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Experimental and Finite Element Analysis of Seat Frame and Bonnet of a Tractor

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Abstract: Tractor is a tracked self-propelled vehicle which is designed to give a high torque at slow speeds. It is used for hauling a trailer or machinery in agriculture. This modern society demanding more food production, so former has to work twice as hard to keep up the agricultural land. Tractors are most important for agricultural field. It is very useful for farming operations. In tractors vibration is occurred in uneven roads. So due to vibration drivers are faced less comfort in riding and hand arm vibration also causes neurological effects and back bone problems. The main objective of the project work is to design and analyze to reduce the vibration of tractor seat frame and tractor bonnet. The vibration analysis has been done through the Experimental analysis of a tractor seat frame and tractor bonnet has been carried out by using FFT analyzer .In order to reduce the in the tractor seat frame, the design is modified by incorporating springs at the bottom of the tractor seat frame. From the random vibration analysis of modified seat frame, it is observed that the vibrations are have been reduced by 15 percent. To reduce the vibration in tractor bonnet, it is also modified by replace the material with existed material. From the random vibration analysis of different materials of the tractor bonnet, it is observed that the vibrations have been reduced by 29.8 percent. The results are validated by comparing results of random vibration analysis with experimental results obtained by using FFT analyzer. From the results it is observed that the vibration at driver seat frame are high which turn causes discomfort to driver. So by incorporating springs vibration has to be reduced 15% of tractor seat frame and 29.8 % by tractor bonnet.
In this project the design has been done by using Creo parametric 2.0 and analysis has been done by using ANSYS software.

I. INTRODUCTION

Tractor is a tracked self propelled vehicle which is designed to give a high torque at slow speeds. It is used for hauling a trailer or machinery in agriculture. Actually the name of that tractor came from the Latin word trahere that means pull and latter. Tractor also a combination of traction and motor. The tractor is developed gradually in the second half of the 19th century and first half of the 20^{th}century that is two wheel drives to four wheel drives. Mainly the tractors are available in India and abroad are divided into 3 types.

1) Wheel tractor
2) Crawler tractors
3) Walking tractors

These all tractors are come under farm tractors. Wheel tractors are again divided into 3 types. General purpose tractors are used for cultivation crops such as tillage, harvesting, sowing and harrowing. Universal row crop tractors are used for inter cultivation operations of crops sown in rows. This cultivation is used in any time from crop germination to harvest. Backhoe tractors are used for construction, light transportation, small demolitions and powering building equipment and digging holes. Road tractors are used for freight transfers. Locomotive tractors are used for railway vehicles and artillery tractors are used for the military purpose. Farm tractors are plays a crucial role for any former. This modern society demanding more food production, so former has to work twice as hard to keep up the agricultural land. Tractors are most important for agricultural field. It is very useful for farming operations. Generally framers are used to reduce the fine particles and grow crops through their bare hands. It is very difficult and harsh work and also very time consuming process. So, from the industrial revolution, the modern forming machines were developing to reduce the farmer work. And the industries also introduced tractors also.
The main focus of the development of tractors is that to modernize the farming process. So, with the help of tractors the farming process was sped up. Increase the amount of grown crops per unit of land through the tractors.

A. Components of sources of vibration in tractor

In a tractor the vibration mainly occurred in 3 parts of the tractor. Those are tractor seat, tractor steering and tractor bonnet. The vibration levels are very high in these 3 parts and causes health effects to the tractor driver and feeling discomfort ride to the tractor driver.

1) *Tractor seat:* The seating comfort of the seat depends upon the stationary and energetic features of seat system. These systems anthropometry information are taken into the comfort and shape design of seat. Seats are one of the most components of vehicles because the driver spent more time in seat component of vehicle. Seat is a design, which either institutive or not with the vehicles. The functioning of the seat is to support, protect and provide comfortness to the seat occupants. The whole body vibration is very important risk factor to the tractor driver. It caused low back pain to the tractor driver as shown in Fig.1. Seating comfort is plays very crucial affect for drivers.

Fig.1Driver position In Tractor Seat

2) *Steering wheel:* A steering wheel also known as driving wheel and hand wheel. These are used in land vehicles and all automobiles. Steering wheel is one of the most components of a vehicle. Without the steering wheel the human beings cannot reach their destination. This steering wheel can be used n buses, tractors and trucks, in all automobile systems. The steering wheel is one of the parts of the steering systems as shown in Fig.2.

Fig.2 Tractor Steering

3) *Tractor bonnet:* Bonnet is having more vibration in tractor then the steering and tractor seat. In tractor bonnet the vibration levels are same in all directions.

B. Mainly affected vibration in tractor parts

In a tractor the vibration mainly occurred in 3 parts of the tractor. Those are tractor seat, tractor steering and tractor bonnet. The vibration levels are very high in these 3 parts and causes health effects to the tractor driver and feeling discomfort ride to the tractor driver as shown in Fig.3.

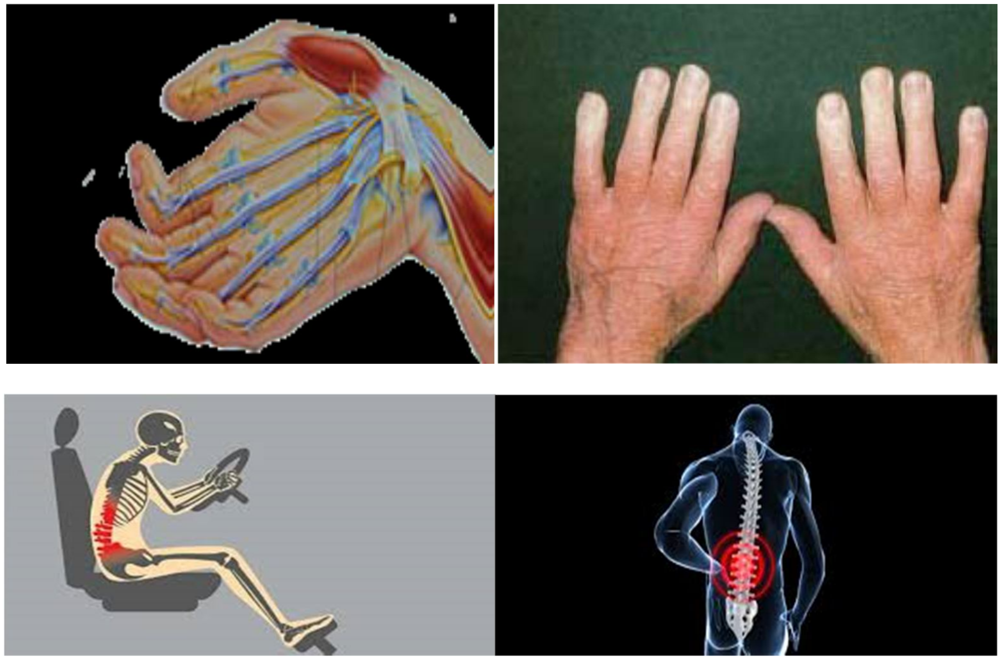

Fig.3 neurological and hand effects due to vibration

From literature review, various studies have been done about the comfort ride and various health effects of the tractor driver. [1]Various methods are proposed to reduce the seat vibration of a tractor. Vibration measured by using different methods of the tractor bonnet also. In this study steering vibration is a major concern due to the related motion of the tractor. By using experimental method vibration in measured with FFT analyzer. [4]& [5] In another study paper introduces about the compression helical spring to reduce the vibration in tractor seat and to reduce the fatigue stresses. New design proposed in this paper to reduce the fatigue stress. This paper determines the natural frequency of the helical spring of vibration analysis of tractor seat. By adding spring to the tractor seat which gives the durability, comfort of the seat of the tractor. [6]The paper deals with the back pain of the tractor driver. They analyzed about age and distribution of the tractor driver. Low back pain modified with oswestry pain questionnaire was used. This analysis shows that natural frequency at different ages. Between the age of 31 to 40 men have got more health diseases like back pain.

II. EXPERIMENTAL SETUP

In experimental analysis vibration response in tractor seat frame and tractor bonnet is determined by using FFT analyzer. Vibration response tested in two conditions:

1) When a tractor is moved on smooth road at 30 km/hr velocity
2) When a tractor is moved on smooth road at 40 km/hr velocity

FFT analyzer consists of accelerometer, data acquisition system which is connected to the laptop to measure the vibration as shown in Fig.4. For a tractor seat frame the accelerometer is mounted on the middle of the seat frame to measure the vibration response that vibration response showed in the laptop through the data acquisition system. For a tractor bonnet also the accelerometer is hold to the one side and that pace vibration response is measured that results showed in the laptop through the data acquisition system

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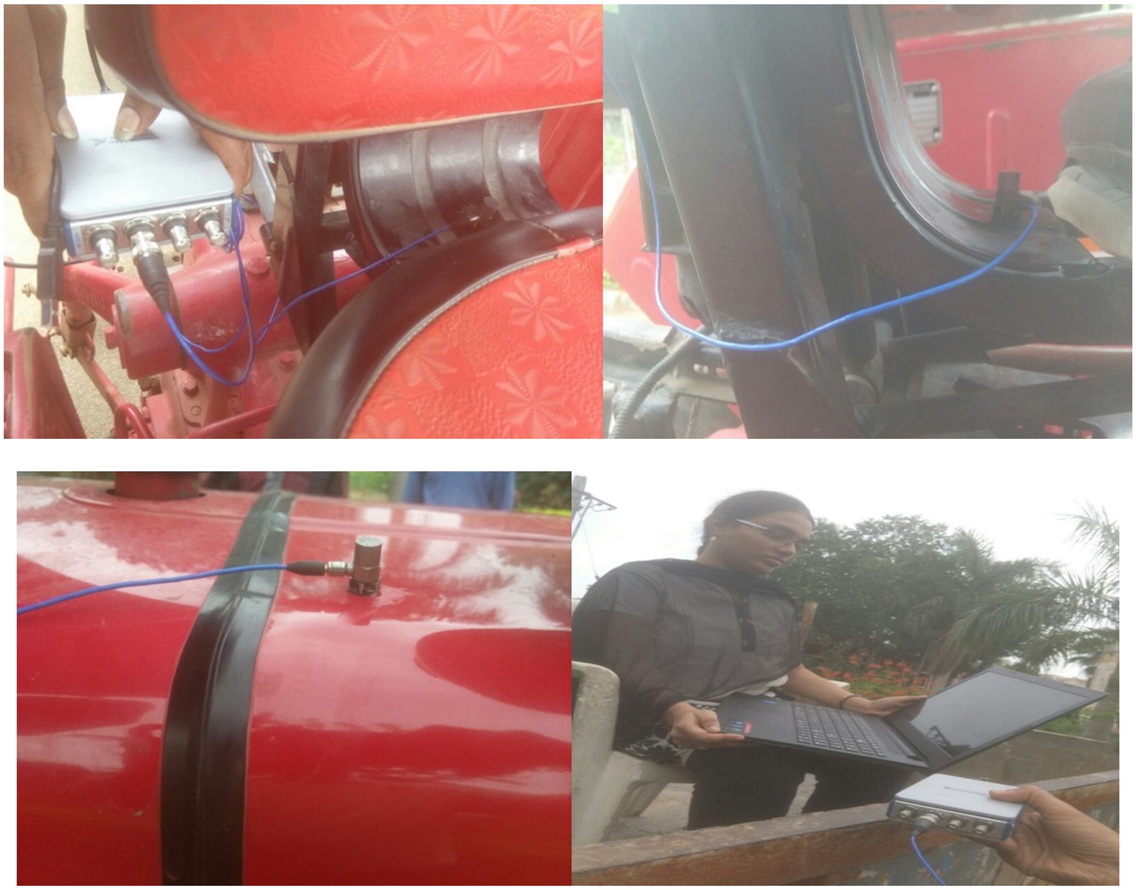

Fig.4 Experimental analysis of tractor seat frame and tractor bonnet by using FFT analyzer

A. Vibration response at tractor seat frame and tractor bonnet at 30 and 40 km/hr velocity

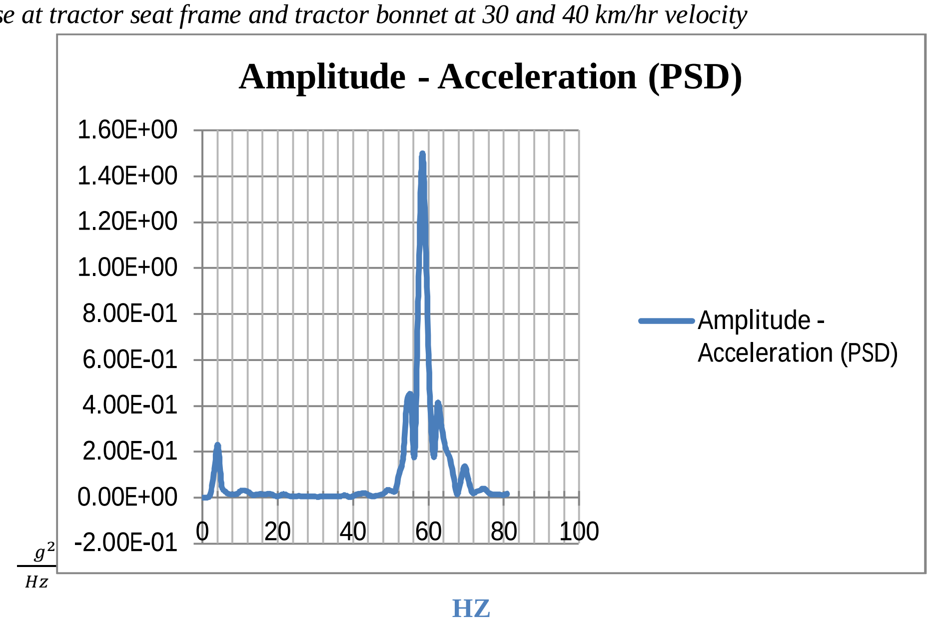

Fig .5Vibration response at 30 km/hr velocity of tractor seat frame

This graph between frequency (Hz) and acceleration (g^2/Hz) at 40 km/hr velocity at tractor seat frame. Here the highest frequency observed at 58 Hz and peak at 3 g^2/Hz.

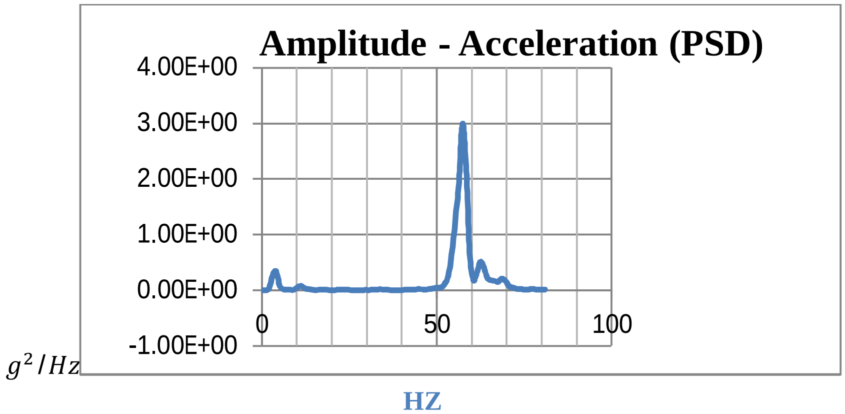

Fig.6 Vibration response at 40 km/hr of tractor seat frame

In tractor seat frame from Fig. 6 and 7 vibration levels are observed at different frequencies corresponding to different magnitudes

B. The results of tractor bonnet at 30 and 40 km/hr by using FFT analyze:

This graph between the frequency (Hz) and acceleration (m/s^2) at 30 km/hr velocity of tractor bonnet. Here highest frequency observed at 5 Hz,27 Hz,47 Hz at peaks 1.04,0.36,1.19 g^2/Hz.

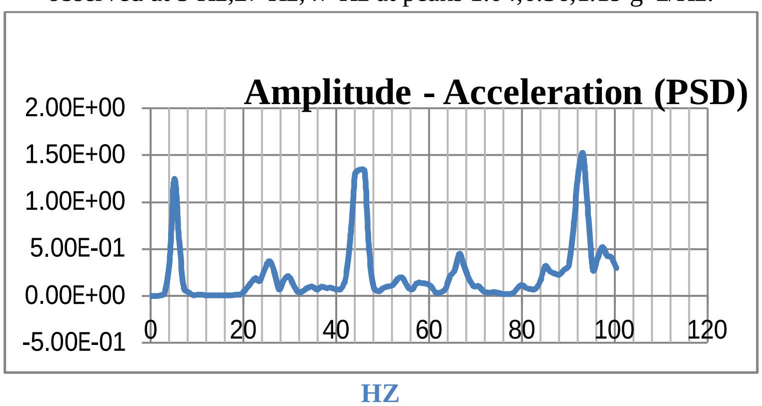

Fig 7. Vibration analysis at 30 km/hr of tractor bonnet

The graph between frequency (HZ) and acceleration (g^2/Hz) of the tractor bonnet at 40 km/hr velocity as shown in Fig.8 . The highest frequencies of tractor bonnet are 5,29and49 Hz observed at peaks of 1.17,1.01 and1.04g^2/Hz acceleration .

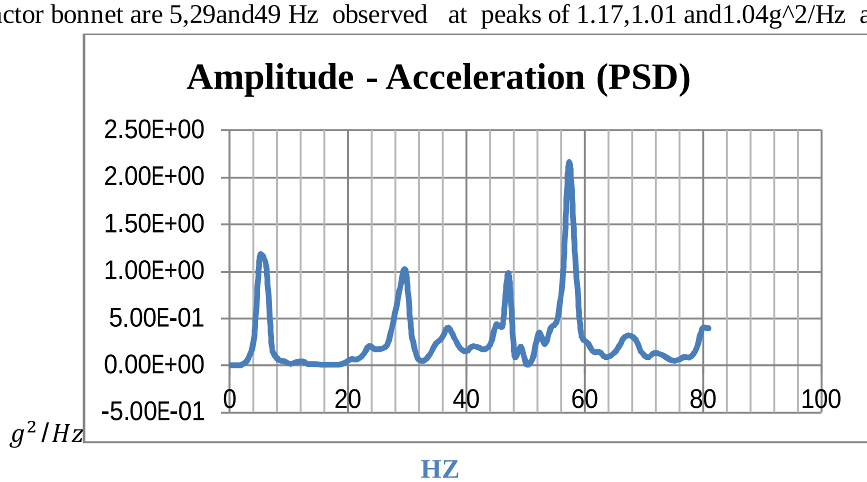

Fig.8 Vibration analysis at 40 km/hr of tractor bonnet

In tractor bonnet from Fig7 and 8 vibration levels are observed. In these figures tractor bonnet has high vibration from starting frequency .4 highest peaks are observed.

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III. MODELLING

In this paper consist of tractor seat frame and tractor bonnet is modelled. The model is created by using Creo parametric 2.0.the tractor seat frame designed based upon the tractor dimensions by adding the springs to the tractor seat frame to reduce the vibration. For the tractor bonnet by changing the material to reduce the vibrations of that part.

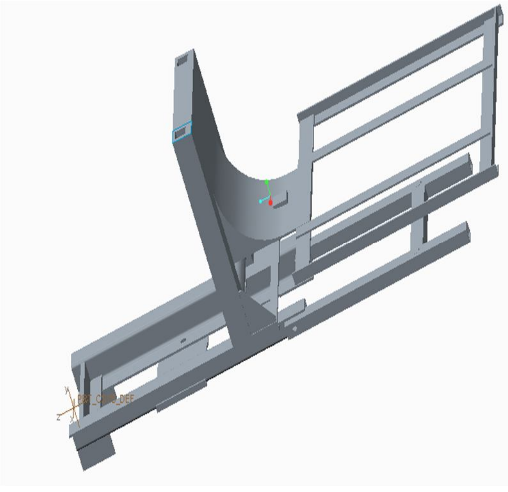

Fig. 9 Tractor seat frame design

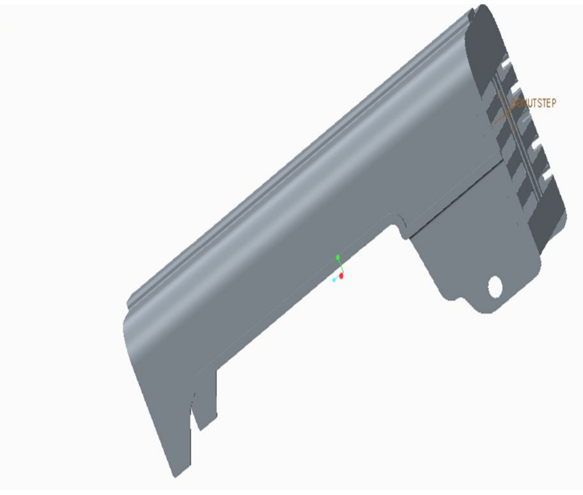

Fig.10 Tractor bonnet design

IV. SIMULATION

In this paper analysis is done by using ansys 15.0. Tractor seat frame is analyzed at 30 and 40 km/hr in random analysis. The natural frequencies are determined by using modal analysis and stresses and deformation is determined by using structural analysis. The same above analysis is done to the tractor seat frame with spring.

A. Static analysis

In this paper the analysis is done by using ansys software 15.0.the results are shown below fig.11.The fixed supports are applied to the bottom of the tractor seat frame and force is applied to the seat of the tractor driver at weight of 1000 kg.

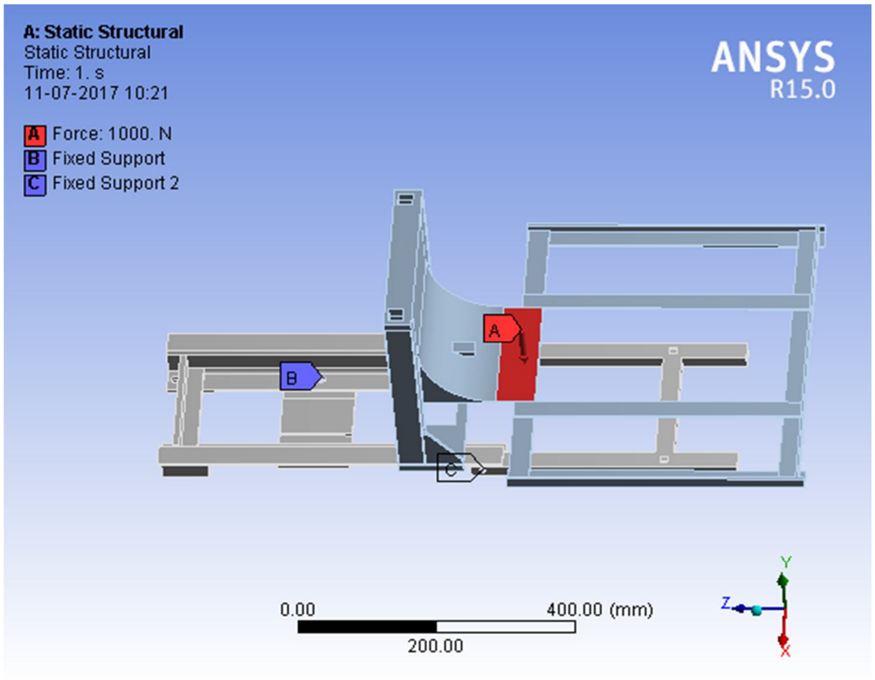

Fig .11 Boundary condition of the tractor seat frame

The maximum stress is observed at 107.94 at the seat frame and the deformation also shown in Fig.12

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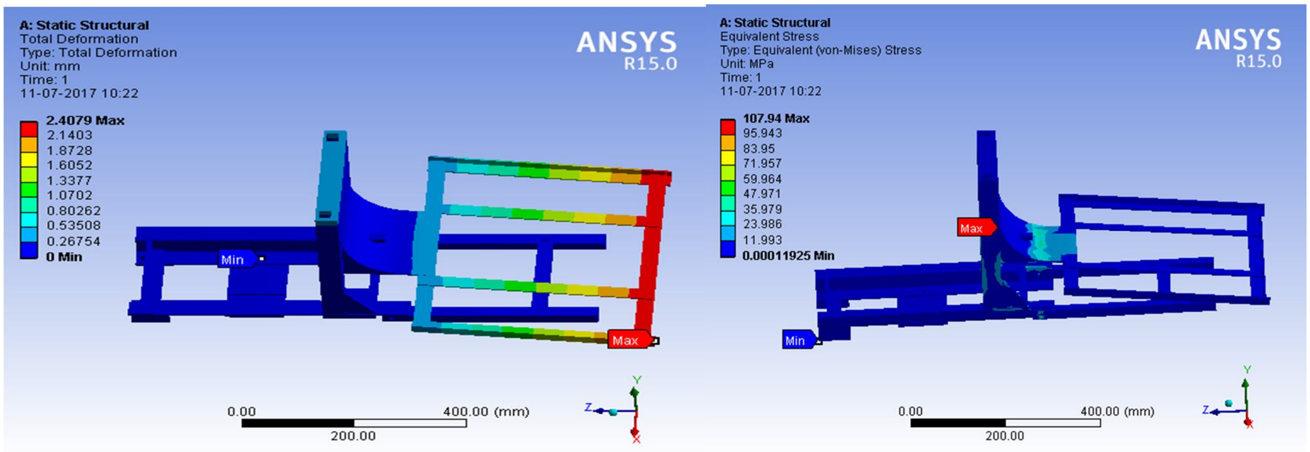


Fig .12 stresses and deformation of the tractor seat frame

B. *Modal analysis*

In modal analysis the tractor seat frame the boundary conditions are shown in Fig.13.The fixed support is bottom of the tractor seat frame and natural frequencies are observed as shown in Fig.14

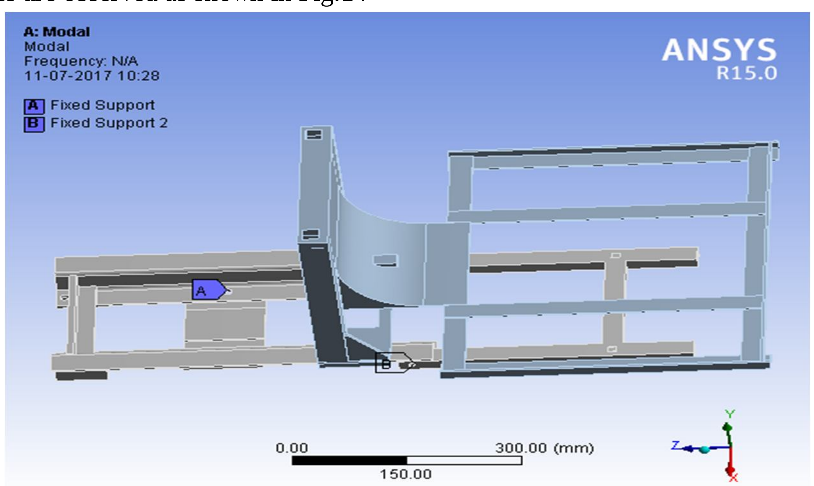
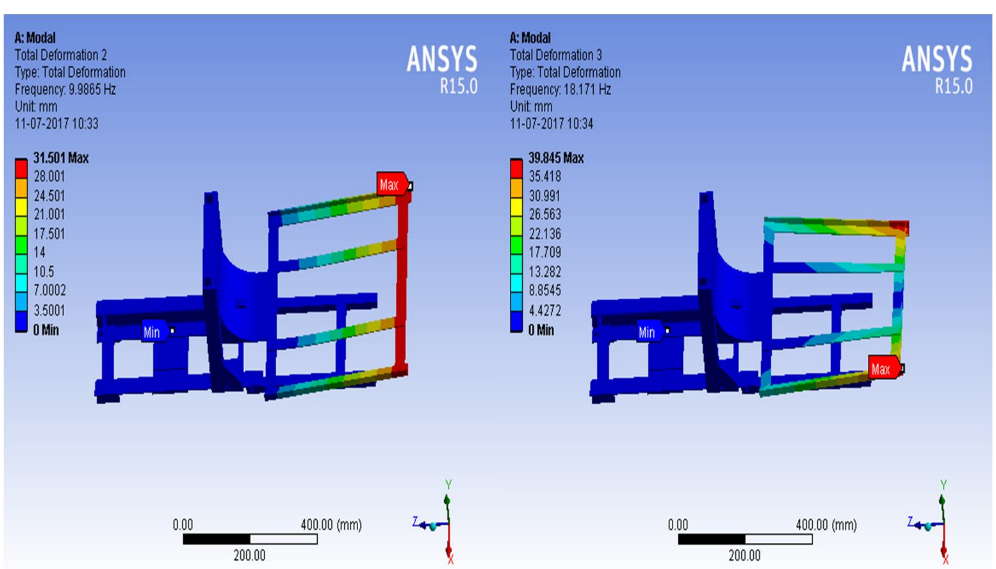


Fig.13 Boundary condition of the tractor seat frame



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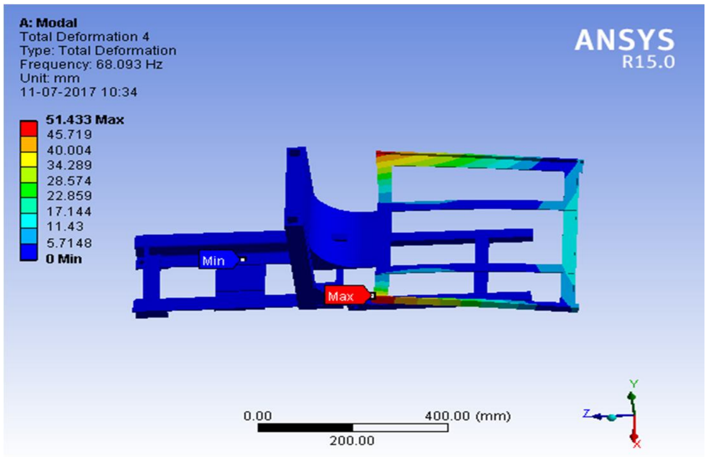

Fig.14 natural frequencies of tractor seat frame

Type of power spectral density has to be specified here. PSD may be velocity, displacement, acceleration, force or pressure. In the present problem PSD of acceleration is applied as input to the tractor seat frame fixed point Analysis has been carried to obtain the response of the seat frame, when the vehicle moving at 30 and 40 km/hr on smooth road. The power spectral density (PSD) of random process provides the frequency composition of the data in terms of the spectral density of its mean square value. The track input PSD describes the frequency content of track roughness. The relation between the PSD and spatial frequency in general is represented as

$S_{PP}(\Omega) = C_{SP}\,\Omega^{-N}$

Where $S_{PP}(\Omega)$ $\rightarrow$ PSD in m^2/cycles/m

C_{SP}, N $\rightarrow$ constants and depend upon type of road

Ω $\rightarrow$ spatial frequency in cycles/m

The above relation in terms of actual frequency is given by

$$S_{PP}(f) = \frac{C_{SP} f^{-N}}{V^{1-N}}$$

Where S_{PP} (f) $\rightarrow$ PSD of displacement

f $\rightarrow$ frequency in cycles/s

V $\rightarrow$ vehicle speed in m/s

Power spectral density of acceleration which is given as input to the tractor seat frame fixed point is obtained by $S_{\ddot{P}\ddot{P}} = f^4 S_{PP}(f)$

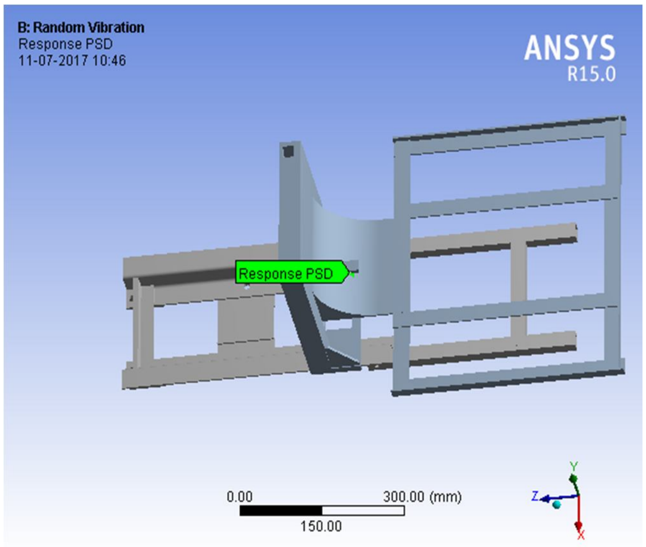

Fig.15 vibration response location of the tractor seat frame

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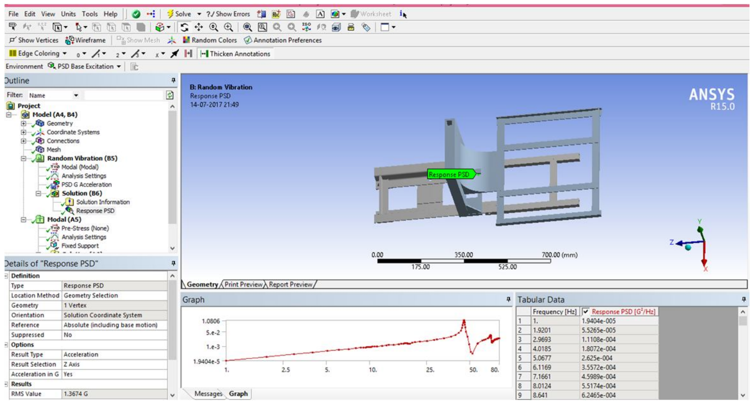


Fig.16 frequency and acceleration values of the tractor seat frame

It is a graph of response versus frequency, where the response may be displacement, velocity, acceleration or force. A PSD spectrum is a statistical measure of the response of a structure to random dynamic loading conditions. It is a graph of power spectral density versus frequency, where the PSD may be a displacement PSD, velocity PSD acceleration PSD Or force PSD.

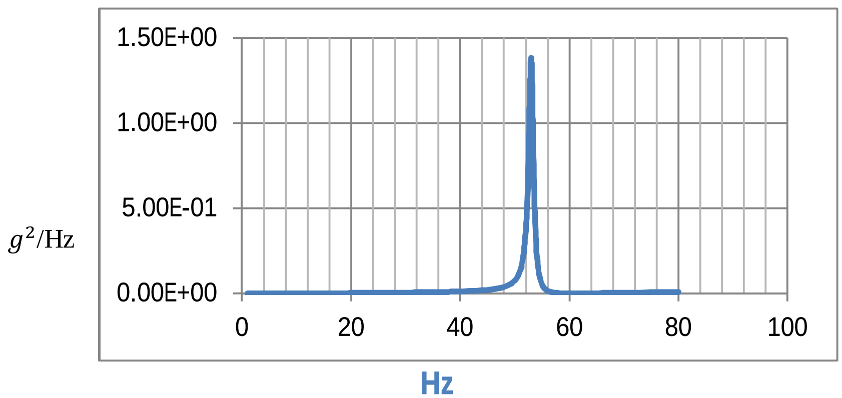


Fig.17Vibration response at 30 km/hr of tractor seat frame

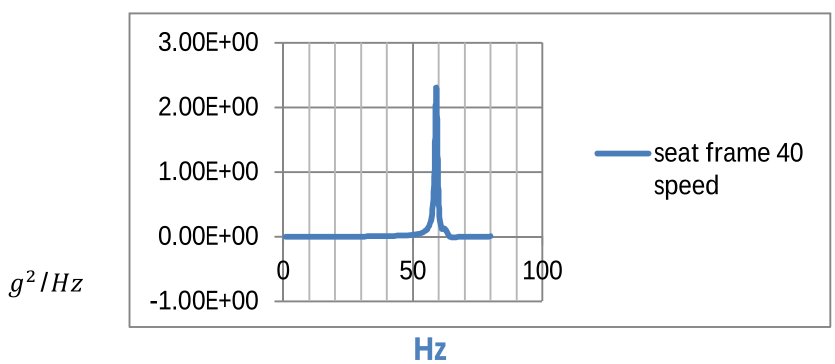


Fig.18 Vibration response at 40 km/hr velocity of tractor seat frame

In tractor seat frame vibrations are observed at different velocities at 30 and 40 km/hr in smooth road from figures 7.18 and 7.19.vibration is increased with increasing velocity. The highest frequency occurred at 58 Hz magnitude of 2.4 and 1.3g^2/Hz.

V. MODIFIED TRACTOR SEAT FRAME WITH SPRING

A. Static Analysis

In modified tractor seat frame with spring the max stress observed at 101.69 Mpa and the maximum deformation observed at ends of the tractor seat frame as shown in Fig.19.

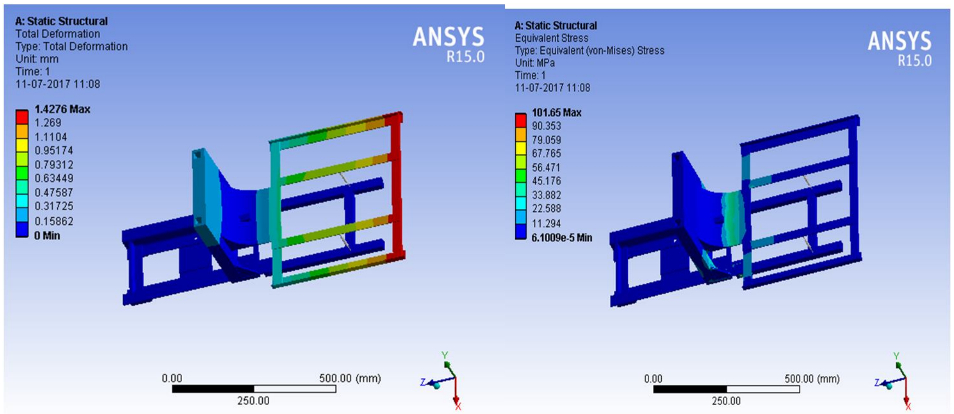


Fig.19 Stress and deformation of the tractor seat frame with spring

B. Modal Analysis

Modal analysis is done for modified tractor seat frame. In boundary conditions the fixed supports are bottom of the tractor seat frame as shown in Fig.20 and the natural frequencies are observed Fig.21

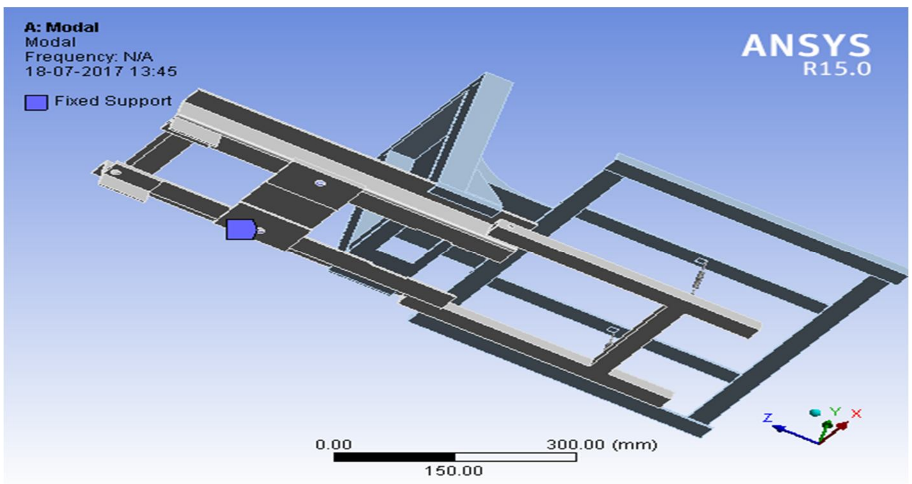
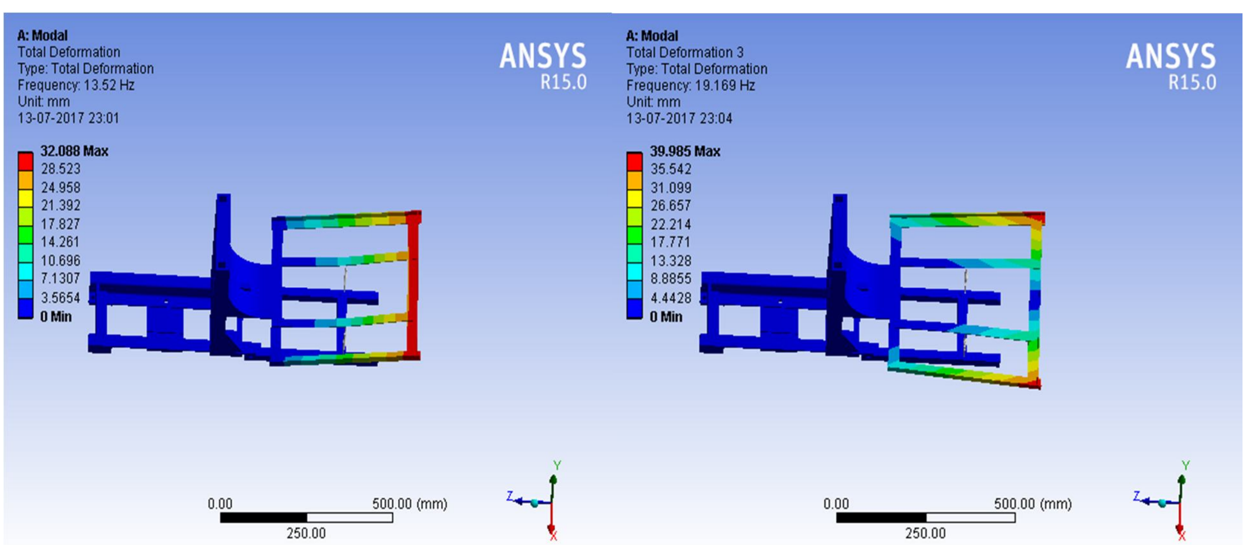


Fig .20 Boundary condition of the tractor seat frame with spring



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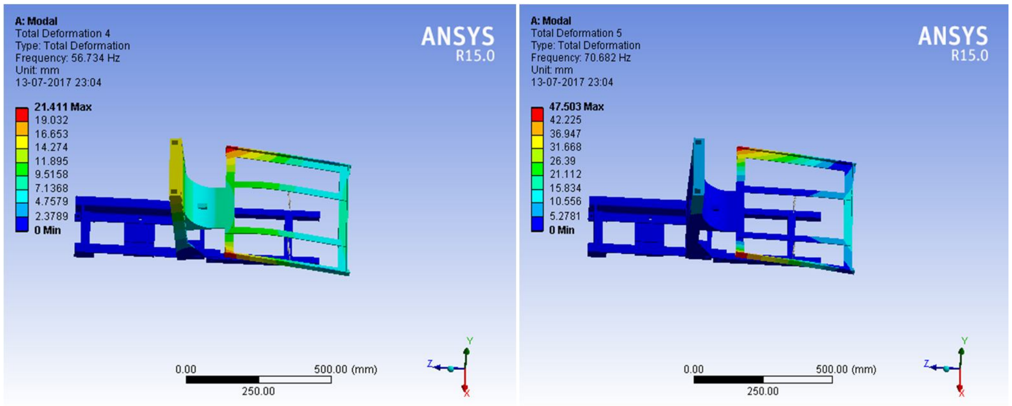

Fig.21 Natural frequencies of tractor seat frame with spring by modal analysis

C. Tractor seat frame with spring random analysis

In random analysis vibration response is determined by giving the input PSD values of the acceleration. In boundary conditions the fixed support is applied bottom of the tractor seat frame and vibration response location on the middle of the tractor seat frame as shown in Fig.22 and 23.

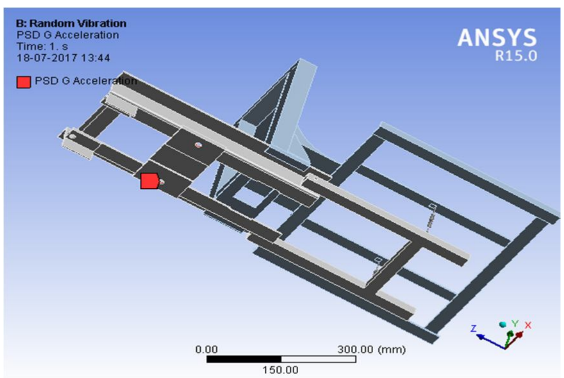

Fig.22 Boundary condition of the tractor seat Frame spring

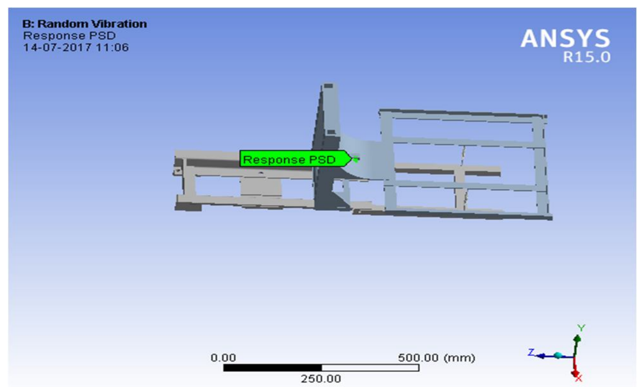

Fig.23 Vibration response location of the seat frame spring

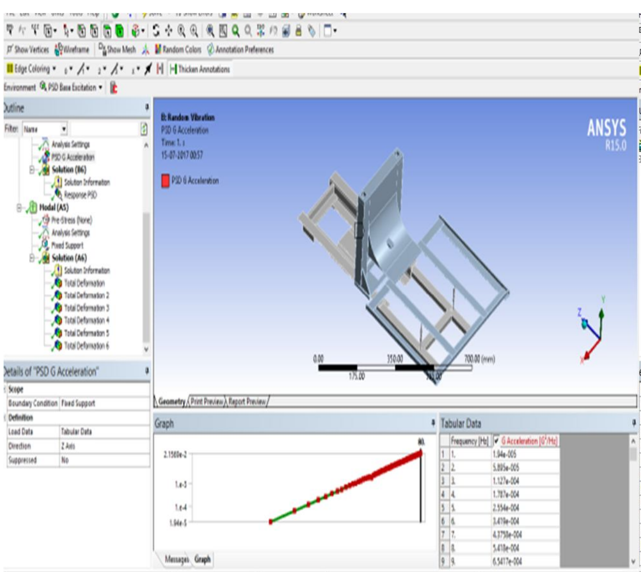

Fig.24 Frequency and acceleration values of the Tractor seat with spring

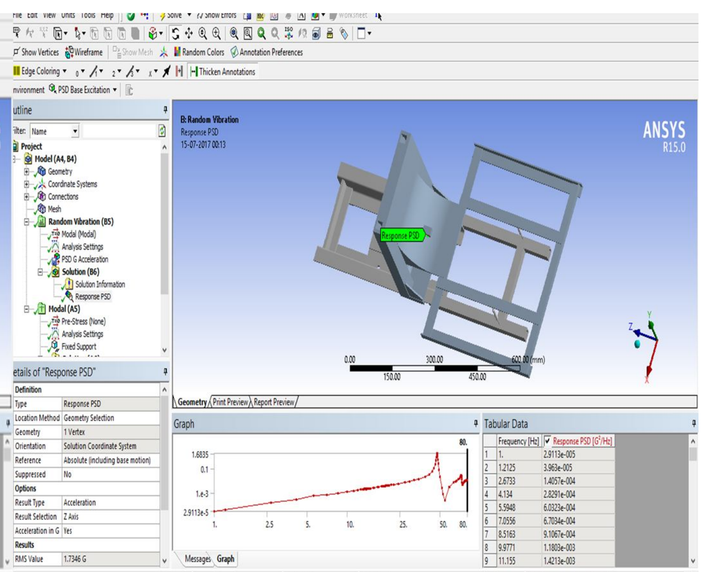

Fig.25 vibration response of tractor seat with spring

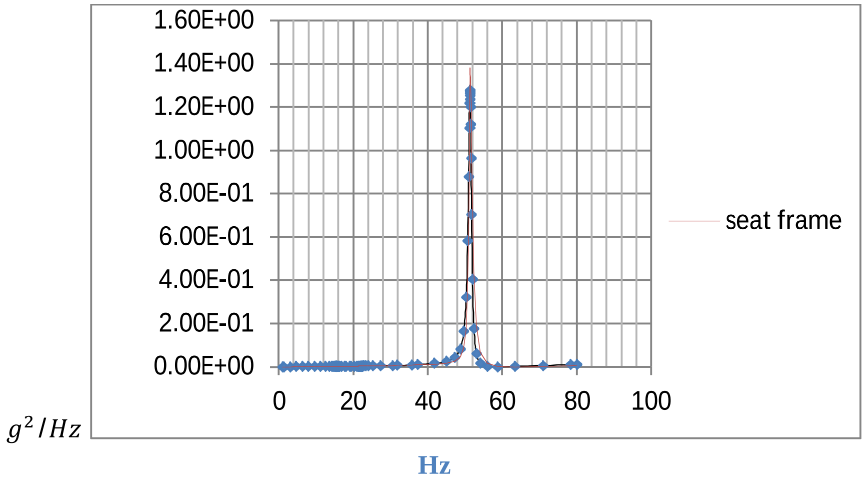

Fig.26 vibration response at 30 km/hr velocity of tractor seat frame with spring

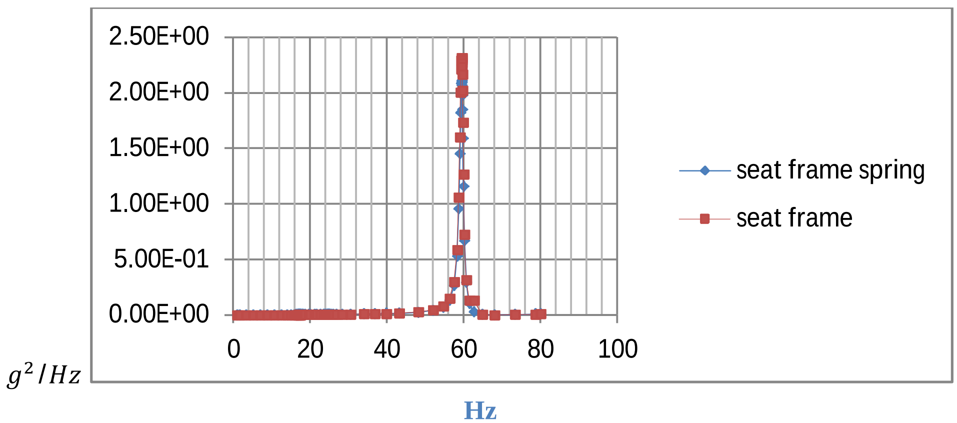

Fig.27 vibration response at 40 km/hr velocity of tractor seat frame with spring

By observing the above graphs for the reduction of vibration between tractor seat frame and the modified tractor seat frame. By doing FEA analysis the vibration response has been determined. So, by incorporating the springs to the modified tractor seat frame the vibration has been reduced to 15 percent at velocity of 40 km/hr as shown in Fig.27

VI. MODAL ANALYSIS OF A TRACTOR BONNET

In modal analysis the natural frequencies are determined as shown in Fig.29.The fixed supports are given to the front of the tractor bonnet as shown in Fig.28.

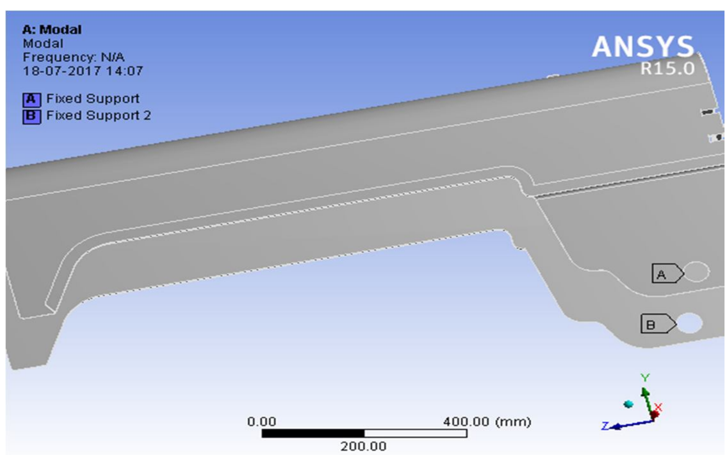

Fig.28 Boundary condition of the tractor bonnet

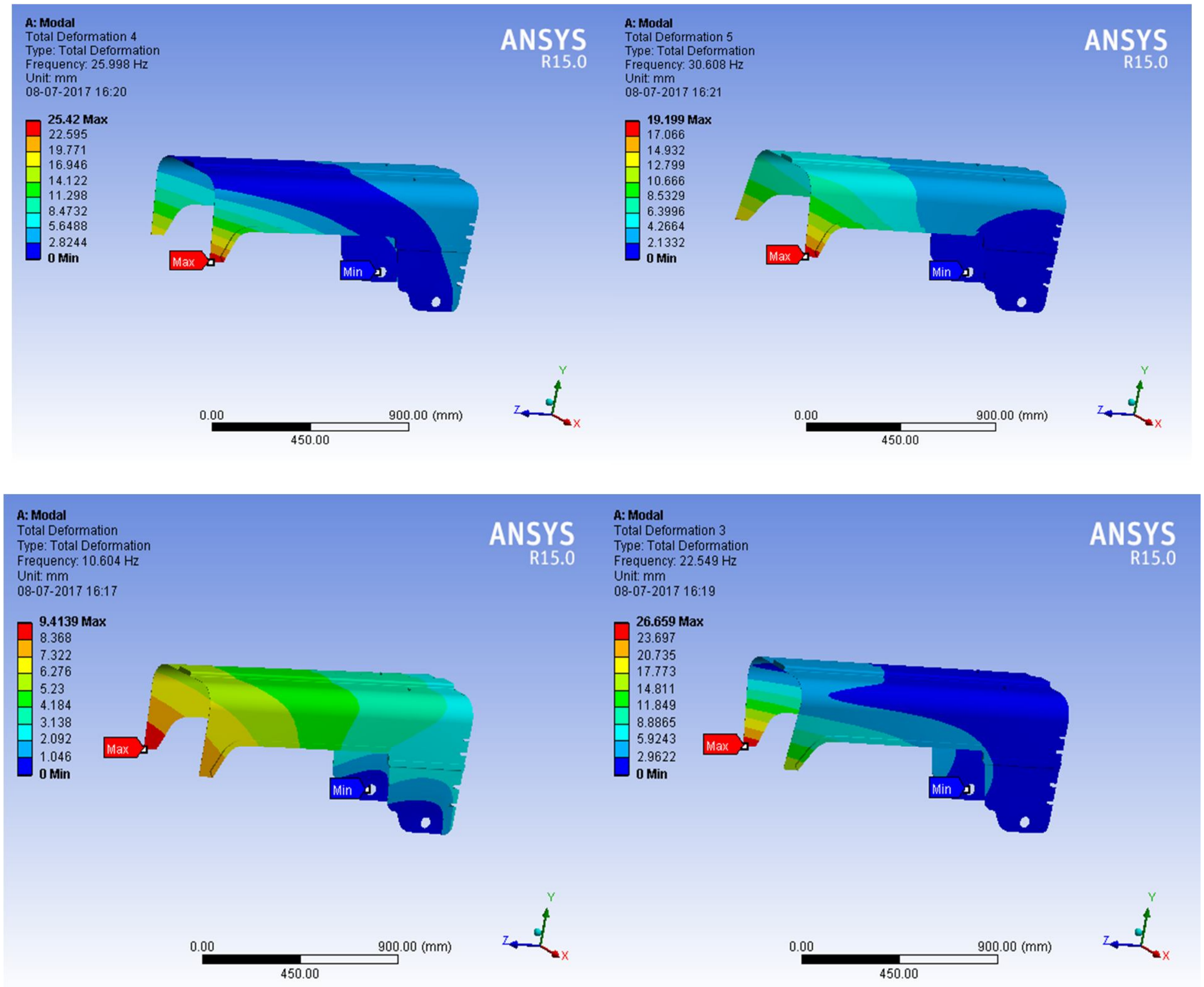

Fig. 29 Natural frequencies of tractor bonnet

A. *Random Analysis Of Tractor Bonnet*

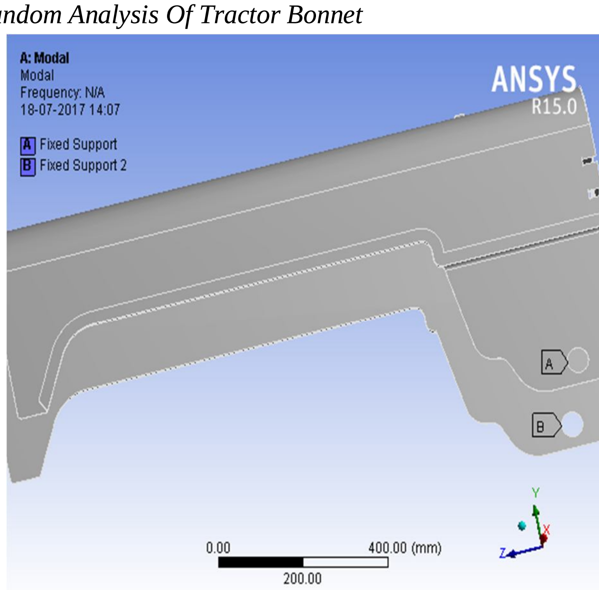

Fig.30 Boundary condition of the tractor bonnet

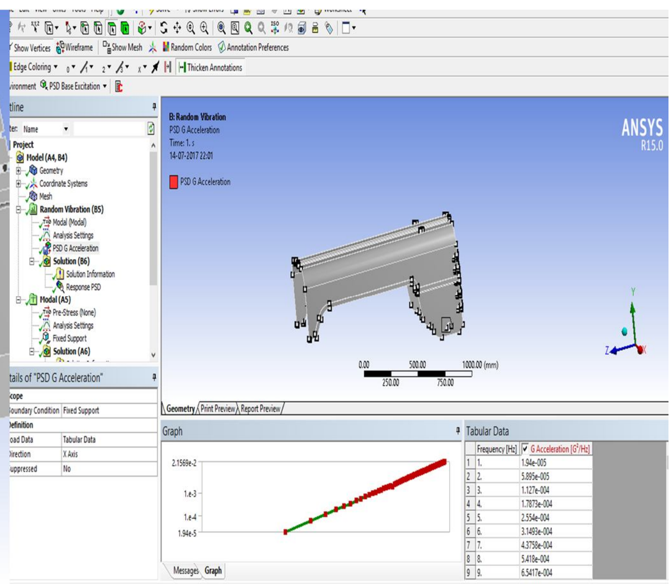

Fig.31 Frequency and acceleration values Of bonnet

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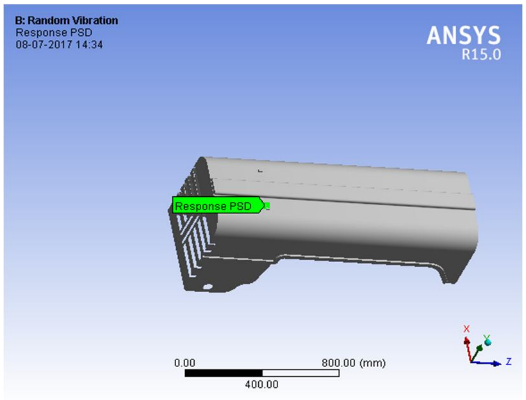

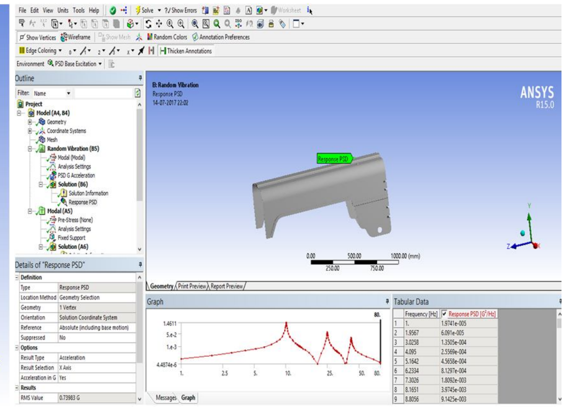

Fig.32 Vibration response location of tractor Bonnet

Fig.33 Vibration response of tractor bonnet

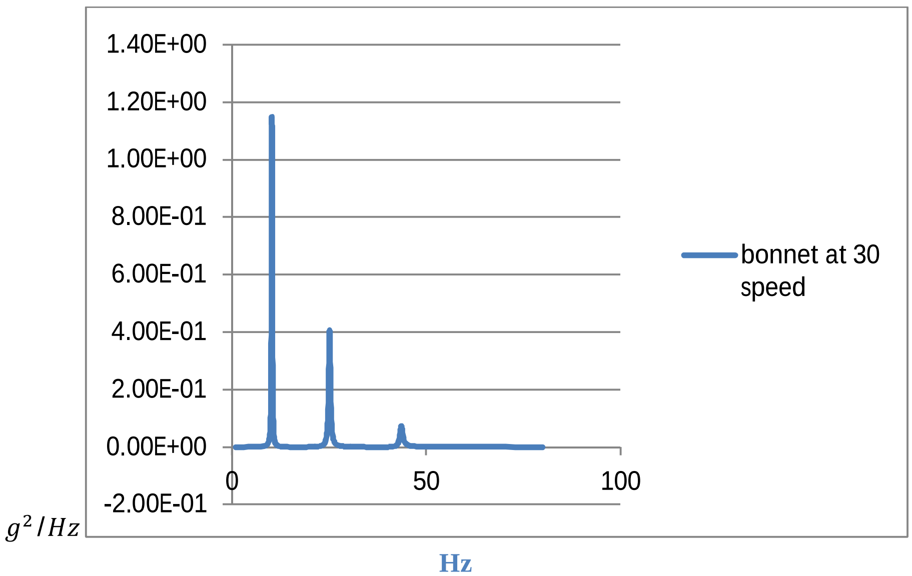

Fig.34 Vibration response at 30 km/hr velocity of tractor bonnet

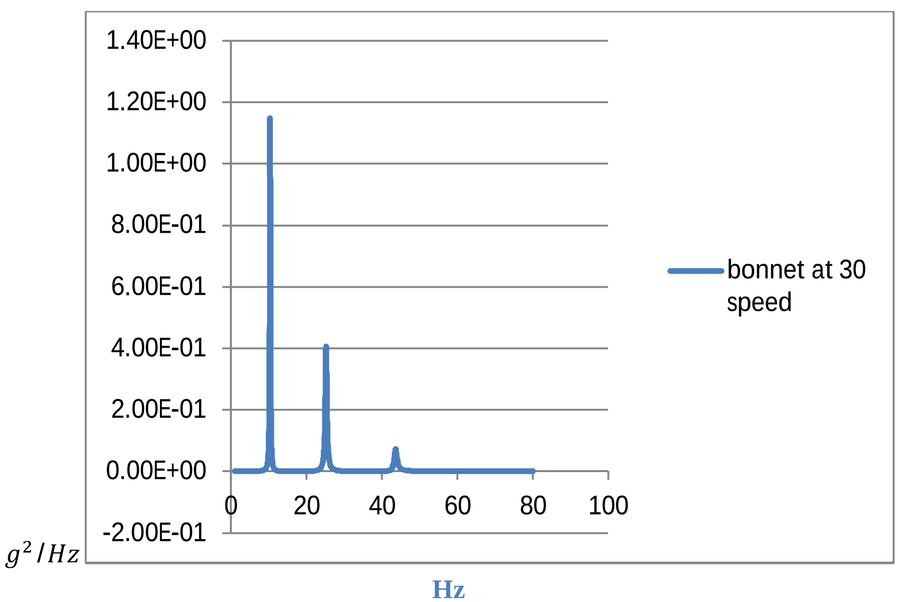

Fig.35 vibration response at 40 km/hr velocity of tractor bonnet

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B. Material properties of different materials

Material properties	Structural steel	Cast iron
density(Kg m^-3)	7850	7200
Young's modulus(Pa)	2e11	1.1e11
Poisson's ratio	0.3	0.28

Material properties	C-C COMPOSITE	CNA alloy
density	1.7g/mm^3	8530 kg/m^3
young's modulus	95 GPa	122.5 GPa
Poisson's ratio	0.32	0.33

C. Vibration response of different materials at 30 and 40 km/hr velocity

Vibration response is determined by different materials instead of structural steel material. The below graphs are showed vibration response at different materials like cast iron and c-c composite material in figure 36, 37, 38, 39 at 30 and 40 km/hr velocity.

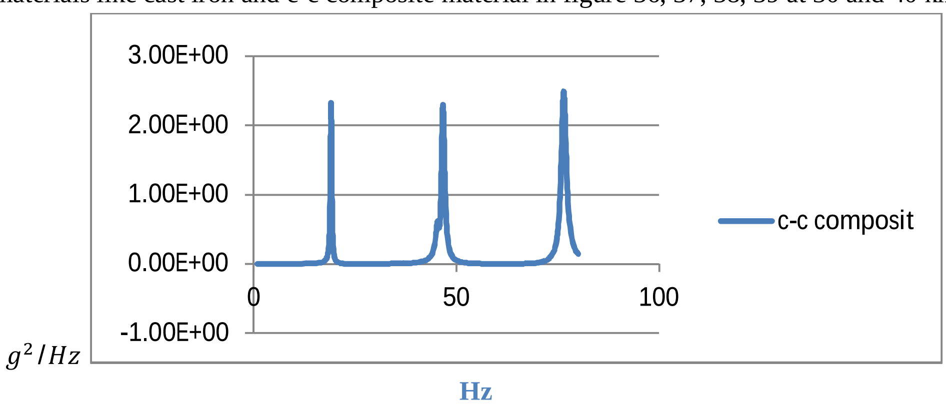

Fig.36 Vibration response at 40 km/hr velocity of c-c composite material

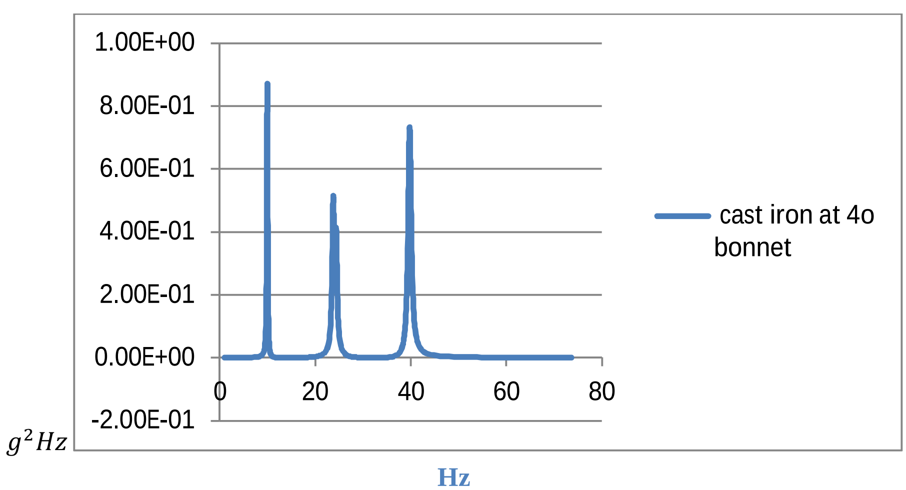

Fig.37 vibration response at 40 km/hr velocity of cast iron material

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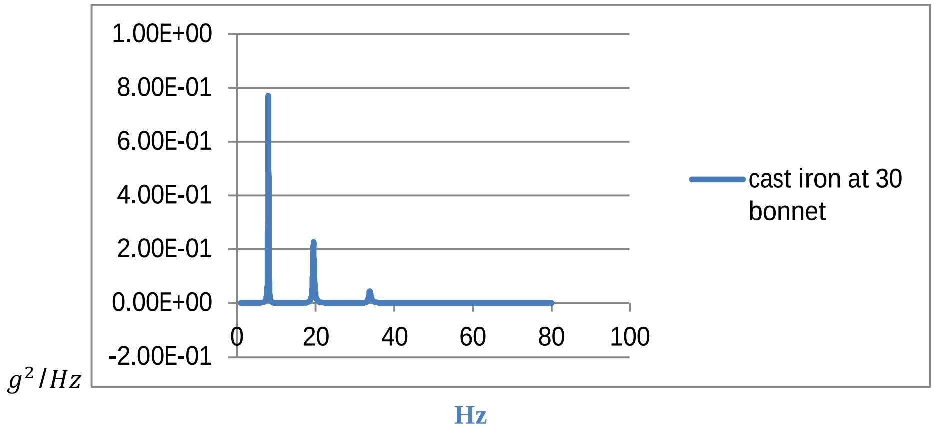

Fig.38 Vibration response at 30 km/hr velocity of cast iron material

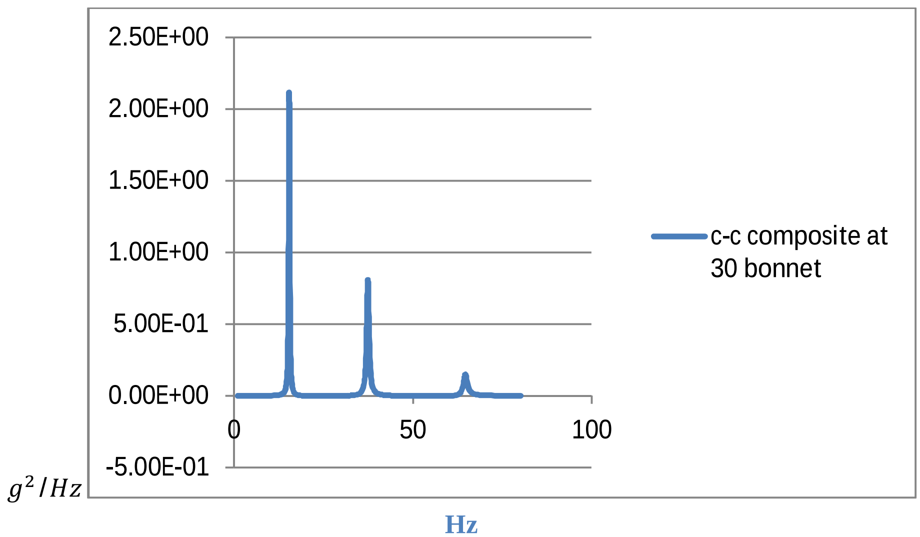

Fig.39 Vibration response at 30 km/hr velocity of c-c composite material

By observing the above graphs vibration response is different for different materials like cast-iron, carbon-carbon composite material, and structural steel. So, the structural steel is existed material for tractor bonnet which produces high vibration. By changing the material properties of tractor bonnet compare to c-c composite and structural steel ,for cast iron material has less vibration, the vibration has been is reduced by 29.8 percent at velocity of 30 km/hr as shown in Fig 38.

VII. CONCLUSIONS

In this paper tractor seat frame and tractor bonnet is designed by using Creo parametric 2.0.the random analysis and modal analysis is done for the tractor seat frame and tractor bonnet by using ansys workbench 15.0.And to compare this results to the experimental analysis of tractor seat and tractor bonnet. In experimental analysis determine the vibration response by using lab view software at two different speeds of 30 km/hr and 40 km/hr.

First in this paper compare the results of vibration analysis in experimentally and by using ansys. After compare the results add the springs to tractor seat frame to reduce the vibration level of tractor seat frame and observe which the suited material for tractor bonnet is by changing the different materials to reduce the vibration levels.

Table 1 Comparison the results of experimental and ansys of tractor seat frame at 30 km/hr velocity:

experimental values			ansys values		
Sl .No	`Frequency(Hz)	Acceleration(g^2/Hz)	Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)
1	58	1.5	1	50	1.1

Table 2 Comparison the results of experimental and ansys of tractor seat frame at 40 km/hr velocity:

Experimental values			Ansys values		
Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)
1	58	4.13	1	54	3.12

Table 3 Comparison the results of experimental and ansys of tractor bonnet at 30 km/hr velocity:

Experimental values			Ansys values		
Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)
1	5	1.04	1	10	1.14
2	25	0.36	2	25	0.39

Table 4 Comparison the results of experimental and ansys of tractor bonnet at 40 km/hr:

Experimental values			Ansys values		
Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)
1	5	1.17	1	9	1.38
2	29	1.01	2	27	0.38

After compare the results of experimental and ansys analysis the design can be modified by using the springs which is below the tractor seat frame and changing the materials of tractor bonnet.

Table 5 Seat frame with spring of random analysis at velocity of 30 km/hr:

FEA values of seat frame			Modified seat frame FEA values of modified seat frame		
Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)
1	50	1.1	1	47	1.0

Table 6 Seat frame with spring of random analysis at velocity of 40 km/hr:

FEA values of seat frame			Modified seat frame FEA values of modified seat frame		
Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl. No	Frequency(Hz)	Acceleration(g^2/Hz)
1	54	3.12	1	47	1.6

Table 7. Changing the different materials for tractor bonnet at velocity of 30 km/hr and 40 km/hr:

Table 7.1 Comparison of experimental values with structural steel material at 30km/hr:

Experimental values			Ansys values		
Sl.No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl.No	Frequency(Hz)	Acceleration(g^2/Hz)
1	5	1.04	1	10.6	1.14
2	25	0.36	2	25	0.39

Table 7.2 Comparison of experimental values with cast iron material at 30 km/hr:

Experimental values			Ansys values		
Sl.No	Frequency(Hz)	Acceleration($g^{2/}Hz$)	Sl.No	Frequency(Hz)	Acceleration(g^2/Hz)
1	5	1.04	1	7	0.74
2	25	0.36	2	19	0.2

Table 7.3 Comparison of experimental values with c-c composite material at 30 km/hr:

Experimental values			Ansys values		
Sl.No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl.No	Frequency(Hz)	Acceleration(g^2/Hz)
1	5	1.04	1	15	2.1
2	25	0.36	2	37	0.3

Table 7.4 Comparison of experimental values with structural steel material at 40 km/hr:

Experimental values			Ansys values		
Sl.No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl.No	Frequency(Hz)	Acceleration(g^2/Hz)
1	5	1.04	1	9	1.38
2	25	0.36	2	27	0.38

Table 7.5 Comparison of experimental values with cast iron material at 40 km/hr:

Experimental values			Ansys values		
Sl.No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl.No	Frequency(Hz)	Acceleration($g^2/$Hz)
1	5	1.04	1	9	0.8
2	25	0.36	2	23	0.41

Table 7.6 Comparison of experimental values with c-c composite material at 40 km/hr:

Experimental values			Ansys values		
Sl.No	Frequency(Hz)	Acceleration(g^2/Hz)	Sl.No	Frequency(Hz)	Acceleration($g^2/$Hz)
1	5	1.04	1	19	2.4
2	25	0.36	2	46	1.3

After comparison of results the experimental values are matched to the ansys results approximately. In experimental analysis highest frequency occurred at two points 58 and in ansys highest frequency takes place at 50 Hz at a magnitude of 1.5, 1.1, for tractor seat frame vibration response at 30 km/hr.

For tractor seat frame vibration response at 40 km/hr highest frequency occurred in experimental analysis at 58 Hz with magnitude of 4.1, coming to ansys results highest frequency occurred at 54 Hz at a magnitude of 3.1

In the above results are observed the tractor bonnet at 30 km/hr having highest frequency occurred in experimental analysis about 3 points. i.e., is 5 Hz, 25 Hz, with a magnitude about 1.0,0.36,coming to ansys results highest frequency occurred at 10Hz,25 Hz, at a magnitude of 1.1,0.3.

In the above results are observed the tractor bonnet at 40 km/hr having highest frequency occurred in experimental analysis about 3 points I .e, 5Hz,29Hz at a magnitude about 1.1,1..coming to ansys result highest frequency occurred at 9 Hz,27 Hz at a magnitude of 1.3,0.38.

After modifying the tractor seat frame with spring the results are compared to experimental results. The results are observed above figure .compare to experimental results in ansys results the frequency is reduced as well as magnitude also reduced from 58 Hz to 47 Hz.

Material is replaced by different materials. After compare the results of tractor bonnet experimental with ansys the tractor bonnet material is replaced by different materials.

Compare to structural steel cast iron has low frequencies and magnitudes 7 Hz, 19 Hz, of 0.7,0.2,g^2/Hz at velocity of 30km/hr.cast iron is having high tensile strength. High yield strength and high elongation properties compare to structural steel.

Compare the structural steel with c-c composite material it has high frequencies and magnitudes i.e. is at 15, 37, Hz corresponding magnitudes at 2.1, 0.3, g^2/Hz at velocity of 30 km/hr.

Compare to structural steel cast iron has low frequencies and magnitudes 9 Hz, 23 Hz of 0.8,0.41, g^2/Hzat velocity of 40g^2/Hz..cast iron is having high tensile strength. High yield strength and high elongation properties compare to structural steel.

Compare the structural steel with c-c composite material it has high frequencies and magnitudes i.e. is at 19, 46, Hz corresponding magnitudes at 2.4, 1.3 g^2/Hz at velocity of 40 km/hr.

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VIII. FUTURE SCOPE

A. In future, by considering the experimental analysis for tractor seat frame with incorporating the springs to reduce the vibration.

B. And by considering the experimental analysis for tractor bonnet with different materials like cast iron and carbon-carbon composite instead of structural steel, to reduce the vibration levels compared to existed material i.e., is structural steel.

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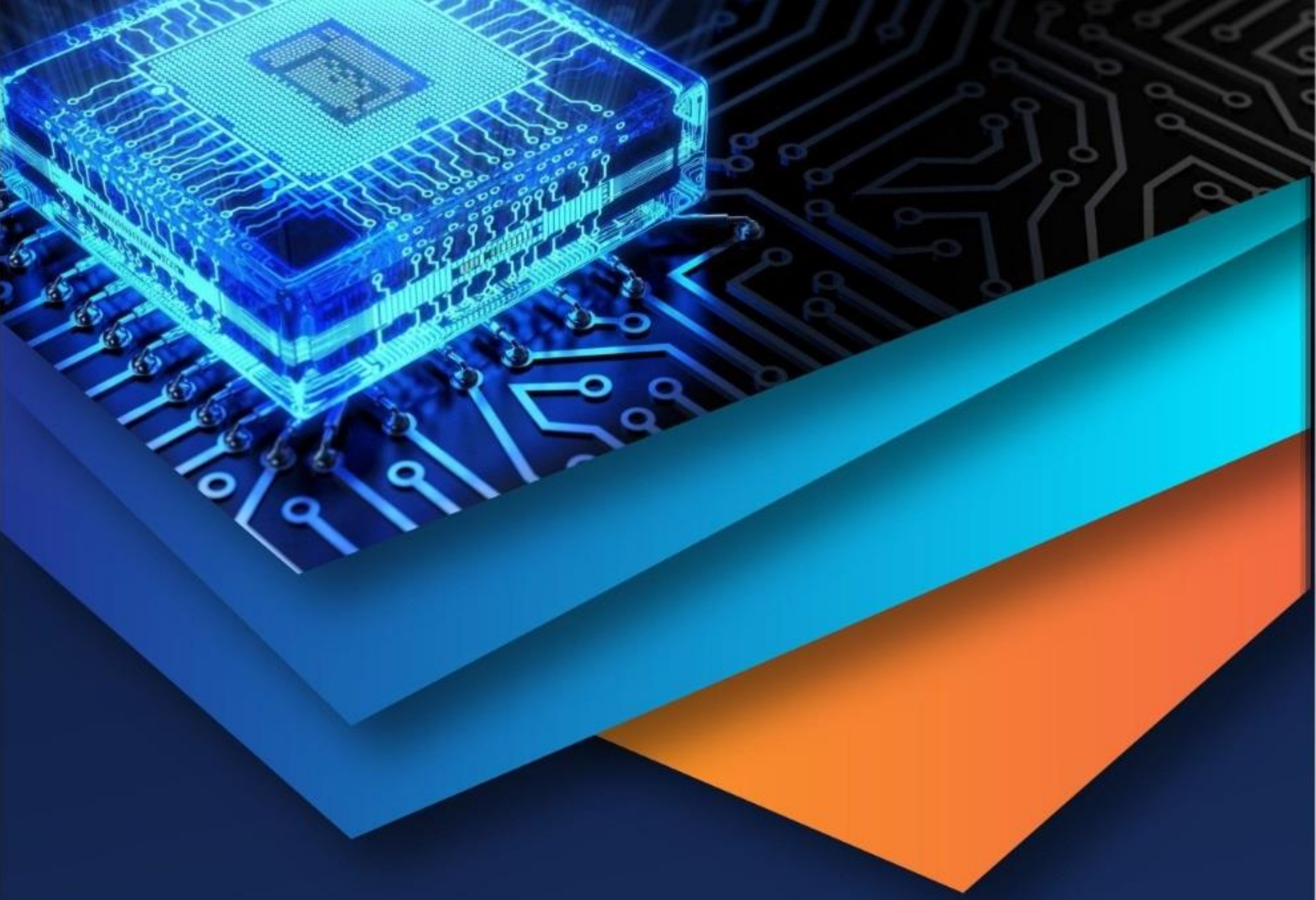

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