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MEDICAL POINT OF VIEW ON PASSIVE SAFETY

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Only modern passive car safety systems can protect drivers inside vehicle during accident. In addition, there are other important conditions: the residual post-accident life-space in the car and rapid arrival of ambulance. However today there is a new research path – simulation (by using digitised model of an anthropomorphic dummy). The analysis of human body behaviour during crash can give useful information for designers of the new passive car safety systems.

Keywords: HIC, accelerations, passive car safety systems, residual post-accident life-space

1. Introduction

According to The Commission for Global Road Safety in the world every year in road accidents died about 1.3 million people. This problem is called a global epidemic, comparable to the number of deaths from malaria and tuberculosis. In the structure of deadly trauma in general is one of the highest places, and among road traffic injuries is most often the cause of death.

Despite some improvement in mortality rate in road accidents (Russian statistics until 2009 believed to be killed in a traffic accident only to those who die within 7 days after the accident. All those who died later in hospitals, official data do not fall *) in Russian Federation over the past year our rates are high – the number of fatalities per 100 injured in road accident in Russian Federation far exceeds the average for the European Union.

In addition, due to late arrival of the ambulance the number of victims increases up to 60%, and as we know the best chance to survive after serious automobile accidents it is to receive adequate medical care in within half an hour from the time of injury. Lack of assistance during "Golden hour" after an accident increases mortality by 30%.

(* Order of the Government of the Russian Federation № 859 dated: November, 19, 2008, Moscow, -"On Amending the Rules for the recording of accidents" - in 2009 to provide records of accidents and information about the wounded, died within 7 and within 30 days from their consequences; This Order is entered into force on January, 1, 2009)

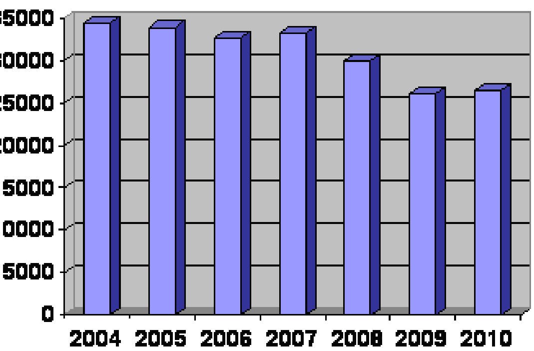

Figure 1. Dynamics of the number of people killed in road accident in Russian Federation for the years 2004–2010. (According to the GIBDD-traffic police of the Russian Federation)

The problem of personal injury in car accidents is discussed in the literature for a long time [1–5]. We consider the impact of shock acceleration on the human body over 10g (g-acceleration due to gravity) duration of less than 1 second (Fig. 2). During this period included the rise time and decay accelerating at the same time there is a sharp movement of the human body and especially the head, often accompanied by a blow of items of equipment cabin and exceeding the physiological limits of endurance of the human body.

There are two types of car safety: active and passive. The passive safety devices includes: airbags for protection against frontal and side collisions and curtains, seat belts with a system of forced tension etc. The most important factor in car passive safety is the residual post-accident life-space in the car. Restraint systems and the life-space were designed to protect people inside the car by taking it upon itself the main force of impact in the collision and its suppression.

In any case, hit occur in such vital parts of the body such as: head, thorax and abdomen. In the process of hitting a person moves toward the collision point. At a speed of 48 km/h this type of attack against human body can be equated to a fall from the fourth floor on solid ground.

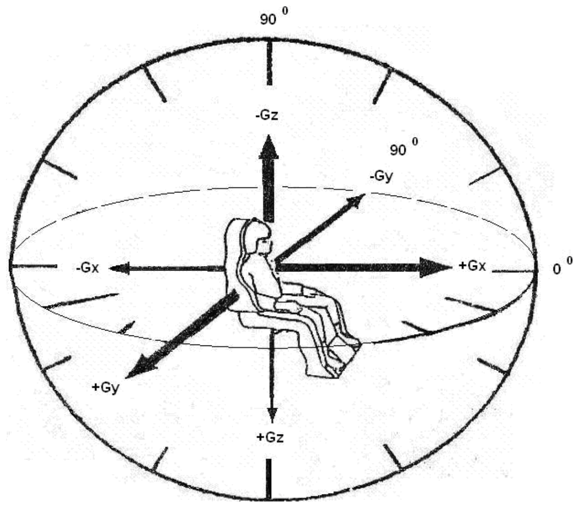

Figure 2. Diagram of the directions of the accelerations

2. Medical Aspects of Problem

From a medical point of view the human skeleton is divided into the following main regions: the skull, spine, chest, upper (including shoulders) and lower (including pelvic girdle) limb. The skull is divided into the following parts: face and brain.

The spine is divided into five regions (Fig. 3): 1 – Cervical (C1–C7) – Seven cervical vertebrae are located between the skull and rib cage. The first cervical vertebra, called Atlas, second – Axis and seventh vertebrae have special characteristics. The four remaining vertebrae are considered as typical. 2 – Thoracic (T1–T12) consists of 12 vertebrae, 3 – Lumbar (L1–L5) consists of 5 vertebrae. 4 – Sacral (five sacral vertebrae), merging with age, form the sacrum. 5 – Coccygeal (four coccygeal vertebrae), in the adult almost merged to form the coccyx.

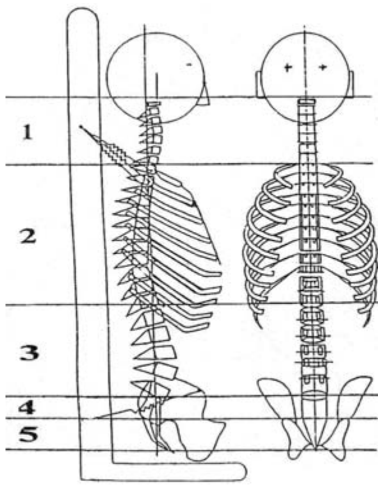

Figure 3. Human spine regions

The impact of a sharp slowdown on the human body is often estimated in the following categories: from tolerant degree till traumatic deaths. Tolerable degree – minor injuries as abrasions and contusions, traumatic – leads to a moderate injury and to a serious injury that can not lead to death. A limiting value under the influence of acceleration of approximately 250g, acting within 0.1 seconds is the limit of tolerance for the + gx axis and for the – gx axis this limit is 150g for 0.1 seconds. The head is attached to the body so that retains a vertical position to accelerate 2g. Cervical vertebral column has the highest mobility. Also need to consider and neck human endurance which is three times lower in hyperextension than hyper flexion and that the neck muscles more endurance load placed on the head in the capital plane. Which is the magnitude of deceleration is considered dangerous? Was found that it depends on the time within which they act on the body. Man is able to withstand large overload for a few milliseconds, or medium overload, but lasts longer.

Now in the world practice assessment head protection from injury based on the so-called “curve of Wayne State”, which describes where begins a concussion and how the threshold value of overload depends on the duration of the shock pulse. With Analysing the selected time interval at which the total level overload were maximally.

The fact that the crash tests with anthropomorphic dummies simulating the behaviour of a real human body (the kinematics of the joints, weight and elasticity of body parts, etc.), we can only estimate the probability of injury. And that's not enough for the maximum overload – the brain can withstand short-term overload of 150g (1–2 milliseconds), and may flatten the skull on wall at a deceleration of 100g, but to act within 10–15 ms. So, we need to sum the value of congestion at a dangerous point of impact. This is the physical meaning of the criterion “HIC” – a Head Injury Criteria, criterion for severity of head injuries. It was used abroad as an estimate of traumatic car for the head of the driver and passengers. HIC indicates the maximum of all possible integrals, taken in the time interval no more than 36 ms with a certain ratio, which (like the curve of Wayne State, which based method for calculating HIC) is defined in the course of experiments on animals and human volunteers. It should not exceed the 1000 conventional units HIC. That is, HIC actually shows “the dose absorbed by the slowdown.” For example, if an overload of 80g acting on the person within 3 ms, then, putting 3 ms on the abscissa of the curve Wayne State, and 80g – on the vertical axis, we get a value that lies below the threshold curve, that is safe (this value is mentioned in the rules № 12 and № 21 UNECE – they set the border to 80g at the time of 3 ms, and the rules of FMVSS 208 recommend 41g at time of not more than 36 ms.) In addition to be transferred to some other criteria: NIC (Neck Injury Criterion), TTI (Thorax Trauma Index), FFC (Femur Force Criterion) etc.

3. Problem Solve

To prevent injuries and fatalities have been specially studied the process of collision of cars. With high-speed cinematography and high-precision sensors and devices were defined types of collisions and shows what happens with people and vehicles during process. There are two processes occur: the first is when the car hits into something and is stopped and the second (more important) when people (especially), not wearing a seat belt hits on something inside the life space. There is three fundamentally different mechanisms injury or death: man hit something, something hit a man, a man falls out of car.

We consider the following types of car collisions: frontal, front-offset, side, rollover and rear.

1. Frontal type of collision is more than 1/3 of all car collisions. During a crash the front end deforms, absorbing the energy of the collision. However, inside the living space of all items and not wearing the driver and passengers are moving forward. In this case, the driver hits the steering wheel while sitting next to a passenger on the dashboard and the windshield. Rear passengers sit in front of hit or hurt them by pinching between the front seats and dashboard. In addition, at high speed collisions are not wearing your people can fall out of the car, breaking the windshield. Seatbelts minimize or prevent injury to persons in this type of collision. And then come into work airbags that protect the head and some car models even knees.

2. Forward-offset collision is characterized by a partial deformation of the front end (called a blow to the incomplete overlap) and is common, for example, when going into the oncoming lane when overtaking incomplete. Life space with this type of collision is suffering as well as at the front style with complete overlap, the front part of the body absorbs some of the shock energy. However, in connection with the direction of overload, especially by dropping the body back probably misses his head on the headrest and injury on the side surface, in connection with the rotation of the car when the rebound from obstacles. Therefore, for this type of collision be developed seats with integrated seat belts, and remove

the seat away from the inner side panels of the car, as well as to develop a new active head restraints designed to capture a greater surface and a new algorithm for response and side-curtain and side airbags.

3. Side collision type most often – is found in more than 40% of the cases from all other types. However, unlike the anterior type of collision body can not absorb enough energy from the small deformation zone in the lateral part of it. It is compressed, reducing the living space. Not wearing people will move to the side in the direction of impact, often hitting each other with a force equal to the force of the collision. Driver wearing your safety belt can in this case it is better to control the situation and avoid a collision drastically changes the trajectory of motion. However, a large number of deaths in side collisions, suggests low efficiency of seatbelts (as opposed to the front collision) and the need for more in-depth study of this type of collision. Apparently in this case it is necessary to use special means of passive safety (including seats with integrated seat belts) and also need to develop research in the field of virtual crash tests (develop a digitised model of an anthropomorphic dummy for side impact EUROSID II – as is already done by MADYMO for dummy HYBRID III).

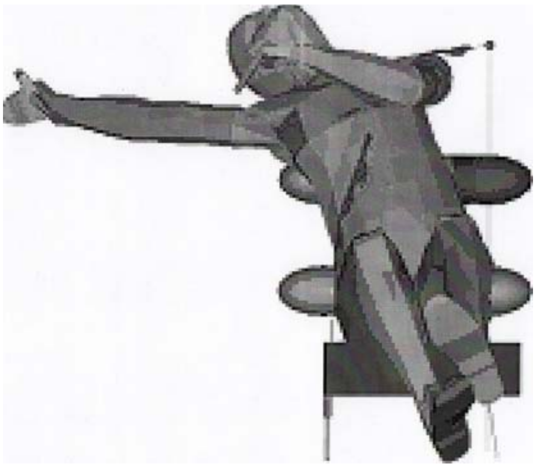

Figure 4. Modelling the biomechanics of the human body during side impact (t = 200 ms).
(Cited by Cristina Echemendia, 2009)

Of interest are the data firm TRW: of all deaths in collisions of 31% falls on the side collision; they found that 9,8% cause of death was head injury and in 6% of chest injuries (47% and 29% respectively). These studies suggest that during the analysis of mechanical and functional durability of the human body for a variety of extreme situations special attention should be paid to the head. This is primarily due to the unique role of the brain in the processes of life. On the other hand, the head is one of the most prone to injury segments of the human body when exposed to different mechanical factors, especially during side impact, leading to severe destruction of the neural network and brain vessels. However, the task of providing head injury prevention is one of the most difficult biomechanical problems, and in this case (side impact) is difficult even informed choice requirements for the quality of protection and injury-range of effects.

4. During vehicle rollover people, especially, wear a seat belt at risk of injury is much more severe than in other types – is the most dangerous of all collisions. With a share of 13 per cent of the total number of collisions they kill over 20 percent of all those who are perishing at collisions. This type of collision could happen at a moderate speed, with the fallout from the car can occur during a light shock when people during rotation car thrown from side to side. More than half of all people are unfastened serious injury inside the cabin until the fallout from the car. During the coup belts are the key to help reduce the risk of injury and prevent death. However, insufficiently strong roof rack and can significantly reduce the life space (Fig. 5).

5. At the back the type of collision occurs discarding the body back to his seat. In this case the so-called whiplash strike (neck hyperextension during upset head back), which leads to injury of the cervical spine, and then, if the person was not wearing, the rebound of the seatback forward, he may be injured as a collision front type. In this case, the headrests, which play an important role in minimizing the trauma of the cervical spine and seatbelts prevents loss of a man from the car. Headrests provide a sufficient level of comfort and allow you to save the living space. However, the need to regulate them so that they have never been below the ear. Thus, when type of stroke is presented, seat belts are used, headrests and other systems such as “WHIPS” – VOLVO firms, for example, should reduce the risk of injury to the person.

Figure 5. Biomechanical model human body during car rollover.
(Cited by Cristina Echemendia and Kennerly Digges, 2009)

4. Scientific Novelty

Recently developed tools and elements of passive safety, and generators located in the living space, such as: the strong body structure, reinforced by additional elements in the design of floor, roof and doors, collapsible dashboards, reinforced seats and headrests, but also automatic protection systems, consisting of: air bags and seat belts with positive tension, energy absorption steering columns, etc. convert any car in a fairly safe means of transportation. At the time of the collision, these tools passive safety features all work together to preserve the life-space and prevent serious injury to persons inside the vehicle; particularly affected the head because it is difficult to fix. These tools will work in most cases prevent from severe injuries, if only the driver and passengers will wear seat belts, which fix the body in the cabin of the vehicle and give the time and place for disclosure of airbags.

In addition there is a tendency timing response elements pre-crash active safety.

5. Conclusions

- Research to develop requirements for perspective vehicles cabin construction (with using dynamic anthropometrics and develop a digitised model of an anthropomorphic dummy) under the influence of shock acceleration, in order to optimise the placement of the elements of Occupant Safety Systems and improve human body injury prevention.
- Develop designs perspective automatic Occupant Safety Systems: Multiple Restraint System (MRS) and the rollover protection system (RPS).
- Simulation of the human body, in order to create mathematical computer models to study the kinematics of human movement within the body when the accident types with the use of the physiological and biomechanical approach (not exceeding the limits of endurance of human body parts and taking into account its possible displacements inside the cabin living space at all stages of an accident).
- Modelling the kinematics and biomechanics of head-neck in a frontal collision with an incomplete overlapping and side crashes.
- Studies on the application of active head restraints and new principles of retention with the use of additional biomechanical elements for applications where conventional systems are not applicable.
- Development of requirements for prospective design of cars, taking into account the application of automatic Occupant Safety Systems for the front, and side collisions, in order to release the lateral space for the establishment of a zone to trigger airbags and curtains and increase safe zone for lateral deformation of the car body.
- Use of the physiological and biomechanical approach for designing advanced structural automotive body in order to minimize the degree of injury are people in them, during the accident and operation of automatic Occupant Safety Systems – i.e. deformable body as a protective shell, the maximum quenching peak overload and having adequate life space.
- Assess the economic efficiency of automatic Occupant Safety Systems new generation cars, taking into account the "value of human life".
- Development of technical standards for vehicles, taking into account international experience and perspective and the requirements for vehicles passive safety.

- Design and manufacture of dynamic simulation for the physiological, biomechanical reactions of the human operator on the impact and shock vibration to produce advanced ergonomic and hygienic requirements for the organization of life space.

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