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Design Optimization of Mirror Post Assembly for Achieving Desired Natural Frequency

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Abstract: The automobiles experience a lot of vibration which causes the mountings to vibrate. These vibrations may hamper the working of the parts. Mirrors are the mounting which is the most reliable source to check the rear sides of the vehicle. The rear-view mirrors must have provided a stable view to the driver when driving. As it's seen that from literature study, Mirrors tends to resonance at low excitation frequency because of vibration coming from engine and road conditions thus it is necessary that design should be robust to avoid resonance. To study the vibrations, finite element method and experimental approaches are the only approaches for complex shapes. The finite element analysis method provides helps in determining the natural frequencies and mode shapes. In this study, we perform modal analysis of rear-view mirror post assembly using Ansys to check the natural frequency at where resonance problem occurs, which effects on the performance of a mirror and made the design optimization by finding 4 iterations. Selection of optimize iteration done on the basis of targeted natural frequency which has achieved the desired goal of a project that is sharp reflected images from the mirror

Keywords: ANSYS, Excitation frequency, FEA, Modal analysis, Natural frequency, Finite Part Methodology (FEM), Rear view side mirror (RVSM), Vibration

I. INTRODUCTION

In India public transport is mostly through passenger commercial vehicle. The working area of people is not near to the living area. Many cities are specially designed in which residential area and industrial area is separately located. Many people come from small town to big cities for a job every day. Town people have to use a commercial vehicle for transit. According to safety commercial vehicle is very useful for long distance. In rural areas commercial vehicles used within town also. It is not possible for everyone to use their own vehicle or have their own vehicle. Cities like Delhi, Mumbai, and Pune most people use public transport services. Public transport is a necessity in bigger cities. Passenger commercial vehicles are specially designed for transporting. The bus is a type of passenger commercial vehicle. The bus is a road vehicle which carries passengers as much as possible with comfort and safety. Buses have the capacity as high as possible. The bus is a good option for commutation and it is economical also. Safety of passengers is the main concern in designing of buses. Driver has to deal with many things during his job. Our cities are crowded having a huge number of vehicles on road especially at peak hours. Everyone is in a hurry to reach somewhere and lack of discipline is also at its peak at this time. Its driver's responsibility to make the journey safe for passengers. Passenger safety starts from an entry in the bus up to exit from the bus. Passenger should feel safe during the journey. Problems occur during entry and exit of the bus. More rush leads to an accident while entering and taking the exit from bus. Bus provides wide doors for entry and exit.

Driver has some controls to drive safely. Bus has very good arrangement for safe entry of passengers as shown in Fig 1. But only this provision is not sufficient for the safety of the passenger in rush hours. Driver has to look after the outlets while stopping and leaving at the bus stops. Rear mirror arrangement is provided to the bus for driver's help. Arrangement of side mirrors is designed so that he can able to judge correctly what is around of the vehicle.

II. LITERATURE SURVEY

Zhiping Zhang, [1] presented work on car rear view mirror simulation and analysis of the dynamic characteristics; they used ANSYS to simulate the vibration frequency and vibration modals of the car rear-view mirror under the condition of excitation sources. The results show that because of low modal frequency of mirror its easily inspired by the engine , powertrain system and road to vibrate, on the basis geometric measurements, guidelines and requests, a sensible decision of the mirror size and introducing position design iterations made for get reed of low modal frequency. Antoine Larchez [2] presented work on initial development of a predictive ways to compensate vibrations of a mirror the new concept for new approach had been developed and the online performance of prediction algorithm is shown. The mean and time-varying characteristics of the vibration signal are measured by Auto-Regressive-Integrated-Moving-Average model. Experimentation was first done to measure the Vibration threshold of human perception. As well as, tests conducted to gets the actual vibration of the Mirror. The comparison of those two frequency responses has shown that perception was the most affected by frequencies in the range of [0,40Hz]

Yogesh kothawade [3] presented work on outside rear view mirror to eliminate the resonance from mirror. In these they use Numerical analysis to finding natural frequency and compared it with excitation frequency coming from engine and road conditions and its found that natural frequency of mirror is below the excitation frequency they change design using two basic things, structural modification either or changing the material properties. material properties like mass density and young's modulus were modified and the natural frequency increased.

Trupti Nirmal [4] Focused on Finite element model for the automobile rearview mirror was created to predict mirror vibration response based on modal analysis study. The materials used in this Experiment were initially provided by the mirror manufacturer and also some modification was done to create the desired output. Hyper mesh Optistruct solver used to build the complete FEA. Vibration modes are predicted for the mirror with a focus on the mirror mounting bracket. The natural frequency obtained from FEA results were co-related with experimental results and after that Iteration was made to get desired natural frequency.

Santosh S. Mangade1 [5] presented work on Vibration analysis on two-wheeler mirror, In that paper mentioned that according to Indian standard the frequency range given for the back view reflect is extending from 0-45Hz however results gotten by the primary characteristic frequency of the mirror is more than the 50Hz. The motor excitation frequency is around 58 to 67Hz so there are chances of resonance. From experimental analysis concludes that the first normal frequency of the mirror gets together is at 59Hz and the main mode shape is interpretation and pivot about Y-hub and

Opposite to Z-hub. There is a great relationship between experimental outcome and FEA results for first common frequency and mode shape. To resolve this problem that tried to reduce the weight of mirror Increase the stiffness of the rod, Reduce the mass of the mirror, Use the material with higher elastic modulus, Add the rib structure inside the mirror, Mount the mirror at the handlebar end so overhang can be reduced of the cantilever beam, Use of spring mass damper system to reduce the vibration, Isolator between glass and mirror holder.

Pravin Patil [6] this paper manages the methodical investigation of the relationship amongst test and FEA results utilizing RADIOSS. Modal analysis is performed to find natural frequency and mode shape of system. Modal analysis results are utilized to give input for response analysis contribution to reaction investigation. Modal analysis performed and found natural frequencies is between 25Hz to 44Hz. In frequency response analysis the excitation given to mirror by accelerating at the turbocharger outlet. 25% engine vibrations were transmitted to frame through isolators and found that High displacement on standard mirror post during engines idle frequency range.

Birajdar Suraj Sadadeo[7] In this paper they performed the vibration analysis of automobile outer rear view mirror with its development and optimization. The existing actual mirror assembly has a first natural frequency of 22 Hz. The target is to suggest and do the modifications in the mirror assembly to bring the frequency value close to 45Hz. They used following method to obtained desired natural frequency, Adding stiffeners to parts that are less stiff in response, Selecting the materials with higher Elastic Modulus, Adding additional clamping/connection points in the assembly to stiffen it, Adding new parts without much affecting the base cad maximum outer dimensions, By removing material in such a way that the stiffness won't reduce, By thinning of the existing rib structure, By using materials with lower density, By introducing cut-outs or holes without affecting the structures stiffness.

M. O'Grady [8] presented work on Automobile Internal Rear-View Mirror, Finite element model were uses to check mirror vibration response. For this they uses ANSYS package. Vibration analysis done on alone bracket and mirror assembly. To verify results of ANSYS experiment method is used. And the results shows good correlation between experimental and FEA results.

Shigeru Ogawa [9] presented work on Side-View Mirror Vibrations Induced Aerodynamically by Separating Vortices In this using experimental method they clarify the side view mirror vibration due to separating vortices its found that mirror has primary natural frequency of 25,30 and 33 Hz, and intensity of vibrations of the mirror is increases with proportion to flow velocity and their frequencies have peak values at 120 and 140 km/h. after that numerical study of mirror was done to capture the external forces vibrating the mirror.

1) *Literature Summary:* Automobile and Ancillary industry design parts with considering its standards. Each design has minimum 3/4 alternatives while designing. The finalized design is the optimized one. Optimum design is decided on basis of part's functional ability and its cost. Every different structure has its own natural frequency. If Natural frequency coincides with source vibration frequency then structure starts vibrate with large amplitude at its peak. It is necessary to find out natural frequency of every proposal for vibration proof structure during working condition. Natural frequency can be found out by actual testing method which means testing of proposals under actual working condition in test lab on test rig. But it is not

economical to manufacture every proposal for testing. Then second method is to do analysis through software. It saves cost and it is very much important in competitive market. Vibration analysis is carried out for finding its dynamic behaviour. In that Modal analysis is way to find out natural frequency and its mode of vibration. In most of paper it's mentioned that mirror is gets vibrate with high amplitude at low modal frequency because of excitation from engine (0 to 45 Hz) and road conditions, so our aim is to eliminate low frequencies to avoid resonance.

III. PROBLEM STATEMENT

Mirror vibration, particularly in passenger buses and the heavy vehicle has a major complaint. Such vibration results in blurry images and this affects driver, vehicle control and safety of the driver and passenger

A. Objectives

1) Design optimization of mirror post to keeps natural frequency of mirror post above the targeted frequency(forty-five Hz) which is excitation frequency coming from engine vibration and road conditions.
2) To obtain optimized mirror post design by FEA.
3) To validate FEA modal analysis results with experimental modal analysis

B. Scope

During this venture vibrational study using FEA and FFT analyzer to be done. To examine which methods are available for measuring natural frequency. Find out which parameter will affect the natural frequency of the mirror post Know how to eliminate vibration of sources to get affected on automotive accessories. Finding the best iteration of design on the basis of natural frequency.

C. Methodology

1) To find the natural frequency and Mode shapes of existing RVSM FEA analysis will do using the ANSYS package.
2) Experimentation of existing design: The modular investigation of the RVSM to be done to locate the principal examination. The setup to be made for the free vibration. The RVSM will fix in the setup and hammer will be utilized to bang the mirror. The underlying excitation was given and vibrations were noted utilizing FFT analyser. From the experimental examination, it will see that characteristic frequencies of the current structure were closing as far as possibly depicted by JIS. As there is reverberation, the abundance vibrations will be seen in the current design.
3) Modification of design: To avoid the vibrations in view of the mirror, it is important to add the stiffness to the mirror. Regular frequency is relying upon the stiffness of mirror section structure and mass of the entire structure. From the connection, we can say that regular frequency is specifically relative to solidness and contrarily extent to the mass of the structure. On the off chance that solidness of structure expands, at that point common frequency of structure increments. In the event, that firmness of structure diminishes, at that point, the normal frequency of structure diminishes (Mass kept constant)
   $Fn \propto K$ and $Fn \propto 1/m$
   Fn = Natural Frequency
   K = Stiffness
   M = Mass
   If the mass of structure increases, then the natural frequency of structure decreases. If mass of structure decreases then the natural frequency of structure increases (Stiffness kept constant).
4) Preparation of proposals and analysis of same.
5) Selection of optimum solution from proposals.
6) Experimental analysis of the optimum design iteration. To validate results.

IV. MODAL ANALYSIS OF EXISTING MODEL

The design of the automotive mirror assembly is carried out using 'FEA'. The automotive mirror assembly is modelled using ANSYS 19.1 software using SOLID 187 element. The advantages of this automotive mirror assembly are that it can be easily tuned to the excitation frequency, so it can be used to reduce the vibration of the system subjected to the variable excitation frequency.

Some new design ideas are created. There are two different ideas that can work out. First one is to change material and see for what is good for automotive mirror assembly and the second option is to change the structure design and to observe the change in natural frequency. Material change doesn't change the natural frequency in long range. So, design change option is good for natural frequency increase.

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A. MESH

Meshing is done by using tetrahedral program-controlled elements. Meshing size is decided as per fine result required with soft behaviour. Meshing size 8 mm is decided and kept the same for all proposals. Meshing is one of the important parts of the analysis. It decides how accurate results are going to come.

Statistics		
Nodes	57765	31863
Elements	38914	17193
Mesh Metric	None	

Fig no. 1: Meshing of Existing Mirror post

B. Material Assignment

Then CAD geometry is imported into ANSYS 19.1 software for modal analysis. Mirror with plastic nylon derivative and other rest of the structure is of structural steel. Density and other isentropic properties have been entered.

Material		
Assignment	mirror	Structural Steel
Nonlinear Effects	Yes	
Thermal Strain Effects	Yes	

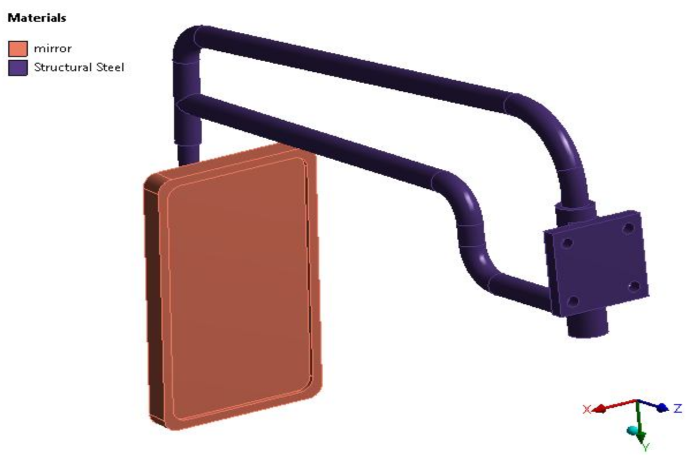

Fig no. 2 Existing RVSM material properties

C. Boundary Conditions

Fixed Support type fixity is given to the one end of the frame for modal analysis.

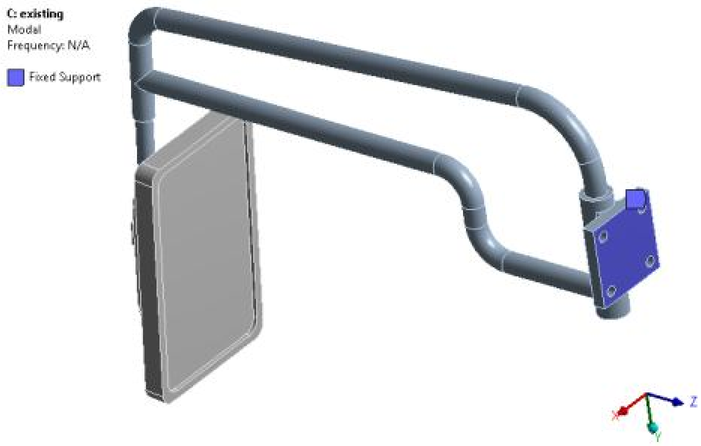

Fig no. 3 Existing RVSM Fixed support

The software provides total deformation of the automotive mirror assembly. An understanding of automotive mirror assembly mode shapes is required so that significant parameters that affect each mode can be determined to allow for the possibility for adjusting different modal frequencies. Following mode, shapes were found using the model developed in ANSYS. The first six natural frequencies obtained are tabulated in the following table and corresponding mode shapes of the absorber are evaluated using finite element analysis by writing an ANSYS program as shown in Fig.

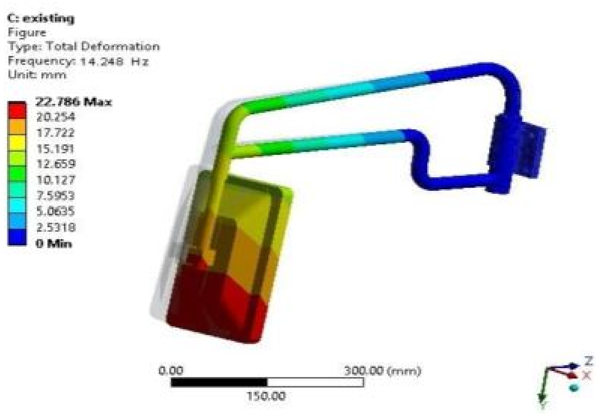

Fig no. 4 Existing RVSM First Mode Shape 1

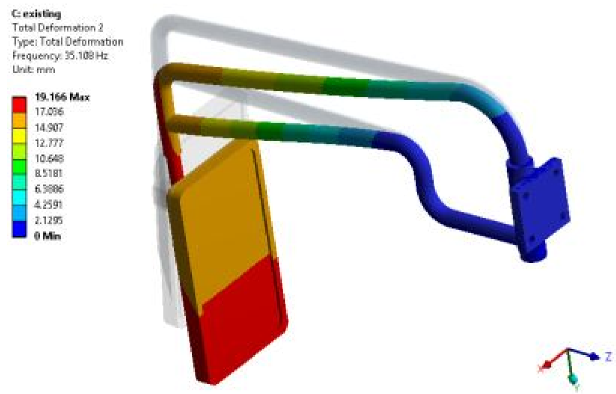

Fig no. 5 Existing RVSM Second Mode Shape 2

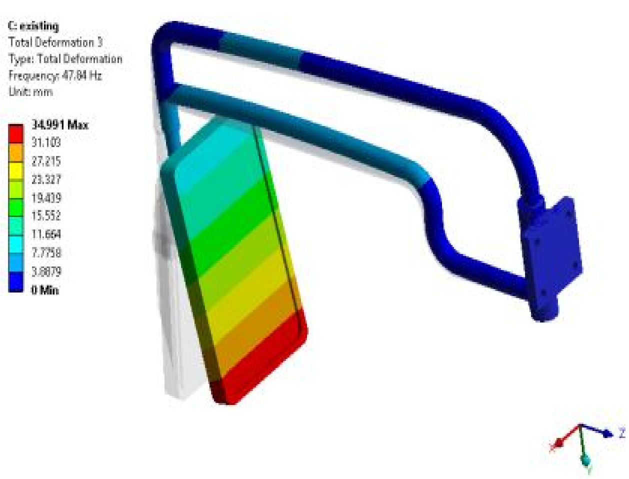

Fig no. 6 Existing RVSM Third Mode Shape 3

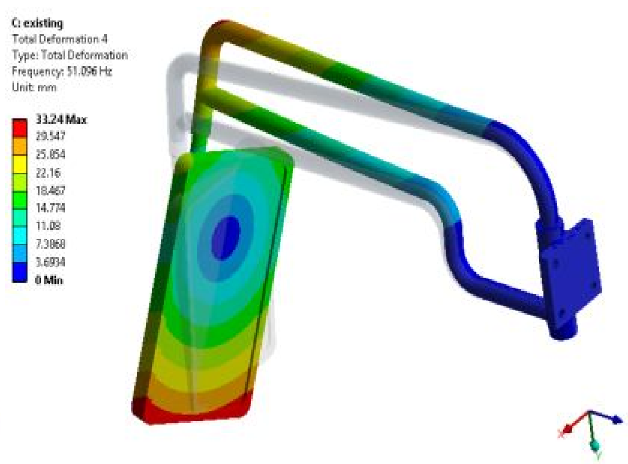

Fig no. 7 Existing RVSM Fourth Mode Shape 4

D. Results From Ansys

Table no. 1 Natural frequency of Existing RVSM

Results						
Minimum	0. mm					
Maximum	22.786 mm	19.166 mm	34.991 mm	33.24 mm	45.727 mm	35.411 mm
Average	13.689 mm	13.397 mm	13.8 mm	11.679 mm	13.798 mm	12.731 mm
Minimum Occurs On	STEM_0					
Maximum Occurs On	MIRROR_0					
Information						
Frequency	14.428 Hz	35.108 Hz	47.84 Hz	51.096 Hz	142.27 Hz	162.92 Hz

The natural frequency calculated through numerical analysis and its seems that the natural frequency is matching with engine vibrations so, It needed to avoid the resonant frequency of existing design and vibration range (0 to 45 Hz) coming from engine. So need to make design iteration for RVSM

V. MODAL ANALYSIS OF ALTERNATE DESIGN

A. Iteration No.1

For Iteration No.1 simply supported frame is used. Its advantage that its mass got reduced than the existing model so, reduction in mass helps in increasing natural frequency. But stiffness also got change. The solution is carried out using the same criteria.

1) CAD Model

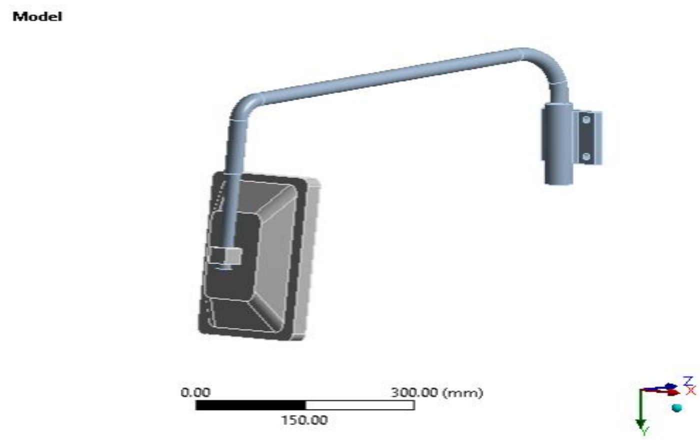

Fig no. 8 CAD model for Iteration 1

2) The First Six Natural Frequencies Obtained Are As Below

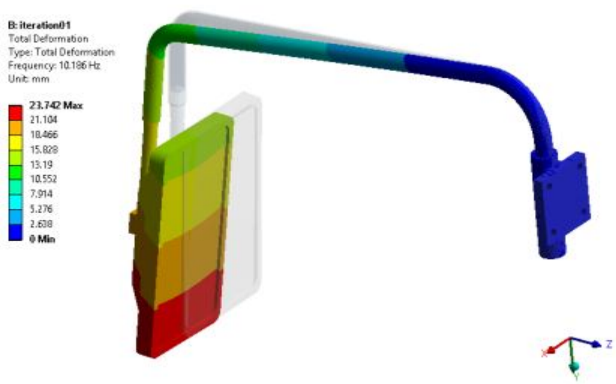

Fig no. 9 Mode shapes 1 for Iteration 1

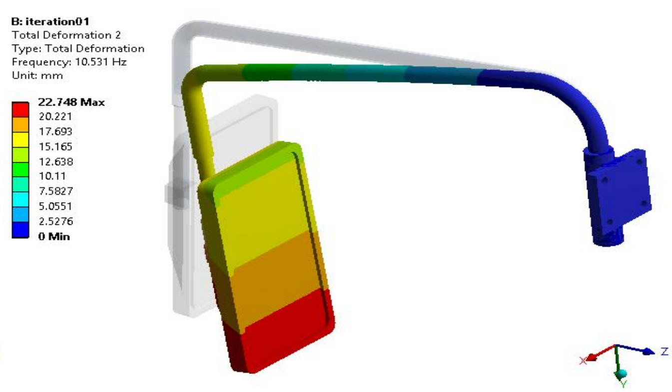

Fig no. 10 Mode shapes 2 for Iteration 1

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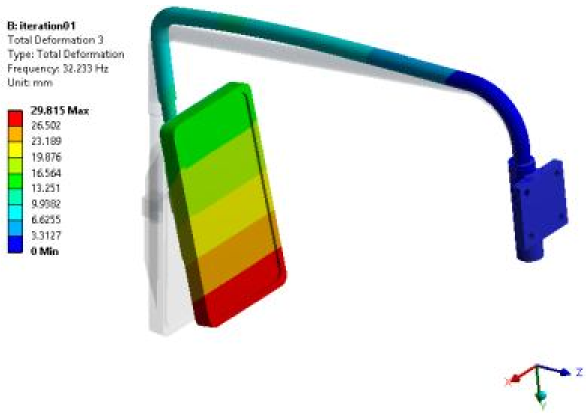

Fig no. 11 Mode shapes 3 for Iteration 1

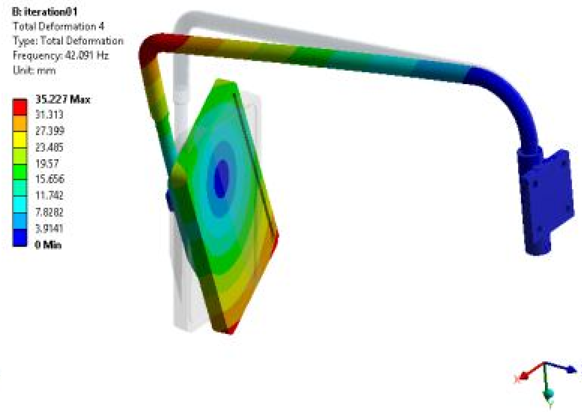

Fig no. 12 Mode shapes 4 for Iteration 1

Natural frequency obtain for mode shapes 1 to 6 are 10.186, 10531, 32.233, 42.091, 122.09 and 149.08 Hz resp. and maximum deflection is 23.742, 22.748, 29.815, 35.227, 44.586 and 35.776 Resp.

3) Results from ANSYS

Table no. 2 Natural frequency of Iteration 1

	Results					
Minimum	0. mm					
Maximum	23.742 mm	22.748 mm	29.815 mm	35.227 mm	44.586 mm	35.776 mm
Average	15.14 mm	14.972 mm	15.619 mm	12.292 mm	15.072 mm	13.579 mm
Minimum Occurs On	STEM					
Maximum Occurs On	MIRROR			STEM	MIRROR	
	Information					
Frequency	10.186 Hz	10.531 Hz	32.233 Hz	42.091 Hz	122.09 Hz	149.08 Hz

B. Iteration no. 02

To eliminate drawbacks of existing model two separate mounting provided for better stiffness and firm support. Supports are in the same plane but not parallel to the plane of the mirror. First support remains the same and another support arm is attached with the support.

CAD model geometry is completed in the same software used before creo. Then this CAD model is used for modal analysis. Analysis details kept same for Iteration No. 02 as well so we can compare all analyses of models. Material kept same. The density of parts entered correctly. Meshing has been done with the same meshing control details. Fixed supports added as per new design. Modal analysis has been carried out and compared with the previous one.

Iteration No. 02 model has more mass than Iteration No. 01. So it will reduce natural frequency. But, stiffness got increase so natural frequency may also increase. Iteration No. 02 has a very stable structure than Iteration No. 02. Natural frequency is going to increase than before because of one supporting arm added with support.

1) Cad Model

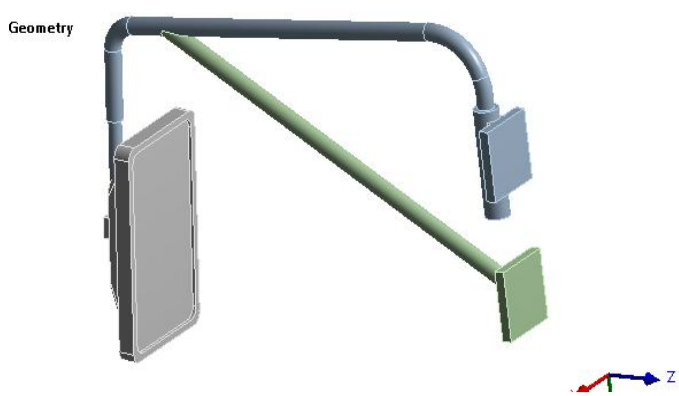

Fig no.13 CAD model for Iteration 2

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2) The First Six Natural Frequencies Obtained Are As Below

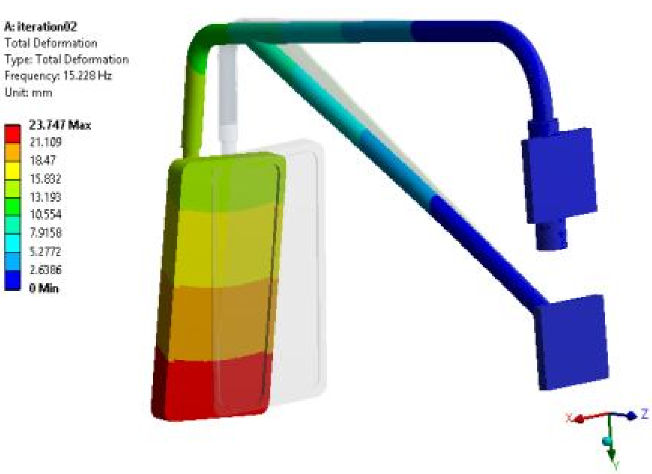

Fig no.14 Mode shapes 1 for Iteration 2

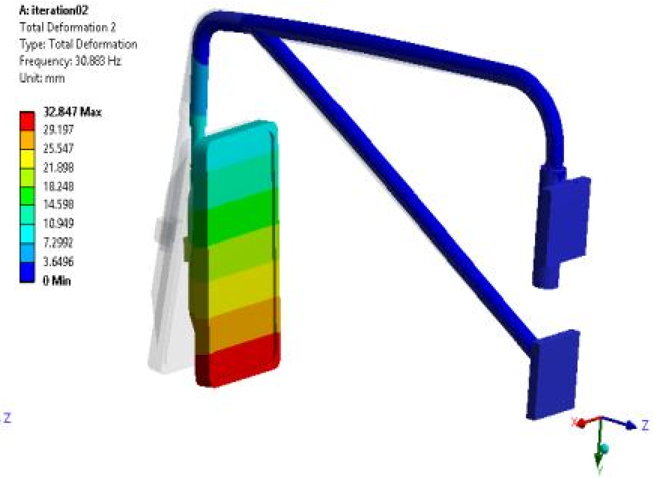

Fig no. 15 Mode shapes 2 for Iteration 2

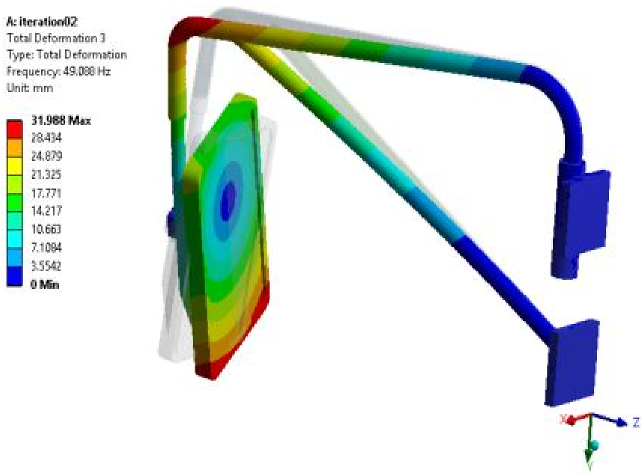

Fig no. 16 Mode shapes 3 for Iteration 2

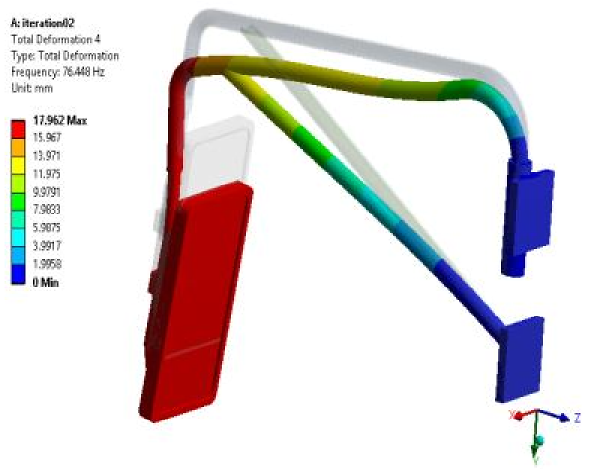

Fig no. 17 Mode shapes 4 for Iteration 2

Natural frequency obtain for mode shapes 1 to 6 are 15.228, 30.883, 49.088, 76.448, 126.68 and 150.44 Hz resp. and maximum deflection is 23.747, 32.847, 31.988, 17.962, 44.553 and 35.829 Resp.

3) Results from ANSYS

Table no. 3 Natural frequency of Iteration 2

Definition						
Type	Total Deformation					
Mode	1.	2.	3.	4.	5.	6.
Identifier						
Suppressed	No					
Results						
Minimum	0. mm					
Maximum	23.747 mm	32.847 mm	31.988 mm	17.962 mm	44.553 mm	35.829 mm
Average	13.198 mm	12.914 mm	10.959 mm	13.095 mm	13.168 mm	12.397 mm
Minimum Occurs On	STEM					
Maximum Occurs On	MIRROR					
Information						
Frequency	15.228 Hz	30.883 Hz	49.088 Hz	76.448 Hz	126.68 Hz	150.44 Hz

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C. Iteration No.3

For Iteration No.3 single vertical bar used which is fixed to framed supports at the ends.

1) CAD Model

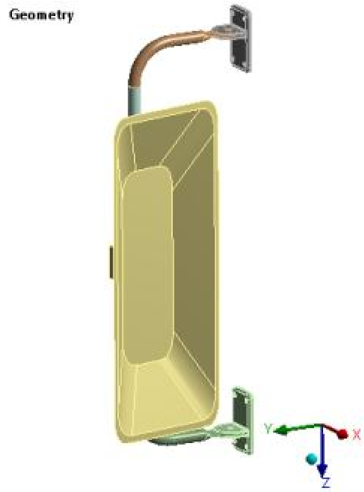

Fig no.18 Cad model for Iteration 3

2) The First Six Natural Frequencies Obtained Are As Below

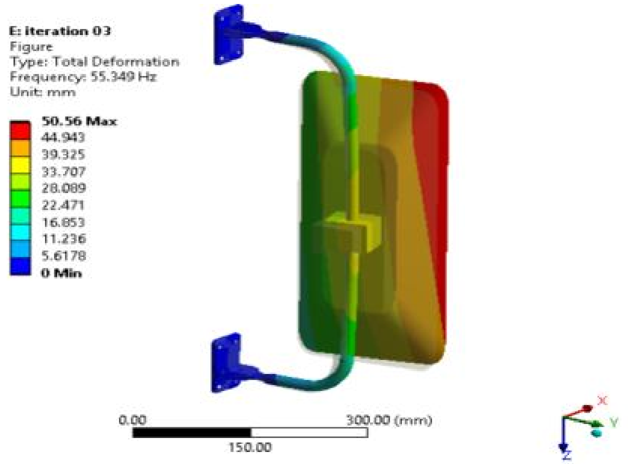

Fig no.19 Mode shapes 1 for Iteration 3

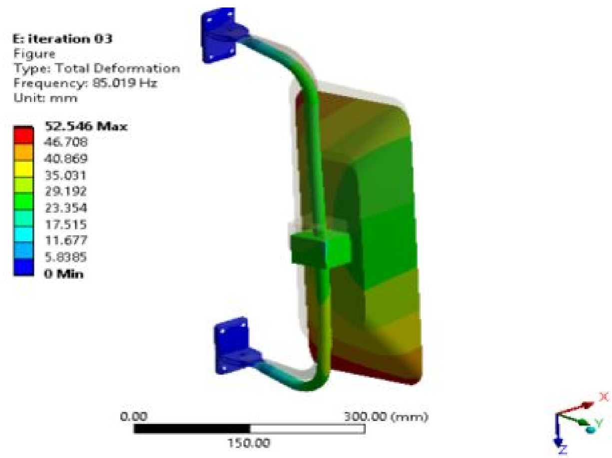

Fig no.20 Mode shapes 2 for Iteration 3

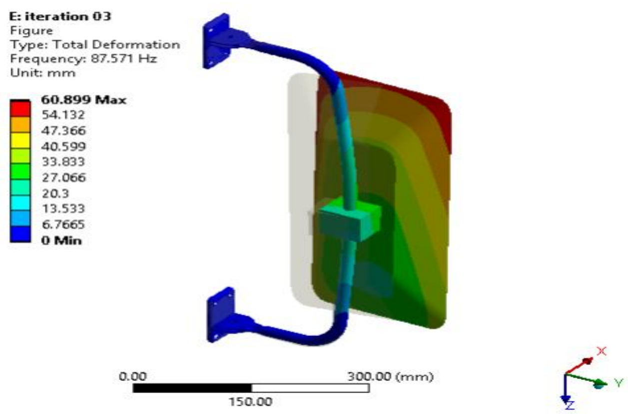

Fig no.21 Mode shapes 3 for Iteration 3

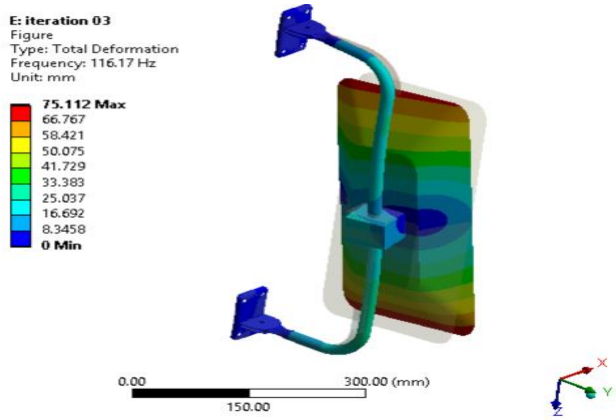

Fig no..22 Mode shapes 4 for Iteration 3

Natural frequency obtain for mode shapes 1 to 6 are 55.349, 85.019, 87.571, 116.17, 14.668 and 169.32 Hz resp. and maximum deflection is 50.56, 52.546, 60.899, 75.112, 72.633 and 79.656 Resp.

3) Results from ANSYS

Table no. 4 Natural frequency of Iteration 3

	Definition					
Type	Total Deformation					
Mode	1.	2.	3.	4.	5.	6.
Identifier						
Suppressed	No					
	Results					
Minimum	0. mm					
Maximum	50.56 mm	52.546 mm	60.899 mm	75.112 mm	72.633 mm	79.656 mm
Average	26.686 mm	27.26 mm	26.735 mm	24.809 mm	26.28 mm	26.105 mm
Minimum Occurs On	MOUNTING_BRACKET_BIG					
Maximum Occurs On	mirror					
	Information					
Frequency	55.349 Hz	85.019 Hz	87.571 Hz	116.17 Hz	146.68 Hz	169.32 Hz

D. Iteration No.4

For Iteration No.4 Plane of mounting is changed which is parallel to the plane of the mirror. Two supports are kept in the same situation. Supports are vertical. A structure like cantilever is changed and became stiffer so that less vibration it can face during working. Mirror kept same. Dimensionally support length is also changed. Position of mirror fixing is also changed.

1) CAD Model

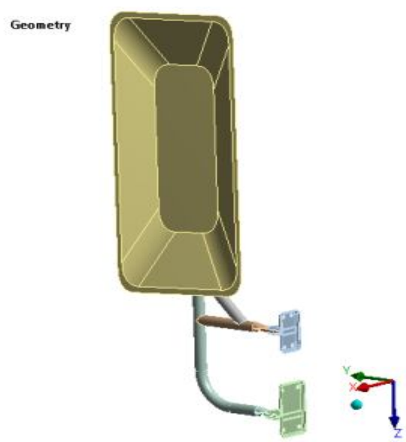

Fig no.23 Cad model for Iteration 4

2) The First Six Natural Frequencies Obtained Are As Below

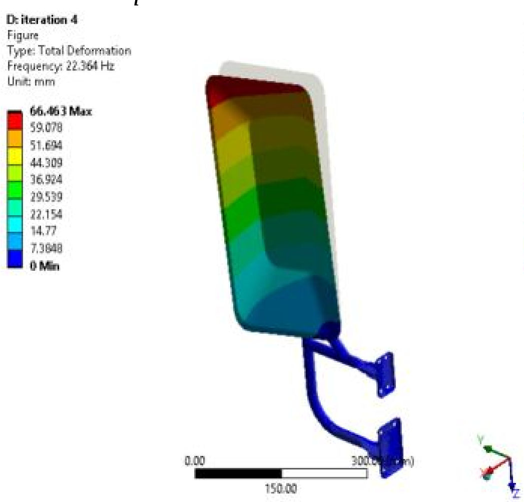

Fig no.24 Mode Shapes 1 for Iteration 4

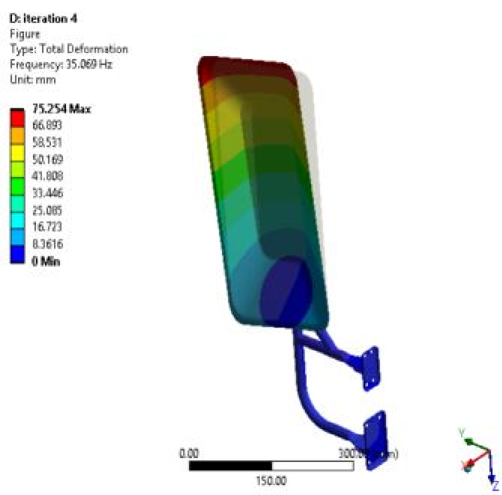

Fig no.25 .Mode Shapes 2 for Iteration 4

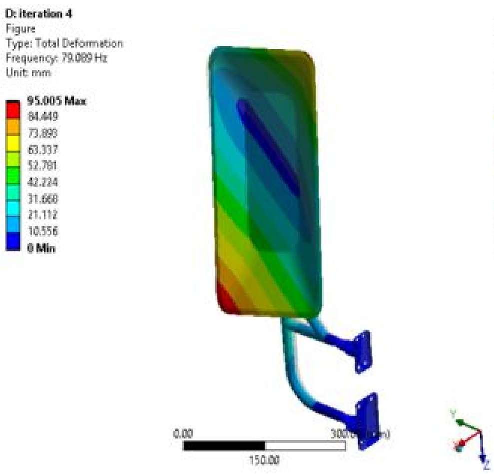

Fig no.26 Mode Shapes 3 for Iteration 4

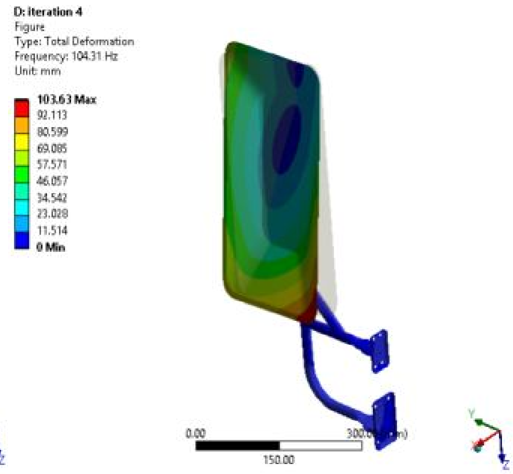

Fig no.27 Mode Shapes 4 for Iteration 4

Natural frequency obtain for mode shapes 1 to 6 are 22.364, 35.069, 79.089, 104.31, 11.851 and 190.26 Hz resp. and maximum deflection is 66.463, 75.254, 95.005, 103.63, 59.246 and 61.049 Resp.

3) Results from ANSYS

Table no. 5 Natural frequency of Iteration 4

Definition						
Type	Total Deformation					
Mode	1.	2.	3.	4.	5.	6.
Identifier						
Suppressed	No					
Results						
Minimum	0. mm					
Maximum	66.463 mm	75.254 mm	95.005 mm	103.63 mm	59.246 mm	61.049 mm
Average	24.811 mm	23.736 mm	25.235 mm	23.937 mm	27.389 mm	27.137 mm
Minimum Occurs On	MOUNTING_BRACKET_SMALL					
Maximum Occurs On	mirror					
Information						
Frequency	22.364 Hz	35.069 Hz	79.089 Hz	104.31 Hz	118.51 Hz	190.26 Hz

E. Conclusion Of FEA Results

Table no. 6 Natural frequency of Existing RVSM

Mode No.	Natural Frequencies				
	Existing Design	Iteration No.1 Model	Iteration No.2 Model	Iteration No.3 Model	Iteration No.4 Model
1	14.428	10.186	15.228	55.349	22.364
2	35.108	10.531	30.883	85.019	35.069
3	47.84	32.233	49.088	87.571	79.089
4	51.096	42.091	76.448	116.17	104.31
5	142.27	122.09	126.68	146.68	118.51
6	162.92	149.08	150.44	169.32	190.26

Existing Design of model has a natural frequency above that Japanese Industrial Standard recommended natural frequency. So, the Existing Design of model leads to be an optimized solution for automotive mirror assembly.

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VI. EXPERIMENTAL ANALYSIS

To validate FEA results it must use experimental analysis and in this, we have used FFT analysis for finding the Natural frequency of the existing model. For analysis, we used Dewe- 43 FFT analyser, acceleration sensors, hammer with load cells.

A. Procedure For Experimentation

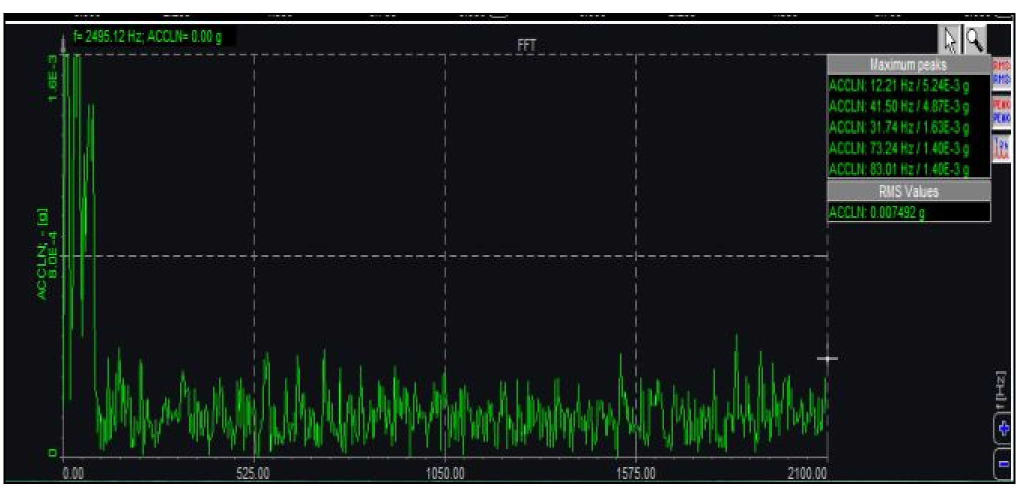
1) At first, it was found out by FEA that Natural Frequency of rear view mirror is less than the standard.
2) In order to carry out the modal analysis of rear view mirror, the assembly was fixed using clamps to the Table in Workshop.
3) After assembly of apparatus in vibration analyser, measurement scheme has to be made, in analyser proper selection of sensors and their channel is made. Measurement parameters are defined.
4) All sensors should be attached to vibration analyser when it is in power-off mode. Proper connections of all sensors are made. Various sensors used are accelerometers and digital stroboscope.
5) The accelerometers are attached to mirror assembly as shown in Figure to measure the natural frequency of mirror assembly.
6) Impact Hammer is used to giving initial excitation.
7) Natural Frequency is measured with the help of FFT Analyser.
8) After data acquisition data is further transferred to Computer for data processing.

B. Experimental Setup For Existing RVSM

Impact hammer was used to excite the RVSM frame at selected points and the resulting vibrations were recorded by means of an Accelerometer held to the specimen through the clamp. At each selected point, the hammer was made to strike for three times means the total length.

Fig no.28 Experimental setup

1) *Experimental Results for Existing RVSM:* The figure shows the experimental result for Acceleration vs. Frequency Graph



Graph no. 1 Graph of Acceleration vs. Frequency

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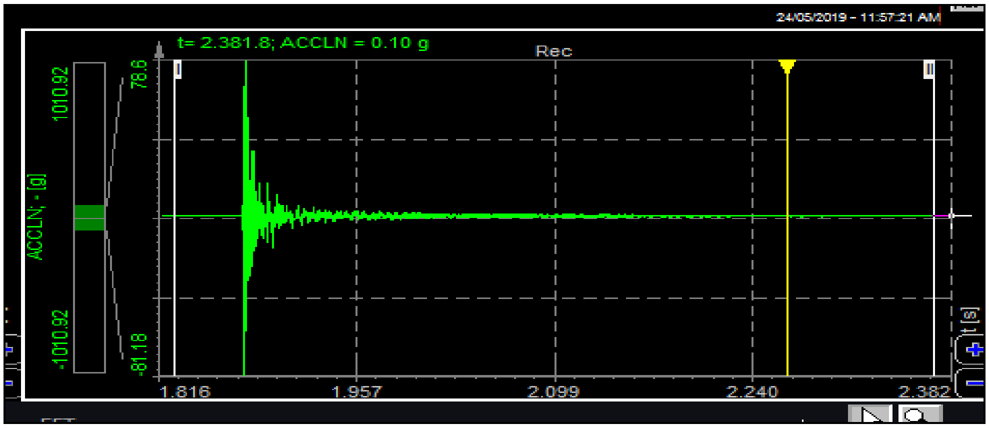
From the following graph natural frequency for existing mirror post obtained from experimental analysis



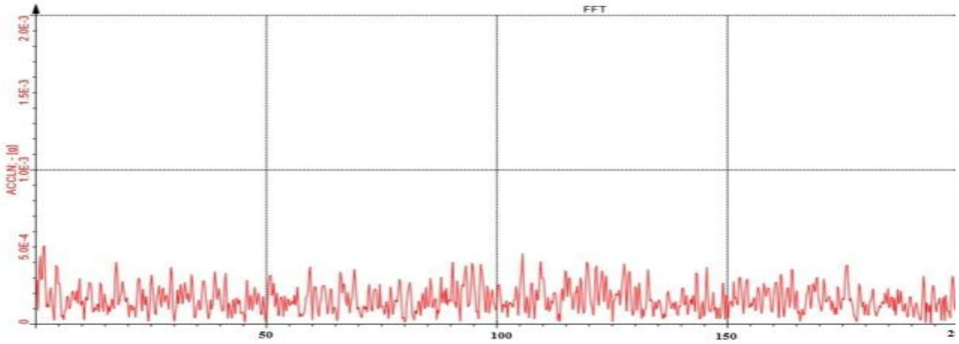
Graph no. 2 Graph of Acceleration vs. Time

C. Experimental Setup For Iteration 3

For Iteration 3 same procedure and rules are followed in these two ends of the post are fixed by using Clamp and noted the Value and frequencies using FFT analyzer.

Fig no. 29 Experimental setup for Modal Analysis for Iteration 3 Design.

1) *Experimental Results for Iteration 3:* From the following graph natural frequency for Iteration 3 obtained from experimental analysis



Graph no.3 Graph of Frequency vs. Acceleration for Iteration 3

Table no. 6 Experimental analysis results

Mode	Frequencies from Experimental Modal Analysis for Existing RVSM [Hz]	Frequencies from Experimental Modal Analysis for Iteration 3 [Hz]
1	12.31	52.24
2	31.74	86.54
3	41.50	122.56

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VII. RESULTS AND DISCUSSIONS

A. Results

Results obtained from FEA modal analysis and Experimental analysis found satisfactory
Below are the results obtained from FEA and Experimental Analysis.

Table no. 7 FEA results for Mirror designs

Modes	Natural Frequency (Hz)				
	Existing Design	Iteration 1	Iteration 2	Iteration 3	Iteration 4
1	14.428	10.186	15.228	55.349	22.364
2	35.108	10.531	30.883	85.019	35.069
3	47.84	32.233	49.088	87.571	79.089
4	51.096	42.091	76.448	116.17	104.31
5	142.27	122.09	126.68	146.68	118.51

The analytical and experimental results show similar values with some deviation. This deviation can be found out in terms of percentage.

Table no. 8 Percentage Difference In Analytical And Experimental Values for Existing Design

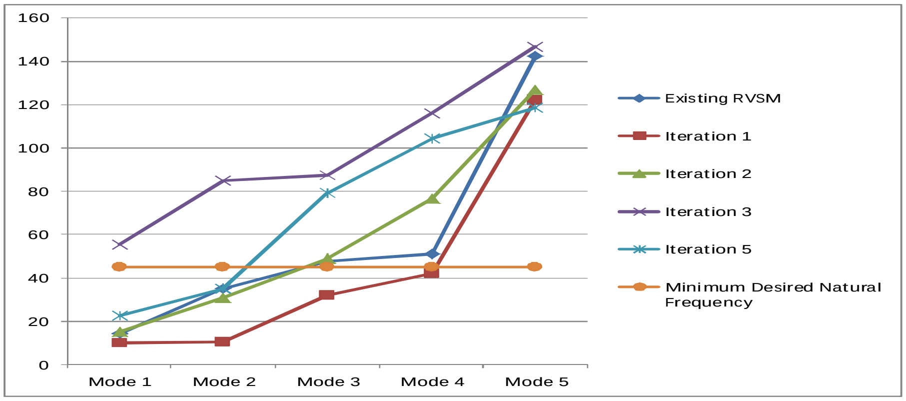
FEA Natural Frequency of Existing RVSM (Hz)	Experimental Natural Frequency of Existing RSM (Hz)	Difference between analytical and experimental values	Percentage difference
14.428	12.31	2.118	14.67%
35.108	31.74	3.368	9.59%
47.840	41.50	6.34	13.25%

It is observed that the least percentage deviation is 14.67% and it is for 14.428 Hz frequency

Table no. 9 Percentage Difference In Analytical And Experimental Values for Iteration 3

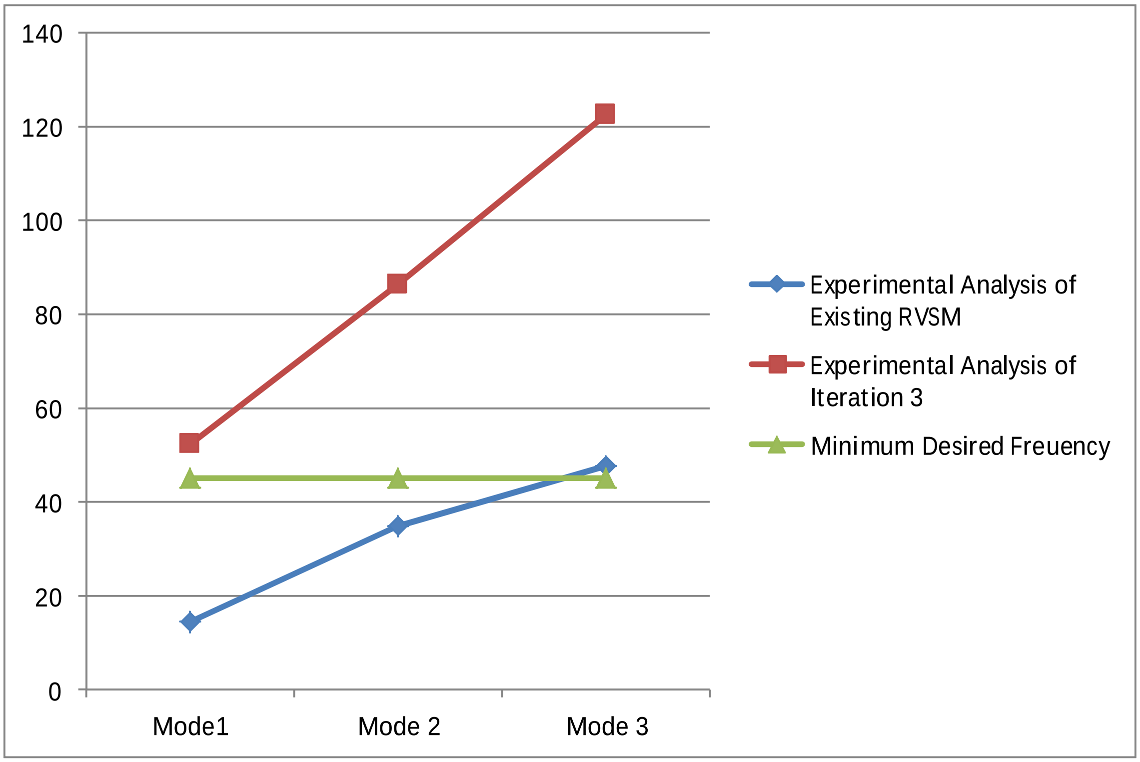
FEA Natural Frequency of Iteration 3 (Hz)	Experimental Natural Frequency of Iteration 3 (Hz)	Difference between analytical and experimental values	Percentage difference
55.349	52.24	3.109	5.61%
85.019	86.54	1.521	1.78%
116.17	122.56	6.39	5.50%

Graphical Comparison of Existing and Iteration Natural frequency



Graph no. 4 Graphical Comparison of Existing and Iteration Natural frequency

Existing RVSM FEA and Experimental analysis Graphical comparison is shown below



Graph no. 5 Graphical Comparison of Experimental analysis for Existing and Iteration Natural frequency

B. Discussions

1) By doing FEA and experimental analysis of existing RVSM we confirmed that it has resonance problem and from results, it's proved.
2) The existing design has a natural frequency which is below Forty-five Hz excitation frequencies.
3) Above that after doing Iteration for RVSM FEA results obtained to get the optimum design on the basis of desired natural frequency.
4) Iteration 1 has its first natural frequency is 10.186 Hz which lower than the desired limit.
5) Iteration 2 has its first natural frequency is 30.883 Hz, it has also natural frequency lower than the desired limit.
6) From Iteration 3, FEA results have obtained natural frequency which is above than desired frequency it's selected as optimum design,
7) Results obtained from FEA and Experimental analysis are matching.

VIII. CONCLUSION

The following conclusions were made from the work presented here from the study

A. From FEA and experimental analysis, it's understood that the resonance problem is due to the faulty design of the mirror post, not the mirror.
B. The base design was studied for natural frequency and found that natural frequency of the base model was below the Forty-five Hz which is needed to be more than Forty-five Hz as studied in the literature survey.
C. Experimental analysis results were matching with FEA analysis so we can correlate that base design is faulty. From the results of FEA analysis, Proposal 3 has a range of natural frequency from 55.349 to 146.68 Hz. Which avoiding existing model resonance frequency and more than Engine excitation frequency.
D. Mirror post design iteration 1, 2 and 4 is not giving satisfactory results.
E. It's proved that Iteration 3 is an optimized solution for rear-view side mirror

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IX. FUTURE SCOPE

A. In future the study the effects of air drag can be considered while designing.

B. Further the design can be modified by carrying out weight reduction using composite material without affecting its primary function.

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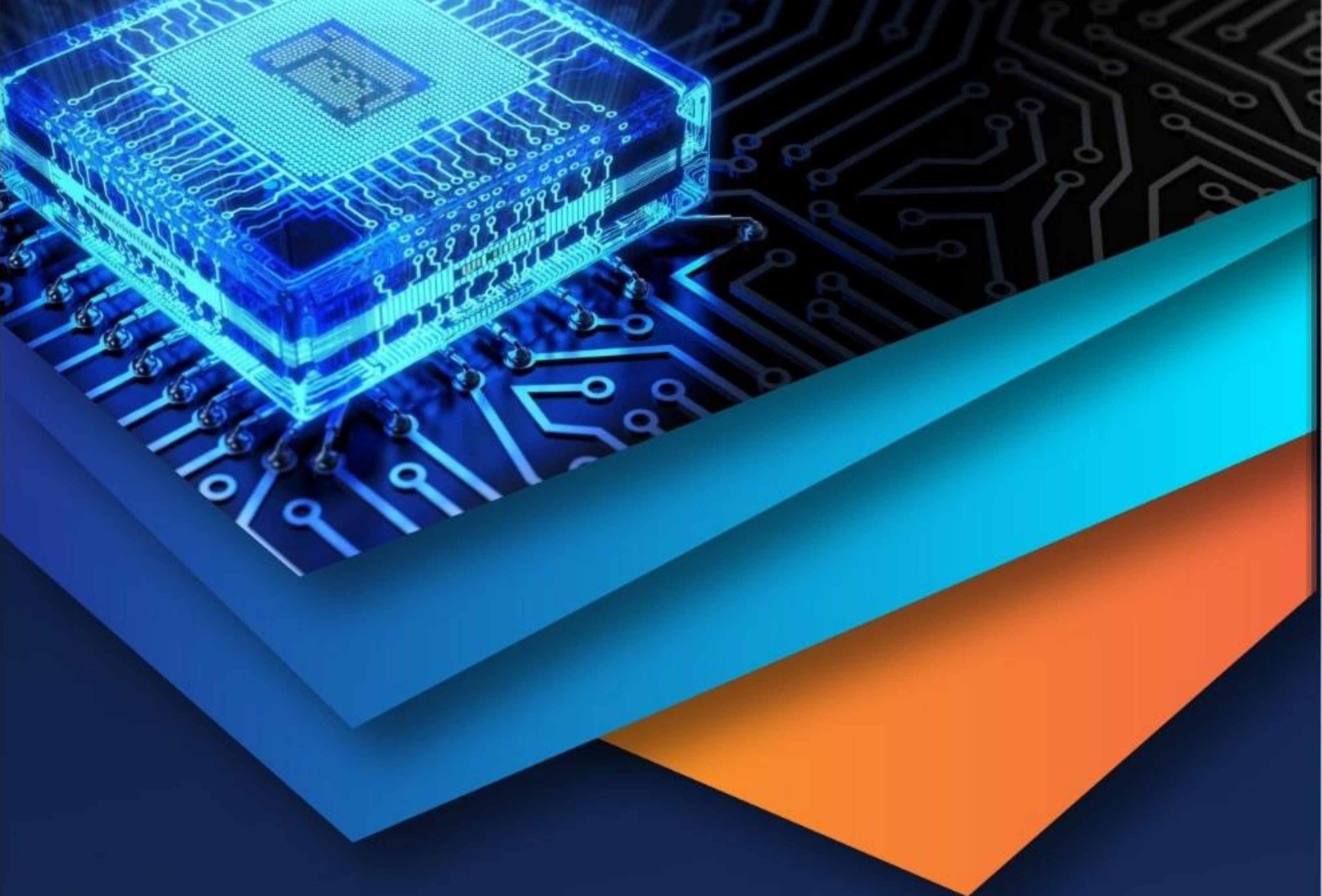

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