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APPLICATION OF MECHANICAL IMPEDANCE METHODS TO SEAT TRANSMISSIBILITY

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INTRODUCTION

An understanding of the dynamics of the seat-man system is required if seats are to be designed to optimally reduce the effects of vibration on health, performance and comfort of man. Seat-design cannot be based on the dynamic response of a seat loaded with a rigid mass. International Standard 5982 |1| defines a standard whole-body driving point mechanical impedance of the sitting human body subjected to vertical (z-axis) vibration on a hard flat seat. The Standard suggests that this information could be used in the design of isolation systems such as seats but there is no known application of the Standard for this purpose. Here, mechanical impedance methods are used to measure the dynamics of a conventional soft vehicle seat with a man sitting on it, and it is shown how these methods can be used to predict seat transmissibility.

The Seat-Man Dynamic System

In principle, the seat and the man comprise a non-linear, multi-input, multi-output dynamic system. A simplified representation (Figure 1) assumes that the compliant part of the seat has negligible mass and that there is a single rigid interface between the seat squab and the man.

Measuring the force $F(\omega)$, the acceleration $a_{sm}(\omega)$ at the base of the seat and the acceleration $a_m(\omega)$ at the seat-man

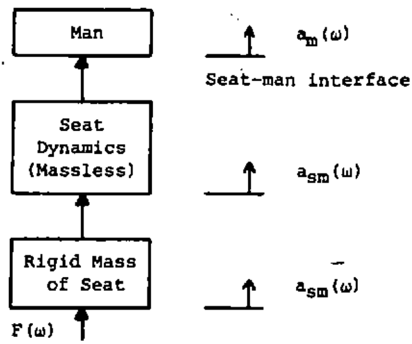

Fig.1. Representation of seat-man system.

interface gives the apparent mass of the cushion-man system,

$$A_{sm}(\omega) = \left[\frac{F(\omega)}{a_{sm}(\omega)}\right] - \left[\begin{matrix}\text{mass of rigid}\\ \text{part of seat}\end{matrix}\right] \qquad (1)$$

and the seat transmissibility, $T(\omega) = \dfrac{a_m(\omega)}{a_{sm}(\omega)}$ (2)

For this representation,

the apparent mass of the man is, $A_m(\omega) = \dfrac{A_{sm}(\omega)}{T(\omega)}$ (3)

and the impedance of the seat is, $Z_s(\omega) = \dfrac{j\omega\, A_{sm}(\omega)}{1 - T(\omega)}$ (4)

A knowledge of both $A_m(\omega)$ and $Z_s(\omega)$ is required in order to optimise vehicle ride by making changes to the components of the seat.

Predicting the Seat Transmissibility

If the seat transmissibility $T(\omega)$ is measured, then the impedance of the seat is given by, $Z_s(\omega) = j\omega\, A_m(\omega)\, \dfrac{T(\omega)}{1 - T(\omega)}$ (5)

where $A_m(\omega)$ is the known apparent mass of the body on the seat.

Knowing the impedance of the seat, $Z_s(\omega)$, the seat transmissibility can be predicted for a man with apparent mass $A_m(\omega)$,

$$T(\omega) = \frac{Z_s(\omega)}{j\omega\, A_m(\omega) + Z_s(\omega)} \qquad (6)$$

METHOD

Test results are reported for a seat with the backrest removed. A wire and spring suspension on a tubular steel frame supported a foam block over which the cover of the seat was tightly fitted. The seat was mounted on a force platform consisting of a plate supported on four force transducers. Gaussian random vertical vibration (0.25-20 Hz, 1 m/s^2 rms) provided by the Human Factors Research Unit's 1-metre stroke hydraulic vibrator was used. Vibration at the seat-man interface was measured with a thin 200mm diameter disc placed directly underneath the subject's ischial tuberosities. The subject's feet rested flat on the vibrator table. Measurements were also made:

(i) without the feet supported;

(ii) with the subject sitting directly on top of the force platform (a hard flat seat surface);

(iii) with a 36 kg mass resting directly on the seat cushion.

RESULTS

Transfer functions were calculated using cross-spectral density methods with a resolution of 0.125 Hz. The apparent mass of the subject on the soft seat is compared with that on the hard flat seat in Figure 2. When the subject's feet are not supported the apparent mass is increased below about 5 Hz.

The massless impedance of the soft seat is shown in Figure 3. The commonly assumed parallel spring and and viscous damper model has been fitted to the data. Whilst such a component model is crude, it may give a useful prediction of the seat transmissibility (Figure 4) using equation (6) and the apparent mass of the subject on a hard flat seat.

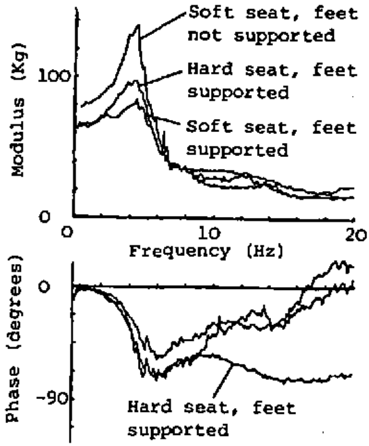

Fig.2. Apparent mass of subject for three conditions.

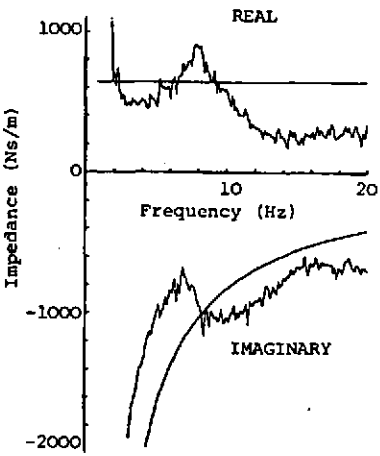

Fig.3. Impedance of seat and fitted model (smooth line).

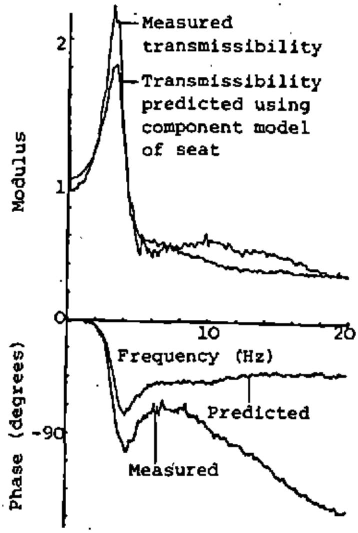

Fig.4. Transmissibility predicted with model compared with measured transmissibility.

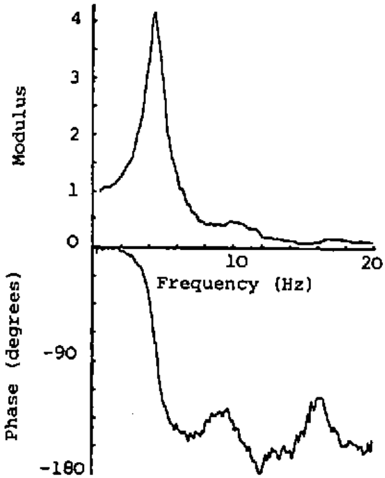

Fig.5. Transmissibility of seat with a mass.

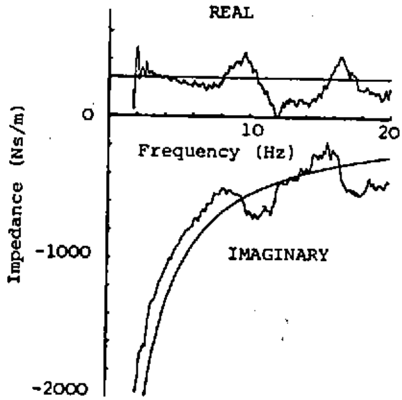

Fig.6. Impedance of seat with a mass and fitted model (smooth line).

The seat transmissibility measured with a mass on the seat cushion (Figure 5) has a larger peak transmissibility than that with a man. Using equation (6) it gives the impedance of the seat (Figure 6). The seat appears to have less stiffness and damping than with the subject.

CONCLUSIONS

A method to measure the mechanical impedance of a seat has been illustrated, assuming that the dynamics of the seat are massless and that there is a single rigid seat-man interface. The apparent mass of the man on the soft seat was similar to that on a hard flat seat surface.

The transmissibility of a seat depends upon the dynamics of the body on the seat as well as the dynamics of the seat. Hence, seat transmissibility measures applicable to man cannot be obtained directly with a pure mass on the seat. Furthermore, the impedance of a seat loaded with a mass has been shown to be different from the impedance of a seat loaded with a man.

REFERENCE

|1| International Organization for Standardization, "Vibration and shock - mechanical driving point impedance of the human body", ISO 5982, (1981).