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Vibration Measurement and Vibration Reduction of Steering Wheel of an Agricultural Tractor

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Abstract*:* ***A tractor is a vehicle specifically designed to deliver a high Torque at slow speeds, for the purposes of hauling a trailer used in agriculture .Steering wheel vibration is major concern in determining the operator comfort in agricultural tractors. Any engineering system possessing mass and elasticity are capable of relative motion. When this motion repeats after a given interval of time, then this motion is known as vibration. In many cases it is undesirable and is a form of wasted energy. This is particularly true in tractors and farm machinery as they generate noise, break down parts and transmit unwanted forces and movements to different components. Vibrations and noise in tractor are generated due to rotating and reciprocating parts, vibrations in engine components, exhaust gases and flow of hydraulic fluids. In this paper, we deal with the reduction in vibration of steering wheel of an agricultural tractor by providing isolation. Isolation makes use of materials and mechanical linkages that absorb and damp these mechanical waves. Also the vibration in steering wheel is measured experimentally and also by using software.***

Keywords: Steering wheel, Vibration, isolation, tractor, comfort

1. Introduction

The term hand arm vibration is frequently used to refer to vibration from power tools, but it does not clearly indicate whether the hand and arm are the origin of the vibration. The term vibration is used to include shocks and movements of any kind. They may result from machine and terrain factors. During the last years, the mass of agricultural tractors has decreased due to the development of strong lightweight materials. The operators of agricultural tractors are exposed to whole body vibrations and shocks. Whole body vibrations are usually transmitted via the seat, the floor and feet, and hand arm. One of the most critical issues in designing and using agricultural tractors is to minimize the vibration level. Excessive exposure to hand transmitted vibration can induce disturbances in blood flow in the fingers and neurological functions of the hand and arm. This is called as hand arm vibration syndrome. HAVS causes symptoms in fingers, hands and arms, as a result of using vibrating tools. It used to be called vibration white finger. The name was changed to HAVS, as other symptoms may occur in addition to white fingers. There are two widely followed strategies for preventing the adverse effects of vibration.

1) Vibration control at excitation source itself
2) Vibration isolation by taking appropriate action in the transmission path.

ISO 5349-1:2001standard outlines the methodology to correlate the measured vibration from steering wheel to hand-arm vibration syndrome through two parameters namely,

1) 8-hour energy equivalent frequency weighted vibration total value and
2) Number of years in which 10% of the operators exposed to vibration may develop hand-arm vibration syndrome.

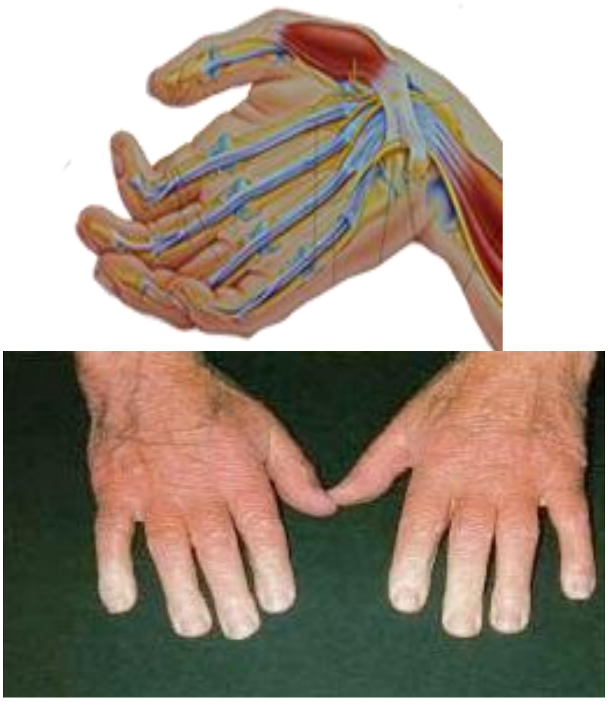

Figure 1: Effect of hand arm syndrme

2. Methodology

Steering wheel vibration on various tractors in the specific power range to be compared and one tractor have to choose for further study and improvement. Following methodology must be adopted in this work.

- Comparison of steering vibration of various tractors in specific power range.
- Selection of one tractor for further study and improvement
- Detailed experimentation on the tractor and analysis of results
- Identification of primary cause of vibration
- Concept generation, detailed design and proto type making of improved design
- Mathematical modeling of steering wheel vibration and simulation in FEA software
- Comparison of present and improved design as per ISO

5349 standard.
- Comparison of computed and measured vibration.

3. Experimental Setup

The experimental setup consists of data acquisition system of FFT analyzer, transducer and personal computer with FFT analyzer software installed. The data acquisition was made possible using tri axial transducer (B&K Endevco model ISOTRAN.) was made by piezoelectronics, 9.929 mV/g, 10.07mV/g and 10.10mV/g sensitive's in x, y, z direction respectively, that was connected to laptop using 4 channel cable. The accelerometer converts acceleration into voltage which is fed to the signal conditioner. The setup was supportive to the sampling rate of 26,400 per second. Accelerometers were positioned in one or more locations such steering wheel, steering box. However the mean values were recorded. The recorded data was auto stored in text/excel files in the laptop.

4. Experimentation Procedure

Procedure to measure the vibration on tractor steering is very much standardized. Vibration measurement on tractor steering have been performed, vibration are measured along x- as axis vertical axis. The measurements were taken in all three directions. The tractor initially was parked near farm and engine was started. The reading were taken at steering box and steering wheel as shown in figure Then the tractor was driven on rough road surface with varying speed and reading were taken at both locations. Tests are carried out on MAHINDRA 575 model on farm field and rough road which is shown in figure Mahindra 575 from Mahindra and Mahindra Ltd. is a 4 strokes, direct injection diesel run tractor with a capacity of 2.5L. The power of tractor is 45hp. The test is carried out on tractor without any trailer attached.

Experimentation was carried out in two stages
Stage I: Measure the actual vibration produced in tractor steering wheel and steering box
Stage II: Measure the vibration level when damper is provided by producing given level on electrodynamic shaker machine.

5. Various Materials for Damping Purpose

As most automotive vibration isolators are made of elastomeric compounds. So the study of the various damping materials becomes essential for our purpose. There are various rubber materials with different properties and different applications are available. Hence study of proper materials and their application becomes mandatory. Rubber is the general name for the existing variety of elastomeric materials, and the term "rubber" can refer to both natural and synthetic compounds. Elastomers have the following three distinguishing characteristics:

1) Resilience and energy storage – Elastomers exhibit a high degree of recovery from large or small deformations through repeated cycling, returning approximately to the original dimension without suffering permanent damage, i.e. resilience. Remarkable energy storage capacity plus the ability to withstand repeated flexing attribute to rubber's utility as a spring material for mountings or suspensions for vehicles, machines, engines and instruments.
2) Large deformability- Elastomers exhibit the capability to withstand relatively high amounts of extension within the working range of the material, which, in extreme cases can reach 300%, and the ultimate elongation may reach 1000% of the original length. Comparatively, steel may not be extended more than .5% of the original length without exceeding the elastic limit, and the ultimate elongation seldom exceeds 25%. 3. Low modulus- When exposed to large deformation elastomers exhibit low stress levels. Rubber is seldom subjected to stresses greater than 6895 kPa (1000psi). Elastomeric dampers works well at the resonance hence it will be beneficial to use the dampers to reduce the vibration level. Additional ingredients are also used in the formulations of both natural and synthetic rubber elastomers to provide specific performance characteristics, and the function of these ingredients is outlined in the following table:

Table 1: Properties of material and applications [8]

	Elastomer	*Major properties*	*Application*
1	Natural Rubber	Broader properties Excellent tensile strength and tear resistance	Powertrain mounts, shock and strut mounts, front axle bushings, mounts
2	Butyl	Inert, excellent weathering resistance, high damping	Bumpers, vibration dampers
3	Poly-Urethane	Excellent weathering resistance, high gum strength, high damping	Body mounts, jounce bumpers, suspension bushings
4	Poly-butadiene	Resilience and low temperature flexibility better than NR and IR	Same as Natural Rubber

6. Mathematical Model

With the introduction of dampers in the system, a simple mathematical model was developed to predict the vibration at the steering wheel. When a dynamic system is excited by the motion of the support point, the same is considered as a support motion or base motion problem.

Let y and $x1$ be the harmonic motion of support base and displacement of steering box respectively. Let $x2$ be the displacement of steering column and wheel assembly. $m1$ and $m2$ are the masses of steering box and steering column-wheel assembly respectively. The free body diagrams of masses $m1$and $m2$ are shown in Figure . The derived equation gives the transmissibility from the engine to the steering wheel.

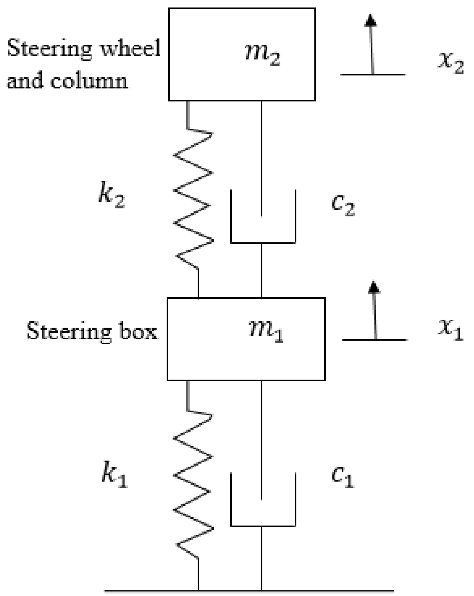

Figure 2: Two DOF model

After drawing free body diagram:
Equation of motion for *m2* is given by Eq.

$$m_2\ddot{x}_2+c_2(\dot{x}_2-\dot{x}_1)+k_2(x_2-x_1)=0$$

Similarly, equation of motion for *m1* is given by Eq. and Eq.

$$m_1\ddot{x}_1+k_1(x_1-y)+c_1(\dot{x}_1-\dot{y})=k_2(x_2-x_1)+c_2(\dot{x}_2-\dot{x}_1)$$

$$m_1\ddot{x}_1-k_2(x_2-x_1)-c_2(\dot{x}_2-\dot{x}_1)+k_1x_1+c_1\dot{x}_1=k_1y+c_1\dot{y}$$

Combining equations into matrix form

$$\begin{pmatrix} m_1 & 0 \\ 0 & m_2 \end{pmatrix}\begin{Bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{Bmatrix}+\begin{pmatrix} c_1+c_2 & -c_1 \\ -c_2 & c_2 \end{pmatrix}\begin{Bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{Bmatrix}+\begin{pmatrix} k_1+k_2 & -k_2 \\ -k_2 & k_2 \end{pmatrix}\begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix}=\begin{Bmatrix} k_1y+c_1\dot{y} \\ 0 \end{Bmatrix}$$

Assuming $y=Ye^{i\omega t}$, $x_1=X_1e^{i(\omega t-\phi)}$ and $x_2=X_2e^{i(\omega t-\phi)}$

Solving for *X2/Y*

$$\frac{X_2}{Y}=\frac{\begin{vmatrix} k_1+k_2-m_1\omega^2+i\omega c_1+c_2) & k_2+i\omega c_2 \\ -k_2-i\omega c_2 & 0 \end{vmatrix}}{\begin{vmatrix} k_1+k_2-m_1\omega^2+i\omega(c_1+c_2) & -k_2-i\omega c_2 \\ -k_2-i\omega c_2 & k_2-m_2\omega^2+i\omega c_2 \end{vmatrix}}$$

The magnitude of the transmissibility from engine to steering wheel is given by

$$\left|\frac{X_2}{Y}\right|=\sqrt{\frac{(k_1k_2-c_1c_2\omega^2)^2+((k_1c_2+k_2c_1)\omega)^2}{(k_1k_2-(m_1k_2+m_2k_1+m_2k_2+c_1c_2)\omega^2+m_1m_2\omega^4)^2+((k_2c_1+k_1c_2)\omega-(m_1c_2+m_2c_1+m_2c_2)\omega^3)^2}}$$

7. Methodology for vibration reduction

Due to the complex fabricated structure it is difficult to provide more stiffness since it will increase the weight. This will corresponds to increase in the natural frequency. Hence it will be beneficial. The present steering is one of the lightest in its range. To avoid the resonance we have to reduce the weight since to get desirable natural frequency. This is practically impossible to execute. Since damper works good at resonance hence it will be beneficial to provide elastomeric damping to reduce much vibrations. From the study of different elastomeric materials discussed in section it is found that Polyurethane as an axial damper.

Isolation was provided at the mounting of the steering box by pads. The pads were constraints with the studs. The axial damper was selected of compressive stress of 143kPa. Polyurethane has very good damping characteristics at resonance. A hardness of 60A was chosen for the damper. It shows better results than other elastomeric materials like natural rubber, NBR, EPDM.

8. Measurements and readings

Measurements were made in all three directions as shown in Figure. the Xh, Yh and Zh 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.

Readings further taken were studied for the next stage. The values obtained at the steering wheel and the steering box were taken and given input to the electrodynamics shaker machine and then results were measured with FFT analyzer with the help of piezo electric transducer.

Figure 3: Accelerometer mounting at steering wheel

Figure 4: Accelerometer mounting at steering box

9. Reading taken with the use of FFT analyzer

Figure 5: Reading of Accelerometer at steering wheel

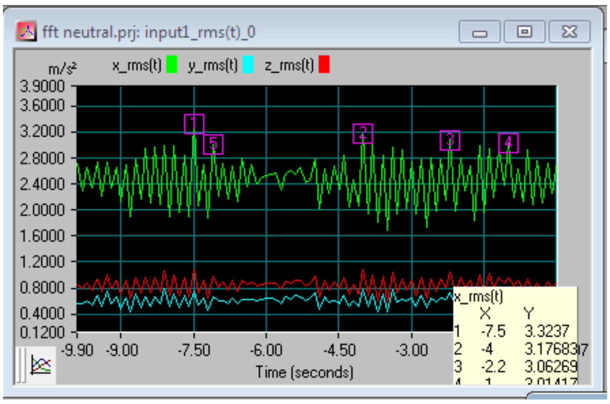

Figure 6: Accelaration vs time at steering wheel

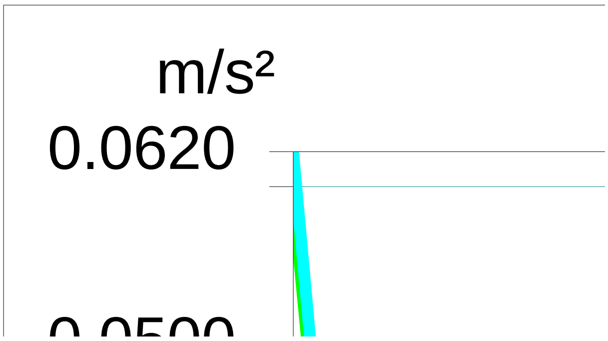

Figure 7: Acceleration vs frequncy graph at steering box

10. Reading taken with the use of FFT analyzer with damper

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 electrodynamic shaker machine was developed and manufactured by Sarswati Dynamics Pvt Limited, Pune. The shaker is essentially an electro-magnetic assembly comprises of electro-magnetic cicuit cinsisting of stationary (field) and moving coil which is part of head that moves or vibrates. The whole steering system was mounted on shakertop plate ith 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.

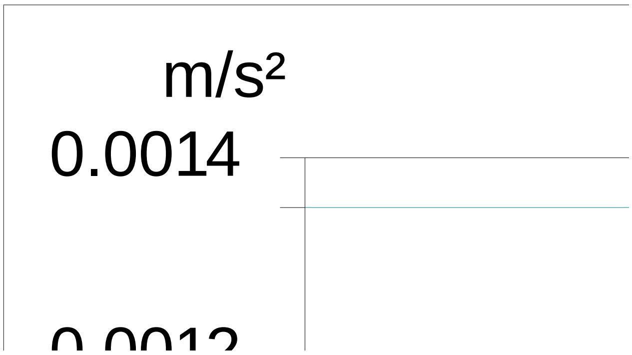

Figure 8 reduced level of frequency with the use of damper

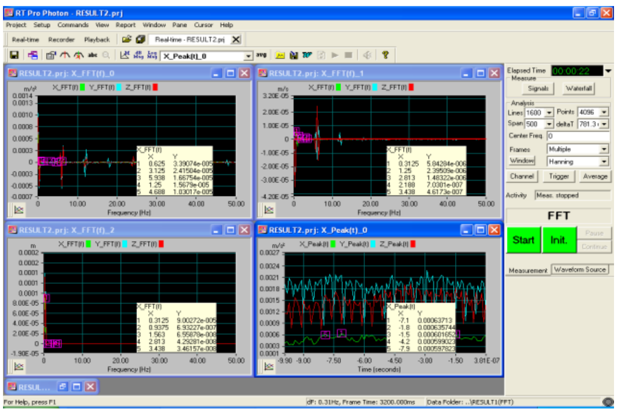

Figure 9: Reading taken at steering wheel with damping provided

Figure 10: Experimental setup on shaker

Figure 11: location of accelerometer when steering system is mounted on shaker machine

11. Result and Discussion

Measurements were taken on Steering of tractor was taken by using FFT analyzer with the help of laptop. Figure-5 shows the vibration level on steering wheel. Likewise, figure 9 and figure-10 shows the vibration level on steering wheel and steering box after providing damper. The vibration level on the steering wheel and box has measured and analyzed and the acceleration and Frequency spectra for the chosen working conditions were obtained. It is found that acceleration (rms) value of steering wheel is about 3.3m/s and after providing isolation it is decreased to 2.7 m/s. that means decrease in the acceleration by about 0.6 to 0.9m/s. The results indicate that the maximum transmissibility was observed in the first two frequency interval (in Hz) i.e.1-25 and 25-50.the frequency interval was 1-25 (steering box), 1-25, 25-50 (base steering), 25-50 (base steering). It is found that the operators of power tools with frequencies below 25 Hz may experience greater muscles/tissues fatigue and symptoms of musculoskeletal disorder when working with extended arm posture. Hence with the use of damping the frequency value decreased upto 10 to 15 Hz which is comfort zone for hand-arm according to the ISO 5349-1:2001

12. Conclusion

The base tractor chosen for study had shown high level of vibrations. It is found that resonance as the primary cause of vibrations produced. Elastomeric damper was found to be the most appropriate solution. The axial dampers provide a reduction of about 33% of total vibration level produced.

References

[1] Kandavel Gowri Shankar, Shrikant Samant, Nrusingh Mishra and Mokashi Rajshekar, "Steering Wheel Vibration Reduction for Agricultural Tractors", SAE International ,(2009)-26-046

[2] V. Gogliaa, Z. Gospodari, S. Kossuti, D. Filipovi, Hand-transmitted vibration from the steering wheel to drivers of a small four-wheel drive tractor, Applied Ergonomics 34 (2003) 45–49

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

[4] K. N. Dewangan, V. K. Tewari , Handle grips for reducing hand-transmitted vibration in hand tractor, International Agricultural Engineering Journal (2010) Vol. 19, No. 2

[5] Eugene I. Rivin, Vibration Analysis vs. Vibration Control, SAE International, (2005)-01-2548

[6] Rajvir Yadav , V.K. Tewari , Tractor operator workplace design-a review, Journal of Terramechanics 35 (1998) 41-53

[7] Thomas A. McKenzie, William J. Hicks and Richard L. Conaway, New Generation of Vibration Isolation for the Conventional Truck Cab ,SAE International (2000)-01-3515

[8] Craig Lewitzke and Ping Lee, "Application of Elastomeric Components for Noise and Vibration Isolation in the Automotive Industry", SAE International, 2001-01-1447