THE IMPACT OF THE CONSTRUCTIVE PARAMETERS OF THE BUMPER OVER THE CONSEQUENCES DERIVING FROM THE PROCESS OF COLLISION

M. Sc. Gjakovski I.[1]; M. Sc. Shareska-Gjakovska V.[2]; Ph.D. Brkovski D.[3] M.Sc. Milev S.[4]
UNIQA Macedonia AD[1], Standardization Institute of the Republic of Macedonia[2], RZ Inter-transsped AD Skopje[3] Macedonia, Faculty of Mechanical Engineering - Goce Delcev University in Stip [4], Macedonia
E-mail: ivan_gjakovski@yahoo.com, shareska.violeta@yahoo.com, dean_brkovski@intertranssped.com.mk, sasko.milev@ugd.edu.mk;

Abstract: *With the analysis and synthesis of the process of crashing, the impact of every factor is estimated in the generation and the development of the accident, and conclusions are drawn regarding the impact of particular elements from the vehicle over the consequences from the accident.*
The bumper system is a component of the vehicle intended to reduce the effects of the bumps on the front and the rear of the vehicle, its components and the shell. The cost of the damage and the protection regarding the bumper are the main criteria used to evaluate the efficiency of the impact of the bumper system, especially at low impact velocity.
This paper is representing the results of a deducted analysis and an investigation of the influence of the bumper system alongside its constructive parameters to the extent of the damage in low impact velocity. The investigation is primarily relating to statistical analysis of average damage, overall weighted average damage and variations in the amount of damage.
KEYWORDS*:* bumper system, accident damage, overall weighted average damage.

1. Introduction

The automotive industry has been known to be very competitive as far as its design and material usage are concerned. The automotive industry always faces greater market pressure to develop high quality products more quickly at lower costs, reduce weight in order to improve fuel efficiency and costs. One of the many purposes of the traffic jam safety measures is a construction of a safe vehicle which regarding its functions is supposed to represent the least influencing factor in the generation of causes that lead to creating detrimental consequences over all participants in the traffic jam and its environment, and, at the same time, in case an accident has occurred, to reduce or to completely baffle all possible consequences. The vehicle, regarding its constructive-technical and exploitative assets, the maintenance during the exploitation and the method of commandeering in traffic is one of the most important factors regarding safety. Starting from this particular definition regarding a vehicles safety in traffic, a broad space for investigation of all parameters is unclogged, which through the stage of projecting will lead to increase in the total value of safety regarding vehicles.

Systematizing the characteristics of the safety of the vehicle according to its specifics, they can be divided into three categories:
- Characteristics of active safety, which include all parameters that have an impact on the possibility of occurrence of an accident;
- Characteristics of passive safety, which include the parameters that have a preventive impact over the consequences of the accident; when the vehicle is partaking in an accident, the construction of the vehicle and the construction of its parts and units and their setting, to enable minimal or no injuries to the passengers in the vehicles and the incoming pedestrians, and also minimize the material damage of the vehicles, participants in the accident, the road and the environment.

- Characteristics of a catalytic safety, which include the parameters which indirectly contribute to the occurrence of the accident or increment the consequences of that accident.

The characteristics of the passive safety refer to all of the parts, units and elements which affect the consequences of the prompted accident in any way. The process of crashing is complex and dependent on various factors and their correlation. The subject of investigation in this paper is confirmation of the contribution of the bumper, with its constructive parameters to the consequences of the crash where the participants are moving with low speed. Through analysis of series of experimental crashes carried out in controlled conditions, certain conclusions will be drawn concerning the estimate of the safety capabilities of the vehicle regarding its bumpers.

There are two significant aspects of the impact of the vehicle on the aftereffects of the accident regarding the bumper:
- The impact over the size of the injuries on a pedestrian regarding the incursion of the vehicle with the pedestrians.
- The impact over the size of the damage of the vehicles participants in the accident.

The main target of this paper is expansion and deepening the knowledge about the impact of the bumper with its constructive characteristics on the damage of the vehicle low impact velocity.

2. The role of the bumper in the safety capacities of the vehicle

The automobile bumper is a structural component of a vehicle that contributes to the improvement of the total asperity of the vehicle and its protection at front or rear impact. The bumper, firstly and mostly is intended to protect the body, the headlights or the stoplights, the indicators, the hood, the coolers and the other safety-bounded components of the vehicles in a low impact velocity.

But of course, the most important factor that affects the outcome of the accident is the impact velocity. The size of the damage of the vehicles is proportional to the impact velocity of the vehicles that partake in the accident. At higher impact velocities their impact over the damage of the vehicles is primary and dominant and the impact of the vehicle with its constructive characteristics and in that context also the bumper, is secondary. At low impact velocities of the vehicles the impact of the construction of the vehicles over the aftereffects of the accident is significant.

In 2002 IIHS conducted a research in traffic accidents in five big cities, recorded in their native departments for estimation of damage of the insurance companies. One of the conclusions of this study was that 14% of the accidents in the urban areas were impact with low impact velocities.

The bumper system is generally composed of four main elements: bumper cover, absorber, bumper carrier and holders, which are used for attachment with the body (the shell) of the vehicle.

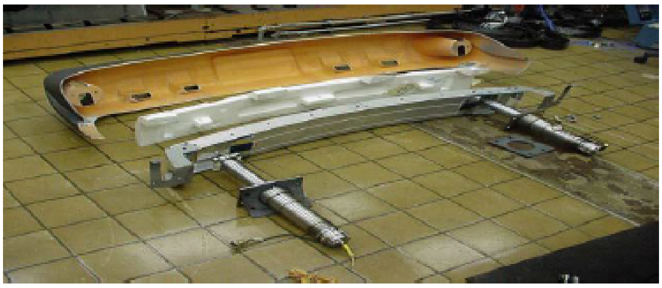

Figure 1: *The main components that constitute the bumper system and their relation [2]*

The leading restricting constructive factor for the bumper system regarding the construction of the entire vehicle is its volume. The bumper cover for the most part has a design function while its function regarding the vehicle's safety is minor. Because of that, and in order to achieve low production costs, this element at today's modern vehicles is only fabricated out of plastic: polystyrene, polycarbonate or acrylonitrile butadiene styrene. The carrier is the most significant element of the bumper system which protects the vehicle against frontal impacts and rear impacts. The carrier is manufactured out of steel sheet, aluminum, fiberglass, composite material or plastic. Commonly, an element which absorbs the energy from the crash is set between the carrier and the cover. Unlike the carriers, the absorbers are made out of low density materials. The bumper system is attached to the shell of the vehicles via holders through a rigid frame or via elastic framework as the newer constructive solutions suggest, using special mechanisms so-called shock absorbers, which have additional meaning, to absorb a part of the kinetic energy of the crash.

The geometry, stability and the capability to absorb energy from the crash are the key qualities of a good bumper system. Its width and length and the vehicle's height position, its capability to prevail the integrity, form and position before and after a low impact collision. The bumper also has to be constructed in a way to be manageably mending, easy and by low costs, after a collision at low speed of the vehicles.

There are various concepts used while projecting the bumpers, even for same class vehicles or models from the same manufacturer. The bumper system is a compromise of its design, its capability to bsorb a part of the energy of the crash and its manufacturing costs. Some manufacturers pay special attention to the style and the visual effect on the account of the safety possibilities of the bumper which results in high damage costs in collision at low speed of the vehicles.
By analyzing the behavior of the bumpers, in the implementation of a controlled series of collisions, a relevant conclusion can be drawn that today's modern bumpers are not improved with safety features in relation to bumpers in older vehicles.

3. Regulatory normative regarding the vehicle bumpers

The need for reaching a certain level of standardized quality of the bumpers sets the necessity for establishing a certain regulative in this area.

ECE Regulation No 42, adopted by the United Nations Economic Commission for Europe, requires the vehicle's safety system to continue to operate normally after the front or rear of the vehicle is under the influence of a pendulum set at 455 mm above the ground, loaded or unloaded at speed from 4 km per hour, along the entire length, i.e. 2.5 km per hour when operating in the corner on the bumper.

49 CFR part 581, American standard, prescribes requirements regarding the vehicles performance in a collision, front or rear, at low speed. The requirements apply to both the front and rear bumper of the vehicle, with a demand to prevent damage to the body and other equipment when hitting a barrier at a speed of 2 miles per hour along the entire length of the bumper i.e. 1miles per hour in a hit of the corner on the bumper.

Canadian regulation is very similar to the American. Also, this area is subject of regulation from the norms, the rulebooks of many scientific organizations, but not the NCAP programs for assessing the safety capabilities of the vehicle.

4. Realization of an engineering experiment. Discussion.

In this paper, by using statistical methods, the dependence of the height of the damage to the vehicle on the characteristics of the bumper system is analyzed and assessed, in the event of a low-speed collision, that is, the subject of statistical analysis are the results obtained from a series of experimental collisions in controlled conditions, realized by IIHS [3], according to the Bumper Test Protocol (Version VIII, September 2010) [4]. In this case, four types of impacts of the vehicle in a stationary obstacle are analyzed, which is simulating a bumper of another vehicle at rest: impact with front bumper, corner impact with front bumper, impact with rear bumper and corner impact with rear bumper.

Figure 2: *Impact with front bumper; corner impact with front bumper;* impact with rear bumper*; corner impact with rear bumper*

The analyzed vehicles are classified into the following four groups: mini urban vehicles, small urban vehicles, medium-sized vehicles and limousines.

The subject of calculation and analysis is the average level of damage segmented by vehicle groups and impact type, overall weighted average damage (OWAD), level of variation and source of variations. In order for the measured sample to be considered relevant for further processing and withdrawing valid conclusions, it is necessary to be made a revision in the case of existence of rough errors and their elimination and to check out the fulfillment of the conditions of normality and homogeneity of the measured sample. For the four groups of vehicles, or their database, using the Grabs test, a conclusion can be drawn as the absence of a rough error. The high values of the p - indicator, significantly larger than the adopted level of risk of 5%, confirm the basic hypothesis that the data in the analyzed bases of the four groups of vehicles, follow the regularity of normal distribution.

TABLE 1: *Average costs of damage from the performance of experimental crashes for the four groups of vehicles.*

From the display it is obvious that the average costs for the calculated damage of the vehicles for the front impact are significantly higher in relation to rear impact whether it is a full or corner impact. Considering the configuration of the vehicle, the greater compactness in the rear as well as the existence of essential parts in the front of the vehicle, this conclusion is completely understandable. To see the level of variation, we will analyze the characteristic sizes of the normal distribution of the so-called overall weighted average damage (OWAD). OWAD is calculated when the amount of damage from the front and rear full impact is multiplied by two, and then collected with the amounts of damage to the corner front and rear impact. The amount thus obtained is divided by six and the value of the OWAD is obtained.

Group of vehicles	FULL IMPACT		CORNER IMPACT	
	Front ($)	Rear ($)	Front ($)	Rear ($)
Mini urban vehicles	2.119	1.388	2.161	706
Small urban vehicles	2.553	1.308	1.505	888
Medium-sized vehicles	2.244	1.455	1.938	1.193
Limousines	3.421	1.657	2.614	1.055

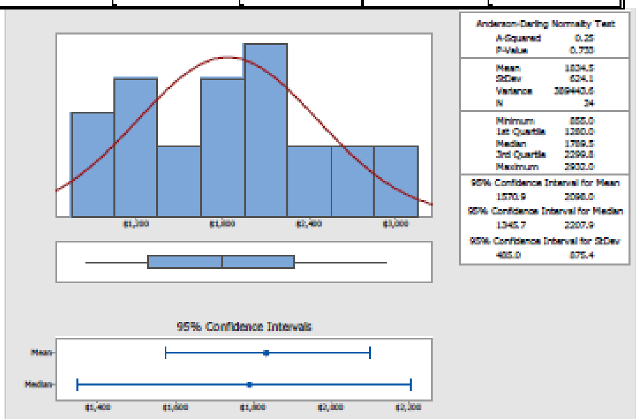

Figure 3: *Diagram of probable distribution of* OWAD *for the group of medium-sized vehicles.*

Although the number of motor vehicles that were the subject of this analysis differed significantly in each of the four groups, the obtained results show a high degree of coincidence. The height of the OWAD (table 2) ranges from $ 1,718 in the group of small urban vehicles up to $ 2,463 for the limousine group.

What is particularly noticeable are the huge coefficients of variation in the height of the OWAD, ranging from 32% to 36%. What is the reason for such variations in the level of damage in the groups?

TABLE 2: *Values of the characteristic sizes in the analysis of the* OWAD *values for the four groups of vehicles.*

Group of vehicles	No. of vehicles in the group	Average OWAD ($)	Standard Deviation ($)	Coefficient of variation (%)
Mini urban vehicles	7	1.776	609	34 %
Small urban vehicles	21	1.718	558	32 %
Medium-sized vehicles	24	1.834	624	34 %
Limousines	11	2.463	884	36 %

Since it is about analysis of the results of destructive tests, the ANOVA method is used to determine the contribution of both factors: the type of vehicle and the impact side (front or rear) on the total variations in the group. In doing so, we must start with the hypothesis for the homogeneity of the examined series of samples, that is, all the samples in the examined series are sufficiently identical for us to be able to consider that we operate with the same types.

From Table 3, it can be seen that the influence of the vehicle on the OWAD of the vehicle type with its structural features and in this context on the bumpers, is significantly greater in relation to the impact side – front or rear. This influence is stronger in full, compared to corner impacts, i.e. at vehicles with larger mass and dimensions compared to vehicles with smaller dimensions and mass.

TABLE 3: *Determining the contribution of the type of the analyzed vehicle and the impact side on OWAD*

Group of vehicles	FRONT OR REAR FULL IMPACT		FRONT OR REAR CORNER IMPACT	
	% Influence of vehicle type	% Influence of impact side	% Influence of vehicle type	% Influence of impact side
Mini urban vehicles	70%	30%	54%	46%
Small urban vehicles	70%	30%	54%	46%
Medium-sized vehicles	100%	0%	80%	20%
Limousines	95%	5%	73%	27%

5. Conclusion

Thanks to the results of the experimental impacts published by the IIHS, potential buyers are able to obtain adequate information about the amount of damage to vehicles at impacts conducted under controlled conditions. It is a motive for vehicle manufacturers to work on improving the performance of bumpers at vehicles, in order to reduce the consequences of a traffic accident at low speeds of the vehicles.

Today's modern vehicles do not have bumpers with better impact resistance compared to older models. In support of this conclusion is the fact that the OWAD for all four groups of analyzed vehicles are higher than $ 1,500, the boundary for poor and unacceptable quality of the bumper, according to the criteria established by IIHS. At the same time, the high level of variations in the OWAD in the realized experiment also speaks of the great possibilities for making improvements of the bumper system regarding the safety measures, starting from the design process and construction, selection of material, up to its testing.

Finally, the experiment and its results, as well as the requirements of customers for bumpers with an increased level of impact resistance, impose the question of the expediency of a more rigorous legal standardization of the quality of the bumper system.

6. Literature

[1] Danev Dragi – Construction of motor vehicles, University St. Cyril and Methodius, Skopje, Faculty of mechanical engineering, Skopje, 2000

[2] J.T.Wang – An extendable and retractable bumper, General Motor Corporation United States, Paper No. 05-0144 ,

[3] http://www.iihs.org/iihs/ratings/bumpers?classType=Midsize%20moderately%20priced%20cars

[4] Insurance Institute for Highway Safety – Bumper Test and Rating Protocol, Version VIII, September 2010,