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RISK OF INJURY FOR THE FRONT AND REAR SEAT PASSENGERS OF THE PASSENGER CARS IN FRONTAL IMPACT

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Abstract

The dynamic loads acting on a human body during a road accident may cause bodily injuries. They are dependent not only on the car structure and applied means of individual protection but also on the anthropometric features of a human body and its location in car. The safety of the car occupants on the rear seats in the passenger cars has been treated as a secondary issue so far. The achieved stage of the structure of that equipment for the rear seat occupants makes an important confirmation of that state. Usually there is no adjustment of the seat belt fixing point position, seat belt pretensioners, seat adjustment. This paper considers the risk of injury for the front and rear seat passengers of the passenger cars on the basis of analysis of dynamic loads that can affect them during the road accident. The attention was paid to the adults and children aged about 10 years.

The dynamic loads were analysed with making use of experimental results of frontal flat barrier impact. During the tests, the passengers are protected by typical passive safety systems on the front and the rear seats. In the evaluation used the criteria of the biomechanical human body resistance to the impact load effect. The attention is paid to relations between a seat occupied in a car and the probability of injuries. The analysis of the laboratory impact tests was preceded by the assessment of risk of injury of the front and rear seat passengers in the real road accidents, which has been prepared based on the literature data.

Keywords: *road transport, vehicle safety, crash tests, safety of passengers, rear seat*

1. Introduction

Together with development of automotive industry, the number of people per one passenger vehicle is systematically decreasing. In Poland, this number decreased from 15 in 1980 to 2.25 in 2010. Common availability of passenger cars results in a fact that the majority of them are mostly used by a driver or a driver and a front seat passenger [25]. Probably due to those reasons, the safety of adults (as well as youth and older children) in the rear seats is rarely evaluated during car certification tests or consumer tests (NCAP).

The source of data on the number of people transported in the passenger cars, their age structure and locations occupied by them in a car is mostly provided by the data on the road accident victims. On the basis of that data from the period of 1991-2006 (USA [11, 19, 21], Sweden [9], France [13]), the following share of the rear seat passengers in the passenger cars has been estimated:

– children and adults (in total): 12–15%,
– children aged under 4 years: 90–95%,
– children aged 4-12 years: 80–85%,
– children aged over 14 years: 70–75%.

The above data clearly indicate that the rear seats are relatively rarely taken by adult persons and are most often occupied by the children. Younger children are rarely transported in the front seat next to a driver. It mostly results from the road traffic regulations, the needs of the car users as well as from the common opinion that the rear seats are safer.

The papers [24, 25] present a comparative assessment of loads that affect the passengers in the front and rear seats during a frontal impact of a car and a rigid barrier, placed perpendicularly towards the direction of the car motion. The analysis has been carried out on the basis of the crash test results given in [22]. The attention was paid to adult persons and children aged about 10 years. It has been found that dynamic loads affecting the rear seat passengers are often many times higher that in case of the front seat passengers. Smaller loads affecting a driver and a front seat passenger result from an advantageous reaction of the air bags, pretensioners and belt force limiters that made the equipment of the front seats only in the considered cars.

The purpose of this paper is to evaluate the risk of injury of the rear seat passengers on the basis of the loads observed in the crash tests, their results are available in [22]. The attention was paid to the frontal impacts, as their effects are the most severe, according to the road traffic statistics. As an example, the value of the accident severity index (fatal victims per 100 accidents) for frontal impacts in Poland is 2.5 times higher than for the side ones (2010). Risk of injuries has been evaluated on the basis of the so-called *Injury Risk Curves*. The way of their development was presented here. The analysis of the laboratory crash test results has been preceded by an assessment of risk of injury of the front and rear seat passengers in the real road accidents, prepared on the basis of the literature data.

2. Classification of injuries of the road accident victims

Descriptions of injuries of the road accident victims use properly prepared criteria. In Poland, a classification defined in the *Decree of the Chief Police Commander no. 635 of 30.11.2006*. It differentiates three groups of victims*: fatal accident victims, seriously injured victims and slightly injured victims*. In many countries (including Germany, USA, Sweden) a more detailed scale of road accident victims is used – the so-called *KABCO Codes*. It includes the following road accident victim categories: killed (K), incapacitating injury (A), non-incapacitating (moderate) injury (B), possible injury – complaint of pain (C) and no injury (O).

It is worth mentioning that the use of other criteria for the classification of the road accident victims has a negative impact on the reliability of comparison of the road traffic safety indexes in individual countries. In Poland, accidents with slightly injured victims (category C according to the KABCO scale) are often recorded as collisions not the road accidents, which reduce their total number. As a consequence, we have a relatively low victim index (at the level of 30–60% of Germany, Sweden and Great Britain) while the fatal victim index in Poland is 2–2.5 times higher than in those countries [10].

The assessment of the road accident victim often uses the *Abbreviated Injury Scale* (AIS). It has been created as a result of the medical data concerning the injuries of the road accident victims (car passengers and pedestrians) and a number indicating the injury rate has been assigned to defined injuries (Tab. 1).

Tab. 1. The Abbreviated Injury Scale versus Fatality Rate [7, 17]

Injury severity AIS	Severity code	Fatality rate (range %)	
		[17]	[7]
1	Minor	0.0	< 1
2	Moderate	0.1-0.4	< 1
3	Serious	0.8-2.1	3.5
4	Severe	7.9-10.6	15
5	Critical	53.1-58.4	40
6	Maximum (currently untreatable)	-	79

Higher rate indicates higher threat to life. Considering the injuries covering at least a particular rate, e.g. AIS3 and the higher ones, the following notation is used: AIS3+ or AIS≥3. A correlation between the injury severity AIS and a risk of death resulting from those injuries is given in Tab. 1. Dependence of injury rates on the risk of death is not proportional, therefore the AIS rates defined for individual parts of body cannot be averaged in case of victims with numerous injuries. In such case the MAIS scale (Maximum AIS) is applied or *Injury Severity Score* (ISS) [18].

The AIS scale was assumed as a standard in the estimation of the risk of injury on the basis of the loads affecting the dummies during the crash tests, as described in point 6 of this paper.

3. The state of safety of the front and rear seat passengers on the basis of the road accident data

Relations between the safety of the front and rear seat passengers have made the subject of studies carried out by many authors. They were performed on a wide scale especially in the 80's and the 90's. The purpose of the analysis was to evaluate the effectiveness of the safety belts as a protection of a driver and a passenger during a road accident. At that time, the safety belts were not as commonly used as nowadays and there were no airbags in the cars yet. The results of those studies clearly confirmed the, unquestionable nowadays, role of the seat belts in the passenger protection and resulted in the regulations on the obligatory use of these belts. At the same time, they were so convincing that they resulted in a common observance and acceptance of the obligation to use the seat belts.

The studies carried out at that time confirmed repeatedly that the rear seat passengers are safer than the front seat passengers are. On the basis of the analysis of injuries of the road accident victims (injured and killed), it has been estimated that the risk of death of a rear seat passenger was smaller by 26–41% compared to a front seat one, even without the seat belts [19]. Those results reinforced the common opinion that the rear seat is safer than the front one.

Meanwhile, the structure and the equipment of modern passenger cars have been significantly modified. Optimized passive safety systems, particularly in case of frontal impacts and in a lower degree in case of side impacts. Since the middle of the 90's, the advanced passive safety systems for the front seat passengers started to be installed on a common basis (a belt system incorporating a pretensioner, a load limiter and an airbag). Since then, not much has been done for the rear seat passengers. The Child Restraint System (CRS), particularly for the youngest ones at the age of up to about 6 years, makes the exception here.

On the basis of the literature data, trends of changes in the front and rear seat passengers of the passenger cars during road accidents in the period of 1975-2007 [1, 4, 13, 19] are presented below. Only the accidents of cars with the rear seat passengers were included. The analyses carried out used the statistical data processing methods, characteristic for the matched-cohort methods applied in the medicine. In order to exclude the influence of other factors on the results, the analyses included many additional factors: sex and age of passengers, their location in a car, type of safety equipment, way of using the seat belts (fastened or unfastened), crash type, year of manufacture and age of a car.

In the paper [4], published in 1988, the results of the analysis of the road accidents in the United States from the period of 1975-1985 are presented. It focused on the death rate of people over 16 years of age, depending on a seat occupied in a car. It was stated that at that time the risk of death of driver and a front seat passenger sitting next to him were similar, regardless of a type of crash. However, the risk of death of the rear seat passengers was 26% lower than for the front seat passengers.

In the paper [19] of 2006, the data of the road accidents in the United States during the period of 1990-2001 was considered. Relative risk of death of the front (without drivers) and rear seat passengers was evaluated by means of the ARR index (*Adjusted Risk Ratio)* – while ARR>1 means higher risk of death for a rear seat passenger than for a front seat one. A fragment of the calculation results is given in Tab. 2. It included, among others, age of passengers and a type of the safety equipment. The second and the third column shows the age structure of the front and rear seat passengers – the number in% means what part of passengers of a particular age occupied a particular seat. ARR values were given separately for the passengers in cars equipped with airbags (only 18% of the front seat passengers had an airbag) and the ones with fastened and unfastened seat belts.

Tab. 2. Adjusted risk ratio (ARR) for death by age of rear seat passengers compared with front seat passengers according to front passenger airbag presence, restraint use and age category, USA 1990-2011 [19]

Age (years)	Front seat (n=22567)	Rear seat (n=34077)	ARR (no passenger airbag)		ARR (passenger airbag present)	
			Unrestrained (n=31996)	Restrained (n=20521)	Unrestrained (n=1557)	Restrained (n=2570)
0-12	7.1%	22.3%	0.71	0.83	0.53	0.62
13-29	53.4%	50.7%	0.70	0.82	0.83	0.96
30-59	24.4%	15.4%	0.75	0.88	0.89	1.03
≥60	15.1%	11.6%	0.88	1.02	0.91	1.06

The majority of passengers had unfastened seat belts (49% of the front seat passengers and 66% of the rear seat ones). For that group of passengers, depending on the age and presence of an airbag, the ARR index amounted to 0.53 to 0.91, i.e. the rear seats turned out to be safer. Transporting unrestrained children on a front seat with an airbag turned out to be very dangerous. In cars equipped with an airbag, in a group of passengers aged 13 years and over, restrained with seat belts, the risk of death on the front and the rear seats were comparable (*ARR*=0.96-1.06). However the risk of the children (0-12 years) in the front seats was higher by 38% than on the rear ones (*ARR*=0.62), i.e. the rear seats turned out to be more safe for them. In general, it was evaluated that the risk of death was smaller by 21% for the rear seat passengers compared to the front seat passengers [19].

Similar way of assessment of safety of the car passengers, depending on the occupied seat, was applied in the paper [13] of 2010. It included the data on the road accidents in France during the period of 1996-2006, involving people aged of 10 years and over, fastened with seat belts. The risk analysis used the AOR index (*Adjusted Odds Ratios*), which describes relations between the risk of death for the rear seat passengers and the risk of death for a driver (ARR did not apply to a driver). Accident victims in four car age groups, registered during the periods: before 1991, 1991-1996, 1997-2000 and 2001-2006 were considered. Calculation results concerning frontal impacts were given on the Fig. 1, where 95% confidence interval was marked next to the AOR index. The AOR index values have the increasing trend from 0.48 to 0.79. In some cars from the period of 2001-2006 *AOR*>1, which means higher risk of death for the rear seat passengers than for the risk of death for a driver.

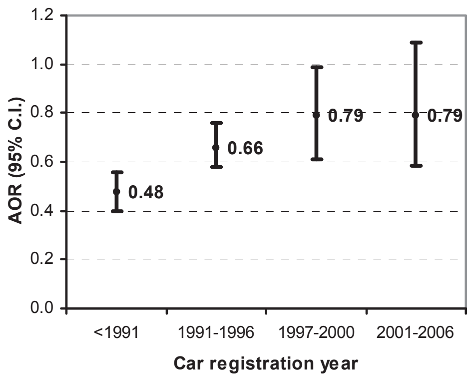

Fig. 1. Risk to be fatally injured for rear passengers compared to drivers according to car registration year, road accidents between 1996 and 2006 (frontal impact) [13]

The paper [1], also of 2010, the safety of passengers aged 9 years and over, in the cars from the period of 1990-2007 (Australia) was considered. Passengers (including a driver) restrained with the seat belts were divided into three age groups (Tab. 3). The second and the third column present the share of passengers from a particular age group in occupying the front and the rear seats – a number in% means what part of the passengers in a particular age group was made by the front seat passengers and the rear seat passengers. The *ARR* and *AOR* indexes, described above, concerned the risk of death for passengers, however the RFR index (rear to front risk) introduced in the paper [1] defines a risk of serious injury or death (AIS3+) for restrained rear seat occupants relative to restrained front seat occupants. Calculation results in Tab. 3 were compared separately for older car models (1990-1996MY) and younger ones (1997-2007MY) that have different passive safety equipment standard.

Tab. 3. Adjusted rear to front risk ratios (RFR) for AIS3+ injury across age groups and model year (MY) categories, Australia 1990-2007 [1]

Age	Front seat,% (n=2417529)	Rear seat,% (n=1196309)	RFR (1990-1996 MY)	RFR (1997-2007 MY)
9-15	26.9	73.1	0.40	0.69
16-50	77.6	22.4	1.14	1.98
>50	68.7	31.3	1.81	3.12

Regardless of the age of passengers, the RFR index values are significantly higher for the passengers in younger car models. It mostly results from the increasing effectiveness of the safety systems for adult front seat occupants, and thus the decreasing risk of injury. Children aged 9-15 are more safe in the rear seats (*RFR*<1), regardless of the year of car manufacture [1]. The risk of injury for the rear seat and the front seat occupants aged 16-50 in older vehicles is similar (*RFR*=1.14), but a front seat in younger cars provides much better protection (*RFR*=1.98). The oldest passengers get the best protection in the front seats (*RFR* = 1.81 and 3.12).

According to the results of studies on the road accident effects, presented above very briefly, despite of various methods of analysis applied by the Authors, one can make a conclusion that the safety equipment in modern passenger cars does not provide the same safety level for the rear seat occupants as for the front seat occupants (Tab. 3). Relations in the risk of injuries for the adult passengers in the first and the second seat row become reverse to the ones characteristic for cars manufactured 20-30 years ago. At the same time, the results of the tests carried out confirm that the rear seats are still a proper place for the children in a car (ARR<1, RFR<1).

4. Safety condition for the front and rear seat occupants on the basis of the crash test results.

The results of the road accident data analysis described above confirm the significant progress achieved in the improvement of the safety systems, offered for a driver and a passenger sitting next to him. That progress is also indicated by crash-test results. The change of the head and chest loads of M50 and F5 dummies (50-centile male and 5-centile female), occupying different seats in a car during the last 30 years is considered below. The data from 1241 crash tests of the new cars (models from the period of 1979-2010) [22] was used for that purpose. A moving at the speed of 56 km/h hit a rigid barrier, placed perpendicularly towards the direction of the car motion. The tests only with dummies in the front seats (1200 tests with M50 dummies and 27 tests with F5 dummies) dominated. A number of crash tests with passengers in the rear seats was very limited: 5 tests with M50 dummies and 9 tests with F5 dummies. Calculation results are shown on Fig. 2. Cars without airbags and cars with airbags (designation AB) are differentiated in Tab. 2 as before. The bars in the chars illustrate the average value of HIC_{36} and C_{Acc} indexes, calculated for dummies in new cars of different years. The result dispersion is given by means of the standard deviation value.

Average values of C_{Acc} index for M50 and F5 dummies in the front and rear seats are comparable here. However, the average value of HIC_{36} index for the dummies in the rear seats in twice as high as for the dummies in the front seats (cars from the period of 2004-2006). Similar relations are indicated by the data from the road accidents described above (*RPR* =1.98 in Tab. 3). The average value of HIC_{36} index for M50 dummies in the rear seats is comparable with the one observed in the front seats before the introduction of the car airbags (period: 1985-1995). In several cars the head injury value for the dummies in the rear seats exceeds the limit value HIC_{36}=1000.

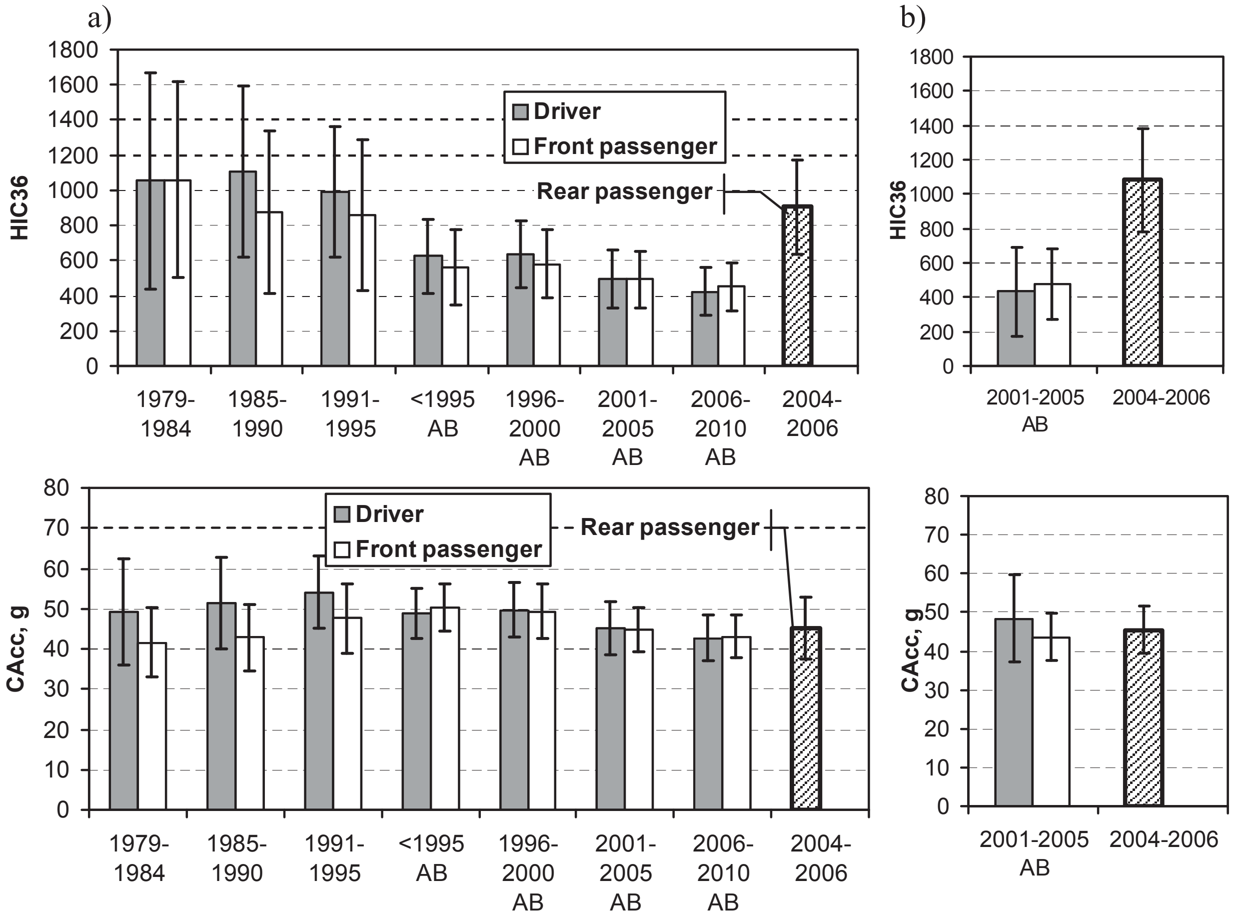

Fig. 2. Trends in the head and chest loads of dummies occupying different seats in a car during a frontal impact with a rigid barrier (56 km/h); a) M50 dummies, b) F5 dummies

A significant reduction of HIC_{36} index after the introduction of car airbags can be observed. During last 10 years, the HIC_{36} index value for the front seat occupants was reduced from the average value of $HIC_{36} = 650$ in 2000 to HIC_{36}=400 in 2010 in the analyzed group of vehicles. At the same time, a decreasing dispersion of analyzed index values can be observed (particularly HIC) in new car models. It can be interpreted as an equalization of the safety equipment standard in various cars.

5. Comparison of the front and rear seat occupant injuries

Analysis of injuries of the road accident victims are carried out in order to obtain information to improve passive safety equipment in cars. They are more and more often considered in the aspect of their costs (medical treatment, rehabilitation, disability pensions etc.) [2, 17].

Front and rear seat occupants in a car are protected by means of safety equipment of various efficiency. Also, the surrounding of the front seats is different from the surrounding of the rear seats. Therefore, the injuries during the road accidents can depend on a location of a seat occupied in a car. Susceptibility to a particular type of injuries also depends on a human anthropometric features and it is different for the children and the adults [20]. The paper [5] states that the most often injuries (AIS2+) of children aged 8-12 years include the head injuries (60%), and then the face, arms and stomach injuries, about 9% each (road accidents in the United States during a period of 1998-2007). Fig. 4 shows a comparison of injury structure (AIS3+) of the front and rear seat occupants [13]. That data concerns people aged 10 years and over restrained with fastened seat belts (France, road accidents during a period of 1996–2006).

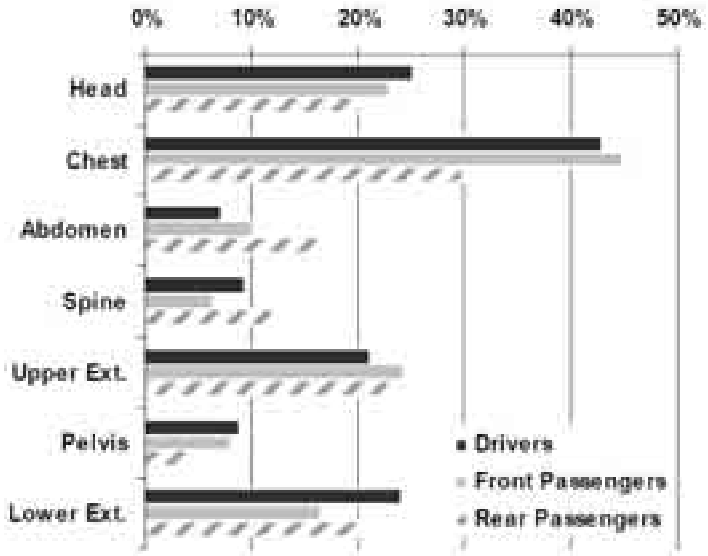

Fig. 4. Injury structure (AIS3+) of front and rear seat occupants [13]

Regardless of the seat occupied in a car, the chest injuries dominate here. They occurred more rarely in case of the rear seat occupants (30%) compared to a driver and a front seat occupant (about 44%). The number of head injuries (including a face and a neck) as well as arms and legs was similar for the front and rear seat occupants (20%). However, stomach injuries occurred more often in case of the rear seat occupants (16%) – over twice as much as in case of drivers (7%).

Considering the above structure of injuries, the following part of this paper pays attention to head and chest loads and injuries.

6. Relations between dummy loads in crash tests and injuries of people in car accidents

One of the most crucial problems in trauma biomechanics is the assessment of the relationship between injury severity and a mechanical load, which causes this injury. If these relations are known, we have a possibility of associating the crash test results, where dummy loads are measured (by means of such physical values as acceleration, force, force moment, displacement) with injuries that a human can suffer during a road accident.

It is difficult to define a relation between a load and a possibility of a human body injury. Basic problems during such analysis result from differences in biomechanical features of a human body and tested objects the so-called surrogates (e.g. cadavers, dummies, animals), anthropometrical differences of human beings and a large number of possible trauma and injury mechanisms. Moreover, that kind of studies are carried out very rarely due to a limited availability of test objects [18].

The risk of body injury is described by means of mathematical functions the so-called *Injury Risk Curves*. They apply to different parts of a body (including head, neck, chest and extremities) and are expressed as a possibility (risk) of injuries in a function of indexes or values referring to the biomechanical resistance of a human body to the impact load effects (e.g. *HIC, Nij*). Separate risk curves are prepared for the loads assigned to particular levels of the AIS scale. The studies within that scope have been carried out by the following authors: P. Prasad, H. J. Mertz, D. C. Viano and E. Hertz [6].

A course of a road accident, in particular the direction of loads affecting the passengers can affect the injury location and severity. Therefore, depending on a test type (e.g. frontal impact, side impacts, rollover) various injury criteria are used, thus different risk curves (e.g. ISO/TR 7861:2003, ISO/TR 12350:2004). For people of various anthropometrical features (represented by measuring dummies, used for crash tests) different *Injury Risk Curves* are applied.

Various probability distributions are applied in the description of injury risk, including logistic, normal, lognormal and Weibull's ones. Their comparative assessments given in the paper [12] and they are assumed as the equivalent ones. The logistic model is commonly used to develop injury risk functions, primarily due to its ease of use [7].

Further part of this paper is focused on the loads of dummy's heads and chests in a frontal impact. A probability of severe head and chest injury at the level of AIS4+ is described by the functions [6, 16]:

$$P_{head}(AIS4+) = \{1+\exp[5.02-0.00351\cdot HIC_{36}]\}^{-1}, \tag{1}$$

$$P_{chest}(AIS4+) = \{1+\exp[5.55-0.0693\cdot C_{Acc}]\}^{-1}, \tag{2}$$

where:

HIC_{36} – Head Injury Criterion (36 ms),

C_{Acc} – resultant maximum chest acceleration (3 ms).

The same functions are applied to the dummies representing a 50-centile male (M50), 5-centile female (F5) and a child aged about 10 years (10YO) [8]. *Injury Risk Curves* according to dependence (1) and (2) are given in Fig. 4. Their course indicates very important information: the injury risk is growing rapidly as the load increases. As an example, at the limit values of HIC_{36}=1000 and C_{Acc}=60 g, the injury risk AIS4+ amounts to about 0.2 but at the values twice as high the injury risk increases by 4 times and reaches a value of about 0.9.

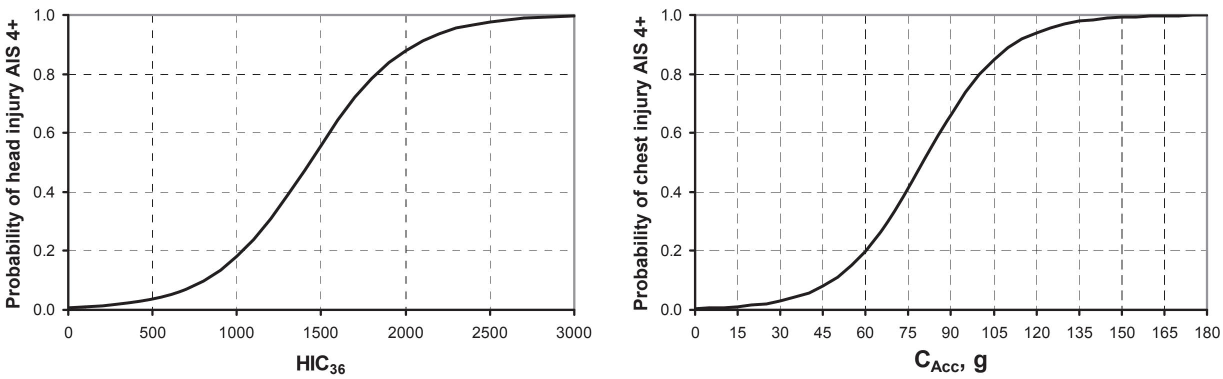

Fig.4. Head and chest injury probability (AIS4+)

The risk of death or disability of a person who suffered many injuries is higher than if the injuries apply only to one part of a human body. It includes P_{comb} – the *combined injury probability criterion*, usually expressed in percentage values. It results from applying the law of additive probability for independent but non-mutually exclusive events. Including (1) and (2) we have [6]:

$$P_{comb} = 1-(1-P_{head})\cdot(1-P_{chest}) = P_{head}+P_{chest}-P_{head}\cdot P_{chest}. \tag{3}$$

Dependence (3) results from an assumption that head and chest injuries are independent which is questionable [15]. Still the P_{comb} index was applied for many years by NCAP (*New Car Assessment Program*) in the assessment of car safety in frontal impacts. Considering a significant progress in the improvement of passive car safety systems, NCAP have applied a new more rigorous assessment criteria since 2011. Loads affecting the dummies in a frontal impact test currently refer to the injury risk AIS3+ (AIS4+ so far) of heads, necks, chests (deflection instead of acceleration) and legs (AIS2+) [14].

7. Assessment of injury risk for the front and rear car seat occupants on the basis of loads affecting the dummies in crash tests

Papers [24, 25] present results of measurements of dynamic loads affecting the dummies in the front and rear seats in crash tests involving passenger cars manufactured during a period of 2004-2006 [22]. They referred to a frontal impact with a rigid barrier. A driver seat and a front passenger seat were occupied by M50 or F5 dummies. The rear seats were occupied by M50 dummies (5 tests), F5 (9 tests) and 10YO (20 tests), fastened with seat belts without pretensioners. A 10YO child dummy was sitting on a support with a back-rest. All cars were equipped with airbags for a driver and a front seat passenger, dummies were fastened with seat belts. In some cars, seat belts were equipped with pretensioners.

Results of these measurements were used here in the analysis of risk of injuries that can affect car passengers in a frontal impact. Attention was paid to the risk of head and chest injuries. Dependences given in point 6 were used in the injury risk assessment. As shown on Fig. 5, the head injury index values HIC_{36} and the maximum chest acceleration C_{Acc} (points on a diagram) were associated with P_{comb} index values (lines on a diagram indicating injury risk limits AIS4+: 10, 20, 35 and 45% respectively).

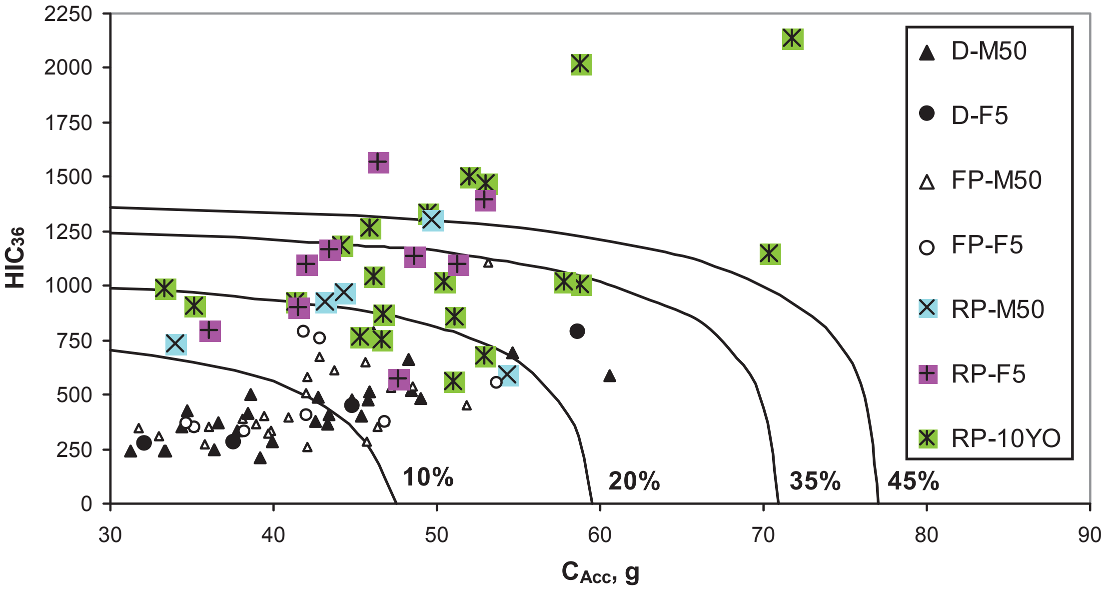

Fig. 5. Association of dummy head and chest loads with AIS4+ injury risk; D- drivers, FP- front passengers, RP - rear passengers

Values of the P_{comb} index calculated for drivers (D-M50 and D-F5) and front seat occupants (FP-M50 and FP-F5) in the majority of analyzed cars do not exceed 10% (HIC_{36} within 200-500, C_{Acc} within 30-48 g). Only in several cars, the values of P_{comb} index are higher than 20%, but do not exceed 35%. However, in case of the rear seat occupants (RP) the risk of injury is much higher: within a scope of 12-46% for M50 dummies, 14-65% for F5 dummies and 16-95% for 10YO dummies.

In order to compare the risk of injury for people in the same car, Fig. 6 specifies the values of the risk injury index for the front seat passengers: $P_{comb}(Front)$ and the rear seat passengers $P_{comb}(Rear)$. The risk of injuries for adult passengers, represented by M50 and F5 dummies, were referred to the same dummies occupying a driver's seat and a front seat (only F5). Child dummies were not placed in the front seats in the analyzed crash tests, therefore the risk of child injury (10YO dummies) were referred to the risk of male injury (M50 dummy) in the front seats (driver and passenger).

Calculation results indicate a significant differentiation of the passenger safety level in tested cars. The risk of severe head and chest injury (AIS4+) for M50 dummies in the rear seats is 2.3-4.4 times higher than in a driver's seat (average 3.1). In case of F5 dummies, it amounts to 0.7-9.7 (average 3.8). The risk of the same injury for a child aged about 10 years in the rear seat is 0.9-8.8 times higher (average 3.7) than for a male (M50) in the front seat.

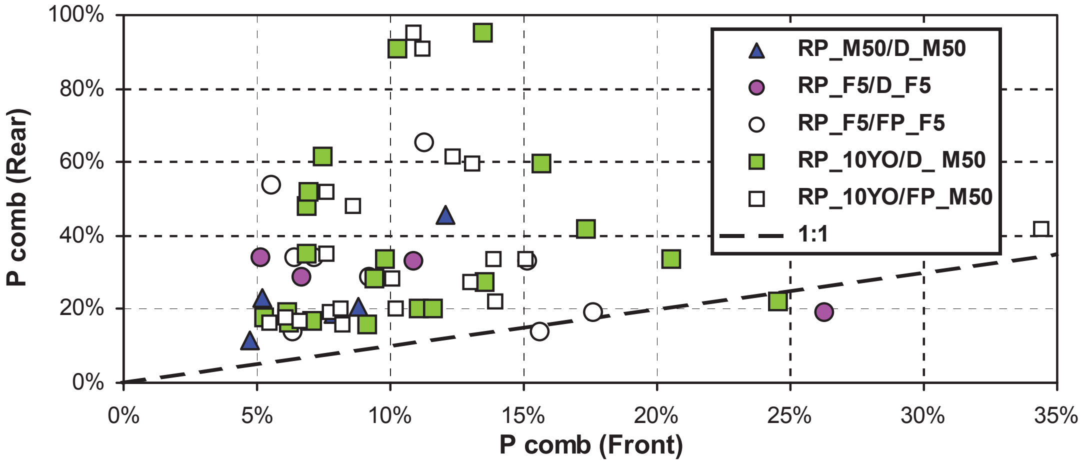

Fig. 6. Comparison of the risk of injury for the front and rear seat passengers; RP - rear passenger, D - driver, FP- front passenger

8. Summary

Condition of safety of the rear seat occupants in passenger cars has been evaluated in the context of the front seat occupants for many years. The result of such assessment was usually favourable for the passengers in the rear seats. The situation has changed after the introduction of advanced systems to protect a driver and a front seat passenger against the effects of frontal impacts. A common opinion that adult passengers in the rear seats are safer is currently doubtful. For the children aged about 10 years, the rear seats are still safer than the front ones. However, the risk of severe injury (AIS4+) is often many times higher compared to the adults in the front seats. It is confirmed by the latest results of analysis of the road accident data and crash test results given in this paper.

Results of calculation of the risk of injury for the passengers are of high significance in the interpretation of loads that are measured on the dummies in crash tests. A high risk of injury for the rear seat passengers indicates an urgent need to improve the safety systems designed for them. That need is confirmed by a change of new car assessment conditions, carried out by the Japanese New Car Assessment Program (JNCAP), where the loads affecting a F5 dummy occupying a rear seat are assessed in a frontal impact since 2009 [23].

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