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A NEW HYBRID REAR CRASH BEAM DEVELOPMENT PHASE FOR LIGHTENING OF BODY STRUCTURE WEIGHT INSTEAD OF CONVENTIONAL STEEL SOLUTIONS

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ABSTRACT

Lightening studies of the vehicles are becoming more and more important with the increase of performance and comfort level requirements. But it is not so easy to adapt the light solutions on the vehicles when thinking material conformity of the parts to each other. So the material selection and definition of the correct material on related body structure is the key parameter for a lightweight vehicle design. The designers are struggling for lightening the total vehicle weight by using alternative materials like aluminium, magnesium, advanced plastics or steels. On this direction a new hybrid rear crash beam is designed by using advanced plastic and steel materials. In this hybrid solution are being used very different design parameters like honeycomb plastic crash box design, like double layered crushing system (softer plastic box + steel travers + rigid plastic box) and also production methods like, plastic injection, steel stamping, welding, riveting etc. All design and production methods have to show a very good harmony during crushing verification of the structure. Gradual energy absorbing, acceleration of the crash beam in to the vehicle structure, interference values into the rear panel and rails are being measured to check this harmony which means that good energy absorbing and protection of the vehicle structure, combustion system etc. Rear rails water infiltration and rear tow hitch performances are controlled for conforming of the rear beam. At the end of the study hybrid rear rail part is confirmed with all aspect and used on serial production with 3.94 kg total weight and gained circa 1.5 kg vs steel rear beam.

INTRODUCTION

This document represents a new solution of rear crash beam for weight reduction purpose and its application on the vehicle body to reduce total weight of the vehicle, thereby energy consumption of the required material and finally CO₂ emissions.

There are several types of methodology and design manner to reduce total vehicle body weight. Material selection is the first thing to consider for lightening the weight. For achieving a cost effective weight reduction study it is essential to use correct material in correct places. With this aspect it is clear that multi material concept is the most common way of cost optimised light body strategies. [1] Steel has the widest usage area on body structure even nowadays. But also CO₂ emission limits are decreasing drastically. So alternative light materials are running into scope of designers such as aluminium, magnesium, advanced plastic composites etc. The automotive designers have to know how of parts performance necessities to be able to select correct type of material. Performance requirement, crashworthiness of the part, formability of the geometry, vehicle target, current homologations etc. must be considered when making correct type of material selection.
Within the lightweight body structure strategy, in this paper a new rear crash system is designed by using different type of materials and processes to reach weight target without compromising performance target of the system like as low velocity impact, high velocity impact and towing tests. In every steps of the project the weight of the new system is optimised with performance results from style approval till launch of the vehicle.

EXPERIMENTAL PROCEDURE
Rear crash beam (or system) is fixed on the rear side of the vehicle, under the rear bumper. This component is designed to protect the vehicle structure during low velocity impacts, to protect combustion system and its layout during high velocity impact and also for towing the vehicle for the malfunction of it. [2] All these functions can be performed with different type of solutions by means of design ways, materials, vehicle target settings etc. But the most important point of the current design strategy is reaching to the targets with a light solution attained with cost efficiency. Some different solutions of the system and their weights can be seen in Fig. 1.

![FIG. 1 BENCHMARKING OF REAR CRASH BEAM](image)

**Rear Crash System and Its Components**
Within this study a new crash beam is designed by using different type of materials. The initial design and its components are listed with the explanation of their functions in the following.

**Cover (A):** Plastic cover is a semi structural but intensively is a geometry stabiliser part and designed for directing the crash impact on to the structural components. During the collision this part takes the load from rear bumper and transmits to the inner parts. Plastic cover part is fixed on to the main steel beam with steel rivets. Steel rivets behaves more robust than the aluminum rivets and they are not broken under crash or fatigue loads. [3] Plastic cover is produced with plastic injection process.

![FIG. 2 COMPLETE AND EXPLODED VIEW OF HYBRID CRASH BEAM](image)

**Central Absorber (B):** The central absorber absorbs the low velocity impact load during the collision. It has a high crushing capacity without any breakage with very big displacement any under the crash impact. Central absorber transmits the load to the main beam. The part has been designed with U shape to guarantee higher energy absorption.
First Crash Boxes (C): Right and left first crash boxes are used for first crash impact energy absorption. [4] They are designed with honeycomb shape. The boxes are produced with plastic injection method. The parts are fixed on the main beam with rivets.

Main Beam (D): Main beam is the main structural component of the system. It is in the center of the system and has the connection with other components. It is produced with conventional press processes. It is spot welded with base plates, fixed with plastic cover part with rivets, metal arc welded with tow bushing. The thickness is optimized with performance targets of the system and also with unification of the process parameters such as min thickness for riveting, or spot welding. Thickness definition is a crucial parameter for arc welding. In case of thinner sheet part usage main beam has burning risk with high temperature during arc welding with towing bush. [5]

The beam has some holes on crash boxes fixing zone to let the pass of the notches of the crash boxes.

Second Crash Boxes (E): Second crash boxes are fixed to main beam and first crash boxes by riveting. They are positioned in the U shaped base plates before the welding operation of the main beam and base plates. After the energy absorption of the first crash boxes, residual collision impact energy is absorbed by these second boxes. Second crash boxes are produced with injection molding process and before injection process small bushes are located in die. These bushes are for creating robust area before screw fixing with high torque values. Second crash boxes have some notches on themselves for making reference and prefixing on main beam.

Base Plates (F): The components which are using for fixing complete system on to vehicle body. U shaped parts houses plastic honeycomb crash boxes (Par G –F) in their U shape. The thickness and the material is important for eliminating plastic strain both on its own geometry and also on body structure especially during towing verification. For towing performance right part is designed with higher thickness than the left one is. Towing bush is arc welded n the right plate and the main beam.

Reinforcement Plates (G): In the next step of the project an additional structural component is created to support the system, especially main beam. The plates are important to minimize central displacement and the distance between the vehicle and crash system during rear central collision.
RESULTS AND DISCUSSION

During design steps of the project there are different types of verification, design limits, norms etc. The most important of them are the feedbacks from packaging to guarantee assembly processes and the limit dimensions not to disturb the environmental components, virtual simulations to perform required performance targets and also from process verifications to be able to produce the components and complete system conforming to projects conditions.

Packaging verifications: According to packaging norms rear crash system can’t touch or make interference with environmental components, alloyed to 8mm min distance with rear bumper and 10 mm with rear lamp components. On the other hand the part can’t have sharp corners and can be fixed on the vehicle without any ergonomic problems by means of work safety and cycle time of the process. Some problematic cases which does not conform to the stated limits are shown in the following.

Min distance error with rear bumper. With the style change of the rear bumper the distance between the crash system and rear bumper is decreased to 3.8mm under target value. The problem is eliminated with the plastic cover and first crash boxes modification. After the modifications some virtual verification have been run again to simulate new situation of the project.

Min distance error with rear lamp housing. With the style change of the rear lamp housing has been updated and the distance between crash system and rear lamp housing is decreased to 6-7mm which is out of packaging target. To reach to 10 mm distance target the plastic cover and central absorbers have been modified and again virtual verification repeated.

Process verifications: Within the rear crash system there are different types of material and consequently there are different types of process. During the advance of the project process verifiers have signaled some process problems. Some of them are shown in the following.

Main beam has a difficult geometry for deep drawing stamping process. After the stamping simulations has emerged the increase of the wall angle of the beam. Another important case which requires a diameter increase is for elimination burr problem. This problem creates assembly problem of the towing bush inside of the main beam.

For protecting the metal parts from corrosion different type of coatings are used. For cost optimised solution the coating
thickness must be selected at min thickness. The observations of currents and voltages measured during the electrodeposition process can be regulated for low cost coating. [6]

In this study to reach metal corrosion protection targets; main bema, base plates welded on main beam and second plastic crash boxes (between plates and main beam) are together coated with cathodic epoxy electro coats. During the process trials some coating overflowed on plastic crash boxes. To eliminate this problem small discharge channel for coating has been opened on front crash boxes.

![FIG.13 DISCHARGE CHANNELS FOR COATING DEPOSITION](image)

**Virtual & Physical Verifications**

**Verification on Component;** during the project development phase some sample parts are produced and energy absorption capacity of the first and second level crash boxes are measured by using free drop test bench. This value is used as a design improvement input. Using this data some project improvements has been applied on the project. Thanks to this free drop bench without high amount of expense the design can be optimized easily. [7] In the following can be found a view from the bench, test equipment and force-displacement diagram of the boxes.

![FIG.14 DROP TEST BENCH](image)

**FIG.15 DROP TEST RESULTS**

The first acceptance criterion of the rear crash system is absorbing the impact energy vs time and displacement. If the absorbed energy lower than the required level than the system is rigid at excessive level. In this case the impact load can be transmitted to directly vehicle structure. So we can see high level plastic deformation on vehicle. This situation is refused by insurance company. On the other hand if the absorbed energy higher than the required level than the crash system is elastic at excessive level, so the displacement so high, as a result the rear bumper can have high plastic deformation. So absorbed energy value has to be optimized vs displacement and time. [8] Within this direction rear crash system is analyzed virtually and measured energy absorption level. After a serial of virtual verification with the optimized crash system the test executed by physically. On first sample parts there were some
inconvenience between virtual and physical verifications. But with process parameter recovery the results matched with each other. In this verification is used only crash system instead of full vehicle. Test view and force-displacement diagram are shown in the following.

Verification on Complete Vehicle; Within the project development phase rear crash simulation have been executed on complete vehicle. All tests have been applied both virtually and physically.

The first test is for measuring performance of the complete vehicle under high velocity impact, called as “Trias33”. The test conditions:

- Overlap 100% rigid
- Impact velocity 52 km/h

TRIAS 33 basically controls the deformations on the fuel pipes and fuel tank. Test result is ok after 27-28 loop in advanced project levels. Some images from the test is shown in the following.

The second test is called as RCAR test.
The RCAR Bumper Test encourages vehicle manufacturers to produce effective bumper systems that feature tall energy absorbing beams and crash boxes that are fitted at common heights and can effectively protect the vehicle in low speed crashes. The bumper systems should also have wide beams that protect the corners of the vehicle in low speed crashes.

In the opinion of RCAR, good vehicle bumper beams should:

- be replaceable without cutting or welding
- be torsion-resistant to carry eccentric loads without twisting
- absorb energy and restrict damage to the bumper system only
- be attached to the body via energy absorbing structures that are inexpensive to
• prevent damage to structural, welded or bonded and other expensive parts [9]

Vehicle velocity: 10.5 km/h

FIG. 20 RCAR BUMPER TEST CONDITION

With the RCAR test simulation maximum plastic deformation has been measured on the vehicle. Like on the TRIASS 33 test also RCAR test has been applied lots of time to reach required level of the system. At the end of the test plastic deformation on body structure has been minimized. An image is shown in the following figure to show plastic deformation risks on body structure.

FIG. 21 RCAR SIMULATION – BOTTOM VIEW

CONCLUSION

In the present study within the body structure light weighing trials a new rear crash beam is designed and controlled by both virtually and physically. It is inspected that for performing all required performance targets it is important that energy absorbing of the crash system has to be graded according to displacement, acceleration and time during the collision. So that the crash beam can respond to different collision test it is designed by using 2 level of crash boxes. Crash boxes are formed with the honeycomb shape for constant impact energy absorbing. The new design has been designed with all aspect of process parameters and analyzed by virtually and physically.

The analysis showed that the new hybrid crash system succeeded all safety and structural tests with 1.5kg weight reduction per vehicle.

NOMENCLATURE

TRIASS 33: Rear impact test with high velocity
RCAR: Rear impact test with low velocity
Homologation: Acceptance criteria defined by government
Upper Force: Measured force from top side of crash box
Lower Force: Measured force from bottom side of crash box

REFERENCES

[9] RCAR Bumper Test, Issue 2.0, September 2010