Tractor Seat Analysis with Experimental and Simulated Results during Tillage

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Abstract- Tractors work in fields and operators are mostly under the influence of negative vibrations as tractors are not provided with any type of suspension systems. These vibrations are harmful for the health of driver as drivers has to work for long hours. The present study is focused to analyse the seat of tractor experimentally by collecting the real time data from tractor seat while working in fields with implements during tillage process. Tri-axial accelerometer was used to collect the actual data from seat base and was stored in data collection unit. Based on the real-time data a dynamic model of tractor along with seat was developed in MATLAB-Simulink for further analysis of vibrations. Measurement of vibrations is the basis for developing a good tractor seat with reduced vibrations.The ISO-2631 standard is accepted by the ministry of health and medical education and American Conference of governmental industrial hygienists (ACGIH) is used for general body vibrations evaluation. Although, there still remained many problems to be solved but this study will provide a good base to work in this direction.

Keywords -Tractor, Implements, Vibration, Modelling and Simulation, Power Spectral Densities.

1. INTRODUCTION

Vibrations up to 12 Hz affect all the human organs, whereas vibrations above 12 Hz have a local effect. Cyclic low frequency (4-6 Hz) movements, such as movements of tires over an irregular road, can cause body resonancegiven by Griffin (1996). Biodynamic research has shown that prolonged exposure to high-intensity body vibrations increases the risk of deteriorating health. The lumbar spine and associated nerve tissue may be affected, metabolism and other internal factors canhave additional effects. According to International Organization for Standardization, the degeneration of intervertebral discs, vertebrae and muscle pain are different effects of whole body vibration.

Griffin (1985), Martin and Smith (2004) suggested that the vibration characteristics which mostly influence human response are the direction, the point of contact with the body, frequency, magnitude, duration etc. Resonance occurs when the excitation frequency matches one of the natural frequency of the system. This results in large oscillations, which are harmful/undesirable. When a system is disturbed and can vibrate by itself, the frequency at which it vibrates without damping and without external force is known as its natural frequency. If the damping is present, then it is; known as damped natural frequency of the system. Most seats exhibit resonance at low frequencies, which results in higher magnitude of vertical vibrations occurring on the seat.

2. MATERIALS AND METHODS

The real time data was collected from the tractor seat. The experiment was conducted for two different implements. First time data was taken from tractor seat when the tractor was moving with plough and second time disc harrow (Fig 2.1) was used as implement for tillage process.

Fig 2.1 Tractor with Chisel Plough and Disc Harrow

During both cases vibrations were measured with tri-axial piezoelectric accelerometer (Fig 2.2). Tri-axial accelerometer was fitted on the seat base of test tractor to measure vibrations transmitted to the seat of tractor. The frequency sensitivity range of an accelerometer was 2-8000 Hz. Every time, acceleration levels were measured simultaneously along three perpendicular directions namely X longitudinal (pitching), Y transversal/lateral (rolling), and Z vertical (bouncing/heave) on the base of the tractor seat.

Figure 2.2 Location of tri-axial accelerometer on the base of tractor seat.

A setup was made for the measuring vibration in X, Y and Z direction(Fig 2.3). The vibration measuring accelerometer was capable to quantify the instantaneous vibration of the X, Y and Z axes at 10 Hz frequency.

Figure2.3 Tri-axial Sensor and Data Acquisition unit setup used for the measurement of vibrations

The tractor was made two run at two constant speed during both cases and the real time data was recorded separately for each case along horizontal, transverse and vertical directions.

3. ANALYSIS OF DATA

The figure 3.1 shows the measured acceleration values in horizontal (x), transverse (y) and vertical (z) directions. The forward speed of tractor was kept constant at 2.30 Km/hr. As the figure shows when tractor was made to work with tillage implements (chisel plough) the measured RMS values of acceleration was highest in transverse (y) direction and lowest in horizontal (x) direction and the vertical (z) direction values lies in between that of lateral (y) direction and longitudinal (x) direction.

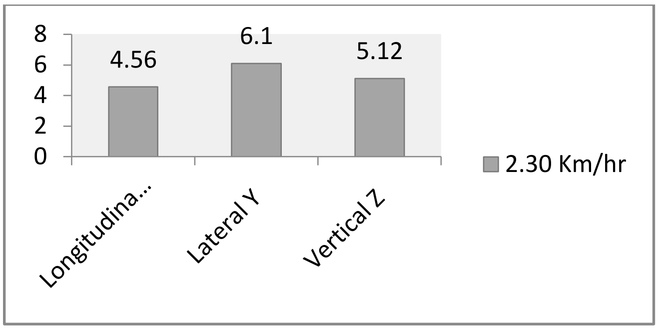

Figure3.1 RMS acceleration in all three directions at tractor's seat with implements

4. SIMULATED MODEL OF TRACTOR -IMPLEMENT SYSTEM

In present work simulation of Full tractor vibration model with hitched implement was created.Moment of inertia and mass of tractor with implements was the key factor in representing the tractor-implement structure. The dynamic model of tractor and implement is shown in figure 4.1. Due to surface roughness front tires and rear tires of tractor are subjected to displacement excitations q_{fz}(t)q_{rz}(t) respectively. Because of the difference in amplitudes of qfz(t)and q_{rz}(t) an angular displacement with respect to centre of mass comes into picture. Due to this angular displacement with respect to mass centre roll, yaw and pitch movements of tractor came into the picture.
The ground excitation relation between front axle and rear axle of the tractor-implement system at any instant i by considering the time lag between q_{fz}(t)and q_{rz}(t) can be expressed as

$$q_{fzi}(t) = q_{rzi}(t+\tau) \qquad (4.1)$$

Whereq_{fzi}(t) and q_{rzi}(t) are displacement excitations at front and rear axles respectively, Ʈ is time lag and can be calculated as

$$\tau = \frac{l_{bf} + l_{br}}{v}$$

Where $l_{bf}$is distance of mass centre between chassis and front axle, l_{br} is the distance of mass centre between chassis and rear axle. Velocity of tractor-implement system is represented by v.

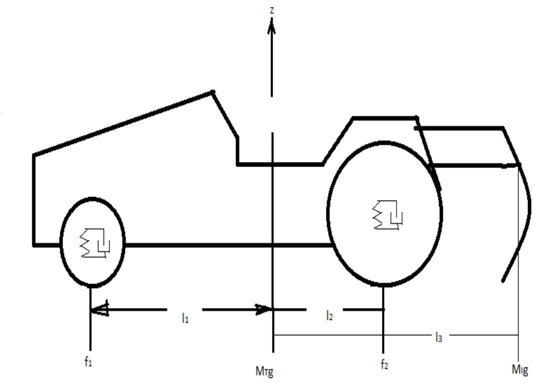

Figure 4.1 Dynamic Model of Tractor Implement System

The motion equations can be expressed as

$$(M_T + M_I)\ddot{z} = f_1 + f_2 - (M_T + M_I)g \qquad (4.2)$$

The displacement of wheels can be calculated as

$$z_1 = z + \left(l_1 + l_3 \frac{M_I}{M_T + M_I}\right) \qquad (4.3)$$

$$z_2 = z + \left(l_2 - l_3 \frac{M_I}{M_T + M_I}\right) \qquad (4.4)$$

The effect of implement on displacement of wheels can be calculated from equations (4.3) and (4.4). So the effective mass of tractor and implement will be expressed by m_t and its effect on wheel displacements, roll, yaw and pitch of tractor implement system will be included by using equations (4.1) to (4.4). Off -road vehicles like tractors operate without primary suspension. The tires play a role of spring cushion due to the bending of the tire and the properties of the air in the reduction of energy. The conventional suspension system of the tractor is modelled as damping of the tires of the tractor and the driver's /operator seat, which is a type of suspension for the operator of the tractor. Since the front axle of the tractor rotates towards the centre of the tractor chassis, this must be considered when modelling the vibration model of the tractor.

5. SIMULINK FULL TRACTOR MODEL WITH IMPLEMENT

Figure 5.1 shows a developed MATLAB- Simulink computer model of the full tractor model.

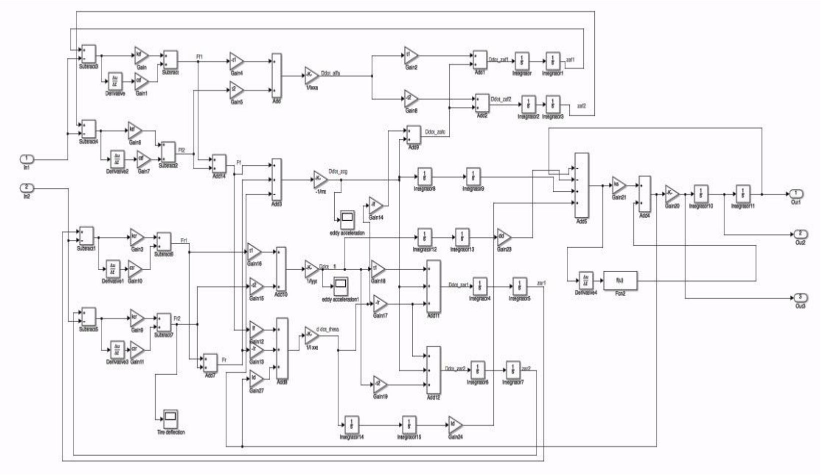

Figure 5.1 Full Tractor-Implement Simulink Model

6. RESULTS AND DISCUSSION

The parameter values of tractor were put into MATLAB Simulink model of tractor with implements and RMS values of simulated model was compared with experimental RMS values. Some parameters was redefined to reduce the percentage error in measured and simulated values. The modified inputs resulted in RMS errors of 5.2%, 1% and 2.2% respectively in X, Y and Z directions. Hence, the modified model indicated that model is reliable in simulating the seat acceleration caused by a tractor moving over random irregularity. To validate the developed vibration model, the results of the modified model obtained in this investigation were compared with the calculation of the RMS value of acceleration and the estimation of the simulation error used by other researchers Adams (2002) Sarami (2009). The modified model showed excellent results with the simulation error of 5.2%, 1% and 2.2%, which was found to be lower than 10% of the developed models of other studies.

7. CONCLUSIONS

As the errors in simulated and measured values are less than 10% so this model can work accurately for vibrations of tractor seat during tillage. As the model is comparable with actual tractor –implement system, a number of other studies can be carried out by changing the input parameters like speed and type of tillage implement in simulated model without performing actually on tractor. With use of this model further studies to design a controller to reduce tractor seat vibrations can be designed.

REFERENCES;

[1] Gu, Z.Q.,Oyadiji, S. O., “Application of MR damper in structural control using ANFIS method”, *Computers and Structures*, 86, pp. 427–436, 2008.

[2] Han,Y. M., Jung, J. Y., Choi, S. B., Choi, Y. T., Wereley, N. M., “Ride Quality Investigation of an Electrorheological Seat Suspension to Minimize Human Body Vibrations,” *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, Volume: 220, pp. 139–150, 2006.

[3] Han, Y. M., Nam, M. H., Han, S. S., Lee, H. G., Choi, S. B., “Vibration control evaluation of a commercial vehicle featuring MR seat damper , *Journal of Intelligent Material Systems and Structures*,13(9), pp. 575-579, 2002.

[4] Hansen, M. R., & Andersen, T. O., “Active Damping of Oscillations in Off Road Vehicles,” *8th Scandinavian Intl Conference on Fluid Power*, 2, pp. 1073-1085, 2003.

[5] Hansson, P. A., “Optimization of Agricultural Tractor Cab Suspension Using the Evolution Method, “*Computers and Electronics in Agriculture*, 12, pp. 35-49, 1995.

[6] Hansson, “Rear axle suspensions with controlled damping on agricultural tractor,” *Computers and Electronics in Agriculture*, 15, pp. 123-147, 1996.

[7] Hansen, M. R., Andersen, T. O., “Active damping of oscillations in off road vehicles,” *8th Scandinavian International Conference on Fluid Power*, 2, pp. 1073-1085, 2003.

[8] Heo, S., Park, K., Hwang, S., “Performance and design consideration for continuously controlled semi-active suspension systems,” International Journal of Vehicle Design, 23 (3), pp.376-389, 2003.

[9] He, Y., McPhee, J., “Multidisciplinary design optimization of mechatronic vehicles with active suspensions,” *Journal of Sound and Vibration*, 283, pp. 217–241, 2005.

[10] Hiemenz, G. J., Hu, W., Wereley, N. M., “Semi-active magnetorheological helicopter crew seat suspension for vibration isolation,” *Journal of Aircraft*, 45, pp. 945–953, 2008.

[11] Hilton, D. J., Moran, P., “Experiments in improving tractor operator ride by means of a cab suspension,” *Journal for Engineering Research*, 20 (4), pp. 433-448, 1975.

[12] Ho, D. W., Niu,Y.,“Robust fuzzy design for nonlinear uncertain stochastic systems via sliding-mode control,” *IEEE Trans Fuzzy System*, 15, pp. 350–358, 2007.