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VIBRATION MEASUREMENT AND ANALYSIS OF TRACTOR DRIVER SEAT VIBRATION IN AGRICULTURAL FIELD

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ABSTRACT
Increased vehicle capacity and speed, induced by higher work costs, creates a lot of vibration problems therefore reducing the vehicle life, working precision and driver's comfort. Suspension systems should be developed in such way that they minimize the transmission of harmful vibrations and shocks as much as possible. The low-frequency range (2–8 Hz) is crucial for good driver comfort and health, and work efficiency. Operators of agricultural equipment perform various duties at work that expose them to a variety of risk factors that may lead to health problems. A few of the health hazards among operators of construction equipment are whole-body vibration and musculoskeletal disorders. The objective of the study was to evaluate the vibrations transmitted through the tractor driver's seat. In this study the vibration transmitted through the seat of a four-wheel drive tractor equipped with different types of instruments were measured on different types of conditions and at different speeds using OR34-2, 4 Channel FFT analyser and analysed according to the ISO standard. From the observations it is seen that the values for the root-mean-square (RMS) accelerations levels measured on the driver's seat was increased above the comfort range of the operator, as forward speed of travel increased under most of the operating conditions that may lead to health problems.

KEYWORDS:RMS Acceleration, Whole body vibration, Health problem, Tractor Seat, Suspension system.

INTRODUCTION
During everyday activities, agricultural machinery operators are exposed to many negative influences that have harmful impact on the operator. Increased vehicle capacity and speed, induced by higher work costs, create a lot of vibration problems, reducing the vehicle life, working precision and operator's comfort. These vibrations especially affect the operators of heavy agricultural tractors where they are transmitted through the tractor seat, results in the whole body vibration (WBV) of a driver. In comparison to obvious improvements in other performances of agricultural tractors the protection of operators from vibrations is unsatisfactory. The tractor chassis does not have any suspension system, and the tires, which are relatively flexible, are only suspension that absorbs the vibrations. Due to this the tractor operators are subject to relatively high-level vibrations. Vehicle Suspension systems should be developed in such way that they minimize the transmission of shocks and harmful vibrations as much as possible. The low-frequency range (2–8 Hz) is crucial for good operators comfort and health, and work efficiency.[6]

A. Tractor seats
Unlike passenger vehicles, the suspension systems of many off-road vehicles, such as tractors, consist only of the tire and the seat, as there is no primary suspension system connecting the vehicle wheel to the chassis. Pre-1960s tractor operators sat in a metal bucket and relied upon a cushion for comfort. Modern tractors incorporate a variety of suspended seat designs including compact mechanical seats for small tractors and self leveling seats in larger tractors. The main design criterion for these is minimization of the root-mean square(RMS) acceleration level of the driver in accordance with International Organization for Standardization (1997)(ISO 2631:1997) comfort levels. The suspension system on most commercially available tractor seats comprises a mechanical spring and damper. This type of system responds passively to vibrations transmitted to the driver from the terrain over which the tractor is driven. The

performance of passive commercial tractor seats has been widely researched and it was found that drivers were often subjected to vertical vibration levels that exceed the ISO exposure limits. The latter found considerable performance differences between eleven commercial seats and the inference is that some commercial passive seat designs are far from optimal. Note that studies into tractor seats tend to focus on vibrations in the vertical direction. However, research into fore-and-aft suspension systems for tractor seats were undertaken and consequently, some commercial seats now offer the option of fore-and -aft isolators.

B. Vehicle Primary Suspensions

Primary suspension is the term used to designate those suspension components connecting the axle and wheel assemblies of a vehicle to the frame of the vehicle. This is in contrast to the suspension components connecting the frame and body of the vehicle, or those components located directly at the vehicle's seat, commonly called the secondary suspension. There are two basic types of elements in conventional suspension systems. These elements are springs and dampers. The role of the spring in a vehicle's suspension system is to support the static weight of the vehicle. The role of the damper is to dissipate vibrational energy and control the input from the road that is transmitted to the vehicle. The basic function and form of a suspension is the same regardless of the type of vehicle or suspension. Primary suspensions will be divided into passive, active adjustable and semi active systems.

C. Spring rates

Passive vertical seat suspension systems incorporate either a mechanical spring or a self-leveling pneumatic system. Both have a limit to the reduction in vibration isolation that they can achieve. Practical constraints due to the allowable suspension working space limit the extent to which vibrations transmitted to the driver can be reduced. Typical commercial tractor seats have a working space of 740 mm. While the use of low stiffness springs is desirable, (they filter a wider range of input vibrations than high stiffness springs) the accompanying increase in length restricts their use. KAB seating (a manufacturer of tractor seats) gave a typical stiffness value for a mechanical commercial seat as approximately 5.5kN/m.

D. Passive Suspensions

A passive suspension system is one in which the characteristics of the components (springs and dampers) are fixed. These characteristics are determined by the designer of the suspension, according to the design goals and the intended application. Passive suspension design is a compromise between vehicle handling and ride comfort, as shown in Figure 1. A heavily damped suspension will yield good vehicle handling, but also transfers much of the road input to the vehicle body. When the vehicle is traveling at low speed on a rough road or at high speed in a straight line, this will be perceived as a harsh ride. The vehicle operators may find the harsh ride objectionable, or it may damage cargo. A lightly damped suspension will yield a more comfortable ride, but can significantly reduce the stability of the vehicle in turns, lane change maneuvers, or in negotiating an exit ramp. Good design of a passive suspension can to some extent optimize ride and stability, but cannot eliminate this compromise.

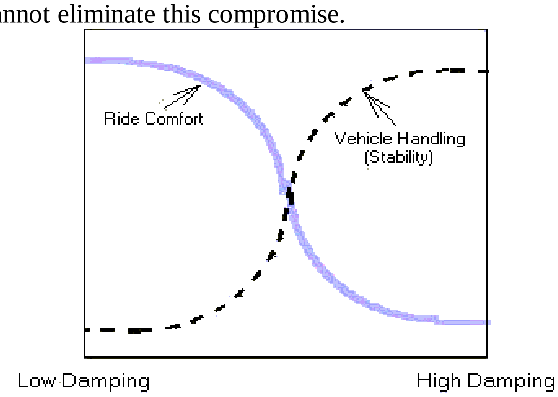

Fig 1. Damping Compromise for Passive Dampers

E. Lowering spring rate

A linear extension spring positioned as shown in Fig.1.5 has a non-linear effective spring rate with respect to the vertical vibrations. This arrangement gives a softening spring rate with respect to the vertical force, see Fig 1.6 and 1.7. As the seat mechanism compresses, the spring rate decreases. When in static equilibrium, the seat has a low vertical stiffness at that point. For a working space of approximately 740mm a seat stiffness of about 4kN/m can be achieved at the equilibrium point. The natural frequency of the seat at the equilibrium point is approximately 1.1Hz. This compares with 1.3Hz for a seat with a stiffness of 5.5kN/m and 85.5 kg mass. Thus, an effectively lower natural frequency can be achieved by using non-linear elements. The stiffness increases as the seat extends and decreases as the seat compresses, until it hits the end stops. Note that the positioning of the end stops is critical in this arrangement, because if the seat passes through a critical point it would collapse. In order to take maximum advantage of the low stiffness characteristics of the system, the end stops are mounted just before the collapse point.

MATERIALS AND METHODS

In this 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 analyser and then analysed 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, ploughing and cultivating) at different road conditions (on road, sugarcane field and flat field) with two different running speeds at 5km/hr and at 8km/hr. from this it is recognised that agricultural tractor operators are exposed to high level of whole body vibration

A. FFT ANALYZER

FFT Spectrum Analyzer takes a time varying signal, like you would see on an oscilloscope trace, and compute its frequency spectrum. 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. It uses for measurements which are very hard in the time domain are very easy in the frequency domain. Consider the measurement of harmonic distortion. It's hard to quantify the distortion of the 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. Another example is noise analysis. Looking at an amplifier's output noise on an oscilloscope basically measures just the total noise amplitude. On a spectrum analyzer, the noise as function of frequency is displayed. It may be that the amplifier has a problem only over certain frequency ranges. In the time domain it would be very hard to tell. Many of these measurements were once done using analogue spectrum analyzers. In simple terms, an analogue filter was used to isolate frequencies of interest. The signal power which passed through the filter was measured to determine the signal strength in certain frequency bands. By tuning the filters and repeating the measurements, a spectrum could be obtained.

Sub-subheading

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RESULTS AND DISCUSSION

Measurement of acceleration on conventional tractor seat

Plough connected to tractor

Frequency	Ploughing flat field rms m/s^2		Ploughing sugarcane field		Plough Transport (on road)	
Hz	05 km/hr	08 km/hr	05 km/hr	08 km/hr	05 km/hr	08 km/hr
0.50	0.3187	0.2679	0.2322	0.2086	0.4121	1.3410
1.00	0.5562	1.0668	1.3620	0.8116	0.3655	0.9251
1.50	0.9655	1.1369	0.8151	1.3294	0.5596	0.5485

2.00	1.0296	2.6989	1.4892	1.0709	1.4498	1.6002
2.50	1.8287	2.4687	0.9619	0.5523	2.3595	1.7655
3.00	0.9192	2.9616	2.6771	0.9680	1.5545	0.9130
3.50	1.4732	2.4772	4.8305	3.3689	2.5539	2.4014
4.00	1.7441	2.4940	3.4370	3.0764	1.5821	1.4168
4.50	4.2158	3.4917	5.8236	7.6823	3.0482	2.3105
5.00	3.0009	3.1641	4.6656	4.7409	2.4865	1.7255
5.50	6.0348	4.3510	6.5383	7.1583	2.9558	3.0477
6.00	5.2484	4.4738	4.0548	6.1488	2.5662	3.9624
6.50	6.1093	3.5139	5.1141	6.7203	2.8352	3.2391
7.00	5.9488	4.0850	3.8538	5.6188	3.3865	3.7425
7.50	4.1657	3.0969	4.9715	3.5728	1.5436	2.6596
8.00	4.5491	1.8308	2.3069	3.9410	1.7379	3.6449
8.50	3.5845	2.4503	3.0931	3.3599	1.2308	2.4116
9.00	2.6993	1.9165	1.6413	2.5684	0.9195	1.4031
9.50	3.8590	1.7581	1.5473	2.7461	1.6524	1.8307
10.00	3.3996	1.5594	1.8258	3.5880	1.7939	1.3791

Cultivator connected to tractor

Frequency, Hz	Cultivating flat field rms		Cultivating sugarcane field		Cultivator Transport (on	
	05 km/hr	08 km/hr	05 km/hr	08 km/hr	05 km/hr	08 km/hr
0.50	0.3299	0.3618	0.2600	0.2117	0.2971	0.3050
1.00	0.3558	0.3107	0.2971	0.2868	0.4517	0.3233
1.50	0.4862	0.4936	0.3608	1.4043	0.6786	0.6089
2.00	0.6409	0.9864	1.4685	2.5485	0.3916	0.3593
2.50	0.6155	0.3501	0.4845	0.7089	0.5382	0.5953
3.00	0.6857	0.5316	1.6224	1.5675	0.6016	0.9616
3.50	1.0725	0.7673	1.1688	1.6094	0.6336	0.8408
4.00	0.8510	1.3811	2.7618	2.5757	0.5539	0.7016
4.50	1.8440	2.8510	3.5237	1.7135	2.3424	2.8951
5.00	2.1813	1.4173	2.3999	1.1958	1.1430	1.8210
5.50	5.0549	3.2421	4.1879	3.5502	3.7674	6.3852
6.00	3.4176	4.4235	2.5037	4.3830	3.9664	4.5730
6.50	3.2488	3.4622	4.6324	4.6022	3.8843	5.6902
7.00	3.7357	2.6514	2.9657	3.0811	2.5305	2.8690
7.50	2.5325	2.0500	1.8086	2.6457	2.1193	2.5575
8.00	2.0716	1.8583	2.5237	2.9507	2.1756	2.2722
8.50	1.5595	1.4693	1.6962	1.9173	1.4658	1.8077
9.00	1.6216	1.1601	1.2872	1.2230	0.8834	0.9922
9.50	2.2337	1.9495	1.2211	1.5524	1.1547	1.4155

10.00	2.6450	2.4748	2.2672	1.0893	1.1928	1.1986

Horrow connected to tractor

Frequency, Hz	Harrowing flat field rms m/s^2		Harrowing sugarcane field rms m/s^2	
	05 km/hr	**08 km/hr**	**05 km/hr**	**08 km/hr**
0.50	0.3183	0.3019	0.2947	0.3410
1.00	0.3375	0.2965	0.7830	1.1392
1.50	0.5598	0.3693	1.2818	2.0216
2.00	0.4669	0.4371	1.2368	1.1789
2.50	0.4368	1.2897	2.6722	1.0113
3.00	1.1388	0.8360	1.7993	1.4498
3.50	1.4464	2.7239	3.1446	2.9095
4.00	1.9809	0.8513	4.2574	3.7003
4.50	1.5970	3.0340	6.3844	2.9802
5.00	1.6884	1.9748	3.1684	3.7576
5.50	5.1635	2.6414	11.1460	8.1312
6.00	4.7850	4.5666	8.3283	8.7487
6.50	3.8019	3.9261	9.7371	5.8850
7.00	4.8572	6.7085	10.7557	7.6520
7.50	4.0829	2.1755	5.6903	4.5031
8.00	2.9423	1.4356	4.6301	4.0471
8.50	2.9434	1.9780	4.6650	4.0718
9.00	2.6802	1.2888	4.1035	2.7309
9.50	2.5279	1.2121	6.0188	5.9858
10.00	2.7173	1.9749	7.0350	5.1423

Several tests were conducted in different conditions considering the type of operation (harrowing, ploughing and cultivating) at different road conditions (on road, sugarcane field and flat field) with two different running speeds at 5km/hr and at 8km/hr and rms acceleration was measured using OR34-2, 4 Channel FFT analyser. From this it is recognised that agricultural tractor operators are exposed to high level of whole body vibration. The rms acceleration level measured in different condition is high upto (7 to 8 m/s^2)than the comfortable range of the operator (1 to 2m/s^2).

CONCLUSION

Agricultural tractor have been identified as a hazardous machine from the aspect of the whole body vibrations. There is a risk for the operators who are exposed to vibrations only one hour a day. The rms acceleration level measured in different condition is high than the comfortable range of the operator. There are number of negative medical effects resulting from operartors being exposed to vibrations. to reducing vibrations, develop a suspension system which gives the vibration witin a comfortable range .

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REFERENCES

[1] A. Marsili; L. Ragni; G. Santoro; P. Servadio; G. Vassalini , " Innovative Systems to reduce Vibrations on Agricultural Tractors:Comparative Analysis of Acceleration transmitted throughthe Driving Seat", Agricultural Mechanization Research Institute (November 2001)
[2] M. Lee, A.H. Bogatchenkov, V.N. Goverdovskiy, Y.V. Shynkarenko, A.I. Temnikov "Position control of seat suspension with minimum stiffness" (November 2005)
[3] Mehta, M. Shyam, Pratap Singh, R.N. Verma , "Ride vibration on tractor-implement system"(September 1999)
[4] 4.C.R. Mehta, V.K. Tewari, "Seating discomfort for tractor operators - a critical review" International Journal of Industrial Ergonomics 25 (2000) 661-674
[5] .A.J. Scarlett, J.S. Price, R.M. Stayner, "Whole-body vibration: Evaluation of emission and exposure levels arising from agricultural tractors" ,Journal of Terramechanics 44 (2007) 65–73
[6] 6.M. Duke; G. Goss, "Investigation of Tractor Driver Seat Performance with Non-linear Stiffness and On–off Damper" Biosystems Engineering (2007) 96 (4), 477–486 (March 2007)
[7] 7.G.J. Steina, R. Zahoransky, T.P. Gunston, L. Burstrom, L. Meyer, "Modelling and simulation of a fore-and-aft driver's seat suspension system with road excitation" International Journal of Industrial Ergonomics 38 (2008) 396–409
[8] 8.G.J. Stein, P. Mucka, "Study of simultaneous shock and vibration control by a fore-and-aft suspension system of a driver's seat" ,International Journal of Industrial Ergonomics 41 (2011) 520-529
[9] H.S.Dhingra 1, V.K.Tewari 2 &Santokh Singh, "Discomfort, Pressure Distribution and Safety in Operator's Seat – A CriticalReview"(July 2003)
[10] 10.A. Carrella, M.J. Brennan, T.P. Waters "Static analysis of a passive vibration isolator with quasi-zero-stiffness characteristic" ,Journal of Sound and Vibration 301 (2007) 678–689
[11] 11.S. Loutridis, Th. Gialamas, I. Gravalos, D. Moshou, D. Kateris, P. Xyradakis, Z. Tsiropoulos, "A study on the effect of electronic engine speed regulator on agricultural tractor ride vibration behavior" ,Journal of Terramechanics 48 (2011) 139–147
[12] 12.C.M. Lee, V.N. Goverdovskiy, A.I. Temnikov, "Design of springs with ''negative'' stiffness to improve vehicle driver vibration isolation" ,Journal of Sound and Vibration 302 (2007) 865–874
[13] 13.G.J. Stein, P. Mucka, T.P. Gunston, S. Badura, "Modelling and simulation of locomotive driver's seat vertical suspension vibration isolation system" ,International Journal of Industrial Ergonomics 38 (2008) 384–395
[14] 14.R. Bluthner, H. Seidel, B. Hinz, "Laboratory study as basis of the development for a seat testing procedure in horizontal directions", International Journal of Industrial Ergonomics 38 (2008) 447–456
[15] 15.P. Servadio, A. Marsili, N.P. Belfiore, "Analysis of driving seat vibrations in high forward speed tractors", Agricultural Mechanisation Research Institute.(May 2007)
[16] 16.KazuhikoOhmiya, " Seat Suspension System For Improving Ride Comfort".
[17] 17KenanMelemez, MetinTunay and Tuna Emir, "The role of seat suspension in whole-body vibration affecting skidding tractor operators", Journal of Food, Agriculture & Environment Vol.11 (1): 1211-1215. 2013
[18] 18.Se Jin Park, Chae-Bogk Kim, Chul Jung Kim, Jeong Woo Leem, "Comfortable driving postures for Koreans", International Journal of Industrial Ergonomics 26 (2000) 489-497