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Design and Vibrational Analysis of Motorcycle Handlebar by FEA Method and correlating it with Test Results

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Abstract: As India is the second largest manufacturer of motorcycles, so most of the population prefer two wheelers for daily transportation. Also there is economic reasons, road conditions, and transportation distance for the people's preference to motorcycle. Driving for long duration exposes motorcycle rider to extreme vibration arised from engine, road surface etc. resulted in severe effects on human health like musculoskeletal disorders, spinal injury, Harm Vibration Syndrome (HAVS), vibration induced white finger, finger numbness etc. So an approach towards motorcycle vibration reduction has to be carried out as the vibration transmitted through hand are of prime importance due to its severity. In this paper approach towards handlebar vibration has been carried by using analytical tools like Finite Element Method (FEM) where Modal vibrational analysis is done to find out response of structure to vibrations. Modal Analysis is well established technique which provides inherent dynamic properties of structure like natural frequency, mode shapes. Then experimental testing carried out for correlation of FEM results. There is good correlation found between software and experimental test results. Aim of this work is to develop method for vibration reduction by using software package (FEM) so, as to reduce time, cost required for experimental testing.

Keywords: Handlebar, Finite Element Method, Modal Analysis, Natural Frequency, FFT.

I. INTRODUCTION

Nowadays ride comfort quality is of prime importance mostly in two wheeled vehicles but unwanted vibration affecting it. In two wheelers as compared with four wheelers riders experiences more vibration because of direct and short paths from vibration source to touch sensitive points like handlebar, seat and foot rest. As the vibrations transmitted through handle-bar assembly are of more importance because, it is users first touch point to the vehicle and important in functionality and safety point of view. As basic handlebar assembly consists of main handlebar, handlebar clamps and bolts and nuts used for clamping.

Whole handle bar assembly is subjected to different types of excitations as experienced from road excitations, bumps, engine vibrations etc. Well established technique like Modal Analysis which provides inherent dynamic properties of structure like natural frequency, mode shapes, etc. is used to find out response of structure to vibrations. Basic Handlebar geometry is shown in Fig 1.

Competition in automotive market is growing day by day makes it more and more necessary to reduce the development time and cost of the product development process. One of the most costly phases in the vehicle development process is the field durability test. High expenses for this phase can be attributed to the number of prototypes used and time/efforts needed for its execution. Also, multiple iterations during designing, building and prototype testing are no longer affordable against the time and cost constraints for developing a competitive product. Today, analytical tools such as Finite Element Method software have been developed such that they will predict the result with high accuracy. In current work ANSYS, FEM Package is chosen to carry out Modal Vibration Analysis.

Fig 1: Handlebar Geometry

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II. LITERATURE REVIEW

ISO Standard 2631-1 [1] this standard is designed for determining effect of whole body vibration on human body. Suggests boundaries in order to standardize on subjectively level of exposition under which a certain vibration condition may be tolerated. Mentioned boundary values are not real limits, but give approximate indications of likely reactions to various magnitudes of overall vibration. However vibration exposure is not only dependent on the magnitude of vibration, but also on the duration of the exposure itself. Reactions of Persons to Whole-Body Vibration Expressed in Terms of the Overall Vibration Value is shown in Table 1.

Table 1-Reactions of Persons to Whole-Body Vibration

Vibration Reaction	
Less than 0.315 m/s2	Not uncomfortable
0.315 to 0.63 m/s2	A little uncomfortable
0.5 to 1 m/s2	Fairly uncomfortable
0.8 to 1.6 m/s2	Uncomfortable
1.25 to 2.5 m/s2	Very uncomfortable
Greater than 2 m/s2	Extremely uncomfortable

ISO Standard 5349-1-2001 [2]Exposure to hand-arm-transmitted vibration can occur from vibrating power tools held in the hands of the operator in the field of manufacturing industry, construction and agriculture, but also from hand-held vibrating controls such as motorcycle handlebars or vehicle steering wheels. It leads to vibration induced white finger (VWF). It also specifies the general requirements for the measurement and evaluation of human exposure to hand-arm-transmitted vibration.

Harale Shivraj, N Gyanendra Roy.,[3] describe in this analysis the handle bar assembly is excited with acceleration derived from road load data over range of 0 to 200 Hz which is an operational frequency to evaluate the strength of mountings on handle-bar in vibration. Using Altair solver code Bulk data Frequency response analysis on handle bar assembly is carried out. In this analysis the handle bar assembly is excited with dynamic loads i.e. acceleration derived from road load data for an operational frequency range to evaluate the strength of mountings on handle-bar in vibration. Pre-processing of Model preparation done using Hyper Mesh and Post processing is done using Hyper View and Hyper Graph. The simulation results for Mirror mounting bracket and Headlamp mounting casing are taken which are correlated with the experimental results in which failure location and pattern is exactly matched. Further design modifications have been incorporated for Mirror mounting bracket and Headlamp mounting casing to meet the strength requirement.

Kalsule, D., Askhedkar, R., and Sajanpawar, P.,[4] Successful attempt has been made to arrive at the solution of the engine induced vibration problem in motorcycle frame by using the right combination of FE modal analysis, FE harmonic analysis and experimental technique. Here Modal and harmonic response analysis has been carried out and these results are matched with Experimental Testing. Then further modification has been carried out in order to reduce overall vibration level upto 80-90%.

Di Puccio, F., Forte, P., Pratesi, A., and Hippoliti, R.,[5] It focuses cause of discomfort for two-wheeled vehicles may be a Hand-transmitted vibration. While there are international standards for the assessment of comfort in whole-body vibration exposure, there are not equivalent guidelines for hand transmitted vibrations. Based on annoyance and injury risk acceleration signals have been analyzed according to different approaches showing that the weighting procedures underestimate a vibration frequency range above 100Hz, which is of some importance in the examined case. Therefore for motor scooter ride comfort assessment a proper weighting function should be defined on the basis of specific tests.

Jaimon Dennis Quadros, et al.,[6] studied, analyzed and obtain the idealized operating conditions of the human body. Prolonged exposure to specific frequencies of vibration might have effects on certain segment of the body. Their analysis has shown that for the given test vehicle and human body model, the ideal operating speed for HERO HONDA SPLENDOR vehicle on the terrain of specified amplitude for given input is found about 49.66 kmph.

S. Agostoni et al.,[7] research work has developed with the aim of investigating motorcycles ride comfort. Particular attention was focused on the handlebar, because this component is directly comes in contact with driver. A well-grounded, repeatable methodology is developed with a proposed view of designing a Tuned Mass Damper (TMD) that

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should capable of absorbing vibrations, i.e. one which is capable of reducing the vibrations transmitted to the driver via the handlebar. The steering balances which placed at the extreme ends of the handlebar of all regular motorcycles is the starting point chosen for this methodology. Structural vibrations reduction is also mean of this paper. Thus, not only reduced driver exposure to engine unbalance vibration, but also improved ride comfort.

Gourav.p.sinha, p.s.bajaj.,[8] examined about the practical measurement of vibration occurring on two wheeler vehicle which are very dangerous when it is transmitted to human body through thigh, footrest, seat &handle. So determining the vibration level occurring in vehicle should be helpful and some steps to reduce it are taken. In this paper from vibration point of view different aspect of riding vehicle on smooth and uneven road carried out.

III.OBJECTIVE AND METHODOLOGY

According to objectives of project following methods has to be followed to conduct the vibration analysis of Motorcycle Handlebar. For which following steps are followed for the achievement of the objective.

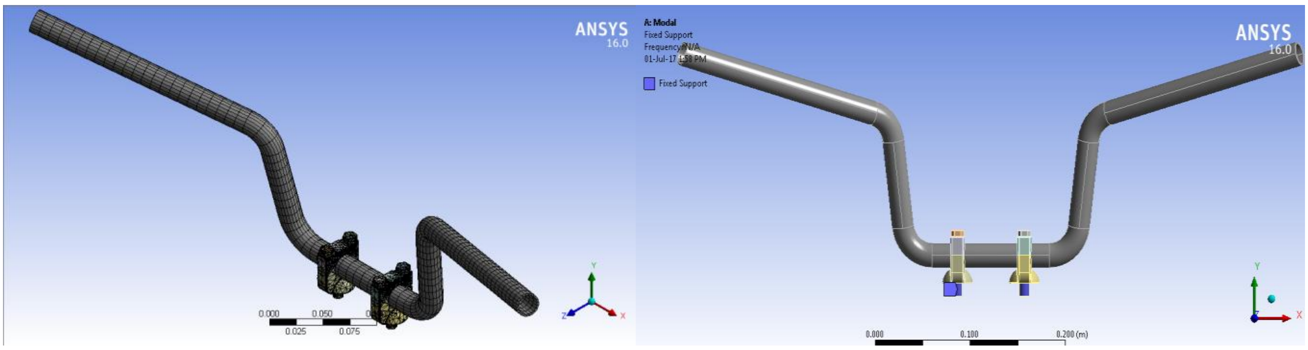
Objectives:
1. To carryout Modal vibrational analysis for Handlebar geometry.
2. To correlate FEM results with the experimental test results.

Methodology:
The outputs of a vibrating system generally, depend upon the geometry, boundary conditions, material properties and external excitations. The vibration analysis of a physical system may be summarized by the four steps:
1. Constrained Modal Analysis using ANSYS FEM package (Ansys version16) to find out the System Level Natural Frequencies.
2. Conducting vibrational analysis test by applying same constraints as used in FEM using Fast Fourier Transform (FFT) Analyzer to find out Natural Frequencies.
3. FEM and test result correlation.

IV.VIBRATIONAL ANALYSIS

FEM ANALYSIS OF HANDLEBAR
'ANSYS v16' FEM package is used to carry out Modal analysis of the motorcycle handlebar. The entire FEM analysis procedure was completed in following steps.

A. Model Preparation
The motorcycle handlebar is an assemblage of main handle bar, Handlebar clamps, clamping bolts, clamp nuts. The ultimate purpose of Finite Element analysis is to create mathematically the behaviour of an actual engineering structure with all nodes and elements, material properties, real constants and boundary conditions. Handlebar geometry is modelled by using dimensions taken from reverse engineering on existing handlebar. Material used for handle is Stainless Steel.
Mesh is generated by using solid mesh command and entering input values such as element length, size and select element shapes and keep the mesh by using free meshing option and then it is redefined again for setting accurate results of mode shapes. Handlebar with mesh is shown in Fig 2(a)
As in actual handlebar is fixed to the motorcycle frame with the help of clamps. These boundary conditions were used for analysis are as shown in Fig 2(b)



(a) (b)

Fig 2: shows the (a) meshed FEM model of the handlebar, (b) Boundary Conditions applied to handlebar

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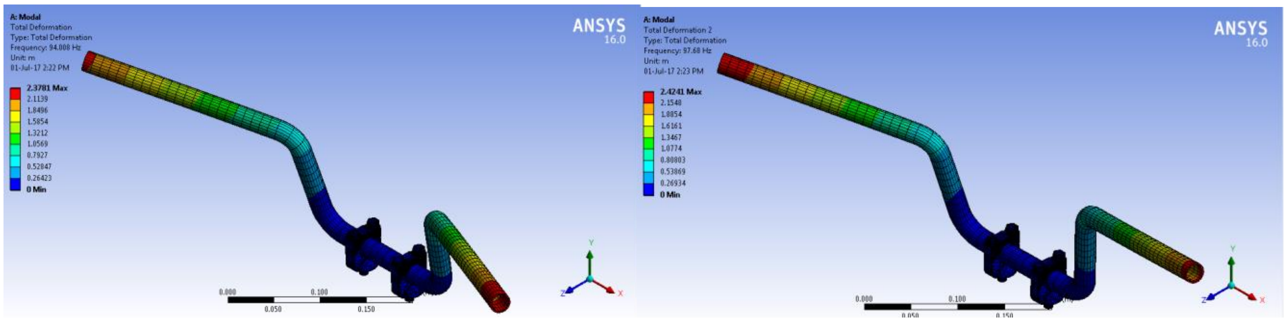
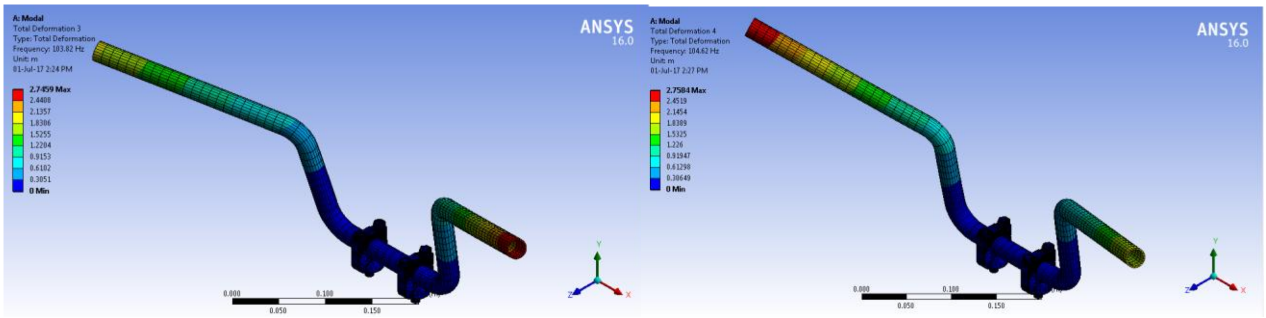
B. FEM Modal Analysis Solution

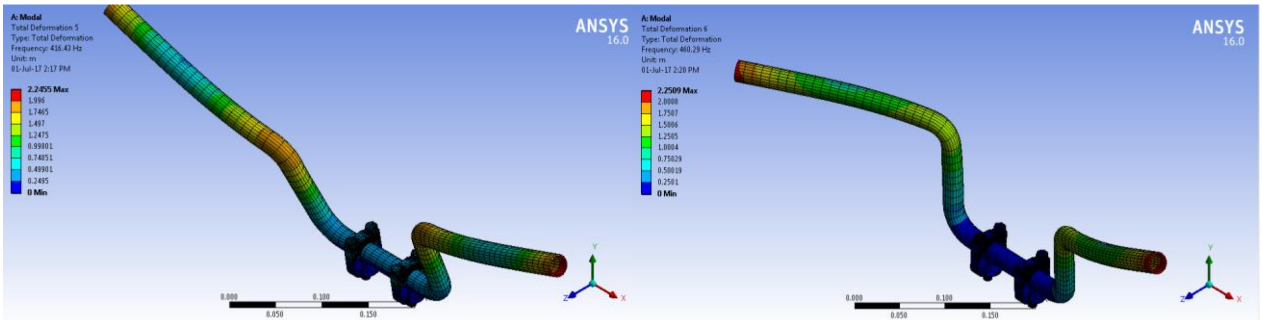
After the geometric model formulation, modal analysis was carried out for the given boundary conditions. Among the different solver available on ANSYS v16 for Modal analysis, of which program control type solver was used to extract the natural frequencies and mode shapes of the motorcycle frame. Vibration analysis was carried out for finding natural response of structure by some impact or displacement. The number of mode shapes required to expand, for the study of dynamic behaviour so here we expand 6 mode shapes as shown in Fig 3.



(i) (ii)



(ii) (iv)



(v) (vi)

Fig 3: represents mode shapes of the motorcycle handlebar at (i) 94.008 Hz (ii) 97.68 Hz (iii) 103.82 Hz (iv) 104.62 Hz (v) 416.43 Hz (vi) 460.29 Hz.

The natural frequencies obtained from modal analysis of handlebar are given in Table 2.

Table 2: Natural frequencies of the motorcycle Handlebar by FEM.

Mode No.	**Frequency (Hz)**	**Mode Shape**
1	94.008	Deflection in lateral direction
2	97.68	Twisting of handlebar
3	103.82	Sea saw bending
4	104.62	Longitudinal bending in upward direction
5	416.43	Twisting & lateral deformation
6	460.29	Bending in longitudinal direction

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EXPERIMENTAL ANALYSIS

The experimental study of structural vibration provides a major contribution to our efforts to understand and to control many vibration phenomenon encountered in practice. The main objective of experimental vibration analysis is to determine the nature and extent of vibration response level and to verify the theoretical FE Models and prediction. The experimental testing was carried out as described below.

A. Experimental Free Vibrational Analysis (Bump Test):
This technique was used to verify the FEM model. Free vibration analysis was carried out for finding natural response of structure by some impact or displacement. The structure was subjected to impact forces and the responses at different locations on handle bar were observed. Figure 4 shows the experimental set up for the modal testing. The boundary conditions used for this experimentation were very similar to that of FEM model as explained above. The FFT analyser with NV Gate software and accelerometers were used to sense and analyse the different modes of the structure. The Fig: 5 shows the experimental modal results of handle bar.

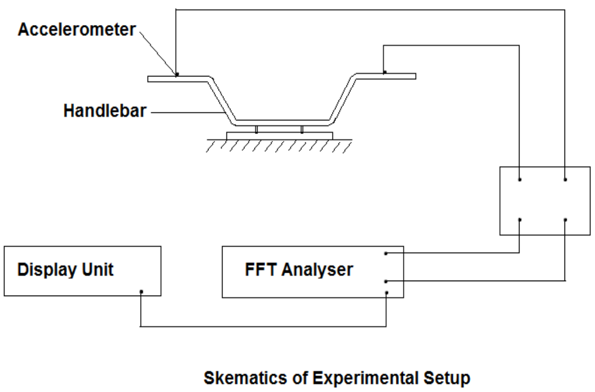

Fig 4: Schematic Setup for experimental test.

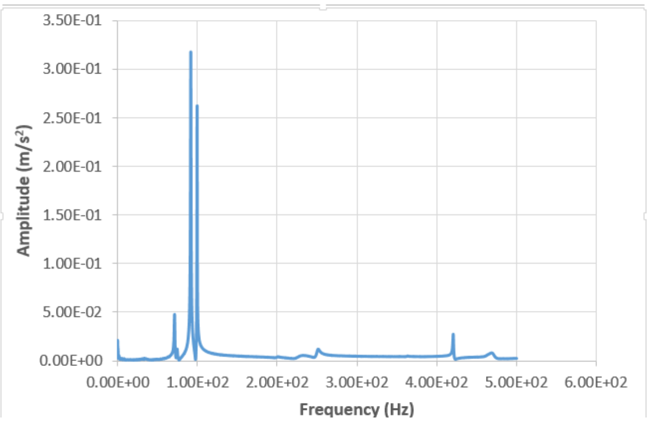

Fig 5: Experimental Modal Analysis Result

V. RESULT CORRELATION

The Table 3 shows that the correlation between the software (FEM) and experimental modal results of handle bar. It indicates that there is good correlation between the frequencies predicted as peaks for the above analysis. The difference in frequency was observed, may be due to absent of seam welding in FEM Handlebar geometry Design. The responses at all location by both method are in good correlation.

Table 3: correlation between the Software (FEM) Results with Experimental Test Result

Mode No.	Natural Frequency's	
	Software Results(Hz)	Experimental Results (Hz)
1	94.008	91.90
2	97.68	94.87
3	103.82	99.80
4	104.62	99.80
5	416.43	421.00
6	460.29	472.00

VI. CONCLUSION

In this paper ANSYS v16 package is used for Modal vibrational analysis of the motorcycle Handlebar assembly. The six different mode shape results are obtained showing different deflections of handlebar assembly. Then experimental vibrational analysis has been carried for the results correlation. The following conclusions have been made from the above study

- As the motorcycle riders are subjected to extreme vibrations transmitted through handlebar so there is need of vibration analysis to be done on it.

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- As there is good correlation between the Software (FEM) results and experimental test results with average error found to be around 2.5% only.
- As Software (FEM) method can predict good results and number of iterations can be taken within less time so, there is no need of actual or prototype formulation to conduct experimental test. FEM approach can be used to reduce design cycle time, number of prototypes and more importantly, testing time and its associated costs.

The work presented in this paper is only early phase of project work. Further handlebar development for vibration reduction by using passive vibration control technique has to be presented in next paper.

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