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Design and Analysis of Medium Utility Chassis of Heavy Motor Vehicle

Miss.Shrisharada Shrirang Mhatre[1], Prof. Gajendra V Patil[2], Prof. Shishirkumar Kadam[3]
[1,3]Mechanical Engineering Department, Pillai HOC College of Engineering, Rasayani, Mumbai India
[2]Mechanical Engineering Department, Pillai College of Engineering, Rasayani, Mumbai, India

***Abstract*— In this work, the harmonic and static structural analyses of the ladder chassis frame are carried out by using ANSYS. Modal analysis through harmonic response of the chassis was done for structural steel and A710 steel materials. It was observed that a particular frequency was close to engine excitation. In this case chassis may experience structural resonance. It is to be noted that harmonic analysis as well as frequency response analysis will not give us stress- strain details. To know the stress- strain details, static structural analysis has been executed. Further assuming the given system to be of single degree of freedom system, Dunkerley's method and Rayleigh's method (for determination of natural frequencies) have been used for computation of natural frequencies analytically. Thus comparison of the natural frequencies of modal analysis through ANSYS workbench and aforementioned methods have been performed. Natural frequencies found to be significantly close and are in excellent agreement with each other. This is one of the novelty of the work. Further, frequency range chosen in the analysis is such that it uses some data from experiments which is another novelty. It should be noted that the given system is not a single degree of freedom system. Further stress and strain details executed with the help of static structural analysis revealed that A-710 is better material choice when compared with structural steel. Obtained results are being exploited to benefit Industry and scientific community for future endeavors. Further, efficacy of developed framework could be extended to other such alike applications.**

Index Terms: **Harmonic Analysis, Static Structural Analysis, FEA, ANSYS.**

I.INTRODUCTION

Chassis can be considered as back bone of the vehicle i.e. vehicle without body is chassis. Function of chassis frame is to provide mounting structure for various components of vehicles such as wheels and tires, control systems, suspension, transmission and power systems and body of the vehicle. Internal and external loads acting causes stress in chassis structure. Aerodynamic field around vehicle body, suspension system, and wheels are the sources of external loads. Power train, mass of body of vehicles, passengers and baggage cause internal loads on chassis. Off road vehicles have chassis structure separated from body whereas passenger vehicles have chassis integrated in body. Structural stiffness is an important factor in vibratory behavior of the body. When other structural requirements are achieved it is not difficult to reach acceptable values in case of small and medium size vehicles.

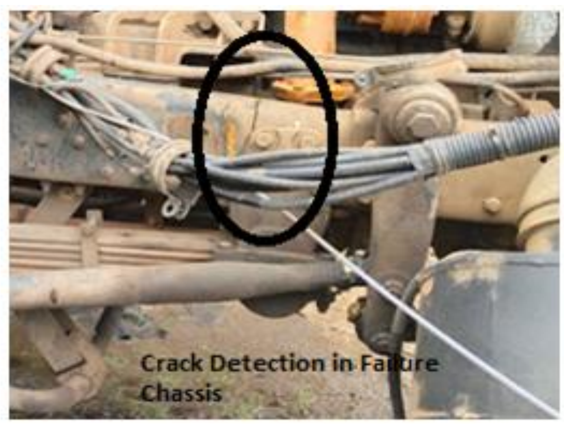


Figure 1 Cracks occurs in Chassis

We identify the failed chassis as shown in picture, this chassis failed closed to leaf spring. No. of such chassis failed in real time applications.

II.RELATED WORKS

Marco Cavazzuti et.al (2010)[1], provides applicability of methodology to obtain general thickness distribution and truss layouts. Model shows remarkable reduction in weight comparison with earlier chassis. These results are achieved by using topology, topometry and size optimizations which are coupled with FEM analysis. Changes to design space, and by forcing a bit more the governing parameters of the optimization process a simpler structure, with a lower number of truss components, could also obtained. This would allow to barter some weight for lower production.

Jesik Shin, Taehyeong Kim (2016) [2] through experimental analysis put forward an aluminum alloy which exhibits high castability, corrosion resistance and excellent specific strength. Which is why such type of new materials are used for manufacturing of different automobile components having simple profiles. Thus the paper come up with various methods such as grain refinement, electromagnetic casting, powder metallurgy, semi solid processes and rapid solidifying are implemented to overcome loop holes exhibited by materials.

M.Chandrasekar et.al (2016) [3], furnishes with brief review on the objective of present to determine the maximum stress, maximum deflection and to recognize critical regions under static loading condition. Static structural analysis of the chassis frame is carried out by FEA ANSYS Method. The advantage of it is the rigidity of the system was analyzed and their resonance could be avoided.

KallappaKhannukar et.al (2015) [4], by Finite Element Analysis study lay the emphasis on dynamic analysis of chassis. The modal analysis is carried out using both analytical and FEA techniques, and the results were found to be in good agreement with each other. The leeway is, the chassis structure can be optimized by varying the design parameters with the help of acceleration response of system.

Christian Schubert, Stephan Pries (2017) [5], proposed work through experimental analysis focuses on detailed investigation of TPA methods applied to a suspension system in the low frequency range. It provides efficient practical alternative to the TPA with direct force measurement, more detailed studies on the validity of methods based on indirect force determination, in particular with mount stiffness, should be further investigated for application of TPA to chassis system in the low frequency range.

DavidePanari et.al (2017) [6], By Computer Aided Tolerancing, proposes an integrated design method that considers an assembly operations before the detail design of the chassis and the concept design of the fixture system. Future work will concern the simulation of this case study with FEA compliant package included in the 3DCS software.

MohdAzizi et.al (2012) [7], aims to model, simulate and perform the stress analysis of an actual low loader structure consisting of I-beams design application of 35 tonnes trailer designed in-house by Sumai Engineering. The stress analysis of low loader chassis is achieved through experimental testing and CATIA. The proposed study will include experimental investigation to determine actual deflection of a similar beam.

III. METHODOLOGY

Study of Medium Utility Chassis
↓
Identification of failure of HMV Chassis
↓
Analysis of existing Chassis and find out reasons of failure
↓
Modified Design of Chassis
↓
Static Structural Analysis
↓
Investigating the different Mode shapes due to loading
↓
Reconstruction of design of MUC of HMV
↓
Result validation

Figure 2

IV. RESULTS

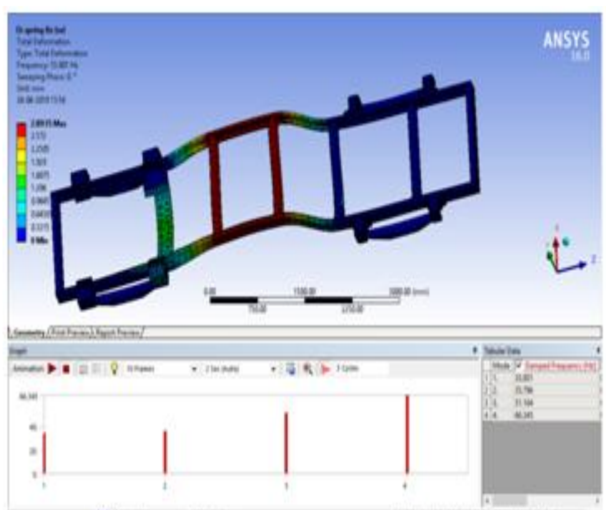


Figure 3 Mode 1 for Structural Steel

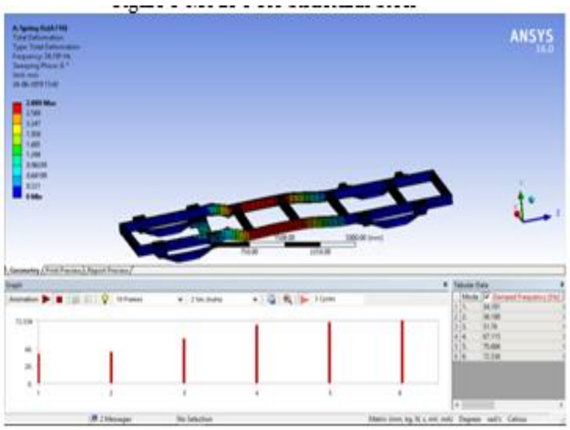


Figure 4 Mode 1 for A 710

Analyatical Results

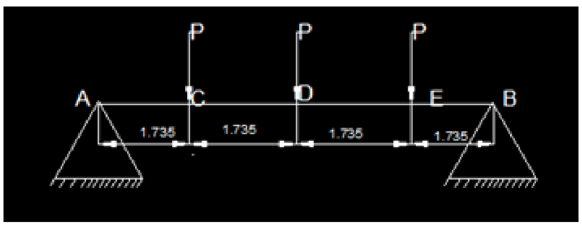


Figure 5 Dunkerley's Method for Structural Steel

$$\frac{1}{\omega_n^2} = \frac{1}{\omega_1^2} + \frac{1}{\omega_2^2} + \frac{1}{\omega_3^2}$$

Deflection of the chassis considered as beam at distance x from left end A,

$$EI\frac{d^2y}{dx^2} = \frac{-Pbx}{l} + P(x-a)$$

$$EI_y = \frac{-Pbx^3}{6l} + C_1x + C_2 + \frac{P(x-a)^3}{6}$$

Applying boundary conditions as

y= 0 at x=0 and y= 0 at x= 1

$$\therefore\ C_2 = 0$$

$$C_1 = \frac{Pbl}{6} - \frac{P(l-a)^3}{6l} \qquad \because [\,where\ x = a]$$

$$\therefore\ y = \frac{1}{EI}\left[\frac{-Pbx^3}{6} + x\left(\frac{Pbl}{6} - \frac{P(l-a)^3}{6l}\right)\right]$$

$$\therefore\ y = \frac{Pbx}{6EIl}(l^2 - x^2 - b^2) \qquad \text{...............} (1)$$

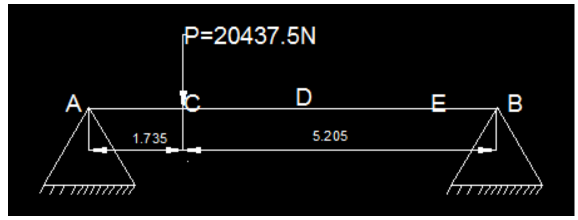
$\therefore$ *Here* $E = 2.05 \times 10^{11}\ N/m^2$

For the inertia (I), width (b), height (h)

$h = 0.5483\ m$ b=1.940m

$$\therefore I = \frac{bh^3}{12} = \frac{1.940 \times 0.5483^3}{12} \therefore I = 0.0266\ m^4$$

Deflection y1 at point C



$y_1 = \frac{p_1 b_1 x_1}{6EIl}(l^2 - {x_1}^2 - {b_1}^2)$ $\therefore\ y_1 =$ $1.468 \times 10^{-5}\ m$

Deflection y2 at point D

$\therefore$ y_2=2.675×10−5 m

Deflection y3 at point E,

$\therefore y_3 = 1.505\times10^{-5}$m

As we know

$$\omega_n = \sqrt{\frac{g}{y}}$$

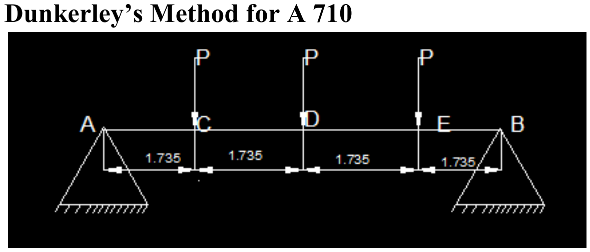
w_1=807.358 r/s w_2=605.582 r/s w_3=807.358 r/s

By Dunkarly's Method

$$\frac{1}{\omega_n^2} = \frac{1}{\omega_1^2} + \frac{1}{\omega_2^2} + \frac{1}{\omega_3^2}$$

$\therefore\ \omega_n = 415.403\ r/s$

Dunkerley's Method for A 710



$\therefore\ \omega_n = 420.58\ r/s$

V.COMPARISON OF RESULTS

Sr. No	Method	Natural Frequency :Structural steel (Hz)	Natural Frequency:A710 Steel (Hz)
1	ANSYS	66.345	67.12
2	Dunkerley	66.113	66.94
3	Rayleigh	66.110	66.95
4	% Error	0.3509,0.3554	0.2688,0.2539

VI.CONCLUSION

This work presents the modal analysis and frequency response analysis through harmonic response of the chassis structure. All the obtained failure mode shapes and frequency response are analyzed in ANSYS WORKBENCH software. It is concluded that at the second, third or fourth degree orders, failure can occur. The extracted natural frequencies of the modal analysis in ANSYS are observed to be in good agreement with thevalues that are obtained by hand calculations using Dunkerley's Method and Rayleigh's Method for both Structural Steel and A710 Steel materials. Further the stress and strains details are studied in static structural analysis which includes total deformation, von-misses stresses and different principal stresses and strains for both the materials. Using all above techniques, we conclude that Material A710 has better overall stiffness and lower effective mass as compared to material structural steel hence it can be used for further developments in chassis structures.

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