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VEHICLE SEAT DYNAMICS MEASURED WITH AN ANTHROPODYNAMIC DUMMY AND HUMAN SUBJECTS

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ABSTRACT - A single degree-of-freedom anthropodynamic dummy has been used to measure the dynamic characteristics of a seat in a car travelling over six different roads. Measurements were also made using twelve human subjects. There were no significant differences between the SEAT values measured using the dummy and the subjects. There was less variability in SEAT values measured using the dummy than when using human subjects. Transmissibilities between the seat-guide and the seat-surface were calculated in the vertical, fore-and-aft and lateral directions and between the seat guide vertical vibration and backrest fore-and-aft vibration. For both sets of measurements, the seat transmissibilities showed a resonance at 4 Hz in the seat-guide to seat-surface vertical and fore-and-aft directions and between 2 and 5 Hz for the seat-guide to backrest transmissibility. Dummy data showed a seat-guide to seat-surface lateral transmissibility resonance at 4 Hz whereas there was no clear resonance in this axis for the subject data. At resonance, transmissibilities were similar between the measurements made using the dummy and subjects for all axes except the seat-guide to seat-surface lateral measurements. At frequencies above 10 Hz the transmissibilities were different for all axes.

1. INTRODUCTION

The measurement of the transmission of vibration through seats currently requires that a human subject sits on a seat and is exposed to vibration. This is unsatisfactory since results may differ between subjects, and laboratory tests require the availability of vibration simulators which are safe for human exposure. Ethical and safety considerations make it desirable that a test is evolved in which seat transmissibility can be determined without exposing the human body to vibration. Measuring the vertical transmissibility of a seat by replacing the occupant with a rigid mass of the same weight does not give an

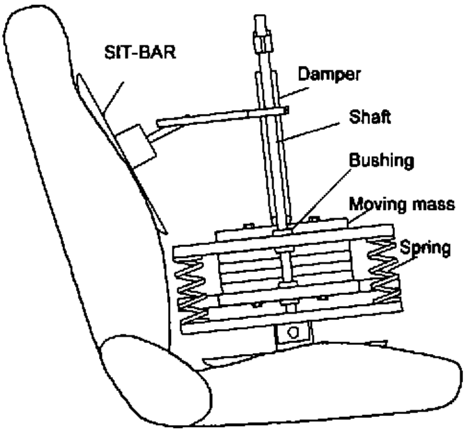

Fig. 1. Anthropodynamic dummy.

accurate result [1]. However, the human subject may be replaced by a dummy with the vertical dynamic impedance of the seated body.

Some previous researchers have fabricated dummies [2 - 4] and concluded that it may be possible to use them in place of a human subject for the evaluation of some suspension seats. Suggs [3] compared a two degree-of-freedom dummy with measurements made using 11 subjects sitting in suspension seats. It was found that the accuracy of the transmissibilities measured using the dummy were dependant on both the subject and the vibration magnitude. Matthews [2] and Tomlinson [4] presented results for single subjects and showed an agreement between seat transmissibilities with a dummy and with subjects in the frequency range 0 to 3 Hz.

A single degree-of-freedom anthropodynamic dummy has been developed to measure the dynamics of car seats of standard construction. A comparison of the transmissibility and the seat effective amplitude transmissibility (SEAT value) measured using the dummy and twelve subjects has been undertaken.

2. EXPERIMENTAL PROCEDURE

The anthropodynamic dummy is shown in Fig. 1. It consisted of a pair of steel precision shafts on which a 46 kg mass could move vertically. A single 739 Ns/m low friction damper was fitted between the mass and an aluminium shaft at the top of the dummy. Compression springs were fitted between each of the four corners of the moving mass and an aluminium base plate. The combined stiffnesses were 50176 N/m. The mass included a pair of steel plates which ran on ball bushings vertically constrained by the shafts. Between these were a central set of steel masses which made up the complete moving mass of the dummy. The dynamic response of the dummy was based on the single degree-of-freedom model of the body developed from measurements of the vertical apparent mass of human subjects [5]. A SIT-BAR [6] was fitted to the base and back of the dummy to provide indentors for the seat on which the dummy was placed. The rigid mass of the frame was 6.0 kg. The static friction measured for the movement of the assembled dummy was 14.2 N.

As part of the evaluation of the anthropodynamic dummy, measurements were made in a small passenger car driven over six roads. Entran EGCSY-240D*-10 accelerometers were used to measure the vibration in three translational axes at the seat-guide and to measure the vibration at the base of the dummy. With human subjects, *HVLab* pads [7] were used to measure vibration in the fore-and-aft direction between the seat back and the subjects and in the three translational axes on the seat surface beneath the ischial tuberosities of subjects. The roads consisted of a motorway, two minor country roads, two major urban roads and a minor urban road. Accelerometer signals were conditioned and acquired directly into an *HVLab* data acquisition and analysis system at 200 samples per second with anti-aliasing filters set at 66 Hz. Transmissibilities from the seat-guide to seat-surface were calculated in vertical, lateral and fore-and-aft directions and from the seat-guide vertical to the backrest fore-and-aft.

The seat effective amplitude transmissibilities (SEAT values) of the seat were also calculated. SEAT values are defined as the ratio of the vibration dose value (VDV) measured on the seat surface compared to the VDV measured on the floor [7]. The VDV is given by:

$$VDV = \left[\int_{t=0}^{t=T} a_\omega^4(t)dt \right]^{1/4}$$

where a_ω is the frequency weighted acceleration using frequency weighting W_b[8]. The SEAT value shows the effectiveness of the seat in improving the ride comfort for a particular input spectrum. A SEAT value less than 100% implies that the dynamics of the seat improve the vehicle ride. A SEAT value greater than 100% implies that the seat dynamics make the vehicle ride less comfortable. SEAT values were calculated for vertical seat motion for each of the roads with both the dummy and the subjects.

Twelve male subjects were used in the experiment with a mean age and weight of 28.6 years and 71.3 kg respectively. For comparison with the subjects, tests were made with the dummy twelve times on each road.

3. RESULTS AND DISCUSSION

Fig. 2 shows median and inter-quartile ranges for transmissibilities of the seat in four axes for all six roads. For vertical motion, the seat had a resonance around 4 Hz with a transmissibility of about 1.5 for each road. There was a dip in the transmissibility for many of the roads at about 2 Hz. For both dummy and subject measurements the variability between runs was greatest at high frequencies and was least around resonance.

Seat-guide to seat surface fore-and-aft transmissibilities showed peaks at 1 to 2 Hz and 4 to 5 Hz. All runs for the seat-guide to seat-surface fore-and-aft transmissibilities showed a similar general shape although there was some variability particularly at frequencies above 15 Hz. At frequencies below 10 Hz the subject and dummy data gave similar results.

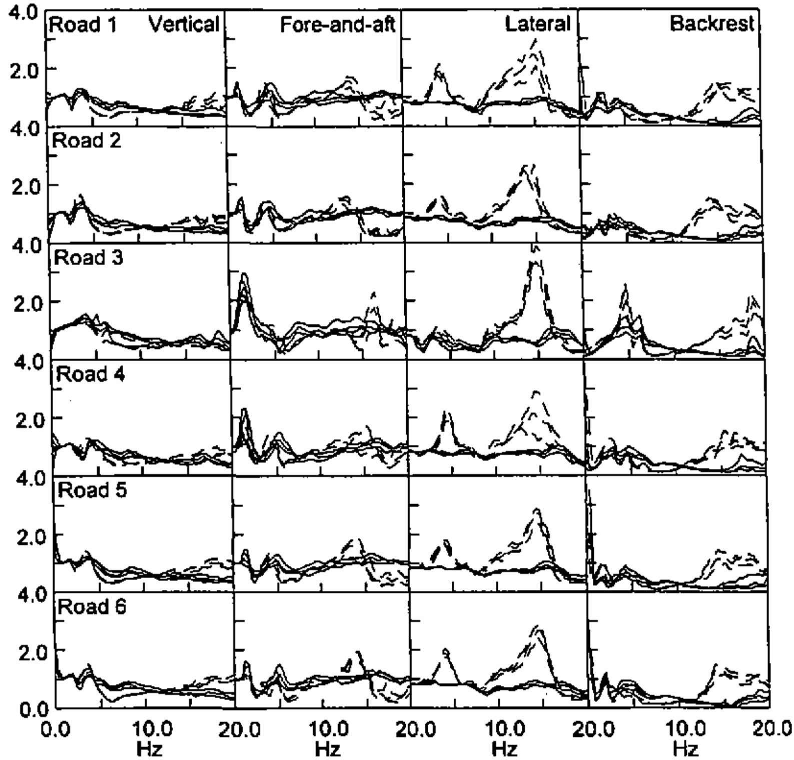

Fig. 2. Transmissibility of a car seat measured on six roads. Median and inter-quartile ranges for 12 subjects (——) and 12 anthropodynamic dummy (-----) tests.

Subject data for the seat-guide to seat-surface lateral transmissibility showed no clear resonance for any of the roads: the transmissibilities were approximately unity for all of the measurements. For dummy data in the lateral direction there were two peaks in the transmissibilities occurring at about 4 Hz and 15 Hz for all six roads. Variability between runs was greatest at frequencies above 12 Hz. For transmissibilities in the lateral direction the dummy and subject data showed few similarities. The dummy was designed to be rigid in the lateral and fore-and-aft directions. The apparent mass of the seated human body in the lateral direction has previously been shown to have resonances at 0.7 and 2 Hz with small apparent mass above 5 Hz [9]. The differences between the lateral apparent masses of the subjects and that of the dummy may have been a cause of the differences in the lateral transmissibilities. Additionally, the dummy had no support in the roll direction equivalent to that provided by the legs of the subjects: the lateral accelerometer would have been affected by roll motion of the dummy due to

Table 1. Median SEAT values measured using dummy and subjects.

Road	Speed (km/h)	W_b weighted acceleration (ms^{-2} r.m.s.)	SEAT value (subject)	SEAT value (dummy)
1	50	0.91	70.7	68.6
2	70	0.89	68.3	71.5
3	120	0.54	72.7	70.3
4	70	0.51	71.4	72.0
5	50	0.95	71.7	73.6
6	50	0.97	75.0	75.9

gravity acting on the transducer.

At the backrest, seat-guide vertical to fore-and-aft transmissibilities showed a peak at about 2 to 4 Hz with both the dummy and subjects. The two sets of data were similar below 10 Hz. Inter-subject variability in these directions was greatest at resonance and at frequencies above 15 Hz. Although only designed to represent the dynamic response of the seated body in the vertical direction, the dummy showed good agreement in the fore-and-aft direction at both the seat surface and backrest at resonance.

Median vertical SEAT values measured with the dummy and subjects are listed in Table 1. Wilcoxon matched-pairs signed ranks test showed that for each road there was no significant difference between the SEAT values obtained using the dummy and those obtained with human subjects ($p > 0.1$). Median and inter-quartile ranges for SEAT values measured using the dummy and subjects are shown in Fig. 3. The data show close agreement between median values measured using the dummy and subjects. For all roads, the inter-quartile ranges for the measurements made using the dummy lie within the inter-quartile ranges for the subject measurements. These results suggest that although there were differences in the vertical transmissibilities measured using the two methods, the influence of the seat on the vertical ride of the vehicle was predicted accurately using the dummy.

4. CONCLUSIONS

During in-vehicle testing of a car seat, the anthropodynamic dummy gave a good indication of the vertical resonance frequency of the seat. For measurements of transmissibility in all axes, the subject results showed greater transmissibilities in the frequency range 6 to 10 Hz than those measured using the dummy. For measurements of the fore-and-aft transmissibilities of the seat cushion and backrest, the dummy gave a close prediction of transmissibility around the resonance. In the lateral direction, the dummy gave transmissibilities with resonances at 4 and 15 Hz whereas the subject data showed no clear resonance in this direction. For vertical motion, there were no significant differences between the SEAT values obtained with twelve subjects and those obtained using the dummy twelve times. It is concluded that an anthropodynamic dummy can be used to replace subjects for measuring seat dynamics. The same SEAT values and representative

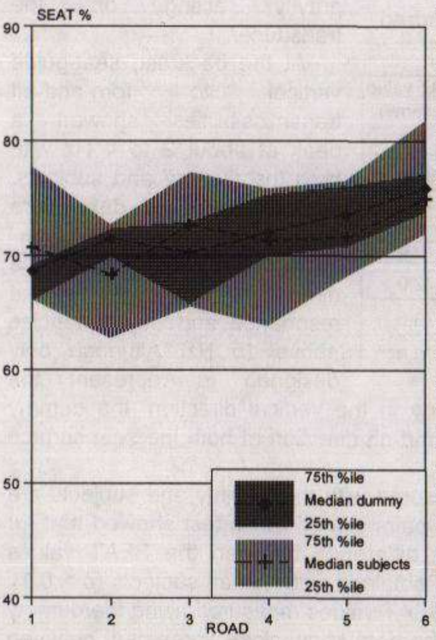

Fig. 3. Median and inter-quartile ranges for SEAT values.

vertical dynamic response of the seat at resonance can be obtained with a dummy.

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