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Vibration Analysis of Two Wheeler Mirror

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Abstract: *It has been observed that above 60Kmph vehicle speed, the mirrors of two wheelers starts vibrating enough to make it difficult to identify what's behind. The vibrating mirror reduces the confidence of the driver to make moves. Shaky mirror and blurred image created safety concern for the rider and pillion rider. This paper revolves around the vibration analysis of "Two Wheeler Rear View Mirror" assembly. The aim of this paper is to study the different vibration modes of rear view mirror and its natural frequencies. The basic reason for the mirror vibration is the resonance with different engine excitation frequencies. For two wheeler mirror the major excitation comes from the Engine. There is generic standard which specifies the natural frequency range for the automobile mirror which includes four wheelers, two wheelers, single cylinder engine and four cylinder engine. Measurement of natural frequencies has been taken with the help of accelerometer, FFT analyzer and SVAN PC++ advanced software used to support measurement files. Actual mirror replicated in 3D models using Creo software. Analytical method includes the Modal frequency response analysis to find out the natural frequencies of the mirror. To find the natural frequency of the mirror assembly manual calculations also been done. Model is prepared in ANSYS Workbench 17.2. The simulation result shows good correlation with the experimental results. The natural frequencies of the mirror is well within the engine excitation at 7000 and 8000 RPM range so resonance is the unavoidable condition responsible for mirror vibration.*

Keywords: *Engine Excitation, Modal analysis, Rear View Mirror, Resonance*

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I. Introduction

While driving bike, the mirror surface of side-view mirrors happens to vibrate. This vibration distorts the reflected image even though the mirror fixture to the handle bar of the bike. This vibration disturbs driver to approach the moves. Mirror vibration can be identified from the blurred image appears in mirror. This phenomenon of mirror vibration directly deals with the safety of driver. There are Indian Standards presents the requirements for internal and external rear view mirrors used in road vehicles like cars, trucks, buses, scooters and motor-cycles. Rear view mirror being a safety item has also been included under Central Motor Vehicle Rules, as mandatory fitment for all motor vehicles. 'Mirrors' means any device consisting of a mirror, holder, adjusting part, support (including an impact protection mechanism), etc Holder' means a part holding a mirror. 'Adjusting part' means a part adjusting the angle of a mirror. 'Support' means a part existing between a mirror, a holder and a car body and supporting the mirror at a specific position. 'Impact protection mechanism' means a mechanism preventing or lightening the hindrance on a crew member and a walker by dislocation, falling down, etc of a mirror in cases of collision, contact, etc, of a human body with the mirror. 'Flat mirror means a mirror having a flat surface. 'Convex mirror means mirror having a convex surface with a definite radius of curvature. The biggest challenge in design phase is to predict the behavior and potential failures as early as possible. We can predict the behavior of assembly by performing "Vibration Analysis". In the case of mirror assembly, receives vibration from engine and road which then transfers to the internal mounting locations. Here it is important to understand dynamic characteristics and the component sensitive to vibration. The dynamic equation for the system can be expressed as follows.

$$m\ddot{x} + c\dot{x} + kx = F$$

Where m, c, k are mass matrix, damping matrix and stiffness matrix respectively. x and F are displacement and force vectors respectively.

II. Background

The significant work has been done in this area to reduce an aerodynamic drag due to external mirror. To analyze aerodynamic drag use of CFD has been done on car mirror. After various tests, author has observed that small changes to the mirror, such as change edges radius, inclinations, adding gutters, and edges, affect the flow both around the mirror and in the rear of the car. The best drag reduction was achieved when the housing curvature of the mirror was changed from rather bulky to flatter model which produced the same drag reduction as having no mirrors at all [1]. The approach employed in this paper was based on adaptive control scheme, performed by dynamically tuning the controller's parametric predictive model. A signal is generated to drive the actuators, which in turn rotate the surface of the mirror in such a way that vibrations are not perceptible. The measured vibration on the mirror surface is the result of two major vibrations of the mirror assembly system. One is motion of the mirror surface around and relative to its axes. The other is the displacement of the entire mirror structure. Since the mirror itself when considered relative to its bracket, has its degrees of freedom only along the rotational dimensions, the active control of the vibration in the mirror is done along theses dimensions [2]. This article explains the successful design of an ORVM needs to study of its vibration characteristics. A successful design is always verified for or revolves around the First Fundamental Natural Frequency of the ORVM. So it's important to achieve a minimum required First natural Frequency for a Mirror Assembly. 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 [3]. Two wheeler handle-bar assemblies is user's first touch point to the vehicle, also it is very complex in construction and important in functionality and safety point of view. As handle-bar assembly consists of head lamp, mirrors, clutch and brake levers, speedometer with plastic coverings which are meant to be for aesthetic appeal Frequency response analysis on handle bar assembly is carried out using Altair solver code Radioss Bulk data. In this analysis the handle bar assembly is excited with acceleration derived from road load data over an operational frequency range to evaluate the strength of mountings on handle-bar in vibration. Model is prepared using HyperMesh and Post processing is done using HyperView and HyperGraph. The simulation results are also well correlated by the experimental results in which failure location and pattern is exactly matched. Further modifications have been incorporated in design to meet the strength requirement. [4]. An 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 a ORVM needs study of its vibration characteristics [5]. IS : 9000 (Part VIII) – 1981 This standard (Part VIII) covers the basic environmental testing procedures for electronic and electrical items for vibration (sinusoidal) test. The guidance details are covered in IS: 9001 (Part XIII)-1981[6]. IS : 10250 – 1982 The object of this standards is to specify the environmental severities encountered in actual service by automotive electrical system [7]. IS 14210: 1994 This Indian Standard specifies the requirements for internal and external rear view mirrors used in road vehicles [8]. Most of the above studies have been done on cars. The same standard applies to two wheeler and four wheeler automobiles. These standards are pretty old and need amendment as per trend change. Now a day's two wheelers are coming with higher capacity engine so the engine excitation and engine natural frequency has increased.

III. Metodology

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 is the function of stiffness and mass. The root cause of the mirror vibration has been found out by experimentation. Experimentation can reveal the natural frequencies of the mirror for certain excitation. Measured natural frequency from experimental modal analysis has to prove in analytical formulation. Manuel calculations and FEA analysis can give the theoretical natural frequencies. It's very difficult to find out the vibration modes of the mirror but in analytical mathematical formulation can easily formulate the natural frequencies their mode shapes.

3.1 EXPERIMENTATION

Below are the factors deciding the threshold natural frequency of two wheeler mirror assembly

- Vibrations coming from engine at 7000 and 8000 rpm speeds (In current case: 58-67 Hz)
- Vibrations coming from road conditions (In current case: 0-15 Hz)
- Vibrations due to wind drag (very unpredictable)

In the case of two wheeler mirror the main source of excitation is engine than the road. The excitation getting from engine is depending on the RPM. Now a day the trends of the engine cubic capacities are changing day by day. Now the higher cubic capacity engine is in market but there is no extensive research has happened on the mirror. Road excitation is in the range of 0-15Hz which is negligible. Frequencies below 20 Hz are not usually considered. The reason is that, lowest idling rpm is usually above 1400 rpm. To limit the scope of the project road excitation has been excluded from the study. To get the natural frequencies of the mirror fixed on the bike modal testing has been conducted. The bike I choose was the 150CC with 9 years old. Single axis accelerometer has been used to capture the acceleration of the mirror. To process the data FFT analyzer has been used. Svan PC++ software installed and which provides functions such as measurement data downloading from instruments to PC, measurement setups creating, basic Leq/RMS recalculation, measurement results in text, table and graphical form of presentation, export data to spread sheet or text editor applications. To take the measurements from single axis accelerometer special arrangement made. Cube of 1 inch sq has been attached to the mirror with special bonding material. Reading has been taken for 7000 RPM and 8000 RPM on Z- axis (Perpendicular to mirror), Y-axis, X-axis respectively.

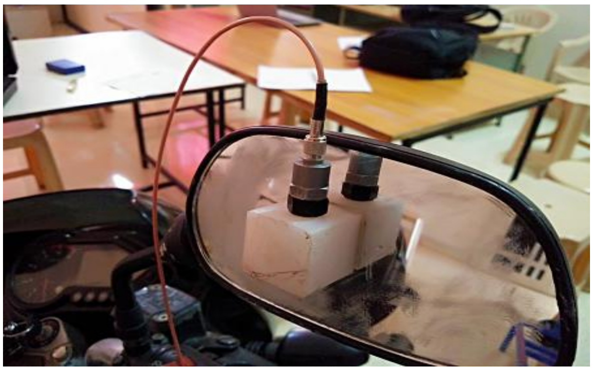

Fig. 1.Accelerometer Mounting

Fig. 2. Experimental Setup

Fig. 2 shows the experimental setup of the project. The measurement of vibration conducted with FFT analyzer and single axis accelerometer. Fig. 1 illustrates the mounting of the accelerometer on the mirror. Nylon block has been attached to the mirror with the bonding material which is used to bond plastic to the glass. The Model 7105A is a high performance IEPE accelerometer available in ±50g to ±1000g dynamic ranges. The stud mounted accelerometer features a welded hermetic construction with a top mount connector. The model 7105A incorporates stable piezo-ceramic crystals in annular shear mode which provide a flat frequency response up to >10kHz. The standard operating temperature range extends from -55°C to +125°C. The SVAN 958 is digital, four channels 0.5 Hz to 20 kHz signal analyzer including vibration meter. It is an ideal choice for the "Human Vibration" and noise measurements in the occupational health and safety monitoring tasks.

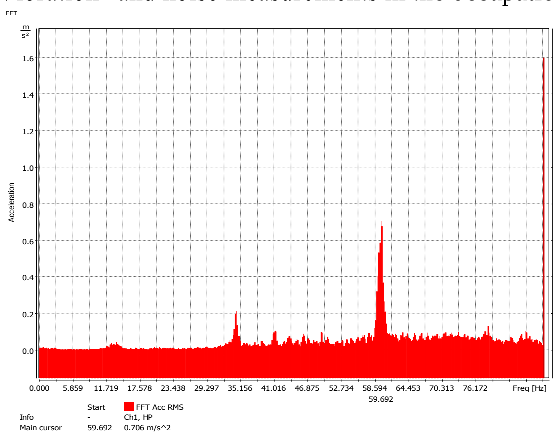

Fig. 3.Accel^{n} vs. Frequency at Z-Axis, 7000 RPM

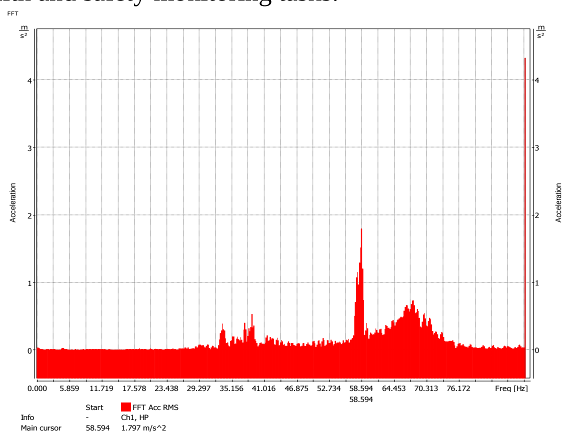

Fig. 4.Accel^{n} vs. Frequency at Z-Axis, 8000RPM

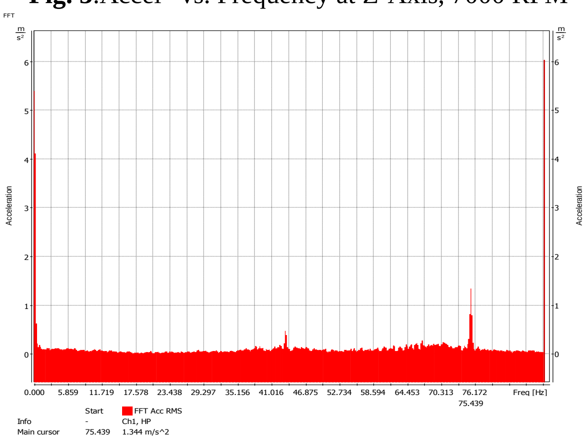

Fig. 5.Accel^{n} vs. Frequency at Y-Axis, 7000RPM

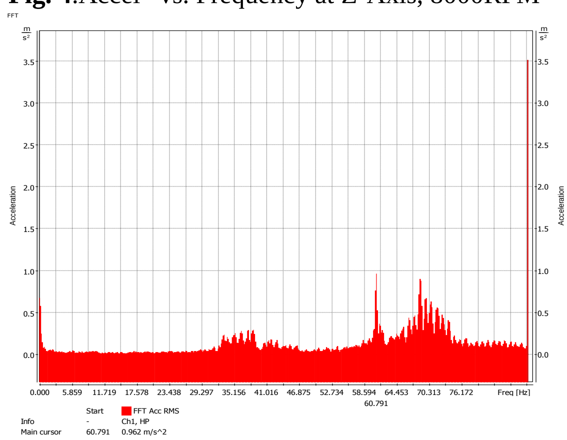

Fig. 6.Accel^{n} vs. Frequency at Y-Axis, 8000RPM

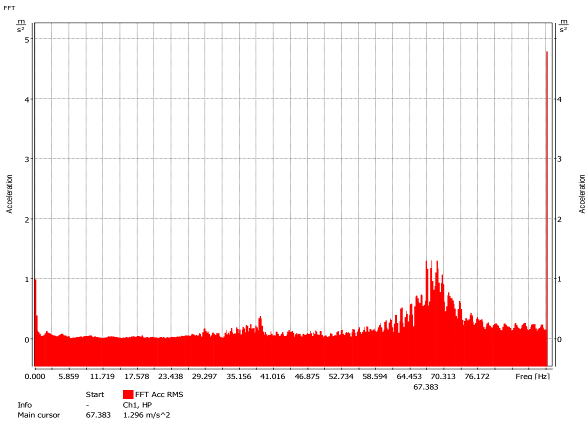

Fig. 7.Accel^{n} vs. Frequency X-Axis, 7000RPM

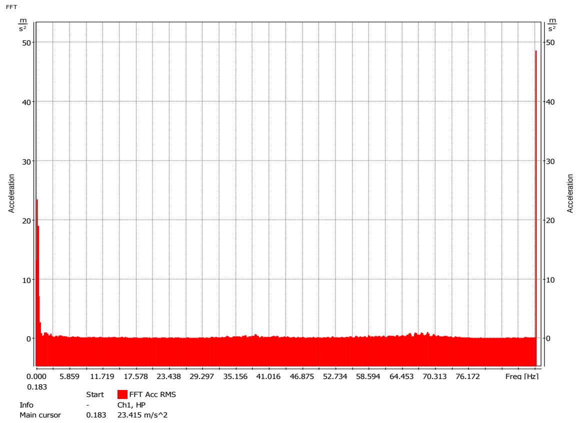

Fig. 8.Accel^{n} vs. Frequency at X-Axis, 8000RPM

Table 1: Experimental Natural Frequencies

Direction	RPM	Natural Frequency [Hz]
Z	7000	59.69
Z	8000	58.94
Y	7000	75.43
Y	8000	60.79
X	7000	67.38
X	8000	-

3.2 Analytical Method

If mirror considered as the cantilever beam then the theoretical natural frequency for cantilever beam with a Lumped Mass at Free End can be formulated with below formulae. When a system is subjected to free vibration and the system is considered as a discrete system in which the beam is considered as mass-less and the whole mass is concentrated at the free end of the beam.

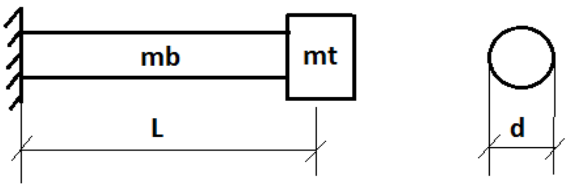

Fig. 9. Cantilever beam with mass at the tip

The governing equation of motion for such system will be,

$$m\ddot{x} + kx = F$$

Input,

Length, L – 212mm
Diameter, d – 10mm
Youngs modulus, E – 210GPa
Density, ρ – 7810 kg/m3
Lumped mass, mt – 1.575 kg
Beam mass, mb – 1.860 kg

Where m is a concentrated mass at the free end of the beam and k is the stiffness of the system. The transverse stiffness of a cantilever beam is given as [10]

$$K = \frac{3EI}{l^3}$$

The beam mass is distributed over the length. However, by taking one-third of the total mass of beam at the free end the system can be assumed as discrete system. Hence,

$$m = \frac{33}{140} m_b + m_t$$

Where, m is an equivalent mass placed at the free end of the cantilever beam and m_b *is the mass of beam. The undamped natural frequency is*

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

The value of natural frequency for the mirror from above equation is, 25.98Hz.

3.3 FE Model Development And Analysis

The prerequisite for the finite element analysis is the 3D CAD model as same as mirror tested. 3D model has been developed as close to the tested model. To develop the 3D model CREO software used. Modal analysis has been used to find the natural frequencies and mode shapes of the mirror. Modal analysis in the Ansys is the "Linear analysis". Any nonlinearity, such as plasticity and contact elements, are ignored even if they are defined. Modal analysis are also required if spectrum analysis or a mode superposition harmonic or transient analysis has to perform. Modal analysis has been performed for first 10 natural frequencies and their respective mode shapes. Total number of elements in the modal analysis is 40686 and total number of nodes is 75146. The base where we mount the mirror with threads length of 15mm has been fixed.

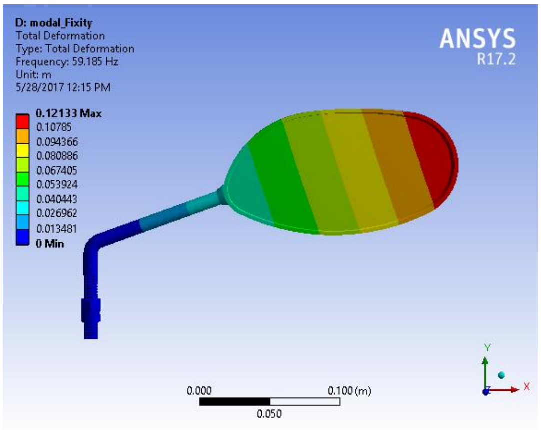

Fig. 10. Plot for first mode and natural frequency

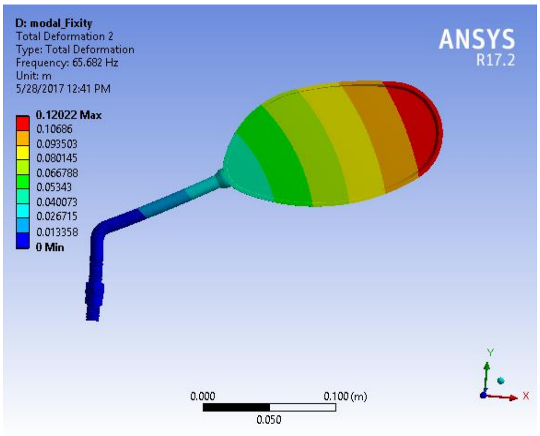

Fig. 11. Plot for second mode and naturalfrequency

Table 2: Analytical Natural Frequencies

Mode	Frequency [Hz]
1.	59.185
2.	65.682
3.	334.71
4.	374.03
5.	487.02
6.	753.3
7.	1264.8
8.	1563.2
9.	2088.9
10.	2320.9

Harmonic response analysis is the analysis in which any sustained cyclic load will produce a cyclic response in a structural system. Harmonic response analysis gives you the ability to predict the sustained dynamic behavior of your structures. Harmonic analysis has been performed on mirror by fixing the end which attached to handle bar and exciting the mirror with unit load.

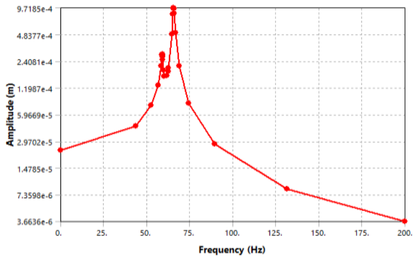

Fig.12. Harmonic Analysis Amplitude vs. Frequency

IV. Conclusion

As per Indian standard the frequency range given for the rear view mirror is ranging from 0-50Hz but above results shows the first natural frequency of the mirror is more than the 50Hz. Engine excitation frequency is around 58 to 67Hz so there are chances of resonance. From experiment, it has been observed that the peak of first natural frequency of the mirror assembly is at 59Hz and the first mode shape is translation and rotation about Y-axis and perpendicular to Z-axis. There is good correlation between experimental result and FEA results for first natural frequency and mode shape. Second peak for natural frequency is at 60Hz from the experiment in Y direction. FEA result also shows the same trend. Second natural frequency from the modal analysis shows 65Hz which is close to the experimented value. Second mode of the vibration is rotational and translation in Y- axis. The first two modes are complicated modes as the body act as a cantilever beam. Results show that the first two frequencies which nothing but the most operating frequencies of the two wheeler which overlap with the engine excitation and that is the reason of resonance. This resonance blurs the image which we see in the mirror. In harmonic analysis we excited the structure by external force by keeping the support fixed. First peak showed in harmonic analysis is also close to 58Hz and 65Hz. This proves that we need to increase natural frequencies above the operating frequency range of the engine which is ranging from 58 TO 67 Hz. There are few recommendations to get rid of the resonance.

- 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 handle bar end so overhang can reduced of the cantilever beam
- Use of spring mass damper system to reduce the vibration
- Isolator between glass and mirror holder

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