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Aspects of the development of a test code for tractor suspension seats

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The low frequency ride vibration of an agricultural tractor can be quite severe and contributes to the high rate of spinal disorders noted among tractor drivers[1]. As a means of improving the ride comfort of the driver, seats are available with mechanical suspension systems which provide a degree of additional isolation from vibrations vertical to the tractor. More sophisticated suspension systems, either for the driver's cab or for the tractor chassis, are being investigated with the aim of providing improved isolation from vibrations on more than one axis, but these are not yet production propositions. This paper concerns the development of a test code for assessing the performance of suspension seats in practical conditions, suitable for use at testing stations in several countries. The requirements are briefly stated, followed by discussion of some particular test techniques and of factors affecting seat performance.

Test code requirements

The assessment to be made through the test code should include not only the performance of the seat as a vibration isolator, and some estimate of the effect of ageing on that performance, but also its efficiency in providing physical support for the driver. It is important that the test code should be simple to carry out and should not involve great expenditure.

Anthropometry Anthropometry defines the suitability of the driver's position relative to the major controls as well as the support provided by the seat itself. It is necessary to prescribe a set of dimensional measurements to be made with the seat attached to the tractor.

Weight range The range of driver weight which can be accommodated by a seat suspension, making full use of any adjustment provided, should be ascertained. A static load/deflection test suffices, and, by including an off-centre load, gives an indication of the lateral strength of the seat.

Vibration level and transmissibility The vibration transmissibility of the seat must be defined, as must the vibration level which is transmitted to the driver when the seat is fitted to a particular tractor. Both must be measured under well-defined test conditions, and the method should account for the vibration susceptibility of the driver.

Durability The performance of a seat should be measured before and after a defined period of "use". This is to provide a measure of its deterioration, not of its fatigue life.

Development of test techniques

The development of techniques required for this test code has been carried out in full at the N.I.A.E. Only those concerned with the dynamic tests will be discussed here.

Test tracks Test tracks are used to provide the input vibrations for measurement of transmissibility and vibration level. Seat suspensions are not linear, and performance is affected by so many factors that it is deemed necessary to use the most lifelike conditions for these measurements. To enable repeatable measurements to be made, two tracks have been constructed of wooden blocks. One is representative of rough, ploughed land which may be traversed at speeds of about 5 km/h., while the other is representative of smoother conditions such as farm tracks over which speeds of 15 km/h would be more common. The profiles of each track were taken from actual field measurements in the wheel marks of tractors, in order to obtain representative cross-correlation between the two tracks of each pair. The samples chosen were those whose power spectral density functions were nearest the average for a number of similar samples, and the length was such as to allow 100 periods of the main frequency of vibration, in this case 3 Hz[2].

Frequency weighting Frequency weighting is applied to the acceleration measurements, which are taken from accelerometers mounted one on the tractor and one on a board between the driver and the seat. The weighting is required to take into account the effect of vibration on the driver, and the shape of the weighting curve follows I.S.O. recommendations for human exposure to vibration[3]. It may be applied in either of two ways. One requires a narrow band frequency analysis of the acceleration signals, the power in each band being weighted before being added to obtain a total weighted mean square level. The other method uses an electrical filter to modify the signal, which may be combined with an analogue squaring and integrating circuit to obtain the weighted mean square level "on-line". Despite limitations to the response of realisable electrical filters, the two methods have given comparable results, and the convenience of direct reading is far more attractive than recording and laboratory analysis.

Endurance rig An endurance rig on which seats can be "aged" in a realistic fashion is needed for the test. Field use is too time-consuming and not sufficiently controllable. Requirements of reliability and economy, coupled with a high rate of utilisation for a single purpose led to the choice of a mechanical vibrator. The resulting machine effectively simulates a tractor and a ground profile. A frame representing the tractor chassis is pivoted at a point representing the front axle pivot attachment. It is supported at the rear, through rubber springs representing the tractor tyres, on a pair of large cams. The profiles of these cams are taken one from each side of a pair of wheel tracks used on the test track, and when the cams are driven round by an electric motor, the motion imparted to the seat attachment point is similar to that obtained under working conditions. The seat is loaded with a simple mass for the 200 hour working period.

Factors affecting seat performance

A number of factors affect the performance of a suspension seat, which is measured as the ratio of weighted r.m.s. acceleration on the seat to weighted r.m.s. acceleration on the tractor. In order to define conditions for seat tests which ensure some degree of repeatability, the effects of all the important factors should be known or estimable.

Driver The driver himself affects the seat performance in several ways. The most obvious of these is the effect of his weight which may be anywhere between 120 lb and 220 lb. Although in general, as would be expected, the greater mass of a heavy driver is the best isolated by the seat suspension, this is not always so. It has been known for the adjustment of suspension pre-load to cause a change in geometry detrimental to performance under heavy loads. At least two weights of driver should be set in any standard test to avoid a biased judgment, but this may not in itself be enough. The build of the driver can have an effect of the same order as a large weight change. How much of this is due directly to body dynamics, and how much is caused by differences of posture is uncertain.

Anthropometry Two anthropometric effects may be noted. The first is the effect of sorkspace dimensions on posture, which affects body dynamics as mentioned above, and also affects the vibration transmission through the driver's hands and feet. The second is the effect of the support provided by the seat, in particular the lateral support. The seat should therefore be tested when correctly fitted to the tractor.

Vibration The isolation properties of the seat suspension vary with the vibration level to which it is subjected, both indirectly through variations in driver characteristics, and directly through changes in seat characteristics. The effects of friction and backlash in the mechanism cause the vibration transmissibility to vary with amplitude, and with the amount of vibration in directions other than that measured. It is for this reason that seats are tested specifically in combination with one tractor at a time, and that track testing is used with two types of track, for generality of assessment, and with accurately regulated speed for repeatability. Note that vibration level varies with speed in a complex fashion depending on characteristics of tractor and track profile, but is on average roughly proportional to speed over the range of interest.

Ageing Ageing affects the friction and backlash in the seat suspension mechanism and may result in creep in rubber springs where these are used. Although friction may decrease during an initial running-in period, operation under rough conditions for 200 hours frequently results in an increase in friction, and a reduction in isolation efficiency.

Variability of results Variability between results can arise from two more factors. One is the production variability of the seats themselves, which may be considerable. The test code is intended as a method for individual seats. Production sampling would involve a multiplication of the test procedure, and a lengthy experiment to determine a satisfactory minimum number of seats to examine.

The other source of variability is in the measurements themselves. Two consecutive measurements of the same variable may differ by 10% or more, despite repeatability of speed to within ± ½%. Single measurements for each figure are therefore quite inadequate, and it is preferable to obtain averages from 3 or 4 runs.

Conclusions

A code for the testing of tractor suspension seats has been put forward for international use, to improve the agreement between measurements made at different testing stations, and is being considered by the O.E.C.D. An effort has been made to ensure that the outlay on equipment needed to implement the code is kept low, bearing in mind the facilities already available at such testing stations. The code itself has been tried in as many aspects as practicable, and may be used to assess individual seats for purposes of comparison. It has been suggested that it should be used to determine acceptability, with enforced limits to vibration levels and to various anthropomorphic measurements, but that is not proposed at present.

References

1. Rosegger, R. and Rosegger, S. "Health effects of tractor driving", J.agric.Engng.Res., 1960, 5 (3) 241.
2. Matthews, J. "Ride comfort for tractor operators, IV: Assessment of the ride quality of seats". J.agric.Engng.Res., 1966, 11 (1) 44.
3. "Guide for the evaluation of human exposure to whole-body vibration". ISO/TC 108/WG7 (Secretariat-19) 36, June 1970.

Figure 1. Acceleration power spectral densities, tractor and seat