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Operational modal analysis of a bike chassis

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ABSTRACT

This paper deals with the experimental validation of vibration analysis of a simple bike chassis. Vibrations are the phenomenon observed by bodies where oscillations take place about an equilibrium point. It is observed in every component. Vibrations in some cases are an unnecessary phenomenon. Vibrations induce cyclic loads which lead to fatigue failure which in turn reduced the lifetime and durability of the product. Modal analysis is one of the methods applied to find the vibration characteristics of a structure. This can be implemented to find the natural frequencies and mode shapes of the structure. In the case of two-wheelers, vibrational analysis is done to reduce vibrations to prevent fatigue failure as well as provide ride comfort. With the help of animated mode shapes, we can infer how the chassis behaves at different frequencies.

Keywords— *Vibration, Motorbike, Automotive, Resonance, Simulation, Experimentation, Validation*

1. INTRODUCTION

Vibrations are one of the underlying phenomena experienced in every day to day object. In the case of automobiles, it leads to cyclic loads which could lead to detrimental conditions within the structures [3].

Cyclic loads produce stress withing the structures which reduce the strength and life of the object in use. If the frequency of the driving force matches one of the natural frequencies of the object, it causes deflections of huge amplitudes [3][8]. Understanding the nature and attempting to study its properties helps us in understanding the dynamic properties of a structure and measuring its vibration parameters [1][9]. Based on the object under study, we need to select an appropriate method of testing. Dimensions, mounting locations, chemical properties, and strength of the material need to be taken into account to select an appropriate method of testing [5].

For the case of performing modal analysis on a bike chassis, the roving accelerometer method was deemed the most appropriate coupled with the impact hammer test [5][6][11]. The chassis of a bike behaves as the skeleton of a human body. While designing a chassis we need to take the static and dynamic loading conditions into account. At the end of the day, our aim is to reduce the amount of discomfort experienced by the rider and to maximize the usage time of the equipment [7].

When performing modal analysis for a structure we have to make sure we are isolating the system from experiencing vibrations or contact with other structures. Hence it is imperative to keep the object in a free-free condition. In this condition, the body will exhibit rigid and elastic modes which are determined by the physical properties of the object. However, when analyzing the vibration properties of a bigger structure such as a building, it is not possible to emulate free-free conditions [2]. While measuring vibrations, we prefer to use an accelerometer as compared to a velometer. The characteristics of an accelerometer enable it to pick up minute displacements with higher sensitivity. The mass of the accelerometer should be minimal compared to the size of the structure to minimize its effect on generated values and due to the metallic nature of the structure under study, we can make use of a magnetic mounted accelerometer [4].

The classical modal analysis deals only with the static conditions of the object in question. The next step is to take a more dynamic approach into account which is to perform operational modal analysis. Operational modal analysis is employed to study the vibration effects on an object under the influence of its working forces. In the case of a bike chassis, we can consider the forces generated by the engine as one of the driving forces for operational modal analysis [10].

Taking the bike chassis into account, the problem we are faced with is to study its modal properties and compare the static modal study with the operational effects induced by the running engine on the chassis.

In this paper, we attempt to find out the natural frequencies of the chassis, the mode shapes generated with computer simulations, and validate this with experimental data acquired via modal analysis. We then expand our work into gaining an understanding of how the natural characteristics change when the operational conditions of a bike are applied to the chassis. Based on data acquired in both the conditions, we then make an attempt to perform mode shape analysis for both the given conditions.

2. DESIGNING AND MESHING

The first step was to design the entire chassis to the exact measurements of a chassis of a Hero Passion pro.

The chassis is made of mild steel and the properties are as listed:
Material: Mild Steel
Young's Modulus: 1.90E+11 N/mm2
Poison's ratio: 0.29
Density: 7680 Kg/m3
Designing of the chassis was done on CATIA V5R21

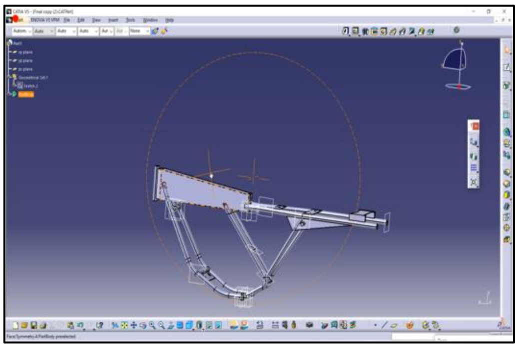

Fig. 1: Catia Design of Chassis

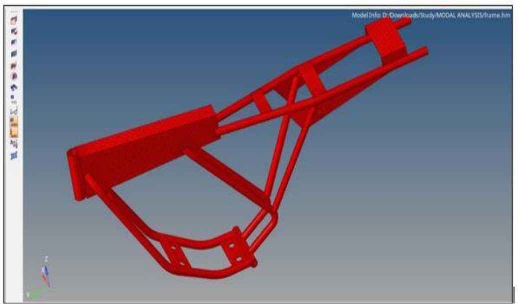

Fig. 2: Meshed model of the bike chassis.

Based on trial and error it was deduced that manual meshing of the model gave the best possible results compared to auto meshing. Manual meshing was done on Altair Hypermesh.

3. MODAL ANALYSIS (SIMULATION)

The meshed model was imported on ANSYS 18.1 to perform modal analysis. The first 6 modes were rigid body modes and were ignored for our study. Modes 7-16 were analyzed along with the frequencies.

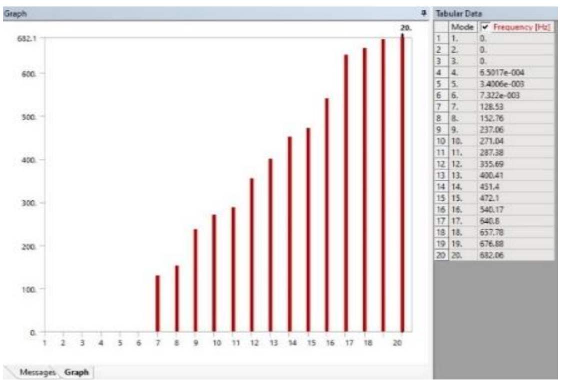

Fig. 3: Free-Free Frequencies

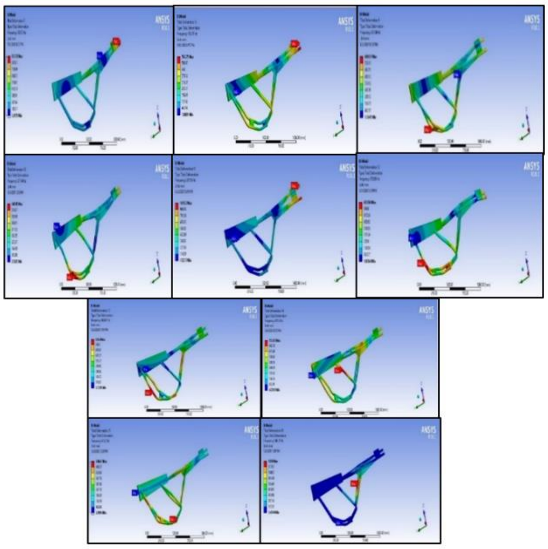

Fig. 4: Mode shape 7-16

4. EXPERIMENTAL VALIDATION

For validating our simulated data, we proceeded to experimentally perform modal analysis and compare the data. For this we made use of MEScope software to perform experimental modal analysis. Roving accelerometer test was the method used to perform classical modal analysis. In this method, the impact hammer was struck at a reference point (21) while the accelerometer was moved around and placed at 60 points in the chassis. A single tri-axial accelerometer was used. An average of 4 hits was taken for each reference point to eliminate disturbance cause by noise and other factors. The input data was displayed in the form of an FRF graph.

All the data is hidden inside the FRF in the frequency domain. The data was extracted using curve fitting method. By constructing a curve that has the best fit for a series of data points, a mathematical function was derived to best explain the behaviour of the chassis.

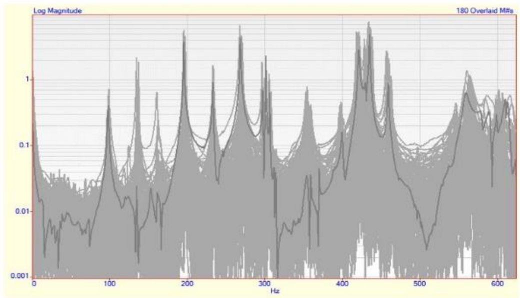

Fig. 5: FRF Graph

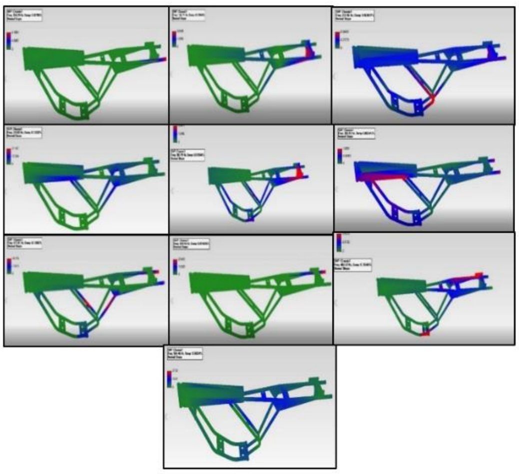

Fig. 6: Mode shapes (Experimental)

We kept a margin of 10% for the difference between the frequencies of computer-generated data and experimental data. We matched the modes of the experimental data with the ones it matched in the simulations. Later we compared the frequencies of the matching mods to make sure they were within a 10% error bandwidth.

Table 1-Data comparison and validation

MESCOPE (Hz)	ANSYS (Hz)	ERROR %
134	128	5
136	152	10.5
231	237	2.5
270	271	0.3
303	287	5.5
358	355	1
417	400	5
428	451	6
463	472	2
564	540	5

Experimental data was validated by making use of the MAC feature in MEScope.

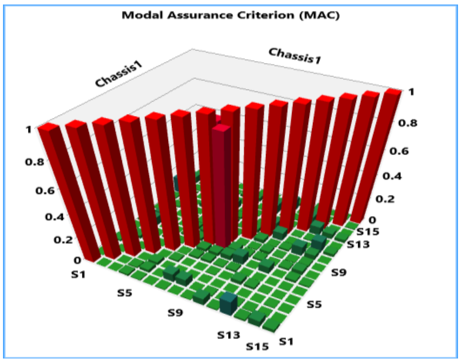

Fig. 7: MAC Graph

5)OPERATIONAL ANALYSIS

The next step was to analyze the computer simulations for the operational conditions of the bike chassis. Chassis was redesigned to include an engine block as a rigid body.

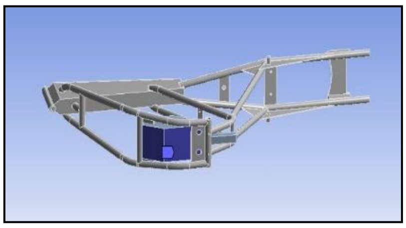

Fig. 8: Chassis & Engine

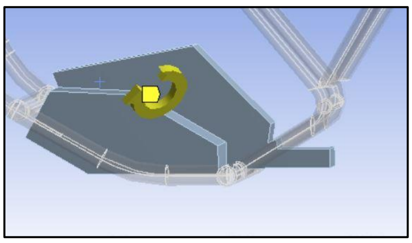

Fig. 9: Boundary Conditions

To replicate the running conditions, we fixed the chassis and engine at its mounting point and provided a rotational velocity of 188rad/sec at the engine followed by a one-unit harmonic load at the engine CG.

Modal analysis was performed on ANSYS 18.1 for the following loading conditions.

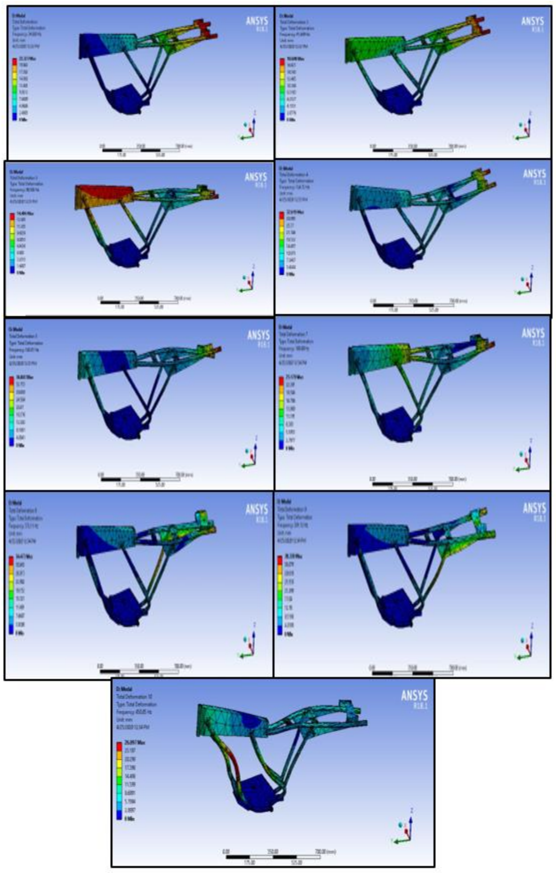

Fig. 10: Mode shapes (Operational Conditions)

Table 2: Frequencies for operational conditions

MODE	FREQ(HZ)
1	34.829
2	41.649
3	96.506
4	124.72
5	163.81
6	197.52
7	199.09
8	372.11
9	381.12
10	450.05
11	455.64
12	501.71
13	568.35
14	582.72

6. MODE SHAPE ANALYSIS

The next step was to compare and analyze mode shapes that were similar when the operational modes were kept side by side with the experimental and computer-generated modes for modal analysis.

Table 3: Mode shape analysis (Mode matching)

Experimental Mode	Experimental Frequency (Hz)	Matching Operational Mode	Matching Operational Frequency (Hz)
1	134	4	124
2	136	5	163
3	231	6	197
4	270	7	200

7	417	9	381
9	463	11	455
10	564	12	500

7. RESULT

Experimental data is a close match with the computer-generated data. This shows that the methodology is a close fit to our intended result, and we have successfully obtained the natural frequencies and mode shapes for the chassis for further analysis. Once our methodology for static modal analysis was validated, we could check for dynamic loading effects simulation and study its effects on the vibration characteristics.

8. CONCLUSION

We have learned from this experiment that the correct way for classical and operational modal analysis is to first analyze the chassis using ANSYS software and then comparing the results from it with values obtained from classical modal analysis experiment. Performing this experiment helps us understand the behavior of the chassis for static and operational conditions. It helped us understand the variation of frequencies for the same observing mode shapes for the different boundary conditions applied by us.

9. SCOPE AND FUTURE WORK

Data acquired from this study can be expanded into experimental operational modal analysis of the bike chassis random vibrations and road loads into account. Experimental operational modal analysis for the entire bike can also be compared with the simulated data. Similar studies can be carried out on chassis of different bikes and compared to the data acquired for this bike chassis

10. REFERENCES

BOOKS

[1] Brüel&Kjær, 1982. Measuring vibration, K Larson and Son; Revised edition (1982)

[2] DJ Ewins,1984, Wiley; Modal Testing: Theory and Practice, by D. J. Ewins, Wiley, New York JOURNAL ARTICLES

[3] Santosh Hiremath, Naresh Kumar, Nagareddy.G, Lakhan Rathod, 2016. Modal analysis of two-wheeler chassis, International journal of engineering sciences & research technology 5(7): 2277-9655

[4] Pavana Shireesha Paningipalli, Dr. F. B. Sayyad, 2016. theoretical and experimental validation of bike chassis for weight reduction, International journal of engineering sciences & research technology 5(10) 2277-8616

[5] Peter Avitabile, Modal Analysis and Controls laboratory, University of Massachusetts Lowell, USA - Experimental Modal Analysis (A simple non-mathematical presentation)

[6] Structural Dynamic Investigation of Motorcycle Chassis Mohamad Nasrul Faez (Universiti Malaysia Pahang) June 2017

[7] A review of Vibrational Analysis of Scooter chassis, Mr. Barister Giri and Prof Shah B.R

[8] Abdullah, N., Sani, M., Rahman, M., & Zaman, I. (2015). A review on model updating in structural dynamics. Paper presented at the IOP Conference Series: Materials Science and Engineering.

[9] Rajput et al., 2013; Z, Abdullah, Sani, & Zaman, 2011. Rajput, Y. S., Sharma, V., Sharma, S., & Saxena, G. (2013). A Vibration Analysis of Vehicle Frame. International Journals of Engineering Research and Application (IJERA), 3(2), 348-350.

[10] Li-rui & Xiao-long, 2012; Wu, 2006). Simulation and Improvement of Vehicle Frame Using FEM. Paper presented at the Proceedings of the 2012 International Conference on Mechanical Engineering and Material Science (MEMS 2012). Published by Atlantis Press.

[11] J. Kooijman, 2008; Packard Experimental validation of a model of an uncontrolled bicycle. Multibody System Dynamics, 19, 27.

