The influence of rear car seat position on the child's load condition during collision

Wpływ położenia tylnej kanapy samochodu na stan obciążenia dziecka w czasie zderzenia

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DOI: https://doi.org/10.17814/mechanik.2017.2.34

The paper presents the results of the crash test aimed at observe level of acceleration of the dummy representing a child at the age of 3 years, seated in the car seat with various angle position of the rear seat of car. The research was carried out during simulated frontal collision at a speed of about 15 km/h. Selected for the child seats II÷III (15÷36 kg) weight category according to Regulation No. 44 of UNECE. Presented results of stand tests are aimed at compare dependence effect inclination angle the car seat and method of fixing it on car seat on examples.
KEYWORDS: transport, safety of children, child seats

Because of the high number of frontal collisions and their tragic effects at high speed, homologation tests and the vast majority of crash tests conducted worldwide [17-19] involve assessing the safety of traffic participants during a frontal crash at a speed of 50 km/h or more. It turns out, however, that as many as 9% of pedestrian accidents experienced in the past century occurred at a car speed of less than 50 km/h and the direction of impact was different [3]. It is worth emphasizing that homologation studies are carried out under unidirectional and symmetrical loading conditions, while in reality, the accident is caused by the effects of forces and acceleration in different directions [16]. In addition, the position, shape and stiffness of the cushion on which the seat is placed vary depending on the make and model of the car.

This paper presents results of dynamic tests performed in conditions deviating from those, in which homologation tests are conducted. During this study, the focus was on the condition of the load and protection of the dummy (representing a three-year-old child) in different ways of setting the car couch and connecting the cushion to the couch.

Carrying a child in a car

Vehicle design and passenger safety have been explored since the 1950s and 1960s [1], but car safety considerations have emerged much later. In Europe until 1973, there were virtually no structural solutions that would protect children in a way comparable to adult protection, such as safety belts [3]. Nowadays, almost in the whole developed world, the car is obliged to carry a
child in a special safety device such as a car seat. The new EU child safety legislation, which was introduced in Poland from 15 May 2015, instead of the age limit (12 years), has introduced another parameter that determines the necessity of transporting a child in a child restraint or child restraint system. Passengers of cars or lighters who are under the age of three must only be carried in child seats. For children 3 years or older, who are less than 150 cm tall and weighing less than 36 kg, it is necessary to use appropriate child restraint.

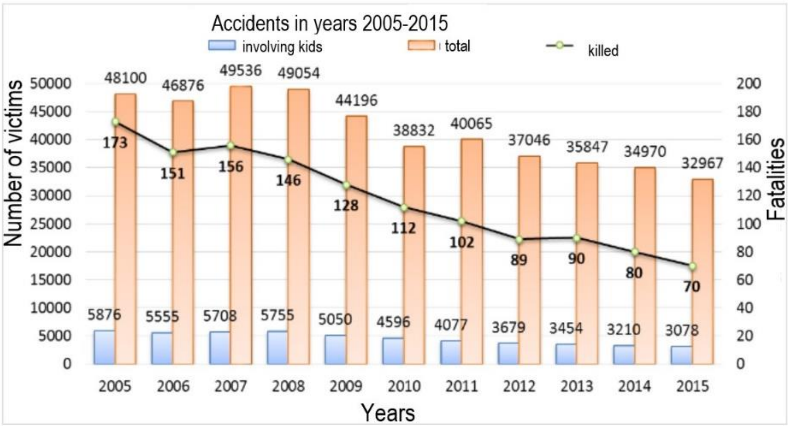

Fig. 1. Accidents involving children and the number of victims in 2005-2015 [4-14]

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The body of a child is differently shaped and has a different biomechanical strength than the body of the adult, so the way of protecting it in the car against the effects of road accidents must be related to the use of a specially designed child restraint device [21]. No device will guarantee complete safety in a wide variety of driving conditions. Statistics from the Police Headquarters in 2015 indicate that in Poland, during the 2820 traffic incidents involving children, 3078 injuries and 70 deaths were reported (fig. 1). In the study [16], it was noted that the injury of children carried in a properly fitted car seat depends on the construction materials used. Moreover, the bad design of the seat can lead to permanent injuries and even death of the child. In practice, the youngest passengers are prepared to travel by adults and are generally better protected from the effects of accidents. Older children, who settle into the seat alone or with little help, are not always properly secured with belts [19, 20].

Bench tests

An attempt was made to investigate the behavior of the baby dummy, placed in the car seat, during a low-speed frontal crash (about 15 km/h), taking into account the different positions of the car seat. The study was carried out at the bench described in [2]. The study used a 15 kg mannequin (which corresponds to the weight of a child about three years old), which contained accelerated sensors in the head and torso (fig. 2). Sensors were also found in the base of the car seat and car couch.

The low impact velocity was due to the limitations of the test bench, which is the real speed during road events, taking into account the relatively high percentage of rear bumps (about 12% of all accidents) or cases of static overturning (about 1%), in which 1% of participants are killed [4-14].

Based on the popularity rankings of cars of different brands, five vehicles were selected for measuring the position and outline of the seat profile and the back of the rear seat. On the basis of these measurements (Figure 3) significant differences (up to several degrees) were found for the angle of the backrest and back seat cushion (see Table). Results of the tests for cars marked E and B, respectively, represent the intermediate (most common) and extreme positioning of the couch (with the highest angle of the seat).

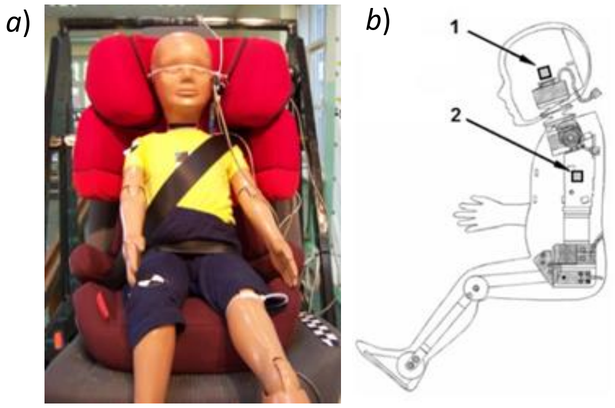

Fig. 2. Car seat with baby dummy prepared for testing (a) and location of sensors (1 and 2) on dummy (b). Own study based on [15]

Fig. 3. Viewing the angles of the seat and seat backrest in selected cars

TABLE. Seat angles and backrest angles (see Figure 3b) in selected cars

	Seat α, °	Support β, °	γ, °
Car A	11	68	101
Car B	22	63	95
Car C	17	64	99
Car D	17	70	93
Car E	14	68	98
Min.	11	63	93
Max.	22	70	101

Choosing car seats for tests

The popular II÷III category (15 ÷ 36 kg) child seats, available for use in the market, with the option of attaching only with a car belt or using an ISOFIX system, were applied in tests. Selected car seats have been rated high in the ADAC tests [17].

The studied seats were marked as: FOTELIK 1 (fig. 4a) and FOTELIK 2 (fig. 4b), respectively. The dummies during each experiment were secured with a car belt (fig. 2a) with the same initial strength.

FOTELIK 1 has a two-part, rigid construction of the carrier (shell) without adjusting the tilt angle of the backrest. The advantage of this design is the deep contoured body stabilizing elements during travel and the height adjustment of the headrest. In this case, the mannequin with the seat was held by the car belt.

FOTELIK 2 is a child seat of the same type, but is additionally connected to the cushion base support structure using an ISOFIX bracket (fig. 4b). The mannequin attached to this seat was also pinned only on the car seat.

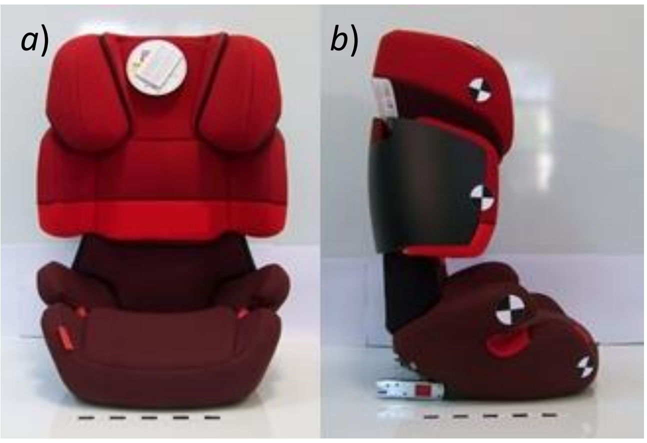

Fig. 4. FOTELIK 1 (a) and FOTELIK 2 (b)

Test results

Dynamic studies carried out at the bench provided results of signals from acceleration sensors and fast camera images. The tests were made for two previously mentioned seats, with different settings for the same car couch - thus eliminating the impact of stiffness on the test results. Sample time lap results are shown in Figure 5. During the crash test, two phases of motion of the dummy are clearly visible. The first is the move of the dummy forward, limited by the belt straps (fig. 6), the second is the return movement, in which the torso hits the backrest and the head into the headrest. In the movie material from the study of a cushioned seat with a higher incline (in car B), it was noted that the car was moving forward as the dummy returned to its initial position. This caused the dummy head to hit the back of the seat in 270 ms (fig. 5), followed by movement of the dummy along with the seat and the impact on the back of the car cushion in about 310 ms.

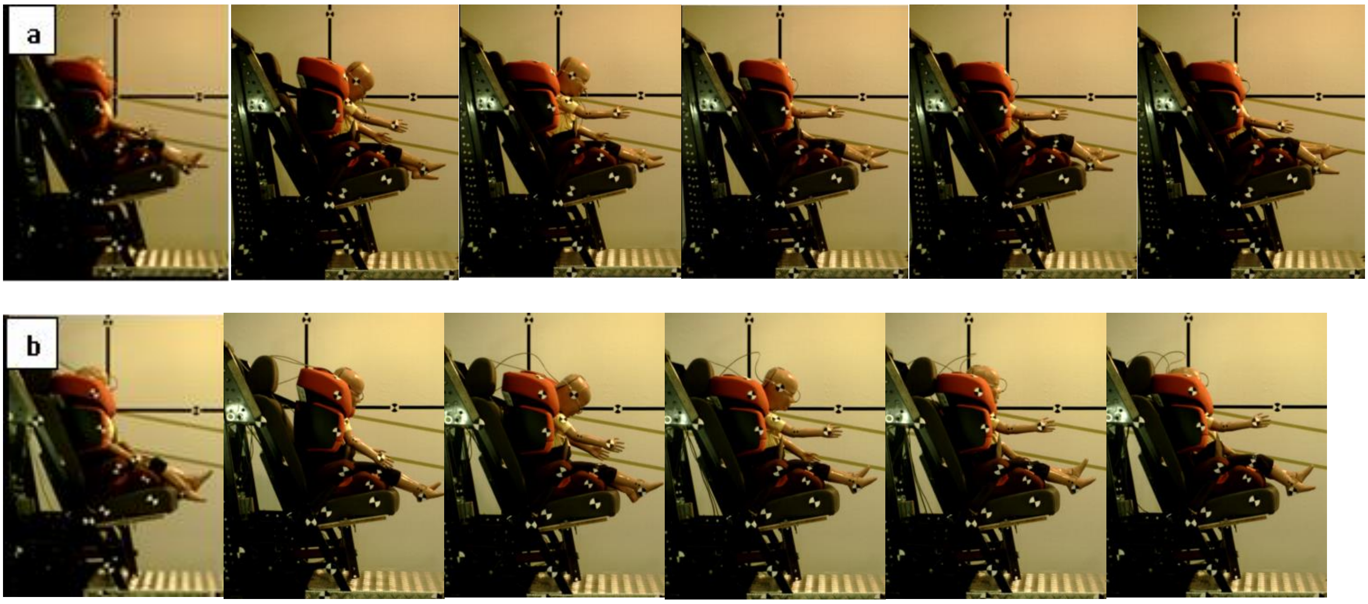

Fig. 5. Frameworks from the test run: a) FOTELIK 2, car B; B) FOTELIK 2, car E

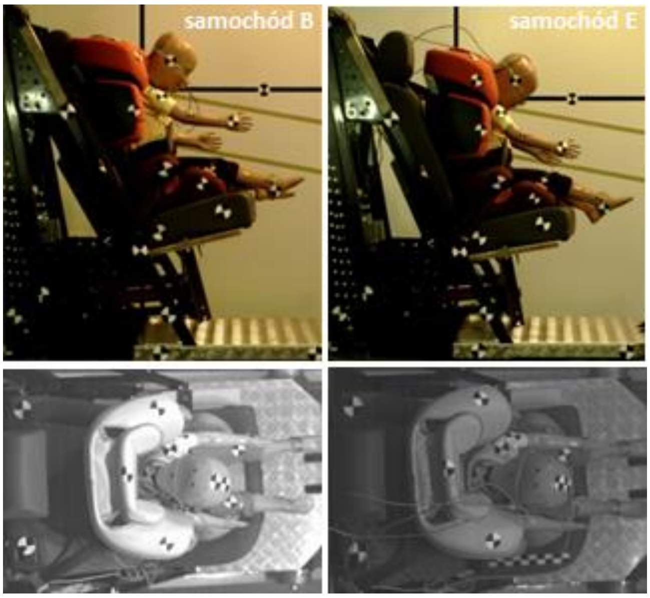

Fig. 6. Quick camera photos - maximum mannequin swing during dynamic test: a-b) side view, c-d) top view

Figure 7 shows the acceleration pattern of the dummy head at two couch settings - suitable for car E and B (fig. 3). In both cases, the influence of the position of the car couch on the character of the load on the individual parts of the body of the mannequin is influenced in the first phase of the crash (up to ca. 0.15 s). At lower values of the tilt angle of the seat cushion in car E, the extra longitudinal head lengths were observed (about 7% for FOTELIK 1 and about 30% for FOTELIK 2) as compared to car B.

Even greater differences were observed in the second stage of the mannequin post-crash movement (during the return movement). Contact of the dummy head with the back of the seat and the subsequent impact on the back of the car seat B visible in the film material (with a higher angle of the seat couch) can also be seen in the course of recorded head acceleration.

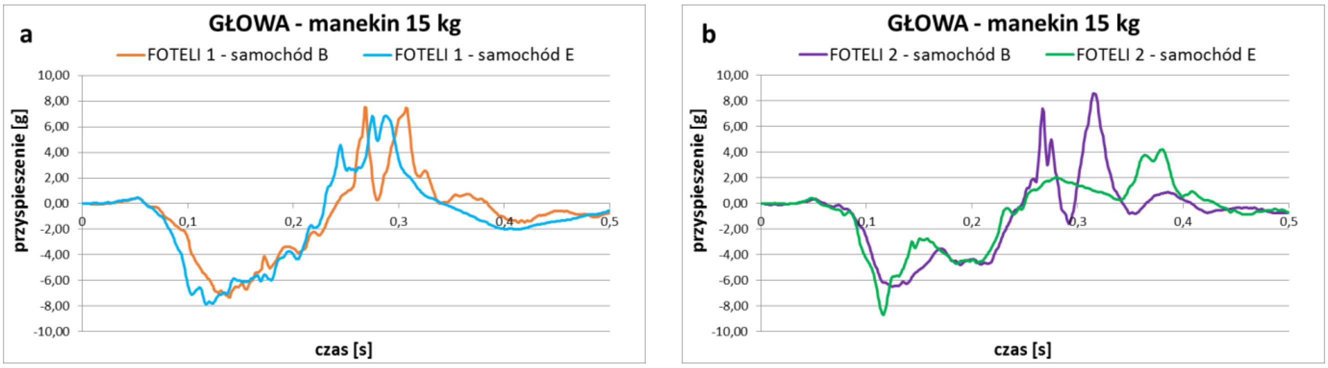

Fig. 7. Dummies head acceleration test run times: *a*) FOTELIK 1, *b*) FOTELIK 2

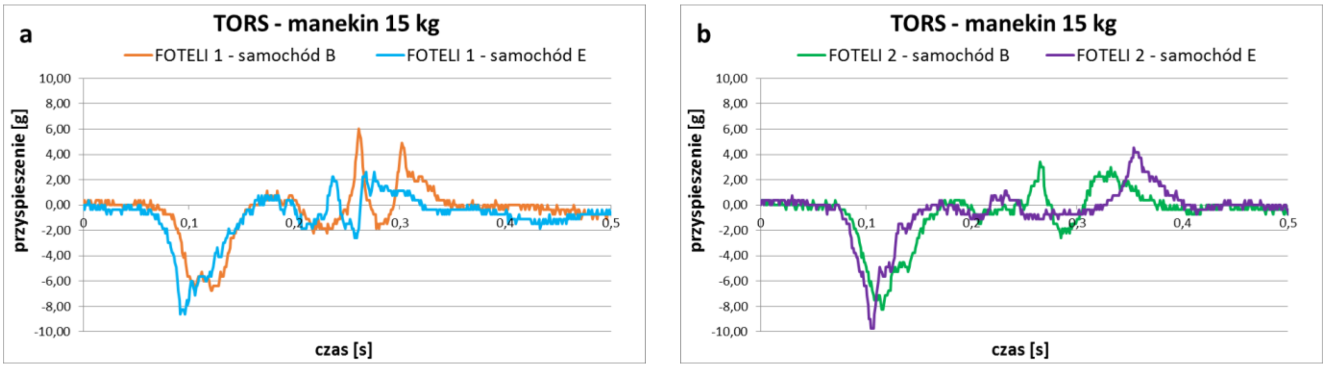

Fig. 8. Dummies torso acceleration test run times: *a*) FOTELIK 1, *b*) FOTELIK 2

The graphs show two distinct local extremes: the first - when the dummy hits the head of the headrest, the second - when the child seat and the head of the dummy strike the back of the car seat. In the case of linking the car seat B with the ISOFIX handle, twice the head load was recorded as compared to the load found for the car seats. The detailed analysis of the film material confirmed different behavior of the car seat structure and movement depending on the angle of the car couch.

Fig. 8 shows the course of the torso load of the dummy. There are also two local extremities of torsion acceleration in the case of a high-angle couch. However, the difference between courses received for different seat settings and seat fastenings is considerably less than for the head.

Conclusions

In the case of collisions at low speed, there is no fear of exceeding the limit values for acceleration values given in the approval regulations and standards for child restraint systems. Presented results of crash tests conducted at low speed indicate, however, significant qualitative and quantitative changes in the nature of co-operation of the seat with couch:

there was a significant effect of changing the angle of incline of the couch to the load on the part of body (and in particular the head) of the child dummy,

in the first phase of the post-crash movement (forward) the extremities of head and torso acceleration are about 7-30% higher for the head and 18-27% for the torso if the seat is placed on a couch with a lower seat angle (car E), there was an increase in head overturns in the back movement of the cushion, which was related to a double stroke - first the mannequin against the seat and then the seat against the back of the car seat; iIt was found that the level of head overload in the return movement exceeds the value recorded for forward movement - the overload at this phase of movement is much more dangerous because of the possible damage to the cervical vertebrae.

The presented results of the research are treated by authors as preliminary results for further, more detailed considerations. It is important to verify the impact of the elasticity-damping properties of the car cushions and other car seat designs as well as direction of collisions on the load conditions of the couch-seat-mannequin system.

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