ANALYSIS OF THE INFLUENCE OF MOTOR CARS’ RELATIVE POSITIONS DURING A RIGHT-ANGLE CRASH ON THE DYNAMIC LOADS ACTING ON CAR OCCUPANTS AND THE RESULTING INJURIES

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ABSTRACT

Side collisions of vehicles participating in the traffic are very common road accidents in Poland. In 2013, such collisions amounted to 29% of all the traffic accidents and they were accountable for 31% of the injured and 18% of the killed among all the accident victims. In spite of a decline in the total numbers of road accidents and of the resulting casualties, recorded for more than the recent decade, the percentages of side collisions of vehicles in the traffic and of the resulting casualties in the total figures have been observed to grow. On the other hand, the severity rate of accidents of this type has been remaining for many years on a stable level while it has been decreasing for other vehicle crash types. This shows that the progress in the protection of motor car users from the effects of side impacts is too slow. Therefore, it seems reasonable to carry out research on the processes that take place during side collisions.

A research project, expected to facilitate the exploration of the course of some processes in result of which dynamic effects are produced by a right-angle collision of two motor cars on car occupants, has now been in progress at the Automotive Industry Institute (PIMOT) in Warsaw. Within the project, six crash tests were performed with the use of 12 passenger cars of the same make and model. At each test, the front of car A crashed into the left side of car B. The pre-impact speed of car A was about 50 km/h and it was twice as high as that of car B. At successive tests, different places on car B were struck by car A. In each car, a Hybrid III test dummy was placed on the front right seat and a Hybrid II dummy was placed on the front left seat. The measuring systems used made it possible to determine the following:

- dynamic interactions between the cars;
- lateral displacements of the torsos and heads of the dummies placed on the front car seats;
- dynamic loads acting on dummies’ heads and torsos;
- relations between the force applied to car B and the dynamic loads acting on the occupants of that car.

The paper includes test results, thanks to which the time histories of the force acting on the impacted car as well as the effect of this force on the displacements and accelerations of the test dummies could be presented. An analysis of the test and computation results has shown that the location of the place of impact on car B has a considerable influence on the loads received by the car occupants. The knowledge of the dynamic loads acting on the occupants of front seats of car B makes it possible to predict the likelihood and scope of injuries to the occupants depending on the relative positions of the car during a collision.

The test and analysis results presented herein will be used for improving the construction of the system of individual protection of motor car occupants, including a system to restrain lateral displacements of car occupants during a side collision.

INTRODUCTION

Side collisions of vehicles participating in the road traffic (referred to as broadside collisions, right-angle collisions, or T-bone collisions if the vehicles moved perpendicularly to each other before the crash) are very common road accidents in Poland. For more than ten recent years, the annual number of side collisions has been exceeding 25% of all the road accidents [3, 11]. The total number of vehicle collisions in the road traffic in Poland and the number of the resulting casualties show a downward trend (Fig. 1). However, the rates of decline in the number of side collisions of vehicles participating in the traffic (Fig. 1a) and in the number of the resulting deaths are far lower than...
the rates of decline in the number of all the vehicle collisions in the traffic and in the number of deaths in such accidents [11].

At side collisions of motor vehicles, a vehicle may be struck either on the occupant’s side of the impacted vehicle or on the side opposite to it (such collisions are often referred to as “near-side collisions” and “far-side collisions”, respectively). Most of the research works dedicated to the side collisions of vehicles are focused on the analysis of the effects of near-side collisions because of the most severe injuries occurring in such a case due to the fact that the occupant (either the driver or the passenger) is exposed to direct contact with the deformed side structure of the vehicle body. However, side impacts are also dangerous to the car occupant seated on the non-struck side. Such collisions (i.e. far-side collisions) may result in severe injuries to occupant’s neck, spine, and head because of the unrestrained lateral movements of these occupant’s body parts in a typical passenger car.

![Figure 1. Number of vehicle collisions in road traffic (a) and number of the resulting deaths (b) in Poland in the years 2002–2013 [11].](image)

Most of the biomechanical criteria commonly used to estimate the risk of vehicle occupants’ bodily injury do not provide a possibility of evaluating the injuries that would result from a side collision of the impacted vehicle and no limiting values applicable to collisions of this type are known [1, 2].

All the above aspects justify the necessity of investigating the processes in result of which dynamic effects are produced by side collisions of motor cars on car occupants. This defines the objective of carrying out the experimental tests referred to herein. The test results and their analysis show, above all, the properties and characteristics of the process how the heads and torsos of occupants seated on front car seats (on both the struck side and the non-struck side) undergo the dynamic effects. The treatment of the results of many different tests as a whole will indicate new precautionary measures that would reduce the risk of injury to vehicle occupants and will help to improve the protection of motor car users from the effects of side collisions.

**METHODS OF THE EXPERIMENTAL TESTS**

A research project, expected to facilitate the exploration of the course of some processes in result of which dynamic effects are produced by a right-angle collision of two motor cars on car occupants, has now been in progress at the Automotive Industry Institute (PIMOT) in Warsaw [7, 8, 9, 10]. Within the project, six crash tests were performed with the use of 12 passenger cars of the same make and model. At each test, the front of car A crashed into the left side of car B. The pre-impact speed of car A was about 50 km/h and it was twice as high as that of car B. The crash tests were carried out on a test yard with dry concrete surface, in good weather conditions. During the tests, the steering wheel was left free and the road wheels of the cars were not braked. In each car, a Hybrid III test dummy was placed on the front right seat and a Hybrid II dummy was placed on the front left seat.

At successive crash tests, the relative positions of cars A and B were changed as shown in Fig. 3. For each of the vehicle configurations, the tests were repeated twice in comparable conditions.
The tests were carried out with the use of Honda Accord cars manufactured in 2000–2002, which were in good technical condition. The cars had undamaged and non-corroded bodies, which had not been previously repaired, as well as driver’s and passenger’s airbags and side airbags, with the latter having been mounted in the front seat backrests; all the airbags were in full working order.

Among the test parameters, the distance $L_{AB}$ between the longitudinal plane of symmetry of car A and the front wheel axis of car B was taken as a reference. This distance defined the vehicle configuration at the instant of the collision; at successive tests, it was $L_{AB} = 0.04$ m, $0.17$ m, $1.25$ m, $1.34$ m, $2.57$ m, and $2.71$ m.

**TEST RESULTS**

The results presented herein give grounds for evaluating the influence of the location of the place in which car B was struck on the generation of dynamic loads in vehicle occupants. Attention was also paid to the displacements of the dummies placed on the front car seats and on the influence of distance $L_{AB}$ on the values of some indicators characterizing the dynamic loads acting on dummies’ heads and torsos.

The measuring systems used made it possible to determine the following:

- dynamic interactions between the cars;
- lateral displacements of the torsos and heads of the dummies placed on the front car seats;
- dynamic loads acting on dummies’ heads and torsos;
- relations between the force applied to car B and the dynamic loads acting on the occupants of that car.

An analysis was carried out for the time histories of the above quantities measured during the period from the instant when car A just came into contact with car B, i.e. from $t = 0$ s, to $t = 0.2$ s. During this period, the following phases of the experiment were observed:

- collision of the cars and temporary contact between them;
- separation of the cars;
- separate post-impact movements of the cars.

**Displacements of the Heads and Torsos of the Dummies Placed on the Front Car Seats**

Figure 3 shows lateral displacements of the test dummies in car B, following the car impact at the crash test with $L_{AB} = 0.17$ m (selected frames of the video record of the test). The values of the lateral displacements of the dummies in relation to the car seat remained insignificant until the instant of $0.04$ s from the beginning of the process of car B being struck by the other car. The front airbags inflation process visibly began after a time of about $0.06$ s had elapsed; the airbags were fully inflated at the instant of about $0.08$ s. The video record of the test shows that the front airbags having been inflated did not limit the maximum displacements of the dummies because the airbags did not come into contact with the dummies. This can be seen from the trajectories of dummies’ heads, which moved clear of the inflated airbags (Fig. 3). The shoulder strap of the seat belt of the right dummy did not
restrain the movement of the right dummy’s torso. This means that the lateral movements of the torso and head of
the dummy placed on the right side of the car was practically unrestrained by the individual vehicle occupant
protection means, i.e. the protection system turned out to be ineffective in such a situation; the maximum lateral
(linear) displacements of the centres of mass of dummy’s torso and head to the left were in this case 0.26 m and
0.42 m, respectively.

![Images showing lateral displacements of dummies']

![Images showing lateral displacements of dummies']

*Figure 3. Example of the lateral displacements of dummies’ heads and torsos, $L_{AB} = 0.17 \text{ m}$."

The lateral movement of the test dummy placed on the struck side of the car (left car side in this case) was
restrained, at first, by the activated airbag mounted in the seat backrest and, afterwards, by the left part of the car
body structure when it was deformed during the impact. The maximum lateral displacements of the centres of mass
of dummy’s torso and head to the left were now 0.16 m and 0.22 m, respectively.

To show the influence of the location of the place in which car B was struck by car A on the values of lateral
displacements of the dummies, the trajectories of dummies’ centres of mass were determined in the $O_{B}X_{B}Y_{B}Z_{B}$
coordinate system rigidly connected with the centre of mass of car B. The computations were made with the use of
time histories of the accelerations recorded by three-axial acceleration sensors located at the centres of mass of
dummies’ torsos and heads and at the vehicle centre of mass as well as the readings of sensors of angular velocities
of the car body around individual axes of the $O_{B}X_{B}Y_{B}Z_{B}$ coordinate system.

The curves in the graphs shown in Fig. 4 represent the lateral displacements (coordinate $y_{B}$ in the $O_{B}X_{B}Y_{B}Z_{B}$
coordinate system) of the centres of mass of the torsos and heads of the dummies placed on front car seats (DL –
dummy on the left seat, DR – dummy on the right seat) as functions of time, determined at four crash tests differing
from each other in the distance between the place of impact on car B and the axis of the car’s front wheels.
The graphs presented in Fig. 4 unequivocally show that for the right-angle impacts characterized by low and high $L_{AB}$ values, the time histories of lateral displacements of the torso and head of the right dummy (Figs. 4a and 4d) are practically identical to each other in qualitative terms and the quantitative differences between them are small. Attention is attracted by high values of the lateral displacements of the centres of mass of the torso and head of the right dummy and high values of the difference between the lateral displacements of the head and torso, e.g. 0.24 mm for $L_{AB} = 0.04$ m and 0.21 m for $L_{AB} = 2.57$ m.

In the case of central impacts ($L_{AB} = 1.25$ m and $L_{AB} = 1.34$ m), the lateral dummies’ displacements can be seen to have followed a different pattern. At these tests, the right and left dummies moved laterally towards the central plane of the vehicle, coming closer to each other in the culminating phase of the collision, i.e. at $t = 0.04–0.12$ s (Figs. 4b and 4c). The lateral displacement of the left dummy (together with the seat) was caused by inward deformation of the struck side of the car body. The centre of mass of the left dummy’s torso moved laterally to the right (in relation to its initial position) by 0.26 m at $L_{AB} = 1.25$ m and by 0.19 m at $L_{AB} = 1.34$ m and this resulted in a collision between the two dummies on the level of their arms. In both cases, the collision between the dummies prevented the leftward movement of the right dummy. On the other hand, the right dummy’s head did not meet any obstacle of this kind and kept moving laterally leftwards, which resulted in increased displacement of the head in relation to the torso having been stopped and in a dangerous reduction of its distance from the left dummy’s head. During the test with $L_{AB} = 1.25$ m, the clearance between the heads of both dummies was reduced to about 0.03 m. The difference in the values of the lateral displacements of the centres of mass of the head and torso of the right dummy reached as high a value as 0.34 m and was definitely bigger than that recorded at the other tests (Fig. 4b). During the test with $L_{AB} = 1.34$ m, the lateral displacement of the head in relation to the torso of the right dummy was smaller but the heads of the two dummies hit on each other at an instant of 0.12 s from the beginning of the process of car B being
struck by the other car. In consequence of the collision between the dummies’ heads, their resultant accelerations reached high values of 56 g and 73 g for the right and left dummy, respectively.

The tests carried out have shown that in the case of car B being struck in its central part, there is a risk of a collision between heads of the occupants of the front car seats. If such a collision does not occur, the head of the occupant of the right car seat will be significantly displaced in relation to the occupant’s torso, which may result in neck injuries.

Determining of the Impact Force Applied to the Vehicle Being Struck

A matter of fundamental importance for the subsequent discussion is the determining of the time history of the force (i.e. the normal and tangential components and the resultant force vector) applied by car A to car B and the point of application of the force. The forces acting on car B during the impact were determined from the results of measurements of the vectors of acceleration of the centres of mass of car A \((a_{xA}, a_{yA}, a_{zA})\) and car B \((a_{xB}, a_{yB}, a_{zB})\) and the angular velocities of rotation of individual cars in relation to the axes of the local coordinate systems \(O_{A}x_{A}y_{A}z_{A}(P_{A}, Q_{A}, R_{A})\) and \(O_{B}x_{B}y_{B}z_{B}(P_{B}, Q_{B}, R_{B})\) rigidly connected with cars A and B.

A model of the dynamics of a car collision was prepared and the model was used to calculate the force of impact applied to car B. The equations of motion of the model were derived with the use of the Boltzmann-Hamel equations for quasi-coordinates (1).

\[
\begin{align*}
\dot{m}_{A} \cdot \dot{U}_{A}^{+} - m_{A} \cdot V_{A}^{+} \cdot \Psi_{A} &= R_{nA} + F_{xA1} + F_{xB2} \\
\dot{m}_{B} \cdot \dot{U}_{B}^{-} + m_{A} \cdot U_{A}^{+} \cdot \Psi_{A} &= R_{xB} + F_{xA1} + F_{xB2} \\
I_{A} \cdot \dot{\Psi}_{A} &= R_{nA} \cdot x_{A} - R_{nA} \cdot y_{A} + F_{yA1} \cdot a_{A} + F_{yA2} \cdot b_{A} \\
\dot{m}_{B} \cdot \dot{U}_{B}^{-} - m_{B} \cdot V_{B}^{-} \cdot \Psi_{B} &= R_{nB} + F_{xB1} + F_{xB2} \\
I_{B} \cdot \dot{\Psi}_{B} &= R_{nB} \cdot x_{B} - R_{nB} \cdot y_{B} + F_{yB1} \cdot a_{B} + F_{yB2} \cdot b_{B} \\
R_{nA} &= R_{nA} \cdot \cos(\gamma_{AB}) + R_{nA} \cdot \sin(\gamma_{AB}) \\
R_{nB} &= R_{nA} \cdot \sin(\gamma_{AB}) + R_{nA} \cdot \cos(\gamma_{AB})
\end{align*}
\]

where:

- \(m_{A}, m_{B}\) – masses of car A and car B;
- \(I_{A}, I_{B}\) – moments of inertia of car A and car B around the vertical axis;
- \(U_{A}^{+}, V_{A}^{+}\) – longitudinal and lateral components of the vector of velocity of the centre of mass of car A in the levelled coordinate system connected with car A;
- \(U_{B}^{-}, V_{B}^{-}\) – longitudinal and lateral components of the vector of velocity of the centre of mass of car B in the levelled coordinate system connected with car B;
- \(\Psi_{A}, \Psi_{B}\) – angular velocities of car A and car B around the vertical axis (yaw);
- \(\dot{U}_{A}^{+}, \dot{V}_{A}^{+}, \dot{U}_{B}^{-}, \dot{V}_{B}^{-}\) – components of the acceleration vectors;
- \(\ddot{\Psi}_{A}, \ddot{\Psi}_{B}\) – angular accelerations of car A and car B around their vertical axes;
- \(F_{A1}(F_{xA1}, F_{yA1}), F_{A2}(F_{xA2}, F_{yA2}), F_{B1}(F_{xB1}, F_{yB1}), F_{B2}(F_{xB2}, F_{yB2})\) – road reaction forces acting on the front and rear axle wheels of car A, with longitudinal and lateral components of the reaction vectors;
- \(R_{A}(R_{nA}, R_{xA}), R_{B}(R_{nB}, R_{xB})\) – impact force applied to car A and its longitudinal and tangential components; force applied to car B and its longitudinal and tangential components;
- \(\gamma_{A}, \gamma_{B}\) – coordinates of the point of application of the impact force (point Z, Fig. 2) in the \(O_{A}x_{A}y_{A}z_{A}\) coordinate system;
- \(\gamma_{AB}\) – included angle between the longitudinal symmetry planes of car A and car B.

The unknowns in these equations are the normal and tangential components of the impact forces \(R_{nA}, R_{xA}, R_{nB}, R_{xB}\) and the lateral road reaction forces \(F_{yA1}, F_{yA2}, F_{yB1}, F_{yB2}\).
After the system of equations (1), consisting of 6 equations of equilibrium and 2 equations describing the relations
between the components of the impact forces applied to cars A and B, had been solved, the values and time histories
of the normal and tangential components of the impact force applied to car B were determined.

Fig. 5 shows the results of computation of the normal component of force \(R_{nb}\). The time history of the normal component \(R_{nb}\) depends to a significant extent on the location of the place of impact on car B. The average value of the normal component \(R_{nb}\) calculated for a time period from 0 s to 0.1 s was:

- for \(L_{AB} = 0.04\) m, \(R_{nb} = 132\) kN;
- for \(L_{AB} = 0.17\) m, \(R_{nb} = 121\) kN;
- for \(L_{AB} = 1.25\) m, \(R_{nb} = 128\) kN;
- for \(L_{AB} = 1.34\) m, \(R_{nb} = 96\) kN;
- for \(L_{AB} = 2.57\) m, \(R_{nb} = 74\) kN;
- for \(L_{AB} = 2.71\) m, \(R_{nb} = 75\) kN.

The extreme values of the impact forces found to occur at successive tests depended on the force of inertia of car B,
tangential reactions on the road wheels, and stiffness of the bodies of both cars in their crumple zones. Each of these
factors has a complex influence on the time history and values of the impact force applied to car B.

![Figure 5. Time histories of the normal component \(R_{nb}\) of the impact force for various \(L_{AB}\) values: a) CFC 60 filter; b) CFC 15 filter.](image)

**Dynamic Loads Acting on the Right Dummy in the Impacted Vehicle**

Fig. 6 shows some examples of the dynamic effects produced by a right-angle collision on car B and on the occupant
of the front right seat. Results of three crash tests, with \(L_{AB} = 0.04\) m, \(L_{AB} = 1.25\) m, and \(L_{AB} = 2.57\) m, have been
given.

The graphs in Fig. 6 represent the time histories of the following quantities:

- impact force applied to car B (“\(R_{rb}\)’’);
- resultant acceleration of the floor of car B under the centre of the front right seat (“front right seat’’);
- resultant accelerations of the centres of mass of the torso and head of the right dummy (“torso” and “head”, respectively).

The curves presented in Fig. 6 confirm the existence of a considerable relation between the effect produced by an external impact on car B and the time histories of the accelerations of right dummy’s torso and head caused by the impact. For \(L_{AB} = 0.04\) m and \(L_{AB} = 1.25\) m, the process of growth in the acceleration of the floor under the front right seat became visible after as short a time as about 0.008 s from the instant when the value of the impact force began to rise. Conversely, this acceleration at \(L_{AB} = 2.57\) m could only be seen after a time of 0.02–0.025 s had elapsed. Interestingly, the beginning of growth in the accelerations of dummy’s torso and head was practically independent of the location of the place of impact on car B; on the other hand, the rates of growth in these accelerations differed from each other. The characteristic values of the accelerations of right dummy’s torso and head for different values of the distances \(L_{AB}\) have been given in Table 1 in a subsequent part of this paper.
Figure 6. Resultant impact force ("$R_B$"), resultant acceleration ("$a$") of the floor under the centre of the front right seat ("front right seat"), and resultant accelerations ("$a$") of the centres of mass of the torso and head of the dummy placed on the front right seat ("torso" and "head", respectively).
ANALYSIS OF THE TEST RESULTS

An analysis of the test and computation results has confirmed that the location of the place in which car B was struck by the other car significantly affected the loads received by that car and its occupants. The knowledge of the dynamic loads acting on the occupants of front seats of car B makes it possible to predict the likelihood and scope of injuries to the occupants depending on $L_{AB}$.

Two sets of indicators, i.e. W1, W2, and W3 as well as W4 and W5, have been proposed for the assessment and quantitative description of the dynamic loads received by motor car occupants during a side impact of the car. The indicators characterize the accelerations and, simultaneously, they are treated here as "per unit" values (related to the unit of mass) of the inertia forces acting on the car occupants. The values of these indicators were separately related to the torso and the head.

- $W_1$ – average acceleration value for a time period from 0.04 s to 0.08 s;
- $W_2$ – average acceleration value for a time period from 0.04 s to 0.10 s;
- $W_3$ – average acceleration value for a time period from 0.04 s to 0.12 s;
- $W_4$ – maximum acceleration value within a 0.005 s time range;
- $W_5$ – maximum acceleration value within a 0.010 s time range.

The influence of the place of impact on car B on the $W_i$ indicator values was analysed with taking into account the following factors that may characterize the impact:

- relative distance $x$ between the point of impact on car B and the front wheel axis of this car ($x = L_{AB}/L$, where $L$ is the wheelbase of car B);
- moment $M_S$ of an impulse of the force of impact against the car side; the arm of the impulse of the force has been assumed as the distance $L_{AB}$;
- moment $M_F$ of the average force of impact against the car side; the arm of the force of impact has been assumed as specified above.

The values of indicators $W_1$–$W_5$ were calculated for the torso and head of the dummy placed on the front right seat of the car and the calculation results have been presented in Table 1 and in Fig. 7.

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<th>$L_{AB}$ [m]</th>
<th>$W_1$ [m/s$^2$]</th>
<th>$W_2$ [m/s$^2$]</th>
<th>$W_3$ [m/s$^2$]</th>
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The calculated values of the indicators characterizing the dynamic loads acting on the dummy’s torso and head were presented as functions $W_i(x)$, $W_i(M_S)$, and $W_i(M_F)$ and then trend functions in the form of second degree polynomials were determined for individual indicators. The approximating functions were selected that were characterized by the highest values of the coefficient of determination.

An analysis of the graphs presented in Fig. 7 made it possible to formulate an important conclusion: the values of the dynamic loads received by car occupants during a right-angle crash depend to a considerable degree on the distance of the point of impact from the front wheel axis (or, to be more precise, from the occupants’ seats), on the moment of impulse of the impact force, and on the moment of the average impact force. Hence, these quantities may be considered as factors characterizing the effects of road accidents of this type. Noteworthy is the fact that each of the...
curves presented (Fig. 7) has its maximum. This maximum occurred at the values of variables $x$, $M_S$, and $M_F$ approximately equal to $x = 0.5$, $M_S = (3\ldots4) \times 10^3$ Nsm, and $M_F = 10^5$ Nm. When the point of impact was displaced from the centre towards the front or rear axle of the vehicle, the dynamic loads acting on the dummies were reduced. These conclusions are consistent with those formulated previously, which were drawn from an analysis of the influence of the location of the side impact place on the values of lateral displacements of dummy’s torso and head. The highest values of the coefficient of determination, or simultaneously the trend functions that best describe the processes under analysis, lead to the following findings:

- The dependence of the dynamic loads acting on the torso on the location of the side impact place is best described by trend functions $W_1(x)$, $W_2(x)$, and $W_3(x)$.
- The above dependence for the head loads is best described by trend functions $W_4(M_F)$ and $W_5(M_F)$.

![Figure 7. Values and trend functions of indicators $W_i(x)$, $W_i(M_S)$, and $W_i(M_F)$.](image-url)
RECAPITULATION

Measurement results obtained from six right-angle (T-bone) crash tests of motor cars during a simulated crossing of a road intersection have been presented. The said results were used to analyse some properties and characteristics of the processes in result of which dynamic effects are produced on the torsos and heads of occupants of the front seats of the impacted car. Time histories and values of the force acting on the impacted car, referred to as “car B”, were determined. As an effect of the impact force acting on car B, time histories of the displacements and accelerations of test dummies placed on the front car seats were recorded.

An analysis of the lateral displacements of occupants of the front seats of car B has provided grounds for the following conclusions to be drawn:

- The lateral displacements of the torso and head of the occupant of the seat on the non-struck side of the impacted car are much bigger than those on the struck side of the car (e.g. at L_{AB} = 0.17 m, the differences in the lateral displacements of the torso and head were 0.1 m and 0.2 m, respectively).
- The individual car occupant protection means practically do not participate in the restraining of lateral displacements of the occupants seated on the non-struck car side.
- Moreover, the absence of the said protective effect results in excessive lateral displacement of the head in relation to the torso (at L_{AB} = 1.25 m, the lateral displacement of the centre of mass of the head exceeded that of the torso by 0.34 m).
- At L_{AB} = 1.25 m, a collision took place between dummies’ torsos in result of their lateral movements and the clearance between the heads of both dummies was reduced to about 0.03 m.
- At L_{AB} = 1.34 m, the lateral movements of the dummies caused dummies’ heads to hit on each other and the acceleration of one of the heads reached a level of 73 g.

When the loads acting on motor car occupants were analysed, five indicators W_i were defined, which were then used to identify the factors that are decisive for the loads acting on the occupants during a side collision of the cars. In consideration of the fact that the dynamic loads acting on the occupant on the non-struck side of car B depend on the distance of the point of impact from the front wheel axis (or, to be more precise, from the occupants’ seats), the following has been ascertained:

- The torso loads are best described by indicators W_1, W_2, and W_3, defined as functions of the distance of the point of impact from the front wheel axis of car B.
- The head loads are best described by indicators W_4 and W_5, defined as functions of the moment of the average force of impact against the car side.

The test and analysis results presented herein will be used for improving the construction of the system of individual protection of motor car occupants, including a system to restrain lateral displacements of car occupants during a side collision.

The tests reported herein were carried out and their results were analysed within an authors’ own research project No. N N509 559440.

REFERENCES


