DYNAMIC BIAXIAL LOADING OF CAR SEATS

Petr LEPŠÍK[1], Vítězslav FLIEGEL[2], Aleš LUFINKA[3]

[1]*Faculty of Mechanical Engineering, TU of Liberec, Studentska 2, Liberec 1*
[2]*Faculty of Mechanical Engineering, TU of Liberec, Studentska 2, Liberec 1*
[3]*Faculty of Mechanical Engineering, TU of Liberec, Studentska 2, Liberec 1*

Abstract
Testing of car seats and evaluation of their quality depends on the testing technology used. Basically we have two options to test the car seat in the car in a real ride or laboratory. Both methods have their advantages and disadvantages. Testing a car seat in a car has a great advantage in performing the test. You just need to sit on the driver's or passenger's seat, choose the right route for driving and the whole test is set, unfortunately the big disadvantage is the repeatability of such a test, e.g. there must always be the same the "test" person is preferably at the same time of the day and the same driver, i.e. the same driving style on a given route in the same weather conditions. From experience, we can say that it will never be possible to 100% reproduce the test. The advantage of laboratory testing is the almost perfect reproducibility of test conditions, but the great disadvantage is the high time required for preparation, e.g. measurement of test signals from real driving, reproducibility of these signals by the control system of the laboratory test equipment.

Key words: *car seat; testing; biaxial loading, measurement standards.*

INTRODUCTION

Testing of car seats in laboratory conditions is performed according to the relevant standards (*ASTM D3574-11; JASO B407-87; DIN EN ISO 3385; JASO B407-871978*). Each standard specifies a test method that corresponds to a particular car seat load regime. The comfort of sitting and the level of fatigue after a long drive with the car depend on the interaction properties of the car seat with the human body at the point of contact with the seat. Reproduction of seat testing in real operation in laboratory conditions requires strict adherence to prescribed standards, i.e., simultaneous multi-axis loading in the vertical and two horizontal directions. Therefore, the test equipment must be increasingly sophisticated, enabling the implementation of load signals in multiple axes. The possibility of comparing tests from real operation and their uniform evaluation also depends on the method of realization of test signals. Of course, the signals must be recorded correctly in the actual driving of the car along the specified route. A number of studies have already been carried out in the area of loading PU foams describing its specific properties (*Han et al., 2011; Werner & Daniel, 2014; Yang et al., 2021*) and describing properties under uniaxial loading (*Fliegel & Martonka, 2015; Martonka & Fliegel, 2016b*). The aim of this paper is to compare influence of one- and two-axes dynamic loading of car seat.

MATERIALS AND METHODS

Testing device

The current test facility was created as an innovation of the existing facility, which allowed the performance of load tests of car seats in only one axis, i.e. vertical in the "z" axis. However, current normative legislation requires testing in two axes, i.e. in the vertical axis and in the anteroposterior axis at the same time. In order to meet the requirements of the standard, we have added a horizontal actuator to the existing equipment, which serves as an exciter in the “x” axis (Fig.1). The excitation range in the vertical axis is plus / minus 200mm and the anteroposterior axis is plus / minus 50mm. These ranges richly cover the requirements of currently valid standards as well as the ranges of measured values of excitation signals in real driving. A great advantage of said test device is the overall energy consumption for the test. Because the exciters are electric, their consumption is an order of magnitude lower than that of their hydrodynamic analogist. A sufficient amount of oil with the required pressure is required for the hydrodynamic hexapod to function properly, but this is created in the unit with the required power. This increases the price of individual tests many times over. There is an expert discussion about the economy and ecology of the laboratory tests performed. Optimization of energy intensity of laboratory tests determines the possibilities of their practical use. The signals required by the test methodology, both measured and generated, will used as test signals. The spatial movement of the seat or the load is then composed of the realized excitation signals. From the preferred fluctuations and frequencies of the excitation signal, we can prioritize the "force" of excitation in individual directions.

Fig. 1 Original test equipment for biaxial loading

Testing loading

Fittings corresponding to the EuroSit III test dummy were used as test loads. The existing test equipment was used to perform the dynamic test. Loads differ in their design. The first type is very similar to the human body, i.e. it is shaped like a moderately static person. This manikin is used both in testing in a moving car as a "passenger" and in static testing of the seat, e.g. for measuring the H-point. The second type of load used is a European copy of a medium-sized statistical person (Fig. 2). It is mainly used for dynamic tests, both with free load, e.g. for determining transmission characteristics, ie dynamic load, and with vertically guided load for determining, for example, seat creep. In this study we used the second manikin.

Fig. 2 Original loading

Principles of control

The actuator is basically an electric motor with a gearbox and a motion screw. This converts the rotary motion of the motor into a sliding motion. The actuator is also equipped with a position sensor which is used for position feedback control. An integral part of the actuator is an external control unit that provides power to the electric motor and implements the position feedback control. The actuator control unit is connected to the user computer in several ways. The RS 485 serial line and software supplied by the actuator manufacturer are used for basic parameter settings. The user application created in the Labview environment is then used to control the movement of the actuator during testing. It uses logical lines for communication, which are used for basic commands and status signals (eg start, ready, etc.). The value of the desired position of the actuator is transmitted by an analog signal, so the speed is not limited, for example, by the transmission speed of the serial line, and position changes can be very fast.

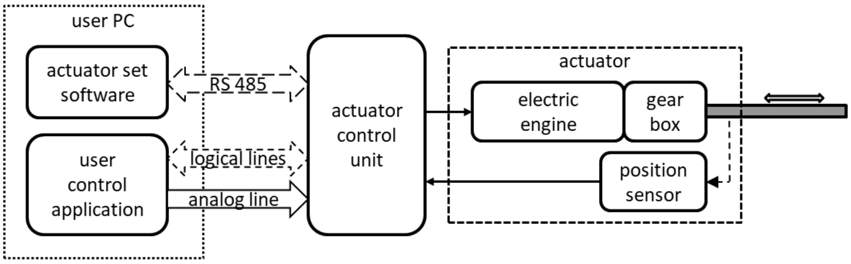

Fig. 3 Block diagram of the basic actuator connection

The test device allows movement in two axes Z and X. It therefore has two actuators, which are controlled simultaneously by the user application. A connection block diagram is shown in the following figure.

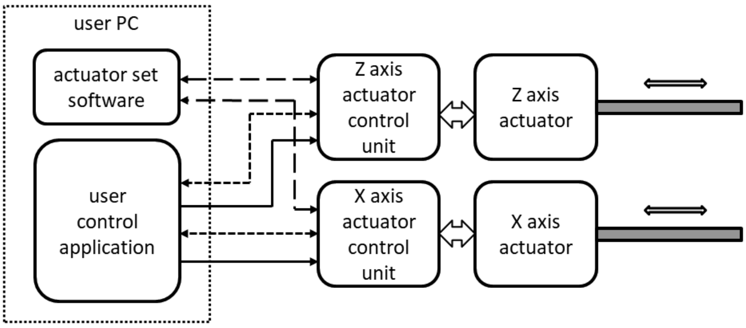

Fig. 4 Block diagram of the testing device actuators connection

The user control application can to use an external file with time record of the excitation signal for the actuator control or can directly generate fundamental harmonic signals. These methods can also be combined, for example the Z axis can be controled with an external file and harmonic signal can to be add to the X axis. This control method was also used for this testing, the Z axis was always excited by the same signal from the file and harmonic signals with different amplitude and frequency were gradually added to control the X axis.

Test signals and measurement

The resonant frequency of passive car seats is usually around 6 Hz. Therefore, an excitation signal in the range of 0.5 to 16 Hz is usually used for the measurement. The frequency increases continuously during the measurement in the specified range and the amplitude of the oscillations is usually set so that the acceleration value of the excitation signal remains constant. Therefore, the amplitude must decrease with increasing frequency of the excitation signal. Such a signal was created for the basic excitation in the Z axis, the value of acceleration amplitude was set to 0.1 G. Its example is shown in the following figure.

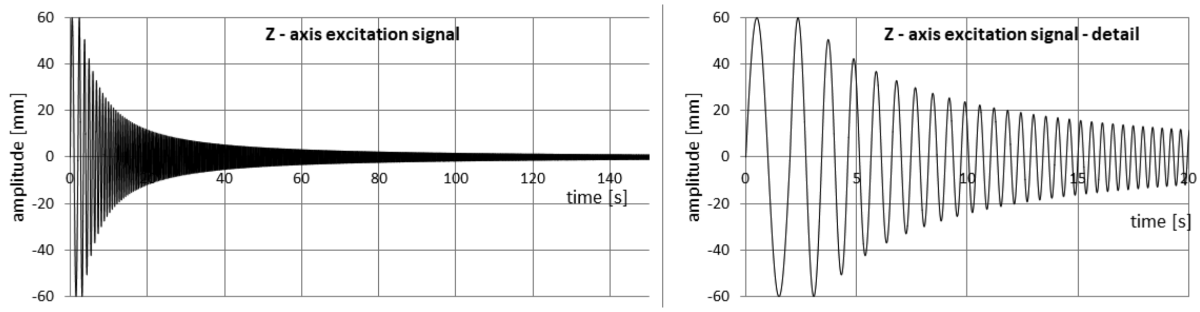

Fig. 5 Test signal for Z-axis excitation

Harmonic excitations in the X-axis direction with different amplitudes and frequencies were then added to this basic Z-axis excitation signal during testing. An example of such a compound excitation is shown in the following figure.

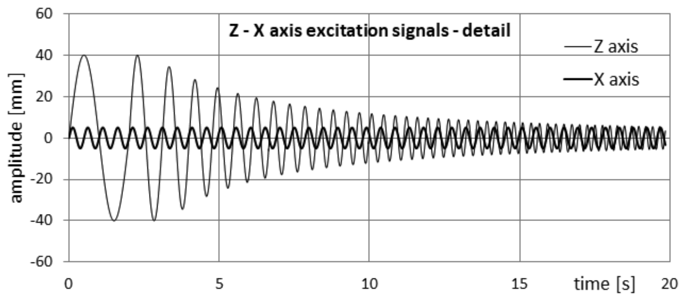

Fig. 6 The example of the compound Z–X axis excitation

The Dewe 5000 measuring device was used for the measurement. Non-contact laser position sensors were used to measure table and mass movements in the Z-axis direction. Two accelerometers simultaneously measured the acceleration of the table and the mass again in the direction of the Z axis. The experiment was further captured by a camera, the image recording is synchronized with the measured data. The sampling frequency of the data was 500 Hz, the camera took 100 images per second.

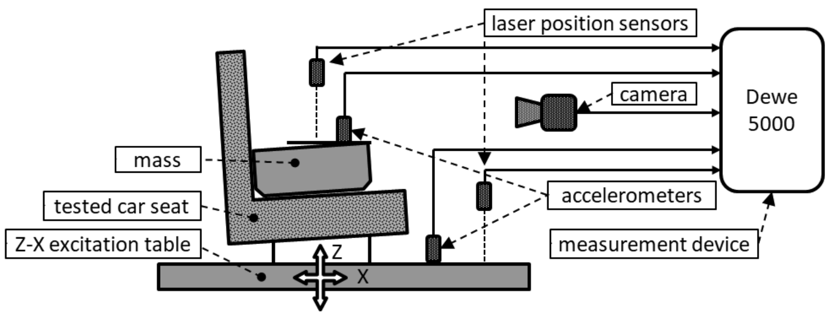

Fig. 7 Block diagram of the measurement arrangement

Mathematical channels for automatic calculation of the amplitude transmission characteristic in real time were defined in the measuring device. In the first step, the amplitudes of the measured signals are detected and the transmission value is calculated as the ratio of the amplitude of the signal from the mass and the signal of the excitation table. Two transfer functions are calculated, one from movements and the other from the accelerations. The result is therefore two transmission characteristics, which should, however, be essentially the same. The double measurement and calculation method was chosen to refine the results and eliminate possible errors. In addition, the course of the amplitude transmission characteristic is synchronized with the image recording. When analyzing the results, the shape of the characteristic can be assigned to the visible oscillations of the mass.

RESULTS AND DISCUSSION

The tests carried out show a significant influence of loading in the horizontal direction on the size of the natural frequency and the size of the transmission. The magnitude of the transmission from the acceleration as well as the values of the natural frequencies for excitation in the Z-axis (5 to 11Hz) and the X-axis with frequencies of 0Hz, 2Hz, 5Hz, 8Hz and 11Hz at 0.1G are shown in Fig. 8.

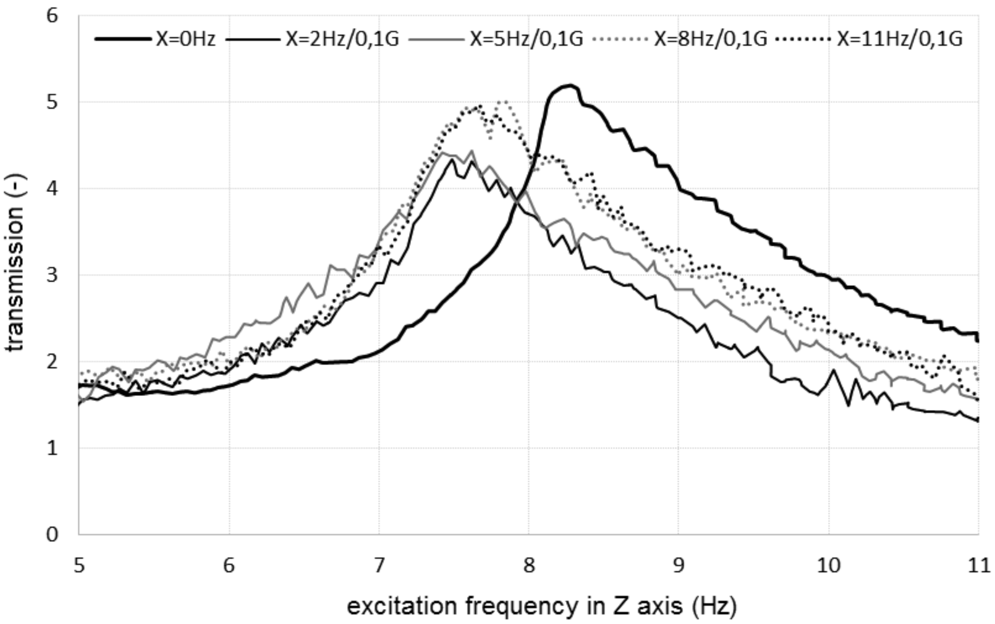

Fig. 8 Test results – Transmission from acceleration for Z-axis excitation 5 to 11Hz and 0.1 G

It can be seen from the figure that there are two effects if we introduce excitation in the X axis. The first effect is that the natural frequency is reduced (from 8.2Hz to 7.8 or 7.4Hz). The second effect is that the transmission value is reduced. A more pronounced drop in transmission was seen at lower frequencies (a drop of 26.5% at 2Hz and 24.5% at 5Hz), at higher excitation frequencies the drop was smaller, 3.8% for 8Hz and 4.4% for 11Hz. The described effects of biaxial loading extend the knowledge gained from uniaxial loading described in the studies (*Fliegel & Martonka, 2015; Martonka & Fliegel, 2016b*) using device (*Martonka & Fliegel, 2016a*). In addition to the above, the performed tests showed the functionality of the developed device (*Fliegel et al., 2019*), which make it possible to carry out tests according to the relevant standards for biaxial loading of car seats (*ASTM D3574-11; JASO B407-87; DIN EN ISO 3385; JASO B407-871978*).

CONCLUSIONS

The aim of the research was to perform initial measurements on the developed device *(Fliegel et al., 2019*) and to compare the influence of one- and bi-axial dynamic loading of a car seat. The results showed a significant effect of horizontal excitation on the transmission in the car seat, when both the transmission and the resonance of the car seat were reduced. In real operation, the car seat is exposed to multi-axial loads, for this reason a 3-axis test device was designed *(Fliegel et al., 2021; Lepsik et al., 2021*), which should bring further refinement of the behavior of the car seat. The subject of further work will be the execution of a more extensive set of measurements at different input parameters (amplitude, frequency) as well as a set of seats made of different foam stiffness and foam thickness. Knowledge of natural frequencies must be taken into account when designing the seats so that there is no unwanted strain on the human body of the crew.

ACKNOWLEDGMENT
This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic and the European Union - European Structural and Investment Funds in the frames of Operational Programme Research, Development and Education - project Hybrid Materials for Hierarchical Structures (HyHi, Reg. No.CZ.02.1.01/0.0/0.0/16_019/0000843).

REFERENCES

1. Standard: ASTM D3574-11. Standard Test Methods for Flexible Cellular Materials—Slab, Bonded, and Moulded Urethane Foams.
2. Standard JASO B407-87: Test code of seating comfort for automobile seats.
3. Standard DIN EN ISO 3385: Flexible cellular polymeric materials - Determination of fatigue by constant-load pounding.
4. Standard JASO B407-871978: Test code of seating comfort for automobile seats
5. Fliegel, V., Lepšík, P., & Martonka, R. (2019). Innovation measurement device of car seats. *7th International Conference on Trends in Agricultural Engineering 2019*, *7*, 127–132.
6. Fliegel, V., Lepšík, P., & Martonka, R. (2021). *A device for simulating a moving vehicle*. UPV. https://isdv.upv.cz/doc/FullFiles/UtilityModels/FullDocuments/FDUM0035/uv035663.pdf
7. Fliegel, V., & Martonka, R. (2015). Characteristics of PU Foam at Long Term Static and Dynamic Loading. *Applied Mechanics and Materials*, *732*, 149–152.
8. Han, S. H., Lu, Z. H., & Liu, Y. J. (2011). Study on Multi-Axial Mechanical Properties of a Polyurethane Foam and Experimental Verification. *Advanced Materials Research*, *311–313*, 301–308.
9. Kia, K., Johnson, P. W., & Kim, J. H. (2021). The effects of different seat suspension types on occupants' physiologic responses and task performance: Implications for autonomous and conventional vehicles. *Applied Ergonomics*, *93*, 103380.
10. Lepsik, P., Fliegel, V., & Lufinka, A. (2021). Innovation of Car Seat Testing Device with Three Axes of Loading. *AD ALTA: Journal Of Interdisciplinary Research*, *11*(2), 331–335.
11. Martonka, R., & Fliegel, V. (2016a). Analysis and construction of measurement device, EAN 2016—54th International Conference on Experimental Stress Analysis. *EAN 2016 - 54th International Conference on Experimental Stress Analysis*, 242–248.
12. Martonka, R., & Fliegel, V. (2016b). Live tests of car seats. *Vibroengineering PROCEDIA*, *7*, 138–141.
13. Werner, B. T., & Daniel, I. M. (2014). Characterization and modeling of polymeric matrix under multi-axial static and dynamic loading. *Composites Science and Technology*, *102*, 113–119.
14. Yang, L., Li, X., Zi, F., Yang, S., Zhang, Z., Qu, J., Dong, Y., & Wu, L. (2021). Dynamic response of graded PVC foam sandwich panel under air blast loads. *Mechanics of Advanced Materials and Structures*, 1–15.

Corresponding author:
doc. Ing. Petr Lepšík, Ph.D., Department of Mechine Parts and Mechanisms, Faculty of Mechanical Engineering, Technical University of Liberec, Studentska 2, 461 17 Liberec 1, Czech Republic, phone: +420 48535 3326, e-mail: petr.lepsik@tul.cz