Suspension Seat Adjustment Parameters and their Influence on Measured Vibration Response: Preliminary Results.

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INTRODUCTION

It is well known that the use of suspension seats which are adequately adapted to specific vehicles can greatly reduce the driver's exposure to whole-body vibration provided that they are properly adjusted such as to optimize the performance of the suspension elements. In recent years, mechanical and air suspension seats have been equipped with several controls , some of them having a direct effect on the seat's ability to attenuate terrain-induced vibration. The driver, forming an integral part of the seat itself, its influence on the seat performance cannot be neglected, nor can the manner in which the seat is adjusted in terms of stiffness (weight control), height, backrest angle and damping. All of these factors are bound to influence the manner by which the cab vibrations are transmitted to the driver and the occurrence of shocks resulting from the seat-driver system hitting the limiting stops. For this reason, it apppears relevant to try to quantify how these various adjustment parameters influence the overall seat performance under various types of excitations, in an attempt to set guidelines for the users of suspension seats as to how exactly they should adjust their seat to get the most performance out of their product. At the same time, these results are used in order to validate a model to predict the behaviour of a seat under various conditions.

METHODOLOGY

Three types of mechanical and air suspension seats have been selected for the tests, although the results are presented here only for the ISRI model 6000 mechanical suspension seat. This seat includes a cross-linkage mechanism, a helicoidal spring and an inclined shock absorber. Seat adjustments are provided for weight, backrest angle, height, fore-aft position, cushion angle, armrest angle and for locking the longitudinal isolator. The seat is loaded with a rigid mass of 63.6 kg, consisting of sand bags, although tests using human subjects are anticipated in the future. For the testing, the weight setting is adjusted at three positions corresponding to mid-ride, 25 mm below mid-ride(low) and 25 mm above mid-ride (high). The total stroke of the suspension is 80 mm. Other adjustments include a backrest angle of 0 and 14 degrees, and a height setting of 275 and 300 mm. The longitudinal isolator is blocked during the tests.

The seat-mass system is installed on a vertical vibration simulator consisting of a platform driven by two hydraulic cylinders having a stroke of 200 mm. This system is driven by a hydraulic pump having a 19 l/min capacity at 21 MPa. The simulator responds to displacement signals up to 25 Hz with a 2 ms^{-2} acceleration achievable only for frequencies exceeding 1.5 Hz. Various safety features are incorporated on the simulator to allow the testing to be conducted using human subjects.

Various excitation signals are used to conduct the tests. These consist of a sinusoidal log sweep excitation providing a constant 25 mm displacement in the 0.5 to 2 Hz range and a constant peak acceleration of 3.95 ms^{-2} in the 2 to 10 Hz range, classes 1 and 2 random excitations designed for agricultural tractors in the ISO 5007 technical report [1], classes I and II random excitations defined in the French standard AFNOR E 58-074 [2] and an IRSST random excitation recorded on fork-lift trucks. These displacement signals are digitized and drive the simulator using a computer.

For the various seat adjustment combinations and the various excitations, vibration signals are recorded using accelerometers fixed on the simulator platform, at the suspension and at the load-seat interface. At each measurement point, the frequency spectrum is recorded in the 0 to 25 Hz range. Using these, the overall unweighted acceleration was computed in the 0.5 to 20 Hz range for each of the settings and measurement positions. The weighted acceleration was then computed, first using the vertical weighting defined in the current ISO 2631/1 standard [3] from 1 to 20 Hz, then using the newly proposed weighting W_b from 0.5 to 20 Hz as presented in the new draft proposal [4] for replacement of the current ISO 2631/1. From these, the "Seat Effective Amplitude Transmissibility" (S.E.A.T.) is formed, representing the ratio of the overall weighted acceleration measured on the seat or the suspension to that measured at the base on the platform. This factor provides an estimate of the seat's ability to attenuate whole-body vibration.

Finally, the suspension and the seat's transmissibility are formed representing the ratio of the frequency spectrum measured at the suspension and on the seat to that measured at the base in the range 0 to 25 Hz. From these, the resonant frequency of the mass-seat system and the transmissibility at resonance are determined for each measurement condition.

RESULTS

Tables 1 to 3 list the maximum and minimum S.E.A.T. values measured at the suspension and at the seat for different types of excitation when the weight setting is adjusted at mid-ride and 25 mm above and below mid-ride. The S.E.A.T. values are obtained by applying the ISO 2631/1 weighting for vertical vibration appearing in the current version of the standard. The variation of S.E.A.T. values appearing in the tables may be attributed to the variations in height and backrest angle adjustments since these were the only parameters changed between low and high values. These include a series of four tests conducted at a height of 275 and 300 mm and a backrest angle of 0 and 14 degrees.

Influence of weight setting

A comparison of the S.E.A.T. values appearing in the three tables shows that values are significantly lower when the seat is adjusted according to the mass on the seat (i.e. mid-ride). The performance of the seat can be greatly deteriorated if the weight setting is not adjusted properly. For example, under ISO 1 excitation, the S.E.A.T. value would range from 0.398 at mid-ride to 0.706 when made too stiff, constituting an increase of 77%. Under Class I excitation, the value could range from .758 at mid-ride to values exceeding 1.0, making the seat unacceptable for this class of vehicle.

Influence of type of excitation

The lowest S.E.A.T. values occur using ISO 1 excitation while the highest occur using Class I, and this for all three weight settings. This is understandable considering that ISO 1 excitation peaks at 3.15 Hz while Class I peaks at 2 Hz. The resonant frequency of the mass-seat lying between 1.2 and 1.4 Hz, very little attenuation is provided at 2 Hz, while attenuation improves at higher frequencies. These results illustrate quite nicely that a seat which is effective in one vehicle will not necessarily be effective in another vehicle characterized by a different vibration class.

Influence of height and backrest angle

It is difficult to dissociate the combined effect of height and backrest angle on the S.E.A.T.. This effect is shown clearly in the tables and explains the % variation between the minimum and maximum S.E.A.T. values. Depending on the excitation and the measurement position (seat or suspension), variations on the order of 10 to 50% may be noted, which would have a significant effect on the estimated performance of the seat and the suspension.

Table 1. Maximum and minimum S.E.A.T. values measured at the suspension and the seat at mid-ride

Excitation		S.E.A.T. at suspension			S.E.A.T. at seat		
Type	$a_w(ms^{-2})$	Min.	Max.	% variation	Min.	Max.	% variation
Sinusoidal	2.02	.391	.475	21.5	.452	.504	11.5
ISO 1	2.26	.382	.431	12.8	.398	.471	18.3
ISO 2	1.58	.566	.596	5.3	.591	.669	13.2
Class I	1.84	.701	.759	8.3	.714	.758	6.2
Class II	1.59	.646	.660	2.2	.661	.713	7.9
IRSST	1.45	.598	.652	9.0	.617	.644	4.4

Table 2. Maximum and minimum S.E.A.T. values measured at the suspension and the seat 25 mm below mid-ride

Excitation		S.E.A.T. at suspension			S.E.A.T. at seat		
Type	$a_w(ms^{-2})$	Min.	Max.	% variation	Min.	Max.	% variation
Sinusoidal	2.02	.493	.586	18.9	.556	.654	17.6
ISO 1	2.26	.406	.470	15.8	.424	.546	28.8
ISO 2	1.58	.599	.657	9.7	.633	.747	18.0
Class I	1.84	1.02	1.11	8.8	1.06	1.30	22.6
Class II	1.59	.967	1.01	4.4	1.05	1.19	13.3
IRSST	1.45	.652	.682	4.6	.685	.716	4.5

Table 3. Maximum and minimum S.E.A.T. values measured at the suspension and the seat 25 mm above mid-ride

Excitation		S.E.A.T. at suspension			S.E.A.T. at seat		
Type	$a_w(ms^{-2})$	Min.	Max.	% variation	Min.	Max.	% variation
Sinusoidal	2.02	.716	1.05	46.6	.753	.939	24.7
ISO 1	2.26	.635	.729	14.8	.706	.833	18.0
ISO 2	1.58	.788	.965	22.5	.927	1.19	28.4
Class I	1.84	1.18	1.20	1.7	1.16	1.22	5.2
Class II	1.59	1.10	1.15	4.5	1.09	1.20	10.1
IRSST	1.45	.969	1.03	6.3	.904	1.14	26.1

CONCLUSION

This preliminary study , although limited since only a rigid load was used, provides some insight on the various factors likely to influence the performance of a suspension seat under different types of excitation. It is seen that the height and backrest angle do affect the overall vibration transmissibility to some extent but not necessarily in an orderly manner. On the other hand, the type of excitation and the stiffness or weight adjustment do have a significant effect on the overall seat performance, where depending on the setting, the S.E.A.T. value can be reduced by as much as 70% with respect to some other setting.

REFERENCES

[1] International Standards Organization ISO Technical Report 5007 (1980). Agricultural wheeled tractors-Operator seat-Measurement of transmitted vibration. 29 pp.

[2] Norme expérimentale AFNOR E 58-074 (1981). Engins de terrassement-Spécifications pour le mesurage en laboratoire des vibrations verticales transmises au conducteur par l'assise du siège. 10pp.

[3] International Standards Organization ISO 2631/1 (1985). Evaluation of human exposure to whole-body vibration-Part 1: General requirements. 18pp.

[4] Fourth Committee Draft on ISO/CD 2631 (1993). Mechanical Vibration and Shock-Guide to the evaluation of human exposure to whole-body vibration. 27pp.