RASĀYAN *J. Chem.*
Vol. 10 | No. 2 |513 - 521 | April - June | 2017
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

FINITE ELEMENT MODAL ANALYSIS OF COMPOSITE HEAVY VEHICLE CHASSIS USING ANSYS

A. Vinod[1*], P. Senthil Kumar[2] B. Rajadurai[1], V. Arun Kumar[1], S. Leoni Ranjith Kumar[1], P. Jayavel[1] and G.R. Anandha Gomathy[3]

[1] Department of Mechanical Engineering, Sri Lakshmi Ammal Engineering College, Chennai, Tamil Nadu, India

[2] Department of Mechanical Engineering, AMET University, Chennai, Tamil Nadu, India

[3] Department of civil Engineering, Sri Lakshmi Ammal Engineering College, Chennai, Tamil Nadu, India

*E-mail : vinodmech90@gmail.com

ABSTRACT

Structural modal analysis is the determination of the natural frequency of vibration of physical structures and their components of mode shape, which is used in this study. This work involves static characteristics to identify the location of the high stress area and natural frequency of the chassis using modal analysis in ANSYS Workbench 15.0 and first eight modes of vibrations are extracted. Analytical modal analysis was carried out to validate the finite element models. Expected natural frequency and mode shape were validated against analytical results. Finally, the modifications of the updated Finite Element truck chassis model were proposed to reduce vibration, improve the weight, and optimize the strength of the truck chassis using American Iron and Steel Institute standards 4140/4130/4340 and AMS 6373C materials.

Keywords: Structural modal analysis, ANSYS Workbench, Chassis, AISI, AMS

INTRODUCTION

Automotive chassis is a skeletal structure on which various other mechanical parts are assembled, in late 1900s the chassis existed in wooden frame with the metal panel arrangement, then wooden frame reinforced with steel was introduced to give the chassis a greater rigidity.[1] Finally, steel ladder frames became common in 1930 with composite material structures. The chassis is the most crucial element and significant component which are basically from steel.[2] The chassis is subjected to stress, bending moment and vibrations. The stress acting on chassis varies with displacement and vibrations.[3] To overcome this failure, chassis requires appropriate strength, stiffness and fatigue properties to withstand these loads on stresses.[4] Modal updating is an important technique in order to create a good model for analysis. Mode shaping is determined by using finite element method were the element is taken as a triangular element for the purpose of fine meshing.[5] The objective of this study is to determine the natural frequencies of a chassis and to study the mode shapes and subject the chassis to modal frequency analysis varying in frequency from 0 – 5000 Hz and study its response in terms of displacement and stress. Many researchers in the automotive industry have taken this opportunity to be involved in the chassis manufacturing technology and the development.[6] The chassis structure was developed using Creo and further analysis i.e., modal frequency has been carried out in Finite Element package ANSYS Workbench 15.0. Modal analysis proved to be very helpful in geometry optimization of the chassis which was one of the aims of the complete study.[7] The benefits of using ANSYS were that mode shapes could be accurately visualized and its accuracy increased for curves to maximize the size to 0.03 m-0.04 m simulation.[8] A graphical variation of number of modes verses the frequency can also be obtained from ANSYS Workbench. Composite material is an emerging trend in engineering for doing research. In this work modal frequency of different material for chassis has been analyzed and studied.

http://dx.doi.org/10.7324/RJC.2017.1021739

EXPERIMENTAL

The existing basic materials for steel chassis were been Aluminum, Carbon Steels, HSLA Steels, Glass Fibers etc. In this study to improve high strength, stiffness, fatigue properties, heavy materials concentrated on strengthening agents were selected. They are the alloy steels designated by AISI & AMS (American Iron and Steel Institute & Aerospace Material Specification) four digit numbers which are more responsive to mechanical and heat treatments than carbon steels. They comprise different type of steels with compositions which exceeds the limitations of B, C, Mn, Mo, Ni, Si, Cr, and Va in carbon steels. Chromalloy is an abbreviation for "chromium, molybdenum steels" used to produce military trucks and aircraft materials. It is not lightweight as aluminum alloys, but has the advantage of high tensile strength and malleability. The material properties are programmed to ANSYS tool.[9]

AISI 4140 known as chromium molybdenum alloy steels provides good hardness penetration uniform hardness and high strength. It is a versatile alloy with good atmospheric corrosion resistant and good reasonable strength up to around 600°F (315°C). It shows good overall combinations of strength, toughness, wear resistance, and fatigue strength. Used in aerospace and oil and gas industries, along with automotive, agriculture, and defense industries.[10]

AISI 4130 known as low carbon, high strength metals contains chromium and molybdenum as strengthening agents. It can be welded easily due to low carbon content. Machinability is easy by conventional methods sometimes difficult due to hardness of the material. Heated at 817°C (1600°F) and quenched in oil. Used in aircraft engine mounts and welded tubes.[11]

AISI 4340 known as aircraft quality steel plates is a nickel-chromium-molybdenum alloy steel resistance and fatigue strength level, good atmospheric corrosion resistant strength up to around 653°F (380°C). Used in forged hydraulic and other machine tool applications.[12]

AMS 6373C is an advanced precision machining equipment which was very new to the steel history. It has good machining and heat treatment properties. Used in forging and tubing.[13]

Table-1: Chemical Composition of each material

	Fe	Cr	Mn	C	Si	Mo	S	P
AISI4130	97.03	0.08	0.40	0.28	0.15	0.15	0.04	0.035
AISI4140	96.78	0.80	0.75	0.38	0.15	0.15	0.04	0.035
AISI4340	95.19	1.65	0.70	0.60	0.37	0.20	0.04	0.035
AMS6373C	95.44	1.44	0.41	0.78	0.44	0.15	0.04	0.035

Modeling in 3D and Analytical Method

3D modeling is a tool and the process of developing a mathematical representation of any three-dimensional surface of an object through specialized software. Models can be created automatically or manually. In this study the model is created manually from the chassis model Indian terrain heavy vehicle dimensions.[5]

Table-2: Specification of heavy vehicle chassis Indian terrain chassis

S. No.	Parameters	Values
1	Density of the chassis	$7.86*10^{-6}$ N/mm^2
2	Chassis width	80 mm
3	Back body chassis load	196200 N
4	Length of chassis	8200 mm
5	Young's modulus	2.1e^5 N/mm^2
6	Thickness	6 mm
7	Front chassis load	19620 N

The objective of the present work is to design and analysis the steel chassis made of different composite materials viz., AISI 4140, AISI 4130, AISI 4340 and AMS 6373C composites. Composite heavy vehicle chassis was created in CREO in iges file format to import in ANSYS.[5]

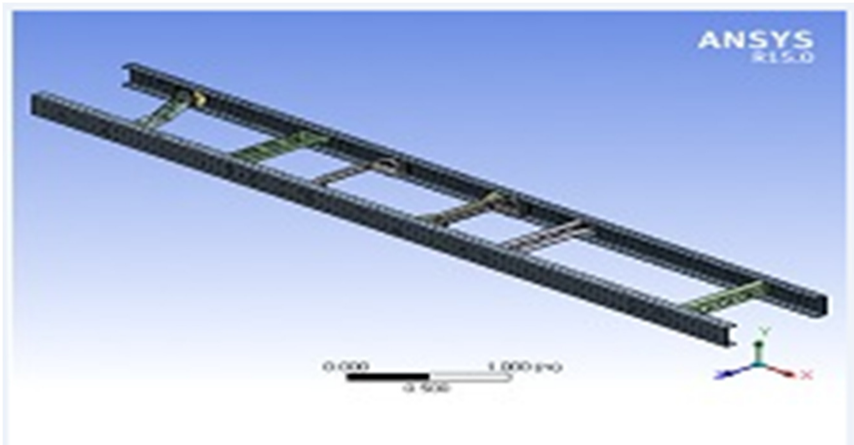

Fig.-1: 3D Model of Indian Terrain Chassis

Analytical Modeling

Analytical modeling is done using ANSYS Workbench R15.0. The engineering data for each composite is programmed in material library. The created 3D model of the Indian terrain truck chassis (Fig.-1) is imported to ANSYS Workbench 15.0. Table-3 shows the material properties of the selected composites. The analysis is carried out using the static model analysis in static loading condition. 8 mode shaped are analyzed.

Meshing

In this study, to get good results the geometry is finely meshed. Some of the settings in mesh under sizing were adjusted and a clear view of the geometry is obtained. Mesh connections exist in connection branch not the Mesh branch. Fig.-2a and 2b. Shows the clear picture of the Mesh due to fine tuning. Table-4a and 4b shows the mesh details. The element size is set to 3.e-002 m. Smoothening is set to medium and coarse mesh is set. The 3D model is discretized into 176552 elements.[11,12]

Load and Boundary Conditions

The conditions of the loads are static. As it is a static load condition the one end of the chassis is fully fixed such that all degrees of freedom are arrested at one end. Analysis type is set to modal analysis. Number of modes to be extracted is set to 8 and the solution is done.[13] The finite element analysis is carried out in this study on steel chassis as well as on four different types of chromyl composites to sixteen different combinations. There are many parameters that contribute to fatigue failures namely: number of load cycles experienced, range of stress experienced in each load cycle, mean stress experienced in each load cycle and presence of local stress concentrations. Together, this analysis shows the frequency distributions and displacements and the comparative analysis of steel chassis determined and heavy vehicle chassis of four different composite materials were simulated.

Table-3: Material Library

	Unit	AISI 4130	AISI 4140	AISI 4340	AMS 6373C
Elastic modulus	GPa	190-210	205	210	190
Poisson ratio	No Unit	0.28	0.29	0.25	0.29
Shear modulus	GPa	80	80	80	80

Vol. 10 | No. 2 |513 - 521 | April - June | 2017

Density	g/cm³	7.35	8.03	7.7	7.85
Tensile strength	MPa	560	655	650-880	724
Yield strength	MPa	460	415	350-590	275
Thermal expansion Coefficient	/ °C	$13.7*10^{-6}$	$12.3*10^{-6}$	$13.3*10^{-6}$	$12.25*10^{-6}$
Thermal conductivity	W/mK	42.7	42.7	25	46.6
Specific heat	J/kg-K	477	473	460	445
Hardness	HB	202	197	199	190
Impact strength	J	54.5	54.5	56	66.6
Melting point	°C	1500°C	1432°C	1445°C	1469

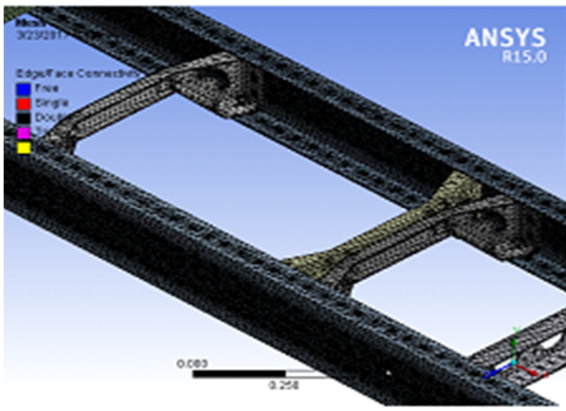

Fig.-2a: Mesh 1

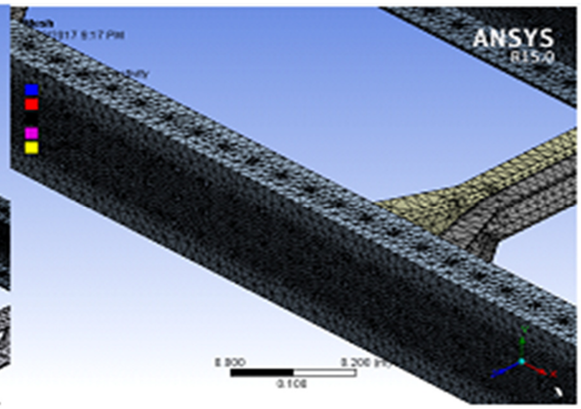

Fig.-2b: Mesh 2

Table-4a: Mesh Status

Statistics	
Nodes	375620
Elements	176552

Creating Composite Element Matrix Combination

Finite Element Analysis (FEA) was first developed in1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems [11]. With the FE analysis a possible sixteen combinations of the alloy are tuned separately and the best four combinations were selected. They were 11, 12, 13, 14, 21, 22, 23, 31, 41… and so on. Were 1 represents AISI 4140, 2 represents AISI 4340, 3 represents AISI 4130, 4 represents AMS 6373C respectively.

Assembly of Element Matrix Equation

The front of the chassis frame is fixed, so that all degrees of freedom are arrested and the Modal analysis is carried out in entire C-Channel chassis and the frequency distribution and displacement patterns are absorbed for every material as shown in figures- 3,4 and 5.

Table-4b: Obtained Mesh Values

Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	$3.e^{-002}$ m

Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	$1.3182e^{-003}$ m

Table-5: Total Deformation

Combination/ Deformations	TD1	TD2	TD3	TD4	TD5	TD6	TD7	TD8
11	0.0853	0.1006	0.1152	0.1121	0.1040	0.0889	0.1165	0.1557
12	0.0897	0.1023	0.1139	0.1172	0.1052	0.0900	0.1157	0.1547
21	0.0894	0.1014	0.1126	0.1161	0.1043	0.0891	0.1144	0.1544
34	0.0865	0.1021	0.1187	0.1132	0.1055	0.0901	0.1164	0.1579
14	0.0872	0.1026	0.1152	0.1165	0.1065	0.0901	0.1173	0.1571
24	0.0857	0.1011	0.1154	0.1126	0.1045	0.0889	0.1168	0.1562
44	0.0908	0.1033	0.115	0.1184	0.1063	0.0910	0.1168	0.1577
43	0.0869	0.1025	0.1176	0.1141	0.1060	0.0906	0.1189	0.1586
23	0.0855	0.1009	0.1153	0.1123	0.1043	0.0890	0.1168	0.1556
31	0.0862	0.1018	0.1165	0.1133	0.1052	0.0899	0.1179	0.1576
13	0.0862	0.1018	0.1165	0.1133	0.1052	0.0899	0.1179	0.1576
22	0.0853	0.1006	0.1152	0.1121	0.1040	0.0892	0.1165	0.1557
32	0.0860	0.1015	0.1189	0.1117	0.1052	0.0896	0.1167	0.1577
33	0.0862	0.1018	0.1165	0.1133	0.1052	0.0899	0.1179	0.1576
41	0.0869	0.1025	0.1176	0.1141	0.1060	0.0906	0.1189	0.1586
42	0.0866	0.1023	0.1200	0.1125	0.1060	0.0903	0.1177	0.1587

Table-6: Frequency

Combinations/ Frequency	TD1	TD2	TD3	TD4	TD5	Td6	TD7	TD8
11	6.37	6.55	16.89	19.57	37.51	40.46	46.85	76.71
12	6.10	6.29	11.05	19.02	37.08	39.88	44.99	75.57
21	6.20	6.32	11.05	19.24	37.24	40.20	45.18	76.88
34	6.38	6.55	16.89	19.58	37.57	40.56	47.21	76.74
14	6.25	6.42	14.22	19.26	37.38	40S.30	46.13	76.22
24	6.38	6.57	16.89	19.61	37.70	40.58	46.96	76.79
44	6.26	6.36	11.33	19.42	37.47	40.53	45.54	76.78
43	6.42	6.59	17.04	19.71	37.74	40.76	47.20	77.29
23	6.36	6.56	16.87	19.56	37.61	40.49	46.89	76.68
31	6.67	6.54	16.9	19.56	37.40	40.434	46.81	76.66
13	6.37	6.54	16.9	19.56	37.47	40.43	46.81	76.66
22	6.37	6.55	16.89	19.57	37.51	40.46	46.85	76.71
32	6.402	6.53	17.24	19.59	37.38	40.44	47.42	76.71
33	6.37	6.54	16.9	19.56	37.47	40.47	46.81	76.66
41	6.42	6.59	17.04	19.71	37.74	40.76	47.20	77.29
42	6.45	6.58	17.39	19.74	37.64	40.73	47.64	77.34

RESULTS AND DISSCUSSION

Analysis of all the sixteen combinations was simulated and the best three results of combinations 22, 23, 24 were derived and discussed. The frequency and deflection variation in each deformation shows the rigidity of the material. In this current work the mode shapes TD1, TD2, TD3 and TD5 are considerably taken into account because these mode shapes are the most common possible static mode shape for a chassis under static loading condition. TD1 denotes latitudinal displacement, TD2 denotes longitudinal displacement, and TD3 denotes twisting deformation while TD 5 denotes bending deformation.

Table-7: Deformation for Optimized combinations

S.No.	Optimized Combinations	TD1	TD2	TD3	TD5
1	AISI 4140 (22)	0.0853mm	0.1006mm	0.1152mm	0.1040mm
2	AISI 4340 AISI 4140 (23)	0.0850mm	0.1009mm	0.1153mm	0.1043mm
3	AMS 6373C AISI 4140 (24)	0.0857mm	0.1011mm	0.1154mm	0.1054mm

Table -8: Frequencies for Optimized combinations

S.No.	Optimized Combinations	F1	F2	F3	F5
1	AISI 4140 (22)	6.37Hz	6.55 Hz	16.89 Hz	37.47 Hz
2	AISI 4340 AISI 4140 (23)	6.36Hz	6.56 Hz	16.87 Hz	37.61 Hz
3	AMS 6373C AISI 4140 (24)	6.38 Hz	6.57 Hz	16.89 Hz	37.70 Hz

Figure-3 denotes the deformation of material AISI 4140 (22) for the deformation TD1 and TD2 as latitudinal and longitudinal deformations on the chassis which exhibits frequency of 6.3781Hz & 6.555Hz, which shows a good range of less deflection in total deformation compared to other combination of composites. It is due to the more amounts of carbon, silicon and molybdenum compared to other composites. It increases the stiffness of the material when subjected to the natural vibration. Due to this factor considering TD1, C22 is 1 time lesser than C23, 1.004 times lesser than 24 and 1.008 times lesser than C32. In this study C11 and C22 shows similar characteristic in deformation it is due to the composite structure and the material constituents within the composites. For the deformation TD3 and TD5as twisting and bending deformations exhibits frequency as 16.89Hz & 37.51Hz. Factors considering TD3, C22 is 1.002 times lesser than C23 and 1.004 times lesser than C24. The content in C22 that is Fe, Cr, Mn, C, Si and Mo is certainly more than C11. The property is stabilized due to the same content of "S" and "P" in AISI 4140 & AISI 4340 Due to some variation the TD6 alone for C11 is 1 time lesser than C22.

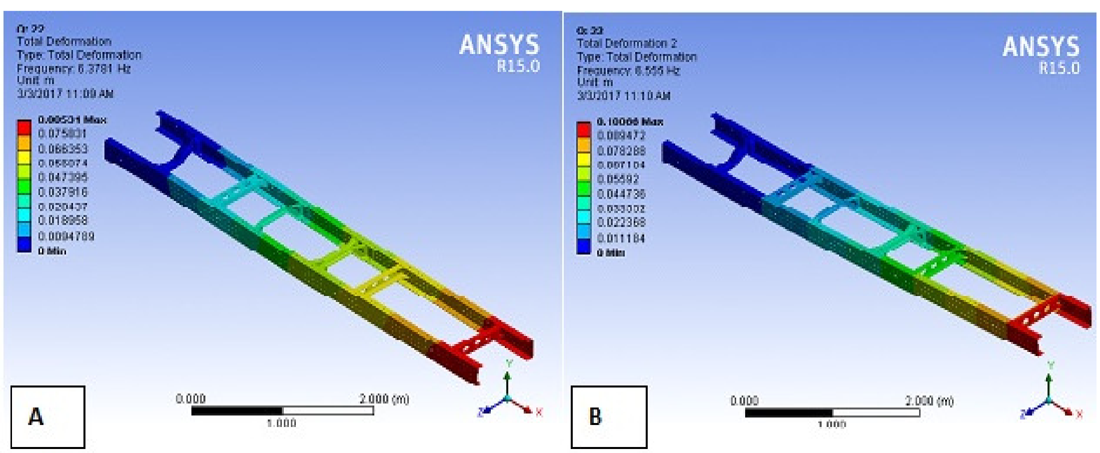

Fig.-3a: AISI 4140 (22) Latitudinal Deformation; Fig.- 3b: AISI 4140 (22) Longitudinal Deformation

Figure-4 denotes the deformation of material AISI 4340 AISI 4140 (23) for the deformation TD1 and TD2 as latitudinal, longitudinal, deformations on the chassis which exhibits frequency as 6.36Hz & 6.56Hz, which shows a good range of second less deflection in total deformation compared to other combination of composites. It is due to the presence of more amounts of chromium, carbon, silicon and molybdenum in AISI4340 compared to other composites. It provides good fatigue strength when subjected to the natural vibration. This factor improves the machining parameters. The elastic modulus and tensile strength plays a vital role. Considerably the density of AISI4140 is higher than the other three materials which give a good damping coefficient.

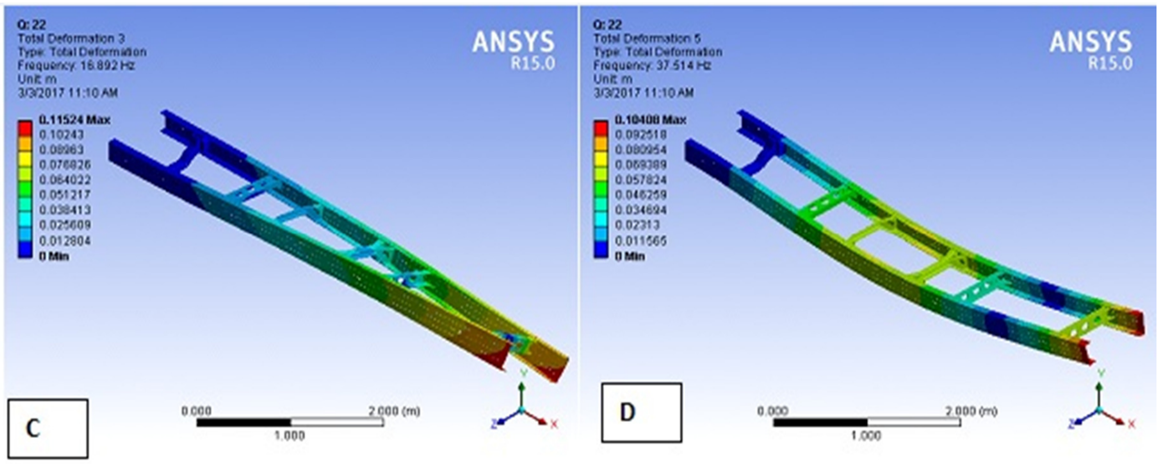

Fig.-3c: AISI 4140 (22) Twisting Deformation; Fig.-3d: AISI 4140 (22) Bending Deformation

For total deformation TD1, C23 is 1.002 times lesser than C24, 1.003 times lesser than 32 and 1.002 times lesser than C33. In this study C12 and C23 shows similar characteristic in deformation it is due to the composite structure and the material constituents within the composites. For the deformation TD3 and TD5 as twisting, bending deformations exhibits frequency as 16.87Hz & 37.61Hz. Factors considering TD3, C23 is 1 times lesser than C24 and 1.01 times lesser than C33. The content in C23 that is Fe, Cr, Mn, C, Si and Mo is certainly more than C21. The property is stabilized to 2 % due to the same content of "S" and "P" in AISI 4140 & AISI 4340 Due to some variation the TD6 alone for C11 is 1 time lesser than C22.

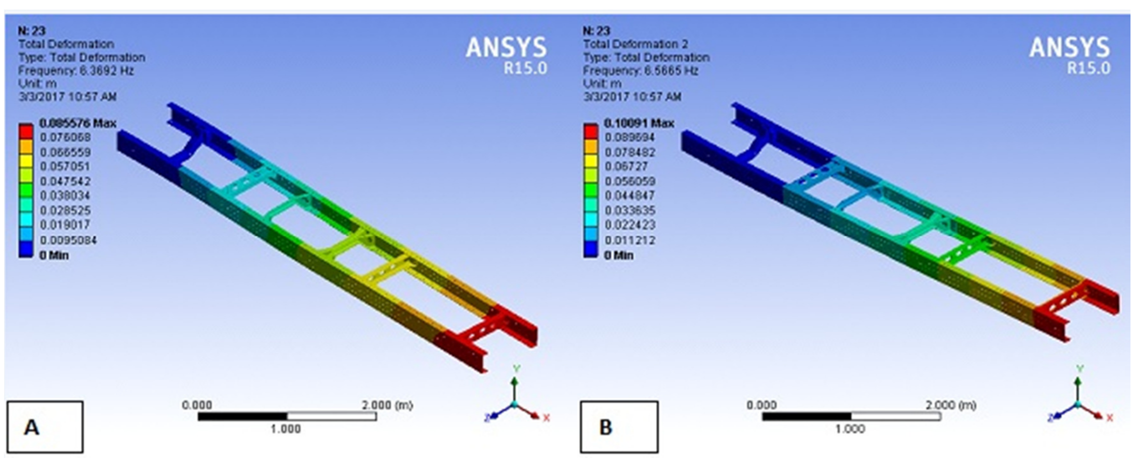

Fig.-4a: AISI 4140 AISI 4340 (23) Latitudinal Deformation; Fig.-4b: AISI 4140 AISI 4340 (23) Longitudinal Deformation

Figure-5 denotes the deformation of material AMS 6373C AISI 4140 (24) for the deformation TD1 and TD2 as latitudinal, longitudinal, deformations on the chassis which exhibits frequency as 6.38Hz & 6.57Hz, which shows a good range of third less deflection in total deformation compared to other combination of composites. It is due to the less amounts of magnesium and more amounts of carbon and silicon compared to other composites. This influences more tensile and ductile characteristic of the material. It emphasizes more vibrational frequency compared to C22 and C23. As the vibration values are comparatively less the other possible combination.

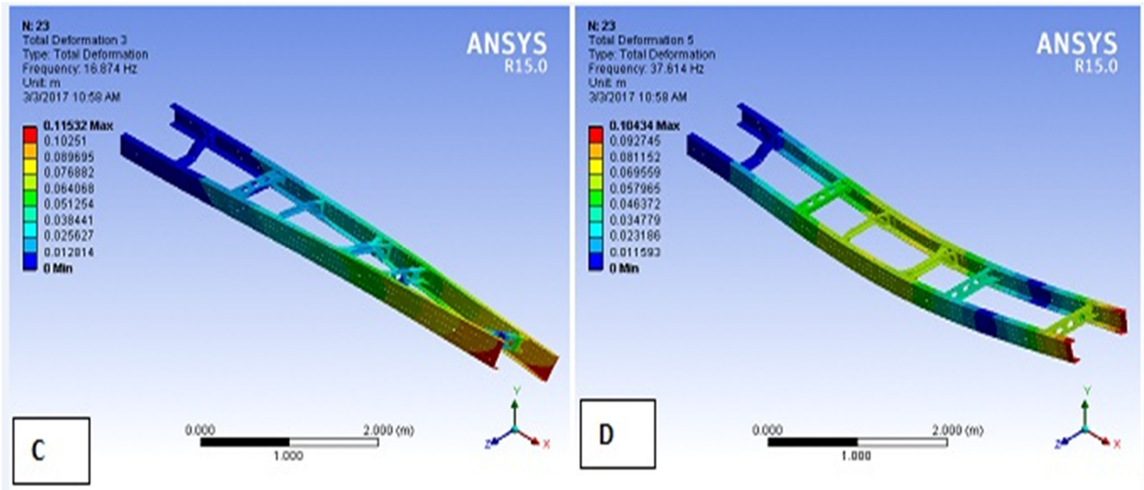

Fig.-4c: AISI 4140 AISI 4340 (23) Twisting Deformation; Fig.-4d: AISI 4140 AISI 4340 (23) Bending Deformation

It is studied as the third best combination. Due to increases in the toughness of the material when subjected to the natural vibration it exhibits a frequency of 76.79 Hz at mode 8. As a result of this factor considering TD1, C24 is 1.002 times lesser than C32, 1.003 times lesser than 33 and 1.002 times lesser than C34. In this study C24 and C21 shows similar characteristic in deformation it is due to the composite structure and the material constituents within the composites. For the deformation TD3 and TD5as twisting, bending deformations exhibits frequency as 16.89Hz & 37.74Hz. Factors considering TD3, C24 is 1 times lesser than C24 and 1.01 times lesser than C31. The content in C24 that is Fe, Cr, Mn, C, Si and Mo is certainly more than C21. The property is stabilized due to the same content of "S" and "P" in AMS 6373 & AISI 4140.The total deformation for the optimized composited is shown in Table-9.

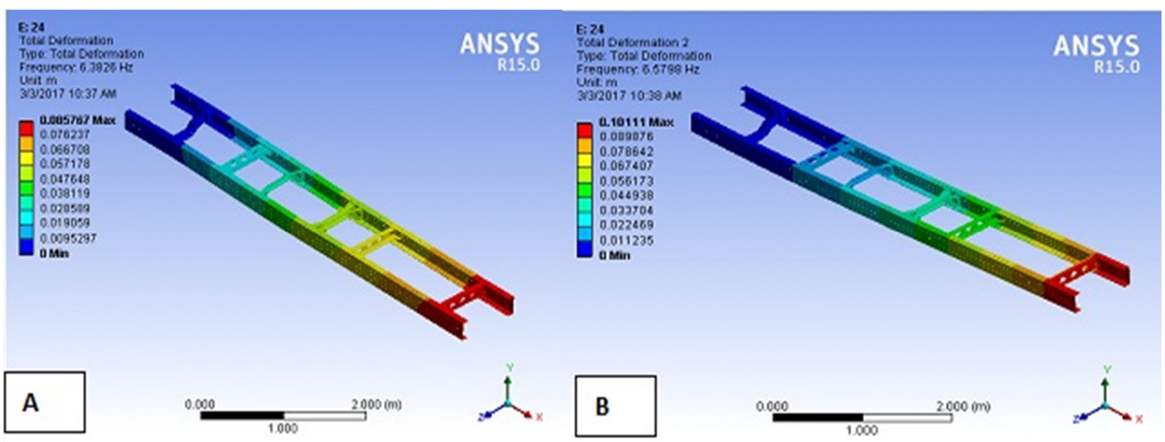

Fig.-5a: AISI 4140 AMS 6373 C (24) Latitudinal Deformation; Fig.-5b: AISI 4140 AMS 6373 C(24) Longitudinal Deformation

Table-9: Density, Frequency and Displacement of optimized combinations

S.No.	Material/Combinations	Density	Frequency	Displacement
1	AISI 4140 (22)	7775 kg/m^3	37.47Hz	0.1040mm
2	AISI 4340-AISI 4140 (23)	7940 kg/m^3	37.61Hz	0.1043mm
3	AMS 6373C-AISI 4140 (24)	7850 kg/m^3	37.70Hz	0.1054mm

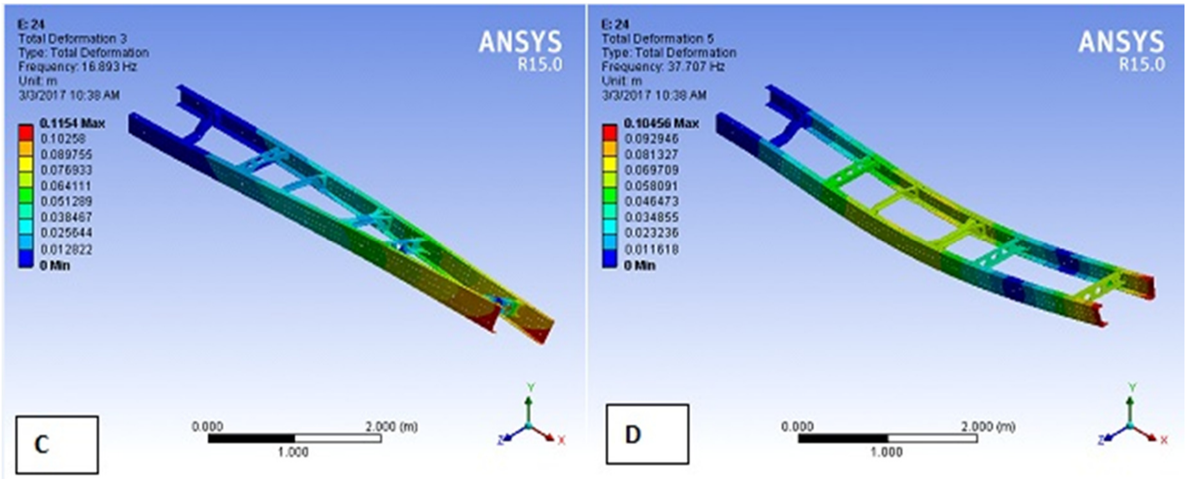

Fig.-5c: AISI 4140 AMS 6373 C (24) Twisting Deformation; Fig.-5d: AISI 4140 AMS 6373 C (24) Bending Deformation

CONCLUSION

On investigating AISI4130, AISI4340, AISI4140, AMS6373C and its 16 combination the corresponding results of displacements and frequencies are shown in table 4 and table 5. Best 3 results are optimized,

1. Combination C22 (AISI4140, AISI4140) is the best compared to other combination
2. Combination C23 (AISI4340, AISI4140) shows 1.01 time more frequency and deformation than C22
3. Combination C24 (AMS6373C, AISI4140) shows 1 time more frequency and deformation than C22

REFERENCES

1. A.N. Savkin, *CAD and Graphics Journal*, **8**, 93 (2012).
2. Abhishek Sharma, Pramod Kumar, Abdul Jabbar and Mohammad Mamoon Khan, *International Journal of Engineering Research & Technology*, **3(6)**, 1778 (2014).
3. Abhishek Singh, Vishal Soni and Aditya Singh, *International Journal of Emerging Technology and Advanced Engineering*, **4(2)**, (2014).
4. C. Karaoglu and N. S. Kuralay, *Finite Elements in Analysis and Design*, **38**, 1115 (2002).
5. D. Nayak, P. Kumar Sharma and Ashish parkhe, *International Journal of Advanced Technology in Engineering and Science,* **2(5)**, (2014).
6. R.Rajappan, and M.Vivekanandhan, *Proceedings of the "National Conference on Emerging Trends In Mechanical Engineering", India,* (2013).
7. J. S.Chetan, C.Panchal Khushbu, and Patel Fajalhusen , *International Journal of Advanced Computer Research*, **2(6)**, (2012).
8. Li Hui and Li Wanqiong, *Automotive Engineering*, **16**, 310 (1994).
9. M. Nouby Ghazaly , *Journal of Mechanical Design and Vibration*, **2(3)**, 69(2014).
10. OR.Kurdi, Abd-Rahman and M N Tamin, *Journal of Mechanical Engineering*, **26,** 76(2008).
11. Nitin S. Gokhale, *Practical Finite Element Analysis* (2009)
12. M.Ravi Chandra, S.Sreenivasulu and Syed Altaf Hussain, *International Journal of Modern Engineering Research*, **2(4)**, 2594 (2012).
13. S. Monika Agrawal and Md. Razik , *International Journal of Engineering Sciences & Research Technology*, **2 (12)**, 2013.

[RJC-1739/2017]