

REVIEW OF ANTHROPODYNAMIC DUMMIES USED TO EVALUATE THE EFFECT OF VIBRATIONS ON SITTING HUMAN (VEHICLE DRIVER)

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Summary

A review of anthropodynamic dummies representing a sitting human body, used for the analyses of vibration comfort in motor vehicles, has been done. In the first part of this study, the structures, technical specifications, and engineering solutions adopted in selected anthropometric dummies have been reviewed. Attention has been drawn to the test conditions (frequency ranges, input types) in which the dummies may be used and to the possibilities of adjusting dummy's mass, spring, and damping characteristics.

The second part of the study comprises results of experimental simulation tests carried out with the use of a KPST dummy built at the Department of Automotive Engineering and Transport of the Kielce University of Technology in comparison with acceleration transmittance curves determined for a human subject with a mass structure close to that of the dummy.

Keywords: anthropodynamic dummy, vibration comfort

1. Introduction

One of the features of a properly designed motor vehicle seat should be adequate vibration comfort offered to potential seat users.

The transmission of vibrations by the seat may be evaluated by field tests carried out in real operation conditions (on a road or testing ground) or by physical simulation (on laboratory test stands).

Based on a review of specialist literature and the tests carried out at the Department of Automotive Engineering and Transport of the Kielce University of Technology to evaluate the propagation of vibrations in a sitting human body, it has been found that if vibration comfort is examined with

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participation of human subjects then problems with repeatability of the examination results are encountered. The primary reason for this fact is great diversity of the dynamic characteristics of human individuals, even if selected from a very narrow age bracket [14]. Changes in the posture (relaxed, tense, straight, etc.) of individual human subjects at specific tests, resulting from their weariness or physical tiredness, constitute another reason for the unrepeatability of test results.

As an alternative in the research on the evaluation of vibration comfort offered by motor vehicle seats, the replacement of human subjects with anthropodynamic dummies is proposed. Thanks to such a solution, the said reasons for the measurement result repeatability problems are eliminated. This paper deals with the possibilities of using anthropodynamic dummies to evaluate the effect of vibrations on a sitting human body.

2. Anthropodynamic dummies representing a sitting human body

2.1. Anthropodynamic dummy developed by C. Suggs

The major components of this dummy shown in Fig. 1 are two masses connected together and situated on the opposite sides of a frame. The dummy has a base made in the form of a plate, which represents the buttocks of the human body modelled and, simultaneously, ensures the dummy to be properly placed on the vehicle seat. The seat tests where this dummy was used were carried out with a sinusoidal input being applied to the seat base; the input amplitude was 4.8 mm and the frequency varied from 2 Hz to 10 Hz, which corresponded to seat base accelerations ranging from 0.75 m/s^2 to 18.8 m/s^2 [12].

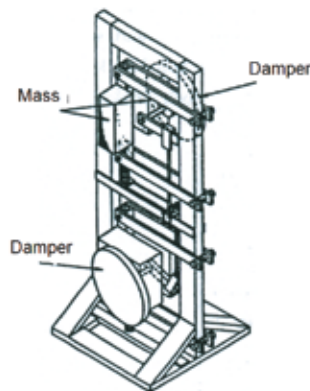


Fig. 1. Anthropodynamic dummy developed by C. Suggs [12]

2.2. Anthropodynamic dummy developed by J. Kinne and R. Melzig-Thiel

The major components of the dummy built by J. Kinne and R. Melzig-Thiel (Fig. 2) are damper with variable damping coefficient, spring with appropriate stiffness, and rocker reducing

the vibrations of the main mass to the vertical direction only. Moreover, the construction of the dummy enables stepwise adjustment of dummy's mass, which may be set to 55 kg, 75 kg, or 98 kg [10, 11]. The statistical scatter of the results obtained at the tests during which the seat under tests was occupied by a real human subject was 20%; the scatter dropped to 10% when the human subject was replaced with the dummy having been developed.



Fig. 2. Testing of a motor vehicle seat with the use of a dummy [4]

2.3. Anthropodynamic dummy developed by N. Mansfield and M. Griffin

The construction of this anthropodynamic dummy has been based on a model with one degree of freedom, designed to represent the vertical accelerations applied as an input to a sitting human body. The dummy has a pair of precisely made steel rolls to guide a 46 kg vibrating mass in the vertical direction. The vibrating mass is linked to the dummy frame by a damper. Moreover, four springs with a total stiffness of 50 176 N/m have been placed between the mass and an aluminium plate. A back support fitted to the shape of the seat backrest prevents the dummy from losing its longitudinal stability [7].

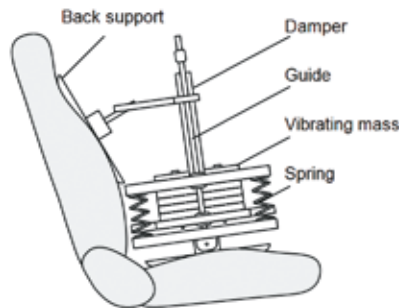


Fig. 3. Anthropodynamic dummy developed by N. Mansfield and M. Griffin [7]

2.4. Anthropodynamic dummies MEMOSIK

The MEMOSIK dummies were built with making use of information about the impedance measured under sitting human's buttocks and the seat-head acceleration transmittance. Based on these characteristics, natural frequencies and the corresponding modal damping ratios were determined.

The **MEMOSIK I** dummy (Fig. 4) could be placed on the seat without using any additional fixing equipment because the low position of its centre of gravity and its appropriately shaped base adequately protected the dummy from stability loss. The design of the dummy made all its masses, dampers, and springs readily accessible, thanks to which they could be easily adjusted. This dummy worked without fault at input frequencies ranging from 1 Hz to 50 Hz [5].



Fig. 4. Anthropodynamic dummy MEMOSIK I [7]

In practice, the ride comfort in passenger cars is measured within a considerably narrower frequency range. Therefore, a dummy named **MEMOSIK II** (Fig. 5a) was built, based on the MEMOSIK I model, with dampers of a different type having been applied. The MEMOSIK II dummy was intended for tests where the input frequencies were to vary within limits from 0.5 Hz to 30 Hz [6]. As the next development step, the MEMOSIK III dummy was built, where the number of vibrating masses (weights) was reduced from 5 to 3 (Fig. 5b).

The main part of the anthropodynamic dummy **MEMOSIK IV** (Fig. 6) was an aluminium plate, to which three vertical guides and a vibration damper module were fastened with the use of special fixtures. Linear bearings were provided in the main mass and the second additional mass, thanks to which the vibrating masses could properly move along the guides. Helical springs were installed between the main mass and the aluminium plate. For the dummy to represent a 50 centile person and a 95-centile person, two additional weights were provided. Two pivotal joints between the aluminium plate and the base of the dummy made it possible to adjust the angular position of the vibrating system [1, 2].

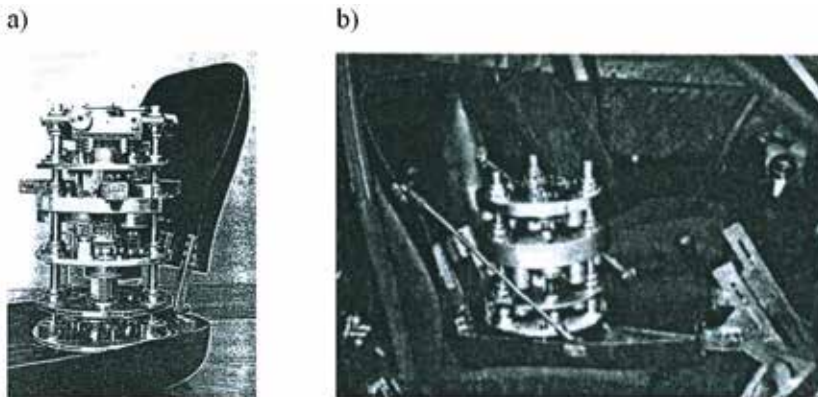


Fig. 5. Anthropodynamic dummies: a) – MEMOSIK II [6]; b) – MEMOSIK III [3]



Fig. 6. Anthropodynamic dummy MEMOSIK IV placed on a motor vehicle seat [13]

The model mentioned above was followed by **MEMOSIK V** (Fig. 7), which was an active dummy developed from the previous model by adding a control system to it. The base shaped in accordance with the human anatomy as well as the back support ensured proper positioning of the dummy on a motor vehicle seat. The MEMOSIK V dummy made it possible to carry out repeatable measurements of vibrations in three directions x , y , and z . The dummy was provided with an "artificial spine" incorporated in its back support to represent the rigidity of the human vertebral column. The dummy could be adjusted to the three standard mass percentiles (F05 – 5%, M50 – 50%, and M95 – 95%) by adding or removing appropriate weights [8].

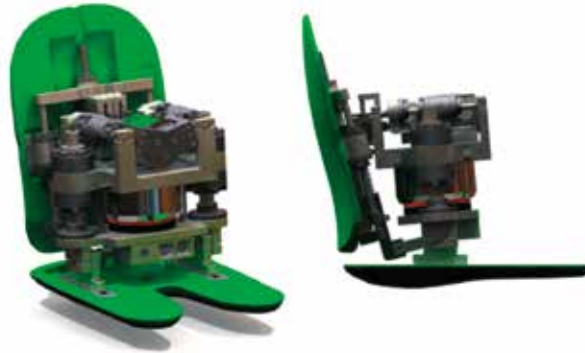


Fig. 7. Active anthropodynamic dummy MEMOSIK [9]

2.5. Anthropodynamic dummy KPST

The anthropodynamic dummy KPST (Fig. 8) was built at the Department of Automotive Engineering and Transport of the Kielce University of Technology [14]. It was based on a model with four degrees of freedom, which represented the propagation of vertical vibrations to three basic regions of a sitting human body.

In the dummy, four distinguished regions of a human body were represented by four masses: mass m_1 corresponded to the mass of the head; mass m_2 corresponded to the mass of the shoulder girdle with thorax, its internal organs and arms; mass m_3 corresponded to the mass of the internal organs of the abdominal cavity inclusive of diaphragm and abdominal integument; and mass m_4 corresponded to the mass of the vertebral column with pelvis and hips as well as forearms with hands.



Fig. 8. KPST dummy placed on a motor vehicle passenger's seat

3. Evaluation of the effect of vibrations on a sitting human body, carried out with the use of the anthropodynamic dummy KPST

Results of experimental simulation tests carried out with the use of the dummy having been built were compared with the curves representing the medians of acceleration transmittance determined for 80 human subjects whose average mass was close to the mass of the dummy (79 kg) (Figs. 9, 10, and 11).

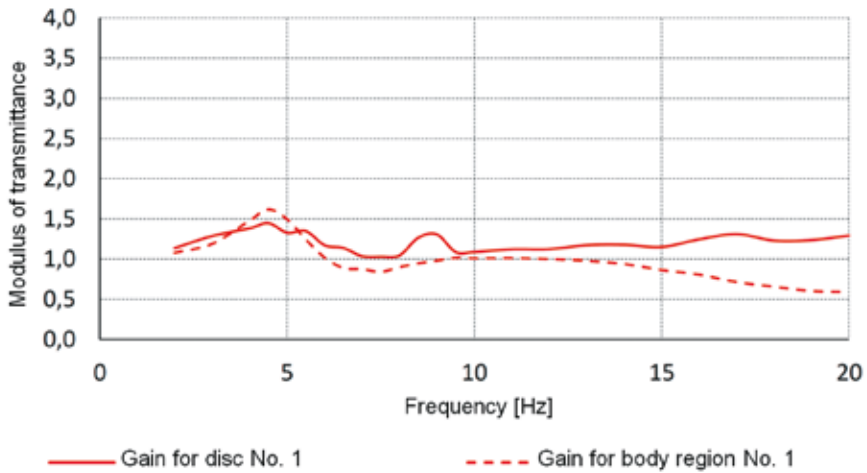


Fig. 9. Comparison of results of the experimental determining of transmittance for disc No. 1 and body region No. 1 (head)

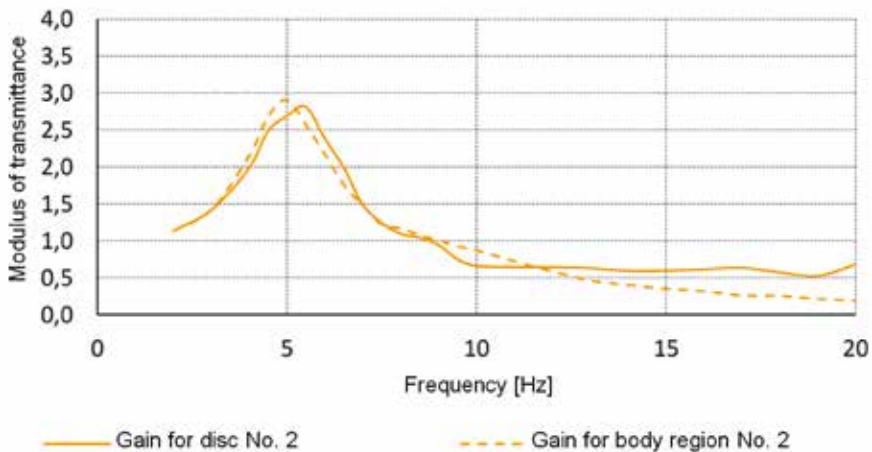


Fig. 10. Comparison of results of the experimental determining of transmittance for disc No. 2 and body region No. 2 (thorax)

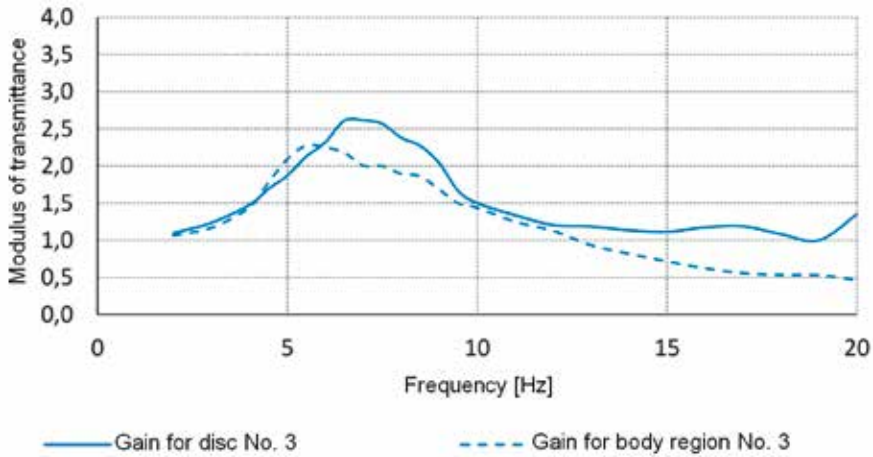


Fig. 11. Comparison of results of the experimental determining of transmittance for disc No. 3 and body region No. 3 (abdomen)

The best consistency, both in qualitative and quantitative terms, can be observed for the curves representing the transmittance of accelerations of mass m_2 and disc No. 2. It can be seen from the transmittance curves that the highest acceleration gain values occurred at frequencies of 5.0 Hz and 5.5 Hz, respectively. The difference between the maximum gain values for these curves was 3.3%.

According to the transmittance curves for body region No. 1 and disc No. 1, the highest gain occurred at identical resonance frequency of 4.5 Hz for both curves. The difference between the gain values at this frequency was 10.6%. In this case, the curves were close to each other in the frequency range from 3 Hz to 12 Hz. At higher frequencies, the differences between the curves increased with growing frequency values.

The lowest consistency between the transmittance curves can be seen in the case of body region No. 3 and disc No. 3. The peaks of these curves appeared at different resonance frequencies, differing from each other by 1.5 Hz, and the difference between the maximum gain values of individual curves was 15%. In this case, the curves best concurred with each other in two frequency ranges: from 1 Hz to 6 Hz and from 9 Hz to 12.5 Hz.

4. Recapitulation

The structure of the anthropodynamic dummies to be used for examining the vibration comfort should correspond to that of a sitting human body, with taking into account the body regions for which the experimental tests are to be performed.

Results of the experimental tests carried out have shown that at least three separate regions should be distinguished in the human body because each of them is characterized

by a different resonance frequency and different acceleration gain levels. This suggests that for satisfactorily good representation of the dynamic reactions of a human body to be obtained, a dummy with at least four degrees of freedom should be used where head, thorax, and abdomen should be distinguished. This requirement is met by the structures of dummies MEMOSIK II and KPST, where the said body regions are separately taken into account. It should be remembered, however, that the number of the degrees of freedom of a dummy must be a compromise between the will to map the human body structure with the highest possible accuracy and the significant practical limitations encountered at the construction of such dummies.

Usually, it is inevitable that a vehicle driver would assume different body positions (with his/her back being put against the seat backrest, with the body sitting straight or hunched, etc.) when driving a motor vehicle. The testing of a seat-driver subsystem with the use of a dummy where the above requirements are not met is questionable.

In the dummies described above, with a few exceptions, their mass structure as well as their spring and damping characteristics can be adjusted (adapted) to the needs. Appropriate sets of weights, damper components, and spring elements make it possible for the anthropodynamic dummies to represent the vertical dynamics of people with different build.

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