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COMPATIBILITY IN TRUCK TO CAR FRONTAL IMPACTS

Lars Forsman Volvo Trucks 3P, Dept. 26602 VLU3 SE-405 08 Göteborg, Sweden

ABSTRACT

One of Volvo's core values is safety. In our policy it is stated that we should not only comply with legal demands regarding safety, but also strive to develop vehicles that are safe in a real traffic environment. The demands from the public to make trucks more impact friendly are constantly increasing. Today, only a few percent of the collisions where trucks are involved causes serious injuries or fatalities to the truck occupants, the majority (about 54 %) of injured persons are car occupants. This means that the front underrun protection system, FUPS, is one of the most effective tools to reduce the number of fatalities in accidents involving trucks.The use of an effective FUPS on the truck will dramatically reduce the number of fatalities in truck to car collisions. In Europe, an estimate is 800 saved lives per year if all trucks were equipped.

The FUPS for the new Volvo FH and FM trucks has been designed not only to comply with the static legal demand, Directive 2000/40/EC, effective August 2003, but also to absorb energy for smaller cars while still being rigid enough to withstand the force from a large car at 65 km/h closing speed and 75 % overlap. This has been achieved by optimising a crumpling tube behind the FUPS beam that connects to rigid parts on the chassis.

The system was developed using FE simulations and verified in full scale testing.Sensitivity studies were performed using an FE car model with different impact heights and offset ratios. The influence of impact angle between the car and the truck was also analysed.For future systems, increased ability for the front of the truck to absorb energy is needed to increase the critical closing speed, and thereby further reduce the number of fatalities in truck to car accidents.

BACKGROUND

When developing the front end of the new Volvo FH and FM range, quite a few demands were set on the structure. One objective was to not increase the weight of the lower front in order not to increase the front axle load. Another was to include a front underrun protection system, FUPS. It should not only comply with the legal demand, Directive 2000/40/EC, which will be effective in August 2003. It should also manage to absorb some of the impact energy in a real frontal impact with a smaller car, while withstanding the forces from a large car. The solution was a beam that carries all the components of the module, such as headlights, washer reservoir, lower insteps etc. That beam is connected to rigid parts of the chassis through a crumpling tube. Finally, the level of energy absorption and the maximum force involved in a crash was investigated for optimisation of the system with the limited space and weight available. It was decided that the Euro-NCAP offset test should be the template. A large car (in this case a Volvo V70) impacts the FUPS at a relative velocity of 65km/h with 75 % car overlap.

COMPATIBILITY

When discussing compatibility, it is obvious that the mass difference between the truck and the car is the outstanding mismatch that cannot be changed. That leaves us the opportunity to optimise the force versus displacement of the FUPS for cars with different weight, stiffness and strength. The height of the front end of the truck varies quite substantially depending on vehicle specifications. This, together with the overlap ratio in an accident, needs to be considered when dimensioning the system. The following paragraphs will describe how the FUPS for the new Volvo FH and FM was developed with compatibility in mind.

ENERGY ABSORPTION

In order to choose optimal parameters for the energy-absorbing element, the following limitations were considered:

- Space available for intrusion into the truck structure.
- The maximum trigging force allowed without causing intrusion into cockpit on a small car.
- Energy absorption level of the crash beams in a car.

Space

Very limited space is available in the front of a Cab-Over-Engine, COE, truck design. The steering and suspension systems together with the engine and its cooling systems occupy the front end. For most trucks, the suspension brackets are the limiting components. Legal demands on vehicle lengths effectively reduce the amount of space available. Any protrusion in the front end of the truck would cause a decreased length of the payload. An exception from the rule for safety installations would make it possible to dramatically increase the performance of the FUPS.

Trigging force

What is a small car? It is a very difficult question to answer. Most modern cars have high safety cage strength, regardless of size. As an example, the Renault Clio develops over 400 kN when impacting a rigid FUPS according to the Group 14 report [1]. The force versus deformation curve was examined for a few cars, and the amount of energy absorbed by the crash structure before the bumper hits the engine was extracted. This energy is not absorbed if the bumper beam of the car misses the FUPS beam. A minimum requirement on the energy absorbing capability could be that amount. To define the trigging force, the results from the Group 14 report [1] was used together with our own experience from tests.

MAXIMUM FORCE

The maximum force is dependent more on the structural characteristics of the car than on the velocity involved. For a modern large car, the maximum force involved in a full barrier crash may exceed 800 kN. This force is reduced since the FUPS is not completely rigid and is not covering the complete front of the car. Due to design, it is not common that the FUPS beam takes the full load. Cooling systems and chassis components are often engaged in the crash. To define the maximum force that the FUPS should withstand, FE crash analyses were performed with data from a large car, in this case a Volvo S80.

VEHICLE HEIGHTS

Commercial vehicles are used in a wide range of applications, all with different demands on the truck configuration. For the FUPS, the most significant parameter is the frame height, and thereby the height of the lower front of the vehicle. The predicted number of vehicles in each segment was used when defining the height to obtain the most effective FUPS. The effect of vehicle height is described in PARAMETER STUDY below.

OVERLAP

Accidents are ranging from a small fraction of the car engaged to a full lateral overlap. Generally, large overlap makes the accident better defined in terms of deformations. The Volvo FUPS has two crumpling tubes, one at each frame member. This means that for a small overlap, only one of the tubes is activated. For larger overlap, both tubes are activated while the trigging force is doubled. If the overlap is very small, the car engine misses the FUPS and it is not possible to stop the car for the velocity used in the test. The effect of overlap is described in PARAMETER STUDY below.

ANGLED IMPACT

At higher speeds, the impact is usually head-on between the truck and the car. At lower velocities, the impact angle may often be larger. This makes it important to verify a good behaviour of the system for angled impacts as well.

PARAMETER STUDY

To analyse the effect on the FUPS considering compatibility, all parameters were analysed in a full-scale finite element analysis model. For the study, the new Volvo V70 was used. The following matrix of parameters was used. Maximum deformation pictures are included in the table.
An angle of 20 degrees with 70% of the head-on impact velocity, i.e. 46 km/h was used to verify the behaviour for the angled impact.

FUTURE

For future FUPS systems, the energy absorbing capacity will be the key issue. One way of increasing the behaviour is of course to allow the front end of the truck to protrude somewhat forward. Another way is to remove rigid objects from the front end of the truck. As cars are constantly improving in frontal crash behaviour with stiffer and stronger bodies, the trigging force can probably be increased as well to allow for more energy to be absorbed.

REFERENCES

[1] EEVC Working Group 14 Report: Development of Test Procedure for Energy-absorbing Front Underrun Protection Systems for Trucks. G. Blaauw et al. 1996

FIGURES & TABLES

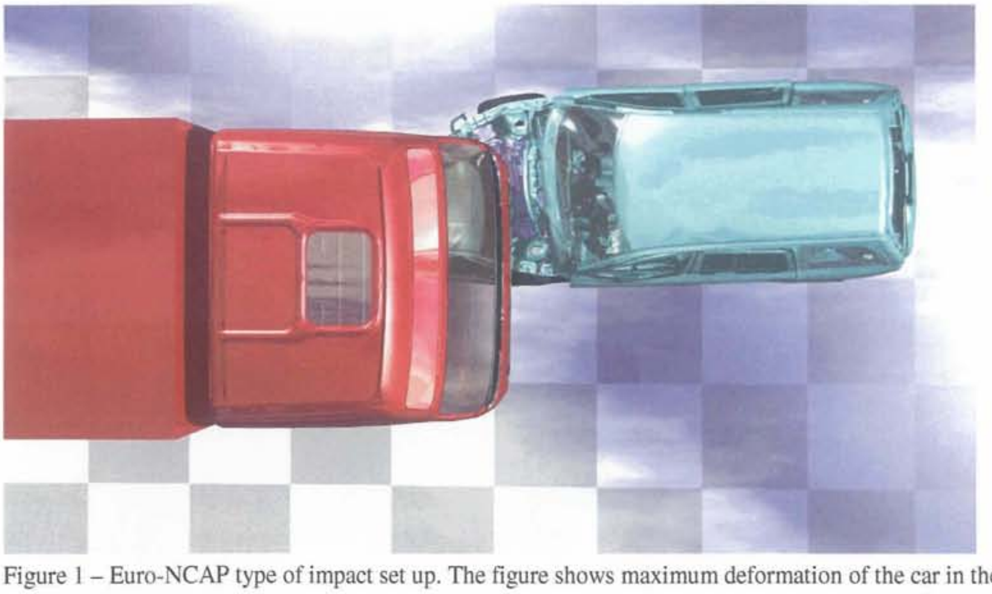


Figure 1 – Euro-NCAP type of impact set up. The figure shows maximum deformation of the car in the crash. Crash FE simulation from above.

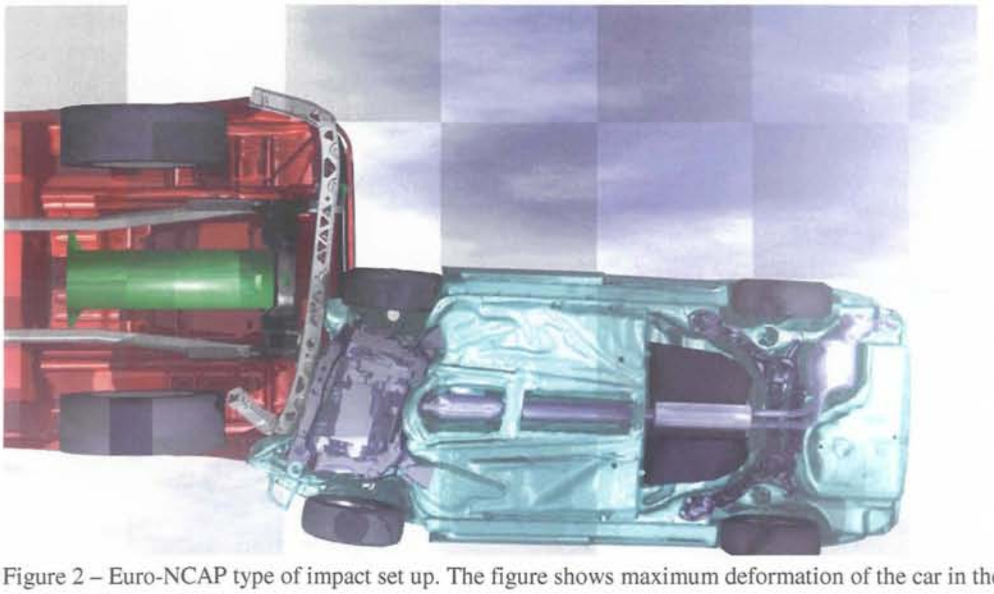
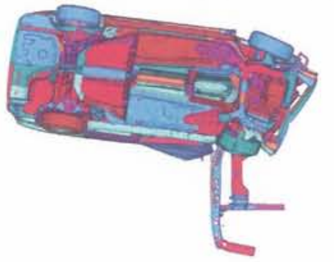
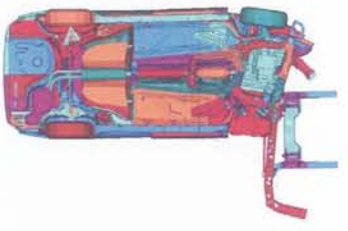
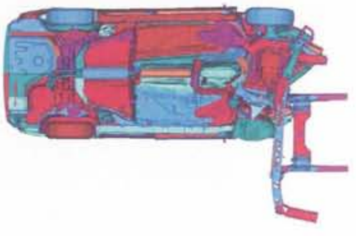
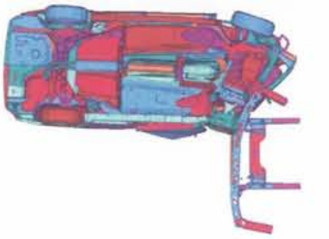


Figure 2 – Euro-NCAP type of impact set up. The figure shows maximum deformation of the car in the crash. Crash FE simulation from below.

Table 1. Matrix of analyses performed to verify the FUPS behaviour. Intrusions at the instrument panel for the car and deformation pictures are included.

Height	75 % Overlap	50 % Overlap
150 mm higher truck	 Intrusion at instrument panel < 100 mm	 Intrusion at instrument panel < 200 mm
Nominal height of truck	 Intrusion at instrument panel < 50 mm	
150 mm lower truck	 Intrusion at instrument panel < 100 mm	 Intrusion at instrument panel < 100 mm

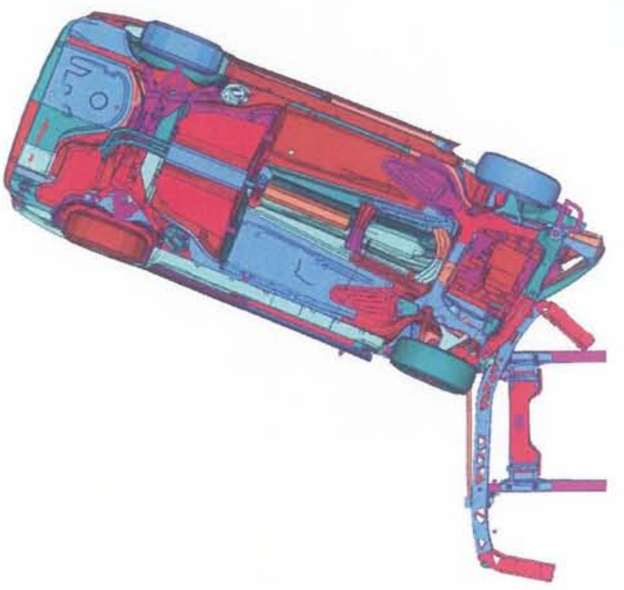


Figure 3 – Angled impact on FUPS, 20 degrees angle, 50 % overlap and 46 km/h.