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50 PERCENTILE DUMMY MOVEMENT ANALYSIS USING TEMA AUTOMOTIVE SOFTWARE

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Abstract

The dynamic loads acting on passengers during road accidents depend not only on the vehicle structure, but also on the properties of the applied passenger and driver protection system. Two-point seat belts are the most frequently used personal protection system for adult passengers in bus vehicles. The paper investigates the thread of dynamic loads acting on the body of a 50 percentile dummy placed in an armchair equipped with two-point seat belts. In order to solve this problem, tests recorded with the Phantom v310 camera were used, the object of which was the Hybrid II 50th dummy, and the recording of the tests was carried out for three different collision speeds. The article presents the results of the crash tests obtained with the use of the TEMA Automotive program. Crash test analysis showing the displacement of the head and upper torso of the dummy located in the limited space between the bus-type seats indicates that standard seat belts do not provide sufficient protection. The article indicates the basis for further research and improvement of the personal protection system of passengers transported in minibuses and buses.

Keywords: safety; dummy; TEMA Automotive; MSC Adams

1. Introduction

According to the United Nations, over one million people worldwide die as a result of vehicle accidents each year. The number of road accident victims in Poland is very large. According to the statistics of the Police Headquarters in Poland, 2,491 people died as a result of road accidents in 2020, while 26,463 people were injured, including 8,805 seriously injured

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[14, 24]. This huge number would be much larger were it not for the complexity of research conducted to improve safety conducted by global research centers [8, 15, 18].

Human injuries leading to injuries or death during road accidents most often occur as a result of excessive, local deformations of the human body caused by hitting vehicle elements or road infrastructure [16, 19, 26]. The next, main cause of injuries in a road accident are the mutual hitting of individual organs of the human body caused by excessive acceleration. Then there is an excessive inertia force of the organs, which causes them to move, and as a result, they hit other stiff organs that make up the musculoskeletal system. This causes them to rupture or break [21, 22, 25]. The injuries mentioned above are mainly caused by speeding, which significantly affects the risk of a road accident and its consequences. In collisions, vehicle speed changes rapidly, resulting in serious injuries to road accident participants [1, 2, 27].

Seats used in buses should be equipped with appropriate systems of protection of transported passengers, which will have appropriate regulation. In many publications, the authors point out to the lack of adequate safety while transporting passengers [3, 7, 17]. The most dangerous maneuver is changing the longitudinal and lateral speed of the bus. The lack of an adequate passenger protection system in this case can lead to serious consequences. The publications pay particular attention to the inability to adjust the seat belt position to the anthropometric features of passengers [4, 6].

In the works [9] the authors observed that both in the case of the two-point safety system and the lack of belts, high acceleration values were recorded in the center of gravity of the head. Based on the research, it was found that only the three-point seat belt system ensures adequate passenger safety. The article presents a model of a crash test dummy in the ADAMS program, which corresponds to a 50-centile male. The model makes it possible to study the dynamics of movement, the distribution of forces and loads on individual parts of the body. The article contains the results of simulation crash tests carried out in ADAMS [11].

Thanks to the crash test dummies, the number of victims in car accidents has decreased over the years [23]. These are perfect devices reflecting the anthropometric structure of the human body, showing the dimensions, proportion and weight distribution of the human body. The latest dummies are used for crash tests performed by vehicle manufacturers and international independent institutions. Their purpose is to inform the consumer about the safety applied in a given vehicle. Mannequins have dozens of sensors that enable reading hundreds of data from the test [5, 10, 12].

The article presents films recorded for the Hybrid II 50th Male 50-centile dummy using the Phantom v310 high-speed camera belonging to the Kielce University of Technology at the test stand at the Automotive Industry Institute in Warsaw. The recordings were made at three different collision speeds. These were later used to create an extensive analysis in the TEMA program. The analysis carried out in the program allowed to understand the problem occurring during road accidents with passengers placed in a bus-type seat with built-in two-point seat belts. For this purpose, diagrams of displacements, velocities, accelerations and trajectories were made for a fixed coordinate system.

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2. Measurements recorded with a high-speed dome camera using a 50-centile male manikin

The camera used to carry out the measurements with the Hybrid II 50th Male dummy is the Phantom v310 high speed dome camera shown in Figure 1. The Phantom v310 camera enables image recording at 3,250 frames per second with a maximum resolution of 1280x800 pixels. With a reduced resolution of 128x8 pixels, the camera can record images at a maximum speed of 500,000 frames per second. Measurements can be recorded in monochrome and colour, and the fill factor is 56%. The measurement time taken with the v310 camera at the maximum resolution is 6.8 seconds [20]. The camera is equipped with automatic exposure control, the minimum duration of which is 1 μs. The light sensitivity according to the ISO 12232 standard is 2,100, the camera can operate at a temperature of 10°C to 40°C.

Fig. 1. A speed dome camera used to record the Phantom v310 measurements [20]

The measurements were carried out using the Phantom v310 high-speed camera belonging to the Kielce University of Technology at the Automotive Industry Institute in Warsaw. The test subjects were Hybrid II 50th mannequins representing a 50-centile male. A high-speed camera was recorded in order to record the dummy's trajectory during the hitting an obstacle. The dummy was placed on the seat with built-in two-point seat belts presented in Figure 2. Two-point belts, the so-called lap joints are used in buses and minibuses, as well as in older motor vehicles located in the middle of the rear seat. The tests were performed for three different crash speeds: 20 km/h, 40 km/h and 50 km/h. Appropriate markers have been placed on the dummy, which can be used to conduct a full analysis of the movement of the tested object.

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Fig. 2. Seats with two-point seat belts

2.1. Research stand

The station where the measurements were recorded is located at the Automotive Industry Institute in Warsaw. Its structure consists of a plate on which armchairs with two-point belts with a dummy are placed. In the front part of the plate there are metal rods in the shape of pistons, which hit the sleeves placed on the wall with additionally equipped polyurethane sleeves during the test. A part of the plate, piston-shaped rods and sleeves are shown in Figure 3 [15].

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Fig. 3. View of the bars, sleeves and parts of the trolley [13]

During the test, the plate is accelerated by means of rubber ropes permanently attached to the ground with sleeves placed symmetrically on both sides of the track along which the trolley moves. The ropes are attached to the trolley with a pin at the rear. The stand allows for stretching the platform with ropes, the number of which can be set each time from 2 to 10, depending on the needs. In order to determine the speed at which the platform is to move with the dummy placed on the seat, the weight is measured and the tension length of the ropes is adjusted, as well as their number. Figure 4 shows the track on which the trolley with the accessories is moving [15].

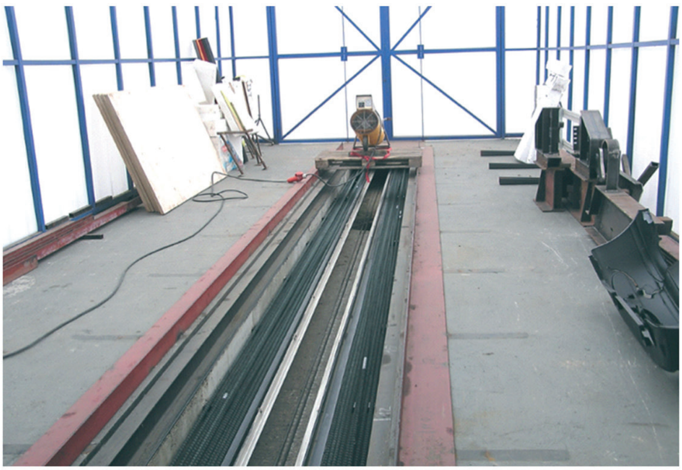

Fig. 4. The track on which the cart moves [13]

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2.2. Measurements made using a speed dome camera

The first test was recorded at a speed of 20 km/h for the Hybrid II 50th Male dummy located in the middle row of seats. The performed measurements were recorded in a resolution of 1024x512 pixels at a speed of 500 frames per second. Figure 5 shows six individual frames that show the movement of the dummy from the beginning of the test successively every 0.07 s.

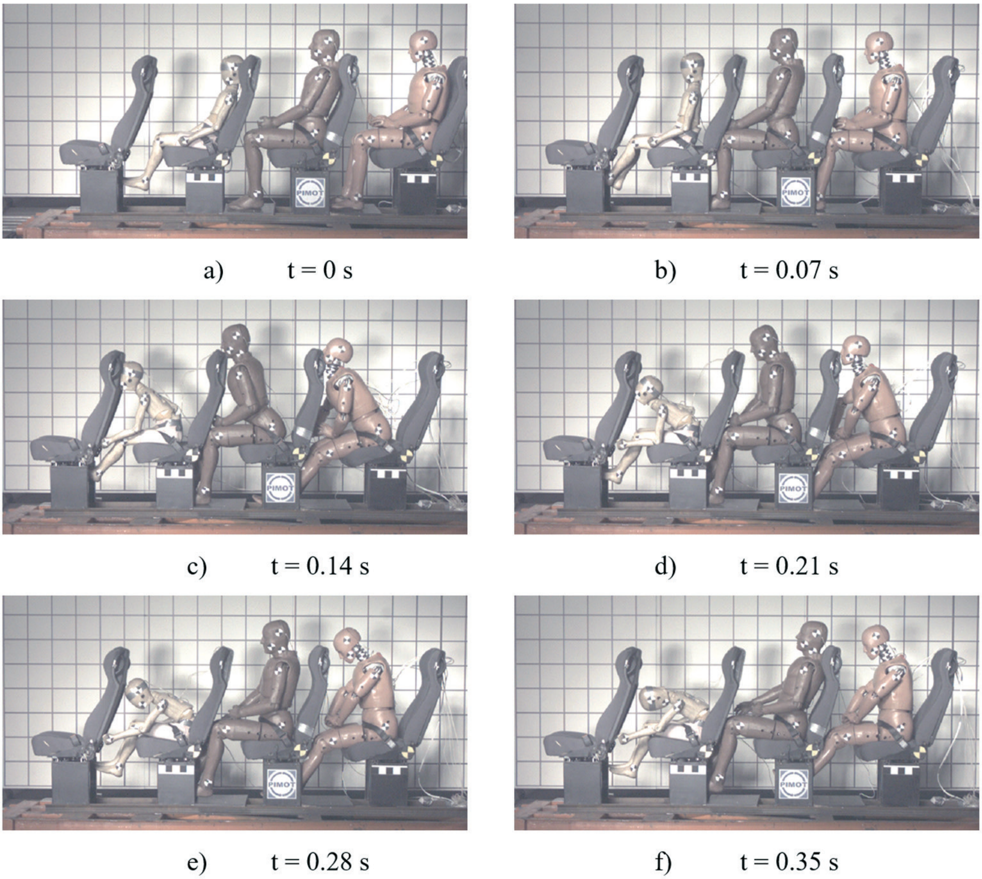

Fig. 5. Cages showing the movement of the dummy at 20 km/h

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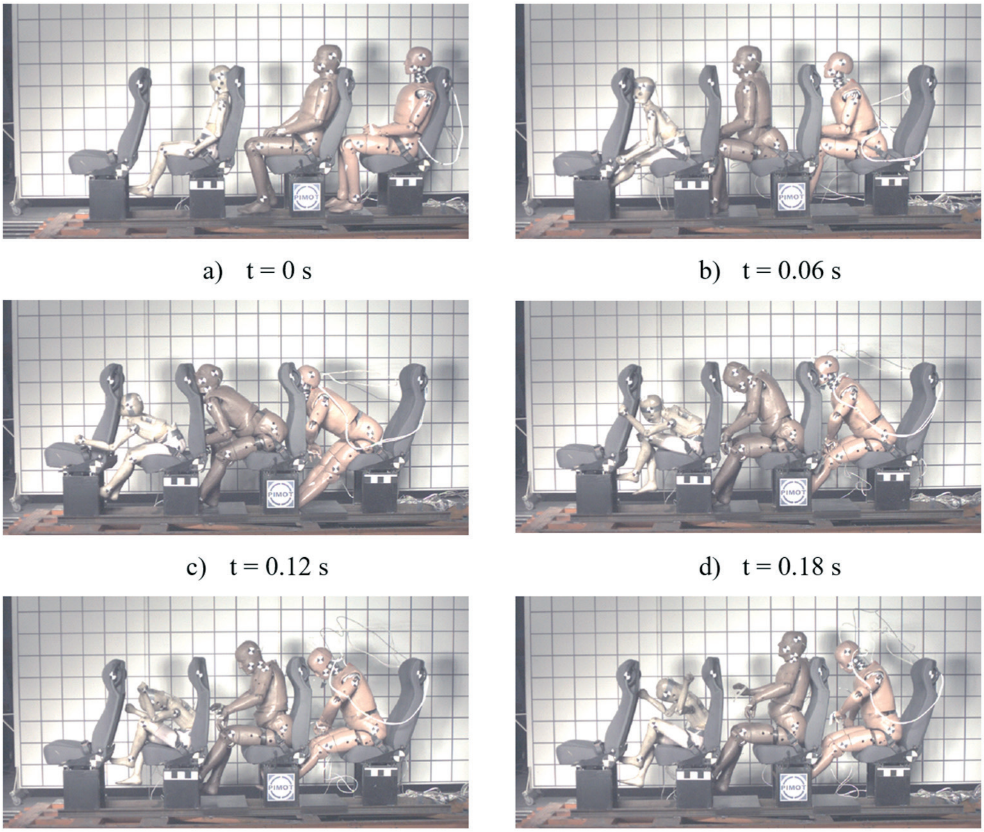
The second test was recorded at a speed of 40 km/h. The performed measurements were recorded in a resolution of 1024x512 pixels at a speed of 500 frames per second. Figure 6 shows six individual frames that show the movement of the dummy from the beginning of the test successively every 0.06 s.



a) t = 0 s

b) t = 0.06 s

c) t = 0.12 s

d) t = 0.18 s

e) t = 0.24 s

f) t = 0.3 s

Fig. 6. Cages showing the movement of the dummy at 40 km/h

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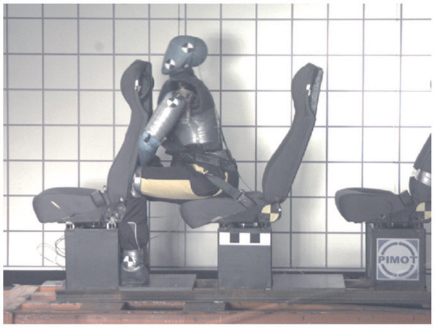
The third test was recorded at 50 km/h for the Hybrid II 50th Male dummy. The performed measurements were recorded in a resolution of 1024x768 pixels at a speed of 500 frames per second. Figure 7 shows six individual frames that show the movement of the dummies from the beginning of the test successively every 0.05 s.

a) t = 0 s



b) t = 0.05 s

c) t = 0.1 s

d) t = 0.15 s

e) t = 0.2 s

f) t = 0.25 s

Fig. 7. Cages showing the movement of dummies at 50 km/h

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2.3. TEMA Automotive

The TEMA Automotive program is the world's leading system for advanced motion analysis in the automotive industry. It is one of the best software used for analysis, ensuring the highest possible accuracy in crash testing. TEMA Automotive takes into account the entire process of uploading an image to the program through automatic tracking and analysis to present the results presented in tables or graphs. Measurements of the change in the shape of the volume of airbags or the acceleration of dummies are some of the many applications in the automotive industry [12].

The Windows-based interface allows you to quickly and intelligently configure the TEMA Automotive software. Associating keyboard shortcuts with menu items improves work in the program. The program supports and analyzes at high speed a large amount of data downloaded or uploaded from high-speed cameras and other sensors. The operator can choose between a large number of tracking algorithms and track an unlimited number of points throughout the chronology of the image. The interface has been completely synchronized, any change of parameters or settings has a direct impact on all parts of the image tracking section as well as the updating of results, charts and tables. The program is equipped with a system that supports all major image formats and has options to control the majority of speed dome cameras available on the market, such as Phantom, Photron, Redlake and others.

TEMA Automotive allows the user to configure the interface in a very flexible way. The exemplary interface presented in Figure 8 enables intuitive work. The operator has full control of the tracking and can be adapted to different applications. Tracking can be manual, semi-automatic, or automatic. TEMA Automotive has a very efficient set of tracking algorithms such as Correlation, Quad, MXT.

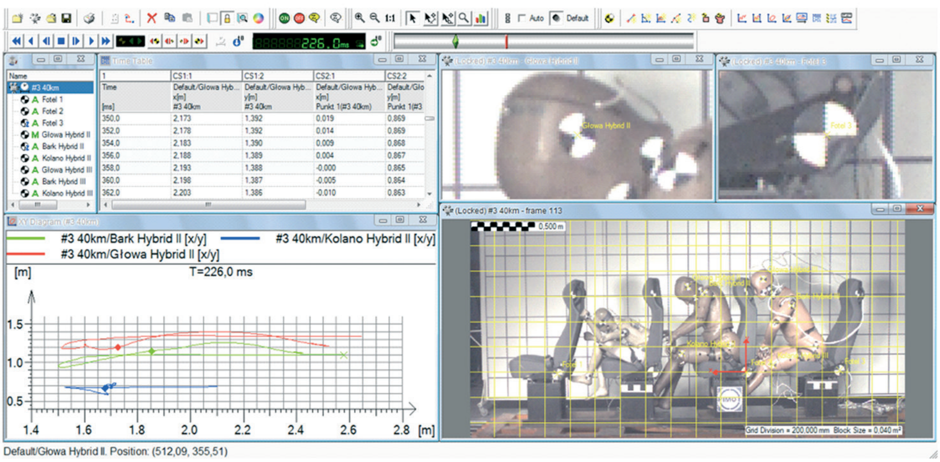

Fig. 8. TEMA Automotive interface

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3. Analysis of measurement results recorded with a high-speed camera in the TEMA Automotive software

The measurements were recorded with the Phantom v310 high-speed camera at the Automotive Industry Institute in Warsaw. The research object was the Hybrid II 50th Male dummy, moving on a bus seat with two-point seat belts, hitting an obstacle at 20 km/h, 40 km/h and 50 km/h. The film frames recorded during the measurements were used for the analysis carried out in the TEMA Automotive program. The functions and capabilities of the software have been used in this chapter to demonstrate the results.

3.1. Crash test analysis of the Hybrid II 50th Male dummy at a speed of 20 km/h

The TEMA Automotive program analyzed the frontal crash test involving a dummy placed on a bus-type seat, fastened with a two-point belt. The analysis was performed for the Hybrid II 50th Male dummy at a speed of 20 km/h for a constant coordinate system. Detailed analysis was performed for the Hybrid II 50th Male head, shoulder and knee. In order to perform a correct analysis, the test start time had to be set in the TEMA Automotive program. Then the so-called reference points necessary to analyze the recorded film with a high-speed camera. The origin of the fixed coordinate system has been hooked in the lower left corner. Figure 9 shows the reference points marked as "Armchair 1" and "Armchair 3". Due to the known distance between these points, which is 1500 mm, a scale was established and a 200 mm grid was created. Figure 9 also shows the points highlighted in red and involved in the analysis, i.e. dummy's head, shoulder and knee.

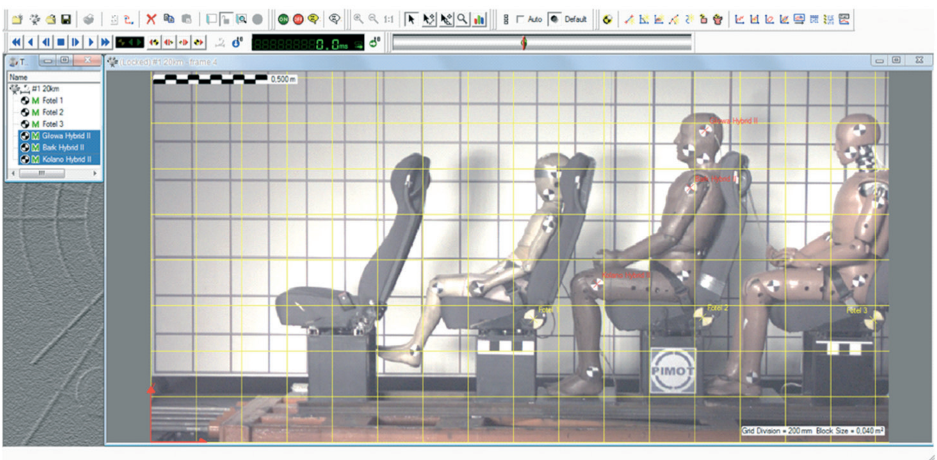

Fig. 9. Points analyzed during the crash test at 20 km/h for a fixed coordinate system

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The graphs below show graphs based on TEMA Automotive data. The Figures 10 to 13 show the displacement, speed, acceleration and trajectory of the Hybrid II 50th Male's head, shoulder and knee, which were made for the fixed coordinate system hooked in the lower left corner for the test performed at 20 km/h.

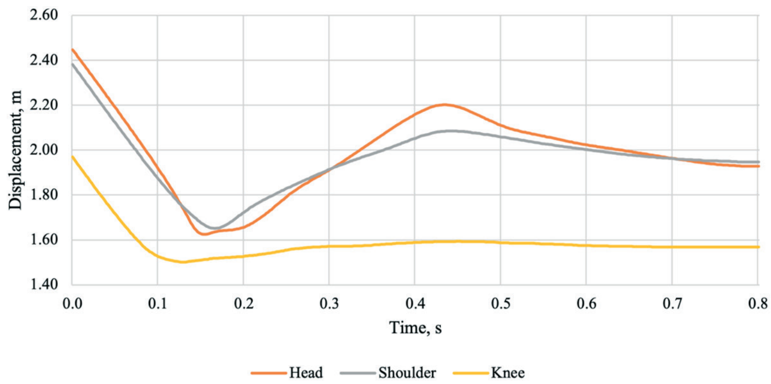

Fig. 10. Graph of the displacement x (t) of the Hybrid II 50th Male head, shoulder and knee for a constant coordinate system

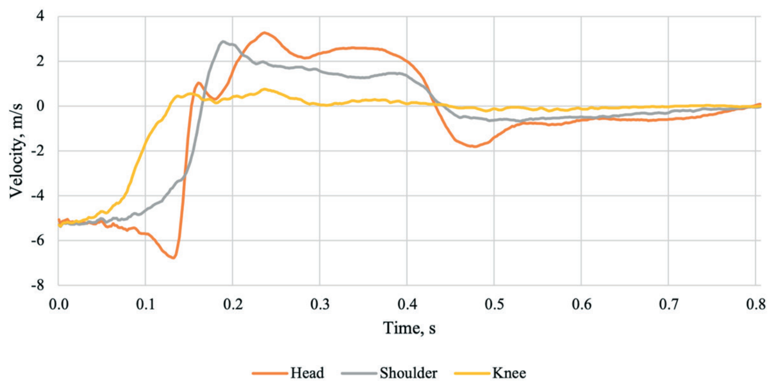

Fig. 11. Graph of the velocity x (t) of the shoulder head and Hybrid II 50th Male knee for a constant coordinate system

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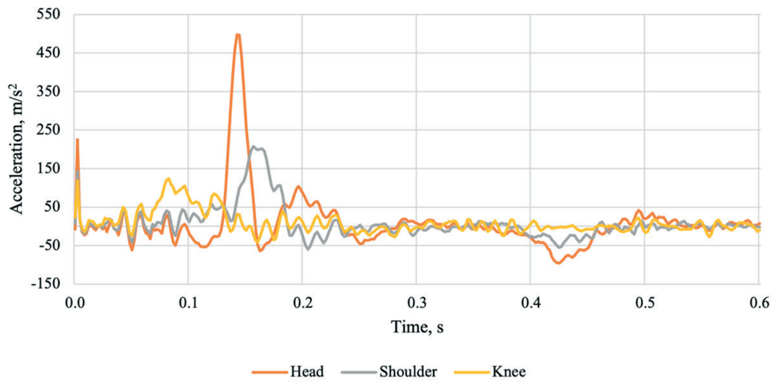

Fig. 12. Graph of the acceleration x (t) of the head of the shoulder and Hybrid II 50th Male knee for a constant coordinate system

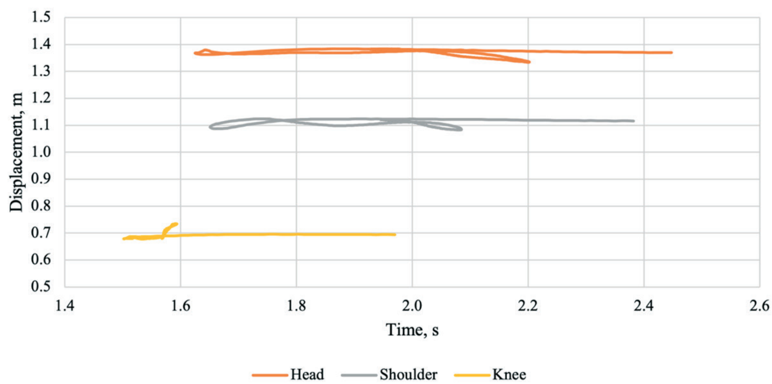

Fig. 13. Graph of Hybrid II 50th Male head, shoulder and knee trajectories for a fixed coordinate system

3.2. Analysis of the Hybrid II 50th Male dummy crash test at a speed of 40 km/h

The following analysis was performed for the Hybrid II 50th Male dummy at 40 km/h for a fixed coordinate system. Detailed analysis was performed for the Hybrid II 50th Male head, shoulder and knee. In order to perform a correct analysis, the test start time had to be set in the TEMA Automotive program as well. Then the so-called reference points necessary to analyze the recorded film with a high-speed camera. The origin of the fixed coordinate system has been hooked in the lower left corner. Figure 14 shows the reference points marked as "Armchair 1" and "Armchair 2". Due to the known distance between these points, which is 1500 mm, a scale was established and a 200 mm grid was created. Figure 14 also shows the points highlighted in red, taking part in the analysis, i.e. the head, shoulder and knee of the Hybrid II 50th Male dummy.

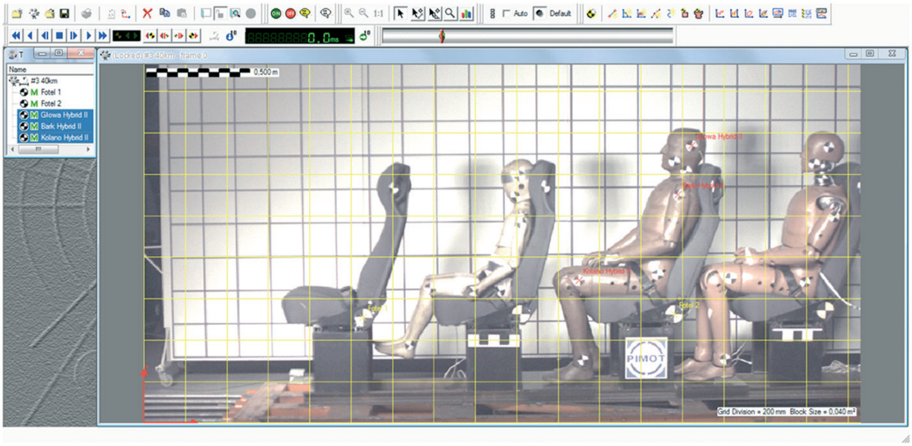

Fig. 14. Points analyzed during the crash test at 40 km/h for a fixed coordinate system

The graphs below show some graphs based on data obtained from the TEMA Automotive program. The Figures 15 to 18 show the displacement, speed, acceleration and trajectory of the Hybrid II 50th Male's head, shoulder and knee, which were made for the fixed coordinate system hooked in the lower left corner for the test performed at 40 km/h.

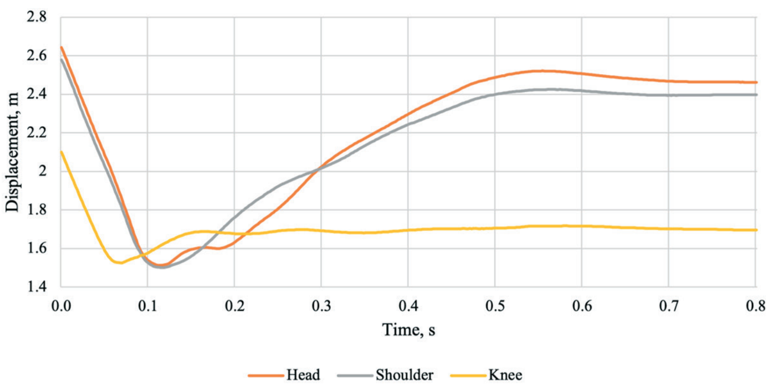

Fig. 15. Graph of the displacement x (t) of the Hybrid II 50th Male head, shoulder and knee for a constant coordinate system

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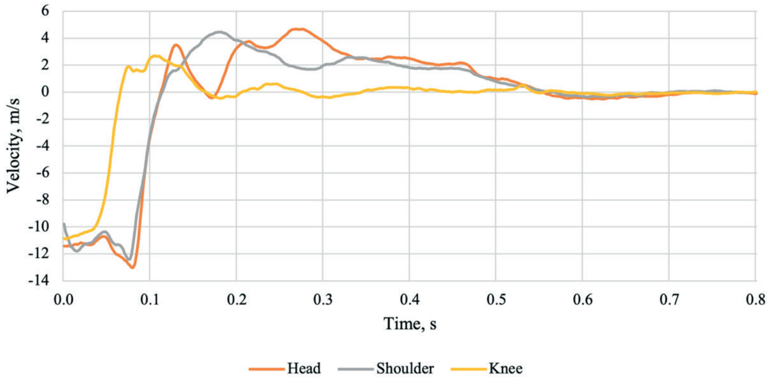

Fig. 16. Graph of the velocity x (t) of the shoulder head and Hybrid II 50th Male knee for a constant coordinate system

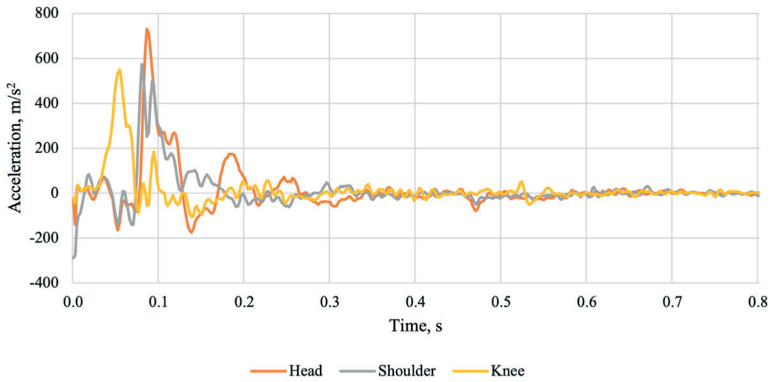

Fig. 17. Graph of acceleration x (t) of the head of the shoulder and Hybrid II 50th Male knee for a constant coordinate system

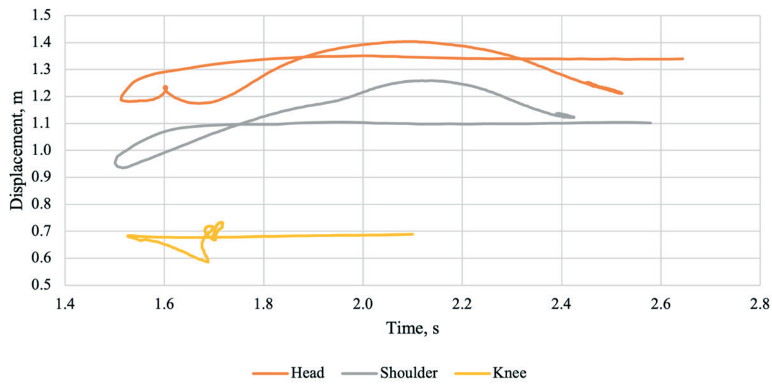

Fig. 18. Hybrid II 50th Male head, shoulder and knee trajectory plot for a fixed coordinate system

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3.3. Analysis of the Hybrid II 50th Male dummy crash test at 50 km/h

The program included the last analysis of the frontal crash test involving a dummy placed on a bus-type seat, fastened with a two-point belt. The analysis was performed for the Hybrid II 50th Male dummy at 50 km/h for a constant coordinate system. Detailed analysis was performed for the Hybrid II 50th Male head, shoulder and knee. In order to perform a correct analysis in the TEMA Automotive program, it was necessary to set the test start time as in the case of previous analyzes. Then mark the so-called reference points necessary to analyze the recorded film with a high-speed camera. The origin of the fixed coordinate system has been hooked in the lower left corner. Figure 19 shows the reference points marked as "Point 1" and "Point 2". Due to the known distance between these points, which is 350 mm, a scale was established and a grid of 200 mm was created. Figure 19 also shows the points involved in the analysis, i.e. the head, shoulder and knee of the Hybrid II 50th Male dummy.

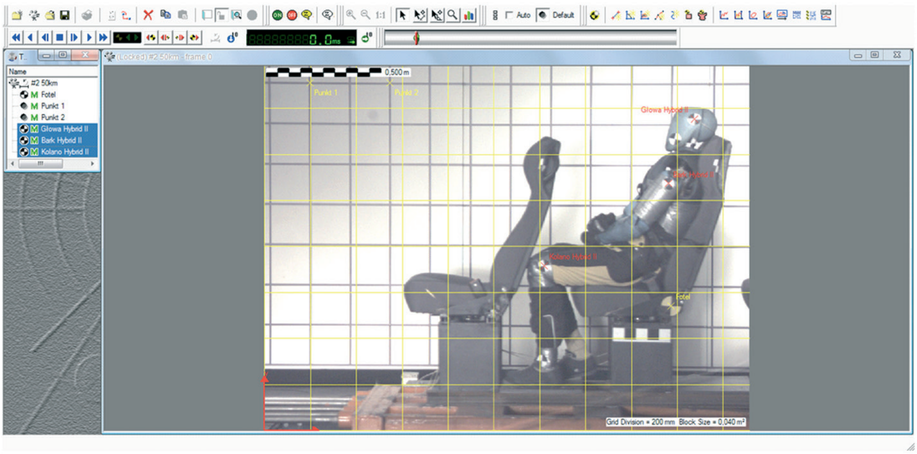

Fig. 19. Points analyzed during the crash test at 50 km/h for a fixed coordinate system

The graphs below show a few graphs made in the TEMA Automotive program. The Figures from 20 to 23 show the displacement, speed, acceleration and trajectory of the Hybrid II 50th Male's head, shoulder and knee, which were made for the fixed coordinate system hooked in the lower left corner for the test performed at 50 km/h.

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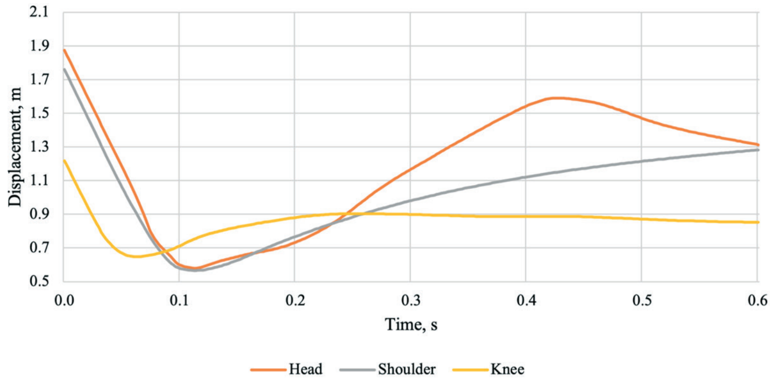

Fig. 20. Graph of the displacement x (t) of the Hybrid II 50th Male head, shoulder and knee for a constant coordinate system

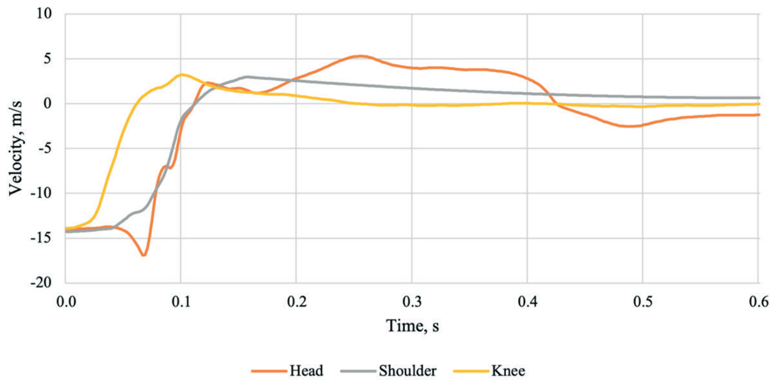

Fig. 21. Graph of the velocity x (t) of the head of the shoulder and Hybrid II 50th Male knee for a constant coordinate system

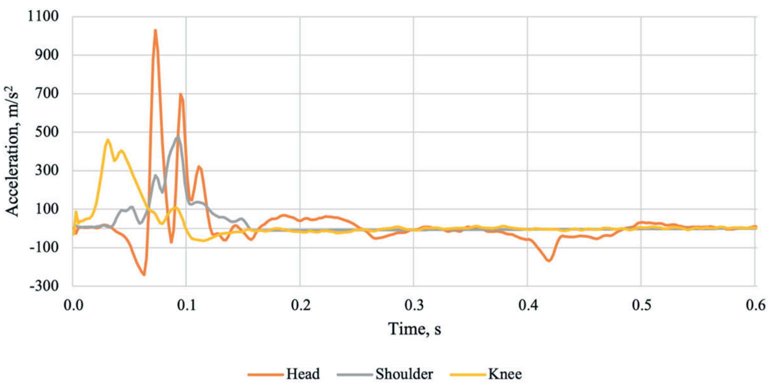

Fig. 22. Graph of the acceleration x (t) of the Hybrid II 50th Male head, shoulder and knee for a constant coordinate system

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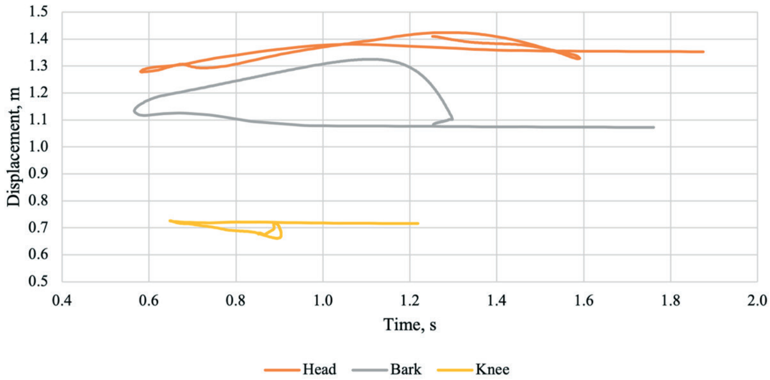

Fig. 23. Graph of Hybrid II 50th Male head, shoulder and knee trajectories for a constant coordinate system

3.4. Comparison of the obtained results of displacement, speed, acceleration and trajectory of the Hybrid II 50th Male dummy for speeds of 20 km/h, 40 km/h and 50 km/h

The graphs below show the displacements, velocities, accelerations and trajectory of the Hybrid II 50th Male's head carried out at different speeds for a fixed coordinate system. Figure 24 shows a diagram of the displacement in the x-axis direction of a dummy head for a constant coordinate system at different impact velocities.

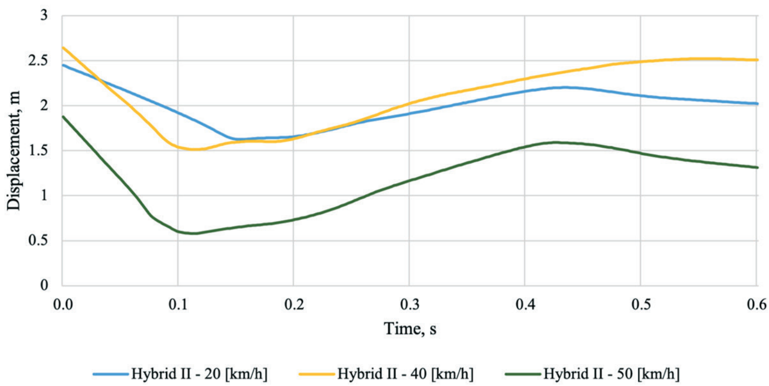

Fig. 24. Displacement x (t) of the Hybrid II 50th Male head

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When analyzing the x (t) displacement graphs of the Hybrid II 50th Male head for three different collision speeds with respect to the constant coordinate system, it can be seen that the greatest displacement x (t) was seen in the dummy's head during the collision at 50 km/h. The maximum displacement in this case was 1.295 m in relation to the fixed coordinate system. The smallest displacement x (t) is characteristic of the Hybrid II 50th Male's head during the crash test at 20 km/h.

Figure 25 shows the graphs of the velocity in the x-direction of the dummy head for a constant coordinate system at different impact velocities.

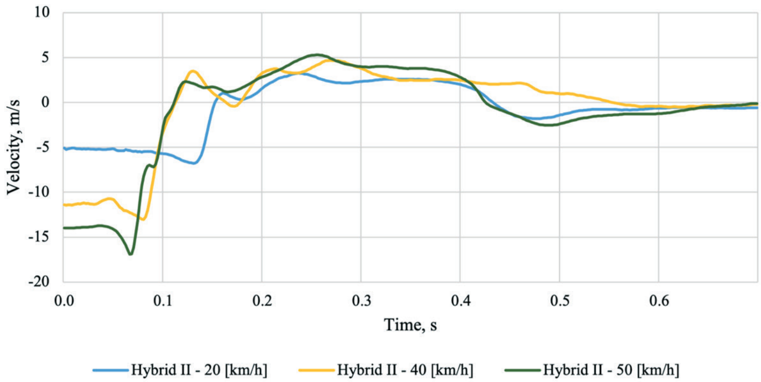

Fig. 25. Head speed x (t) of the Hybrid II 50th Male head

By analyzing the Hybrid II 50th Male head velocity graph, we can characterize the maximum velocities occurring during three different impact velocities in relation to a constant coordinate system. The maximum head speeds of the dummy in the test at 20 km/h were 3.27 m/s. In the crash test at a speed of 40 km/h, the dummy's head was characterized by a maximum speed of 4.68 m/s. The last test performed at a collision speed of 50 km/h was determined with a head speed of x (t) 5.29 m/s. We can notice that the highest speed x (t) of the Hybrid III 50th Male head for three different collision speeds relative to the constant coordinate system was during the crash test at 50 km/h.

Figure 26 presents a graph of the Hybrid II 50th Male head acceleration for a constant coordinate system at different collision speeds.

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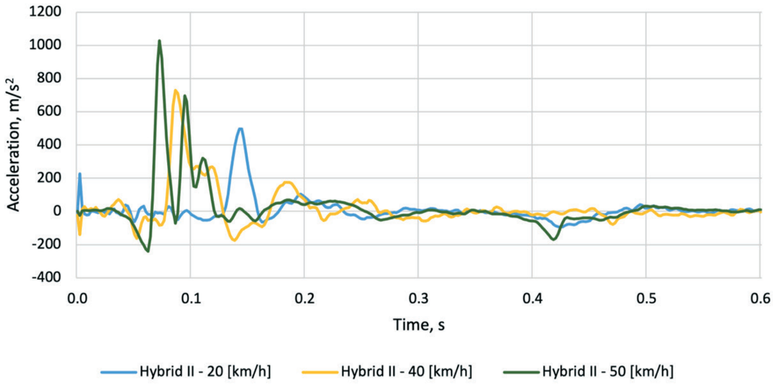

Fig. 26. Acceleration x (t) of the Hybrid II 50th Male head

By analyzing the acceleration of the Hybrid II 50th Male dummy head shown in Figure 26, we can characterize the maximum accelerations occurring during three different collision speeds in relation to the constant coordinate system. The maximum head acceleration of the dummy in the test at 20 km/h for x (t) 497.9 m/s^2. In the crash test at a speed of 40 km/h, the dummy's head was characterized by the maximum acceleration of x (t) 730.6 m/s^2. The last test performed at a collision speed of 50 km/h was characterized by the head acceleration x (t) 1028.9 m/s^2. We can notice that the highest acceleration x (t) of the Hybrid III 50th Male's head for three different collision speeds relative to the constant coordinate system was achieved during the crash test at 50 km/h.

Figure 27, made for a constant coordinate system and different collision speeds, shows the trajectory of the Hybrid II 50th Male's head.

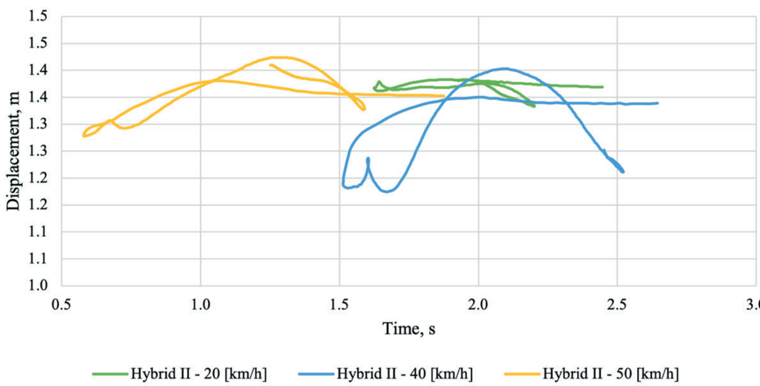

Fig. 27. Trajectory of the center of the Hybrid II 50th Male head

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The trajectory of the center of the Hybrid II 50th Male dummy's head shown in Figure 27, made for three collision speeds with respect to the fixed coordinate system in the lower left corner of the recording, gives us the maximum displacements obtained during the crash test. When analyzing the Hybrid II 50th Male head trajectory diagram for three collision speeds, the main difference is the size of the displacement and the head trajectory. For the 20 km/h test, the maximum head displacement in the x-axis is 0.82 m and the maximum head displacement in the y-axis is 0.05 m. The maximum displacement for the 40 km/h crash test is 1.13 m for the x-axis, while in the y axis it is 0.22 m. The displacement of the Hybrid II 50th Male dummy's head at the impact speed of 50 km/h is characterized by a displacement in the x axis of 1.29 m and in the y axis of 0.14 m. collision speed of 50 km/h, while in the y axis, the largest displacement was achieved by the Hybrid II 50th Male head at the test speed of 40 km/h.

3.5. Comparison of the displacement of the Hybrid II 50th and Hybrid III 50th dummy heads with the KPSIT C50 simulation dummy representing a 50 percentile male

The model of a physical-point crash test dummy is a set of interrelated lumps characterized by adequate damping and stiffness. Each element has the appropriate shape and weight. All elements of the dummy's structure are connected with each other by means of joints that reflect the range of human body movement. The model of the simulation dummy was made in the MSC ADAMS program. The mannequin consists of 17 bodies connected by joints. The torso has been divided into 3 parts: the upper one, which symbolizes the chest, the middle one, which symbolizes the belly, and the lower one, which is the lower abdomen with the hips. The leg is divided into three parts: the thigh, the lower leg and the foot. The hand is also divided into three parts: the arm, forearm and hand, while the head and neck are made up of separate lumps. An anthropometric crash test dummy made in the ADAMS program is shown in Figure 28.

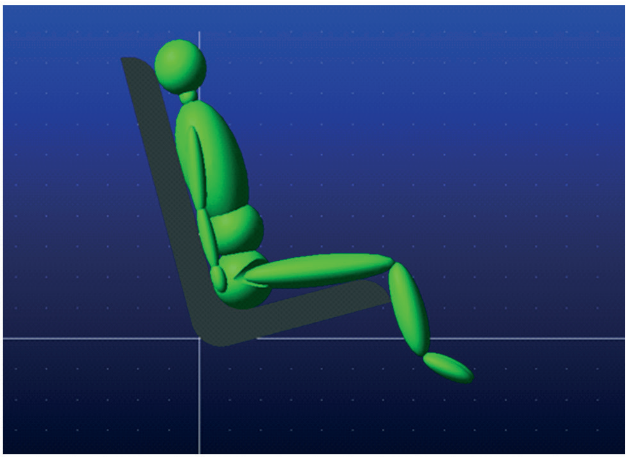

Fig. 28. KPSIT C50 simulation dummy

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Table 1 summarizes the weights of the individual body parts of the designed dummy. The dummy was placed on a vehicle seat consisting of one block with appropriately selected stiffness and damping characteristics. Table 2 shows the lengths of the various sections of the designed dummy.

Tab. 1. The masses of the individual parts of the body of the simulation dummy

No.	Simulation dummy	
	Block name	Mass, kg
1	forearm	4.04
2	arm	4.00
3	hand	0.54
4	shank	10.08
5	foot	0.80
6	thigh	11.98
7	neck	1.54
8	head	4.54
9	hips	11.35
10	chest	17.64
11	belly	12.19
(Σ)	78.70 kg	

Tab. 2. The lengths of the individual sections of the designed dummy

No.	Episode	Simulation dummy
		Length, mm
1	head (GZ)	161
2	neck (ZW)	124
3	chest + belly (WV)	443
4	hip (VH)	110
5	thigh (HK)	310
6	shank with foot (KS)	445
7	arm (BL)	255
8	forearm with hand (LN)	243

Table 3 presents the locations of the centers of mass of the various parts of the designed dummy. The values of the articular angles at the joints of the designed dummy are presented in Table 4.

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Tab. 3. Locations of the centers of mass of individual elements of the designed dummy

No.	Component	Episode	Distance, mm
1	forearm	LN from a point L	155
2	arm	BL from a point B	135
3	shank	KS from a point K	288
4	thigh	HK from a point H	149
5	neck	ZW from a point Z	63
6	head	GZ from a point G	97
7	torso	WV from a point V	245
8	pelvis	HV from a point H	41

Tab. 4. The values of articular angles in the joints of the designed dummy

Joint	$\Delta\varphi$	$\Delta\varphi_{min}$, deg	$\Delta\varphi_{max}$, deg
Z	$\varphi_1 - \varphi_2$	-10	55
W	$\varphi_2 - \varphi_3$	-35	5
V	$\varphi_3 - \varphi_4$	-85	30
H	$\varphi_4 - \varphi_5$	55	195
K	$\varphi_6 - \varphi_5$	-130	0
B	$\varphi_7 - \varphi_3$	-230	0
L	$\varphi_8 - \varphi_7$	0	150

The MSC ADAMS program allows you to create and connect individual dummy blocks with the help of specialized connections imitating the appropriate joints. It enables the introduction of restrictions related to the displacement of individual elements of the dummy's body and the selection of an appropriate range of motion and the number of degrees of freedom.

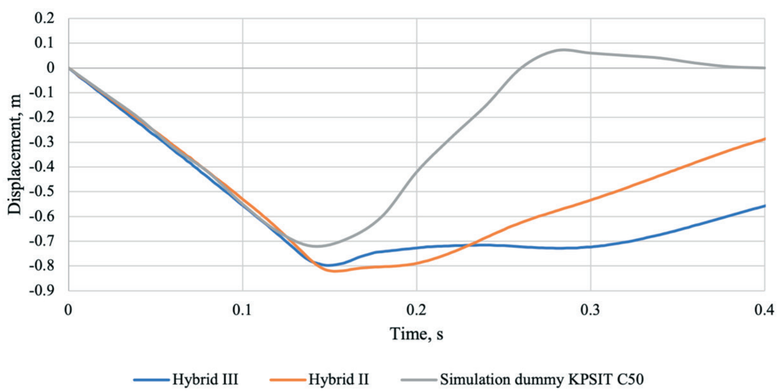

Fig. 29. Comparison of the head displacement in the X-axis direction of the Hybrid III and Hybrid II dummy with the KPSIT C50 simulation dummy during the crash test at the speed of 20 km/h

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The comparison of the head displacement in the X-axis direction of the Hybrid III and Hybrid II dummy with the KPSIT C50 simulation dummy during the crash test at the speed of 20 km/h is shown in the Figure 29. The comparison of the head displacement in the direction of the Z axis of the Hybrid III and Hybrid II dummy with the KPSIT C50 simulation dummy during the crash test at the speed of 20 km/h is shown in the Figure 30. The course of the event test was divided into two parts. The first part lasted from the moment of impact (0.00 s) to 0.14 s. During this time, the head of the Hybrid II and Hybrid III dummy and the head of the simulation dummy were moved forward to the maximum extent. In the second part of the collision, from 0.14 s to 0.26 s, the heads of the dummies compared with each other were moved backwards to the maximum. In the case of the Hybrid II and Hybrid III dummies, the movement of the head back in the second part of the crash test was difficult due to the fact that the heads of the dummies hit the front vehicle seat. In the case of the KPSIT C50 simulation dummy, the dummy's head moved rearward in the second part of the crash test.

In the first part of the crash test, the Hybrid III dummy's head moved a maximum of 0.81 m in the X-axis direction and 0.10 m in the Z-axis direction, the Hybrid II dummy's head moved a maximum of 0.83 m in the X-axis direction and 0.05 m in the Z-axis direction, while the simulation dummy's head moved by 0.72 m in the direction of the X axis and 0.11 m in the direction of the Z axis. The simulation of the crash test of the KPSIT C50 simulation dummy at the speed of 20 km/h with two-point belts showed very good compliance of the simulation dummy head displacement with the Hybrid III dummy's head and Hybrid II dummy in the first part of the impact.

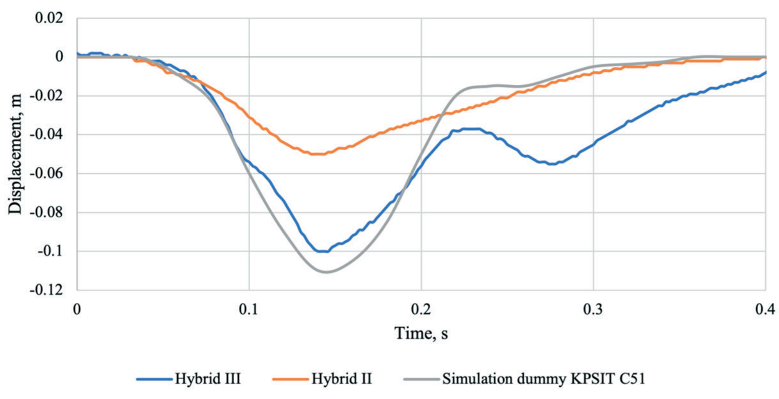

Fig. 30. Comparison of the displacement of the head in the direction of the Z axis of the Hybrid III and Hybrid II dummy with the KPSIT C50 simulation dummy during the crash test at the speed of 20 km/h.

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4. Conclusions

The conducted crash tests with a stationary obstacle and the collected measurements, which were analyzed using the TEMA Automotive program, allowed for the assessment of the safety provided by two-point seat belts for different speeds. For this purpose, a detailed analysis was performed to determine the values of displacement, speed, acceleration and trajectory occurring in the case of collisions at 20 km/h, 40 km/h and 50 km/h. The analysis and graphs were made for the Hybrid II 50th Male's head, shoulder and knee relative to the coordinate system in the lower left corner of the recording. The obtained results clearly show that the two-point belts used in buses and minibuses protect only the lower part of our body, i.e. hips, legs, and feet against excessive displacement when hitting an obstacle. When analyzing the values of displacement, speed and acceleration performed for the Hybrid II head and shoulders, it can be noticed that the highest values occur during crash tests at 40 km/h and 50 km/h. The analysis of the trajectory of individual dummy elements and the acceleration values during crash tests indicates the possibility of injuries to the head, cervical and upper torso as a result of excessive movement in relation to the seat and their impact on the preceding seat.

The MSC ADAMS program allows you to create and connect individual dummy blocks with the help of specialized connections imitating the appropriate joints. It enables the introduction of restrictions related to the displacement of individual elements of the dummy's body and the selection of an appropriate range of motion and the number of degrees of freedom. The program allows you to edit input data such as: velocities, forces, times and initial simulation conditions. MSC ADAMS simulates the behavior over time, so it can repeat the given movements sequentially and calculate their properties. The program environment also contains more complex dynamic elements such as springs, discs or elastic bodies. MSC ADAMS software is widely used in the automotive industry. In this program, simulations of the performance of individual components of a passenger vehicle are created.

The task of seat belts is to keep passengers in the seat by limiting its displacement. In the case of two-point seat belts, the analysis carried out allows us to formulate a thesis that they do not provide us with sufficient safety, but they limit the effects of major injuries in the case of vehicle accidents.

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