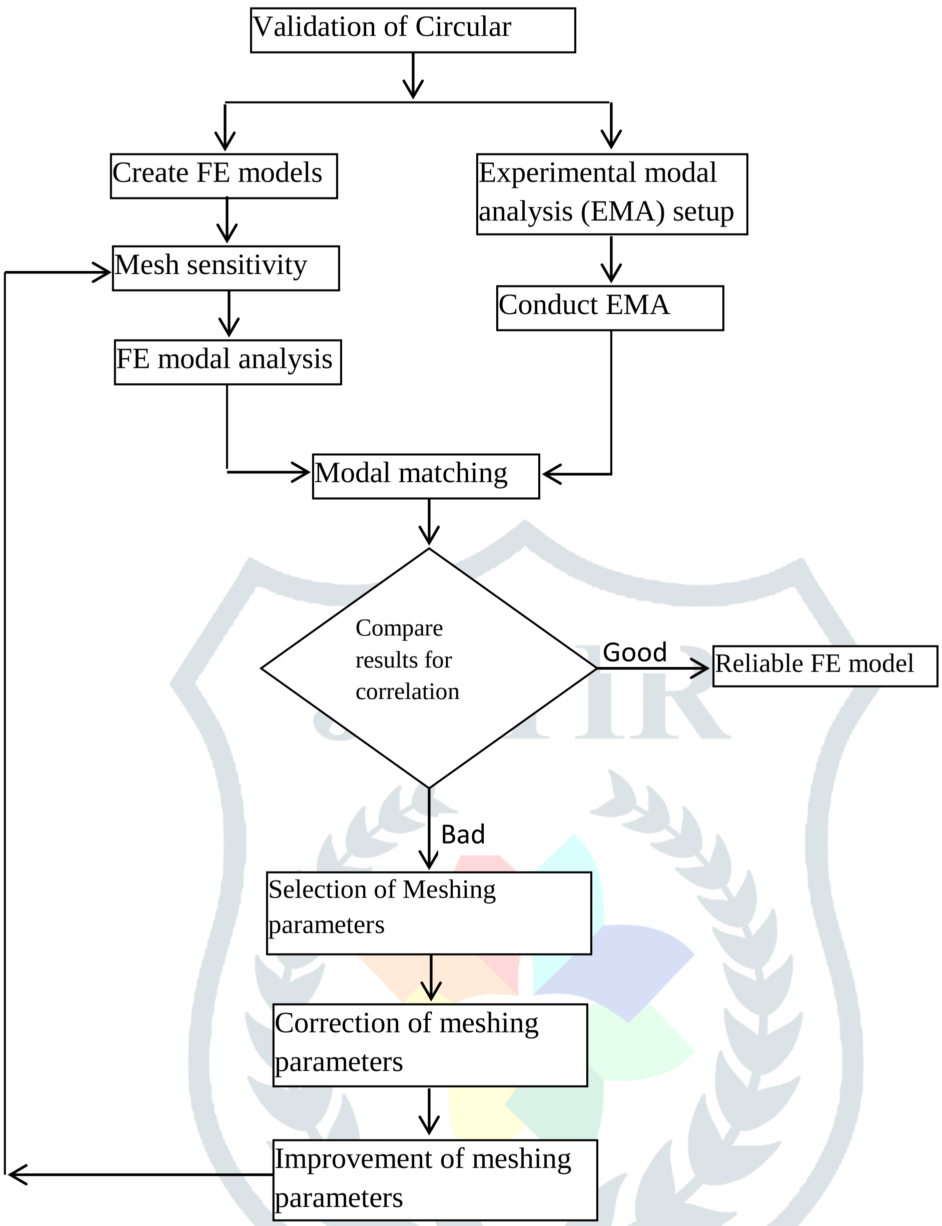


Fig 4. Methodology adopted for validating modal value of Circular plate

1. Modal analysis using Finite Element Technique:

The key to the success of the prediction is the correlation between physical tests and virtual FE modeling of the circular plate. A three dimensional FE model of circular plate was developed and validated for identifying the natural frequencies and mode shapes. Figure 5 shows the 3- dimensional FE model of the circular plate.

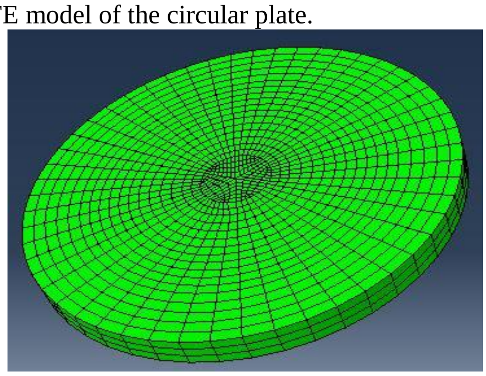


Fig.5. Meshing of FE model of the circular plate

2. Improvement of Meshing parameter:

The accuracy of the results of FEM is extremely a lot of captivated with the mesh size of models. Mesh size are often improved by reducing magnitude relation|ratio} which suggests that the ratio of element's breadth to the peak. 3 totally different mesh sizes area unit applied to a similar structure and 3 modal information sets were obtained. whereas increasing the amount of components natural frequency differs from coarse mesh to the fine mesh. If the results dissent by an oversized quantity, however, it'll be necessary to use a finer mesh for additional iteration.

The mesh sensitivity was varied on circular plate with 3 totally different levels id est., coarse, fine and really fine mesh. The ends up in table three.1 show that the natural frequency distinction between a similar modes once 3 totally different meshes area unit applied within the atomic number 26 model of the circular plate. It are often seen that the utmost distinction in natural frequency, within the frequency vary of interest (0-8kHz, is a smaller amount than five-hitter, that is a suitable price.

Table 3. Natural frequency difference with different mesh densities

Mode No.	Coarse mesh 1836 element	Fine mesh 3623 element	Very fine mesh 6231 element	Difference ratio
	Natural Frequency (Hz)			(Fine & Very fine)
1	2443.7	2410.0	2393.5	0.7%
2	3347.8	3326.0	3295.0	0.9%
3	3356.3	3327.4	3313.2	0.4%
4	6245.7	6205.2	6119.4	1.4%

3. FE Model Updating

The aim of atomic number 26 modification is to scale back most relative errors between the anticipated and experimental results. it's terribly tough to understand precise material properties of the many dynamic structures because of variety of things like variation in material properties, pure mathematics dimensions or changes within the excitation over time. Uncertainties in material properties or structural dimensions is because of producing imperfections or inexact information of fabric properties.

There square measure variety of researchers used EMA to validate their models [1,3].

In this work, atomic number 26 enhancements square measure carried supported changes created within the ratio. Material properties of circular plate square measure given in table four.

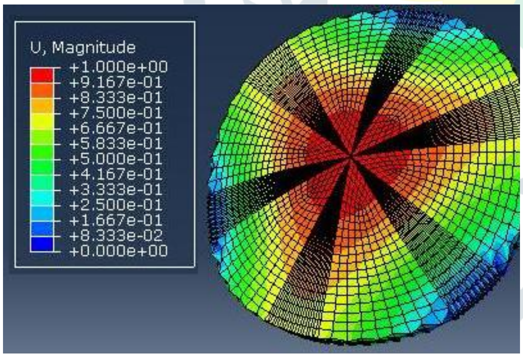
Table 4. Material properties of Circular plate

Material	Density (kg/m^3)	Young's modulus (MPa)	Poisson's ratio
EN24	7840	2.1 X 10^5	0.3

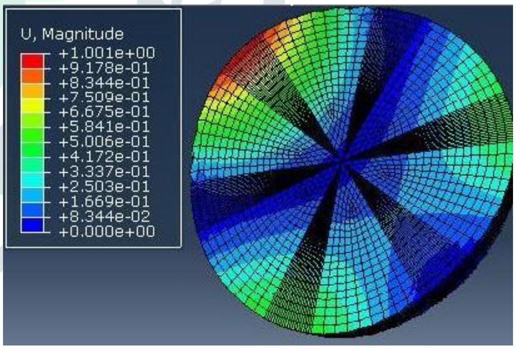
In order to find natural frequencies and corresponding mode shapes, FE modal analysis of circular plate is conducted. The results are presented in the form of displacement contour to indicate maximum and minimum amplitudes, as shown in Figure 6. Modal values of circular plate under free vibration are listed in table 5.

Table 5: Modal values of workpiece in free vibration

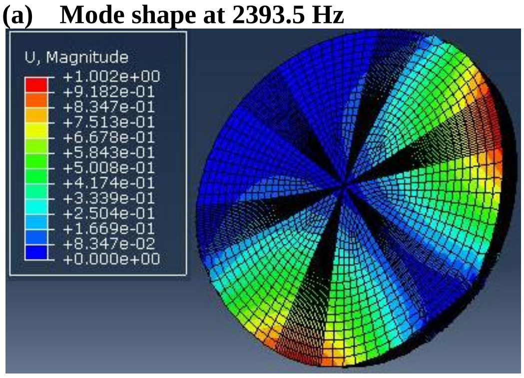
Mode of vibration	1st mode	2nd mode	3rd mode	4th mode
By FEA, F_n (Hz)	2393.5	3295.0	3313.2	6119.4



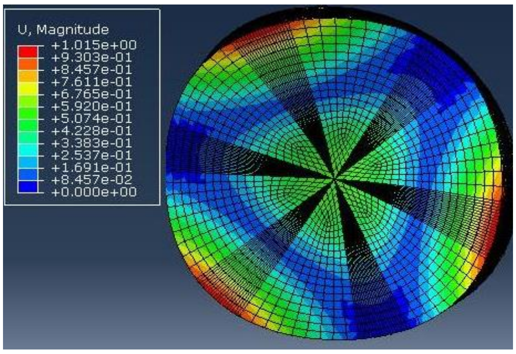
(a) Mode shape at 2393.5 Hz



(b) Mode shape at 3295.0 Hz



(c) Mode shape at 3313.2 Hz



(d) Mode shape at 6119.4 Hz

Fig 6: Four mode shapes corresponding to each natural frequency

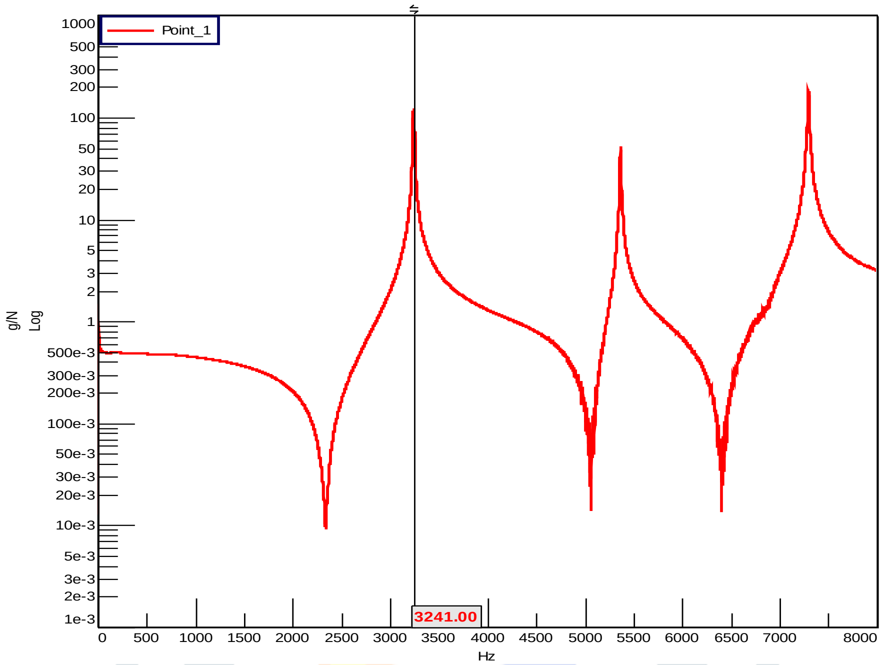
Hence, experimental modal analysis is critical to correlate the measured vibration behavior of circular plate parts thereupon foretold by FEA.

4. **Resonance Frequency measure take a look at Report**

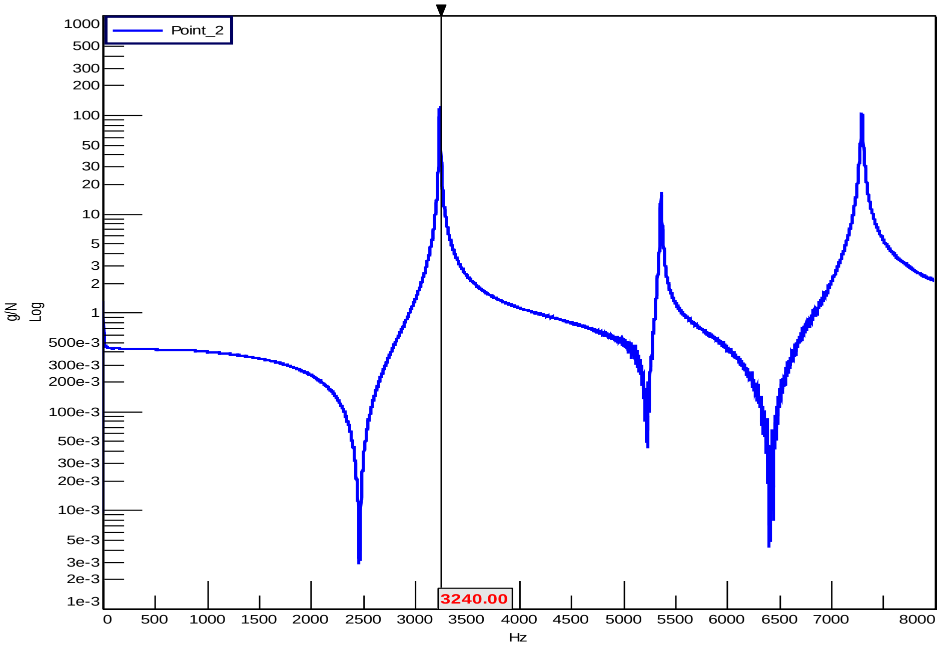
In order to extract modal parameters like natural frequency & mode shapes, the excitation is given throughout experiment and therefore the points at that the responses square measure measured exploitation LMS take a look at software package. The measured FRFs square measure given as input at the various points at that they're measured. The extraction of modal parameters from the measured FRFs is predicated on curve fitting drawback. Curve fitting technique is employed to extract the mode shapes and natural frequencies from the pure mathematics. during this study, the modal peak perform is employed to calculate by summing along the $64000 elements, notional elements or magnitudes of all transfer perform square measure being curve fitted. This perform is most acceptable for revealing the natural frequencies of the structure and validate with Fe results. So, the measured response is taken because the results of given input excitation.

Figure seven shows the FRF results and frequencies at compact points from one to five.

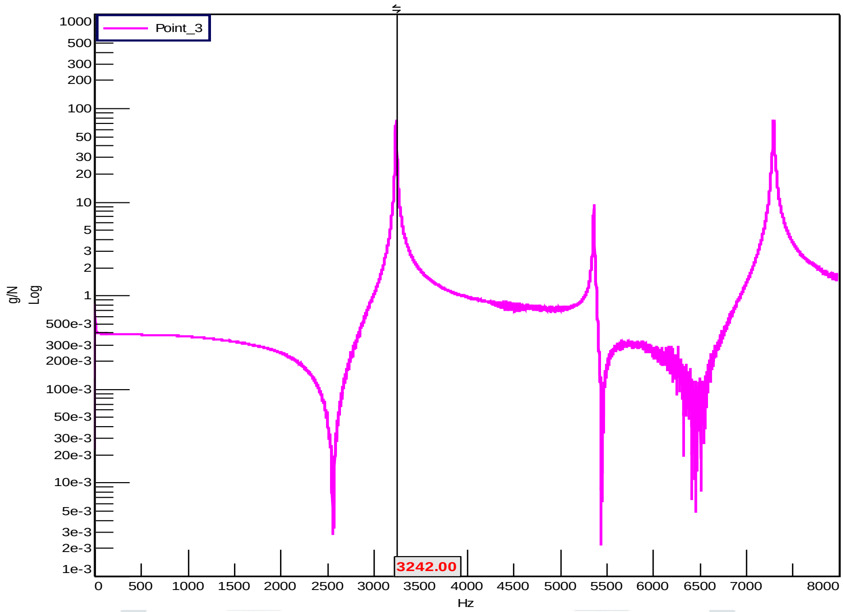
Comparison between the experimental results and Fe results of circular plate square measure given in table half-dozen.



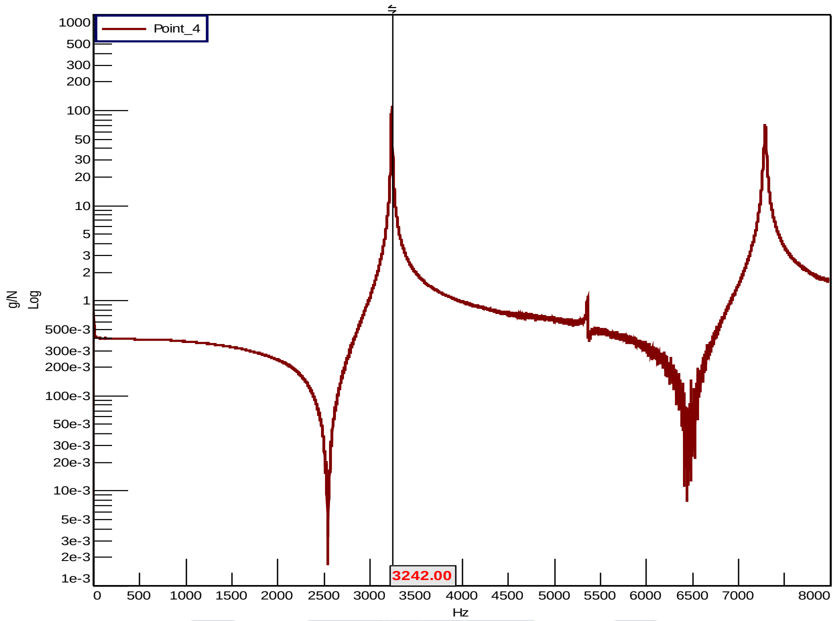
Point 1: 3241.00 Hz



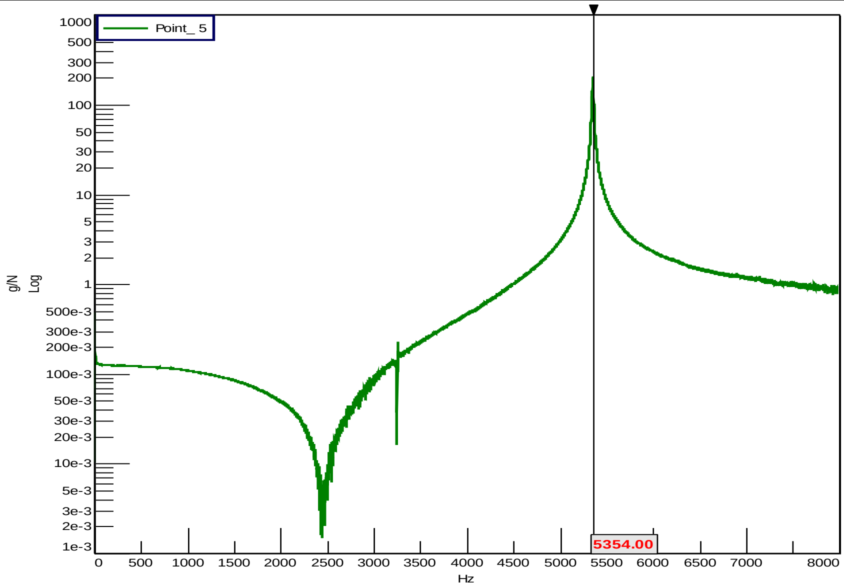
Point 2: 3240.00 Hz



Point 3: 3242.00 Hz



Point 4: 3242.00 Hz



Point 5: 5354.00 Hz

Fig 7. FRFs of impacted points 1 to 5

Table 6. Comparison between experimental and FE results of circular plate

Mode Number	Experimental Modal Results (Hz)	FEA Free vibration results (Hz)	Error (%)
1	3241	2393	0.26
2	3240	3295	-0.01
3	3242	3313	-0.02
4	5354	6119	-0.14

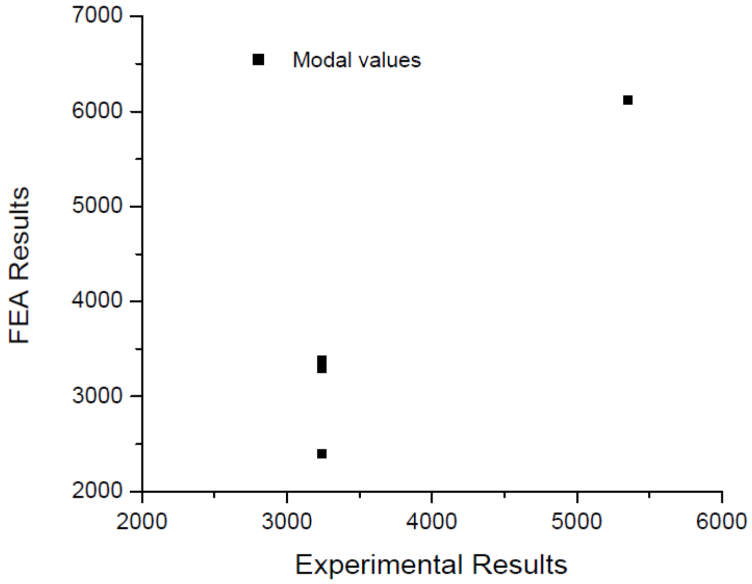


Fig. 8 Comparison of Experimental modal results with FEA Free vibration results

Conclusions

A comprehensive methodology for conducting modal analysis on a circular plate by each metallic element and scientific method is delineated. The natural frequencies and mode shapes extracted from the metallic element model of the parts and assembly area unit found to be in smart agreement with those found from the scientific method and thus might be used for more dynamic simulation studies to research structural issues a lot of earlier within the style cycle

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