# Design Development and Vibration Analysis of MCM300 Headlamp

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***Abstract -*** *Headlamps are playing an important role in the design of a vehicle. Design and development of automotive headlamp in a systematic manner by considering post failures can avoid as much as modification costs and rejection costs as possible and can meet customer requirements. The headlamp assembly receives vibration from engine and road which then transfers to the internal mounting locations. It is important to understand dynamic characteristics and the components sensitive to vibration. The purpose of vibration analysis is to determine the strength of mountings. Practically natural frequency of each part should never match with engine excitation frequency over this range. But at some points we cannot avoid it, which will lead into resonance condition. For this we need to find not only natural frequencies but also the vibration amplitude at that point. This can be achieved by two methods i.e. by experimental analysis viz. by Electro dynamic shaker table and FEM analysis. First, carried out an experimental modal analysis to find the natural frequency and vibration modes. Then analyzed with FEM package, so as to compare working frequency with natural frequency for validation purpose.*

**Keywords:-** *Headlamp, Vibration, Natural Frequency, Electro dynamic shaker, Ansys.*

## I.INTRODUCTION

Headlamp vibration behavior needs to be predicted during the design phase to anticipate two types of issue. One of the main functions of the headlamp is to provide a light beam on the road at night. However beam vibration while driving on paved road is to be avoided for the driver visual comfort. This can be done by predicting and shifting the first frequency above a required frequency. The second issue is to design a robust headlamp which must not fail during the customer vibration specification. Vibration calculation enables to anticipate vibration problems during the design phase prior the launch of prototypes. The time spent in the design phase to solve frequency or stress weaknesses, gives more confidence in the design before the launch of the tools. As a consequence, the time spent during validation phase to solve vibration issues on prototypes is then reduced. However, those design improvements by calculation must be based on reliable finite element results.

The validity of headlamp vibration model has been verified by performing correlation between experimental and modal analysis. However headlamps due the complexity of their assemblies present a non linear behavior [1], especially for excitation levels representing the worst driving condition on paved road.¨

Automotive headlamp is one of the major styling parts and also in current days it is one of the technology-driven parts of a vehicle. It is mounted in front of the vehicle to illuminate the road during night time or low visibility. Design and development of automotive headlamp in a systematic manner by considering post-failures can avoid as much as modification costs and rejection costs as possible and can meet customer requirements. In the design and development stage for automotive products, it is important to determine the test specifications to discover defects early and improve reliability. In this paper, the accelerated testing methods, which include time and frequency domain methods, the frequency response, and other parameters of the materials, are presented. Furthermore, we construct a vibration specification from the time domain to the frequency domain.[3]. G. Phani Sowjanya [5] analyzed a vibration fixture of various sizes and shapes. Material properties and geometrical configuration of different vibration fixture with hole pattern on the plates and compare results of each fixture. According on this result decided which fixture is best for vibration analysis of product. Nilesh [7] did the design of vibration checking fixture for headlamp and carried out experimental modal analysis & FEA analysis to determine natural frequency and optimized the weight of fixture.

Headlamps illuminate the road space in front of the car and must meet the requirements of all users of the road. In particular, the low-beam functions are subject to legal regulations designed to protect oncoming traffic from being dazzled.

Automotive headlamp components are highly controlled products that must conform to performance standards. The primary components of headlamps are lens, reflector and bulb. Bulb produces light for illumination. Bulb is positioned in the focal point of a parabolic reflector by means of standard holders fixed on the casing of headlamp assembly. The concentric beams produced by the bulb impact the reflector that directs light to illuminate roads. In the earlier design of headlamps outer glass lens was used as diffuser for achieving illumination distribution.[9]

## II.PROBLEM STATEMENT

As the automotive industry becomes increasingly competitive, automobile parts manufacturers are under extreme pressure to improve the quality of their parts, while at the same time reducing costs. During running of vehicle the headlamps are continuously under vibration condition. This vibration transfers to the internal parts mounting locations. Therefore it is important to understand dynamic characteristics and the components sensitive to vibration. The purpose of vibration analysis is to determine the strength of mountings for avoid resonance condition in headlamp and its internal parts. This analysis and modification is done during design stage which increase the confidence in the design before launch tooling and reduce the no of test for validation.

## III.OBJECTIVE

The basic objective of this work are:

- To design the headlamp as per GM standard rules & regulation.
- Design & define mounting strategy of headlamp on vehicle according to 3-2-1 principle.
- Mounting design of headlamp is capable to sustain vibration and transfer minimum amount of vibration in to internal parts mounting to satisfy minimum frequency criteria of the customer.
- Development of finite element model and its finite element analysis to predict residual stress profile.
- To determine natural frequencies of headlamp using FEA software.
- Experimental validation and testing of the results of analysis.

## IV.SCOPE

The headlamp assembly receives vibration from engine and road which then transfers to the internal mounting locations. This project describe the mounting strategy of lamp on vehicle and headlamp internal part mounting. It is important to understand dynamic characteristics of the headlamp and the components sensitive to vibration. Mounting design of headlamp is capable to sustain vibration and transfer minimum amount of vibration in to internal parts mounting to satisfy minimum frequency(>35 Hz) criteria of the customer. In this project vibration analysis (Modal Analysis) is done by FEA software and done on Electro dynamic Shaker table available at Mangeti Marelli Motherson Autosystem Pvt Ltd . The purpose of vibration analysis is to determine the strength of mountings.

## V.THEORY

SHOCK RESPONSE SPECTRUM AND VIBRATION SPECIFICATION: The SRS is a method used to estimate the response of an item to an input shock, with the information presented as a frequency spectrum. The principle is that the shock signals enter into a serial Single Degree of Freedom filter system (SDOF), as shown in Figure 1. Each filter has a specific frequency range and specific system damping values. The SRS is composed of the maximum response values in each frequency. The mathematical formula is

$$M\ddot{x}+C(\dot{x}-\dot{u})+K(x-u)=0$$

where

x(t) : the absolute displacement of the mass M

u(t) : the displacement of the base

C : damping coefficient

K : spring stiffness coefficient

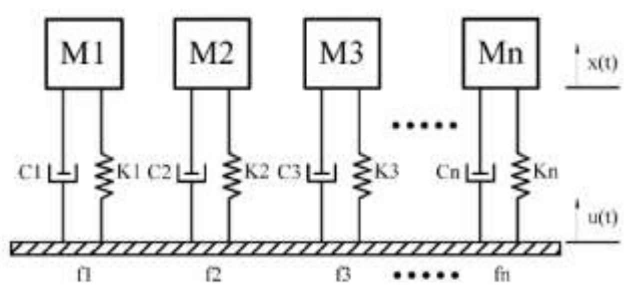


Figure 1- Shock Response Spectrum Model

Using the Laplace Transform and assuming that the initial values of *x(t)* and *u(t)* are equal to zero, we can obtain another mathematical form,

$$\frac{X(s)}{U(s)}=\frac{2\varsigma\omega_n s+\omega_n^2}{s^2+2\varsigma\omega_n s+\omega_n^2}$$

where

X(s) and U(s) : Laplace Transformation of X(t) and u(t)

ζ : damping ratio (ζ=0.05)

ω : natural frequency

The Extreme Response Spectrum (ERS) is another response spectrum, which is similar to the SRS. The difference between the ERS and SRS is that the ERS is applicable to stationary processes, but the SRS is used to represent only non-stationary processes. Therefore, the test ERS must be smaller than the lifetime SRS to ensure that we do not accelerate the test too much and that we apply loads reasonably. The mathematical formula for the ERS is presented as follows,

$$ERS(f_n) = \sqrt{\pi \cdot f_n \cdot Q \cdot PSD(f_n) \cdot \ln(f_n \cdot T)}$$

where

$f_n$ : natural frequency

Q : dynamic amplification factor

PSD : power spectrum density ($g^2/Hz$)

T : vibration test time

## VI.PRESENT THEORIES & PRACTICES :-

By using Modal analysis method we can describe a structure in terms of its natural characteristics which are natural frequency and Modal shapes. Modal analysis involves process of determining the modal parameters of a structure to construct a modal model of the response. Finite Element Analysis (FEA) and Experimental Modal Analysis (EMA) have different solving technologies for and vibration problems. Experimental modal analysis is used to explain a dynamics problem and vibration in structure. The first natural frequency post-test shall not have degraded > 15% compared with the pretest value; however, it shall be > 35 Hz in every case.[6]

## VII.MODEL AND MESHING OF HEADLAMP :-

CATIA V5 used to model the design of Headlamp. After modeling, Meshing done in Hyper mesh & Modal analysis done in Ansys 15.0 FEM for vibration analysis. Natural frequencies found at 6 modes of vibration.

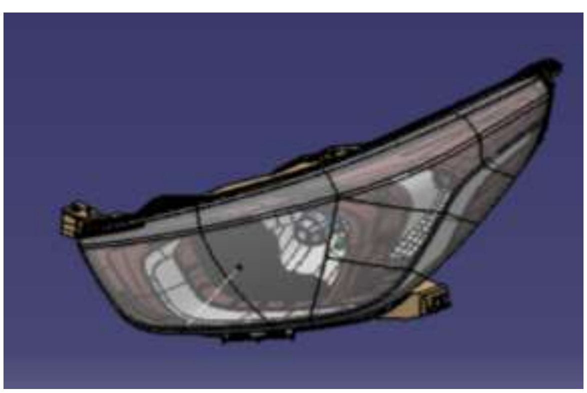

Figure 2 - CAD Model of MCM300Headlamp using Catia

The different material properties selected for Headlamp are as:

- **Housing**
1) Density = 1.22 E-09 Tonnes/mm$^3$
2) Elastic Modulus = 4500 MPa
3) Poisson Ratio = 0.42
4) Yield Stress = 28 MPa
- **Outer Lens**
1) Density = 1.20 E-09 Tonnes/mm$^3$
2) Elastic Modulus = 2300 MPa
3) Poisson Ratio = 0.37
4) Yield Stress = 90 MPa
- **High Beam Reflector**
1) Density = 1.97 E-09 Tonnes/mm$^3$
2) Elastic Modulus = 11000 MPa
3) Poisson Ratio = 0.298
4) Yield Stress = 90.5 MPa
- **FTS Reflector**
1) Density = 1.97 E-09 Tones/mm$^3$
2) Elastic Modulus = 11000 MPa
3) Poisson Ratio = 0.298
4) Yield Stress = 90.5 MPa
- **Retainer Bracket and Motor Retainer bracket**
1) Density = 1.31 E-09 Tonnes/mm$^3$
2) Elastic Modulus = 2600 MPa
3) Poisson Ratio = 0.37
4) Yield Stress = 58 MPa
- **Motor Retainer bracket**
1) Density = 1.31 E-09 Tonnes/mm$^3$
2) Elastic Modulus = 2600 MPa
3) Poisson Ratio = 0.37
4) Yield Stress = 58 MPa

Material and Mass details of each part of headlamp is tabulate below.

| **Parts** | **Material** | **Mass (Tonnes)** |
|---|---|---|
| Housing | PP TD40 | 5.415e-04 |
| Outer Lens | PC | 5.216e-04 |
| Outer Black Bezel | PBT | 3.348e-04 |
| Metalized Bezel | PBT | 5.337e-05 |
| High/ Low Reflector | BMC | 2.997e-04 |
| Internal Leveling Motor | Steel | 4.999e-05 |
| Motor Retainer Bracket | POM | 3.312e-06 |
| FTS Reflector | BMC | 1.224e-04 |
| Motor Mounting Bracket | PA66 GF30 | 1.130e-05 |

| | | |
|---|---|---|
| Bulb Shield | Steel | 6.581e-06 |
| Spring Locking Plate | Steel | 2.051e-06 |
| **Total Mass (Tonnes)** | | **0.002022** |
| **Total Mass (Kgs)** | | **2.022** |

Table 1 - Material & Weight of Headlamp parts

## VIII.MODAL ANALYSIS OF HEADLAMP :-

After generating the model of headlamp by using CATIA software then analysis is done by using Hyper mesh & Ansys. The Mounting strategy of headlamp on Vehicle is shown in below figure.

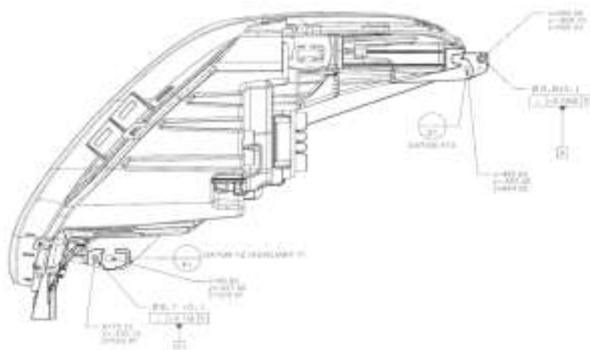

Figure 3. XYZ & YZ Datum of headlamp

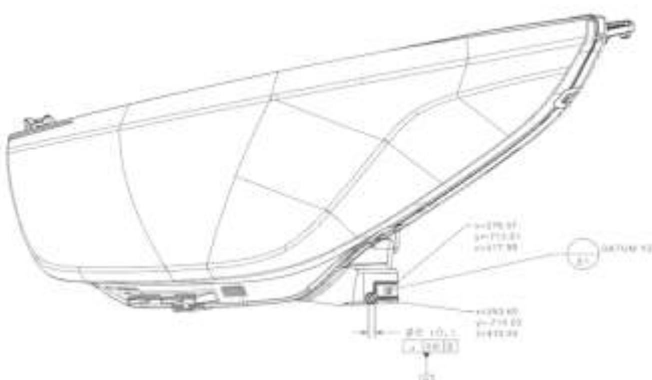

Figure 4. YZ Datum of headlamp

Headlamp Assembly model is mashed in Hyper mesh software.
Total No of Elements = 229644
Total no of Nodes = 74511

Figure 5. Headlamp meshed model using Hyper mesh

The result obtained by modal analysis for first six natural frequencies are determined and tabulated as follows:

| MODE No. | FREQUENCY (Hz) |
|---|---|
| 1 | 86.722 |
| 2 | 115.907 |
| 3 | 158.704 |
| 4 | 180.914 |
| 5 | 217.032 |
| 6 | 224.357 |

Table 2 - 1st six Natural Frequency of Headlamp

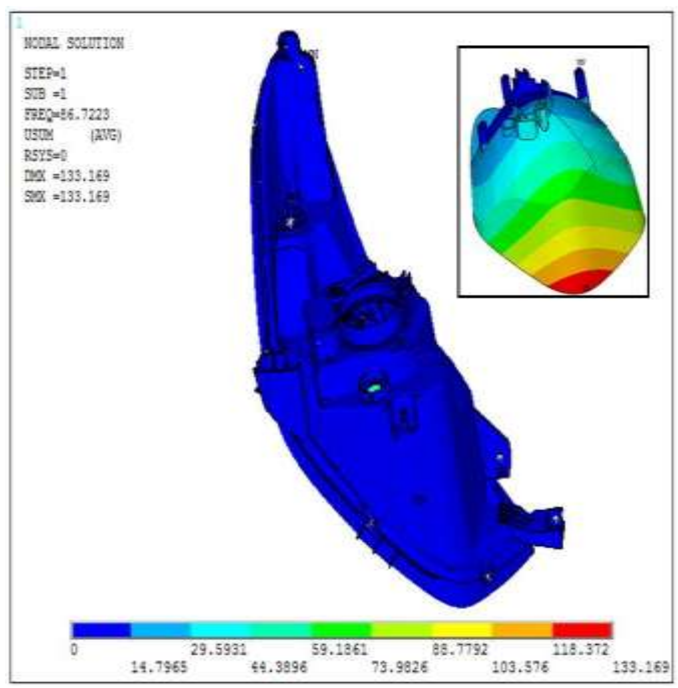


Figure 6. 1st Mode shape of headlamp

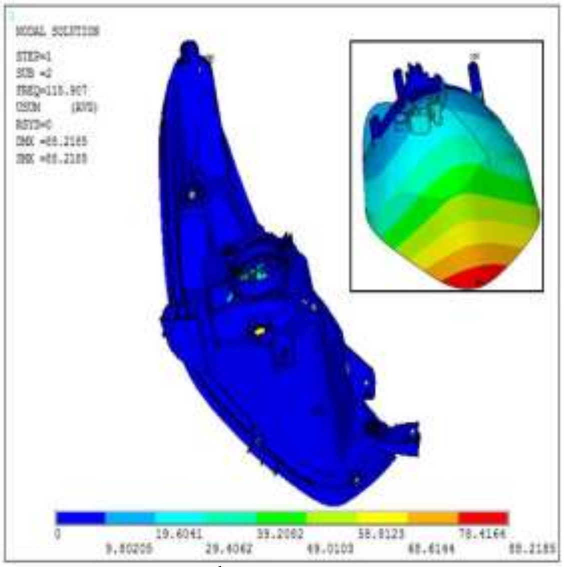

Figure 7. 2nd Mode shape of headlamp

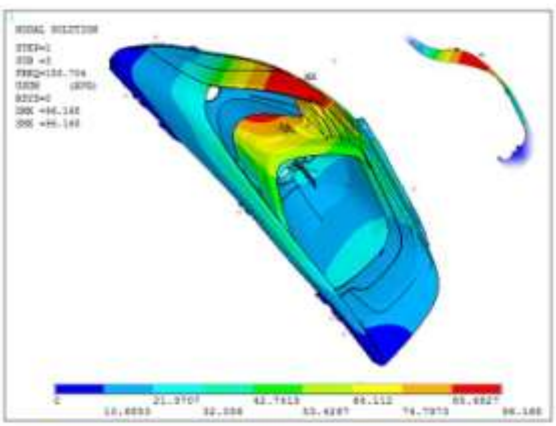

Figure 8. 3rd Mode shape of headlamp

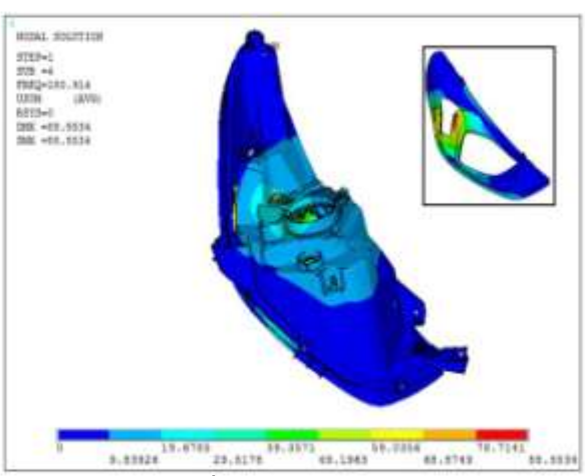

Figure 9. 4th Mode shape of headlamp

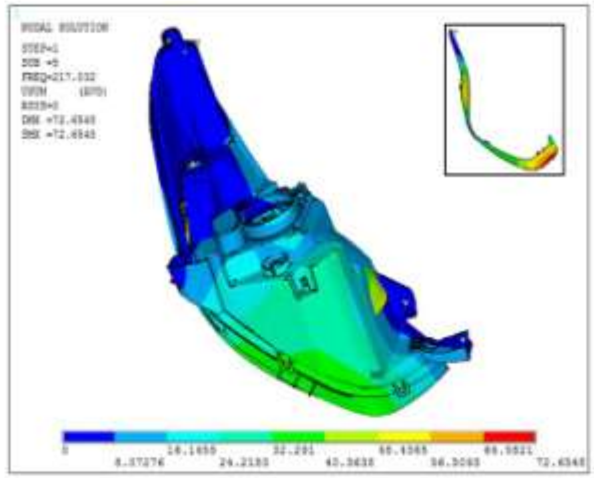

Figure 10. 5th Mode shape of headlamp

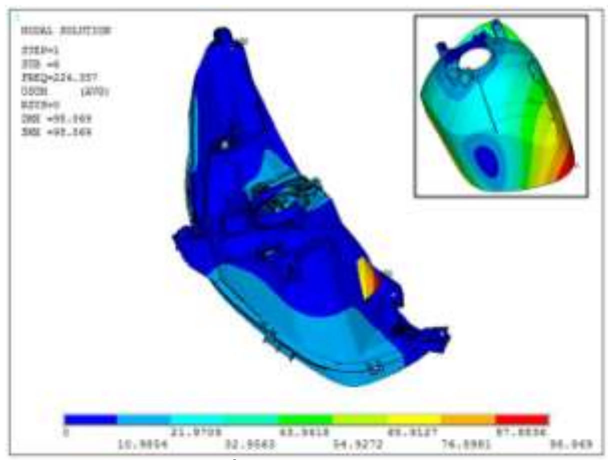

Figure 11. 6th Mode shape of headlamp

## IX.EXPERIMENTAL VALIDATION :-

The experimental validation is done by using Electro Dynamic Shaker Table. The experimental setup consists of shaker table, data acquisition system, transducer and computer with analyzer software installed. The data acquisition was made possible using tri axial transducer (B&K Endevco model ISOTRAN.) was made by piezoelectronics, 9.929 mV/g, 10.07mV/g and 10.10mV/g sensitive's in x, y, z direction respectively, that was connected to computer using 4 channel cable. The accelerometer converts acceleration into voltage which is fed to the signal conditioner. The setup was supportive to the sampling rate of 26,400 per second. Accelerometers were positioned in one or more locations such Headlamp housing , lens, reflector, bulb shield, FTS etc. However the mean values were recorded. The recorded data was auto stored in the computer. The items used in the experimental setup are shown in figure.

Figure 12. Experimental setup at Magneti Marelli

The Electro-dynamic vibration system or shaker is used to generate vibrations with a fixed excitation frequency and amplitude to test the durability of the automotive light assembly. A shaker table is available at Magneti Marelli Motherson Autosystem Pvt Ltd according to the company standard and ARAI standard. Specification of Shaker table is given below.

| | |
|---|---|
| Model | SHE 080 |
| Shape | Square |
| Platform size | 800mmx800mm |
| Mounting Holes | M10 SS Inserts with 100 mm matrix |
| Useful Frequency range | 5Hz to 2000Hz (with resonance window) |
| Working platform Material | Mg. Alloy |

Table.3 Specification of Shaker table

The result obtained by Electro dynamic shaker table for six natural frequencies are determined and tabulated as follows:

| MODE No. | FREQUENCY (Hz) |
|---|---|
| 1 | 79.228 |
| 2 | 107.10 |
| 3 | 150.77 |
| 4 | 181.31 |
| 5 | 200.18 |
| 6 | 227.57 |

Table 4 - 1st six Natural Frequency of Headlamp by experiment

Figure 13. 1st Mode shape of headlamp by Experimental

Figure 14. 2nd Mode shape of headlamp by Experimental

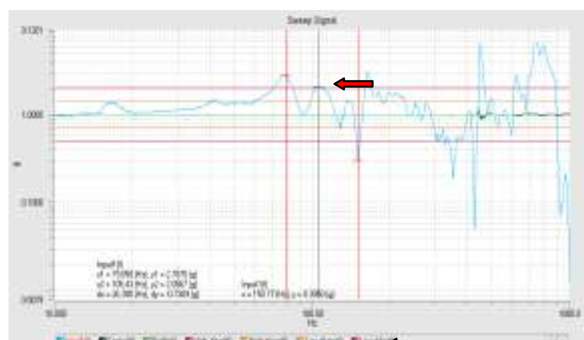

Figure 15. 3rd Mode shape of headlamp by Experimental

Figure 16. 4th Mode shape of headlamp by Experimental

Figure 17. 5th Mode shape of headlamp by Experimental

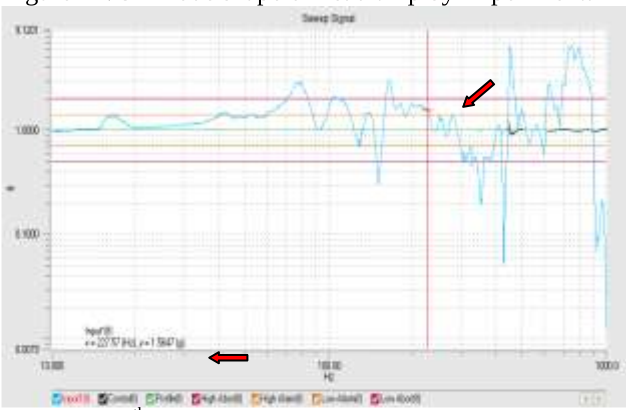

Figure 18. 6th Mode shape of headlamp by Experimental

Figure 12-17 shows the mode shapes of headlamp by experimental method. The graph shows sinusoidal form. If the sinusoidal wave cross upper or lower limit of orange line, then we get natural frequency at that point.

## X.RESULT & DISCUSSION :-

TABLE-4 shows the comparison for 1st six natural frequencies of vibration of Headlamp by FEM package and Electro dynamic vibration shaker table. The comparison shows that the natural frequency obtained by both methods agree with each other.

| MODE No. | FREQUENCY By FEA (Hz) | FREQUENCY By Experiment (Hz) |
|---|---|---|
| 1 | 86.722 | 79.228 |
| 2 | 115.907 | 107.10 |
| 3 | 158.704 | 150.77 |
| 4 | 180.914 | 181.31 |
| 5 | 217.032 | 200.18 |
| 6 | 224.357 | 227.57 |

Table 5 - Comparison of natural frequency by FEA and Experiment

The experimental data was used to validate finite element model representing the real structure. The result indicates that the FE model shows a good correlation with the experimental model for the mode shape.

## XI.CONCLUSION:-

Headlamp design and vibration analysis (Modal Analysis) is presented in this study. The following major conclusions can be drawn from the present study:
It is observed that the first natural frequency by FEA & EMA is 86.722 Hz & 79.228 Hz respectively which is satisfied customer requirement (>35 Hz) to avoid the resonance condition in the headlamp assembly.

- Natural Frequency by FEA analysis and Natural Frequency by experimental modal analysis. The natural frequencies from both methods agree with each other. Which are useful in design & development of headlamp to avoid the resonance.
- The purpose of vibration analysis is to determine the strength of mountings.
- The accelerometer-based system is able to detect failures in automotive light assemblies.
- Location of accelerometers is critical to measurement performance.

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