THE VIBRATION ANALYSIS OF AUTOMOBILE OUTER REAR VIEW MIRROR WITH ITS DEVELOPMENT AND OPTIMIZATION

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Abstract

The external and internal mirrors used particularly in high mass recreational and commercial vehicles are prone to vibrations. Effect of undesired vibrations in the mirror assembly like blurring of image, breaking of the mirror glass, breaking of plastic mounting bracket due to resonance is a major challenge and requires vibration analysis based studies during the development stage of the mirror assembly. The purpose of this study was to carry out vibration analysis on a basic pre-existing mirror assembly from an OEM (original equipment manufacturer) and further develop this assembly to increase its first fundamental frequency above the target specified by the OEM.

Finite element model for the automobile rear view mirror was created to predict mirror vibration response based on modal analysis study. The design changes in various parts of mirror assembly were done in solid works and the Hypermesh 9.0 was used to prepare the FEA model. The materials used in this FEA model were initially provided by the mirror manufacturer and also some modification was done based on the study. Hypermesh Optistruct solver was used to build the complete FEA ORVM model. Vibration modes were predicted for the mirror assembly with a special focus on the mirror mounting bracket as it's the only part through which the vibrations transfers to mirror assembly in actual vehicle. The natural frequency of the first mirror FEA model was correlated with the first test results and then further iterations were done using this FEA model to predict the changes required in material and geometry to achieve the target frequency value.

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1. INTRODUCTION

Automobile rear view mirrors are engineering components that must meet very stringent vibration criteria, the reflected image must not be distorted even though the mirror fixture to the windscreen or the roof or the mirror fixture to a pillar of the BIW is subjected to some kind of vibration fro vehicle and road. There must be no distortion regardless of the material frequencies of the mirror assembly, i.e. Even if they coincide with those of the natural frequencies of the BIW A-pillar on which the Outer Rear View Mirrors (ORVM) are normally mounted. Aspects of the design such as case material, structure and stiffness, glass weight and supports, the behavior of the ball and socket joint and the connection of the bracket to the automobile are all critical to the vibration behavior of the mirror. At the moment in mirror design, many tests are required to access the performance of the mirror and this both time consuming and expensive. Computerized design and development aids that would be able to predict the response of the proposed design would be very advantageous. In the work described in this article, the finite element method, using the Optistruct package, was used to predict the vibration response of the selection of outer rear-view mirrors using mirror geometry imported from CAD files.

Initially the 3D CAD of the mirror assembly was created from 2D drawings. The first natural frequency of the first FEA model of ORVM was matched to the first natural frequency value of the mirror assembly received from the test and the first model was thus considered as the base model in the development of computerized design and development aid of the mirror.

2. EXISTING PROBLEM

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.

The main hindrance in meeting the functional requirements of a RVM on road comes from the issues faced due to mirror vibrations.

And hence a successful design of an ORVM needs study of its vibration characteristics. A successful design is always verified for or revolves around the First Fundamental Natural Frequency of the ORVM. And so it's important to achieve a minimum required First natural Frequency for a Mirror Assembly.

This threshold value of First Normal Mode or natural Frequency is the outcome of vibrations coming from vehicle body and the vibrations due to air drag when the vehicle is moving on road. And is generally decided by the OEMs or Automobile manufacturers based on various factors as mentioned below [1].

2.1 Factors Deciding The Threshold Natural Frequency Of Mirror Assembly

- Vibrations coming from car engine at different speeds (In current case: (28-43 Hz))

- Vibrations coming from road conditions (In current case: (0-15 Hz))
- Perception of reflected Image by drivers' eyes (General Finding: (20-25 Hz))
- Vibrations due to wind drag (very unpredictable)

Considering the other uncertain causes of vibrations during the actual vehicle and mirror assembly's life cycle a factor of safety is considered and the threshold frequency close to 45Hz was decided as a target first natural frequency of the mirror assembly. So the aim of the work is to increase the first natural frequency as close as possible to 45Hz while meeting the constraints as manufacturing feasibility, cost and weight [2][3].

3. METHODOLOGY

The natural frequency is a function of elastic stiffness of the part and it's mass. The following formula gives the natural frequency of a spring mass system in mathematical form [4].

$$f = \frac{1}{2\Pi}\sqrt{\frac{k}{m}}$$

From the above equation it is clear that the frequency can be increased by following ways -

3.1 Either by increasing the elastic stiffness of the mirror assembly.

The elastic stiffness in turn can be increased by

- 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.

3.2 By reducing the mass of the mirror assembly.

Mass of the mirror assembly could be reduced in the following ways

- 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.

By implementing combination of both the ways mentioned in 1 and 2 above.

4. MODELING OF COMPLETE MIRROR

There are total thirteen to fourteen different important parts in the complete mirror assembly and a decision of how to model these parts in FEA was made based on their geometric characteristics and there functionality. The mirror housing, back plate, mirror plate, mirror mounting bracket cover was modeled using the 2D shell elements. The Mirror housing bracket, mirror base bracket, mirror regulation cover and regulation base were modeled using the 3D tetra elements. A slightly larger element size was used to mesh the mirror housing case and the mirror plate whereas the mounting bracket and the housing bracket were models with small tetra elements to capture the geometry properly. The reason is that the stiffness play major role in determining the natural frequency of the assembly and features that provide stiffness of the mounting bracket should be captured properly. Again the importance of the accuracy in the geometry and the optimum mesh density were noted through various studies.

Some of the connections between the inner parts of the assembly were snap fits and these were modeled in FEA just by capturing the connection areas more precisely. It was realized in the studies that just modeling these areas precisely was not sufficient, but multiple node's rigid connection was necessary in these areas to represent the equivalent stiffness. The connection between the main housing and the base bracket was done using rigid spider and beam. From various simulations and the deformation behavior, most precise method of modeling and connection was decided [5].

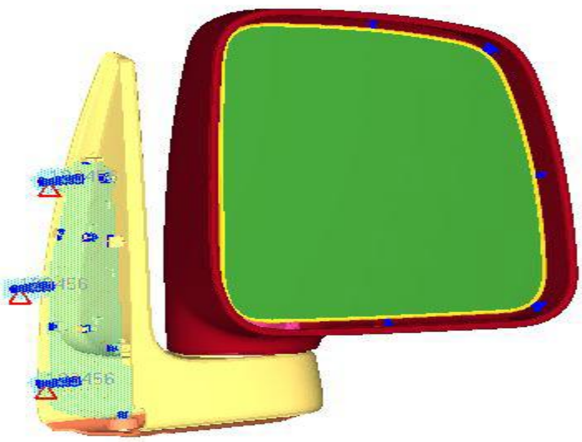

Fig-1: FEA Model of Complete Mirror Assembly

5. MODAL ANALYSIS IN FEA

3D cad data were generated from the 2D drawings of the mirror assembly and meshing and model preparation for the modal analysis was done in Hypermesh using the Optistruct user profile. Load case setup for the modal analysis and simulation was also done in Optistruct. Many iterations were done with material changes, basic rib thickness changes, with minor geometric modifications to observe how the natural frequency is affected with these changes and finally after getting the initial approach of where to add stiffness and where the mass could be reduced without affecting the functionality of various parts in the assembly, major geometric modifications were suggested and carried out with the help of cad software's. These models were then submitted for modal analysis and the results were observed.

The proposals are the outcomes of much intermediate iteration with various possibilities.

- Proposal 1- In this proposal the initial material assumption was changed from PP GF30% UV

(Polypropylene 30% Glass Fiber Ultraviolet) to ADC12 (Aluminum Die Cast).
From this proposal it is found that first natural frequency increased from 22Hz to 35.6Hz.

- Proposal 2-Here we add the lock end at end of base and cover plate in first proposal design. By adding lock end it increases the stiffness hence correspondingly increase in first natural frequency of system.
- From this proposal it is found that first natural frequency increased from 35.6Hz to 35.9Hz.
- Proposal 3- There is no sufficient connection between snap plate and the Bracket cover .This is the place where the assembly lacked stiffness hence we extend the three ribs on base.
- From this proposal it is found that first natural frequency increased from 35.6Hz to 38.4Hz.
- Proposal 4- Here we added small ribs in the housing bracket in third proposal design.
- From this proposal it is found that first natural frequency increased from 35.6Hz to 44.4Hz.
- Proposal 5- Cylindrical portion of housing bracket extended in fourth proposal design.
- From this proposal it is found that first natural frequency increased from 44.4Hz to 45.6Hz.
- Proposal 6- In fifth proposal design we extended cylindrical portion and upper closed section of cylindrical portion removed due to manufacturing constraints and instead splines are added on original cylindrical portion to maintain stiffness.
- From this proposal it is found that first natural frequency increased from 45.6Hz to 44.4Hz.

6. VIBRATION TESTING

We achieved the first natural frequency close to 45Hz as per the target value while meeting the constraints as manufacturing feasibility, saving in cost and reduces the weight of mirror assembly.
After the successful design changes with FEA model making intermediate iterations, building a prototype of model as per final design changes. Vibration testing of a prototype has been taken place in a parent company. Due to confidentiality requirements, the current mirror manufacturer has not provided the details; a representative setup for ORVM testing has been shown below.

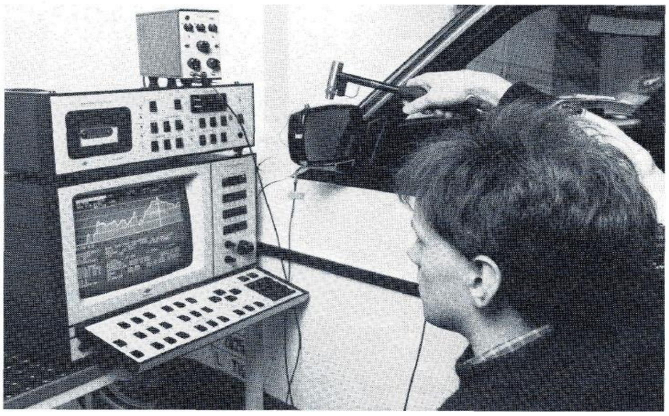

Fig-2: Modal Testing Setup for ORVM

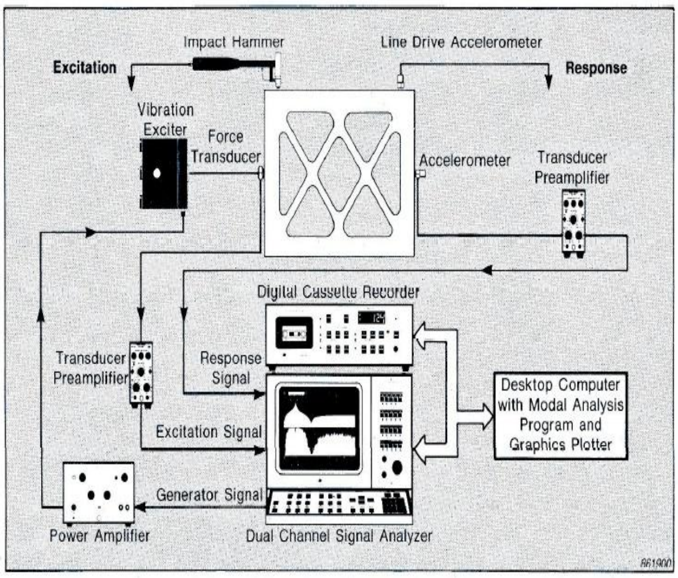

Fig-3: Data Processing Setup for ORVM Modal Testing

The testing over the final mirror model based on Proposal-6 was carried out in the test lab and good correlation was observed in the FE and Test results.
All the detail results are not shared from the company.

7. CONCLUSION

Structural vibration analysis is a multifaceted discipline that helps increase quality, reliability and cost efficiency in many industries. Analyzing and addressing structural vibration problems requires a basic understanding of the concepts of vibration, the basic theoretical models, time and frequency domain analysis, measurement techniques and instrumentation, vibration suppression techniques, and modal analysis.
The base mirror model was studied in various aspects and after much iteration six important design modification proposals were shared with the manufacturer showing increasing trend of first natural mode of mirror assembly. FE results were validated by the lab test and a good match was observed for Proposal-6, which also met the weight constraint and found feasible for manufacturing.

8. REFERENCES

[1]. Design and Optimizing Side View Mirrors. Martin Olsson. Dept. of Applied Mechanics. Vehicle Engineering and Automotive Systems, Chalmers University of Technology, Sweden.
[2]. Adaptive Modeling of Vehicle Mirror Vibrations by Predictive Compensation by Antoine Larchez and Fazel Naghdy.
[3]. O'Grady M., McCarthy B., et al. (1996). "Vibration in an automobile internal rear-view mirror" Mechanical & Corrosion Properties, Series a (Key Engineering Materials), Vol.118-119, pp.35-42.
[4]. Theory Of Machines by R.S.Khurmi & J.K.Gupta.
[5]. Practical Finite Element Analysis by Nitin Gokhale and Sanjay Deshpande.