Some selected methods and purpose of the low speed tests for estimation of the vehicle bumpers vulnerability to damage

Wybrane metody oraz cel badań zderzaków samochodowych w aspekcie testów zderzeniowych przeprowadzanych przy niskich prędkościach

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Presented are the worldwide applied methods of tests to vehicle bumpers under low speed impact conditions. Identified are the purpose of such tests with essential requirements to be met in their performance procedure specified. Also described is rig test to the car bumpers as an alternative issue to the most popular procedures.
KEYWORDS: vehicle bumper, impact, low speed

Crash tests on motor vehicles are associated with research to determine the level of safety for vehicle users or road users. An image of a high-speed vehicle and then striking a fixed obstacle almost reminiscent of Euro NCAP's tests. Few people realize that there is a similar verification made at low vehicle speeds [10]. What is the significance of such tests? It turns out that huge. US Insurance Institute for Highway Safety statistics show that, for example, in 2000, there were 16.4 million car accidents, of which 82% were non-risk passenger traffic collisions. It was emphasized that 70% of repair costs are related to collisions following low vehicle speed.

The element that first encounters obstacle in front and rear impacts on the vehicle is the outer bumper element. Today it is made of plastic, but in the past it was a steel stamped part. Research involving the assessment of accidental damage resulting from low-speed collisions shows that, the cost of repairing the bodywork can vary by more than five times depending on their resistance to mechanical damage. The cost estimate created in this way is taken into account by insurance companies during the valuation of the insurance premium. It is worth stressing that crash tests at low speeds are also an element of vehicle approval.

Interestingly, there is a lack of universal standardization in the interpretation of crash tests conducted at low speeds. The result is not only the speed of the vehicle (or barrier), but also the different test pattern. For this reason, it is important to analyze the research procedures available on the market.

In university laboratory conditions, it is rarely possible to carry out such crash tests. It is therefore worth noting that alternative job interviews, which may involve some doubt, are worth discussing.

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Fig. 1. An example of a frontal impact test at 6 mph by Thatcham. The shock barrier and test procedures defined by RCAR were used for the test. Tested vehicles: a) Toyota Auris, whose accident repair costs were estimated at $ 810; b) Subaru Impreza, whose repair costs amounted to $ 4150 (source: Thatcham)

ECE R42

ECE R42 is one of the regulations on the international (European) list of homologation tests. The full title of the regulations is: "Uniform provisions concerning the approval of vehicles with regard to their front and rear protective devices (bumpers, etc.)" [8]. The Regulations assume that the protection of a motor vehicle is primarily provided by external components that have direct contact with the obstacle encountered by the vehicle. The test aims to illustrate the potential damage caused by a low-speed collision. All components of the vehicle should be able to withstand the impact of the tests. It is also not permitted to cause serious damage that would prevent further operation of the vehicle.

The striking element may be mounted on a horizontally moving auxiliary system or be part of a pendulum. The rules specify two types of tests: frontal and corner. The frontal test consists of two hits in the front bumper and two hits in the rear bumper. One strike corresponds to an unladen vehicle, the other one to be loaded. The tested vehicle should be struck at 4 km / h. In case of corner test the impact is carried out on both sides of the vehicle. It should be at 30° at 2.5 km/h.

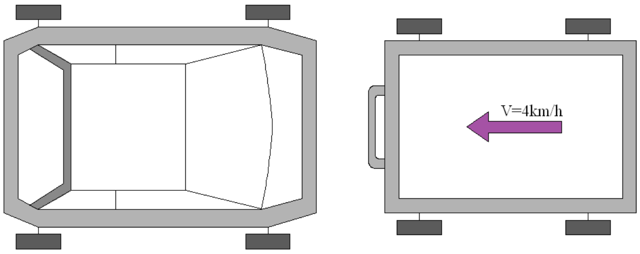

Fig. 2. Impact pattern - frontal test according to ECE R42

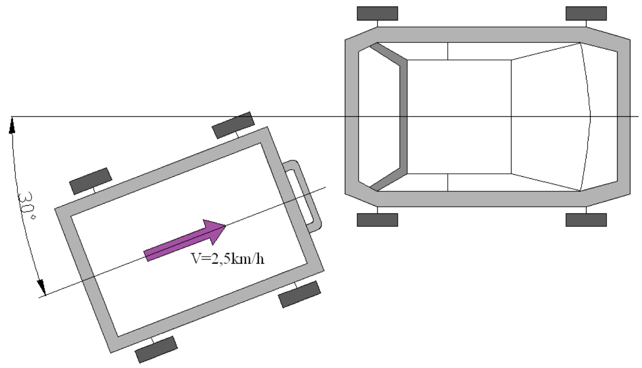

Fig. 3. Impact pattern - corner test according to ECE R42

FMVSS 581

Defined by the Federal Motor Vehicle Safety Standards (FMVSS), the 581 "Bumper Standard" homologation regulation is an American equivalent of the European ECE R42 test [9]. However, one must be aware of the differences between these tests. Contrary to ECE R42 regulations, the FMVSS regulation 581 requires the introduction of a vehicle which then moves only with inertia forces. Towing is typical. When all the broadly defined test conditions are met, the vehicle accelerated to 2.3 mph should hit the opposite obstacle. It is also recommended to perform side impacts at a speed of 1.3 mph. Alternatively, crash tests can be carried out using the pendulum system [3].

Fig. 4. Pendulum test stand for ECE R42 and FMVSS 581 homologation tests (source: A & G Technology)

RCAR

RCAR's activities since 1972 have been aimed at extending the development of bumper systems and energy-efficient systems to automotive manufacturers. It includes To eliminate damage caused by collisions, which did not have to come. It was always critical to reduce the cost of car body production if it appeared to interfere with the most common bumper system and eliminated the crossbar, for example, by replacing it with less durable solutions.

The basic frontal impact test involves towing the car, speeding it up to 10 km/h, and striking a rigidly fixed obstacle [4, 6]. The side test is performed as an extra, but its results are equally important. The test results and vehicle inspections show that motor vehicle manufacturers often do not use any system that could improve the protection of the lateral vehicle zones during collisions at low speeds. Unfortunately, soft construction often contributes to damage to the elements just behind the bumper, mudguards, lamps, radiators and engine compartment cover. Characteristic for this test is that the test object only in 15% coincides with the set against the obstacle. The impact is at 5 km/h.

More and more emphasis is also put on the fact that all manufactured vehicles have bumpers at the same height. As a result of differences in the height of bumpers, the costs of repairing vehicles are significantly increased after a collision [1, 5].

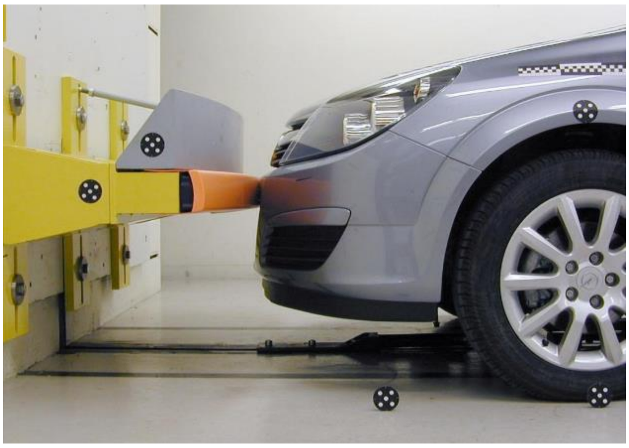

Fig. 5. Complete test stand equipped with barrier system and vehicle towing system (source: RCAR)

Fig. 6. Different height of bumpers in passenger cars and off-road vehicles is a significant cause of the cost of repairing vehicles after their collisions (source: RCAR [7]).

TABLE I. IIHS organization report: repair costs for selected RCAR vehicles at 10 km/h for frontal impact and 5 km/h for corner impact (Source: IIHS)

Brand Model Produc-tion pe-riod	Test 1 	Test 2 	Test 3 	Test 4 
Chevrolet Aveo 2007–2011	1071$	1437$	1370$	612$
Honda Fit 2007–2013	1124$	1216$	3648$	999$
Hyundai Akcent 2006–2011	3476	839$	2057$	831$
Kia Rio 2006–2011	3701$	1758$	3148$	773$
Mini Cooper 2006–2013	2291$	2637$	929$	743$
Smart ForTwo 2008–2013	1480$	663$	631$	507$
Toyota Yaris 2007–2012	1688$	1167$	3345$	474$
Ford Escort 1981	86$	0$	383$	0$

Stationary research

The stationary tests can be performed when traditional tests are not possible. They are often used in technical colleges and research laboratories, including those related to the automotive industry. In the case of strength tests of vehicle bumpers, a stationary test bench can be constructed which, when properly configured, can be used to analyze several different test models (during tests they can be assembled using intermediate components). Nevertheless, this involves taking into account the studied structures even at the design stage of the CAD environment. The complete design of the test bench should include the selected measuring equipment and load-inducing systems.

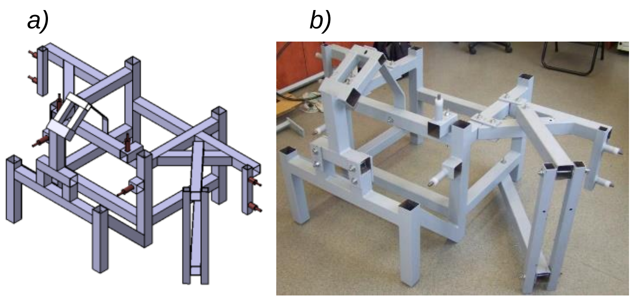

Fig. 7. Design of test bench: a) in CAD environment, b) under laboratory conditions

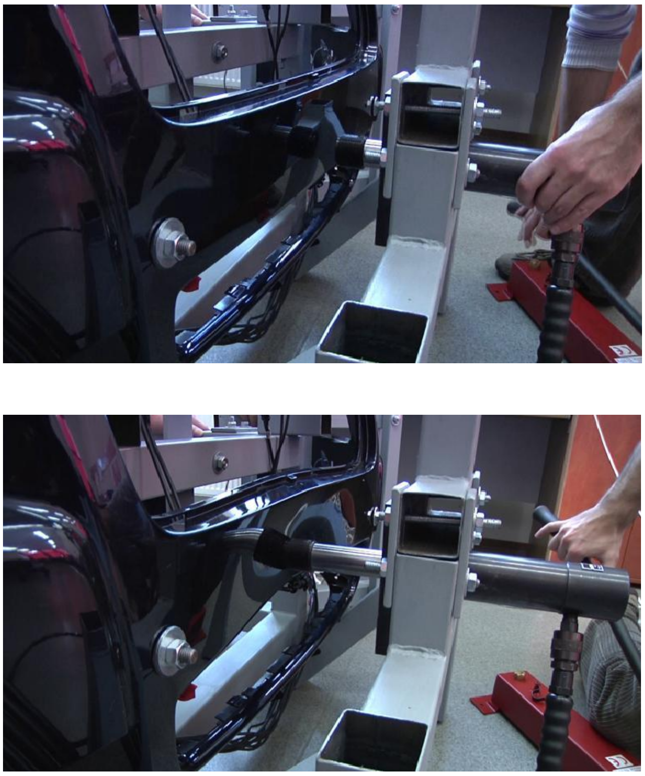

Fig. 8. Use of a hydraulic cylinder to load a car stopper on a stationary test bench

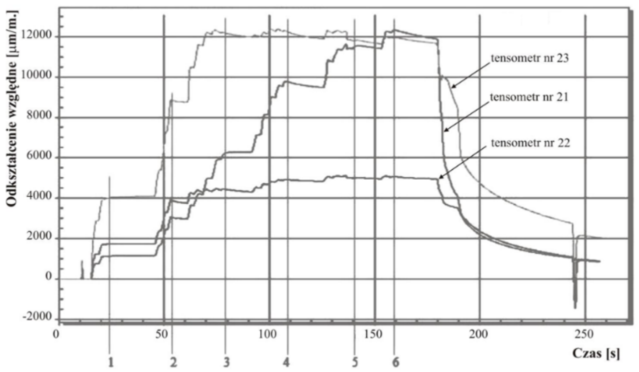

Fig. 9. Exemplary results of relative deformations obtained by resistive stress measurement in static load test

TABLE II. Values of force acting and selected computational values for relative deformations presented in fig. 9

Trial	Trial time, s	Value of acting force, N	Maximum strain during load, µm/m			Main stress, σ_1, MPa	Main stress, σ_2, MPa	Stress reduced by Huber-Mises hypothesis, MPa
			Extenso-meter 21	Extenso-meter 22	Extenso-meter 23			
1	23,5	40	1123	1719	3997	3,86	0,43	3,66
2	54,4	83	3023	3868	814	8,76	1,63	8,07
3	79,9	162	6253	4428	12161	12,61	3,50	11,27
4	109,6	221	9744	4908	12209	14,66	7,44	12,69
5	141,1	287	11534	5019	11831	15,67	9,29	13,65
6	159,4	305	12334	5068	11974	16,36	9,89	14,27

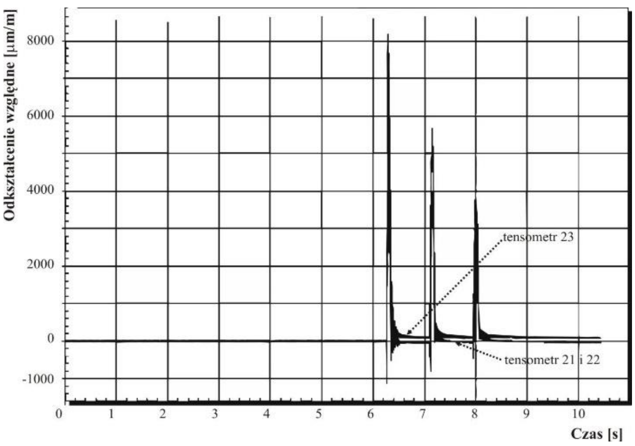

Fig. 10. Exemplary results of relative deformations obtained by resistance strain method in dynamic load loading test

TABLE III. Speed of the striking weight and the selected computational values for the relative deformations shown in fig. 10

Trial	Speed of the striking weight, m/s	Maximum deformation during strike, µm/m			Main strain, σ_1, MPa	Main strain, σ_1, MPa	Stress reduced by Huber-Mises hypothesis, MPa
		Extenso-meter 21	Extenso-meter 22	Extenso-meter 23			
1	0,41	227	495	741	0,81	0,28	0,71
2	0,81	1229	1963	2598	3,11	1,70	2,70
3	1,20	1620	3144	3138	4,30	2,88	3,80
4	1,59	2244	3933	4068	5,51	3,80	4,89
5	1,96	2724	4247	4870	6,30	4,21	5,56
6	2,32	3856	4345	5447	7,09	5,28	6,38
7	3,28	7762	4013	8182	10,84	6,92	9,51

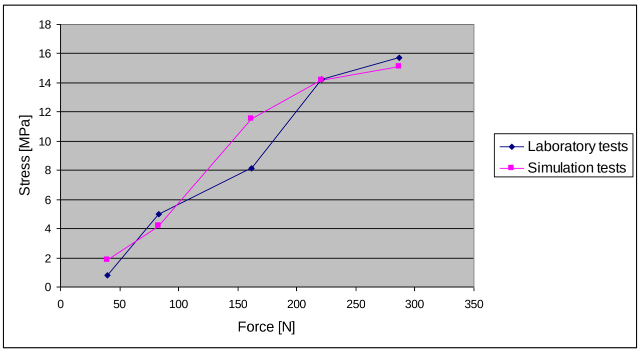

Fig. 11. Comparison of experimental results and simulated stress curves recorded for static studies

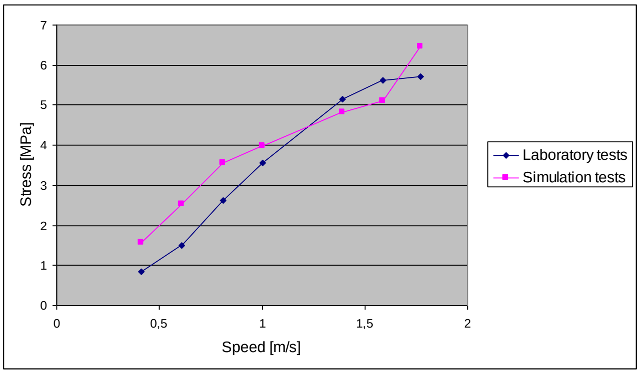

Fig. 12. Comparison of experimental results and simulated stress curves recorded for dynamic studies

The method of loading the selected structures depends primarily on the nature of planned tests. Static tests are perfect for all kinds of dynamometers. Alternatively, hydraulic or pneumatic systems are available. For dynamic tests referring to homologation tests, different types of pendulums are recommended. Their design differs primarily by the shape of the striking element.

In addition to the standard displacement measurements, the study should be extended to measure strain by using resistive strain measurements. This allows for a careful observation of the reaction of an element to a given load. Such information may be used in the future to propose structural changes to increase the strength of the test element or change the material.

It is common practice to perform endurance simulations before laboratory testing begins. Contrary to appearances, they are not intended to replace laboratory testing, but merely serve to create an overall picture of the research. Due to them, one cannot only optimize the test stand based on e.g. predicted displacements, but also deploy strain gauges so that they are in areas that one wants to investigate [2]. The results of laboratory and simulation tests show differences among themselves, which may arise even from the construction of material models and the level of their simplification in the virtual environment, material instability in the entire volume range of the material to be tested, or numerical accuracy.

Conclusions

Vehicle strength testing procedures in terms of their impact resistance at low speed vehicles are not ultimately standardized. On the other hand, it can be assumed that they are described by two groups of studies. The first is homologation testing where the impact velocity is 4 km/h in frontal impact and 2.5 km/h in side impact. The second group is a study aimed at estimating vehicle repair costs. In this case, the world usually uses a speed of 10 km/h. Similarly, the same crash test procedures can be grouped. In homologation tests, the vehicle is most often struck by a pendulum or moving barrier. On the other hand, for other groups, the vehicle is towed towards the immobilized obstacle.

Stand-alone tests will probably never replace the entire vehicle test, but will be used where strength analysis of a single component is required. In the context of the research conducted on the outer bumper element, it should be emphasized that the image of displacement and deformation recorded in this way may allow for the accurate recording of damage resulting from pre-established burdens, which directly relates to the concept of crash tests performed at low speeds. Such results are a valuable source of knowledge not only for potential damage, but also for the cost of repairing them. Although the use of this method for manufacturing elements will probably already be known in some sense, such prototype research opens up access to the knowledge that can be used before a given element or system is considered to be constructively ready.

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