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State of the art on pedestrian safety simulation

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Analysis and modelling

ABSTRACT

Purpose: The aim of this work is to explain the work of Design Methods' research group of Department of Mechanical Engineering of Salerno University, in the field of research regarding vehicles pedestrian safety problem, taking care to finite element methods and models used and developed for vehicle design and optimization.
Design/methodology/approach: Our developed models show a very good Numeric/Experimental correlation, and we've numerically certified our virtual impactors, designed following EEVC-WG17 specification. These impactors have been tested also at higher speed and we have obtained a good correlation with some problems because of the critical behavior of the foam solved following different model-design optimization methods.
Findings: Best results obtained and explained in this paper are concerning impactors modeling and certification, and Experimental/Numerical correlation of full impact tests.
Research limitations/implications: The achievement of the maximum possible pedestrian safety performance, compatibly with the others, sometimes conflicting, performances, is one of the main objectives to reach, for the automotive industry by now and, above all, for the future.
Practical implications: According to a surveying by European Community research committee, the risk of die for pedestrians and cyclists because of street incidents is eight/nine times higher than one of the occupants of motor vehicles. From statistics we've found that the greatest part of these accidents is due to the collision of the pedestrian on the front part of motor vehicles, and that fact affects the considerations on the passive safety.
Originality/value: The most Important Automotive industries had understood the impact of new regulations about homologation and began to study the problem and particularly how to introduce new Homologation parameters in their Product development cycles, today based on Virtual Prototyping of the Whole Vehicle and final Physical testing of few physical prototypes.
Keywords: Impactors' modelling; Simulation methodology; Design methodology; Pedestrian safety

1. Introduction

The most Important Automotive industries had understood the impact of new regulations about homologation and began to study the problem and particularly how to introduce new Homologation parameters in their Product development cycles, today based on Virtual Prototyping of the Whole Vehicle and final Physical testing of few physical prototypes.

The achievement of the maximum possible pedestrian safety performance, compatibly with the others, sometimes conflicting, performances, is one of the main objectives to reach, for the automotive industry by now and, above all, for the future.

Statistic studies carried out in the last decades have underlined how pedestrians, prevalently children and elderly men, are a high risk category in the car accidents, in particular in the urban areas: according to a surveying by European Community research committee (CEC 2001), the risk of death for pedestrians and cyclists because of street incidents is 8, 9 times as high as one of the occupants the motor vehicle.

In particular, in the European Union each year about the 20% of the dead in car accidents were pedestrians (EEVC, European

Enhanced Vehicle-safety Committee, "Improved test methods to evaluate pedestrian protection afforded by passenger cars", 1998; ETSC, European Transport Safety Council, "Safety of Pedestrian ad Cyclists in Urban Areas", 1999). In the world this percentage varies from 14% in US (NTSHA1, "Traffic safety facts 1994", 1995) to 47% in Thailand (D. Mohan, J. Kajzer, K. Bawa Bhalla, S. Chawla, S.Sarabjit, Conference on the biomechanic of the impact, 1995).

From statistics one finds that the greatest part of these incidents is caused by collision of the pedestrian with the front part of motor vehicles, and this fact heavily influenced considerations about pedestrian passive safety: the reaction to this problem has caused a detailed research study by specific Working Groups of the EEVC, focused on characteristics of vehicle front part design.

After all EEVC studies, in order to evaluate pedestrian damage, caused by a motor vehicle, scientists proposed three kinds of impactors, for different tests:

- Legform on bumper: to simulate the leg impact on bumper
- Upper-legform on bonnet and on bumper: to simulate the pelvis impact on bonnet/bumper.
- Headform on bonnet: to simulate the head impact on bonnet.

The F.E.M. software is used for the tests simulation, in order to reduce costs and times necessary to the pedestrian tests realization. The initial steps involved F.E.M. models definition, in order to reproduce elements that play fundamental role in the phenomenon: impactors and cars.

The aim of this work is to try to determine the state-of-the-art of the work of Design Methods' research group of Dept. of Mechanical Engineering of Salerno University, in the field of research regarding vehicles pedestrian safety problem.

2. Description of work methodology

This work consists in trying to determine the state-of-the-art regarding vehicles design, within pedestrian safety environment, taking care to finite element methods (FEM) and models used for vehicle study and development.

The full part of our information comes from our research group in industrial design of the Dept. of Mechanical Engineering, University of Salerno, which for five years has developed researches about pedestrian safety. Our principal results are reported below.

3. State-of-the-art about the passive pedestrian safety

3.1. General remarks

In this section there is the description of the most important our (research group in industrial design of the Dept. of Mechanical Engineering, University of Salerno) results presented in several paper and conference.

Below we report the our research results, organized by topics divided in impactors' modelling, simulation methodology and design methodology.

3.2. Impactors' modelling

The Salerno University research group has found out that a statistical approach, based on the variance analysis, allows appraising the influence of the foam CF-45, that cover ACEA/NCAP leg impactors, on the results of the tests required for the safety of the pedestrians in case of accident [1-2].

Figs. 1 and 2 show elaborated results and corresponding variance.

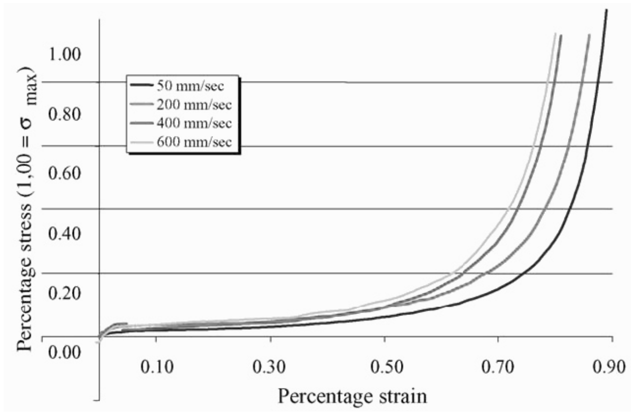

Fig. 1. Foam tests results

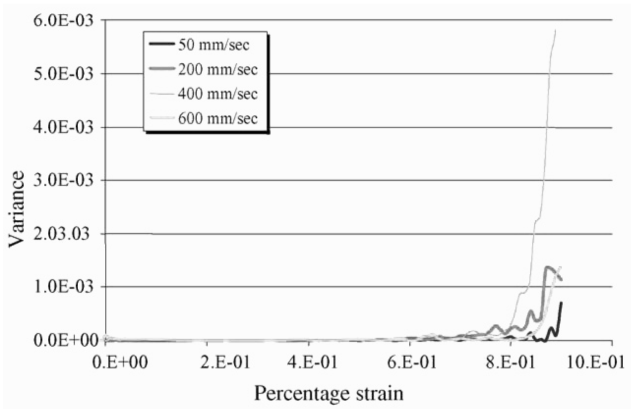

Fig. 2. Variance vs. deformation

The selected values of deformation define the necessary groups for the analysis of the tension. They are selected realizing a kind of blocking, operation that will also have repeated for the other types of test-tubes, and that drift from an attentive observation of the experimental curves. In effects, it is clear that a statistical analysis in general and especially a variance analysis is so much more necessary and somehow interesting as better it is the disorder between the curves, and consequently, between the points of deformation. For this reason we have defined the points of deformation with a bigger density in the final part of the curve, where the dispersion increase of the points of the corresponding curves to a date abscissa.

Once gotten the groups of the values of tension, a variance analysis is performed in the groups for which the experiment is relative to a not-varied ANOVA, as the term is unique and it is represented by different levels of speed and with a determined number of observations for each deformation.

If we analyse for example some kinds of foam, we note that they present a very complex structure, and we realize that it is difficult to develop a physical model, and even more difficult to build a numerical model representing the tested foam [3].

Results more in harmony with the reality could get with statistic or fuzzy methodologies, or with methodologies, however, derived from the theory of the information, that allows the best use of the information drawn from the experimental proofs or from the theoretical models that our potentiality allows us to develop [4–5].

This testing methodology, that represent a very particular case because of his realization by an hydraulic back controlled facility for achieving a constant strain rate during tests, have given results easily to use in Explicit FEM codes, and allowed a very good numerical/experimental correlation using simple numerical and simple FEM model.

We have to do the same tests with higher strain rate (i.e. higher controlled compression velocity) in order to achieve good results in simulation at higher compression velocity (crash velocity, 10 m/s); we've to use the modified Hopkinson Bar, in order to achieve this results.

3.3. Simulation methodology

The Lower-leg Impactor in PamCrash environment has been simulated, using the ESI formulation of the Knee that uses two kinematic joints with the same properties of the human knee joint.

The Numeric/Experimental correlation is not so good because of the critical behaviour of the kinematic joints in PamCrash when the forces are not perpendicular in respect to the leg axis.

For this reason, our research group have modelled a new very complicated kinematic joint not using the definition of PamCrash but simulating the complete mechanical behaviour of TRL impactor's knee joint, in order to obtain a good correlation.

We have also calibrated the stiffness and the viscosity of real joint using the characterisation made for ESI impactors.

After this work of modelling the Impactor was tested by the simulation of the Certification Test in order to obtain the same results of the experimental test (2003) [6].

The attention on Child Head impact phenomena (the high priority impact both for WG17 and for ACEA protocol) and on the factors that affect the increase of HIC values has been placed. Other studies had demonstrated that in the middle area of the bonnet the acceleration peak, that heavily affects the value of HIC, strictly depends on "structural" parameters of the bonnet; one of our research group's paper is based on this studies and has reproduced, using numeric simulation, the Child impact dynamic (a very low-energy impact....only 150 Joule), in order to demonstrate the importance of kinetic phenomena despite of the deformation's one.

We have justified the validity of formulated hypothesis by the comparison of impact simulation of ACEA and WG17 test; these protocols are different for impactor mass and impact speed. Child Head impact simulation in accordance with WG17 protocol was made and correlated to physical tests made on a FIAT Punto 60 by TNO (with an average correlation index of ±10%) (2003) [7].

A new impactor has been modelled, in order to respect the indication given by new homologative norms, but especially to make good experimental/numerical correlation in our experiment tests, both for Child and for Adult Head impactors.

The new FEM models have the same number of finite-elements as the oldest one and have a very good stability in calculation, both in certification tests and in experimental test on bonnet.

Our research group, in 2004, has modelled the new certification tests and made the simulation runs, reaching a very good correlation result.

The more important part of the work is the certification of impactors and their testing on a real case of pedestrian impact in order to correlate the experimental test on the vehicle (2004) [8].

Our research group after the work of impactors' modelling (legform and upper legform ones) has tested the Impactor by the simulation of the Certification Tests, as described in the EEVC and EuroNCAP norms, in order to obtain the same results of the experimental test. The Numeric/Experimental correlation is very good and we had numerically certified our impactor.

We have also made several tests, whose experimental results are published, at higher speed and we have obtained some correlation problems because of the critical behaviour of the flesh at high speed simulation but the results on different cases show the same output behaviour, giving us an instrument to solve that problem (2004) [9,10].

3.4. Design methodology

Our research group has developed a research focused essentially on vehicle configuration and on material's characteristics in the predictable impact zone of pedestrian and on the vehicle. The aim was to create, for child head impact, the same condition of first phase of impact, in which local stiffness play the main rule of the game, realizing a test-case by using a CAD-CAE parametric/variational model of car-bonnet [11].

Moreover in another work it was analyzed how energy absorption in head impacts, and therefore HIC value, is influenced by the capability of free deformation of the hood, that depends from the distance of the under bonnet elements – engine parts, battery, suspensions domes, other structural parts – from the bonnet itself, and how to compensate the effects of these elements through its rigidity. Our final purpose consists in determining the optimal combination between these two parameters (bonnet stiffness and free deformation space), in order to reduce the aggressiveness of the car front part in case of pedestrian impact (HIC values possibly under 1000), without excessively penalizing other performances - particularly the containment of volumes, weights and therefore fuel consumptions - that are the most important required performance for a new car [12].

Another research developed by our group proposed a new method based on virtual reconstruction of the surface which envelopes all the deformation surfaces in internal part of the bonnet. The deformed shape of bonnets has been evaluated using FEM explicit code PamCrash. Using a Pre-processor we have reconstructed, starting from a points' (FEM model's nodes) clouds, a new surface of maximum deformed bonnet. This surface was processed and rapid prototyped as a puzzle of shells with their support. This prototyped surface was super-imposed on the real under-bonnet layout of car and will allow to easily evaluate where and how much our deformed bonnet could hit the hard-parts of the Engine Lay-out. Our results have shown a new easy and fast method to evaluate the potential performance of the front part of a vehicle in Child head impact only reconstructing, with a reverse engineering operation, the bonnet shapes (surface) and, after a simple processing, rapid prototyping the deformed bonnet-shape, in order to avoid to take all the under-bonnet layout with a reverse engineering operation, that could be more difficult and very time-consuming [13,14].

4. Conclusions

In this paper we underline the development and certification of pedestrian impactors presented by our research group; actually there are a few of certified impactors' model in few FEM software (Pam Crash, Radioss, LS-Dyna, Madymo) [15].

The most important research results are reported, regarding the finite elements dynamic simulation in passive safety environment. Particularly, impactors modelling and certification are in the first rank, besides studies for improving the vehicle performances within pedestrian safety environment.

The results come from our research group in industrial design of the Dept. of Mechanical Engineering, University of Salerno, which for five years has developed researches about pedestrian safety.

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