Vibration Measurements and Analysis of Agricultural Tractors Operating on Traditional and Electronic Regulator

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Summary

Results and analysis of vibrations recorded from different models of agricultural tractors (≥ 70 kW) operating on traditional and electronic regulator are presented in this paper. For recording the vibration level of the tractors, it was necessary to obtain measurements under different operating conditions and surfaces (on the asphalt road, in the field aggregated with implements). Three single axis accelerometer sensors type AS-065 with a frequency range of 1 Hz to 15 kHz were used for vibration measurements. These accelerometer sensors were mounted on the body of the seat in mutually orthogonal axes. A Vibrotest 60 (Brüel & Kjaer) portable data logger and analyser were used to monitor, record and distinguish the appropriate frequency ranges. The magnitude of the vibration is expressed in terms of Root Mean Square values (RMS). RMS accelerations for each measurement axis are consistently higher when the constant speed mode is used (electronic regulator).

Key word: *agricultural tractor, seat vibration, traditional regulator, electronic regulator*

Introduction

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, new knowledge of material properties has emerged, and improved analysis and design techniques have appeared. However, in spite of these developments, the vibration excitation has increased in magnitude. Furthermore, the efficiency and speed of agricultural tractors has increased so that vibrations are higher, and tractors often contain high power sources which create new vibration problems (Servadio et al., 2007).

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 (Goglia et al., 2006). Whole body vibrations produce systemic effects on the entire body (Buchholz et al., 1997). The exposure of tractor operators to high vibration levels for extended periods of time can cause vascular, neurological and musculoskeletal disorders, which are usually permanent in character (Fairley, 1995).

One of the most critical issues in designing and using agricultural tractors is to minimize the vibration level. Different seat test procedures and suspension systems are evaluated and used on agricultural tractors in order to prevent operators from occupational diseases caused by vibrations. Burdoff and Swuste (1993) measured the isolation properties of 11 seat suspensions in the laboratory, using standardized vehicle vibration spectra, as well as the isolation properties of seat suspensions which were fitted in vehicles driven over typical surfaces. Hostens et al. (2003) proposed a new improved suspension system that includes an air spring with additional air volume and variable air damping. Duke and Goss (2007) found that a tractor driver seat equipped with a spring with non-linear stiffness and an on-off damper can achieve a 40% reduction in rms acceleration levels compared to the linear, passively damped seat, with no end stop impacts.

Tractor ride vibration has been extensively studied both theoretically and practically, but the effect of electronic engine speed regulator on tractor ride behaviour has not received any attention. Electronic regulator allows the operator to increase or decrease engine speed like a traditional (conventional) regulator. A traditional regulator operates with statism, which means that it operates with a speed drop of about 7% from idling to full load speed. Also, the electronic regulator provides an additional function: depressing the HOLD/RESET push button will memorize the entered speed. The act of memorising the engine speed automatically engages the isochronous operating mode, which maintains the engine speed constant even when the load changes (Same Deutz-Fahr Group S.p.A., 1996).

Results and analysis of vibrations recorded on the body of the seat from different models of agricultural tractors (≥ 70 kW) operating on traditional and electronic regulator are presented in this paper. For recording the vibration level of the tractors, it was necessary to measure under different operating conditions and surfaces (on the asphalt road and in the field aggregated with implements).

Material and methods

Tests were conducted using two four wheel drive (4WD) tractors (Table 1). Tractor cabs have been approved as safety cabs to meet the most stringent international standards. They are suspended on 4 robust rubber shock-absorbers (silent block) which reduce vibrations to the minimum. The driver's seat equipped with shock absorber mechanism, upholstered with arm rests and back rest, has 4 adjustments: height adjustment, position adjustment, angle adjustment, and sensitivity adjustment.

The experiments for each tractor were carried out separately because it was not possible to instrument all tractors at the same time. Tractor vibrations were tested on road transportation (asphalt) of 1500 m length and on a farm field aggregated with plough and disc harrow. The forward speed of the tractors was set up at 12 km/h for road transportation (smoother track) and at 5 km/h for farm field (rougher track), which was maintained constant for all tests. The forward speeds corresponded to 2500 rpm engine regimes. During the tests, the inflating pressure of the tyres was 1.6 bars and the weights of the two operators were 80 kg and 90 kg. Each measurement started with the machine in the same position on the track. Twelve repetitions were carried out for each test.

To measure vibrations, the following instrumentation was used: a) A Vibrotest 60 (Brüel & Kjaer) portable data logger and analyser were used to monitor, record and distinguish the appropriate frequency ranges, and b) three single axis accelerometer sensors type AS-065 with a frequency range of 1 Hz to 15 kHz were used for vibration measurements. The vibration acceleration sensors were attached on the body of the seat, above the shock absorber mechanism. The vibrations were measured along three orthogonal axes, longitudinal (back to chest), transverse (right side to left side) and vertical (driver pelvis to head) directions. Frequency spectra were analysed in the one-third (1/3) octave band, from 1 to 100 Hz. The magnitude of the vibrations is expressed in term of Root Mean Square values (RMS).

Table 1. Technical specifications of the examined tractors.

Technical specifications		Tractor A Lamborghini 950 PREMIUM	Tractor B Hürlimann 135 DTV
Engine type		1000.4 WT	1000.6 WT
Rated power	kW / HP	70 / 95	97 / 132
Rated engine speed	rpm	2500	2500
Speed regulator		Electronic	Electronic
Transmission type		Fully synchromesh	Fully synchromesh
Hydraulic lift		Electronic	Electronic
Front power lift		Without front power lift	With front power lift
Driver's seat		GRAMMER	SABLE
Rear—Front tyres		16.9R34—14.9R24	480/70R34—420/70R24
Length x Width x Height	mm	4123 x 2000 x 2660	4590 x 2250 x 2905
Wheel base	mm	2373	2750
Total weight	kg	3650	5280

Results and discussion

Results of the measurements are given as acceleration values obtained from the one-third (1/3) octave band analysis. Frequency spectra were obtained for all three single axes (X-Y-Z) under different operating conditions and surfaces (on the asphalt road and in the field aggregated with implements). The results are graphically represented in figures 1-4.

Figure 1 shows the results of rms acceleration for the driver's seat on the X-axis and Y-axis during the test on the asphalt road with tractor B. Accelerations were lower, when tractor B operated on traditional regulator, along the X-axis (acceleration average value=0.037 ms^{-2}) with respect to electronic regulator (acceleration average value=0.055 ms^{-2}). Two peaks were found (one at 1.1185 ms^{-2} at 30.31 Hz and another at 0.5391 ms^{-2} at 1.88 Hz) [Fig. 1(a)]. The average acceleration recorded during the operation of the electronic regulator (0.0055 ms^{-2}) along the lateral Y-axis was also higher with respect to the traditional regulator (0.0038 ms^{-2}) [Fig. 1(b)].

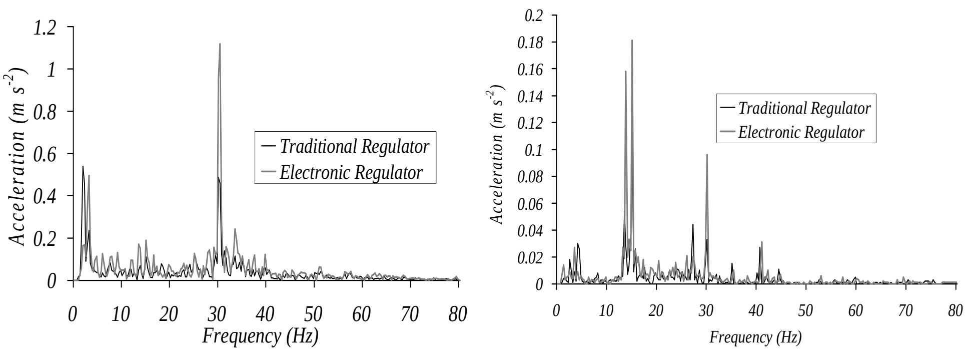

Figure 1: Frequency analysis of rms acceleration for the driver's seat on the X-axis and Y-axis during the test on the asphalt road with tractor B.

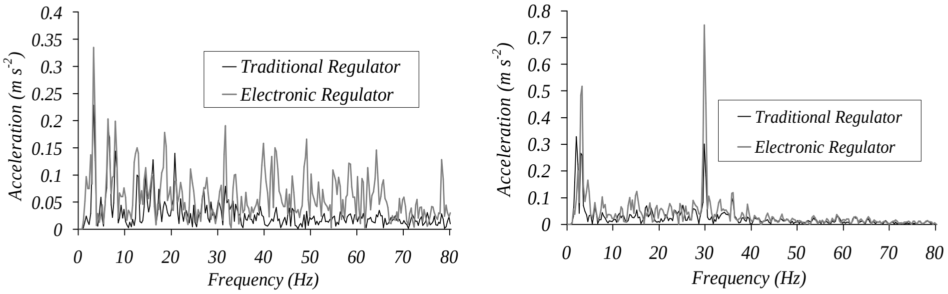

Figure 2: Frequency analysis of rms acceleration for the driver's seat on the Z-axis during the test on the asphalt road with tractor A and tractor B.

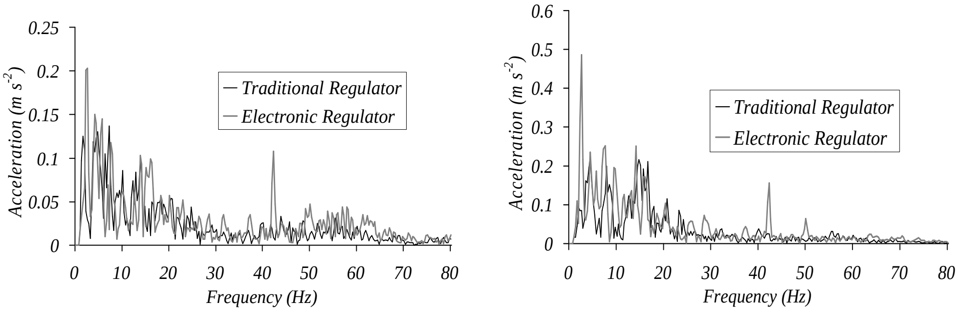

Figure 3: Frequency analysis of rms acceleration for the driver's seat on the X-axis and Z-axis during the test with tractor A in the field aggregated with plough.

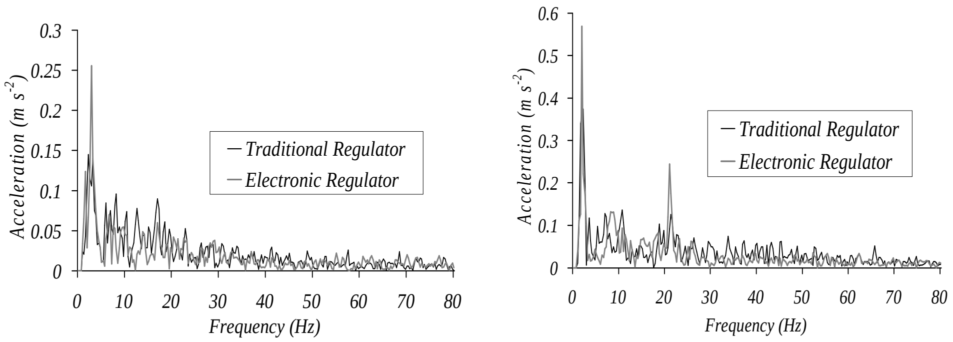

Figure 4: Frequency analysis of rms acceleration for the driver's seat on the X-axis and Z-axis during the test with tractor B in the field aggregated with disc harrow.

Figure 2 shows the results of rms acceleration recorded from the driver's seat on the Z-axis during the test on the asphalt road with tractor A and tractor B. In both tractors, the average acceleration recorded during the operation of the electronic regulator along the Z-axis was higher with respect to traditional regulator. In fact, with respect to tractor A, the average acceleration (0.061 ms^{-2}) recorded during the operation of the electronic regulator was found higher in comparison to the traditional regulator (0.028 ms^{-2}) [Fig. 2(a)].

Finally, Figures 3 & 4 show the frequency analysis of rms acceleration related to the driver's seat on the X-axis and Z-axis during the tests with tractors A & B in the farm field aggregated with different implements. When tractor A was aggregated with a plough and it was working with electronic regulator, the average recorded acceleration was observed to be a little higher than when using a traditional regulator (0.028 ms^{-2} vs 0.023 ms^{-2} along the X-axis and 0.042 ms^{-2} vs 0.034 ms^{-2} along the Z-axis). On the contrary, when tractor B was aggregated with a disc harrow and it was operating on an electronic regulator, the average recorded acceleration was observed to be a little lower than when using the traditional regulator (along X-axis the acceleration average value for the traditional regulator was found 0.022 ms^{-2} vs 0.019 ms^{-2} of the electronic regulator).

Conclusions

Based on the results obtained from the frequency analysis of vibrations measurements, it is quite certain that the use of an electronic regulator (constant speed mode operation) can cause higher accelerations over all three axes of the tractor's driving seat comparing it with the traditional regulator, especially during transportation. The differences in the rms values of accelerations recorded on the driver's seat are less, when tractors are aggregated with implements when working in the farm field.

The recording of higher vibration levels during operation of the electronic regulator could be attributed to the actions of the electronic regulator. During its operation, the electronic regulator adjusts the engine speed to stricter upper and lower limits and thus operates faster than the traditional regulator. This results in higher speed adjustment per unit of time, which in effect leads to higher corrective accelerations of the tractor. These accelerations are transmitted through the body of the tractor and induce higher modes of vibrations in all three directions.

Further research is needed in order to clarify the effects of implements and quantify the effect of increased vibrations on the health of the operators.

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