

## ANALYSING VIBRATION CHARACTERISTICS OF CAR CHASSIS UNDER CENTRAL GOVERNMENT LAW RESOURCE ACT IS 14884 (2000) FOR SAFE AND COMFORTABLE DRIVING USING 3D MODELLING TECHNIQUES AND FEA WITH FATIGUE LOAD, FREQUENCY AND SHAPE MODEL

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**Abstract.** *Comprehensively explores chassis design in the automotive industry, focusing on mitigating vibrations and enhancing vehicle safety. The study delves into the intricate dynamics of chassis construction by utilizing Noise, Vibration, and Harshness (NVH) characteristics. The paper uses advanced 3D modelling techniques with CATIA V5 and Hyper mesh software to determine the natural frequency and analyze the mode shape of vehicle chassis structures. These analysis serve as a foundation for improving assembly methods and understanding the dynamic behaviour of chassis under various loads and real-world road conditions. The proposed idea identifies dynamic properties such as mode shape, frequency response, and stress distribution as critical factors influencing chassis performance. Factors contributing to dynamic vibrations, including power train unit forces, tyre responses, and structural deficiencies, are analyzed to introduce design alterations and safety enhancements. The primary objective is to reduce vibrations, extend chassis lifespan, and enhance vehicle safety during operation. Modal analysis and Finite Element Analysis (FEA) are employed to investigate dynamic behaviour and identify critical deflection regions, providing valuable insights for implementing practical solutions in automotive chassis design.*

**Keywords:** *Dynamic vibration, Modal analysis, Mode shape, Stress distribution, Modelling*

### 1. Introduction

The automotive industry faces mounting pressure to accelerate product development cycles, diversify vehicle offerings, and enhance development efficiency amidst increasing complexity in automotive systems. This complexity, driven by rising labour and material costs, necessitates numerical simulation in vehicle development. This multidisciplinary approach encompasses various disciplines, such as driving simulation, structural analysis, and crashworthiness, alongside specialized areas like acoustics and electromagnetic compatibility. Over the past two decades, Finite Element Methods (FEM) numerical simulations have become integral to the automotive sector's product development process. They play a crucial role in addressing Noise, Vibration, and Harshness (NVH) analysis challenges, which are paramount considerations in automotive design. NVH issues significantly impact customer satisfaction, including power train, road, wind, and component noise. Various NVH models are employed during vehicle development to mitigate these issues, focusing on resonance behaviour and structural faults. The chassis, the vehicle's backbone, bears the weight of components, payload, and reaction forces. Depending on the vehicle's application, different chassis types are utilized, such as the monocoque type for

passenger vehicles and the ladder frame type for heavy-duty trucks. The ladder frame chassis offers superior rigidity, modification flexibility, and ease of mounting cargo-carrying bodies.

Analyzing the vibration characteristics of the car chassis through finite element analysis (FEA) with fatigue load, frequency, and shape models is essential for ensuring structural integrity and driving comfort. This paper presents a comprehensive analysis, including CAD modelling, frequency response calculations, and stress distribution assessments. Experimental validation of FEA results further enhances the reliability of the analysis. The primary objective is to minimize vibrations, extend chassis life, and enhance safety during vehicle operation. The modal analysis serves as a vital tool for studying dynamic behaviour and identifying critical deflection regions that could lead to vibration issues and fatigue failure. Through FE vibration analysis, this paper aims to establish mode shapes and natural frequencies, facilitating informed design decisions for automotive chassis development.

## 2. Literature review

Numerous studies have concentrated on the causes of vehicle chassis breakdown and the solutions provided by dynamic vibration analysis. Zhang and Tang 1998, used FEA to explain and contrast the inherent frequencies of vehicle chassis with an experimental setup. Topa et al. 2009, addressed the dynamic analysis of a truck chassis and a simulated chassis to determine the dynamic forces. Ahirrao and Bhosle 2020; Zhang and Tang, 1998, discussed using different computational techniques, including FEA, to analyze the vibration characteristics of car chassis and optimize parameters for safe and comfortable driving. Ramachandran et al. 2018, focused on developing an alternative material for engine mounts that exhibits good damping and stiffness characteristics, using Al6061-SiC Metal Matrix Composites (MMC) integrated with rubber. Happian-Smith 2001, discussed the analysis of the vibration characteristics of a go-kart chassis using a FEM and FFT analyzer to ensure safety and comfort during driving.

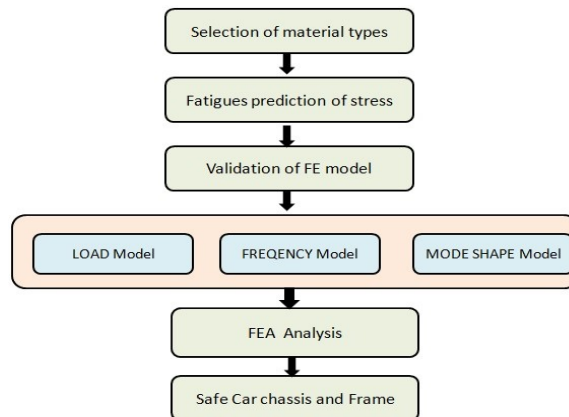
Marzuki et al. 2015, discussed the analysis of vibration characteristics of a car chassis using FEA with fatigue load, frequency, and shape model. The author discussed the vibration characteristics of an automobile suspension system using an adaptive control method but did not mention FEA, fatigue load, frequency, or shape model. A conveyor stand's linear static structural FEA is discussed to best understand the impacts of various stress distributions and shearing deformations. Analyzing the vibration characteristics of a car chassis for safe and comfortable driving using FEA with fatigue load, frequency, and shape models is an essential aspect of vehicle design.

Different materials and techniques are used to reduce vibrations and increase passenger safety and comfort (Ahirrao and Bhosle, 2020; Deulgaonkar, 2019; Ramachandran et al., 2018). The selection of overall dimensions, such as wheelbase, track width, and overall height, plays a crucial role in the vehicle's dynamic behaviour (Dhandapani et al., 2018). Composite materials, such as Al6061-SiC Metal Matrix Composites (MMC), are increasingly used for their good damping and stiffness characteristics. FEA is used to evaluate the dynamic behaviour and deflection of the vehicle structure. The natural frequency of the car structure should be reduced to improve human operational comfort. Vibration analysis is an effective technique for increasing the performance of the vehicle and optimizing the design for safety and ride comfort. Many researchers focused on designing space frame race car chassis structures, analyzed mode shape frequencies and characteristics using ANSYS, and investigated the vibrational characteristics of the car chassis through modal analysis to determine natural frequencies and mode shapes.

### 3. Proposed work framework and plan of car chassis

Analyzing the vibration characteristics of a car chassis is essential for ensuring safe and comfortable driving. Excessive vibrations can compromise vehicle stability, discomfort occupants, and accelerate structural fatigue. Engineers rely on advanced techniques like FEA to optimize chassis design for vibration performance.

FEA, widely used in the automotive industry, incorporates fatigue load modelling to assess chassis durability under dynamic conditions, identifying critical areas prone to fatigue failure. Frequency analysis, another crucial aspect, helps identify resonant frequencies that amplify vibrations, guiding design modifications to mitigate discomfort. Accurate shape modelling,



facilitated by finite element meshing, ensures precise representation of the chassis in simulations. By combining FEA with fatigue load modelling, frequency analysis, and shape modelling, engineers gain insights into vibration characteristics, enabling them to optimize chassis design for improved ride comfort and safety. Various types of fatigue loads, including road irregularities, acceleration, braking, cornering, and payload variations, are considered in FEA. By simulating these loads, engineers can assess chassis response and ensure durability over the vehicle's service life, ultimately enhancing the driving experience. while the Parliament of India has got down to provide a practical regime of proper to data for citizens to comfortable get right of entry to to records underneath the manipulate of public government, a good way to promote transparency and duty inside the working of each public authority, and whereas the attached e-book of the Bureau of Indian requirements is of particular interest to the general public, in particular disadvantaged groups and people engaged inside the pursuit of schooling and information, the attached public safety standard is made available to promote the well timed dissemination of this information in an correct manner to the general public.

**Figure 1. Proposed Framework**

#### 3.1. Load model

The chassis of a vehicle plays a crucial role in ensuring safety and preventing failure. Constructed with a high safety factor, it must withstand various loads to avoid permanent harm and costly recalls. Channels, whether C-type or box-type, form the chassis structure,

with dimensions determined by the load it must endure. By dimensioning the chassis according to locally necessary load-bearing capabilities, weight can be reduced without compromising strength. A car chassis experiences different vibrations during operation, affecting performance and passenger comfort. Engineers create mathematical models based on sensor vibration data and develop simulations to predict chassis behaviour under various conditions. This process enables engineers to identify design improvements for reduced vibrations and enhanced ride quality, ultimately leading to more comfortable and efficient cars.

### ***3.2. Frequency Model***

A frequency model is crucial for analyzing car chassis vibration. It describes the chassis' natural frequencies and vibration modes under different conditions. Engineers use FEA to develop this model, dividing the chassis into elements and analyzing their vibration behaviour. By combining these behaviours, engineers create a complete frequency model, typically represented as vibration modes with corresponding natural frequencies. This model helps predict the chassis' response to various inputs and optimize the structure and suspension system for improved ride quality and reduced vibrations.

### ***3.3. Mode shape model***

In car chassis vibration analysis, the mode shape model illustrates the deformation pattern of the chassis structure at specific natural frequencies. Developed using Finite Element Analysis (FEA), this model divides the chassis into elements and solves equations of motion to determine deformation patterns. Every mode shape represents a natural frequency that describes the vibration of the chassis. These models improve ride quality through design by pointing out places vulnerable to vibration-induced stress. The result is a set of mode shapes that describe how the car chassis vibrates at each natural frequency (Moaaz and Ghazaly, 2014; Patel et al., 2013).

## **4. Materials and methods**

A vehicle's performance is heavily influenced by its gross vehicle weight and engine power. As weight increases, chassis vibrations intensify, and acceleration improves. High-strength chassis cross-sections are necessary to reduce failures, enhance safety, and lower weight to meet the demand for exceptional riding comfort. Utilizing low-density materials with superior bending and compressive strengths helps reduce engine weight without compromising safety.

A precise understanding of dynamic qualities is essential in designing heavy-duty truck chassis frames for demanding environments like mining and construction sites. Lightweight frames aimed at improving fuel efficiency and reducing emissions have gained attention. FEA and experimental verification are commonly used to determine dynamic properties. Modal analysis methods, including reference-based stochastic subspace identification, are employed for online applications, facilitating the study of frame dynamics during road testing and predicting vehicle handling performances.

**Table 1. High strength steel types**

S.No	High strength steel types	
1	Young's Modulus	2.0 X 105Mpa
2	Density	7.85e-6kg/mm3
3	Thermal Expansion	1.2e-51/°C
4	Tensile Yield Strength	250Mpa

**Table 2. Car load distribution of System parts and weights**

S.No	Systems Weight (N)	
1	Engine CG	20356
2	Transmission CG	10399
3	Hydraulic Tank CG	5592
4	FuelTank CG	9320
5	BodyCG	554265
6	TractiveEffort	339436

#### 4.1. Modal Analysis

Modal analysis is a method for figuring out a machines or structure's natural frequencies and mode shapes. The most basic kind of dynamic analysis is this one. The output of a modal analysis can be used to carry out more specific dynamic analysis tasks like harmonic response analysis and transient analysis, among others. Based on the natural frequencies identified by modal analysis, harmonic analysis uses frequency response curves to identify which vibration modes contribute most significantly to the dynamic response of the structure.

#### 4.2. High strength structural steel

The specific material properties of high-strength structural steel may vary depending on the grade or specification used. The information related to the car manufacturers' steel grade selection can be found in Table 1. It selects steel grades that balance strength, stiffness, and other properties to meet the desired performance requirements while minimizing vibrations and ensuring safety and comfort. High-strength structural steel plays a significant role in mitigating car vibrations and enhancing overall vehicle performance. Here's how high-strength structural steel contributes to reducing vibrations in car chassis. High-strength structural steel in car chassis construction contributes to vibration reduction through its stiffness, damping properties, reduced weight, enhanced crashworthiness, and design flexibility. By effectively controlling vibrations, high-strength steel helps improve ride comfort, stability, and overall vehicle performance. The specification of the chassis includes Young's modulus, moment of inertia, bending, and torsional is shown in Table 2. According to the equilibrium condition of the equation, the bending and torsion left ramp and right ramp loads were calculated manually, and the fatigue life, section modulus, chassis thickness, and tire reaction forces were validated using FE analysis. (Kim, 2006) explained the Design improvement of a truck chassis based on thickness.

The reactions of  $R_A$  and  $R_B$  with the load acting on the beam have been shown in Figure 2 and Figure 3. A section has been considered in span BD at a distance  $x$  from A. As per the

Macaulay's Theorem, the maximum deflection has been found in the points A and B as follows:

$$M_{xx} = \frac{6.5x^2}{2} + R_c x - 0.724 + R_D x - 3.064$$

As per the Macaulay's Theorem

$$M_{xx} = EI \frac{d^2 y}{dx^2} = \frac{6.5x^2}{2} + 12.311x - 0.724 + 12.311x - 3.064$$

Integrating with respect to x

$$EI \frac{dy}{dx} = \frac{-6.5x^3}{3} + 12.311x - 0.724 + 12.311x - 3.064 + C_1$$

Again integrating with respect to x

$$EI * y = \frac{-6.5x^4}{4} + 12.311x - 0.724 + 12.311x - 3.064 + C_1 x + C_2 \quad \text{--- (1)}$$

Now, applying boundary conditions at C, x = 0.724 m and y = 0

$$0 = \frac{-6.5(0.724)^4}{4} + 0.724 C_1 + C_2 \quad \text{--- (2)}$$

Boundary conditions at D, x = 3.064 m and y = 0

$$0 = \frac{-6.5(3.064)^4}{4} + 12.311(3.064) - 0.724 + 3.064 C_1 + C_2 \quad \text{--- (3)}$$

Solving equations (2) and (3), we get the value of  $C_1$  and  $C_2$

$$0 = -0.0744 + 0.724 C_1 + C_2 \quad \text{--- (4)}$$

$$0 = -23.870 + 26.289 + 3.06 C_1 + C_2 \quad \text{--- (5)}$$

After simplification,  $C_1 = 5.7796$  and  $C_2 = 4.1096$

Substituting the values in equation (1)

$$EI * y = -0.27x^4 + 2.05x - 0.724 + 2.05x - 3.064 + 5.7796x + 4.1096 \quad \text{--- (6)}$$

Here the equation (6) is the general equation of deflection. The deflections at the supports C and D are found to be zero.

Deflection at A, i.e. at x = 0

$$y_A = \frac{1}{EI} * 4.1096$$

Therefore,

$$y_A = \frac{4.109610^0}{EI} \text{ kN- mm}^3$$

Deflection at B, ie., At  $x = 3.788 \text{ m}$

$$y_B = \frac{1}{EI} \times 4.1096$$

Therefore,

$$y_B = \frac{4.109610^6}{EI} \text{ kN} \cdot \text{mm}^3$$

So, the maximum deflection has been found the points A and B

Therefore,  $y_{max} = y_A = y_B = \frac{4.109610^6}{EI}$

According to IS 800: 2007 (15)

Maximum allowable deflection in beam =

$$\frac{\text{OVERALL LENGTH}}{\text{GROUNDCLERANCE}} = \frac{3788}{300} = 12.6 \text{ mm}$$

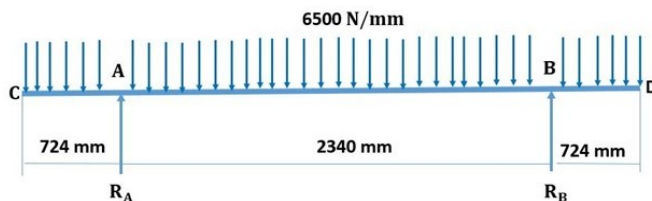


Figure 2. Reaction forces and load acting on the beam



Figure 3. Calculations for bending moments

#### 4.3 Calculate frequency model of a car chassis for safe frame

Calculating the frequency model of a car chassis involves determining its natural frequencies, which is crucial for designing a safe and robust chassis frame. This is achieved

through experimental testing and FEA simulations. Experimental testing measures chassis vibrations under various conditions, while FEA creates a digital model to predict vibrational behaviour. Engineers aim to design the chassis with natural frequencies well-separated from expected loads and vibrations to avoid resonance, which can lead to excessive stress. For example, if a car's expected road bump frequency is 5 Hz, engineers ensure the chassis natural frequencies are higher to prevent resonance. This ensures safe operation, especially on bumpy roads. The formula in Equation 7 can be used to determine the beam's natural frequencies:

$$F = m/(2 * L^2)) *(E * I) \text{ ----- (7)}$$

In this case, F is the beam's natural frequency, then m is the mass of the beam per unit length, L is the beam's length, E is the material's modulus of elasticity, and I is the beam's second moment of area.

**Table 3. High strength steel types**

Mod e	Frequenc y	Total Deformati on (mm)	Mod e	Frequen cy	Total Deformati on (mm)
1	0	2.9	13	52.2	9.28
2	0	2.2	14	41.678	7.04
3	1.5422	3.5	15	8.4821	11.2
4	2.9645	2.7	16	16.30475	8.64
5	4.1762	4.6	17	22.9691	14.72
6	5.2762	4.2	18	29.0191	13.44
7	23.52	5.7	19	129.36	18.24
8	26.384	7.6	20	145.112	24.32
9	41.376	7.7	21	54.567	24.64
10	53.773	6.2	22	68.456	19.84
11	62.533	9.5	23	78.9	30.4
12	64.069	7.8	24	102.345	24.96

#### 4.4 Calculate mode shape for natural frequency

Mode shapes describe a structure's vibration pattern at a particular natural frequency. Engineers use FEA simulations for car chassis to calculate mode shapes, aiding in understanding deformation and stress distribution. By analyzing mode shapes, engineers can identify areas of potential failure and make design changes for a robust chassis. For example, mode shape might show areas of maximum displacement in red and minimum displacement in blue, illustrating how the chassis deforms during vibration. Similarly, for a chassis with a mass of 1200 kg and a wheelbase of 2.5 meters, FEA can determine mode shapes for specific natural frequencies, aiding in design optimization for safety and durability. Mode shapes can aid in identifying areas of high stress and potential failure in the chassis structure and can help engineers make design changes to ensure a safe and robust chassis frame. Table 3 provides the deformation values at different vibration frequencies.

### 5. Result Analysis

### 5.1 Experiment setup

The strain gauges installed in the main frame's crucial locations are shown in Figure 4 and Figure 5. The bending test is the purpose of this experimental apparatus. For the test, four actuators were employed. Each actuator with a capacity of 10 tons was acting on the front suspension mounting point, and each actuator with a capacity of 27 tons was acting on the rear suspension mounting point; these are the vertical components of the front and rear suspension mounting points. Table 4 lists the experimental strain gauges locations from 1 to 66, experimental stress value and analytical stress values, respectively. Table 5 lists the experimental strain gauges locations from 67 to 132, experimental stress value and analytical stress values, respectively.

**Table 4. Strain gauge locations**

<b>L o c a t i o n s</b>	<b>Experim ental stress values (Mpa)</b>	<b>Analyt ical stress values (Mpa)</b>	<b>Diffe rence</b>
1	-7.16	-10.33	3.17
2	4.21	-8.22	4.21
3	11.47	17.47	-6
4	-16.15	-11.09	-5.06
5	9.63	12.18	-2.55
6	11.99	9.55	2.44
7	-52.64	-55.14	2.5
8	-37.61	-48.44	10.83
9	30.61	32.83	-2.22
10	44.99	43.52	1.47
11	-64.91	-60.09	-4.82
12	-54.12	-59.03	4.91
13	-35.58	-41.07	5.49
14	54.57	53.43	1.14
15	-74.48	-76.66	2.18
16	-26.63	-26.8	0.17
17	48.13	-50.08	-1.95
18	66.01	68.08	-2.07
19	-81.33	-85.84	4.51
20	-51.38	-53.49	2.11
21	31.24	-38.22	-6.98
22	57.08	52.12	4.96
23	49.19	51.34	-2.15
24	-29.37	-27.83	-1.54
25	-82.47	-73.26	-9.21
26	6.11	9.04	-2.93
27	19.81	21.24	-1.43
28	-5.95	3.41	-9.36
29	-9.21	-10.78	1.57

<b>L o c a t i o n s</b>	<b>Experim ental stress values (Mpa)</b>	<b>Analyt ical stress values (Mpa)</b>	<b>Diffe rence</b>
30	-2.06	-3.74	1.68
31	12.07	9.63	2.44
32	2.5	-1.48	3.98
33	3.85	4.06	-0.21

<b>Lo ca t i o n s</b>	<b>Experim ental stress values (Mpa)</b>	<b>Analyt ical stress values (Mpa)</b>	<b>Diffe rence</b>
34	-15.62	11.03	- 26.65
35	-7.74	8.43	- 16.17
36	8.62	9.7	-1.08
37	-177.4	-172.3	-2.7
38	52.38	-44.69	7.69
39	10.42	23.37	- 12.95
40	110.3	97.83	12.47
41	-66.15	71.98	5.83
42	-16.88	15.38	- 32.26
43	62.83	-64.71	-1.88
44	3.63	-2.17	5.8
45	-2.23	-2.41	0.18
46	-2.41	2.53	-4.94
47	-115.7	-117.6	1.9
48	-52.66	-42.51	- 10.15
49	28.86	29.64	-0.78

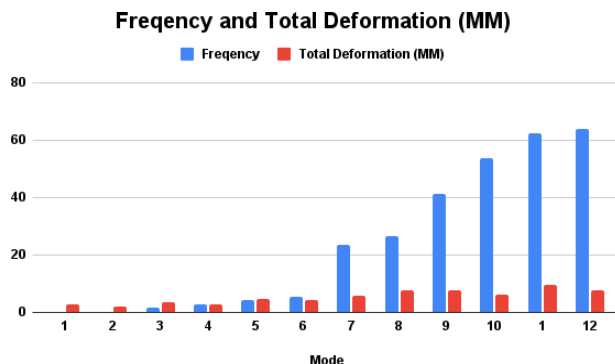
Lo ca tii on s	Experim ental stress values (Mpa)	Analyt ical stress values (Mpa)	Diffe rence
50	137.2	130.08	18.12
51	-130.2	- 142.49	12.29
52	34.7	30.26	4.44
53	134.8	129.81	4.99
54	-138	- 139.72	1.72
55	-29.1	-35.31	6.21
56	66.24	57.81	8.43
57	117.9	101.18	16.72
58	121.9	- 126.89	-4.99

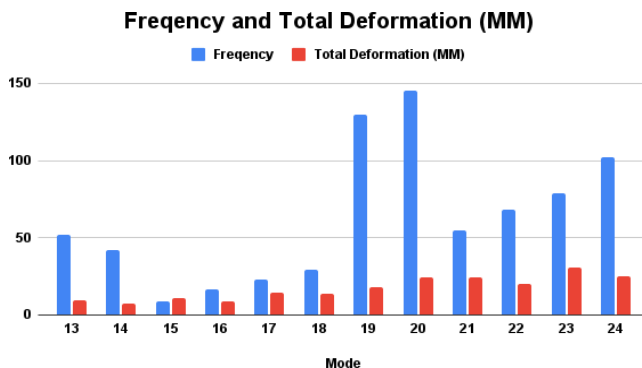
Lo ca tii on s	Experim ental stress values (Mpa)	Analyt ical stress values (Mpa)	Diffe rence
59	21.5	37.75	- 16.25
60	127.4	155.11	- 27.71
61	19.42	-18.46	0.96
62	-9.02	-10.53	1.51
63	-14.95	-15.36	0.41
64	20.57	-19.18	1.39
65	-17.93	-10.24	-7.69
66	18.59	15.56	3.03

**5.2 Measurement of Experimental and Validation method**

Incorporate the design improvement research and record the effects on the strength of the chassis to calculate its bending and torsion strength. Then, assess the chassis fatigue strength using the method of a modified frame’s fatigue test. Stress values were derived from analytical and experimental solutions in this investigation. The values are incredibly close and nearly identical when comparing the two solutions. The calculated safety factor is 2.9, within the advised standard deviation.

**Figure 4.Frequency and Total Deformation (MM) with Mode(1-12)**





**Figure 5. Frequency and Total Deformation (MM) with Mode(13-24)**

The safety factor is 4. As a result, the design of the frame support structure is secure. The original component's stress study was conducted using computer simulation utilizing finite element modelling. By using the materials' monotonic stress-strain curves, the stresses were determined to be elastic. The stress distribution was brought on by a 54500 kg load imposed at the chassis's center of gravity. 224.2 MPa was the highest possible Von-misses stress value. This amount is higher than the material's yield stress. Since the stress-strain relationship is no longer linear once the stress reaches the steel's stress yield value, this stress value is not the natural stress acting on the component. Only in the linear stress-strain domain, the finite element model calculations are valid.

**Table 5. Strain gauge locations**

Location	Experimental stress values (Mpa)	Analytical stress values (Mpa)	Difference
77	-259.64	-	-49.325
67	-28.64	36.155	7.515
68	16.84	-28.77	45.61
69	45.88	61.145	-15.265
70	-64.6	38.815	-25.785
71	38.52	42.63	-4.11
72	47.96	33.425	14.535
73	-210.56	192.99	-17.57
74	-150.44	169.54	19.1
75	122.44	114.90	7.535
76	179.96	152.32	27.64
77	-259.64	210.315	-49.325
78	-216.48	206.605	-9.875
79	-142.32	143.745	1.425
80	130.968	187.005	-56.037
81	-178.752	268.31	89.558
82	-63.912	-93.8	29.888
83	115.512	175.28	290.792
84	158.424	238.28	-79.856

<b>L o c a t i o n s</b>	<b>Experim ental stress values (Mpa)</b>	<b>Analyt ical stress values (Mpa)</b>	<b>Differ ence</b>
85	-195.192	- 188.84 8	-6.344
86	-123.312	- 117.67 8	-5.634
87	74.976	- 84.084	159.06
88	136.992	114.66 4	22.328
89	118.056	112.94 8	5.108
90	-70.488	- 61.226	-9.262
91	-197.928	- 161.17 2	-36.756
92	14.664	19.888	-5.224
93	47.544	46.728	0.816
94	-14.28	7.502	-21.782
95	-22.104	- 23.716	1.612
96	-4.944	-8.228	3.284
97	28.968	21.186	7.782
98	6	-3.256	9.256
99	9.24	8.932	0.308

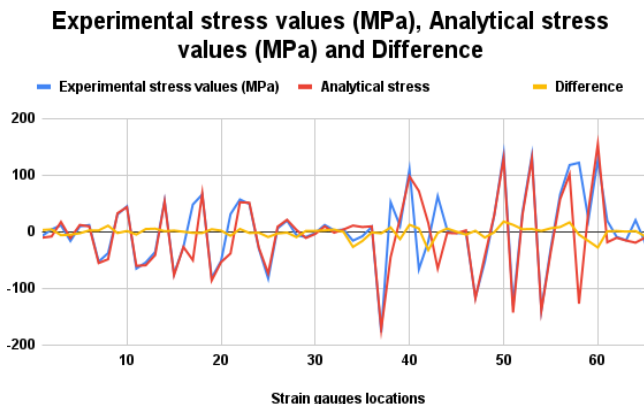
<b>Lo ca tii on s</b>	<b>Experim ental stress values (Mpa)</b>	<b>Analyt ical stress values (Mpa)</b>	<b>Differ ence</b>
100	-37.488	24.266	-61.754
101	-18.576	18.546	-37.122
102	20.688	21.34	-0.652
103	-425.76	- 379.06	-46.7

<b>Lo ca tii on s</b>	<b>Experim ental stress values (Mpa)</b>	<b>Analyt ical stress values (Mpa)</b>	<b>Differ ence</b>
104	125.712	- 98.318	224.03
105	25.008	51.414	-26.406
106	264.72	215.22 6	49.494
107	-158.76	158.35 6	-317.116
108	-40.512	33.836	-74.348
109	150.792	- 142.36 2	293.154
110	8.712	-4.774	13.486
111	-5.352	-5.302	-0.05
112	-5.784	5.566	-11.35
113	-277.68	- 258.72	-18.96
114	-126.384	- 93.522	-32.862
115	69.264	65.208	4.056
116	384.16	286.17 6	97.984
117	-364.56	- 313.47 8	-51.082
118	97.16	57.494	39.666
119	377.44	246.63 9	130.801
120	-386.4	- 265.46 8	-120.932
121	-81.48	- 67.089	-14.391
122	185.472	109.83 9	75.633

Lo ca tii on s	Experim ental stress values (Mpa)	Analyt ical stress values (Mpa)	Differen ce
12 3	330.12	192.24 2	137.878
12 4	341.32	- 241.09 1	582.411
12 5	60.2	71.725	-11.525
12 6	356.72	294.70 9	62.011
12 7	54.376	- 35.074	89.45

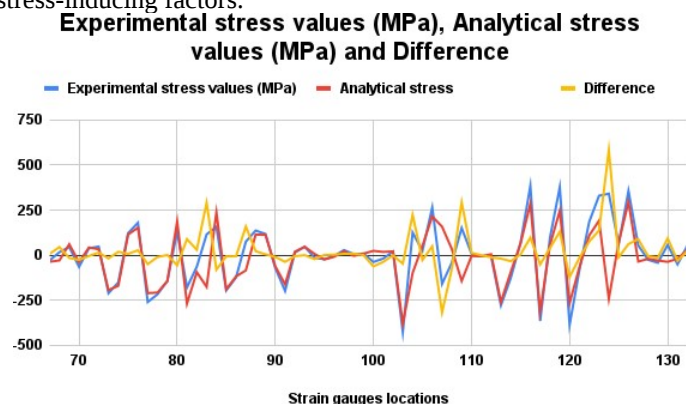
Lo ca tii on s	Experim ental stress values (Mpa)	Analyt ical stress values (Mpa)	Differen ce
12 8	-25.256	- 20.007	-5.249
12 9	-41.86	- 29.184	-12.676
13 0	57.596	- 36.442	94.038
13 1	-50.204	- 19.456	-30.748
13 2	52.052	29.564	22.488

However, this rough computation suggests that the local stress exceeds the steel's yield strength. The most effective method for reducing the active stresses on the longitudinal stringer was external support and parameters. The dimensions of the external sheet and the locations of their weld spots varied amongst the suggested variants. Since introducing the chassis' greater thickness enhanced the component's strength, the maximum stresses acting on the model's entire rear rail structure are less than on the original model. Despite higher stress, the model was chosen for cost and speed of manufacturing considerations. The original components and reinforced stringers of a chassis were put through a quasi-static compression test. The design improvements are incorporated and the effects on the strength of the chassis is calculated. The chassis' fatigue strength using the method of a modified frame's fatigue test is analysed. Figure 4 and Figure 5 show the stress and deformation results. In comparison, both results were almost close to the accurate results. The factor of safety is within the standard and recommended value. Therefore, the vehicle chassis frame is in a safe condition; further, we can upgrade the vehicle chassis. Stress analysis of the chassis was performed through FE simulation. The stresses and total deformation were determined by stress and a number of cycles; the load distribution is 9908.10 N (Refer Table 2 applied on the center of gravity of the chassis). The maximum von Misses stress on the chassis is 138 N/mm<sup>2</sup>. This is higher than the yield strength of the material. The FEA calculations are valid only in the linear stress-strain relation. The basic calculations indicated that the local stress exceeds the material's yield strength.



**Figure 6. Comparison of Experimental and Analytical Values with Location(1-66)**

The car’s vibration chassis plays a pivotal role in ensuring the vehicle’s structural integrity, safety, and overall performance. The comparison of experimental stress values and analytical stress values, derived from complex mathematical models becomes a critical endeavour when considering their spatial distribution or location across the chassis. Experimental stress values involve the deployment of strain gauges and sensors strategically placed on the chassis components. These sensors capture the dynamic forces and vibrations experienced by the vehicle during various driving conditions and help understand how stress manifests across the chassis under actual operational scenarios by measuring strain at different locations. The analytical stress values stem from sophisticated FEA that simulate the intricate interactions between the chassis, road conditions, and forces applied. These models take into account material properties, geometries, and external loads. The output is a virtual representation of stress distribution, providing insights into how the chassis responds under different stress-inducing factors.



**Figure 7. Comparison of Experimental and Analytical Values with Location (67-132)**

When experimental stress values closely match the analytical predictions regarding spatial distribution, it validates the accuracy and reliability of the analytical model. This validation empowers engineers to trust the model's predictive capabilities for design, optimization, and safety evaluations. Any differences identified can lead to model refinements for enhanced accuracy. The comparison is integral to evaluating the vehicle's structural integrity, and identifying locations with high-stress concentrations through experimental data aids in pinpointing potential weak points or areas prone to fatigue. The analytical stress values provide insights into how these stress concentrations arise under simulated conditions, guiding necessary design adjustments. Addressing the stress concentrations revealed by the comparison enhances vehicle performance and safety. Eliminating or mitigating stress-induced vulnerabilities improves the car's handling, ride comfort, stability, and overall roadworthiness. Comparison of experimental and analytical stress values are shown in Figure 6 and Figure 7. This comparison is a cornerstone of automotive engineering. This process validates analytical models, guides design decisions, ensures structural robustness, and ultimately contributes to creating efficient, safe, and durable vehicles throughout their operational life.

## 6. Conclusions

Analyzing vibration characteristics in the car chassis plays a pivotal role in ensuring safety and comfort during driving experiences. By employing FEA techniques coupled with fatigue load modelling, frequency analysis, and shape modelling, engineers gain valuable insights into the structural behaviour of the chassis. This comprehensive approach identifies critical areas prone to fatigue failure, and design enhancements can be made to optimize the chassis for longevity and performance. Furthermore, understanding the chassis' natural frequencies and mode shapes allows for the identification and mitigation of resonant frequencies, thereby minimizing uncomfortable vibrations. Ultimately, integrating FEA with fatigue load, frequency, and shape modelling facilitates the development of safer, more durable, and more comfortable vehicles, ensuring an enhanced driving experience for occupants while maintaining structural integrity.

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