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A Study of Reduction in the Vibrations of Steering Wheel of Agricultural Tractor

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ABSTRACT
Steering wheel vibration is one of the major factor in determining the operator's comfort in an agricultural tractor. Over the past 20 years automobile quality and consumer perceptions and demands have been an increasing part of the vehicle engineering process. This project deals with study of vibration related issues in steering wheel of tractor. The design and analysis of steering system plays a major role for determining the root cause for the problem. Main sources of steering wheel vibration are found to be engine imbalance, resonance of steering system, lesser damping, road / field induced vibration. Steering vibration study was conducted on various tractor models and one tractor was identified for improvement. Upon detailed analysis on that particular tractor, it was found that the resonance of steering system with engine excitation is the root cause for excessive vibration. Various methods such as shifting the natural frequency away from the second order engine frequency and increasing damping coefficient to reduce the vibration amplitude at resonance are considered to reduce vibrations due to resonance. Axial damper concept is used for vibration reduction. Analysis is done in Matlab Simulink with two degree of freedom model with base excitation.
Keywords: Steering wheel, vibration, dampers, frequency, resonance, amplitude.

I. INTRODUCTION

The term hand arm vibration indicates the vibration from power tools. This vibration occurs due to shocks and movements of power tools. Recently using light weight material the weight of agricultural tractor is reduced. The operator of tractor undergoes whole body vibration transmitted through seat, feet and floor and hand arm. The important thing is to minimise the vibration, because the vibration disturbs blood circulation in fingers and neurological functions of hand and arm. This is known hand arm vibration syndrome (HAVS). Vibration causes uncomfort and failure of various parts of tractor. Tractor Operator undergoes two types of vibrations; one is whole body vibration transmitted via seat, foot and floor ; and the another is hand vibration transmitted via steering wheel and hand control knobs

To prevent the adverse effect of vibration two strategies are used as follows;

I) Controlling vibration at excitation source.
II) Isolation of vibrations in transition path by taking appropriate action.

In these two strategies the I) viz. controlling vibration at excitation source is the best option. Many times, the vibration reduction objective also comes with other constraints of product design like packaging, design simplicity, product development lead time etc. So that this subject have great importance.

In India 13% of the total occupational deaths are due to hand arm vibration syndrome

Vibration exposure action value(rms): 2.5 m/s^2
Vibration exposure limit value(rms): 5 m/s^2

- If this condition is left untreated, it becomes progressively worse; it becomes irreversible, and in extreme cases can lead to very serious problems, such as gangrene.

Fig: Effect of HAVS

Objectives

- To measure the vibration level produced in steering of agricultural tractors.
- To find out the different sources of vibrations.
- To study ambient excitation produced in the steering.
- To do vibration analysis of steering wheel of tractors using analytical and experimental ways.
- To simulate the model in Matlab containing the various parts e.g. steering box, steering column, steering wheel.
- To reduce the vibrations produced by using different vibrations reducing techniques.

II. METHODOLOGY

Vibrations of steering wheel in some determined power range is compared and specific tractor is selected for study and development. Following methodology is adopted in this work.

1. In specific power range make a comparison of vibrations on different tractors.
2. Choose one tractor for study and development.
3. Determination of main cause of vibrations.
4. Experimentation and analysis of results.
5. Constructing mathematical model of vibrations in steering wheel and simulation in FEA software.
6. Sorting the differences in present and improved work in design.
7. Making comparison of computed and measured vibrations.

Vibration Reduction Techniques:

After taking vibration measurements and identifying problems, next task is to fix them. This usually means suppressing by modifying the structure to eliminate the unwanted vibrations effects. There are many methods available for vibration suppression which includes source isolation, absorbers, damping treatment and active suppression. The examples that follow show techniques of vibrations suppression in rotating equipment.

Isolation:

Treating the source of vibrations is the most effective and often most economical solution to vibrations problems. The rotating unbalance may cause the entire structure to vibrate. This can be solved by balancing the rotor and eliminating the vibrating source. Another method of isolation is to add highly damped material between the source and the structure. For example, automobile engines have larger rubber mounts to isolate the chassis from engine.

Absorbers:

Often, in the situation of a noise or vibration problem which is caused by a resonant condition, it is not practical to reduce noise or vibration levels through isolation techniques alone. A vibration absorber is simply a mass-spring-damper system added to the structure and tuned to the same frequency as the offending vibration. The mass-spring-damper system resonates and vibrates with large magnitudes. Thus eliminating or reducing the vibration transmitted from the rest of the structure and reducing the structure and vibration transmitted to other parts of the structure. Standard practice in the automobile industry is to use tuned mass dampers or vibration absorbers to reduce the vibration of many mechanical and structural systems. The problems with the passive dampers are that they add considerable weight to the system and are only effective within the narrow band of frequencies. ATA offers the opportunity to considerably reduce the vibration of a mechanical device in a wider band of frequencies while using less weight.

Measurement of Vibration level in tractor :

It is known that vibrations entering the hand contains contribution from all these measurement direction. The measurement was taken in three directions X i.e. vertical, Y i.e. longitudinal and Z i.e. transverse axis respectively.

Initially tractor was parked on a rough surface. Engine was started. The readings were taken at steering box and steering wheel. Then tractor was driven in rough surface with varying speed and readings were taken at both locations.

Experimental Procedure:

Stage I:

It is known that the vibration entering the hand contains contributions from all three measurement directions. Therefore, measurements are made in all three directions as shown in Figure6.1.The X_h, Y_h and Z_h axes are termed as vertical, longitudinal and transverse axes respectively. The tractor was parked on a rough road surface and the engine was started. Measurements were taken with the gear in neutral position. Initially, the engine speed was increased from idling to various speeds slowly and steadily over a period of 2-3 minutes and the measurements were made. The vibration was not significant at low speeds and it became significant only after certain speed. This was done considering the scarce availability of testing resources. At each engine speed, vibration was measured for a period of 30-40 seconds and stored in the computer for further analysis.

Fig: Accelerometer mounting at steering box

Fig: Accelerometer mounting on steering wheel(running)

Figure shows the measurement setup for the vibrations measurements. The accelerometer was mounted on the steering box as shown. The accelerometer was mounted with the help of wax. The accelerometer was mounted on the steering wheel of tractor. Figure shows the top view of the mounting location of the accelerometer. Vibrations are transmitted from the engine to the steering box and then from steering box to the steering wheel via steering column. Hence, the piezoelectric accelerometer is mounted on the shown location. It gives the maximum transmitted vibration level.

Measurements and Readings

All reading at steering wheel at running condition:

The vibrations are transmitted from engine to steering box and then transmitted from box to steering wheel. Hence it becomes necessary to study the vibration level at the steering box. The accelerometer was mounted on the steering box and acceleration, velocity and displacement. The readings taken for further analysis

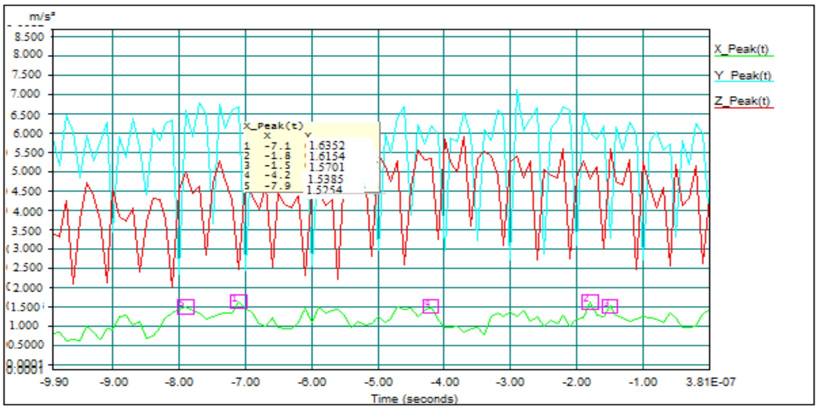

Fig: Acceleration readings at steering wheel in running condition

Figure shows the acceleration level at the steering wheel when the vehicle is at running condition. The rms readings in all three directions are used to calculate the vibration exposure level at the steering wheel. The graph shows the levels in the y and z directions are dominant compared to the vibration level at neutral condition.

Steering box vibrations when vehicle is in running condition

Tractor works in fields on road rough surface. The tractor is driven at speed of 15km/hr. It is found that the vibration level found was much higher as compared to the vibration level at the steady condition.

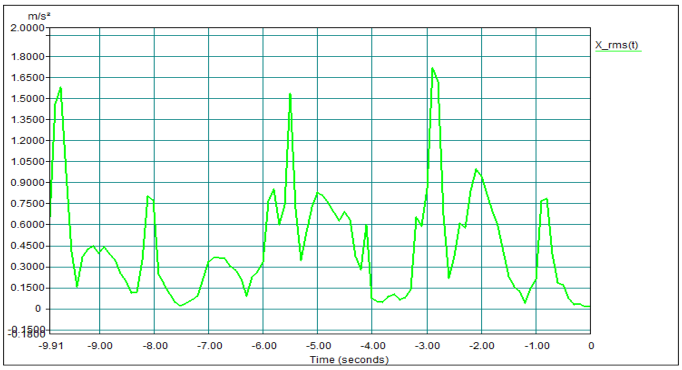

Figure: R.m.s. values in X direction

Above figure shows the rms values of acceleration in x-direction when the vehicle is in running condition on rough road surfaces. The maximum rms value obtained is 1.732 m/s^2

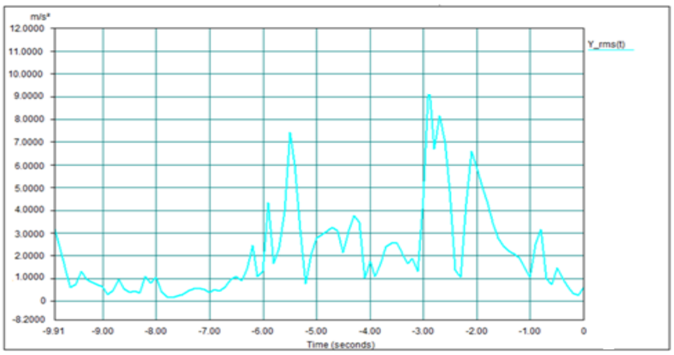

Fig: acceleration Y_rms vs time when vehicle is running

Above figure shows the rms values of acceleration in Y-direction when the vehicle is in running condition on rough road surfaces. The maximum rms value obtained is 9.127m/s^2. The vibration in Y-direction are dominating than in X-direction.

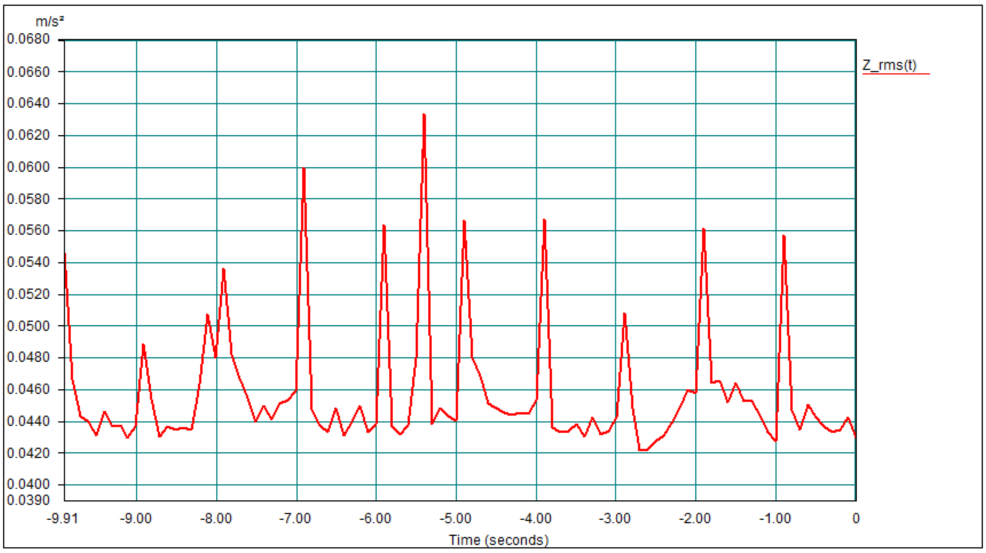

Figure: Acceleration Z_rms at running condition

Above figure shows the rms values of acceleration in Z-direction. The maximum rms value obtained is 0.0623 m/s^2. It is much lesser than in X and Y direction

Stage II

This is second stage of experimentation. In this stage the use of measured values of the acceleration and frequency from the selected tractor were studied. The peak and rms values of acceleration, velocity and displacement were chosen and input is given to the electrodynamic shaker machine. The whole steering system was mounted on shakertop plate with the help of designed fixture. the inputs were given and by giving all specified inputs, the shaker was operated The vibration level was measured with the help of accelometer described in section. following graphs shows the reading taken from the shaker machine experimentation. The steering system was mounted on the shaker machine with the help of designed and specified mounting dimensions. The peak values of the acceleration that are taken from the sample tractor were recorded and given as the input to the electrodynamic shaker machine. The input values of peak vibrations at the steering box and steering wheel are given input to the system. The dampers were mounted between the steering system and mounting plates.

Fig: steering system is mounted on shaker machine

Figure shows the setup for the experimentation of the steering system on the electro dynamic shaker machine. The exciter, steering system is shown. The accelerometer is located at the same location where the readings on the actual tractor are taken to obtain the maximum possible transmitted vibrations.

Fig: Experimental setup on shaker with damper

Figure shows the mounting of accelerometer on steering wheel. The measurements taken are used for analysis purpose. Similarly, damper was mounted on the steering system at the mounting position. As the vibrations are transmitted from the steering box to the steering wheel, it is necessary to measure the vibration at steering box also.

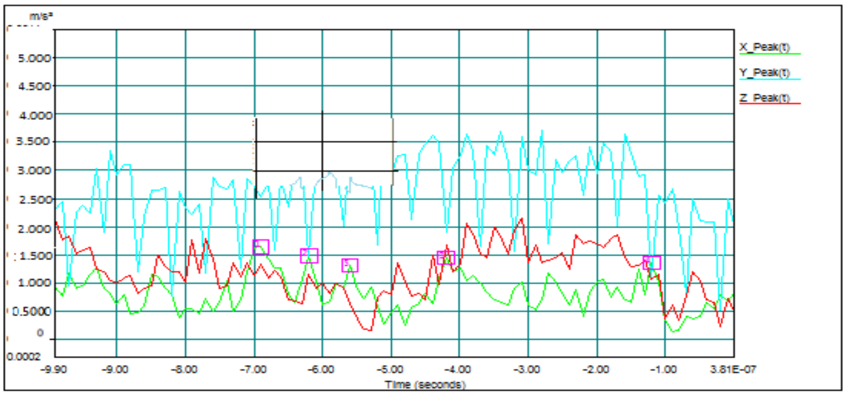

Fig: Reading of Accelerometer at steering wheel at running condition

Above graph shows the rms values of the acceleration, at the steering wheel in all x, y, z directions when the vehicle is in running condition on rough road surfaces. The maximum rms value obtained is 3.7 m/ s^2 , 2.7m/ s^2 , 1.7 m/ s^2 respectively

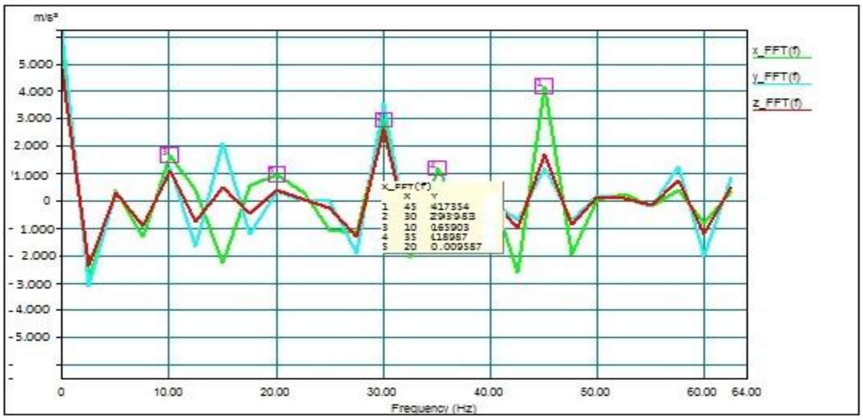

Fig: Reading of Accelerometer at steering box at running condition

Above graph shows the rms values of the acceleration, at the steering box in all x, y, z directions when the vehicle is in running condition on rough road surfaces. The maximum rms value obtained is 4.18 m/ s^2 , 2.8m/ s^2 , 2.7 m/ s^2 respectively

Vibration analysis
Vibration analysis at steering wheel and steering box on actual tractor:

An exposure points system simplifies the risk assessment procedure. The exposure point values equivalent to the action and limit values in the current guidance are as follows:

Exposure Action Value of 2.5 m/s² A (8)
Exposure Limit Value of 5 m/s² A (8)

All of the dig-team operatives are likely to exceed the Exposure Action Value of 2.5 m/s² A (8). However, none of the operatives are likely to exceed the Exposure Limit Value of 5 m/s² A (8) when using the measured equipment for the reported usage times.

For steering box:
With reference to these graphs high peak r.m.s. value in X, Y, Z direction are as follows.
X = 1.6142 m/s², Y = 9.0352 m/s², Z = 0.0643 m/s²
Vector Sum
As per standard vector sum is find out are as follows

$$a_{hv} = \sqrt{1.6142^2{}_{hwx} + 9.0352^2{}_{hwy} + 0.0643^2{}_{hwz}}$$

a_{hv} = 9.17 m/s^2
A (8) Daily Exposure
As per Eq. No. 1.3 Daily Exposure is find out are as follows

$$A (8) = 9.17\sqrt{\frac{5400}{28800}}$$

A (8) = 4.03 m/s^2

For steering wheel
X = 1.61 m/s², Y = 6.6 m/s², Z = 5.9 m/s²
Vector Sum
As per standard vector sum is find out are as follows

$$a_{hv} = \sqrt{1.61^2{}_{hwx} + 6.6^2{}_{hwy} + 5.9^2{}_{hwz}}$$

a_{hv} = 8.99 m/s^2
A (8) Daily Exposure
As per Eq. No. 1.3 Daily Exposure is find out are as follows

$$A (8) = 8.99\sqrt{\frac{5400}{28800}}$$

A (8) = 3.89 m/s^2
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Vibration Analysis of the steering wheel and steering box with the use of dampers:
Steering wheel
After use of damper the vibration exposure values at steering box
X = 3.8 m/s², Y = 2.3 m/s², Z = 1.8 m/s²
Vector Sum
As per standard vector sum is find out are as follows

$$a_{hv} = \sqrt{3.8^2{}_{hwx} + 2.3^2{}_{hwy} + 1.8^2{}_{hwz}}$$

a_{hv} = 4.74 m/s^2
A (8) Daily Exposure
As per Eq. No. 1.3 Daily Exposure is find out are as fallows

$$A (8) = 4.74\sqrt{\frac{5400}{28800}}$$

A (8) = 2.06 m/s^2

At steering box
X = 4.18 m/s², Y = 3.8 m/s², Z = 2.7 m/s²
Vector Sum
As per standard vector sum is find out are as follows

$$a_{hv} = \sqrt{4.18^2{}_{hwx} + 3.8^2{}_{hwy} + 2.7^2{}_{hwz}}$$

a_{hv} = 6.26 m/s^2
A (8) Daily Exposure
As per Eq. No. 1.3 Daily Exposure is find out are as follows

$$A (8) = 6.26\sqrt{\frac{5400}{28800}}$$

A (8) = 2.74 m/s^2

III. RESULT AND DISCUSSION

Using FFT analyzer measurements were taken on steering of tractor.After providing damper fig shows the vibration level on steering wheel and steering box. After measuring the vibration level on steering wheel and box it is analyzed and the acceleration and frequency spectra were obtained. It is observed that acceleration value of the steering wheel which is about 3.3 m/s2 and after providing isolation it is reduced to 2.7 m/s2.. It is found that with frequencies greater than 25 Hz the operator of power tools may experience greater muscle's / tissues fatigue and symptoms of musculoskeletal disorder when working with extended arm posture. Hence when using damping the frequency value decreased upto 10-15 Hz which is comfort zone for hand arm according to the ISO 5349 - 1:2001.

IV. CONCLUSION

Agricultural tractors have been identified as a hazardous machine from the aspect of the whole body vibrations. There is a risk even for those drivers who are exposed to vibrations only one hour a day. There are many negative medical effects resulting from drivers being exposed to vibrations. When the influence of vibrations is short-termed, the symptoms are short breathing, nausea and disturbed balance, whereas long-term influence causes disorders in psychometric, physiological and psychological systems. Although well-known world manufacturers are dedicated to reducing vibrations, most of the world’s tractors are 20 and more years old and do not meet basic ergonomic requests. Here, the effects of vibrations are especially evident. This is why it is important to measure vibration levels constantly, evaluate them and determine the risk for driver’s safety .It has been found that among the different operations selected for the study, the level of hand arm vibration acceleration varied from 4.1 to 3.1 m s-2.

REFERENCES

[1]. Fornaciari L., Pochi D., Vassalini G., Gallucci F, “ Investigation of the vibration transmitted by agricultural tractor to the driver under operative condition”, International Conference: September 15-17, 2008

[2]. Emanuele Bianchini, “Active Vibration Control of Automotive Steering Wheels”, SAE 2005-01-2546

[3]. Rob Brauch, Larson Davis “Vibration Analysis and Standards, A Review of Vibration ExposureRegulations, Standards, Guidelines andCurrent Exposure Assessment Methods”,

[4]. Tewari.V.K*, Vidhu.K.P., Ashok Kumar Arudra, Sweeti Kumari, “Reduction of hand transmitted and whole body vibrationsexperienced by tractor operators by using piezo crystal material”, Agric Eng Int: CIGR Journal,Vol. 15, No.2 209.

[5]. Ahmed Abd Ali Hamid, Dr. Mudhfer Kareem Abdullah, Dr. Ahmed Abdul Hussein Ali, Ali Fahad Fahem, “Effect of Steering Wheel Vibration on drivers Hands in a Two-WheelDrivers Hand tractor”, Volume 17 December 2011 Journal of Engineering

[6]. M.S. Shayaa , J.A Giacomin, E. Dormegnie * and L. Richard, “Human Perception Of SinusoidalRotational Steering Wheel Vibration”.

[7]. Helmut W. Paschold and Alan G. Mayton, “Whole-BodyVibrationBuilding Awareness in SH&E”.

[8]. V.K. Tewari; K.N. Dewangan; Subrata Karmakar, “Operator’s Fatigue in Field Operation of Hand Tractors” , Biosystems Engineering (2004) 89 (1), 1–11

[9]. Monarca D., Biondi P., Cecchini M., Santi M., Guerrieri M., Colantoni A., Colopardi F., “Transmission of vibrations from portable agricultural machinery to theHand-Arm System (HAV): risk assessment and definition of exposure timefor daily action and exposure limits” ,International Conference: September 15-17, 2008 Ragusa – Italy

[10]. Craig Lewitzke and Ping Lee, “Application of Elastomeric Componentsfor Noise and Vibration Isolation in theAutomotive Industry”, SAE TECHNICALPAPER SERIES 2001-01-1447

[11]. Ping Lee, Ali Rahbar, “Active Tuned Absorber forDisplacement-On-Demand Vehicles”, SAE 2..5-01-2545