USABILITY OF COMPUTER SOFTWARE FOR SAFETY DETERMINATION BY SIMULATING A "CAR TO CAR" AND A "LARGE VEHICLE TO CAR" ACCIDENT

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Abstract

The purposefulness as well as necessity of cars safety determination has been exhibited. Moreover, the principles of the finite element method (FEM) have been explained as well as its usefulness as a crash testing simulation tool. The programs which have been established in order to explore possibilities of virtual testing have been described. The paper contains the designs of the large vehicles passive safety devices. The problems concerning simulations of large vehicles – cars accidents have been emphasized. Moreover, the conversion of the experimental testing in to the virtual testing has been pointed out along with its advantages and disadvantages. Furthermore, the paper describes the proposition of the safety improvement in case large vehicle – car accidents investigated with aid of virtual crash testing. The last mentioned system is especially important in terms of truck tractor with a trailer where slipping is very dangerous due to the fact that it can cause breaking the connection and in consequence roll over. Another, new solution which improves passive safety could be the "active bumper". The passive safety devices are necessary to reduce danger as well as provide passengers with maximum possible comfort what but a way also improves safety.

***Keywords**: transport, vehicle, safety, accident, simulating*

1. Introduction

Crash tests are the simulations of the most common types of car accidents. Measurements taken in crash tests are useful sources of information, which help improving vehicle safety design and occupant's protection. The results are published in a form of a scale represented by stars which correspond to the probability of life-threatening injuries.

It is obvious that real accidents have variable scenarios, the number of possible collisions considered in crash tests was, however reduced to the most important in terms occupants safety as well as frequency of their occurrence. Those scenarios have been classified by ISO 6813 norm.

ISO 6813 includes:
- Frontal impact,
- Side impact,
- Rear impact,
- Rollover,
- Fire,
- other.

The great number of necessary tests, during which prototypes are destroyed, is a significant price of determining the safety. Therefore the cars are initially tested by means of computer software (using finite element method (FEM)) Thanks to this kind of simulation, cars manufactures can predict behaviour of the vehicle. Moreover, engineering with a computer aid allows performing a non standard test. For instance the variability of human posture can be considered. During actual crash test, specific types of dummies (**A**nthropomorphic **T**esting **D**evice ATD) are used. The ATD are highly advanced devices capable of simulating human behaviour during the impact [10]. Dummies however, provide accurate information only on behaviour of an occupant with similar posture. It does not apply, for example, to a person with overweight or a pregnant woman. Another important issue concerning numerical simulation is the possibility of simulating wide rage of physical domains, sizes of tested element as well as product features (i.e. noise, vibration and harshness, vehicle handling). The general objective is to support the development of vehicles with minimum prototype testing [4].

2. Fem as a crash testing tool

Generally, the finite element method consists in transferring the uniform construction into a non-uniform one, which is calculable or at least easier to calculate. The continuous loads are replaced by a static set of equivalent forces, attached to the nodes. Interaction between elements occurs in the nodes. Hence, stiffness of the model is always smaller then stiffness of a real construction [7].

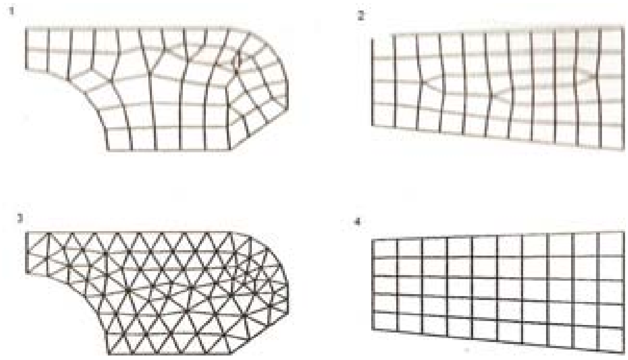

Fig. 1. Dependence of the mesh shape with respect to the element shape [7]

In other worlds, the tested element is "separated" into finite amount of smaller elements connected with each other by the nodes. Usually the small elements have the shape of a square or a triangle. This process is referred as meshing. The accuracy of the calculation increases along with the number of the elements. Unfortunately, the time of calculation increases as well. It has been determined that applying square shape of a finite of element improves the results of the calculation. Moreover, such a shape does not cause the artificial orthotropy. Furthermore, the more regular are the elements applied, the more accurate calculation results are obtained. The shape of elements depends mainly on their location within the area of the tested object. Few different shapes of mesh are exhibited in the Fig. 1 [7].

All calculations consist in determining the resistance of the material first, next the dynamics, multi-body models and finite elements are analysed [4]. Calculation performed by means of FEM starts by entering the finite number of elements and in consequence the nodes, then the external loads are applied. Next step is selection of the element type and thus linear approximation of the model (its degrees of freedom). Then the matrix of the stiffness is calculated as well as the inertia matrix and forces vectors. After that the stiffness matrix is transformed from the local system in to the global system. Calculated matrixes and forces are summed in order to determine the global stiffness matrix. On the basis of these data the displacement of the nodes as well as the stress inside the element and in the nodes can be calculated. [7]. Finite Elements Method covers wide range of features required in order that safety is determined. As it was already stated, thanks to FEM all kinds of impact (i.e. car to car, car to barrier etc. see Fig. 2) as well as the behaviour of the human during the impact (for instance in the pedestrian impact test or behavior of the passengers during crash see Fig. 3) can be simulated.

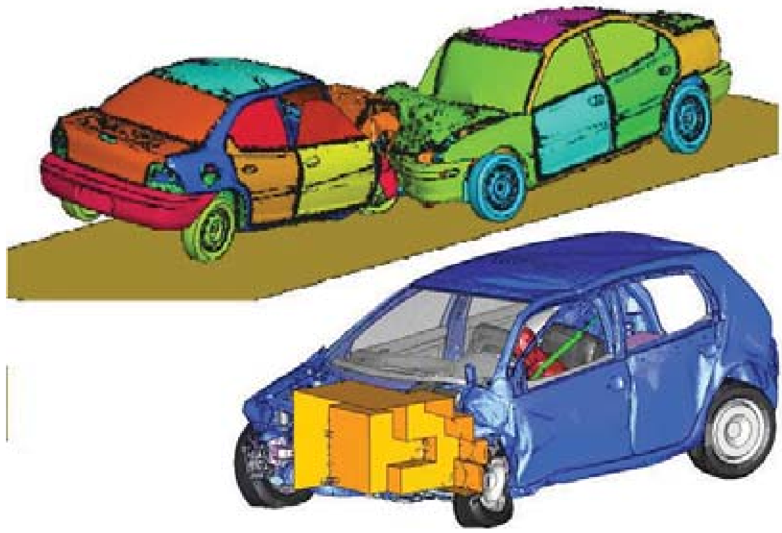

Fig. 2. Pam Crash impact simulation [1, 5]

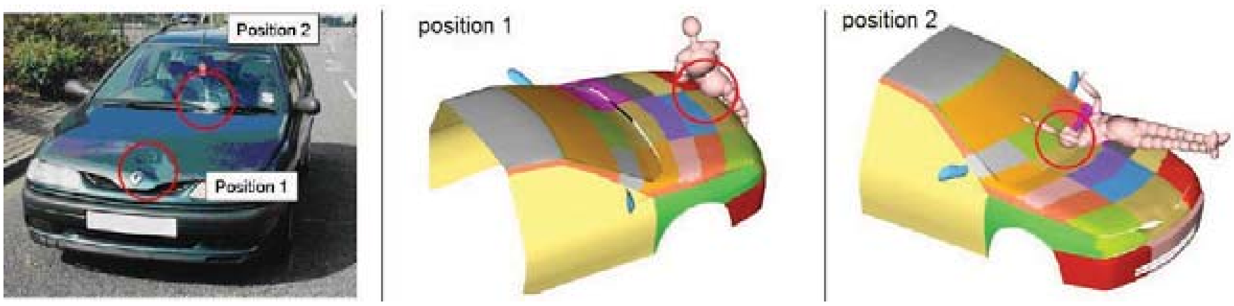

Fig. 3. Pedestrian impact simulation [3]

In the year 2005 the EEVC Group 22nd has been established in order to explore possibilities of testing vehicles by means of computer software. European Economic Commission (EC) has brought up several projects which are in charge of developing the virtual testing in Europe. Improving passive safety of the vehicle is carried out according to VITES (VIrtual Testing Extended vehicle passive Safety). The improvement of human FE model is coordinated by APROSYS SP5 (Biomechanics), which stands for Advanced Protection Systems and HUMOS (HUman MOdel for Safety) project. In to this project three finite element whole human body models were implemented. Those models were used in order to perform reliable virtual test, in which different types of impact were simulated. On the basis the data provided by the "Cadaver Project" and humans anatomy it is possible to simulate behaviour of the vehicles occupant and thus reduce the risk of life threatening injuries.

Virtual crash testing is commonly performed world wide. The comparison of virtual and real frontal impact test is exhibited in Fig. 4 [2]. The most common software used for this purpose are: Abaqus, Ansys, Nastra, Nisa, Cosmos, Pam- Crash. Those programs are mainly based on CAD design [7], hence transferring model of a car into FE model is very easy. The virtual crash testing (for example NCAP protocol, presented in Fig. 5) due to its repeatability is capable of simulating crash test according to all known norms and provides satisfactory accuracy.

Fig. 4. The comparison of virtual and real frontal impact test [8]

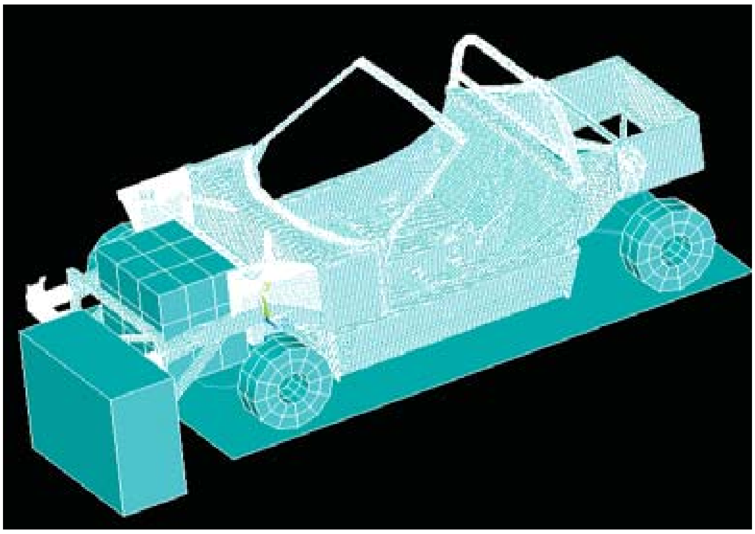

Fig. 5. Final model of the vehicle and the barrier [2]

Virtual testing depends, however, on the calculation power of computer. Unfortunately, computational power provided by the present computers is insufficient in order that the experimental crash tests in completely replaced. Therefore the virtual testing is rather a supplement for the actual crash testing. It is used for instance for determination of the physical phenomena within the material or simulating a selected part of the vehicle during the impact. The overall data are nowadays still obtained by means of the experimental crash test.

3. Cars compatibility

Due to large variability of cars design, it is impossible to take into account the crash accidents of all the models. Obviously, the design of the cars can not be changed in the direction of the unification. The stringer is mainly responsible for ensuring the safety during the impact by accumulating impact energy. However, as it can be seen in Fig. 6 the stringer is placed in different highs. Installing a bigger bumper does not improve the cars crashworthiness due to the fact that, bumpers produced nowadays, are only capable of restraining impact with maximum speed of 10 km/h [10].

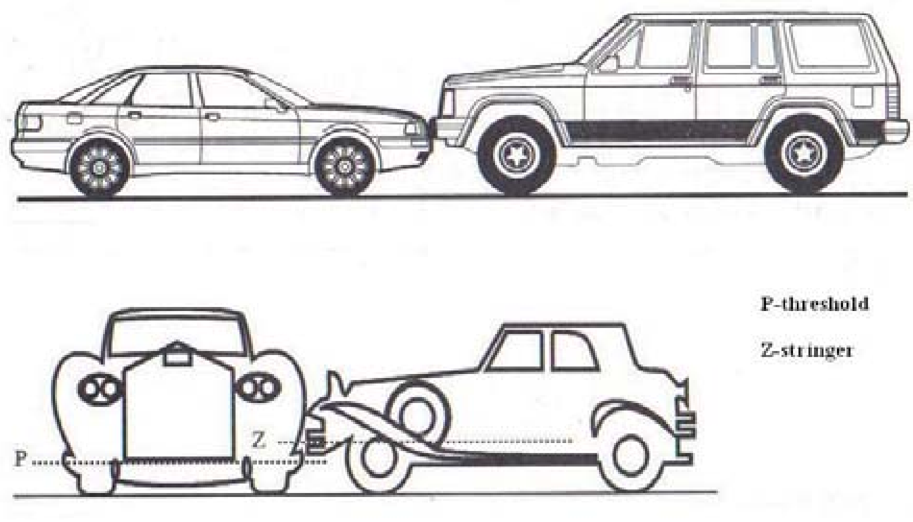

Fig. 6. Cars incompatibility [10]

The law of compatibility

During the frontal crash of the cars, moving with the relative velocity smaller then double value of the “design velocity” (*The design speed is defined as a maximum speed which will not cause the passengers compartment intrusion.*) whole impact energy will be accumulated by fronts of the cars and consequently passengers compartment intrusion will not occur. Another words, if the velocity of the cars, with different masses, which crashed against the rigid barrier is twice bigger then the relative velocities of the same cars impacting each other then whole impact energy will be accumulated by front of the car and consequently the passenger compartment will not be intruded. This phenomenon is commonly called the law of compatibility [10]

Large truck’s passive safety devices

The lack of compatibility is a significant problem in case of the large truck - motor car impact. It is obvious that trucks stringers are placed higher than in case of a motor car. It is extremely dangerous since much smaller and lighter car simply goes underneath the truck and the stringers will not accumulate the impact energy. Moreover, in caste of frontal impact a car can hit the oil sump, engine bearer etc. Friction, which occurs during the sliding of truck’s and car’s surfaces produce high temperature, hence the accident is even more dangerous. In order to reduce a possibility of the fatal accident the trucks are equipped with front and rear bumpers installed at this approximately the same height as in motor cars. Those bumpers are shown in Fig. 7. Unfortunately, such a design is incapable of accumulating much energy due to its short deformation zone. Most of impact energy has to be dissipated by means of a single car deformation zone while in the case of a car to car impact the energy is dissipated by means of deformation zones of two cars involved in the crash. Taking the rear bumper into consideration (Fig. 7 (2)) it is necessarily to point out that such design is able of accumulating greater amount of impact energy in comparison with the front bumper (Fig. 7 (1)). The rear bumper will be simply pushed by impacting car towards front of the truck and consequently the impact speed will be decreased. Of course, rear bumper has to be blocked after some distance in order to prevent car sliding underneath the trailer. Otherwise this kind of accident in the case of high speed can cause decapitation of the occupant.

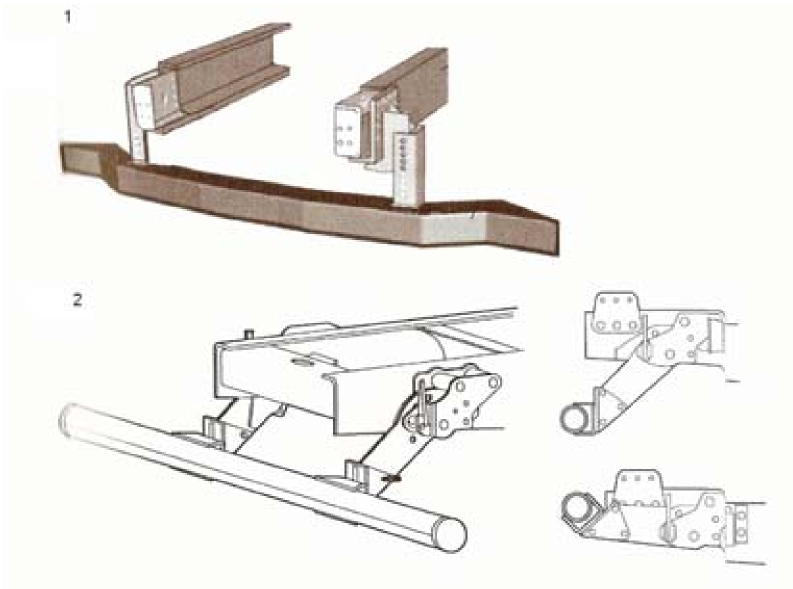

Fig. 7. Truck bumpers. 1 - front bumper, 2 - rear bumper [10]

4. The "active bumper"

Passive safety devices installation is nowadays obligatory for any kind of vehicles. Most of common vehicles are equipped in such systems for instance ACC (*Adaptive Cruise Control*) which alerts the driver in case of an approaching obstacle or ESP (*Electronic Stability Program)* which prevents vehicle form sliding sidewise, ABS (*Anti-Lock Braking System*) which decreases the braking distance, ASR (*Acceleration Slip Regulation*) which prevents a vehicle's wheels from slipping while starting etc. The last mentioned system is especially important in terms of truck tractor with a trailer where slipping is very dangerous due to the fact that it can cause breaking the connection and in consequence roll over. Another, new solution which improves passive safety could be the "active bumper".

As it was already pointed out, trucks do not have great deformation zone. Truck – car impact is equivalent to the car – rigid wall impact. The active bumper is designed in order to "extend" truck's deformation zone with almost not noticeable change of the appearance.

The active bumper working principia

A regular bumper is installed on the actuators mounted to the stringers. Truck is equipped in a radar and laser range-finder which is responsible for detecting the approaching car. Based on the truck and the car's speed computer will determine the relative velocity. As soon as relative velocity exceeds the velocity established as a boundary line the pyrotechnic explosion initiated inside, the actuators cylinder will throw the bumper to some distance in front of the truck. When the desired distance is reached the servo valves will lock in order to ensure accumulating the impact energy. When the impact energy is capable of forcing the pistons all the way back, the energy will be intercepted by stringers. So the active bumper is an extension of the deformation zone. It is crucial to eject the "active bumper" in the right time. When vehicles are too, close the bumper will not be shot out due to the fact that it can simply "punch" approaching motor car. It is obvious that such a scenario would escalate the danger of life threading injuries. Assuming that two cars are travelling with speed of 60 km/h "active bumper" has to be fixed in position ready to take the impact when the cars are 15 m away form each other. The "active bumper" will be independent form the driver. It will be triggered by means of an impulse send by computer when established boundary condition is bridged. Thanks to this solution driver will not be disturbed by any kind of an acoustic alert. Moreover the system's independence will reduce involved ejection time.

5. Conclusions

The passive safety devices are necessary to reduce danger as well as provide passengers with maximum possible comfort what but a way also improves safety. However, most of passive systems used nowadays are mostly aimed at alerting driver by means of different kind of sounds. The reaction is mainly dependent on a driver's reflex. In case of the "active bumper" the responsibility of deciding form deciding whether the bumper should be ejected or not is taken from the driver due to the short time required to place the bumper in to a right position. Stressed driver will not be able to trigger the system in time. Moreover, thanks to mentioned design the deformation zone will be extended and the stiffness control carried out by means servo valves, which can release appropriate amount of gas from actuators, will be possible.

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