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EXPERIMENTAL VERIFICATION OF THE USE OF DUMMIES FOR TESTS IN EMPIRICAL RESEARCH

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Abstract

The issues related to the use of test dummies for experimental research in the field of automotive engineering have been addressed. The article discusses the historical introduction and development of the dummies in the biomechanical tests, which have contributed to the replacement of, previously conducted tests on corpses or volunteers. The evolution of dummies development Evolution of the dummies construction development to the present times has been presented. Question was raised: what is the "similarity" between the dummy living human being. Contemporary dummies reflect very well features of the human body are made of good quality materials and can be equipped with numerous sensors performing various measurements. Comparative empirical tests carried out with an adult dummy and a living adult of similar parameters such as: size (weight and height) body proportions have been presented. The impact of vibrations on the human occupant riding a motor vehicle was examined, with road tests being carried out of realized driving on various road surfaces within that work and with the data recorded being analysed in the time domain and frequency domain. In the time domain, time histories of the accelerations recorded were analysed and the root-mean-square (RMS) acceleration values were calculated. In the frequency domain, the power spectral density (PSD) values and the absolute transmittance (amplification) values were determined for the acceleration signals recorded. The analysis of the measurement results for the ability to absorb vibration by living human being and the dummy has been done. The differences and similarities between the living human subject and the test dummy have been presented from the point of view of utilizing such subjects for experimental tests.

Keywords: *dummies, experimental tests, human body vibration*

1. Introduction

One of the characteristic features of the present-day level of technological development is the widespread use of dummies in experimental tests.

In the post-World War II period, biomechanical tests were conducted on human cadavers or volunteers. However, it was very difficult to find a cadaver that was free of bodily injuries and internal damage. Additionally, the lack of volunteers and (or perhaps first of all) moral questions induced engineers to start work on test dummies that would "represent" or "supersede" living human subjects in this role. The construction and degree of technological advancement of the dummies was gradually developed for the muscles, joints, and other elements of the human body to be adequately represented [1-3, 5], see Figs. 1 and 2. In 1949, Samuel Alderson created a dummy named "Sierra Sam", Fig. 1. It was the first dummy that looked to some extent like a human being. It represented a 95th percentile male and became a model on which the construction of the next, more anthropomorphic dummies was based, where much effort was made to represent the muscles, joints, and other elements of the human body with the best accuracy [2]. An example may be the Hybrid II dummy version, designed by Alderson Research Laboratories in 1972 and modified by General Motors and The National Highway Traffic Safety Administration (NHTSA), where improvements were introduced to the design of knees, spine, and shoulders [3]. An example of a new generation dummy can be seen in Fig. 3. Its skull was made as a one-piece aluminium casting, coated with a vinyl skin. Its neck consists of rubber segments and an aluminium structure. Inside the structure, as it is in all the Hybrid III adult dummies, there is a central part with a cable, thanks to which the human neck movements are perfectly represented by movements of the dummy's neck. The thorax is composed of six ribs made of high-strength steel and based on damping material. The damping material makes it possible to obtain a precisely shaped thorax deflection vs. force characteristic curve that would be close to the deflection characteristics of the human thorax. The sternum is provided with a potentiometer, which measures its rotational displacement. The lumbar spine is specially shaped, without bends, so that the dummy can be used in both straight and sitting position. There is a cable passed along the lumbar spine centreline to raise the spine durability and to endure a wide range of spine reactions to stimuli. The pelvis is an aluminium casting coated with polyurethane foam and vinyl leather. The femurs and tibiae are provided with instruments to estimate the possibility of bone fracture and to evaluate the possible injuries to the knee and knee ligaments [4].

Fig. 1. The Sierra Sam dummy [2]

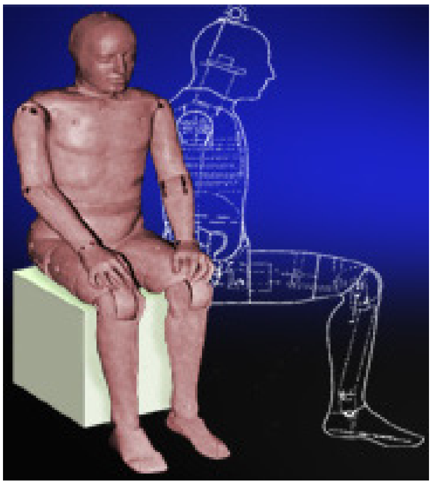

Fig. 2. Hybrid II 50th percentile male dummy [3]

Fig. 3. Example test dummy of new generation: a 95th percentile male dummy of the Hybrid III family [4]

From the automotive engineering point of view, noteworthy is a steady growth in the time spent by people in their motor cars. Therefore, dynamic development takes place in the testing of motor vehicles, both on roads and on test rigs. In this connection, a trend towards widespread use of test dummies can also be observed [6].

Why are dummies used for the tests? It would be ideal if the measurements could be carried out on living individuals. In practice, however, this would be difficult, or even impossible at all in certain situations for safety and health as well as moral considerations. While the participation of an adult in tests of some kinds could be thought of, it is difficult to imagine that a child could be subjected to such experiments.

At the Automotive Industry Institute (PIMOT), dummies are used *inter alia* for tests within research on the impact of motor vehicle vibrations on vehicle occupant's body [7-13].

In consideration of the above, however, some questions should be asked. What is the "similarity" of the test dummy to a living human subject? To what extent can the dummy be useful for tests so that the test results could be applicable to a living human being?

2. Experimental road tests

To verify the results of tests carried out with the use of dummies, comparative tests were carried out at PIMOT with the use of a Hybrid II dummy and a living adult, comparative with each other in respect of their height and body mass. The same acceleration sensors with the same measuring channels were used for the tests. The sensors were located as follows:

– for the Hybrid II dummy, the sensors were placed in dummy's head and thorax,
– for the living human subject (a male), the sensors were placed on his head and thorax.

For the tests, the following symbols have been adopted:

– CzG meaning the sensor placed on the head of the living adult,
– CzB meaning the sensor placed on the thorax (torso) of the living adult,
– H2G meaning the sensor placed in the head of the Hybrid II dummy,
– H2B meaning the sensor placed in the thorax (torso) of the Hybrid II dummy.

The measurements were carried out on test road sections with dry surface, representing three road surface types (Fig. 4-6).

Fig. 4. Test road section with "even" surface (asphalt)

Fig. 5. Test road section with "rough" surface

Fig. 6. Test road section with a "speed bump"

2.1. Time domain analysis

Comparisons between example vertical vibration acceleration vs. time curves, recorded for the dummy (H2) and the living human subject (Cz), have been shown in Fig. 7 and 8.

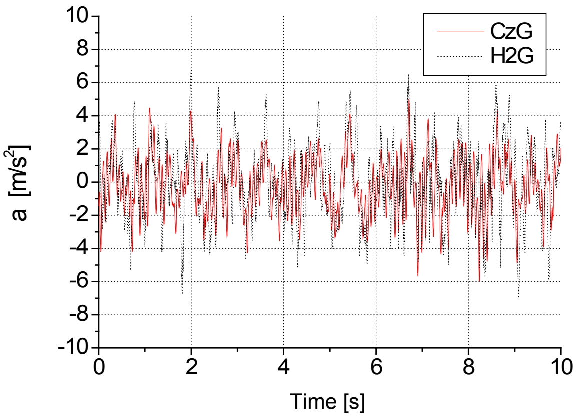

Fig. 7. Head acceleration vs. time curves: a comparison between CzG and H2G

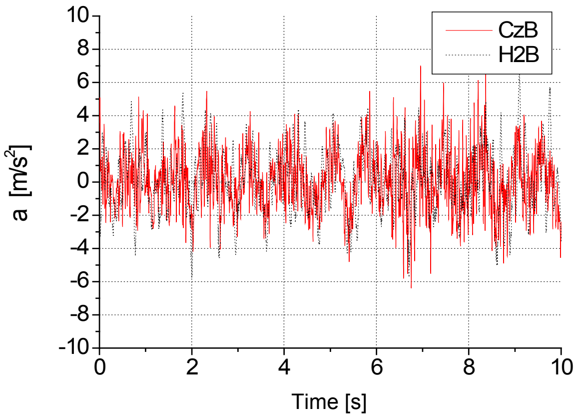

Fig. 8. Thorax acceleration vs. time curves: a comparison between CzB and H2B

The RMS values of acceleration signals for the dummy (H2) and the living human subject (Cz) have been presented in Tab 1. In qualitative terms, the acceleration vs. time curves having been recorded coincide with each other; actually, a statement may be made that the acceleration vs. time curves having been recorded for the dummy (H2) and the living human subject (Cz) show a qualitative similarity. However, quantitative differences can be seen: the acceleration values for H2 exceed those for Cz by about 30 %. The fact that the acceleration values recorded for the dummy were higher than those for the living human subject may be considered as reflecting a favourable trend, because the dummy H2, unlike the living human subject, does not damp the vibration amplitudes. The RMS values of the acceleration signals recorded, given in Tab. 1, confirm the above findings.

Tab. 1. RMS values [m/s^2] of the acceleration signals recorded

RMS acceleration, H2G	RMS acceleration, H2B	RMS acceleration, CzG	RMS acceleration, CzB
4.537	3.955	3.486	3.235

2.2. Frequency domain analysis

Based on the signals recorded, dynamic characteristic curves were also determined in the frequency domain. Power spectral density values (PSD) of the accelerations recorded for the dummy (H2) and the living human subject (Cz), compared with each other, have been presented in Figs. 9 and 10.

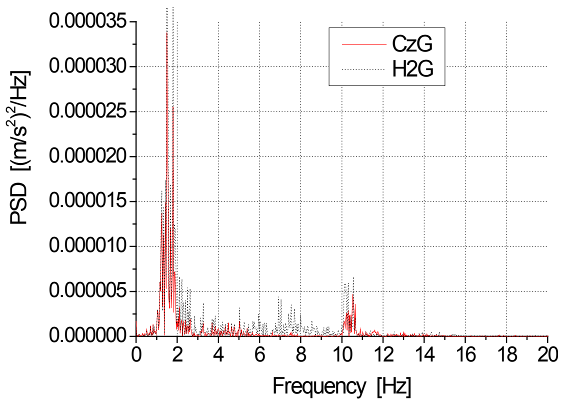

Fig. 9. Power spectral density values of head acceleration: a comparison between CzG and H2G

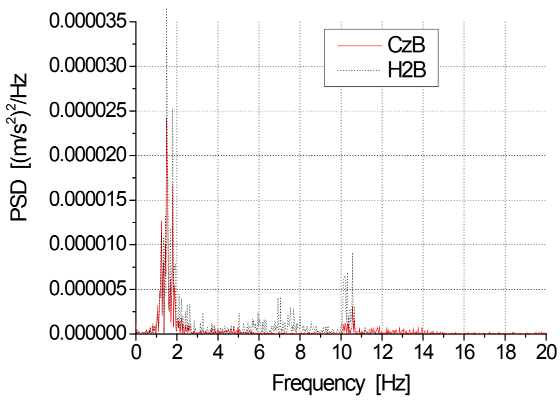

Fig. 10. Power spectral density values of thorax acceleration: a comparison between CzB and H2B

The power spectral density (PSD) curves provide a convenient tool for analysing the signals recorded. In the frequency domain, one measure that is more very characteristic is available. The relations between the input signal (in this case, excitation represented by the signal measured on the motor vehicle floor) and the output signal (in this case, the Cz and H2 response signals) are dynamic characteristics, also referred to as transfer functions (transmittances), amplification functions, or amplitude-frequency characteristics. The knowledge of such characteristics is utilized for examining system properties in respect of the frequencies transmitted. In the case under consideration, the characteristics of this type will be a complement, based on the PSD curves, to the analysis carried out as described previously.

Figures 11 and 12 show example graphs of the absolute values of the transmittance (amplification) between the accelerations recorded for:
- floor (P) and head (H2G and CzG), i.e. P/H2G and P/CzG, respectively, Fig. 11,
- floor (P) and thorax (H2B and CzB), i.e. P/H2B and P/CzB, respectively, Fig. 12.

2.3. Recapitulation of test results

Based on the graphs shown in Figs. 9-12, the following findings may be formulated:
1) The Hybrid II dummy (H2) is more susceptible to the effect of vibrations in the 1-11 Hz frequency range and shows a stronger response to vibrations at such frequencies. This is considered favourable because the amplitudes of vibrations within this frequency range are not damped;
2) Lower $|H_{zz}|$ values for the living human subject (Cz) in the 1-11 Hz frequency range may indicate higher absorption of vibrations by the living human body than it is in the case of the dummy at such frequencies;

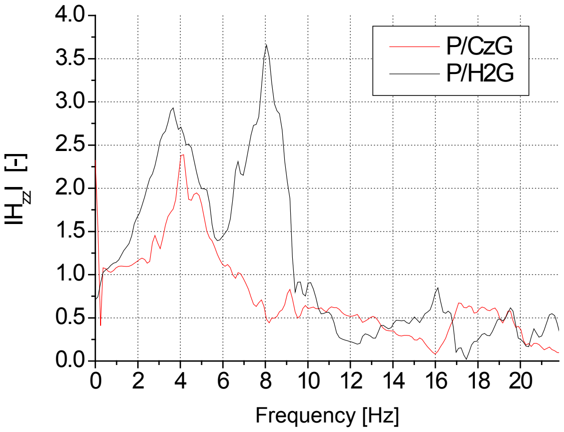

Fig. 11. Absolute acceleration transmittance values (floor-head): a comparison between P/CzG and P/H2G

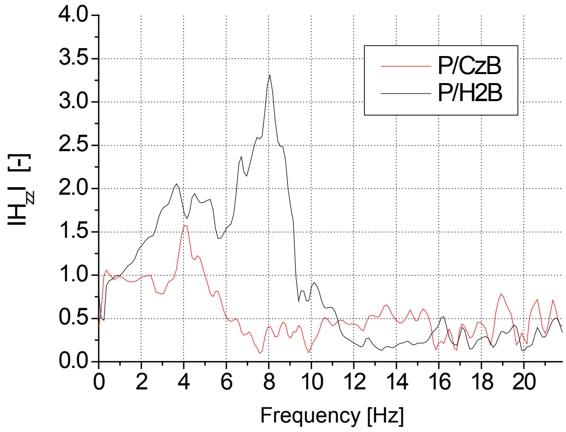

Fig. 12. Absolute acceleration transmittance values (floor-thorax): a comparison between P/CzB and P/H2B

3) The Hybrid II dummy (H2) shows lower vibration damping in comparison with the living human subject (Cz);
4) The Hybrid II dummy (H2) is particularly susceptible to the effect of vibrations in the 6-11 Hz frequency range. This is considered favourable because the effect of vibrations in this frequency range is not disregarded ("lost");
5) Lower PSD values for the living human subject (Cz) in the 6-11 Hz frequency range may indicate higher absorption of vibrations by the living human body than it is in the case of the dummy at such frequencies;
6) The quantitative differences in the acceleration values recorded (Fig. 7 and 8, as well as Tab. 1) show that the living human body absorbs vibrations to a higher degree in comparison with the dummy.

The higher acceleration values occurring for the dummy as against the living human subject show a favourable trend because the effect of "hidden" vibration damping does not take place in the former case. On the other hand, it should be remembered that the human body absorbs vibrations to a higher extent in comparison with the dummy (due to the complexity of human body structure), which translates into lower vibration values recorded in the case of the living human subject.

3. Conclusion

The human body characteristics are very well represented in the present-day test dummies. Such dummies are made of high-quality materials and may be provided with tens of sensors that can be used for a wide variety of measurements [4]. Thanks to this, accurate analyses can be carried out, e.g. at specific decelerations.

Modern anthropometric dummies offer a possibility and ease of replacement of individual body parts and accessibility to the instrumentation. In modern designs, the dummy can be used in both sitting and standing position. In general, a steady development trend can be observed in the dummies offered.

The above comparisons between the living human subject (Cz) and the Hybrid II dummy (H2) made it possible to show the reasonability of the using of dummies for empirical tests.

In consideration of the above, the following statements may be made:

– to a specific extent, there is a "similarity" of characteristics of the test dummy to those of the living human subject, confirming the possibilities of using the dummies for research tests,
– the test dummies may be useful for tests conducted so that the test results thus obtained might be applicable, to a specific extent, to living human beings.

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