# NEW HEADLAMP CONCEPTS AS KEY TO OPTIMISATION OF VEHICLE FRONT ENDS IN CONSIDERATION OF PEDESTRIAN PROTECTION

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## SUMMARY

Seeing and being seen well have been playing a decisive role as elements of active safety since the invention of motor cars. In this context, Hella has made a decisive contribution to the high level of performance of today's headlamps thanks to its numerous innovations of the past 100 years, and has also prepared pioneering concepts for the future [1].

More recent targets reveal , however, that headlamps also play a key role with regard to the passive safety of vehicles – particularly in accidents involving pedestrians. In almost 70% of all pedestrian accidents the primary contact zone is in the corner areas of the vehicle front end.

Using this background knowledge, Hella is working closely with the Institut für Kraftfahrwesen in Aachen to optimise headlamp constructions with regard to energy absorption and deformation behaviour in the event of a crash. Drop tower tests and crash simulation have been carried out within this framework.

For these tests the basic conditions were chosen following the EEVC WG17 tests with the hip impactor. The mechanical interface between the headlamps and the front end module was reproduced for the drop tower tests in such a way that it corresponded to the installation conditions in the vehicle and at the same time was suitable for modelling in crash simulation.

The experimental investigations were used to analyse measures to optimise existing devices. Furthermore, drop tower tests were carried out with the aim of validating FE crash calculation models. More complicated attempts at optimisation for headlamps were able to be examined using the validated FE models.

In this paper, the qualitative results of the investigations and initial solutions derived will be presented. In particular, the basically high elasticity of headlamp casings of classic design and the extremely high ductility of PC cover lenses can be proved.

Different solution concepts will be presented and evaluated. Regulations covering shape and notes about design will be partly explained in detail.

## INTRODUCTION

During vehicle-pedestrian accidents initial impact is usually between leg and bumper. Since the blow is below the body's centre of gravity, the pedestrian experiences a moment of momentum which leads to a rotational movement and propels the upper part of the pedestrian's body towards the vehicle. The second contact is then usually the thigh or the hip hitting the front edge of the vehicle's bonnet. It is during this blow that one of the vehicle headlamps is often hit. Rigid components on the front edge of the bonnet can have a significant effect on the pedestrian's injuries. In order to keep injuries to thighs and hips as minor as possible, the rigid components on the front edge of the bonnet must be designed more to be more flexible. This includes the front headlamps in particular. [2,3]

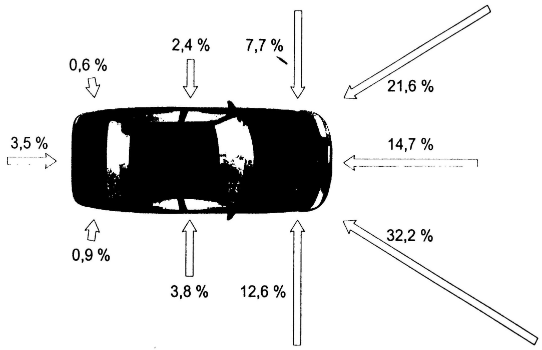



**Figure 1 Initial contact of pedestrians during vehicle-pedestrian collisions**

## DROP TOWER TESTS

During the tests with the hip impactor according to EEVC WG17 [4] in the headlamp area, these proved to have a considerable influence on the results of the tests due to their stiffening effect. In order to reduce the stress on pedestrians and keep to the prescribed limits of EEVC, the headlamps have to be optimised. Drop tower tests provide a good opportunity to carry out targeted component optimisation, where individual headlamps can be tested in isolation from the rest of the vehicle. Component tests allow the most important factors of influence on the impact behaviour of headlamps to be recorded and measures towards optimisation to be examined at an acceptable expenditure level.

For the investigations illustrated below, tests using the headlamps of a representative middle of the range vehicle will be presented as an example. The mass of the headlamp is approx. 1.5 kg. The headlamp casing is made of polypropylene and the cover lens of polycarbonate.

The drop tower used at ika is shown in figure 2, [5]. The drop weight is guided in two rails and is equipped with an acceleration recorder. During impact, the acceleration signal of the impactor and the path-time course of the impactor is measured at 10 kHz. The impact force can be determined using the acceleration signal and the mass of the impactor. In addition, digital high-speed video cameras record the deformation of the component at 1 kHz. [2]

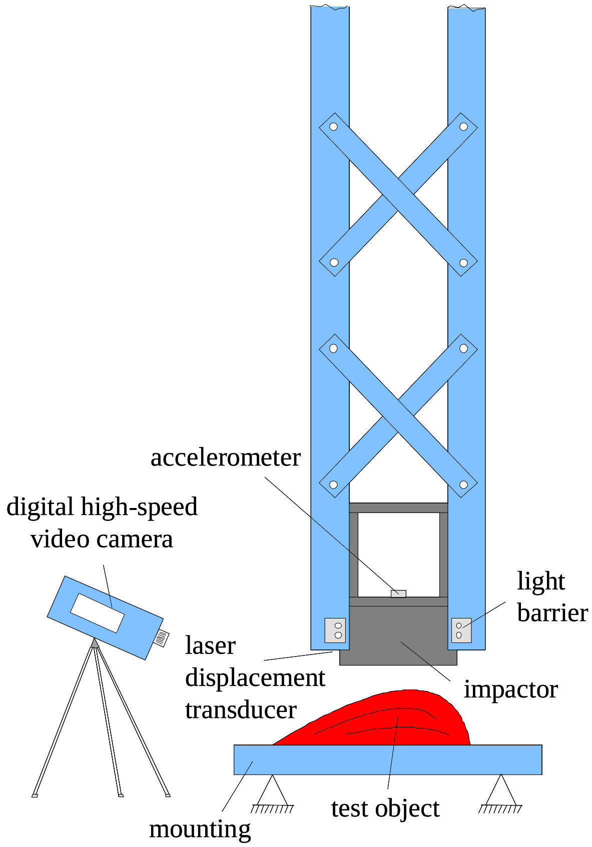



**Figure 2 Drop tower**

During the drop tower tests with the headlamps the basic conditions were chosen in such a way that the hip impact test of EEVC WG17 was reproduced. With the aid of a swivelling frame the impact angle was set according to the values given by EEVC for the corresponding vehicle, figure 3.

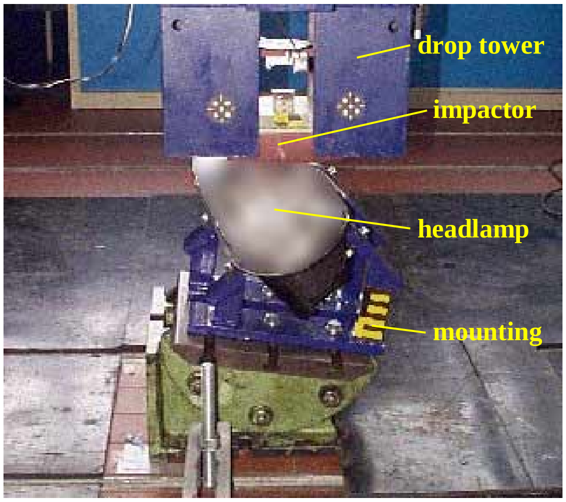



**Figure 3 Mounting of headlamp**

For the drop tower test a lower impact energy was chosen than the impact energy of the hip impactor in the EEVC WG17 test, since during the tests on complete vehicles the bonnet, bumper cover and radiator carrier also absorb energy. The impact energy was set using the impactor mass. Since the material behaviour of plastics is strongly dependent on the speed of load applications, all the headlamps were tested at the speed prescribed by EEVC WG17 for the appropriate complete vehicle test.

The mounting of the headlamp in the vehicle is guaranteed by four attachment points which are fastened to the very rigid front end structure of the vehicle. For this reason an ideal rigid attachment of the equipment was designed for the drop tower tests. On the one hand, this minimised the influence of interfering factors in the test. On the other hand, ideal rigid attachments can be easily reproduced in crash simulation, so that the drop tower tests could be consulted for the validation of crash calculation models.

For the tests, an impactor with a cylinder-shaped impact surface and a diameter of 100 mm was used. This impactor can also be represented well in simulation. In order to reproduce the EEVC WG17 hip impact test more exactly, it is also possible to use an impactor consisting of a cylinder with a 50 mm diameter and a foam layer 50 mm thick.

**Influence of the impact energy**

Initially the influence of the impact energy on the crash behaviour of the headlamps was examined. To do this, the mass of the impactor was varied from 2.5 kg to 5.66 kg, so that impact energies from 25 % to 40 % of the energy prescribed for the hip impact test were achieved. An impact spot in the central area of the headlamp was chosen, a spot which is particularly rigid and would thus be likely to cause high stress values. Initially, headlamps without fog lamps were tested.

The qualitative force-time course for two different levels of energy is represented in figure 4. During the test with the impactor weighing 4.25 kg the impact force increased greatly in the first 2.5 ms. Then the casing near the impact spot began to give way. The force increased again shortly after this and reached its maximum value after 4.5 ms. Due to the damage to the casing the impact force fell again briefly. As the casing was deformed further, the force increased again due to the rigid effect of the reflector and reached a further maximum value after 8 ms. At this point, one of the attachment tabs of the headlamp became detached and the force fell. Maximum deformation was achieved after 14 ms.

During the test with the impactor weighing 5.66 kg the amount of maximum force was similar and was also limited by one of the attachment tabs becoming detached. Maximum deformation was only reached after 18 ms. The greater deformation with this dropped load led to considerably more damage to the headlamp than in the test with the impactor weighing 4.25 kg.

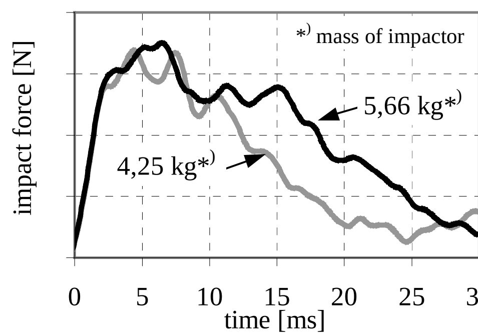



**Figure 4 Impact force in dependence on the impact energy**

The deformation behaviour of the headlamp is shown in figure 5. What was remarkable in the tests was the high level of elasticity of the polycarbonate cover lens. Although the cover lens was directly in the area of impact and was greatly deformed over an area of 70 mm, it was not damaged. Such behaviour is a very positive signal for pedestrian protection, since no splitters and sharp edges are produced, which can cause cuts.

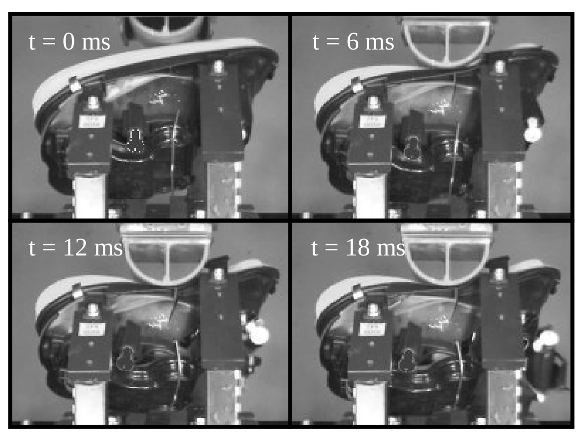



**Figure 5 Deformation behaviour of the headlamp**

### Influence of the mass of the headlamp

The impact force on the impactor is influenced both by the structural rigidity of the headlamp, by the rigidity of the attachment and the inertia of mass of the headlamp. In order to determine the impact force which results solely from the inertia of mass of the headlamp, a test was carried out using a freely suspended headlamp under the drop tower. The component was fixed in place under the drop tower using very thin threads, which give way at the slightest load. The headlamp could thus move completely freely after its initial contact with the impactor.

The impact spot and the impact angle during the test with the freely suspended headlamp corresponded to the position of the components as they were fixed in the frame. The test was carried out using an impactor weighing 4.25 kg.

The force-time course of the test with the freely suspended headlamp is shown in figure 6. The test shows that even with this rather small and at 1.5 kg light headlamp the impact force increases to 70% of the force reached in the mounted condition solely due to the inertia of the mass.

This means that optimum solutions can only be achieved by specific influencing of the rigidity on the equipment itself, while optimisation of the fastening system would be helpful but not sufficient.

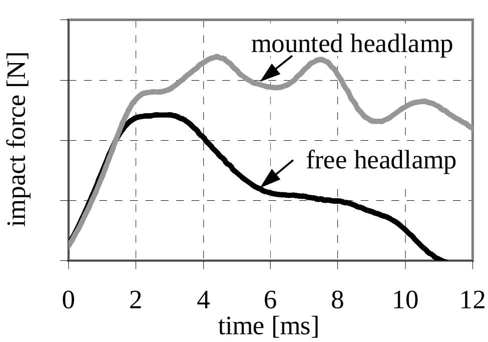



**Figure 6 Impact force due to the inertia of mass of the headlamp**

### Variation of the impact spot

The headlamp tests were also carried out at a second spot on the rim of the components. Figure 7 represents the comparison between the impact on the rim and at the centre with an impactor weighing 4.25 kg. During impact on the rim of the headlamp, the impact force initially increased rapidly. Since the impact force was passed very asymmetrically into the headlamp and the load in the rim area became very high, the casing collapsed after only 3 ms. The attachment tabs broke off and the force dropped sharply. Deformation was more than 80 mm. In comparison to the impact on the central area the impact energy was broken down unfavourably.

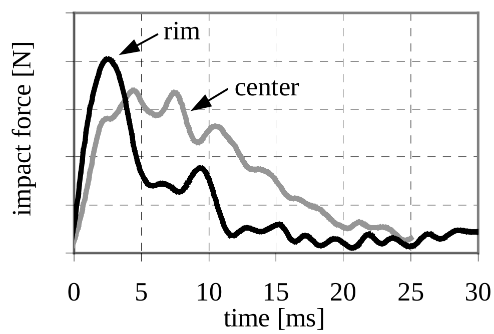



**Figure 7 Impact force at two different impact spots**

## OPTIMISATION OF THE HEADLAMP

In order to demonstrate attempts at optimising headlamps with regard to pedestrian protection, various modification measures were implemented on the headlamps. The aim of the optimisation was to break down the impact energy at as low a force level as possible and with as little deformation as possible. These conditions are fulfilled with a rectangular shaped course of deceleration. First, initial solution concepts were examined experimentally.

### Optimisation of the connection casing-cover lens

The adhesive joint between casing and cover lens was modified with the objective of enabling the connection to shear off in the case of impact, thus allowing the cover lens to move backwards out of the way. Such a construction could be achieved in a series part by a clip connection, for example, as illustrated in figure 8. With this construction, the behaviour on impact can be influenced by the size of the stop, the form of the rubber seal and the geometry of the joint.

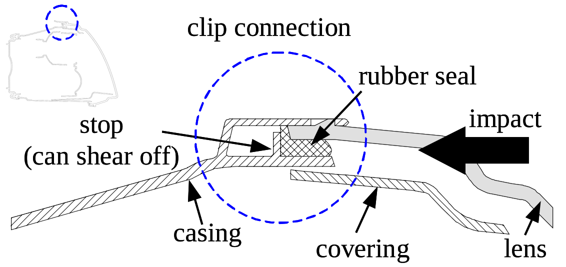



**Figure 8  Optimisation of the adhesive joint**

On one of the headlamps the adhesive joint was designed in such a way, that the cover lens can move backwards out of the way. At the same time notches were made in the casing. The headlamp was tested with an impactor weighing 4.25 kg on the impact spot at the rim.

Figure 9 illustrates the result of the test with the modified headlamp in comparison to the series part. Energy absorption has been significantly improved. The maximum impact force was 20% lower with the optimised component and the maximum deformation fell from over 80mm with the series component to 62mm with the optimised headlamp.

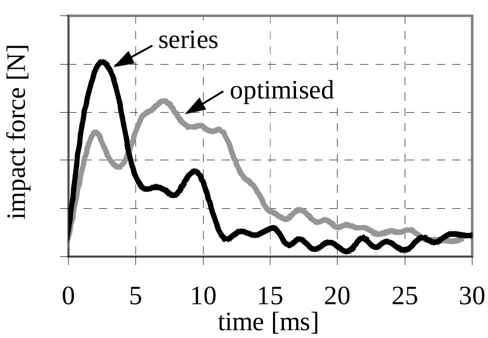



**Figure 9  Impact force with optimised adhesive joint**

**Foam mounting**

An alternative technique of attaching headlamps to vehicles was examined using drop tower tests in which the headlamps were not fixed to the rigid frame but rather embedded in a foam mounting of EPP. This foam mounting should improve crash properties thanks to its ability to absorb energy.

For the tests with the foam mounting, the same impact angle and spot were set as for the tests with the rigid frame. The central impact spot with the impactor weighing 4.25 kg was tested.

The results of the test with the foam mounting are shown in figure 10. The maximum impact force was 15% lower with the foam mounting than with the rigid attachment. Thanks to the energy absorption by the EPP foam, there was considerably less damage done to the headlamp.

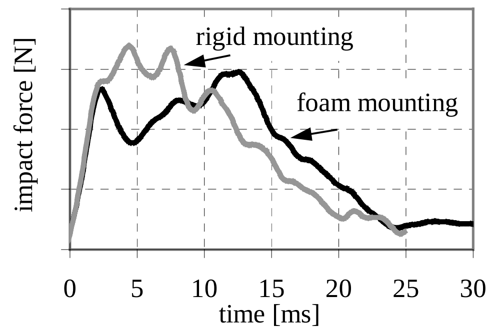



**Figure 10  Impact force with foam mounting**

When optimising the mounting techniques of the headlamp onto the vehicle, it must be taken into account that the inertia of the mass of the headlamp is already responsible for a significant part of the impact force. The lower the mass of the headlamp, the more efficiently energy absorption elements can be used between the headlamp and the vehicle.

**HEADLAMP CRASH SIMULATION**

For optimisation of vehicle components with regard to pedestrian protection at an early stage of development, the use of numerical aids, such as the Finite Elements Method (FEM) has advantages over experimental investigations. Explicit FE-codes are particularly well suited for the simulation of dynamic drop tower tests. In the following, crash simulation using LS-DYNA for optimising headlamp construction with regard to pedestrian protection will be presented.

First, an FE-model of the headlamp was created and aligned with the test results of various drop tower tests. The FE-model consists exclusively of shell elements with an edge length of approx. 4 mm. Material models were chosen with which elastic-plastic material behaviour dependent on the expansion rate can be illustrated.

The results of the validation tests with the impactor weighing 4.25 kg are shown in figure 11 and figure 12. The course of the force in the simulation corresponds well with the measured data. The course of the impact shows that the image of damage in the simulation correlates well with the test results.

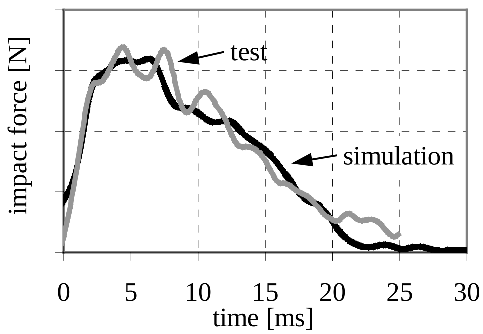



**Figure 11 Validation of the drop tower tests with the impactor weighing 4.25 kg**

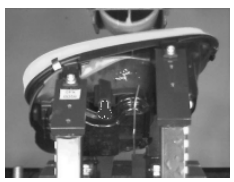
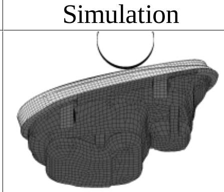
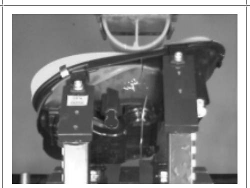
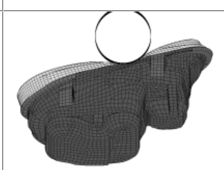
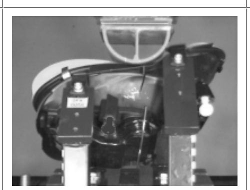
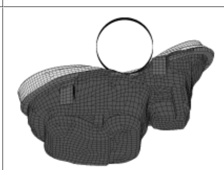
| | Test | Simulation |
|---|---|---|
| t=0 ms |  |  |
| t=4 ms |  |  |
| t=8 ms |  |  |

**Figure 12 Comparison of the deformation behaviour in tests and simulation**

**Optimisation of the headlamp in crash simulation**

With the aid of crash simulation, further more complicated optimisation measures were analysed. On the one hand, the sealing joint was modified in the simulation model in such a way that the cover lens can move out of the way over the rim of the casing. On the other hand, energy-absorbing EPP foam was used at the mounting points of the headlamp. Thirdly, the design of the casing and the reflector was optimised with regard to pedestrian protection. Impact force was able to be significantly reduced with the optimised headlamp, figure 13.

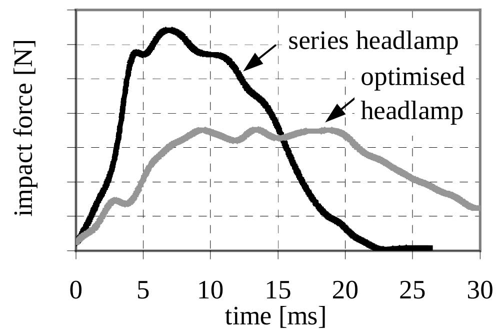



**Figure 13 Optimisation of the headlamp in crash simulation**

## CONCLUSIONS

Drop tower tests using series components and modified headlamps allow criteria for the design of pedestrian-friendly lighting units to be established. The deformation path depends on the maximum permissible force and the amount of energy which must be absorbed by the headlamp during hip impact. In this deformation range, the headlamp should not reveal any rigidity cracks. In this way it can be guaranteed that in the case of higher loads higher deformation paths occur, but that the level of force remains constant.

When designing casing and attachment tabs, care must be taken that their failure does not lead to a collapse and thus a resistanceless giving-way of the headlamp. This can occur particularly if the load on the headlamp is asymmetrical, e. g. if impact spots are on the rim. For asymmetrical stress the force should be passed over the cover lens into the large area of the complete casing width, for example.

The cover lens should not be subject to stress up to breaking point in order to avoid cuts to pedestrians. The drop tower tests prove, however, that PC cover lenses have an extremely high level of ductility even in cases of high dynamic stress.

The impact force can be reduced by predetermined breaking points in the casing, by reducing the structural rigidity of headlamps and by an optimised connection between cover lens and casing. The impact force is also greatly influenced by the inertia of masses. Complicated optimisation measures can be analysed even at an early stage in development with the aid of crash simulation using explicit FE codes.

**LITERATURE**

[1] Dr. Lachmayer, R. , Dr. Eichhorn, K.
Scheinwerfer von morgen – multifunktional und hochintegriert
Automobiltechnische Zeitschrift ATZ
101 (1999) 12, Seite 1026 - 1031

[2] PHILIPPS, M.; FRIESEN, F.
Optimization of Vehicle Front Ends with Regard to Pedestrian Safety Using Experimental Testing and Numerical Simulation
8. Aachener Kolloquium Fahrzeug- und Motorentechnik, Aachen, 1999

[3] KALLISKE, I.; FRIESEN, F.
Improvements to Pedestrian Protection as Exemplified on a Standard-Sized Car
17th International Technical Conference on Enhanced Safety of Vehicles, Amsterdam, 2001

[4] EEVC/CEVE
EEVC Working Group 17 Report
Improved test method to evaluate pedestrian protection afforded by passenger cars
European Enhanced Vehicle-safety Committee, 1998

[5] DITTMANN, R.; PARR, T.; OLDERS, S.
The ika/fka Facilities for Crash Tests and Simulation aid Project Examples
Euromotor Course New Advances in Body Engineering, Institut für Kraftfahrwesen Aachen, Aachen, 1998