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ANALYSIS OF TRAFFIC COLLISIONS BETWEEN VEHICLES AND PEDESTRIANS AIMING AT REDUCING THE INJURY POTENTIAL

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ABSTRACT

In the paper herein we analysed the level of trauma on the head and thorax of the pedestrian during collisions with a motorcar. The goal is to establish some concepts aiming at reducing the level of injuries suffered by pedestrians behind the contact with the frontal area of vehicle.

1. GENERALITIES

Traffic accidents involving pedestrians make the subject of a contemporary issue. About 80% of the traffic accidents, out of which more than half are fatal, are produced in urban areas and on the main roads. The braking before the impact occurs in 70% of these accidents, which reduces the impact speed to 20 km/h. As a result, the pedestrians are hit at low speeds; 90% of accidents are produced at average speeds of about 48 km/h or even less, as shown in figure 1. Accidents at low speeds are preferable because the chances to reduce the injuries upon pedestrians, through constructive changes of cars, are much higher at these speeds. These items of information have generated deep researches upon the impact at speeds ranging between 0 and 48 km/h.

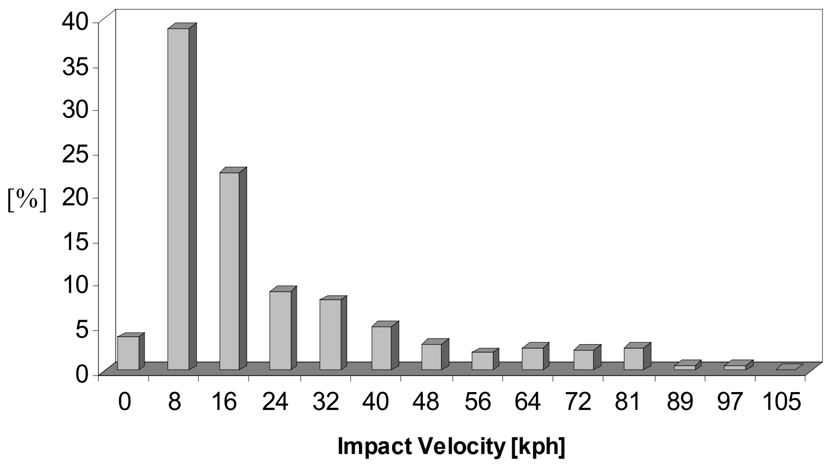

Fig 1. Percentage of traffic accidents, taking into account the impact speed

The most injured areas of the body are the head and the thorax. The legs' injuries that are less serious are more frequent. In figure 2 there is presented the injuries distribution on the body areas as well as their cause, for impact speeds not exceeding 8 km/h.

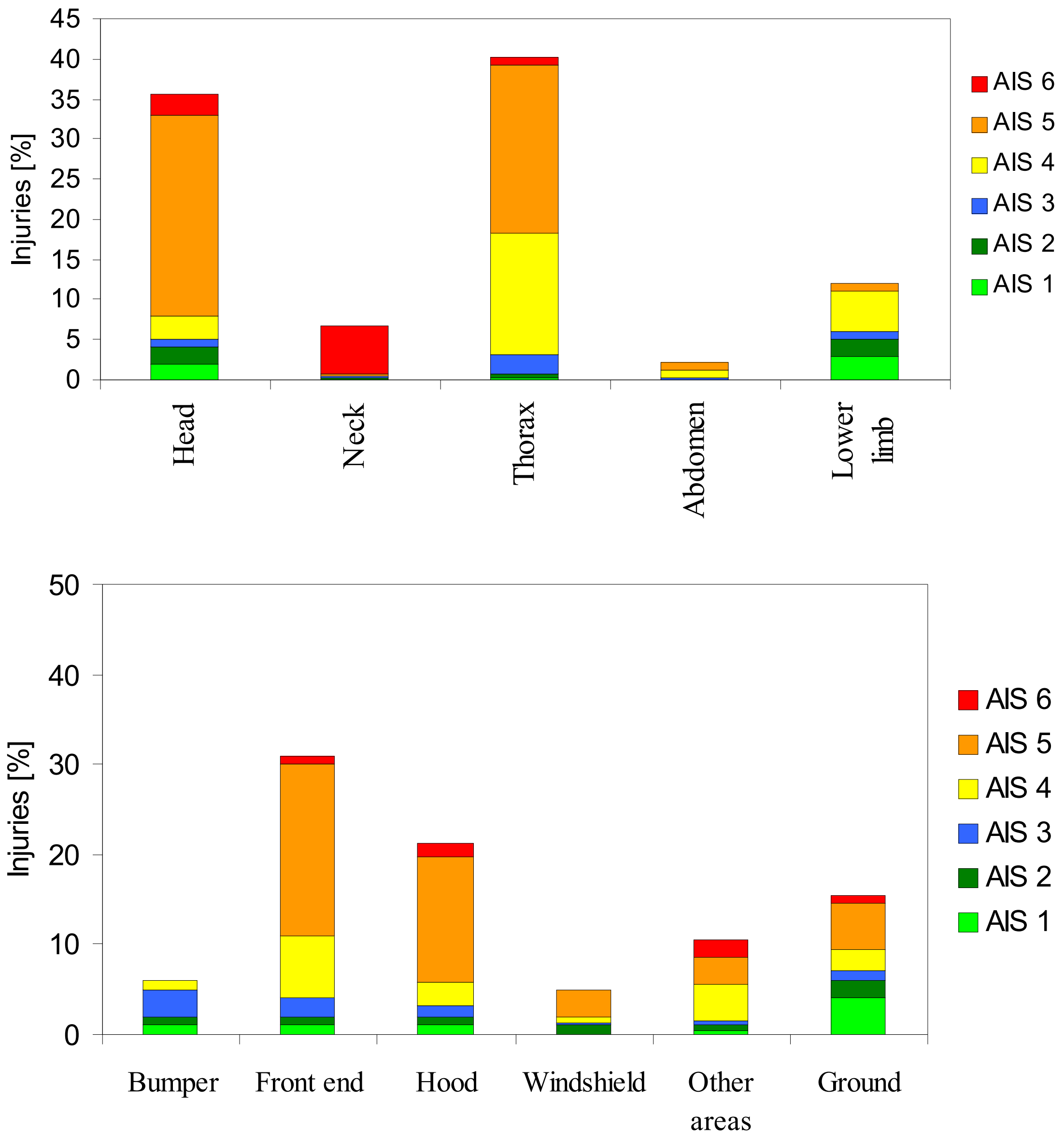

Fig.2. Percentage of injuries and their seriousness, taking into account the impact source

There is also presented the percentage of injury seriousness levels. The injuries at thorax and head level represent three quarters of the damages suffered by the pedestrian. All car-pedestrian contacts generating at least 2% injuries are presented herein. The head, thorax and legs impacts with the hood, fender, front end and bumper are subsequently mentioned. They cause about 50% of the injuries suffered by pedestrians, at vehicles driving speeds of up to 48 km/h.

Young people are generally involved in all types of car accidents. Statistics show that the pedestrians who are up to 15 years old represent 40% of the total number of accidents victims. The traumas suffered by children represent a significant part and continues to draw the researchers' attention.

The initial efforts that include measurements of long-lasted injuries show an increase with about 25%, as relative importance, of the head and leg traumas and a 25% reduction of the thorax trauma seriousness. There is a call for more researches in order to establish the importance of injuries and handicaps decrease during the car-pedestrian impact.

During the past few years the car design has been changed in USA, Europe or Japan, which determined the modification of injury distribution. Nowadays the cars have low front end and short hoods, which tends to change the impact point of child's thorax and head from the car's frontal part to the hood and fender surface and to move a significant percentage of the head impacts with the hood towards the windshield. At present we are confronted with the increase of light trucks and VANs, used as personal cars and that subsequently generate collisions with pedestrians. It is vital to collect new data on accidents involving pedestrian in order to understand the nature of accidents.

In the light of the above-described information on traffic accidents, various organisations all over the world have set up a research and development programme specifically aiming at reducing the injuries consequences after the car-pedestrian collisions. The contacts considered are the head impact with the hood, fender and pavilion; the thorax impact with the car's frontal part, hood and fender; and the leg's impact with the bumper and with the car's frontal part. The strategy is similar for all three regions of the body.

Consequently, at the beginning there is conceived a simulation experiment of the impact, which explains the designing of part components testing device and the development or confirmation of the injury-related criteria. The part components of the testing equipment are then used in order to assess and identify the configuration of the car causing the most insignificant injuries. At the end, if necessary, there are brought structural changes to cars in order to prove their efficacy in diminishing the injury seriousness.

2. RESEARCHES UPON HEAD INJURIES

The head protection against hits is of great interest. The brain, skull and tissues injuries may be caused by a variety of mechanisms. The injuries include tearing, abrasions, fractures and other forms of tissue destruction. These are almost always caused by excessive motion of one side of the head as compared to the other one. The scalp tearing is the effect of some mechanical cutting actions that separate different parts next to it. The cranium fracture occurs when the osseous structure of the skull is submitted to bending efforts greater than it can bear without breaking. The brain contusion represents an area of blood collection caused by sanguine vases that were too strongly stressed.

In order to protect these types of injuries there can be adopted various approaching ways. Two of them are as follows: padding designing and loads distribution. The head impact may lead to cranium deformation and, in case there do not occur fractures, the brain tissues can be damaged under the influence of cranium deformation. Even if the cranium is not stressed at bending there are still going to occur brain deformations. It is the minimisation of these damages that make up the objective of head protection.

2.1. Considerations upon materials

The materials may be classified in two large categories: plastic and elastic. The plastic material does not regain its initial form after the deformations occurring during the collision. Under a total compression of the material the deformation speed reaches the minimum, 0 value. It can be said that the entire kinetic energy was dissipated (absorbed). The material is elastic if after the impact it regains its initial form. In this case the energy is not absorbed and the head regains the initial speed in opposite direction. The maximum force developed does not modify, but the time taken for its action doubles.

Most of the current materials are not perfectly elastic or plastic but somewhere in-between. If the length of the force application is the objective to be followed, there will be used mostly the plastic materials. Provided that the material submitted to forces action is to be used several times there is to make use of materials that regains the initial form after loads. The best material would be one that deform plastically and that slowly regains its form and the strength and is able to resist to subsequent loads.

The force occurring when hitting a material depends not only on the material deformation under the force action but also on the value of the surface on which it actuates and on its inner strength.

The force developed during the impact depends on the material characteristics at the moment of accident. This characteristic is defined as the strain-stress ratio. The stress is defined as the force applied on the area unit, while the effort is the strain divided through the initial thickness of the non-deformed body.

There is a connection between the seriousness of the injury, expresses as maximum AIS, death probability (POD) and the head injury criterion (HIC). This verifies the fact that a HIC value of 1000 stands for an exact parameter of the serious injury threshold (AIS = 3 and POD = 7%), and a HIC of 1500 seems to be a threshold of serious injury (AIS = 4…5 and POD = 26%).

2.2 Assessment of head injury potential

The testing methods of components at impact was used in order to assess the injury potential resulted after the impact with vehicles having various characteristics. Since the impact speed for more than 90% of the traffic accidents involving pedestrians is below 48 km/h, and since the ratio between the head impact speed and the vehicle-pedestrian impact speed is of about 0.9 – 1.1, most of the part components submitted were tested at impact speeds lower than 40 km/h. The potential of injury seriousness at the experimental impact was mainly assessed with HIC. Good performances are indicated at collisions simulations with pedestrians, which give values of HIC lower than 1000.

The results obtained after the components impact testing suggest that three areas with injury potential may characterise the vehicle frontal surface. The hood center is defined as the surface framed at more than 150 mm from any of its edge. The hood-fender area include the hood surface limited to 150 mm from edges as well as the upper part of the fender frame. The hood rear surface is comprised between the windshield low edge and an imaginary line at 150 mm at the front of the hood rear edge, see figure 3. The accidents data show that the impact point of the pedestrian's head is uniformly distributed within the limits of these areas.

Fig.3. The hood areas with different injury potential

The impacts with the hood's central part generate a large variation of the HIC and there results the POD values similar to those in other areas. Some hoods seem to provide a good protection for the head. As a consequence, there were developed detailed tests for the central surface of the hood. The hoods of some motorcars, light trucks and VANs were analysed in detail. There can be achieved considerable decreases of the injury degree if the hoods' central surfaces are similar to those generating reduced values of the HIC. The hood rear area, however, generates severe impacts as compared to those produced within its central area. In figure 4 there is illustrated the fact that the impact within the hood rear area produces greater values of the HIC than within the central area. The impacts produced within the hood-fender area generate greater values of the HIC than all the impacts produced in the other hood areas mentioned above.

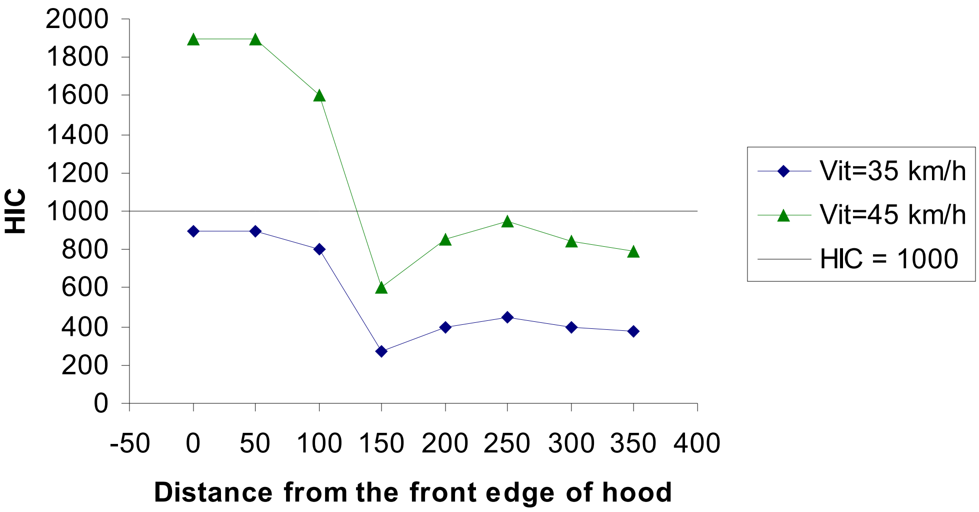

Fig.4. Percentage of injuries and their seriousness for different areas of the body

The characteristic areas of the vehicle affecting the impact seriousness comprise the space between the hood surface and the components in the engine compartment, the material used to manufacture the hood and the hood reinforcing structure.

The experimental results suggest that for impact speeds ranging from 35 to 45 km/h, the head must determine dynamic deformation of the hood surface ranging from 58 to 76 mm, so as to maintain the HIC values below 1000. The deformations may exceed the distances between the hood and the components in the engine compartment if the engine devices are not rigidly mounted. In most cases, these components are rigid and massive as compared to the pedestrian's head and the plate the hood is made of. These observations suggest that the impact of the pedestrian's head with the external frame, that assures a space larger than 58 mm to the nearest component in the engine compartment, may cause only minor potential injuries.

When designing motorcars' hoods and protection helmets, at first sight, one of the main objectives is to maximise the area of the surface that interacts with the human being's head during the impact. Great forces induce great accelerations and are associated with pronounced deformations – this may look as a contradiction. It is not a contradiction out of the following reasons: by increasing the quantity of the material interacting with the head during the collision there increases the absorbed kinetic energy and there is subsequently minimised the energy transfer towards the head. If the great force developed in this process is lower than the force necessary for injury occurrence there can be said that the hood is well designed.

The material the hood is made of also influences the injury seriousness. The tests results show that the conventional sheet-steal plate of both hood and fender absorbs the head impact energy, producing low forces and consequently low values of the HIC. There was tested a hood made of aluminium and it presented the expected energy absorption characteristics. The great dynamic deformations that were noticed in this test suggested the need for more distance between the hood and engine devices. Hitting some hoods made of composite fibres indicates the fact that some hoods presents weak energy absorption characteristics and are considered to be more rigid than most hoods made of steal. Consequently, it is more likely to be confronted with serious injuries of the head at the impact with hoods made of composite plastic materials than in case of a hood made of steal. The reinforcing structure of the hood affects, at its turn, the seriousness of the head injury at impact with the hood. The test conducted with two vehicles with almost identical aspect from geometrical point of view and with different reinforcing structures showed that the vehicle with the "strongest" reinforcing structure caused more serious injuries than the vehicle with the "lightest" reinforcing structure of the hood.

3. RESISTANCE LIMITS OF THORAX AT FRONTAL IMPACTS

Many of the results obtained in earlier researchers, making reference to thorax resistance limit were later reviewed by specialists. Some of them were used to design the Hybrid III dummy, designated to test the human being-motor car frontal collisions.

In case of serious injuries, the superior limit, of vertebral column acceleration does not have to exceed 60 g in case of frontal contact accidents. The Hybrid II and III dummies were conceived in order to measure the impact strength in accordance with the federal norms FMVSS 208 [1], [5]. The first one measures only the acceleration of the vertebral column, the Hybrid II model measuring simultaneously the chest compression. 40 g accelerations actuating throughout 100 ms or less were tolerated by subjects. Only in one case it was managed to bear 45 g in a period of time similar to the first one. Following the constant rates of 1000 g/s there was observed that the human being cannot bear the value of 30 g. Eiband showed that the bear limit of the thorax submitted to accelerations decreases together with the exposing time increase.

Following the researches, by examining the results of some dozens of tests fulfilled in laboratory, there was concluded that the seriousness of thorax injury is proportional with the specific quality of energy it has to absorb. At the same time the accidents seriousness is inversely proportional with the value of the contact surface between the motorcar and the pedestrian's thorax and with the time when it is achieved the energy transfer.

NHTSA developed a large range of components that represent the thorax for simulating the pedestrian impact under laboratory conditions. The configurations were made for children ageing 3, 6, 9 and 12 years old and the adult man was configured according to the criterion of 50% resemblance. Since the pedestrians follow a trajectory perpendicular on the one of the car that hit them, the components were conceived to simulate the most representative accident conditions, the side impact with the chest. The components of the testing devices were designed to create the conditions of distributed load, generating real contact for each group of age. The design lays its basis on an analytical model, with mass, of the thorax. The dummy and testing devices biofidelity provided similar "answers" to those of the human body. The parameter used to assess the answer of these components comprises the acceleration and the relative deformations at the level of ribs and vertebral column as well as the reactions.

The thorax surrogates are testing devices, able to provide repeatable answers, similar to those of the human body. They simulate the impact conditions with distributed stress. The injury criteria are used to point out the forces, accelerations and deformations with the aim of assessing the level of injury seriousness. The criteria used to assess the thorax injuries are identical with the criteria used for the occupants of a vehicle cockpit submitted to side shock: Thorax Trauma Index (TTI), Criterion of Viscous Injury (V*C) and accident.

The Peugeot-Renault Association measured the thorax reactions and deformations throughout a range of tests. The International Organisation of Standards (ISO) formulated recommendations for the data obtained from dummies testing.

4. CONCLUSIONS

The conception, form and materials used in automotive industry are different nowadays than 20 years ago. The front end of motorcars is lower and with more fluent shapes; the hoods are shorter; the plastic materials, lighter, are largely used to manufacture the vehicles' frontal part, and the dashboard are mainly made of plastic materials. The tests have indicated that the fenders and the hoods made of plastic materials are to be very carefully conceived in order to minimise the impact effects upon the pedestrian's head. Lowering the car's profile and the bumpers may bring advantages to both pedestrians and cockpit occupants in case of a side impact. The VANs are more and more often used as family cars, more than the commercial motorcars. These changes stress the need to gather more and more data on traffic accidents, aiming at refining the information and at increasing the researches efficacy.

The head and thorax trauma generate the same damages, but the researches conducted during the last years have showed that a moderated injury (AIS 2) of the brain may have long-term effects or even permanent effects, a result that is not produced in case of moderate thorax injury.

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