Design Optimization of Motorcycle Mirror to Reduce Vibration for Clearer Image of Rear View

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ABSTRACT

The side mirror is used to get the rear-view image of the vehicle. It is necessary for vehicle dynamics. Rider can see all-around traffic coming from backside in these mirrors. As per traffic annual data, many accidents happen due to malfunctioning and not observing mirrors at the proper time. "Mirror" vibrates too much during vehicle running condition on the road. Hence this research paper/project mainly focuses on the design optimization Motorcycle "Mirror" to reduce vibration for better rear-view image.

Keywords: 2W Mirror, Mirror Design, Regulation, Safety, Design & Development.

1 Introduction

In 21st Century – Vehicle technology is growing rapidly. Motorcycles are used most of the time for commuting & mobility. In today's era Vehicle & customer safety is at the topmost priority during design & development. Hence Safety parts/components to be designed at topmost care. "Mirror Assembly" is also passive safety component of the "Motorcycle". This component plays important role in Vehicle & Customer safety. In Motorcycle "Mirror" vibrates too much during vehicle running condition on the road. This is very common problem almost in all high end (higher cc >300cc) vehicles. In contrary till date no prominent/major work has been done on this issue. Hence this project mainly focuses on the "Mirror" design optimization to reduce vibration for better rear-view visibility. This focuses on the modal analysis of the "Mirror Assy." part.

Basic mechanical engineering techniques are used to determine the root-cause of mirror vibration & countermeasure found out for the same with the use of various resources (CAE, Test equipment, CAD software etc.). "Mirror Assy" designed in such way that natural frequency of the part (Mirror) is shifted far away from the engine & road excitation frequency occurred at mirror mounting region.

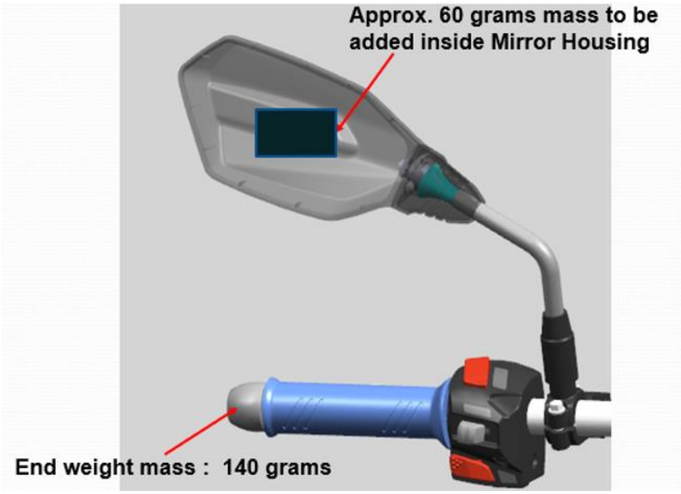

Fig.1 *Mirror Assy Base 3D model + Addition of 60-gram mass inside Housing.*

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2 Materials and Methods

Theoretical analysis of "Mirror assembly" is done using mechanical engineering term of frequency fn = ½ π √k/m.

Modal analysis (Frequency, Acceleration, amplitude, displacement) of "Mirror assembly" is done using CAE software-Hyper mesh & CAD (3D) model created in software-Unigraphics.

Experimental analysis (Actual measurement of Acceleration, amplitude, displacement, Frequency) of "Mirror assembly" is done using Accelerometer & FFT analyser.

3 Theory and Calculation

3.1 Theoretical analysis/calculations

Iteration 01: Base 3D Model of Mirror (Without addition of Mass inside mirror housing) Calculate the Natural Frequency of the mirror (Assume as a Cantilever Beam):

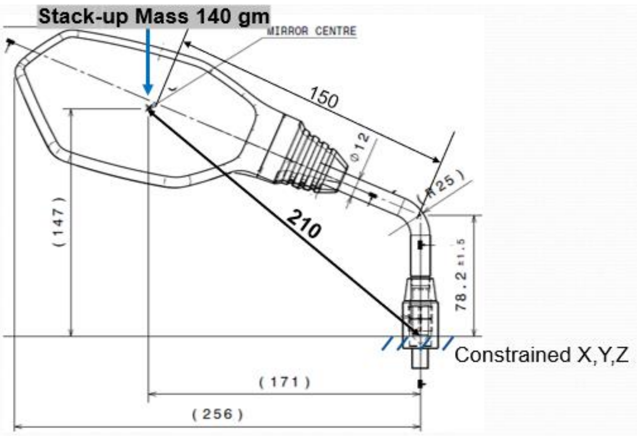

Fig.2 *Base mirror model – without mass*

fn = ½ π √k/m .... (1)

Known (given):

Mass (m) : 0.14 kg = 1.4N

Length (L) = 210mm = 0.21m

Steel Rod Mod. Of Elasticity (E): 210000 MPa.

Dia. of steel Rod (Ø) = 12mm.

Moment of Inertia (M) = π/64 D4 = 1017.87 mm4

k (Stiffness) = F / δ (static) …. (2)

F (Force = m x g): 1.4 N

δ static (Deflection) = PL^3 / 3EI. …. (3)

Where,

P: Load in N

L: Length of Beam in mm

E: Modulus of elasticity in MPa.

δ static = (1.4 x 2103) / (3 x 210000 x 1017.87) = 0.02mm = 0.02 x 10^{-3} m

k (Stiffness) = F / δ (static) = 1.4 / 0.02 x 10^{-3} = 70000 N/m.

fn = ½ π √k/m = ½ π √70000/0.14 = 110 Hz.

Hence Natural Frequency of the mirror without mass

fn =110 Hz.

Similarly, Iteration 02: Base 3D Model of Mirror (With addition of 60 gm Mass inside mirror housing):

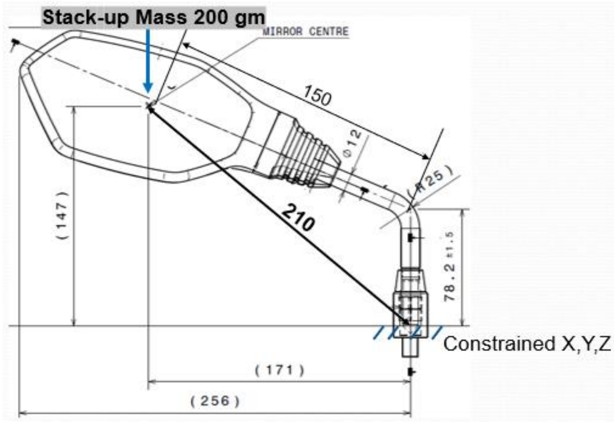

Fig.3 *Mirror model – with 60 gm mass*

Natural Frequency of the mirror with 60 gm mass fn = 90 Hz.

*It is important/necessary to know the actual values of vibration characteristics of a system/part. This is because the theoretically calculated values may be different from the actual values due to assumptions made in the analysis.

3.2 Modal analysis

Iteration 01: Base 3D Model of Mirror (Without addition of Mass inside mirror housing).

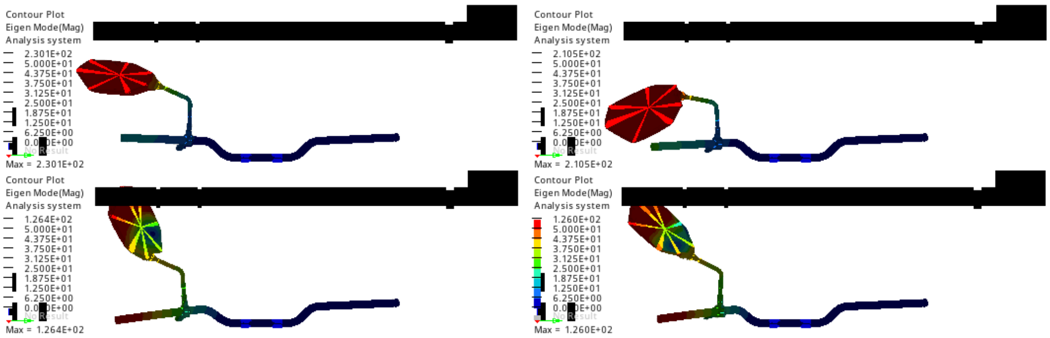

Fig.4 *Mirror (without mass in housing) Assembly Natural Frequencies (modal analysis)*

"Mirror Assembly" without mass natural frequencies are 71, 75, 130, 135 Hz.

The First Natural Frequency Observed in the "Mirror Assembly" (without mass) Model is 71 Hz which is almost matches with the excitation frequency of 74 Hz at mirror mounting region. Hence Resonance will occur & mirror image/rear view distortion will take place. Need to shift this Natural Frequency of the "Mirror Assembly" component to avoid the resonance. For study purpose we have checked the first natural frequency response & observed displacement is 4.4mm.

Iteration 02: Base 3D model + Addition of 60-gram mass inside Mirror Housing.

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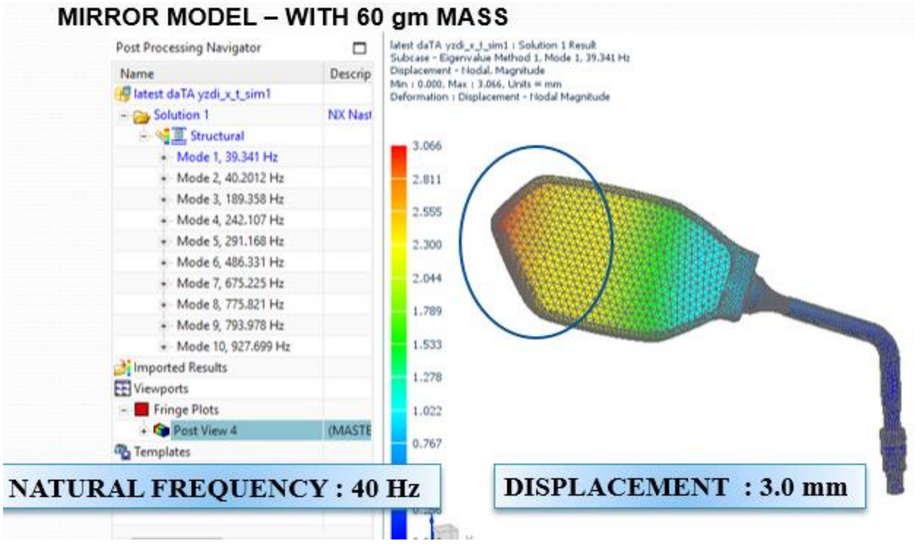


Fig.5 *Mirror (with 60 gm mass) Assembly Natural Frequencies, displacement (Modal analysis).*

The observed first natural frequency is 40 Hz & displacement is 3mm which is less as compare to without mass model (Iteration 02).

CAE Observations:

Table 1. *CAE observations & comparison*.

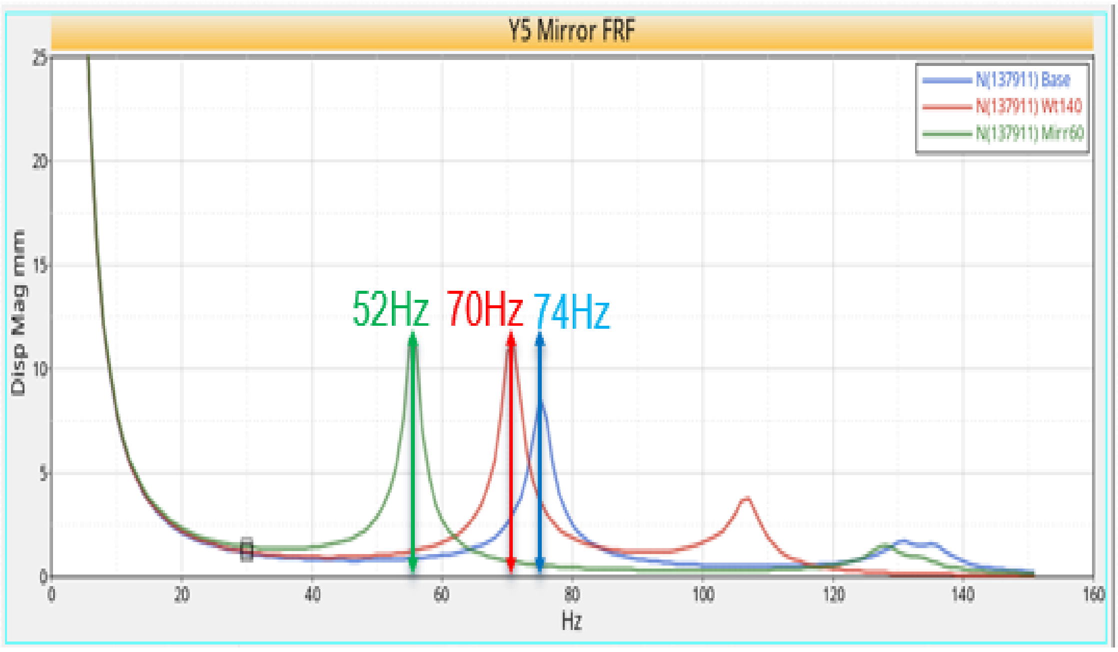
Iteration	Natural Frequency (Hz)	Excitation Frequency (Hz)	Resonance Condition
01. Without Mass	71	74	Yes
02. With Mass 60 gm	52	74	No

Iteration 02 is Ok which fulfils the objective.

3.3 Experimental analysis

Fig.6 *Set-up used to collect the vibration data on actual vehicle mirror mounting region.*

Accordingly using accelerometer & FFT analyzer above data "Acceleration Vs Engine RPM" can be converted into "Acceleration Vs Frequency" as shown below. The first excitation Frequency is 74 Hz (Mirror Mounting region). Hence the "Mirror Assembly" natural frequency shall not be in the range of 60 to 90 Hz. Vehicle Mirror mounting excitation data:



Graph 1. *Various configuration actual measurements.*

Table 2. *Various configuration actual measurements*.

Sr. No.	Configuration	First Frequency (Hz)
1	Mirror Mounting Excitation	74
2	Mirror without mass	70
3	Mirror with 60 gm mass	52

1. Based on frequency analysis & actual measurements, It is clearly shows that addition of mass inside mirror housing improves the mirror performance.
2. Basically, we have shifted the natural frequency (52 Hz) of the mirror away from excitation frequency (74 Hz.).
3. In subjective test (actual road test) Mirror gives satisfactory result on vehicle. With this configuration it is possible to get the clearer image of rear view at any speed.

1 Results and Discussion

Virtual & Actual measurement are almost matching. Theoretical values are differed due to assumption made in the analysis.

Table 3. *Actual Vs CAE Vs Theoretical comparison.*

Sr. No.	Configuration	Actual/ Experimental	Virtual CAE	Theoretical Calculations
1	Mirror Mounting Excitation Freq. (Hz)	74		
2	Mirror without mass Freq. (Hz)	70	70	110
3	Mirror with 60 gm mass Freq. (Hz)	52	40	90

Base 3D Model of Mirror (Without addition of Mass inside mirror housing).
Iteration 01 (71 Hz) is not Ok due to resonance. Due to resonance mirror image/rear view distortion will happen.
Base 3D model + Addition of 60-gram mass inside Mirror Housing.
Iteration 02 (50 Hz) is Ok since "Mirror" natural frequency is far away from excitation frequency. Hence mirror image/rear view distortion will not happen. This proposal resolved our concern effectively. Accordingly, Iteration/proposal 2 will be adopted for the SOP
Test conducted on the actual component: On road vehicle running test at various speed (20 to 80 KMPH) & various road conditions. Rear view visibility found Ok.
Based on all successful completion of CAE & Actual testing activities: Mirror Assembly designed & developed, Implemented in production for New Adventure type Motorcycle.

2 Conclusions

"Mirror "design optimisation Done to reduce vibration for better rear-view visibility. Basically, mass addition in the mirror housing is very effective to reduce the vibrations. Modal analysis is required to perform for mass optimisation. Design the "Mirror Assembly" (Target 50 Hz) in such way that it's Natural frequency shall be far away from excitation frequency (60 to 90 Hz.). Accordingly Design optimisation improves the component life. Design optimisation improves the vehicle dynamics & safety during riding condition on the road. TGR (Things gone right)/TGW (things gone wrong) horizontal deployment in all future developments can be done.

*Advantages:

1.Better Rear View Mirror visibility & improved performance.
2.Improves vehicle dynamics & safety.
3.Life of the component increased because of less vibrations in the part.

*Disadvantages:

1. Part Cost increases.
2. Mass increased.

(This is safety component hence small cost & mass increase is no issue).

*Applications:

1.Two Wheelers
2.Three Wheelers
3.MTB Cycles

*Future scope,

1.We can simulate the "Mirror Design" with multiple weight at various position, high stiffness effect on mirror vibration.

2.We can simulate the "Handle End weight" tuning & overall effect on Mirror performance.

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