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Dynamic analysis and structural simulation of aluminum composite material based automobile chassis

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ABSTRACT

The vibration in automobiles is an important issue to be noted in which the road excitation forces on the automobiles create the vibration and noise due to random vibration that affects the comfort of the passengers; hence this paper aims to investigate aluminium based polymer composite structure analysis in which the effect of random vibration can be check by using the steady-state, modal and random response analysis using the power spectral densities (PSD) and the resonance frequency in which the recommendations can be made using the optimization of the structure of the displacement for the safe application of the loads with the lightweight structure. The resonant frequency of the structure is determined as the 57 Hz.

1. Introduction

The vehicle structure is the skeleton supports the engine and the body parts that stabilize the vehicle vibration and force acting on it. The objective of the structure analysis is to increase the vehicle comfort by providing proper suspension system like the springs and the engine mount [1,2]. Here the boundary condition is the arresting of the frame with respect to the degree of freedom. The vehicle model is modeled such that the weight of the material is less and due to that the magnitude of the vibration caused should not be increased [3,4]. Here the vehicle suspension frame work is considered as a quarter models for the analysis. The aim of these studies is to look at a quarter vehicles with the goal of dissecting comfort while taking into account the compliances in safety and the model has a suspension top mount and a solid setup [5,6].

There has been constant development in the innovative work in the various parts of cars. Indeed, a significant number of the significant designing developments have at long last been carried out in vehicles, and many are likewise being done as of now. PC supported designing strategies have helped in the plan interaction by diminishing the time taken for a plan examination and giving many designing arrangements where plans can be affected without assembling models. Computer-aided engineering techniques have been developed to decide car parts vibration reactions and the commotion from such segments. Limited component techniques have been utilized for underlying examination to decide the pressure-actuated in segments due to the exposed static and dynamic burdens. Due to the dynamic loads on the structural components, vibration occurs and is measured. The generated vibration is propagated as the longitudinal sound waves and enters the passenger's ear both in the vehicle's interior and exterior. Hence, researchers reduce and control the vibration and noise in automotive vehicles. It has been identified that computer-aided design is one of the recent techniques used to analyze by creating the model and evaluating it as a real-time situation. The product life development done using the CAD software is quite less expensive and time-consuming.

A study has been done on the dynamic behaviour of the automobile's chassis using the FEA technique; as a method of analysis, the modal analysis is carried in both the analytical and cad. The results were obtained and found good the values are compared. In addition to that, the optimization of the structure using the design parameters are also done for finding the natural frequency and the resonance frequency of the structure for better output results [1]. Garud et.al. [3] had done a research work using the Chassis of the automobile considering the constraints of stress at the top condition, deflection and critical conditions under various loading conditions and also carried out the design optimization using the simulation techniques for the reduction of the weight of the Chassis based on

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the material properties and structural parameters. Sani et al. [5] made an investigation on the dynamic characteristics of the car chassis structure using two methods like the experimental modal analysis and the modal testing method. In this method, parameters like the natural frequency, damping factor, and the various mode shapes have been obtained using the testing method of hammer impact and the shaker test. Subsequently, the results were obtained using the data analyzer in which the signals obtained by the sensors are analyzed using the time domain and frequency domain analysis. It was concluded that the different results are about five percent in both the methods. Tomar et al. [7] had done a modal analysis of a chassis frame to determine the natural frequency and subsequently the mode shapes to identify the resonant frequency due to the vibration in the chassis frame and the weight of the chassis is optimized based on carbon epoxy material using the CAE Software CATIA in which the modeling had been accompanied. Gajbhiye et al. [8] a study on the truck chassis that carries a load of the car engine and the body and hence the vibration during the running condition of the truck and hence a modal analysis is performed on the virtual truck chassis frame also the mode shapes and the natural frequency of the truck frame is analyzed using the finite element technique and hence the load application and the running condition is kept in the safe range. Ashok Reddy et al. [9] conducted an investigation on the Chassis of the three-wheelers is done using the CAE the chassis model of the three-wheelers is created and harmonic analysis is done in which the prototyping model analysis given the values of the vibration characteristics like the damping and the displacement and stress values and hence the time and cost of the actual testing of the Chassis is reduced. Madem Naresh et al. [10] carried a research work on analyzing the heavy vehicle chassis made of composite polymer material. The weight and material properties of the conventional Chassis are enhanced. Here he has used an epoxy-based polymer composite of the fibre material reinforced in the steel material in which the structural and modal analysis is done. The analysis is done in the ANSYS and the standard Chassis. The new composite material chassis showed the structure's better properties and mechanical properties like the tensile strength, stiffness, and corrosion resistance are highlighted in the result.

Nanang Ali Sutisna et al. [11] has introduced a plan of electrical vehicle chassis, explicitly a FEM reproduction is utilized to show the diverse sort of burden and response on the vehicle. The principal objective in this examination is to foster an electric vehicle with a suspension bar, where the edge will have a self-suspension framework. The edge configuration will be made as unique hardware. This exploration will zero in on how an electric vehicle undercarriage withstands a certain heap with a characterized limit condition. The examination is directed utilizing the Finite component Method utilizing ANSYS programming. The principal examination is the Von-Misses Stress, the wellbeing factor, twisting, twist shear pressure and vibration. Prażnowski et al. [12] had done experimental work on a passenger car which explains the wheel balance due to the vibration in the car is checked for the random vibration for the running condition of the car and the environment of the road surface conditions d. it is observed that the longitudinal vibration of the car body tested for the speed ranges of 50 km to 11 km per hour using the frequency domain analysis and the power spectral density. Durga Prasad et al. [13] has observed that the aerospace vehicle is subjected to different type loads acting on it apart from the aerodynamic, thermal and inertial loads a vibration is also a form of load that is acting on the structure of the aerospace vehicle and here the random vibration of the airframe is done and the results of the analysis are obtained and the reason for this is the design modification is required to reduce the vibration of the airframe and improve the safety and comfort in the aerospace vehicle. The present study is intended to carry-out the dynamic analysis along with the structural simulation of the automobile chassis made-up of aluminum composite material.

2. Computer-aided analysis

It is known that various analysis methods are available using the CAD and CAE here as our objective is to do the static analysis to find the stresses and displacement in the chassis frame and to find the natural frequency and mode shape is modal analysis is used [14,15]. For finding the resonant frequency due to road excitation, random vibration analysis is used and finally the optimization of the structure optimization is done. The software used here is the CATIA V5 in which the model is created and the model mentioned above and the analysis is done [16,17].

3. Static analysis and optimization

The chassis frame is modelled using the CATIA V5 using the various commands and the analysis properties of the aluminium material are assigned. The 3D model of the chassis frame is shown in below fig and the static analysis is performed to find the deformation, displacement and stresses using the static analysis and the frame are identified with the maximum stress and the maximum displacement [18,19]. After identifying it the optimization of the chassis frame taking the material displacement and the material weight is taken as the constraint. Fig. 1 and Fig. 2 elucidate the stress and displacement diagram.

4. Modal analysis

The chassis frame that connects the engine and the vehicle's body is modeled using the available dimensions in 3D using the software CATIA V5. As the excitation force acting by the road on the chassis are normally random, it is required to analyze the chassis frame for the modal analysis to find the natural frequency, resonant frequency and mode shapes. The random vibration shows the behaviour of the chassis mode shape shown in Fig. 3 for the applied frequency ranges and the resonant frequency value in the critical location [20,21]. Hence, the modal analysis is done in the CATIA V5 and the random vibration in the ABAQUS. The aluminum composite material values of the density, modulus of elasticity, and Poisson's ratio are applied. The boundary conditions and the frequency ranges are specified as 20 to 200 Hz. The analysis considers the low-frequency range and the damping properties based on the material properties as 10%. The results are shown in Table 1 and Table 2.

5. Random vibration

Randomness is a property of the excitation or input, not of the mode shapes or natural frequencies. It is a non-deterministic motion, which means that future behaviour cannot be accurately anticipated. A car driving on a bumpy road, wave height on the lake, or the strain imposed on an aviation wing during flight are all common examples. Statistical or probabilistic techniques are typically used to treat structural response to random vibration. The most common technique to define random vibration is to measure the spectral acceleration density (ASD). The square root of the area under the ASD curve in the frequency domain is the root means square acceleration (GRMS). The GRMS value is a statistical measure used in mechanical engineering for structural design and analysis [22,23]. It is often used to indicate the total energy of a certain random vibration event.

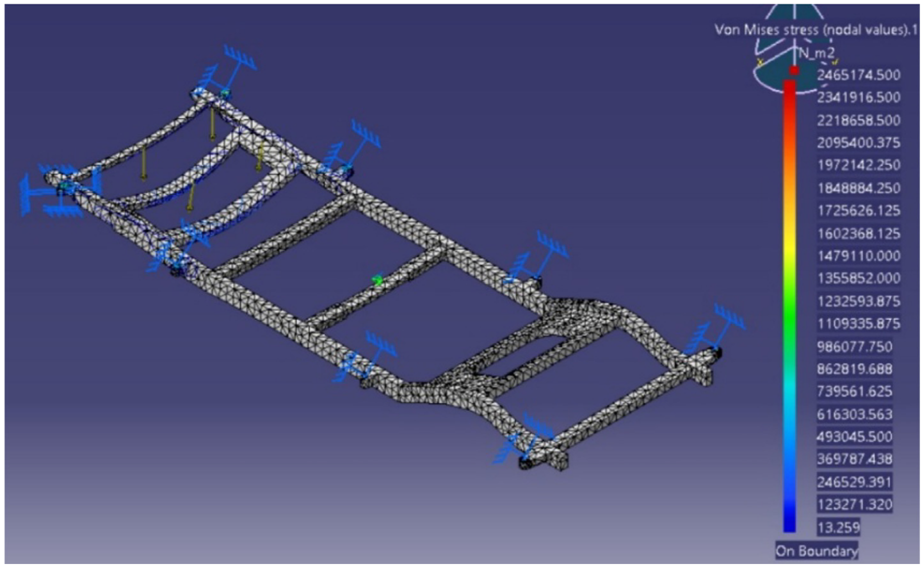

Fig. 1. Von-mises stress of the chassis frame.

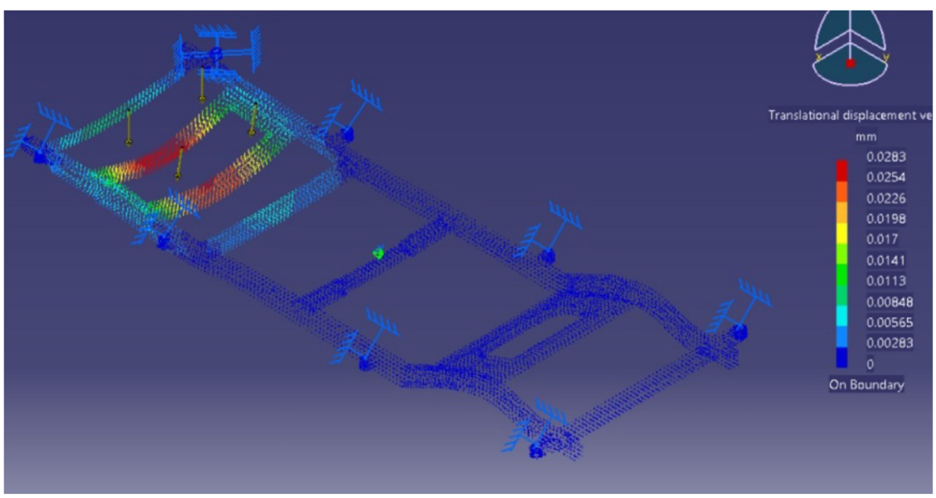

Fig. 2. Displacement of the chassis frame due to engine force.

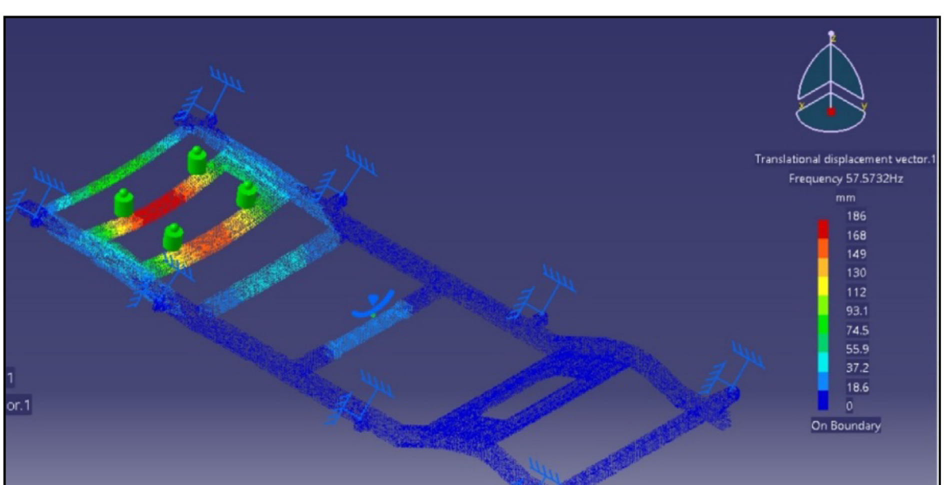

Fig. 3. Modal analysis showing translational displacement and frequency.

Table 1
Modal stability Vs frequency.

Modenumber	FrequencyHz	Stability
1	5.7573	3.5763×10^{-13}
2	7.7820	2.5351×10^{-9}
3	9.6993	9.6385×10^{-9}
4	10.387	1.0646×10^{-7}
5	10.716	1.0631×10^{-7}
6	12.540	1.2601×10^{-6}
7	12.617	7.7657×10^{-6}
8	13.221	5.7697×10^{-6}
9	14.109	3.1354×10^{-5}
10	14.603	1.7205×10^{-4}

6. Results and discussion

After doing the modeling of the Chassis using the CATIA, the mode is shifted to the generative simulation technique in CATIA, which is called the static analysis initially, the material is defined as the aluminum and the meshing of the structure is done using the meshing technique available in the octree in the CATIA and the boundary conditions are declared using the fixing of the frame condition available in which the chassis frames are fixed at the projected brackets where the fixing of the frame and Chassis after that the load is applied at the pressure of 1000 N on the front side of the location of the engine and the analysis is computed to get the output of the results. After the identification of the maximum displacement 0.028 mm, it is intended the displacement values shows the amplitude of the structure and as a method of the optimization in which the structure parameters like the thickness length and the weight and the vibration characteristic of the stiffness values the displacement may be reduced through optimization and the product optimization in the CATIA is chosen. As the modeling of the chassis frame and the subsequent procedure of the Modal Analysis and the random Analysis here in this project, the modal analysis is first done using the CATIA V5 to find the modal shape and natural frequency and the resonant frequency and the random frequency shows the resonant frequency values concerning the range of the frequency experience in the chassis frame and showing the power spectral density (PSD) and hence show how it can be reduced. The material properties of the model are assigned as the aluminum composites of density 2750 kg/m^3. The young's modulus as 69 GPa and the Poisson's ratio as 0.3. After assigning the values, the modal analysis with the frequency ranges as 20 to 200 Hz is given for the subsequent 10 mode shapes and random vibration response shown in Fig. 4 is given the values 1,1.5,2,2.5,3,3.5 concerning the frequency ranges as 20,50,75,100,150,200 in the PSD for the calculation purpose. Also, the mesh values are given as the size of 200 and the element types as the tetrahedral shapes. The graph showing the comparison of the mode and frequency in Fig. 5 and the displacement due to the vibration structure and the stress are compared in Fig. 6

Table 2
Modal participation.

Mode	FrequencyHz	Tx(%)	Ty(%)	Tz(%)	Rx(%)	Ry(%)	Rz(%)
1	5.7573	0.00	0.15	34.60	20.77	0.00	0.00
2	7.7820	0.00	0.32	29.24	27.54	0.00	0.00
3	9.6993	0.00	0.39	0.78	0.15	0.00	0.00
4	10.387	0.00	0.14	2.39	1.36	0.00	0.00
5	10.716	0.83	0.00	0.00	0.00	0.09	1.47
6	12.540	7.86	0.00	0.00	0.00	7.85	1.39
7	12.617	24.13	0.00	0.00	0.00	2.25	15.50
8	13.221	0.00	0.11	0.40	0.70	0.00	0.00
9	14.109	8.35	0.00	0.00	0.00	0.26	1.71
10	14.603	0.00	0.18	2.94	6.73	0.00	0.00
	Total	41.18	1.28	70.37	57.25	10.45	20.07

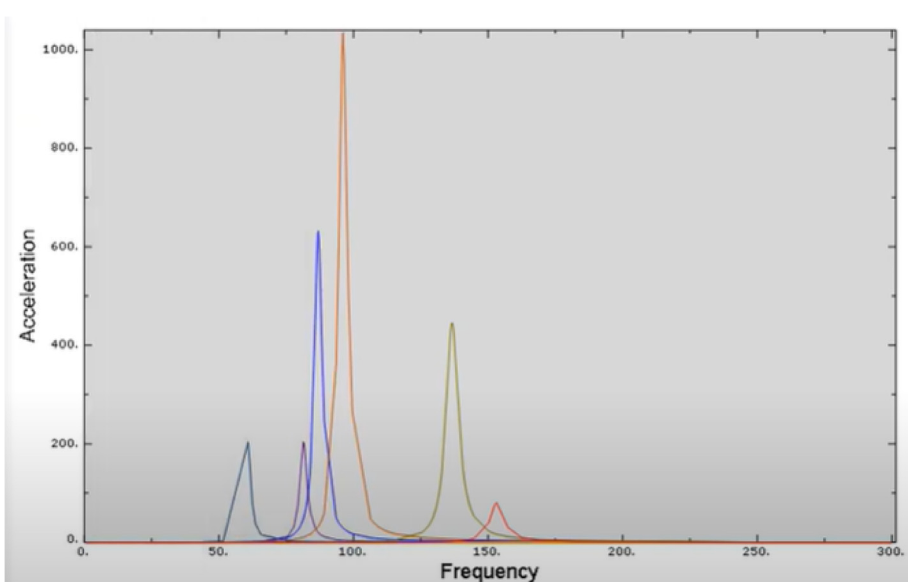

Fig. 4. The maximum, minimum and resonant frequency (53 Hz).

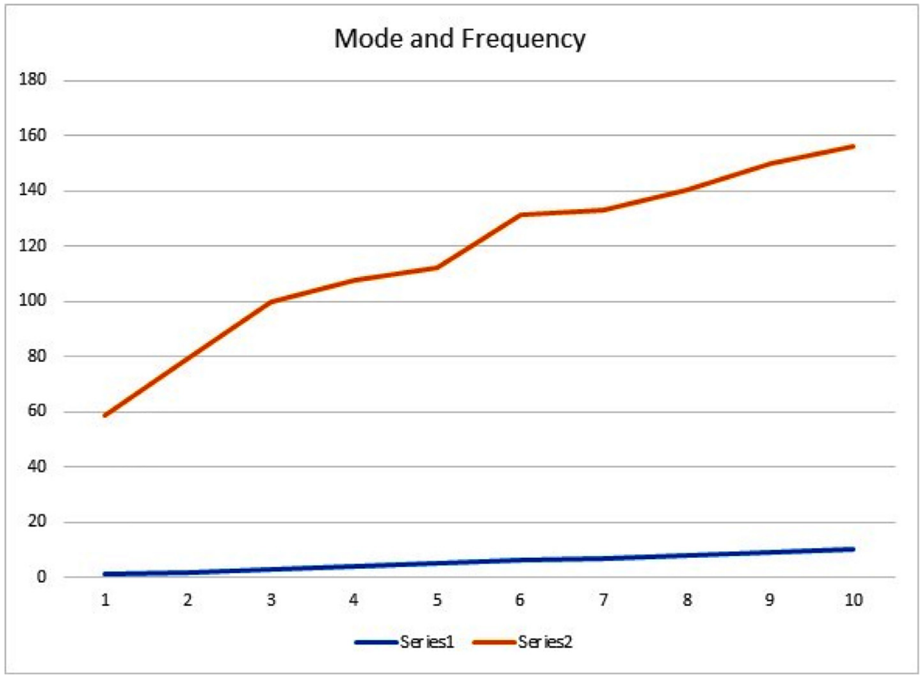

Fig. 5. Frequency and the Mode values.

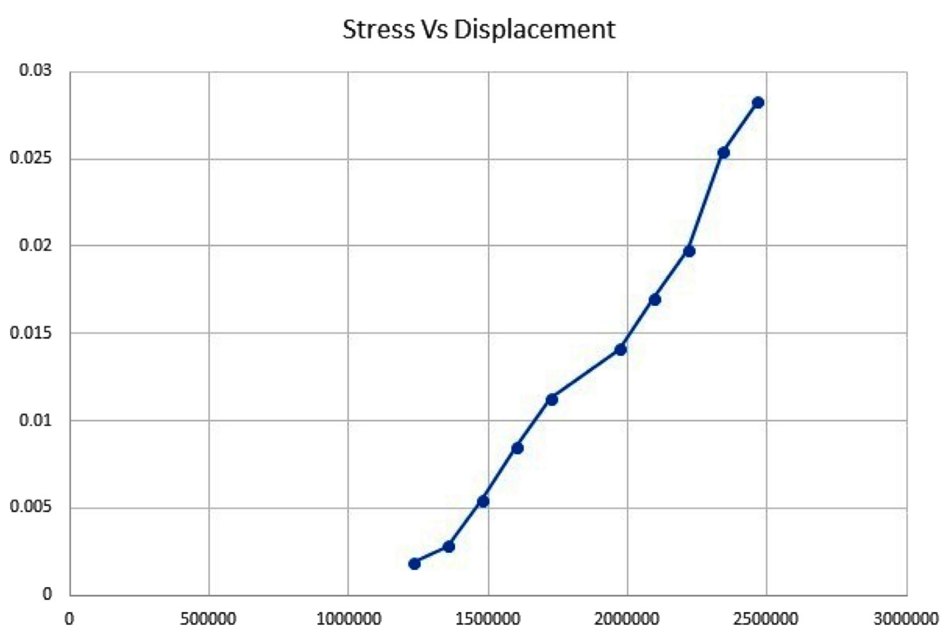

Fig. 6. The stress and displacement.

7. Conclusion

The vibration analysis due to the engine excitation is done with the modal analysis. It identifies the maximum and the resonant frequency during the chassis frame analysis. The road excitation is done with the random analysis in which the modal analysis shows the various mode shapes of the frame in which the natural frequency for each mode is tabulated along with the stress values, and from this the resonant frequency is identified as the 57 Hz. Hence, all other frequency varying from the 20 to 200 Hz values as the range and in the random vibration analysis the power spectral density (PSD) shows the g^2/Hz in which the values have been taken from the engine PSD.

CRediT authorship contribution statement

M. Muzakkir Ahamed: Conceptualization, Methodology, Supervision, Writing – review & editing. **L. Natrayan:** Investigation, Data curation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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