G. N. Kadam, 2021, 9:4
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Investigating of Agriculture Tractor Seat Vibration Using Passive Suspension System on ANSYS Software

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Abstract- Operators of agricultural tractor perform various tasks at work that expose them to a variety of risk factors. During their work, agricultural tractor operators are exposed to different negative influences, due to which vibrations are especially harmful. Long term exposure of tractor driver to vibrations induced by agricultural tractor operations may lead to various health problems. It is widely recognized that agricultural tractor operators are exposed to high level of whole body vibration (WBV) during specific farm operations. WBV may leads to Low back Pain (LBP) and spinal cord related diseases, therefore the objective of the study is to reduce the level of ride vibrations experienced by tractor seats appear to be necessary and some possible methods of achieving significant improvements. In the present study, The vibration transmitted through the seat of a four-wheel drive tractor equipped with front suspension axle and shock absorber for the implement, were measured using OR34-2, 4 Channel FFT analyzer and then analyzed in terms of root mean square (rms) accelerations according to the ISO standard. Several tests were conducted in different conditions considering the type of operation (harrowing, plugging and cultivating) at different road conditions (on road, sugarcane field and flat field) with two different running speeds. Then we developed a new suspension system for tractors seat using spring and dampers to reduce the vibration energy and frequencies up to a suitable range for the operator. The vehicle dynamics model of tractor with tandem suspension is modeled and simulated in analysis software ANSYS and optimize the parameters of the seat to achieve rms acceleration in the range of 'Health guidance caution zone' (HGCZ) so that it gives the ride comfort for the operator.

Keywords: Vibration, Low Back Pain, RMS acceleration, Tractor seat, Suspension System, Springs, Damper, Frequency, etc.

I. INTRODUCTION

Vibration is one of the most commonly investigated ergonomic factors affecting workers health and work efficiency. Human vibration is defined as the effect of mechanical vibration on the human body. Around the world, millions of people are exposed to mechanical vibrations while working. The effect of vibration is critical in terms of human health, working comfort, work productivity, work quality, and work safety. Long-term exposure to whole-body vibration (WBV) may cause serious health issues, including spinal column problems and lower-back pain, depending on the magnitude, frequency, direction, duration, and distribution of the vibration on the human body.

In addition to the workers' health, their safety, comfort, and working efficiency are also adversely affected by WBV exposure. Workers from many occupations are exposed to WBV on the road or off-road vehicles. Much research has been done investigating the exposure of farm tractor operators to high levels of WBV.

Tractors do not usually have suspensions, thus, vibration levels in tractors are higher than in other road vehicles. The tyre-axle and axle-frame suspensions of road vehicles are not available on tractors; rather, the only suspension is between the frame and cabin and the seat.

Vehicles which drive over rough terrain have vibrations induced in them by the uneven surfaces over which they travel. If these vehicles had no suspension system every bump over which the vehicle travelled would be directly transmitted to the vehicle's operator. The inclusion of a suspension system in the vehicle absorbs some of the most damaging vibrational frequencies.

However, a suspension system introduces its own resonance frequency to the vehicle and therefore the magnitude of the vibration produced at this resonant frequency will be greater.

In comparison to other vehicle performances of agricultural tractors, the protection of drivers from vibrations is unsatisfactory. The tractor chassis does not include suspension, and the tires, which are relatively flexible. There is virtually only a seat suspension that absorbs the vibrations. This is why the tractor drivers are subject to relatively high-level vibrations.

At present, there is a need for the development of agricultural tractor that enables more comfortable and safe performance of various agricultural tasks.

With regard to tractor operations, one of the important points in the design and use of tractors is the invention of comfortable seats that can prevent occupational diseases caused due to whole-body vibration.

1. Whole Body Diagram:
Whole body vibration refers to the vibration transmitted to the body from the supporting surface like feet, buttock of a person driving a vehicle; vehicles which drive over rough terrain have vibrations induced in them by the uneven surfaces over which they travel. If these vehicles had no suspension system every bump over which the vehicle travelled produced vibration which is directly transmitted to the vehicle's operator.

2. Harmful Frequency Range:
Whole-body vibration is harmful to human because it excites the natural frequency of the body. The dynamics of the human body has been researched to determine which frequencies are most harmful.

Gniady's and Bauman from Aura Systems determined the natural frequencies of the human body in the sitting position. The human body usually has a natural frequency between 4 and 5 Hz.

3. Effect of Whole Body Diagram:
Vibration is one of the most commonly investigated ergonomic factors affecting workers' health and work efficiency. Around the world, millions of people are exposed to mechanical vibrations while working. Vibration in a working environment may produce a wide range of effects.

The effect of vibration is critical in terms of human health, working comfort, work productivity, work quality, and work safety. Long-term exposure to whole-body vibration (WBV) may cause serious health issues, including spinal column problems and lower-back pain, depending on the magnitude, frequency, direction, duration, and distribution of the vibration on the human body.

In addition to the workers' health, their safety, comfort, and working efficiency are also adversely affected by WBV exposure. Workers from many occupations are exposed to WBV on the road or off-road vehicles.

Much research has been done investigating the exposure of farm tractor operators to high levels of WBV. Tractors do not usually have suspensions, thus, vibration levels in tractors are higher than in another road vehicle.

The tyre-axle and axle-frame suspensions of road vehicles are not available on tractors; rather, the only suspension is between the frame and cabin and the seat.

4. Types of Seat Suspension System:
- Active Suspension System

- Semi Active Suspension System
- Passive Suspension System

II. PROBLEM STATEMENT

1. Research Gap:

- A significant amount of analysis on tractor seat vibration has been done and it is observed that the vibration level induced is much higher than the comfort level of the operator.
- A significant amount of experimental and analytical work has been done on the suspension of the tractor seat. The reason is that the vibration of the tractor seat can be reduced to the comfort level of the driver.
- On the other hand, very little attention has been paid analytically to reducing vibration by using new passive suspension system.

2. Problem Statement:

From the critical discussion on literature survey and gaps identified from the literature, the problem statement for the current project will be, to reduce the vibration of tractor seat by using a new spring damper passive suspension system so as to get comfort to the operator and analyse with the current suspension system.

3. Objectives of the Study:

The main aim of this dissertation work is to reduce the vibration in tractor seat up to the operators comfort level, by developing a new suspension system.

In order to achieve this, there will be the following objectives.

- Measurement of dimensions of the conventional tractor seat and the consideration of specification of the tractor. Take the readings of accelerations by using FFT analyzer.
- Comparison of measured data with ISO standards.
- Develop and design a new suspension system with the existing system for reducing the vibration transmitted through the seat.
- Take the reading on the modified seat to check the ride comfort thereby increasing the potential of the operator and finding out the parameters for modified seat.
- Compare the results obtained from the existing seat suspension and modified seat suspension.

III. METHODOLOGY

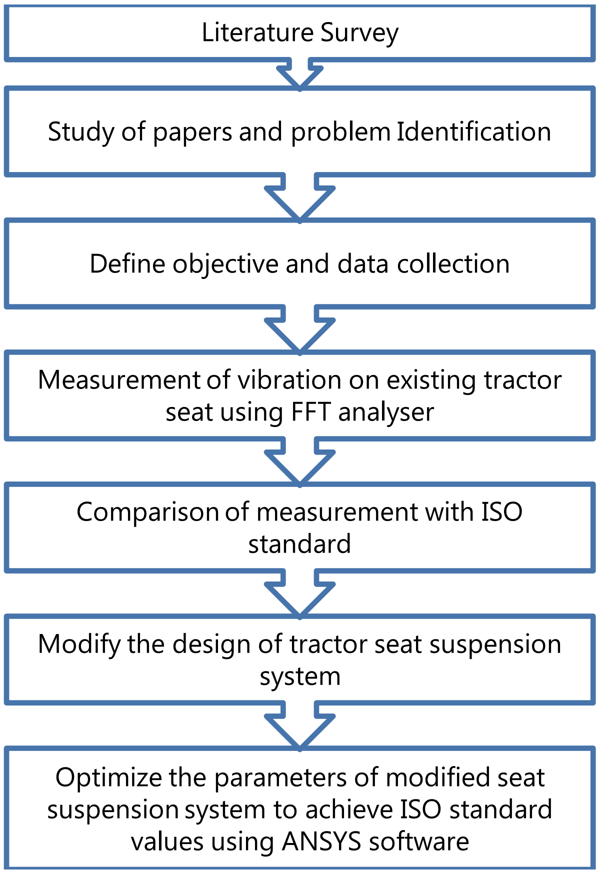

Fig 1. Layout of the Paper

1. FFT Analyser:

It is a property of all real waveforms that they can be made up of a number of sine waves of certain amplitudes and frequencies. Viewing these waves in the frequency domain rather than the time domain can be useful in that all the components are more readily revealed. Each sine wave in the time domain is represented by one spectral line in the frequency domain.

The series of lines describing a waveform is known as its frequency spectrum. Dynamic signals are seldom of simple type. They are a combination of sine waves with different amplitude, frequency and phase. In order to know all these complex signals are to be broken to individual components.

Identifying frequencies are difficult in the case of complex waveforms. The breaking the complex signal in to various sinusoidal components is achieved by transforming signals from time domain to frequency domain. Fourier Transform is one of the techniques used for this.

Fig 2. FFT Analyzer.

Fourier's theorem states that any waveform in the time domain can be represented by the weighted sum of sines and cosines. The FFT spectrum analyzer samples the input signal, computes the magnitude of its sine and cosine components, and displays the spectrum of these measured frequency components. Some measurements which are very hard in the time domain are very easy in the frequency domain.

The measurement of harmonic distortion is hard to quantify the distortion of a sine wave by looking at the signal on an oscilloscope. When the same signal is displayed on a spectrum analyzer, the harmonic frequencies and amplitudes are displayed with amazing clarity.

The advantage of this technique is its speed. Because FFT spectrum analyzers measure all frequency components at the same time, the technique offers the possibility of being hundreds of times faster than traditional analog spectrum analyzers. In the case of a 100 kHz span and 400 resolvable frequency bins, the entire spectrum takes only 4 ms to measure.

To measure the signal with higher resolution, the time record is increased. But all frequencies are examined simultaneously providing an enormous speed advantage.

IV. MODELLING, ANALYSIS AND DATA COLLECTION

1. Tractor Seat:

Two conventional seats in current production were used for this investigation is shown in the fig. The seat was a compact design for use in farm tractors with the suspension components mounted behind the backrest.

Seats had covered with foam cushions, steel coil springs, oil dampers and rubber end-stop buffers. The seat is directly attached to the chassis. Therefore most of the forces transmitted to the driver through seat suspension.

The seats are considered representative of seats mounted on many off-road machines. The design of seats mounted on tractors, earthmovers, and industrial trucks are similar and consist of a suspension (springs, damper, guiding system), a cushion, and two sets of end-stop buffers, one to limit the free upward travel and the other to limit the downward travel.

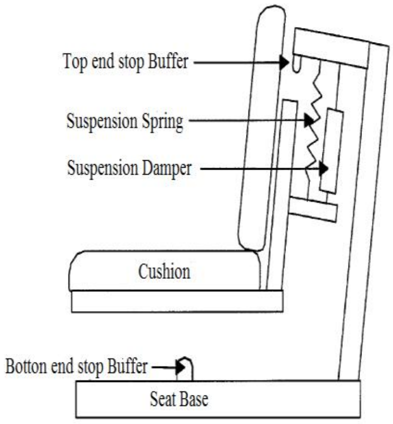

Fig 3. Conventional Tractor Seat.

The seat mounted on the tractor had four bar linkage type suspension with two helical tensile springs (spring constant 11.3 N/mm) and a hydraulic damper (damping coefficient 0.920 N-s/mm) in parallel.

It consists of top end stop buffer and bottom end stop buffer to limit the displacement in the vertical direction. One operator of normal physique and mass (60 kg) was used throughout these tests. The spring and damper absorb the shock and vibration arises during riding of the tractor.

The tri-axial seat accelerometer was mounted on the operator's seat at a point on the interface between the operator and his seat to measure ISO weighted r.m.s. acceleration levels along, vertical direction as per International Standard (ISO 2631/1, 1985). The tests were conducted on three different surfaces, a grain field, and sugarcane field and on the road during the transport for three different conditions plugging, cultivating and harrowing.

2. Measurement of Vertical RMS Acceleration at 05 Km/Hr for Conventional Tractor Seat:

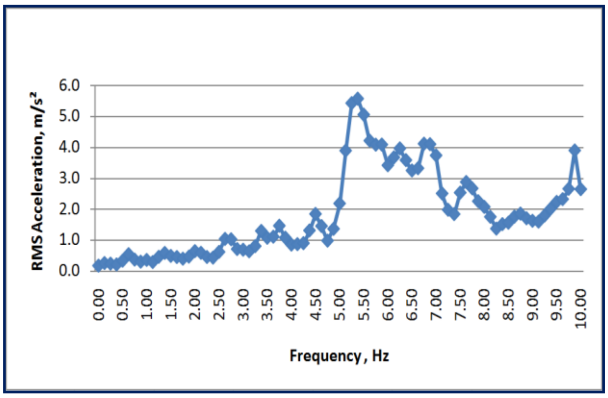

Fig 4. Chart 1: Cultivating Flat Field with Conventional Tractor seat at 05 km/hr.

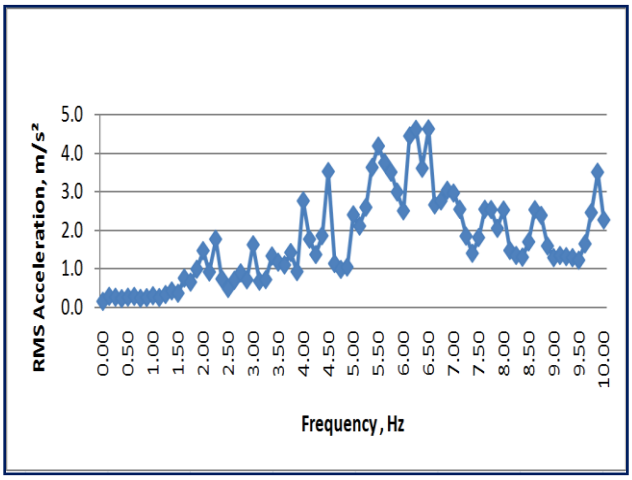

Fig 5. Chart 2: Cultivating Sugarcane Field with Conventional Tractor seat at 05 km/hr.

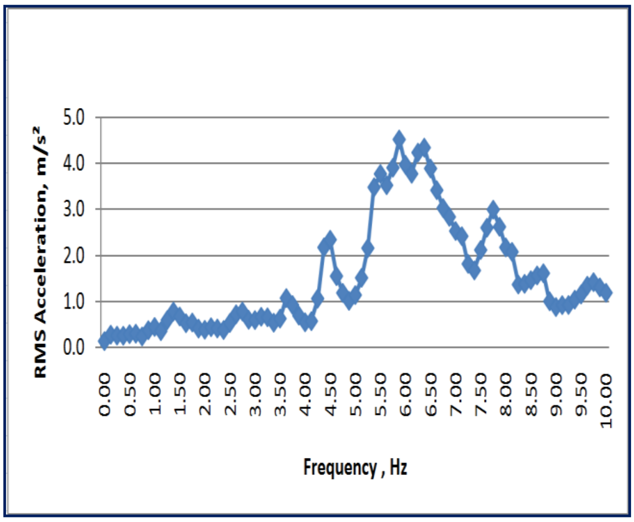

Fig 6. Chart 3: Cultivator on road with Conventional Tractor seat at 05 km/h.

3. Measurement of Vertical RMS Acceleration at 08 Km/Hr for Conventional Tractor Seat:

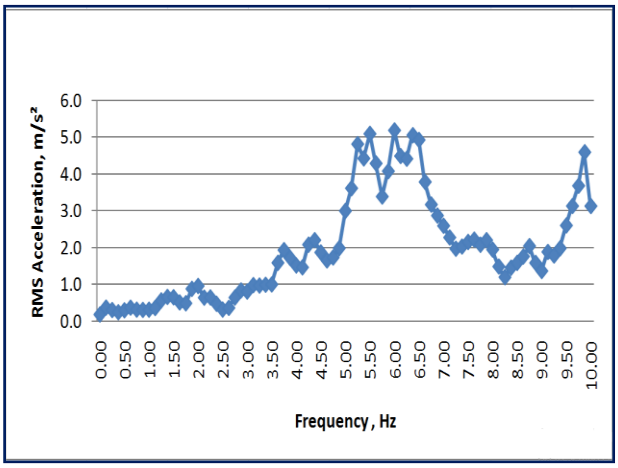

Fig 7. Chart 4: Cultivating Flat Field with conventional tractor seat at 08 km/hr.

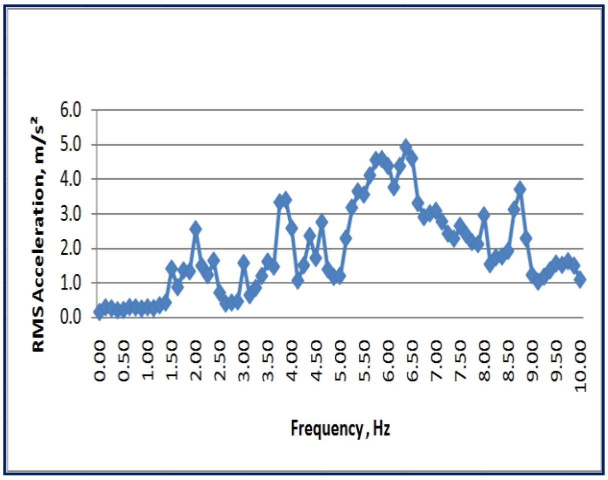

Fig 8. Chart 5: Cultivating Sugarcane Field with conventional tractor seat at 08 km/hr.

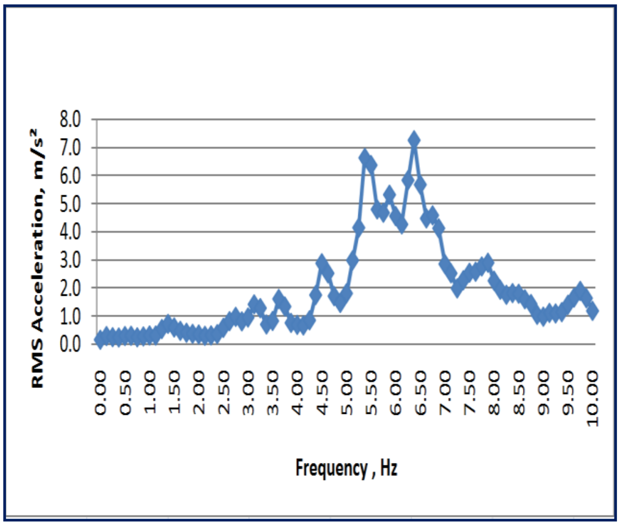

Fig 9. Chart 6: Cultivator on road with conventional tractor seat at 08 km/hr.

V. MODIFIED TRACTOR SEAT ANALYSIS

1. Modified Tractor Seat:

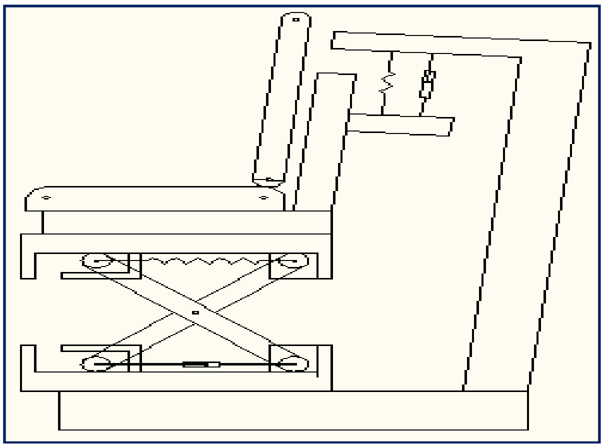

Fig 10. Modified Tractor Seat.

The modified seat configuration is shown in fig. It consists of a spring and damper system. The spring and damper are connected parallel to each other. The spring and damper are connected to each other by using cross bars which are hinged at the centre.

One end of the spring is hinged to one end of the bar and is fixed to the seat of the tractor, where the other end of the spring is hinged to the one end of the other bar by using the roller. Similarly, the damper one end is hinged to one end of the bar which is fixed to the chassis, where another end is hinged to bar using a roller. The system consists of an end stop as shown in fig.

2. Design of springs:

Table 1. Dimensions of Springs.

Specification	Symbol	Dimension
Diameter of spring wire,	D	3.5 mm
Outer diameter of spring,	D_{outer}	20 mm
Inner diameter of spring,	D_{inner}	13 mm
Mean diameter of spring,	D_{mean}	16.5 mm
Length inside hooks (Free length)	L_{free}	300 mm
Number of active coils,	N_a	79
Body length,	L_{body}	280.2 mm
Hook length 1,	L_1	9.75 mm
Hook length 2,	L_2	9.75 mm
Types of Hooks,		Machine hooks
Spring index,	C	4.714
Spring rate (Spring constant)	K	8.1231 N/mm2
Material shear modulus,	G	0.8×10^5 P_a
Maximum shear stress possible,	τ_{max}	839.299 P_a
Wahl correction factor,	w	1.33
Pitch of coil, P = $\frac{\text{Free length}}{(z-1)}$ = 300/8	P	3.8 ≈ 4

3. Measurement of Vertical RMS Acceleration at 05 Km/Hr for Modified Tractor Seat:

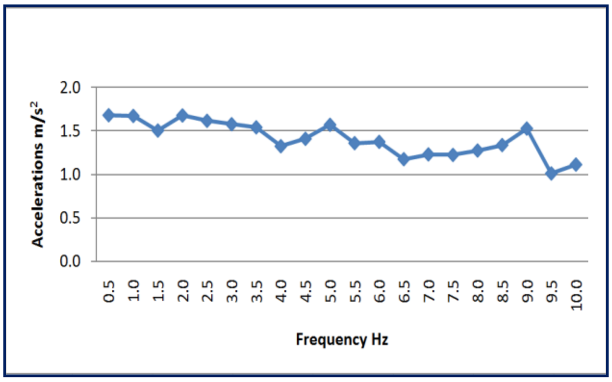

Fig 11. Chart 7: Cultivating Flat Field with modified tractor seat at 05 km/hr.

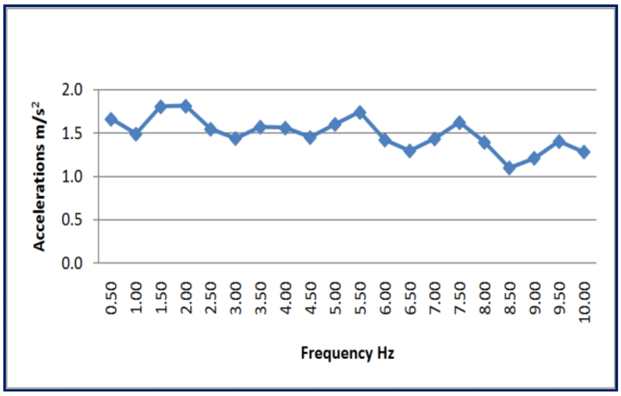

Fig 12. Chart 8: Cultivating Sugarcane Field with modified tractor seat at 08 km/hr.

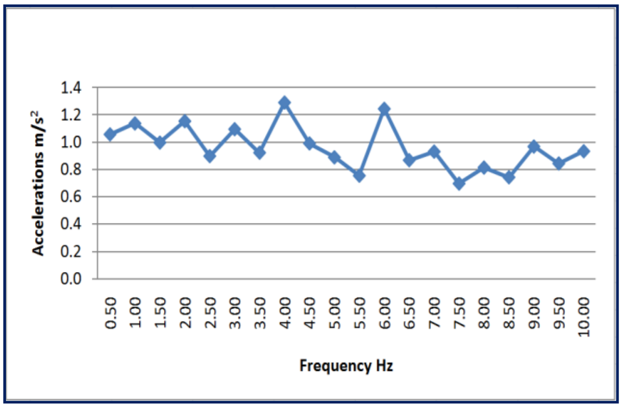

Fig 13. Chart 9: Cultivator on road with modified tractor seat at 05 km/hr.

4. Measurement of Vertical RMS Acceleration at 08 Km/Hr for Modified Tractor Seat:

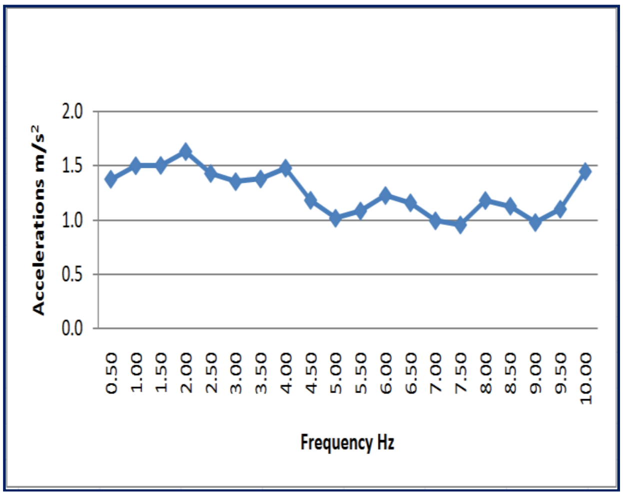

Fig 14. Chart 10: Cultivating Flat Field with modified tractor seat at 08 km/hr.

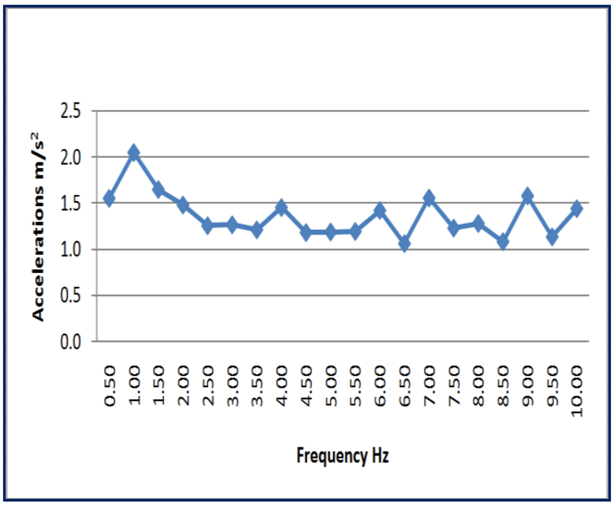

Fig 15. Chart 11: Cultivating Sugarcane Field with modified tractor seat at 08 km/hr.

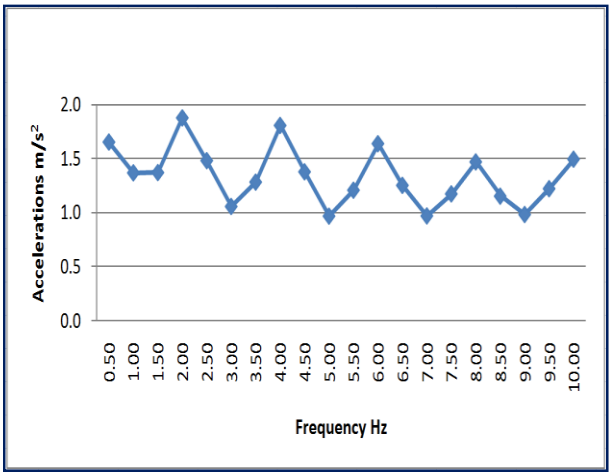

Fig 16. Chart 12: Cultivator on road with modified tractor seat at 08 km/hr.

5. Modelling on ANSYS:

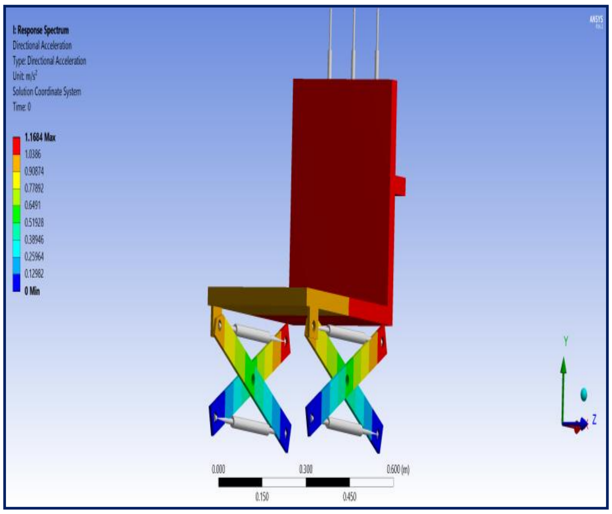

Fig 17. RMS acceleration with Cultivator on flat field.

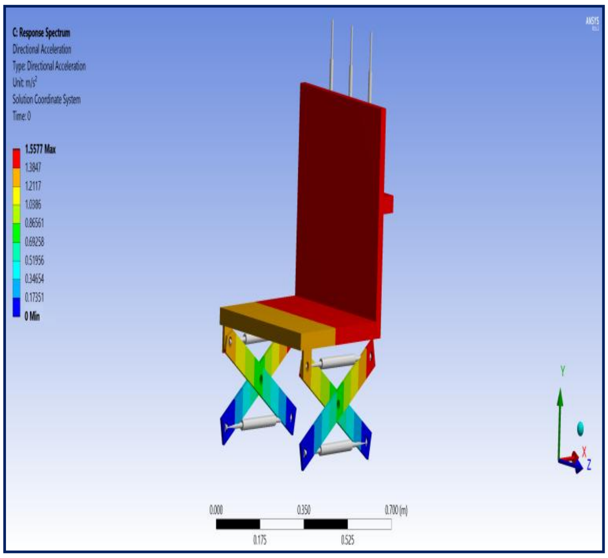

Fig 18. RMS acceleration with Cultivator on Sugarcane field.

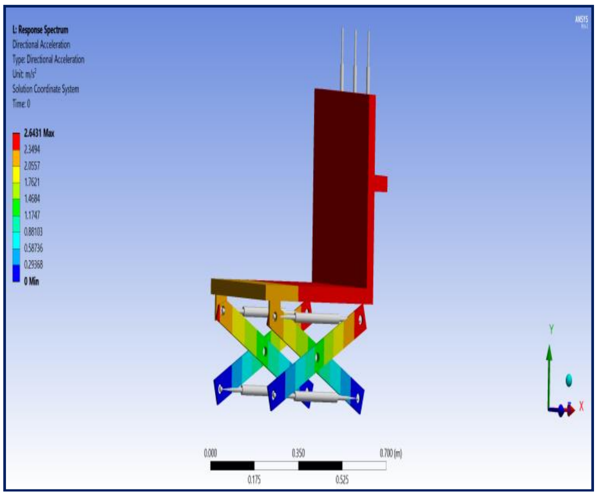

Fig 19. RMS acceleration with Cultivator on Road.

VI. CONCLUSION

The several tests were carried out on present agricultural tractor seat on different conditions at two different speeds 5 km/hr and 8 km/hr and comparison of measured values of conventional tractor seat root mean square (rms) acceleration with ISO 2631-1 indicates the magnitude of frequency weighted rms acceleration in vertical direction have been exceeded the upper limit of 'Health guiding caution zone' in all terrain tractors.

The acceleration was in the range of 1.5 - 7.5 m/s^2 with plough, with 1 - 6.5 m/s^2 cultivator and 2 - 10.75 m/s^2 with harrow. The vibration level compared with the ISO 2631-1, there was a significant increase in discomfort to the operator's low back, trunk, shoulder hip and adverse effect on the spine.

Using spring and damper below the seat an equivalent suspension system is designed for and rms acceleration on the seat is measured using FFT analyzer.

The measured values of modified tractor seat shows that the vibration is able to reduce from harmful frequency range to near safe zone of 'Health guiding caution zone' in the range of 1.5 - 3.3 m/s^2 with plough, 1 - 1.8 m/s^2 with cultivator and 1.5 - 3 m/s^2 with harrow. Tractor seat with conventional suspension system identified to be above the HGCZ and with the modified suspension system was identified to be near the HGCZ as per the ISO 2631 standards.

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