INVESTIGATION OF DYNAMIC CHARACTERISTICS OF 2-WHEELER SUSPENSION USING PNEUMATIC EXCITATION

RUSHABH SANTOSH NIMBALKAR
ME Student, Department of Mechanical Engineering (Design)
Tssm's Padmabhooshan Vasantdada Patil Institute of Technology, Bavdhan, Pune - 411021

D.C.DESALE
Professor, Department of Mechanical Engineering (Design)
Tssm's Padmabhooshan Vasantdada Patil Institute of Technology, Bavdhan, Pune – 411021.

Abstract—* *A system of mechanical linkages, springs, damper that is used to connect the wheels to the chassis is known as suspension system. It has usually done two works-controlling the vehicle's handling and braking for safety and keeping the passengers comfortable from bumps, vibrations. There are many types of shock absorbers available in market /industry different kinds of techniques are there to reduce shocking effect on running vehicles and to make a ride comfortable. In present research design and development of test set-up of shock- absorber with optimized design of spring is to be performed. Design of three different spring of dimension and experimental setup in is designed in CATIA software. To obtain optimized design of spring with damper in ANSYS software to calculate elastic force and elongation in ANSYS. Modal analysis of experimental setup with optimized spring with damper to determine natural frequency and mode shape using ANSYS software. Experimental testing of setup by FFT technique and acceleration value using impact hammer test and pneumatic excitation.

Keyword – Spring damper experimental setup, FFT

I. Introduction

A Mechanical framework made by numerous parts which are having movement and vibration. Here and there movements and vibrations can be valuable however inordinate vibration makes distress individuals, damage to machines and structures and wear of machine parts, for example, course and apparatuses. The drivers of vehicles during are presented to vibration due the unequal pivoting portions of the machines or by the street surface lopsidedness. The most concerning issue to traveler is that they are presented to vibrations in a recurrence go from very nearly 0 to 20 Hz. This sort of distress makes that the driver and travelers lose fixation, get worn-out right-on time and following quite a long while it can effects affect their wellbeing. Most current vehicles are outfitted with shock absorbers to hose the vibrations caused to the vehicle body when going over lopsided streets. They structure a basic piece of the vehicle suspension framework and helps in restricting body development of the vehicle, settling the ride and tires just as cutoff the damage caused to the vehicle skeleton. Another significant capacity of the shock absorber is to keep the vehicle tire in contact with the ground consistently, even on a rough street. Remembering these basic capacities, stresses created in the shock absorber and the subsequent redirection are the two most significant parameters to be dealt with while planning a shock absorber for any vehicle. As a significant gadget utilized in suspension frameworks of current vehicles, the shock absorber is mounted between auto scaffold and casing for damping the vibration brought about by lopsided street to direct incautious load. In this manner, the damping execution of the shock absorber is of significance to running perfection, working unfaltering quality and through limit of vehicles. With requesting necessities for security and solace of driving vehicle, examine on the shock absorber have increased increasingly more consideration, including its high recurrence execution, tests for damping trademark, temperature control, commotion issue, and so forth.

Shoukun Wang et al. [1] In this paper it presents the pressurized water driven shaking table has been produced for damping trademark probes shock absorbers. The damping qualities and relating probes the twofold cylinder water driven shock absorber are investigated right off the bat, and its damping power model is likewise constructed. An open-closed loop ILC strategy is proposed to beat the asymmetry, vulnerability and nonlinearity of the water powered control framework. At that point framework rule and real parts of the shaking table are depicted, and the model of pressure driven actuator, formed of servo valve controlled deviated chamber with damping load, is investigated. Created by such electro-pressure driven control innovation, this using pressurized water driven shaking table has been applied to the damping trademark examination of a sequential of shock absorbers in a vehicle get together plant of Beijing, and has accomplished perfect execution, with 50 kN greatest load power, 0.1 m vibration abundancy, 5 Hz greatest vibration frequency, 1 mm position control exactness (sine vibration with 0.05 m abundancy and 2 Hz frequency) and 24 h steady span.

I.V. Ryabova et al. [2] In this research it presents the analytical confirmation of the nearness of two inefficient areas in vehicle suspension impacting cycle in straight shock absorber work. It is determined based on investigation of the element's conditions for the straight single-bolster single-mass vibrating framework with fixed flexible and damping qualities at symphonious kinematic unsettling influence. The assessment of vehicle suspension proficiency dependent on the estimations of inefficient power beat proportion for known effective control calculations of flexible damping normal for pneumatic shock absorber. In this way, it is scientifically demonstrated the presence of two inefficient work areas of shock absorber in wavering pattern of vehicle suspension on the case of single-mass single-support vibrating framework with unregulated versatile and damping attributes. The consequences of trial reads for different sorts of vehicles suspensions are affirmed also, show that the impact of the straight water powered damper is coordinated to speeding up and sufficiency of the sprung mass relocation of the vehicle. Accessibility of inefficient work zones of shock absorber in wavering cycle of vehicles suspension requires expanding its damping properties in these regions based on present day techniques for the attributes control.

Yang Ping et al. [3] In this paper it presents study on microstructure oil-damping shock absorber for the security of electronic packaging segments in vibration-influence situations. The nonlinearity of the oil consistency, the oil stream qualities, and the coupling between the oil and the physical structure were remembered for a numerical model of the oil-damping shock absorber to constrict vibrations. The consequences of multi-parameter-coupled dynamic tests show that the scientific model precisely recreates the genuine physical arrangement of the oil damping shock absorber. The model could be utilized for building plans of vibration-influence seclusion of electronic-bundling segments. A scientific model of the dynamic conduct of the shock absorber was created to depict all the material science in the shock absorber.

Ninbo Liao et al. [4] In this journal it presents to give a methodical examination to plan or assessment of a shock absorber for assurance of electronic gear framework in cruel vibration-impact condition. A tale Si-oil coupling damping shock absorber is structured and made through coupling Si-oil, elastic ball and spring by cunning strategies. A nonlinear unique model for the shock absorber is introduced by breaking down the inside liquid powerful marvel as for the model. An epic oil coupling shock absorber was researched for support of electronic in framework. It has a great powerful execution and controllable plan capacity. A numerical model of the dynamic conduct of the shock absorber has been created so as to depict the attributes happening inside the shock absorber, the numerical reenactment shows the model can mimic the real shock absorber in rough. It shows plentifulness and frequency of excitation, just as oil consistency, proportion of damping territory are the key factor to guarantee the exhibition of the shock absorber.

II. PROBLEM STATEMENT

The shock absorber of the vehicle is going failure in many cases now we concentrate on a load which is acted maximum in the damper spring during the sudden impact of the vehicle in the un even roads. In that conditions load acting in the spring are damped load from the tire weight of the vehicle and person who riding the vehicle.

III. OBJECTIVES

1. Study and understanding the passive suspension system of 2-wheeler vehicle.
2. Design and development of test set-up of shock-absorber with optimized design of spring.
3. Design of three different spring and experimental setup in CATIA software.
4. To obtain optimized design of spring with damper in ANSYS software to calculate elastic force and elongation in ANSYS.
5. Modal analysis of experimental setup with optimized spring with damper to determine natural frequency and mode shape using ANSYS software.
6. Experimental testing of setup by FFT technique and acceleration value using impact hammer test and pneumatic excitation.

METHODOLOGY-

- Initially research paper relevant to the topic is gathered and after going through research papers, shock absorber setup is examined.
- A 3-D CAD model will be prepared by studying the conventional design of mini setup for spring damper setup.
- Prepared 3-D model will be transferred to ANSYS software and proper meshing will be created on the model for further analysis.
- For determining the mode shape, natural frequency along with elongation with different spring damper modal analysis with respective damping coefficient will be provided and performed in ANSYS software.
- A prototype of the model will be manufactured.
- FFT analysis will be performed on the spring damper setup to determine acceleration at respective springs.
- Validation of experimental and numerical results.

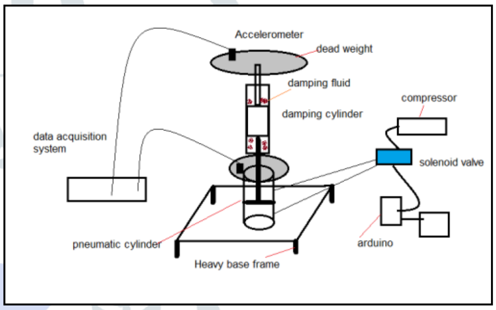
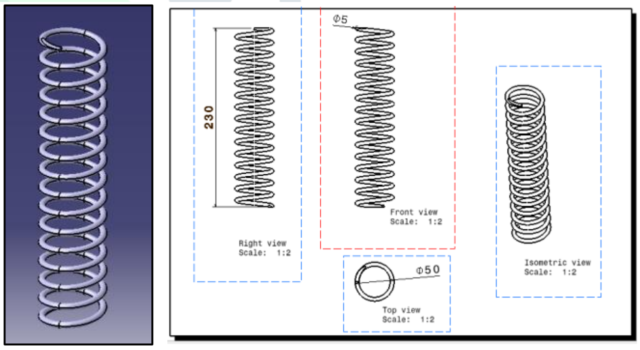
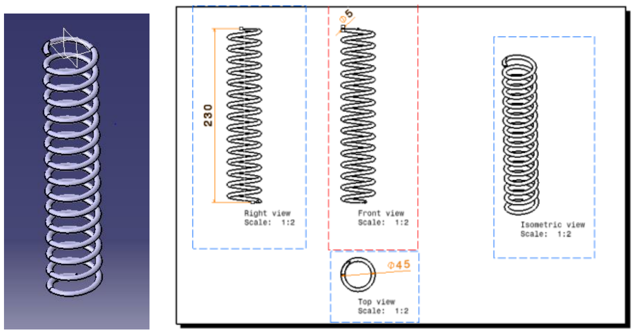


Fig 1 Schematic layout of experimental setup





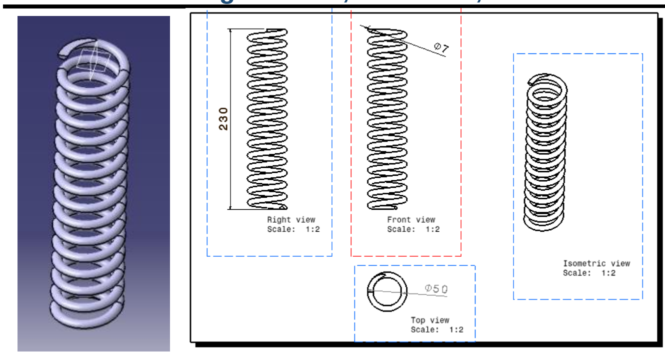


Fig. CATIA and drafting of different spring dimensions

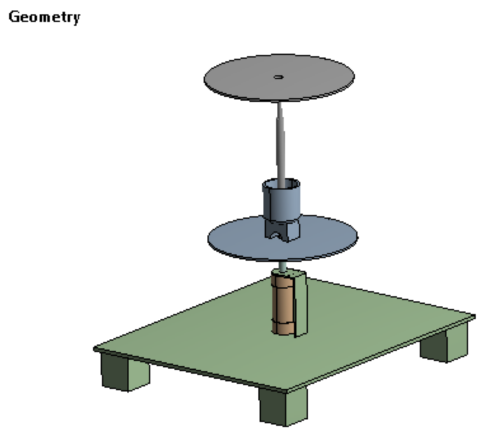
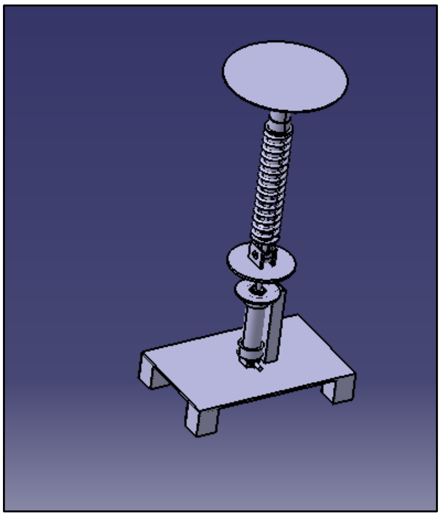


Fig. 4 Geometry imported in ANSYS



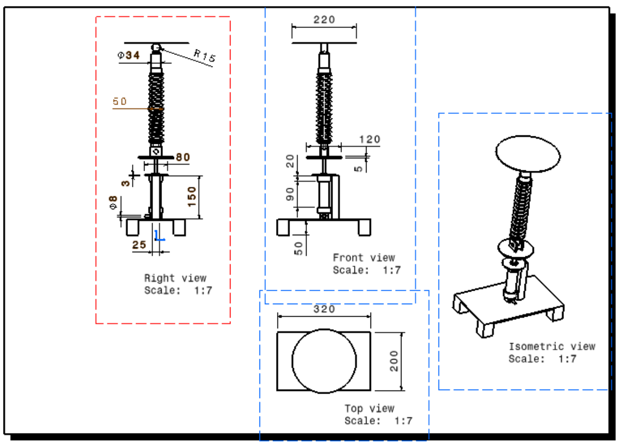


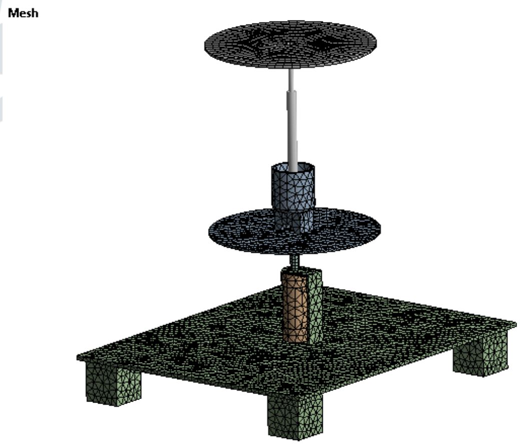
Fig. CATIA and drafting of spring damper experimental setup

TO CALCULATE SPRING STIFFNESS, FORMULA IS AS FOLLOWS

- $K = (G \times d) / (8 \times C^3 \times N)$
- G- Modulus of rigidity – steel – 80 GPa – 80×10^3 MPa
- d- diameter of spring wire in mm
- D- Diameter of coil of spring
- N- Number of turns
- C- (D/d)- Spring index

PARAMETER	SPRING 1	SPRING 2	SPRING 3
COIL DIAMETER (mm)	50	45	50
SPRING WIRE DIAMETER (mm)	5	5	7
NUMBER OF TURNS	16	16	16
SPRING STIFFNESS (N/mm)	3.125	4.28	12

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Multiphysics solutions. In ANSYS after importing geometry in module meshing is performed also known as discretization process. In meshing whole component is breakdown or discretized into small elements to solve finite element equation at nodes. In present tetrahedral mesh is used for analysis. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model.



Statistics	
Nodes	38386
Elements	18002

Fig.5 Meshing of oil damper set-up

After meshing of oil damper set-up nodes are 38386 and elements 18002.

Boundary Condition

A boundary condition for the model is that the setting of a well-known value for a displacement or an associated load. For a specific node you'll be able to set either the load or the displacement but not each. Displacement in z direction is applied with fixed support at base plate to avoid degree of freedom in other to axis. In present oil damping is converted into spring element in ANSYS to perform as viscous fluid by applying stiffness and damping.

Details of "Longitudinal - Part7 To Part5"	
Graphics Properties	
Definition	
Material	None
Type	Longitudinal
Spring Behavior	Both
Longitudinal Stiffness	12. N/mm
Longitudinal Damping	0.2 N·s/mm

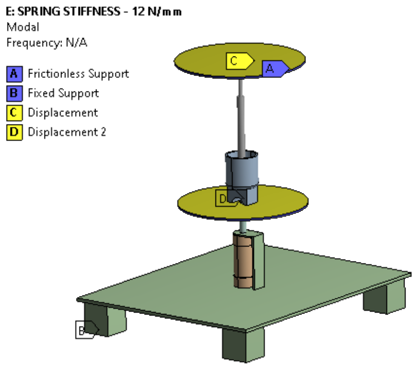


Fig 6 boundary condition of oil damper set-up

Results

In finite element method the total deformation and directional deformation are general terms irrespective of software being used. Directional deformation may be place because the displacement of the system in a very particular axis or user defined direction. Total deformation is that the vector sum of all directional displacements of the systems.

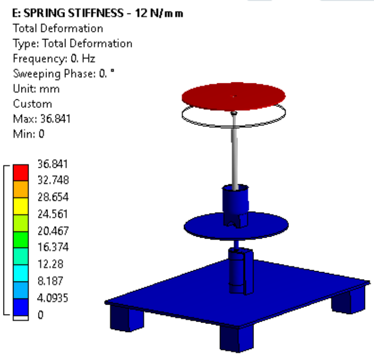


Fig 7- Mode shape 1

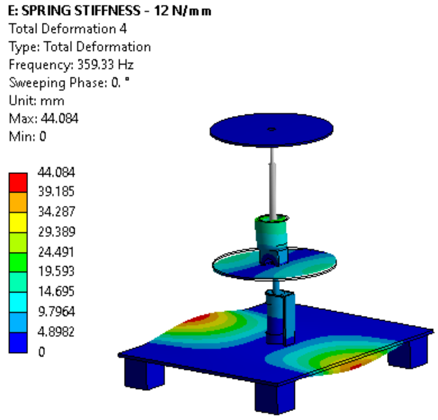
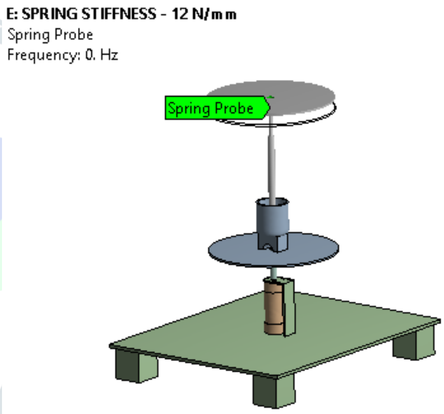


Fig 8 -Mode shape 4

Table 1 - Tabular representation of the mode shapes with respective frequency.

	Mode	Damped Frequency [Hz]
1	1.	0.
2	2.	0.
3	3.	144.92
4	4.	359.33
5	5.	405.3
6	6.	432.29

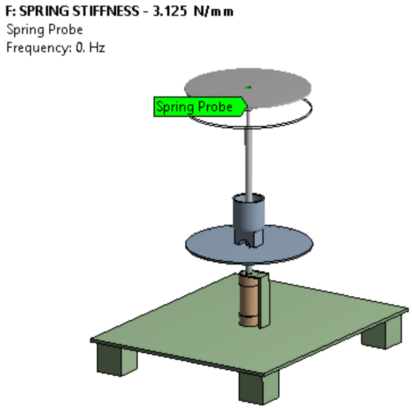


Maximum Value Over Frequency	
Elastic Force	16248 N
Elongation	32.495 mm

Maximum Value Over Frequency	
Elastic Force	446.93 N
Elongation	37.244 mm

It is observed that using spring with stiffness of 12 N/mm we get elastic force around 446.93 N with elongation of 37.24 mm.

FOR SPRING WITH STIFFNESS – 3.125 N/mm

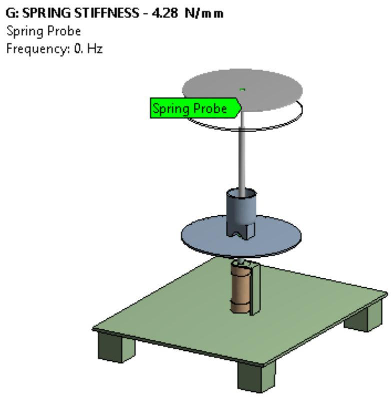


Details of "Longitudinal - Part7 To Part5"	
Graphics Properties	
Definition	
Material	None
Type	Longitudinal
Spring Behavior	Both
Longitudinal Stiffness	3.125 N/mm
Longitudinal Damping	0.2 N·s/mm

Maximum Value Over Frequency	
Elastic Force	117.52 N
Elongation	37.606 mm

It is observed that using spring with stiffness of 3.125 N/mm we get elastic force around 117.52 N with elongation of 37.606 mm.

FOR SPRING WITH STIFFNESS – 4.28 N/mm



Details of "Longitudinal - Part7 To Part5"	
Graphics Properties	
Definition	
Material	None
Type	Longitudinal
Spring Behavior	Both
Longitudinal Stiffness	4.28 N/mm
Longitudinal Damping	0.2 N·s/mm

Maximum Value Over Frequency	
Elastic Force	160.79 N
Elongation	37.568 mm

It is observed that using spring with stiffness of 4.28 N/mm we get elastic force around 160.79 N with elongation of 37.568 mm. It is observed from analysis that spring with stiffness have been optimized design for manufacturing and testing experimentally. For stiffness of 12 N/mm elastic force required is greater and less deformation or elongation than other to spring with specified dimensions

EXPERIMENTAL SETUP

MODAL ANALYSIS

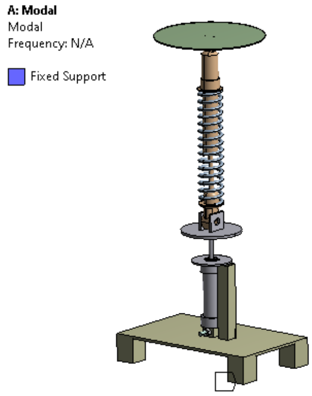
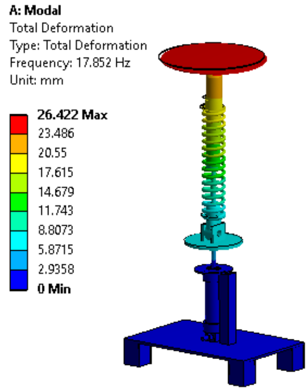
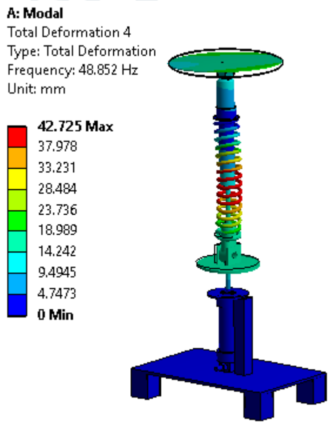


Fig. Spring with damper setup



MODE SHAPE 1



MODE SHAPE 4

Table. Tabular data of natural frequency

	Mode	Frequency [Hz]
1	1.	17.852
2	2.	20.64
3	3.	35.615
4	4.	48.852
5	5.	53.714
6	6.	70.515

EXPERIMENTAL TESTING

Fast Fourier Transform

The experimental validation is done by using FFT (Fast Fourier Transform) analyzer. The FFT spectrum analyzer samples the input signal, computes the magnitude of its sine and cosine components, and displays the spectrum of these measured frequency components. The advantage of this technique is its speed. Because FFT spectrum analyzers measure all frequency components at the same time, the technique offers the possibility of being hundreds of times faster than traditional analog spectrum analyzers.

Impact Hammer Test

Impact excitation is one of the most common methods used for experimental modal testing. Hammer impacts produce a broad banded excitation signal ideal for modal testing with a minimal amount of equipment and set up. Furthermore, it is versatile, mobile and produces reliable results. A phenomenon commonly encountered during impact testing is the so called "double hit". The "double hit" applies two impulses to the structure, one initially and one time delayed. Both the temporal and spectral characteristics of the "double hit" input and output are significantly different than a "single hit". The input force spectrum for the "double hit" no longer has the wide band constant type characteristics of a single hit. The relationship of the system's parameters with respect to data capture requirements is evaluated. The effects of exponential windowing are developed to examine the effects on the estimated spectra and modal parameters. Finally, the "double hit" phenomena is examined by combining the results from the single degree-of-freedom system excited by two impulses, one of which is time delayed. The results from these related studies are combined to provide insight into data acquisition guidelines for structural impact testing.

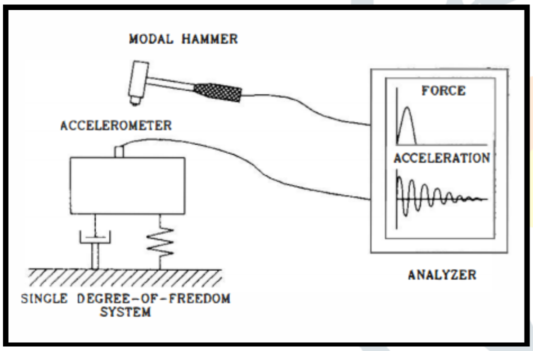


Fig. Block diagram of FFT

Fig. Experimental testing setup

Experimental Procedure

- After completion of spring with damper testing reading was taken.
- first, we had applied constant pressure of 2 Bar to pneumatic cylinder of dimension 25 x 50 on which damper was mounted.
- For applying constant force on spring with damper Solenoid valve and Arduino Uno circuit was used.
- Then accelerometer was placed at output section of pneumatic cylinder on which spring with damper was mounted and then reading of acceleration was taken.
- after that accelerometer shifted to the output section of damper plate and reading of acceleration was taken.

EXPERMENTAL TESTING FFT PROCEDURE

- Initially fixture is designed according to existing boundary condition as per FEA results.
- FFT consists of impact hammer, accelerometer, data acquisition system in which each supply is applied to DAS and laptop with DEWSOFT software to view FFT plot.
- Accelerometer is mounted at surface as per high deformation observed in FEA results along with initial impact of hammer is placed for certain excitation to determine frequency of respective mode shapes.
- After impact FFT plot are observed on laptop and comparison of FEA and experimental results are analysed.

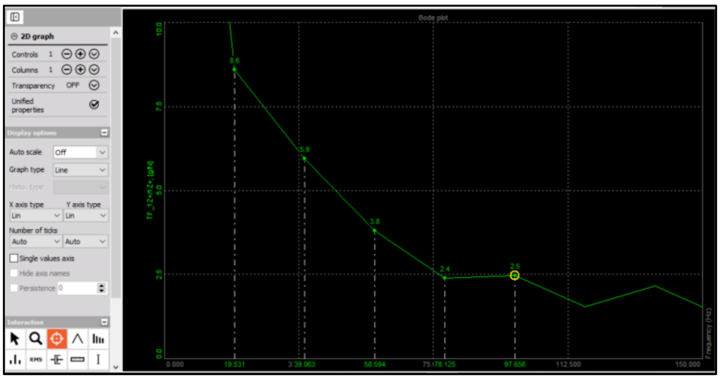


Fig. FFT plot of spring with damper setup

Tabular Data

	Mode	Frequency [Hz]
1	1.	17.852
2	2.	20.64
3	3.	35.615
4	4.	48.852
5	5.	53.714
6	6.	70.515

Table. Comparison of spring with damper setup FEA and FFT results

MODE SHAPE	FEA	EXPERIMENTAL
1	17.85	19.53
2	20.64	19.53
3	35.61	39.06
4	48.85	58.59
5	53.71	78.12

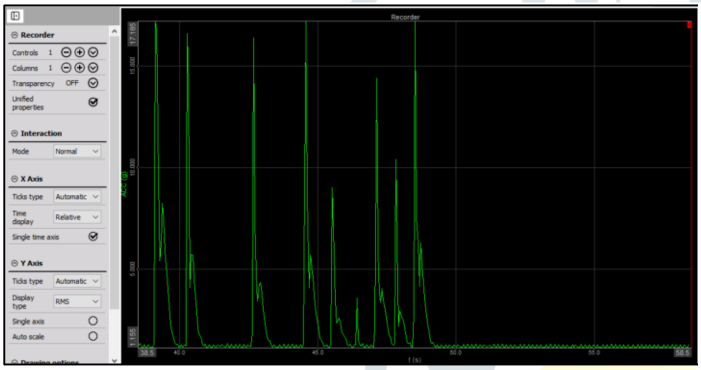


Fig. FFT plot of acceleration of excitation of pneumatic exciter of spring with damper

Maximum acceleration is observed around 17.14 m/s^2

Conclusion

- In present research spring with damper characteristics of different dimension of spring are selected along with design of experimental setup to measure acceleration and frequency.
- Spring with optimized dimension is selected after FEA analysis for manufacturing and experimental testing it with damper for FFT test.
- Initially in FEA analysis spring stiffness values are varied as per damping to obtain elongation and elastic force. It is observed that increase in spring stiffness damping coefficient decreases elongation along with increase in elastic force.
- Modal analysis of experimental setup is performed to determine natural frequency along with respective mode shape and experimental FFT technique is utilized for comparison of result. It is seen that natural frequency obtained by both FEA and FFT are similar in range.
- Acceleration obtained from FFT result are observed around 17.14 m/s^2 for pneumatic excitation.

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