FRONT UNDERRUN PROTECTION SYSTEMS FOR TRUCKS. CONSIDERATIONS ABOUT THE BULLET AND TARGET VEHICLES FOR A TEST PROCEDURE

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ABSTRACT

The present paper describes the activities of the INSIA (University Institute for Automobile Research) for the definition of the test procedure for the validation of a Front Underrun Protection System for trucks. After a review of the activities of the EEVC Working Group 14 in this field, the possible configurations of the test are discussed. This includes a proposal for the definition of the target and bullet vehicles to be used in dynamic tests, and a first approximation to the type of parameters to be measured.

BACKGROUND

Truck accidents represent a significant factor in the overall road accident scene. Analysing the European problem (1997), trucks with a gross vehicle weight of more than 3.5 tonnes are involved in around 20 % of the fatal road accidents; and approximately 60 % of these are car to truck accidents. The injury risk in accidents involving heavy vehicles appears to be far greater for occupants of opponent vehicles, specially for cars. And this risk increases in the case of car to truck frontal collisions.

EEVC WG14 started in 1994 a research programme for defining the requirements of energy absorbing front underrun protection systems for truck, and for the development of a test procedure for these devices. The overall objective of the project, consists of developing a test procedure and performance standard for energy – absorbing front underrun protection systems for trucks in order to reduce the injuries to passenger car occupants in frontal collisions. The Spanish partner in this working group is INSIA (University Institute for Automobile Research).

The strategy in selecting a test procedure is to identify tests that have the potential to improve the crash protection provided across a broad range of real-world impact conditions. The crash test conditions, e.g., impact speed, impact angle, test devices and configurations, must be carefully selected to be representative, as much as possible, of the real car to truck crashes.

In March 1995, the Working Group 14 concluded a statistics analysis of accident data involving car-to-truck frontal collisions in most countries of the European Community. The analysis resulted in the definition of typical accident parameters in car-to-truck frontal collisions, and the specification of a representative type of accident. The following typical accident parameters have been chosen:

- Impact speed: 75 kmh
- Overlap: 75 %.
- Collision angle: 0 º.
- Occupants: two occupants in the front seats.

During the EEVC WG14 research programme (starting in September 1995), and for establishing the effect of the Front Underrun Protection Devices (FUPD's) in terms of injury, several car to truck crash tests were carried out:

- A first car to truck crash tests matrix was performed. The truck was fitted with a Rigid Front Underrun Protection Device, and impact speed was about 56 kph.

- In a second car to truck crash tests matrix, the truck was fitted with an energy-absorbing Front Underrun Protection Device, and the impact speed was about 75 kph.

These tests provided information about the protection provided for the energy-absorbing FUPD's installed in the trucks. At the same time, they provide information for the properly definition of the evaluation tests to be proposed.

The aim of the next task of the project is to propose guidelines for the definition of a test procedure less complicated, easier and unambiguous than car to truck crash tests. This test should be carried out without vehicles, to evaluate the behaviour of the

FUPD independently of the truck attached to, and of the impacting car considered.

OBJECTIVES

Based on the previous topics, the next objectives are proposed:

- Discussion of the type of test to be performed, static or dynamic.
- Proposal of the main guidelines for the definition of the target and the bullet vehicles in a dynamic test without car and truck.

STATIC IN FRONT OF DYNAMIC TESTS

The static test consists of applying different values of quasi-static forces in points of the Front Underrun Protection Device, verifying the final deformation of such element. In this procedure, only the FUPD is necessary. This configuration of test has been used in other devices, such as the Rear Underrun Protection Device according to the Directive 97/19/CE.

The main advantage of a static test is the low cost for developing. Nevertheless, this test can not take into account the real behaviour of the device during the interaction process in a real frontal car to truck accident.

The dynamic test consists of carrying out a full scale crash test using two vehicles, one of them with the FUPD fitted. This is a more expensive solution, but it reproduces better the vehicles behaviour in a real collision.

Different suggestions about the vehicles to be used in the tests are considered in the next paragraphs.

TARGET AND BULLET VEHICLE CONSIDERATIONS FOR THE DYNAMIC TEST

Target vehicle

The final objective of the test consists of evaluating the aggressiveness of this device for the car, not to measure the damage in the truck. Thus the truck with the Front Underrun Protection Device installed in it can be replaced by an element representing it.

During the definition of the target element replacing the truck, the next options should be considered:

Option 1: fixing the FUPD directly to the typical concrete block of the tests laboratories.

The main advantages of this option are:

- Very easy for installing.
- Low cost.

Opposite to that, this solution shows an important disadvantage: it increases the impact severity for the same car mass and velocity, due to the concrete block does not absorb any energy as compared with the full scale crash test, where:

- The FUPD support and the front elements of the truck result deformed. (figure 1).

Figure 1. FUPD support and front elements of the truck deformed after a crash test carried out by TNO.

- The truck does not work as a rigid block because it shows a final speed just after the impact.

Option 2: fixing the FUPD and a section of the front of the truck (where it is installed in) to the concrete block.

This option, compared with the previous one, increases the complexity and the cost of the tests. Nevertheless, it would show a better performance, reproducing the actual behaviour of the FUPD during the crash test.

For developing this test procedure, the next topics should be evaluated:

Size of the truck section.
Resistant elements mounted on this section.
Difficulties for fixing the truck section to the concrete block.

Bullet vehicle

The aggressiveness of the FUPD for any car impacting the truck should be estimated. A representative standard car has to be defined.

The car can be replaced by a mobile barrier. During the definition of the bullet vehicle replacing the car, the next options should be considered:

<u>Option 1:</u> moving rigid barrier.

The mass of this barrier could be defined taking into account the average value of the European car fleet.

The main advantage of this option is the low cost of the bullet vehicle. Opposite to that, this solution does not represent the real behaviour of the car during the car to truck crash, due to:

This barrier can not represent the existing geometric and stiffness incompatibilities existing between the car and the truck.

All the energy involved is absorbed by the FUPD.

<u>Option 2:</u> moving deformable barrier (Figure 2).

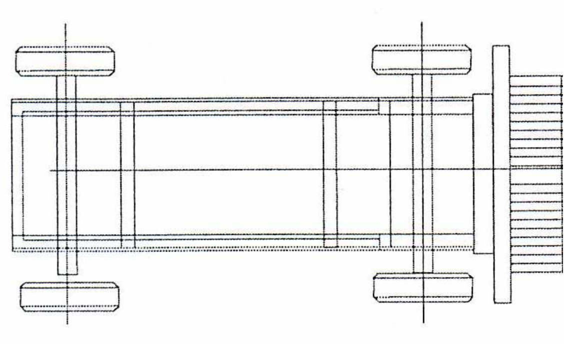

Figure 2. Moving deformable barrier.

In this approach, the large variety of structural designs of the front of the vehicles would introduce a high complexity in the test procedure. Nevertheless, some general ideas are proposed in the next lines.

Mass of this barrier will be defined taking into account the average value of the European car fleet.

The *geometry* of the deformable element, located in the front of the moving barrier, could be defined considering the average dimensions of the main resistant elements existing in the European car fleet. As a first approach, the next design could be taking into account (Figure 3).

The geometric definition of the different areas could be developed using the INSIA database, prepared by this Institute in the EEVC WG15 ("Improvement of crash compatibility between cars" project). The main resistant elements in the car body have been selected. These elements have to be chosen from the point of view of the sort of collision that we want to study.

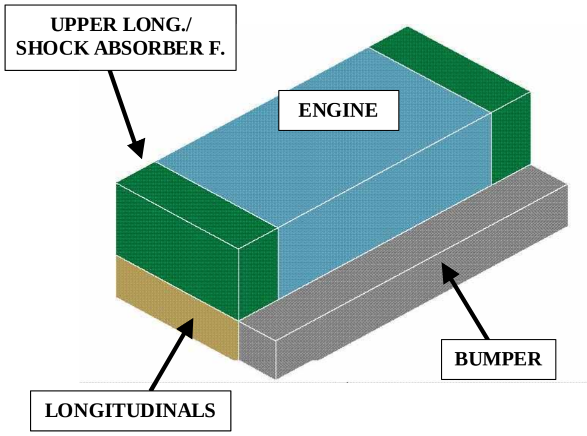

Figure 3. Sketch of the deformable element of the moving deformable barrier.

Detailed measurements have been taken from exterior and interior elements, spread to a total number of 74 models selected from the main vehicle manufacturers at Spain. All of them have been sold for 1997. Using the information available from the previous measurements in vehicles, the geometric characteristics of the main resistant elements involved in collisions between cars will be defined.

The distribution of these models according to the *mass* is shown in the following figure (Figure 4).

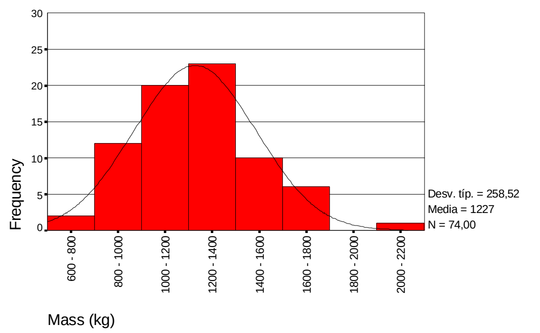

Figure 4. Distribution of car models (INSIA database) by mass.

A great number of resistant elements, which can be involved in case of collision, have been taken into account during this analysis. These elements are the next ones:

FRONT ELEMENTS:

- Bumper heights.
- Longitudinal member heights.

- Distance between longitudinal members.
- Longitudinal member width.
- Engine heights.
- Engine and Gearbox width.
- Front bumper - Engine distance.
- Front shock absorber fixing width.
- Front shock absorber fixing height.
- Bonnet leading edge height.

SIDE ELEMENTS:

- Front bumper - Front axle distance.
- Front axle - A Pillar distance.
- A Pillar - B Pillar distance.
- B Pillar - C Pillar distance.
- B Pillar - Rear axle distance.
- Roof sill heights.
- Floor sill heights.

The *stiffness* of the different areas in the deformable element should be defined to make it equivalent to a standard car, from the point of view of its behaviour in the considered collision type.

The parameters of the standard vehicle should be defined starting from test data of different car-to-truck and car-to-barrier crash test over several models representative of the European fleet. Representative parameters of deceleration pulse and force distribution can be obtained as averaged values of the ones obtained for the different models.

The force-deflection curve of each area of the deformable element, representing its progressive stiffness as proposed by INRETS, should then be defined. It may be done making use of a spring-lumped mass model to simulate the collision process. The shape and values of the force–deflection curve of the spring corresponding to each area must be adjusted to reach the desired values of parameters from global deceleration pulses and force distribution, near to the ones defined before for the standard car.

This option represents the real behaviour of the FUPD in a real accident. Opposite to that, it shows an important disadvantage: the high cost.

Finally, and during the definition of the moving deformable barrier, the previous activities developed by other groups of experts should be studied, such as:

Experiences during the definition of the 96/79 CE Directive (Frontal impact), and the 96/27 CE Directive (Side impact).

Results from the EuroNCAP crash tests.

TEST PARAMETERS TO BE MEASURED.

In case of the dynamic test, and since the bullet vehicle does not contain a dummy, new criteria based on energy absorption or deceleration in the compartment of the bullet car have to be defined.

CONCLUSIONS.

During the definition of a test procedure, a high number of parameters has to be considered. In the case of a test procedure for Front Underrun Protection Systems for Trucks, an initial question should be solve: static test or dynamic test.

The final solution should reach the optimum compromise between cost and performance.

Taking into account the options proposed in this report:

A static test applied on the FUPD is the cheaper solution, but it does not represent the real behaviour during a real collision.

A dynamic test, considering the FUPD fitted to a section of the truck and a moving deformable barrier as bullet vehicle, is the more expensive solution, but it reproduces the real behaviour during a real collision.

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