ANALYSIS OF GEOMETRIC VARIABLES OF THE FRONT OF
THE VEHICLE IN THE PEDESTRIAN PROTECTION

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ABSTRACT
Pedestrian protection is one of the main research fields inside the automotive safety and one of the main pillars of innovation in the automotive industry. Data accident shows that each year died 6000 people in Europe as a consequence of a traffic accident. The lower extremities are represented by the lower legform impactor in the laboratory tests. The lower legform that is being used nowadays is the one of the TRL. The magnitudes that it measures and the biomechanics limits are:
- Acceleration; with 150 g as a limit value.
- Knee bending angle; angle between tibia and femur, with 15º as a limit value.
- Shear displacement; gap between tibia and femur, with +/- 6 mm as a limit value.

The main target of this research project is to obtain a simplified model to analyse and to predict the behaviour of the front of the vehicle in the lower legform pedestrian protection.
The parametric model has been done thinking into account 2 main aspects:
- The possibility to maintain the contact points between the front of the vehicle and the lower legform impactor, basic to determine the dynamics of the impactor.
- The possibility to change the geometric configuration of the parts of the front of the vehicle, to see how the influence is when introducing changes in the original configuration.

First results show that this simplified model correlates with the original one; so this simplified model can be used to predict the results of the vehicle in pedestrian protection. In this research project, the variables which have been analyzed are mainly:
- The longitudinal gap between the main crossbeam and the pedestrian crossbeam.
- The vertical gap between the main crossbeam and the pedestrian crossbeam.
- The longitudinal gap between the main crossbeam and the skin of the front.
- The vertical position of the whole front compared to the legform.
- The speed of the impact.
- The material of the non-metallic components of the front.

The results found in the creation of this model with the relations of the geometric variables of the front of the car indicate that there is a relation between the increasing of the high of the car and the increasing acceleration and knee bending in the lower legform impactor and when there is a decreasing high of the front there is an increasing shear displacement in the lower legform impactor.
Moreover, when the longitudinal gap between the main crossbeam and the pedestrian crossbeam increases in a positive way, the knee bending and the acceleration increase and when the gap increases in a negative way, the shear displacement increases.

1. INTRODUCTION

Pedestrian protection is one of the main research fields inside the automotive safety and one of the main pillars of innovation in the automotive industry. Data accident shows that each year died 6000 people in Europe as a consequence of a traffic accident. If we have a look inside Spain, each year there are more than 600 people died and in the cities, the 40% of traffic accidents victims are pedestrian.

OEMs are developing new solutions to avoid injuries in pedestrian crashes, improving the front of the vehicle and the compatibility with the pedestrian in the field of passive safety. But another research line is to detect the pedestrian and avoid the contact between the car and the pedestrian inside the field of active safety.

EuroNCAP has modified recently the final score rate, giving to the pedestrian protection tests an increasing value. The three tests that nowadays are done are related to the three following anatomic zones in the body: lower extremities, related to the lower legform impactor, femur and pelvis, related to the upper legform impactor, and the adult or child head, related to the headform impactor. In the latest years, the total score follows an increasing line and some vehicles achieved the maximum stars possible.

The lower legform that is being used nowadays is the one of the TRL. The magnitudes that it measures and the biomechanics limits are:
- Vertical acceleration, with 150 g as a limit value.
- Knee bending angle, measuring the angle between tibia and femur, with 15° as a limit value.
- Shear displacement, measuring the gap between tibia and femur, with +/- 6 mm as a limit value.

But another new impactor appeared in the latest years to compile more information in the test. The Flex-PLI impactor has summed to the TRL one, and it has a major number of sensors and information. Nowadays, the correlation between both impactors is something to be done and studied.

Simulation tools in the pedestrian protection field are becoming a basic point of study when the vehicle is designed. Three kinds of software are used nowadays:
- Finite element software.
- Multi-body software.
- Accident reconstruction software.

2. STATE OF THE ART

The shape of the front of the vehicles is including new changes everyday. While some years ago the most important thing to take into account was aerodynamics, nowadays pedestrian protection concepts are considered from the first design and in all development process as the same level than aerodynamics. In the Figure 1, this evolution is shown in the design of the models of the same OEM.
3. REFERENCE MODEL

It is necessary to build a model of the front part of the vehicle to study the level of pedestrian protection that the car has. The parts included in the extern skin of this front zone and the parts that give the stiffness are needed in the model. The minimum parts needed to have a representative model inside the pedestrian protection field and to study the behaviour of the lower legform are the following:

- Extern skin that determines the shape of the assembly and the possible contact points.
- Skin reinforcement that gives stiffness at the crossbeam’s zone and joins the lower and the upper ventilation grilles of the bumper.
- Spoiler.
- Pedestrian crossbeam.
- Lower and the upper ventilation grilles.
- Deformation crossbeam.

In the Figure 2 it is shown a possible model reference of a vehicle.

But if the front shape of the vehicle is analysed, the conclusion that the main contacts between the skin and the lower extremities are in three different points can be achieved. These three points are:

- Contact with the lower extremity (knee zone) and the bumper crossbeam zone.
- Contact with the lower extremity (tibia lower zone) and the spoiler zone and the pedestrian crossbeam.
- Contact with the lower extremity (femur upper zone) and the crossbeam zone and the bonnet lock.

This reference model is created to analyse the behaviour of the geometric variables and its influence in the results achieved by the impactor. But, before beginning with the simulations, a correlation must be done between the simulation and the real models.
The results obtained by the simulation model show that there is a high correlation level with the real model. The results obtained in the same configuration of the front of the vehicle are shown in the Figure 3.

Figure 3. Comparison between the results of the simulation model and the real model.
4. RESULTS AND DISCUSSION

Most important variable analyzed are:
- Longitudinal gap between the crossbeam and the pedestrian crossbeam.
- Vertical gap between the crossbeam and the pedestrian crossbeam, always with the crossbeam remaining in the same initial position.
- Whole height of the front of the vehicle.

4.1. ANALYSING THE LONGITUDINAL GAP BETWEEN THE CROSSBEAM AND THE PEDESTRIAN CROSSBEAM.

Most important results and conclusions achieved are:
- When the longitudinal gap between both crossbeams increases positively, the maximum acceleration and the average acceleration in the whole impact decrease.
- Kinematics and dynamics of the impactor show that a positive increase of the longitudinal gap involves better energy absorption of the front.

4.2. VERTICAL GAP BETWEEN THE CROSSBEAM AND THE PEDESTRIAN CROSSBEAM.

It must be taken into account that when designing and defining the different simulation configuration, the crossbeam is always remaining in the same initial position, and it is the pedestrian crossbeam the component which is displaced.
- There is no a big difference in the results when changing the vertical gap between crossbeams. The nowadays impactor (TRL) doesn’t give enough information to understand the influence when changing the contact point in the lower contact between the impactor and the front of the vehicle, with the pedestrian crossbeam.

4.3. WHOLE HEIGHT OF THE FRONT OF THE VEHICLE.

The height of the front of the vehicle is one of the most important variables to take into account when analysing pedestrian protection in the lower legform context. Most important results are:
- When the height of the front of the vehicle increases, the rotation of the lower legform decreases and the acceleration values increase.
- The evolution of the bending angle value is analogue to the one detected in the acceleration values.
- But, the share displacement presents the maximum values when the contact point with the crossbeam is close to the knee.

The evolution of the results has been compared with the results obtained in crash tests laboratory. The relation between the behaviour found with the simulation model and the one obtained after analysing the real tests shows that the difference between them is less than a 5%, and so, the possibility to obtain and setup a virtual front model of the car can be achieved.
5. CONCLUSIONS

The global conclusion achieved in this research is that it is possible to obtain a simplified model of the front of the car to study the evolution of the behaviour when impacting with the lower extremities of a pedestrian, taking into account the different configurations of the front of the car.

The main geometric variables analyzed in this first step of the research are the X gap and the Z gap between the crossbeam and the pedestrian crossbeam and the height of the front of the vehicle. The Z gap is non-representative because of the nowadays instrumentation of the impactor is not enough to determine the influence of changing the contact points with the car.

This simplified model could represent a basic tool to empower and to improve lower extremities pedestrian safety.

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