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Hydraulic stand for testing automatic seats model development

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A new design scheme for testing the car seats with hydraulic drive has been proposed, a mathematical model of stand work process has been developed, the movement of mass center in the car seat has been theoretically proved. It is determined at the expense of what factors it is necessary to develop special stands necessary for an adequate various seats check or seat configurations, which simulate long-term seats use during a short time period. The special stands car seats of different configurations work analysis simulation close to the real operation conditions on cars is carried out. The basic parameters and operating modes that characterize working processes in the conditions of operation are established. The mathematical dependence, which characterizes the work process of the stand for testing the car seat with a hydraulic drive, is obtained. The movement of car seat masses center depending on the influence factors is determined.

Keywords: model of car seat with hydraulic drive, mathematical model of the stand, coordinates of mass center movement, radius, speed

Розроблення моделі стенду для випробування автомобільних сидінь з гідروприводом

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Розглянуто різноманітні конструкції сидінь, які, як правило, перевіряються на потенційне використання в транспортному засобі з метою розробки місць, і є стійкими до деформацій та вібрацій. Визначено, за рахунок яких чинників необхідно розробити спеціальні стенди, необхідні для адекватної перевірки різноманітних сидінь або конфігурацій сидінь, які імітують багаторічне використання сидінь протягом короткого періоду часу. Проведено аналіз роботи спеціальних стендів імітації автомобільних сидінь різних конфігурацій в умовах, близьких до реальних умов експлуатації їх на автомобілях. Встановлено основні параметри та режими роботи, які характеризують робочі процеси в умовах експлуатації. Визначено необхідність забезпечення плавності регулювання процесів, підвищенні ефективності перевірки автомобільного сидіння, зменшенні рівня енергоспоживання при використанні стенду для випробування сидінь. Розроблено, спроектовано та досліджено стенд для випробування автомобільних сидінь з гідравлічним приводом робочих органів; досліджено імітацію дорожніх умов та підвищено ефективність перевірки. Запропоновано нову конструктивну схему стенду для випробування автомобільних сидінь з гідравлічним приводом; розроблено математичну модель робочого процесу стенду; теоретично доведено переміщення центру мас на автомобільному сидінні. Одержано математичну залежність, яка характеризує робочий процес стенду для випробування автомобільного сидіння з гідравлічним приводом. Визначено переміщення центру мас автомобільного сидіння залежно від факторів впливу.

Ключові слова: модель автомобільного сидіння з гідроприводом, математична модель стенду, координати руху центру мас, радіус, швидкість



Formulation of the problem. The constant increase in the requirements for the quality and comfort of the car seat characterizes the modern automotive industry state. The car seat plays an important role in the car. The quality of the car seat depends on comfort, driver fatigue while driving, and the driver's health.

Other functions are also assigned to the seat: it should provide a reliable fixing of the driver, and also enables long journeys to be carried out without fatigue.

Improving car seat quality seat is due to high requirements for car seats (DSTU, technical documentation and UNECE). Therefore, in order to ensure safety and comfort of the driver, it is necessary to check the car seat on specialized stands. Checking the car seat enables to check it for compliance with the conditions, which are specified in the technical documentation, DSTU and UNECE.

A promising direction is the development of new structures and improvements to existing stands for testing car seats. Application in such machines of a hydraulic drive provides an opportunity to ensure smoother working processes adjustment, improve the car seat checking effectiveness, reduce energy consumption.

The article is devoted to the development, design and modeling for the car seats testing stand with a hydraulic drive of working bodies. This setting enables to adjust the amount stand of motion in a wide range, the ability to simulate certain road conditions and improve the test effectiveness.

Recent research analysis. There are several designs of existing equipment for testing car seats.

Patent US 6386054 B1 "Mannequin assembly and method of testing seats which utilizes the assembly" (Mannequin and seating method using a stand).

This design uses a mannequin that can create conditions for accelerated seat length. The mannequin provides a force that simulates both the weight of the person against the attached seat part and the forces created against the seat back by the human movement [3].

In order to significantly minimize or reduce the appearance of scratches or deformations, various configurations or "seat designs" are typically checked for potential use in the vehicle in order to develop spaces that are, in fact, resistant to such deformations [3]. To adequately test these diverse seats or seat configurations, tests and stands should be designed to simulate the use of seats for a short period of time.

One device used to simulate a car seat is a mannequin or mannequin unit that has a common human form. In particular, the mannequin is stationary or passively placed inside (on the seat), which needs to be tested, and then the seat is tested for vibrational stability, since the dummy passively lies inside the seat.

Another characteristic example is the device for testing seat is patent US 6386054. The device belongs to

mechanical testing products field, in particular for testing the seats of the wheeled vehicles.

The technical result is the seat back movement dependence on the attachment of effort when tested in accordance with the method described in the regulatory documents [4].

This technical result is achieved by the fact that seat load mechanism is located on a rigid basis, the seat can be installed with the vehicle floor part, which enables the most reliable way to reproduce the seat fastening mechanism. Transfer of load from load device to load cells is carried out using cables with the blocks system. The stand design enables to adjust the height and force application angle to ensure the seats widest range testing possibility [4].

The device belongs to the products mechanical testing filed, in particular for testing the wheeled vehicles seats, [4]. Its disadvantage is cumbersome design.

It is known the device US 5373749 A "Vehicle head restraint tester" The car headrest tester is taken as a prototype. At the stand, forces are applied to the selected parts of the car seat. The stand includes the transmission parts of the effort, which are fitted with the ability to rotate around the overall axis of rotation. Drives connected to the transmission parts of an effort, apply effort to any selected configuration seat back segments - simultaneously or sequentially [4].

This stand is designed to assess the suitability of seats for the Federal Motor Vehicle Safety Standard requirements № 202 and can not be used to assess compliance with UNECE Regulation requirements 80 and 14. As the requirements of these rules provide for other loading regimes and other parts are loaded. The patent does not describe how to attach seats, although the test results depend on their fixation method. In addition, the loading unit is designed for a fairly complex scheme with several worm gearboxes and hydraulic motors. To overcome the aforementioned shortcomings, the stand scheme rooted in the scientific work is proposed.

Automobile seats must meet the strength and safety requirements by the established regulatory documents, GOST, Technical Regulations, UNECE Regulations, etc. Therefore, there is a need for the development of a specialized stand to carry out tests on the seats conformity to these requirements. [4].

Identification of previously unsettled parts of the general problem. Analytical and operational studies of existing stands for testing car seats have shown that for today there is a need for the development of such equipment that have a wide capabilities range, are effective, energy-saving and able to handle high performance indicators. Therefore, a new test bench for hydraulic seats with a hydraulic drive is suggested.

Hydraulic drive use enables to have fine adjustment within wide limits, increasing the efficiency of the test process.

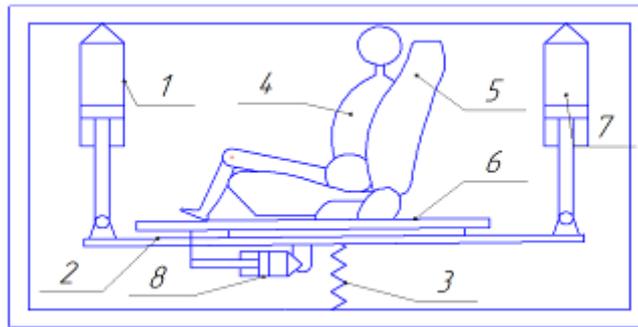


Figure 1 - Constructive scheme of the test bench for hydraulic seats with hydraulic drive
1,7, 8 - hydraulic cylinder; 3 - elastic element; 4 - mannequin; 5 - car seat; 6 - platform

Assignment statement and methods of its solving.

To achieve smoothness of process control, increasing the effectiveness of the car seat check, reducing the power consumption when using the bench while testing the seats, the study is formulated as follows:

- to create, design and test a stand for testing car seats with a hydraulic drive of working bodies;
- to investigate the imitation of road conditions and improve the inspection effectiveness;
- to study the possibility of adjusting the motion amount in a wide range.

Study results and their discussion. The stand with a hydraulic drive operation principle is as follows (Figure .1). Mannequin 4, which is made in the form of a human body, is made in order to simulate human movements as much as possible while driving, securely attached to the car seat 5. Mannequin 4 is made of cast-iron or cast aluminum. Mannequin 4 itself is assembled from several parts that resemble man's bones. On the mannequin 4, sensors are installed, where test indicators are removed and transmitted to the computer. With the help of hydraulic cylinders 1,7,8 (5 hydraulic cylinders are installed on the stand), the stand can simulate different road conditions, as well as check the lower car seat part 5 for durability.

The hydraulic pump moves out the liquid from the water boiler and flows through the pipeline to the hydraulic cylinder 1. Hydraulic cylinder 1 loads platform 2, all other hydraulic cylinders remain stationary, then one side of platform 2 falls down to some angle. The car seat masses center 5 shifts towards the application of forces. The car seat 5, along with the mannequin 4, where the sensors are mounted, also leans and the sensors send data to the computer. The spring 3 resists this force, it can try to turn platform 2 into its original position. This example simulates a car hit in a pit with one wheel.

If two front hydraulic cylinders are loaded and the hydraulic cylinder 8 is loaded and the remaining hydraulic cylinders remain stationary, the front part of the platform 2 is lower evenly and the moving platform 6 moves in the rod direction. The car seat 5 along with the mannequin 4 also bends to a certain angle. Sensors that are installed on the mannequin 4 respond and send data to the computer, where it is possible to see the amount of movement and how far

the masses center has shifted. The spring 3 also counteracts this force and tries to turn the platform back to its original position. This is an example of loads that mimics getting into the car front wheels pit.

Load of hydraulic cylinders 1, 7, when all other hydraulic cylinders remain motionless, incline platform 2 on the side. The car seat 5, along with the mannequin 4, also lean toward the side, the sensors mounted on the mannequin will react to a certain extent and transmit measurements to the computer. From these measurements it is found out the number of system movements in this position and how much the car seat masses center shift. The spring 3 will attempt to turn platform 2 back to its original position. This example of loads imitates the car movement on an uneven road.

The front hydraulic cylinders sharp loading and the hydraulic cylinder 8 sharp loading, which is then gradually rotated to its original position, will cause the platform 2 to drop sharply downwards, and the moving platform 6 shifts horizontally towards the action of the hydraulic cylinder 8, after which it returns to its original position together with the hydraulic cylinder 8. It causes the car seat 5 along with the mannequin 4 to move sharply in the hydraulic cylinders action direction. Sensors installed on the mannequin respond and record the system movement amount, and are also sent to the computer. Where it can be seen how much the center of the masses has shifted. Data loads imitate an accident of the car, which crashed from behind.

If load the front hydraulic cylinders and smoothly load the hydraulic cylinder 8, other hydraulic cylinders remain stationary. The front portion of the platform 2 is lowered downward, and the moving platform 6 moves smoothly towards the action of the hydraulic cylinder 8. The car seat 5 accepts some loads and the mannequin 4, where the sensors are installed, recording these movements. Due to the sensors installed on the mannequin 4, it can be seen the amount of the system movement and at what distance the center of the masses has shifted from the original position. This load example simulates the car braking at a certain speed.

This stand serves to check the car bottom seat for durability and compliance with the DSTU requirements, technical regulations and UNECE regulations, and also due to this stand the system movement

amount and car seat masses moving the center under certain conditions can be found.

The test bench for hydraulic seats with motor can simulate any road conditions, so it can be observed how the car seat behaves in one or another situation. Thus, the proposed design provides car seat convenient and efficient inspection. The stand includes a hydraulic system that helps to more accurately capture data more accurately and has a large range of regulation. Additionally, angle measurement devices for measuring seat deflection, power adjustment devices, controllers and automatic control devices are added to the stand. This system reduces the time to test the car seat while maintaining the test results accuracy.

In stand test purpose view for motorized seats equipped with hydraulic cylinders and hydraulic drive, the following requirements should be followed when constructing a mathematical model of work. In order to achieve the stand maximum efficiency, one should strive to minimize energy consumption, and the stand must meet the requirements of DSTU, technical regulations, UNECE regulations, etc.

Proceeding from the foregoing, in order to minimize energy consumption, it is necessary to adhere to the rules, according to which at each moment of time the power stand consumption is as small as possible, but that the condition for achieving a sufficient fluid supply in the hydraulic cylinder.

The work principle is as follows. From the water tank 6, the liquid is absorbed through an unregulated pump 5 with constant flow direction and fed to a hydraulic distributor with electromagnetic control 2 (figure .2). In the neutral position of the hydraulic distributor spool, when the pump is running, the pressure on the pipeline between the pump and the distributor begins to increase, with the safety valve 4 running and the liquid merges back into the tank. When changing the position of the spool open passage sections in the distributor and the liquid begins to enter the hydraulic cylinder 1 piston cavity. From the hydraulic cylinder rod cavity fluid through the drainage line passes through a hydraulic distributor, regulated chokes with a servo 3 and a filter 7, falls into the drains in the tank.

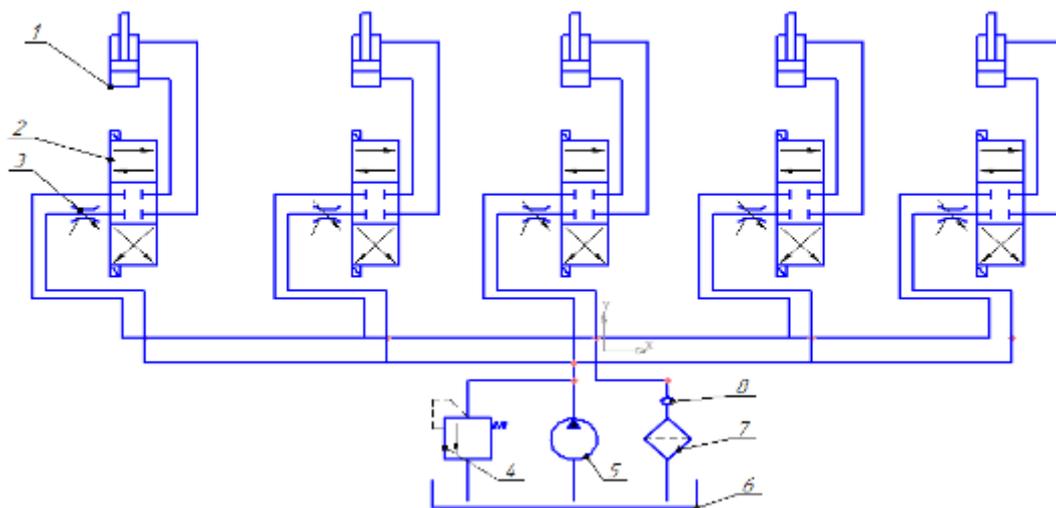


Figure 2 - Hydraulic diagram of the test bench for car seats

1 – hydraulic cylinder; 2 – hydraulic distributor; 3 – servo-choke; 4 – safety valve;
5 – hydraulic pump; 6 – a water jacket; 7 – filter; 8 – check valve

The translational movement velocity of the hydraulic cylinders rods is controlled by the chokes. Rods reversal is carried out by switching the positions of the hydraulic distributor. In stem emergency stop (for example, an insurmountable effort) the pressure in the system increases, thereby causing the opening of the safety valve and the discharge of the working fluid into the tank.

Due to modern capabilities and the complex electronic control systems development, the implementation of such a system in the hydraulic cylinders managing process can ensure the system reliability (long inter-repair period, control and shutdown during excessive pressure on the system, interconnection with the onboard computer, etc.), profitability (ensuring

the equipment operation within the rational parameters limits and operating modes), ergonomics (ease of use) and safety techniques (many types of hearing during system operation occurrence prevention).

To achieve such a requirement, it is necessary to determine the energy source and all consumers in the system, there nature, principle and regularities. The next step should be to determine the total amount of energy consumed at different system operating modes and to obtain patterns according to which to adjust the amount of energy generated by the source according to the required value at each time point.

Checking the car seat on the stand using a hydraulic drive is a complex process that should be analyzed as the operation of the hydraulic cylinder and the hydrau-

lic motor. Also, the amount of energy used to load the car seat is considered.

In this booth (Figure 3), the spring acts as a leveling device so that the stand returns to the starting position.

Since the forces acting on the stand force the center of mass to shift, then there is a need to calculate the point of mass center moving.

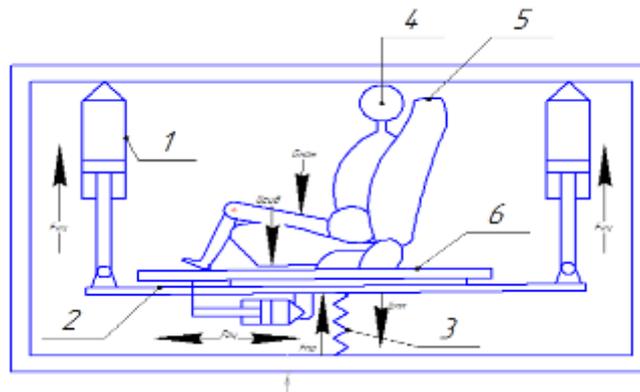


Figure 3 – Scheme of forces acting on the test bench for testing a car seat with a hydraulic drive
1 – hydraulic cylinder; 2 – platform; 3 – a spring; 4 – a mannequin with sensors;
5 – car seat; 6 – mobile platform

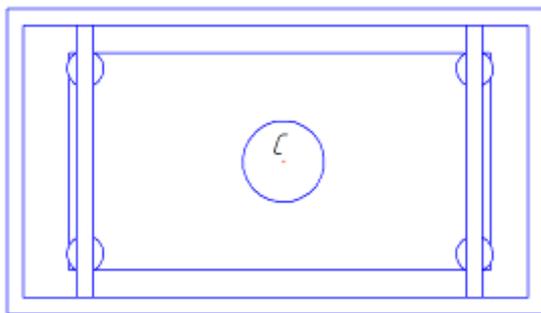


Figure 4 - Test stand mass center scheme for hydraulic seats with hydraulic drive

To determine the stand mass center displacement, the system movement amount should be known. The system motion amount is called the geometric sum of all system material points motion

$$\bar{K} = \sum m \cdot g \quad (1)$$

where \bar{K} – amount of system movement; according to it motion amount projections on the coordinate axis are obtained.

$$\begin{cases} \bar{K}_x = \sum m \cdot g_x = \sum m \cdot \frac{dx}{dt} = \sum mx \\ \bar{K}_y = \sum m \cdot g_y = \sum m \cdot \frac{dy}{dt} = \sum my \\ \bar{K}_z = \sum m \cdot g_z = \sum m \cdot \frac{dz}{dt} = \sum mz \end{cases} \quad (2)$$

The theorem on the system movements amount is formed as follows. Vector derivative from the system motion amount is equal to the main vector of all external forces applied to this system

$$\frac{d\bar{K}}{dt} = \bar{R}^{(b)} = \sum \bar{F}^{(b)} \quad (3)$$

The system mass center is called the geometric point C, whose coordinates are determined by the formula:

$$\begin{aligned} X_c &= \frac{\sum mx}{M} \\ Y_c &= \frac{\sum my}{M} \\ Z_c &= \frac{\sum mz}{M} \end{aligned} \quad (4)$$

where M – the system mass, while x, y, z – the material points coordinates of this system.

Assuming that in the center of masses is the system entire mass, then the system motion amount is equal to the mass center motion amount. Thus, it is got

$$K = M \cdot g_c \quad (5)$$

Here:

$$\begin{cases} K_x = M \cdot g_{cx} = M \cdot x \\ K_y = M \cdot g_{cy} = M \cdot y \\ K_z = M \cdot g_{cz} = M \cdot z \end{cases} \quad (6)$$

If the mass center acceleration C is equal to F, then it is got

$$M \cdot \bar{\omega}_c = \bar{R}^{(b)} = \sum \bar{F}^{(b)} \quad (7)$$

Proceeding from this, the final formula according to which this system is calculated, has the form:

$$K_x = \frac{P}{q} \cdot V_c \cdot \cos \varphi \quad (8)$$

where

$$\frac{P}{q} = m \quad (9)$$

$$V_c = r \cdot \omega \quad (10)$$

where r – is the circle radius; ω – mass center angular velocity.

$$\omega = \cos \varphi \cdot t \quad (11)$$

where t – time for which system will change its position. We accept $t = 30$ s.

Hence, the final formula has the form

$$K_x = m \cdot r \cdot \omega \cdot \cos \omega t \quad (12)$$

Based on Figure 5, to find out the masses center movement an equation should be made

$$\begin{cases} X_l + Y_l = L^2 \\ Y_l = \operatorname{tg} \varphi \cdot X_l \\ X_l < 0 \end{cases} \quad (13)$$

where L – length to mass center; $\operatorname{tg} \varphi$ – tangent of the mass movement center; X_l, Y_l – displacement coordinates.

Then, if this system is solved, it is got:

$$X_l + \operatorname{tg} \varphi \cdot X_l^2 = L^2 \quad (14)$$

Proceeding from this equation, it is obtained

$$X_l + (1 + \operatorname{tg} \varphi) = L^2$$

$$X_l = \sqrt{\frac{L^2}{1 + \operatorname{tg} \varphi}} = -L \sqrt{\frac{1}{1 + \operatorname{tg} \varphi}} \quad (15)$$

$$Y_l = -\operatorname{tg} \varphi \cdot L \sqrt{\frac{1}{1 + \operatorname{tg} \varphi}} \quad (16)$$

Having solved these equations, coordinates are got. Use the formula to find out the displacement

$$S = \sqrt{(X_l - X_a)^2 + (Y_l - Y_a)^2} \quad (17)$$

where S – mass center displacement in the coordinate plane.

It is the final formula, according to which the masses center displacement is calculated.

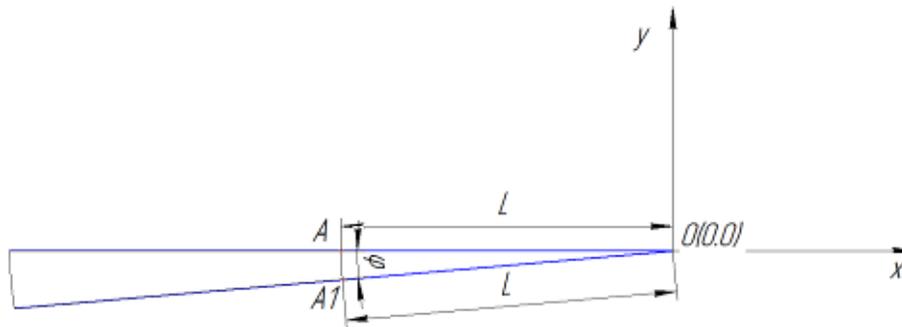


Figure 5 - Mass center moving scheme

Table 1 - Parameters that affect the movement of the mass center

№	Angle of platform φ^0	Radius R мм	Movement V	Amount of movement S , мм	V_1	S_1	V_2	S_2
0	0	75	75	0	75	0	75	0
1	1	76	75,99	3	76,99	4	77,99	6
2	2	77	76,95	5	78,09	7	80,95	10
3	3	78	77,89	7	80,89	10	83,89	13
4	4	79	78,808	8	82,8	12	86,79	16
5	5	80	79,7	9	84,67	14	89,64	19
6	6	81	80,55	10	86,52	16	92,49	22

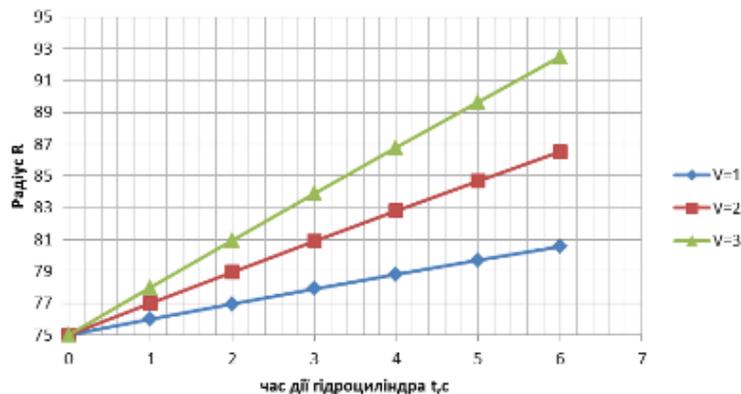


Figure 7 - Mass center moving graphical dependence of radius from speed

On this dependencies graph, the increase in the system movements amount depending on the circle trajectory under the linearly directed forces influence is clearly seen. At the same time, the masses center shifts along the whole trajectory. Characteristic is the nonlinearity, which is due to the quadratic effect of the circle trajectory.

The first curve (Figure 7) shows the center displacement of mass at speed $V = 1 \text{ cm / s}$ for a certain time period. In this curve there is observed a mass center slight displacement, because the hydraulic cylinder rod speed is small and the mass center point of moves to a small distance (Table 1).

The second curve (Figure 7) shows the mass center displacement at a speed $V = 2 \text{ cm / s}$ for a certain time period. In this case, the mass center displacement is greater than in the first case. Because at a speed of 2 cm / s , the radius that passes through the point over the same period of time is also increased (Table 1).

The third curve (Figure 7) shows the mass center displacement at a speed $V = 3 \text{ cm / s}$ for a certain time period. On this curve, the mass center displacement is even greater than the second (Table 1).

Conclusions. The mathematical dependence, which characterizes the work process of the stand for car seat with a hydraulic drive test, is obtained. The car seat masses center movement depending on the influence factors is determined. According to these data it can be concluded that the smaller the seat masses center displacement itself, the less negative impact is on the person. It also determines the impact of impulses on both human health and the car seat itself. Therefore, it is very important that the seat complies with the technical documentation, DSTU and UNECE. Indeed, from the car seat depends on the driver health and the transport efficiency.

Therefore, the presented stand use gives the opportunity to test the car seat, check it on the mass center displacement and control the pulse values, so that the seat design meets all the parameters.

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