STRUCTURAL PERFORMANCE: CHALLENGES WITHIN THE AREA OF TENSION BETWEEN SAFETY, LIGHTWEIGHT AND ECONOMICS

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ABSTRACT

Structural safety still plays a significant role in the development and optimization of vehicle safety. This fact is reflected by the increase of rating and mandatory requirements like the revised FMVSS 208 and recently introduced small overlap test protocols. Related safety measures could lead to a major conflict when it comes to weight issues with impact on fuel efficiency and costs. To resolve this challenging conflict as far as possible, targeted measures such as innovative technical solutions and intelligent development methods are required. This paper will present an innovative vehicle safety and structure concept as well as balancing measures by the example of the new Mercedes-Benz SL roadster. The SL integrates an all-aluminum body and is the first mass-production Mercedes employing this type of design. Making the entire bodyshell from aluminum reduces the weight of the cell by 24 percent. Viewed across the entire life cycle (including the manufacturing phase), the new bodyshell concept of the SL reduces CO_2 emissions by 15 percent over the predecessor model. This innovative structure concept gives rise to a lightweight occupant cell with pronounced structural rigidity for high structural performance. It facilitates a light yet stable cell compound for a highly rigid occupant cell. This concept leads for example to good results in frontal small overlap tests without any additional measures**.** The crash test program for the development of the bodyshell was effectively supplemented with targeted simulations based on CAE methods. Therefore existing CAE methods had to be augmented to accommodate the lightweight construction of the new SL. Among the structural safety the SL has a wide portfolio of safety measures with respect to the Mercedes Benz integrated safety concept.

INTRODUCTION AND MOTIVATION

In the last few years, there has been a declining trend in the number of traffic accidents in the European Union. In 2011, for example, 4,009 people died in car accidents in Germany as opposed to the 7,503 traffic-related deaths recorded in the country in 2000. This 47 percent drop can be attributed to a number of traffic safety measures that have been implemented as well as ongoing advancements in vehicle safety. To propagate this trend, engineers will continue to place a great deal of emphasis on safety as they develop new passenger cars. Convertibles and roadsters pose a particular challenge in this regard. Whereas roadsters must offer a high level of agility and therefore integrate a lightweight design that has an effect on the vehicle's structure, convertibles by definition lack a permanent roof and therefore require more outlay than closed vehicles. Targeted compensation measures are needed to increase body rigidity and safety, especially when it comes to rollover accidents. Since these vehicles are usually not manufactured in high numbers, the fine line between safety, lightweight design, and cost effectiveness takes on new meaning. Development must therefore exploit technological possibilities and state-of-the-art methods to realize success in this segment.

METHODOLOGY

Four-Pillar Strategy for Integrated Safety

The development of the Mercedes-Benz SL shows how the safety equipment fitted to roadsters builds on the principle of integrated safety. This strategy takes into account the entire chain of events leading up to an accident and meets the legislative and rating requirements that provide a solid basis for safety as well as incorporates a "real-life safety concept" that is oriented toward actual traffic and accident scenarios and reflects the knowledge that has been gained from conducting accident research in

particular. The strategy of integrated safety from Mercedes-Benz comprises four pillars [1],[2]:

•Safe Driving

•Preventive Action

•Adaptive Protection

•Save and Rescue

Consistently applying this strategy translates into significant technical outlay in terms of development and manufacturing and can increase vehicle weight, thus going against the cost and weight objectives defined for the development program. To achieve as optimum a balance as possible, coordinated measures (*Figure 1*) must be implemented that require technical solutions and intelligent development methods and processes.

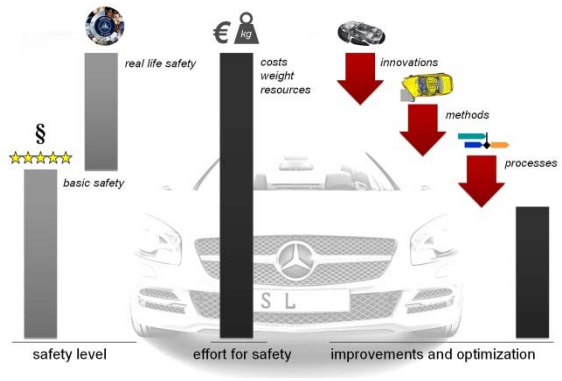

Figure1. Area of tension between safety, light-weight and economics

This paper discribes the safety concept as well as balancing measures as a result of the development process.

RESULTS

Safe Driving

The assistance systems in the new SL benefit safety and comfort. Speed Limit Assist detects posted speed limits via an on-board camera and displays them in the instrument cluster as well as on the head unit. Active Blind Spot Assist warns the driver of a potential collision when a lane is changed due to the presence of another vehicle occupying the neighboring lane in the driver's blind spot. If the driver ignores the warnings provided by the system and proceeds to change lanes, Active Blind Spot Assist engages by actively braking the vehicle to avoid an accident. Active Lane Keeping Assist engages if the roadster inadvertently crosses a solid or dotted line marking the left or right side of the lane. In this scenario, the driver is warned by a vibration of the steering wheel. Should the driver not respond to the warning indicating that a solid line is being crossed, Active Lane Keeping Assist can trigger targeted braking of the wheels on the opposite side of the car via the ESP system to guide the vehicle back into the lane.

Preventive Action

An advanced safety feature is the standard PRE-SAFE system, which is an anticipatory system designed to protect occupants. If it detects an acute risk of an accident, it reflexively activates precautionary protective measures for the vehicle occupants, also including the reversible belt tensioning function which ensures that the occupants are better secured so that the seat belts and airbags are able to perform their protective function to the full during an impact [3]. Passengers are also protected in the event of a rollover. During normal driving, two rollbars are fully retracted in two cartridges fixed to the bodyshell in the area behind the seat backrests. When the crash sensor detects a potential rollover, the airbag control unit sends a signal and the trigger mechanism is activated. Two pretensioned compression springs in each cassette then extend the rollbars to their support position in a fraction of a second. PRE-SAFE Brake is also available as an option and is ordered together with the DISTRONIC PLUS adaptive cruise control system. When PRE-SAFE Brake detects the acute risk of a rear-end collision, it is able to trigger autonomous emergency braking. This occurs in two stages. Approximately 1.6 seconds before the estimated time of the collision, the vehicle brakes autonomously using about 40 percent of maximum braking performance, at which time the driver is also haptically warned and the reversible PRE-SAFE occupant protection systems are activated as a preventive measure. If the driver does not respond, PRE-SAFE Brake autonomously activates the maximum braking power around 0.6 seconds before the collision to reduce the severity of the impact. The system acts as an "electronic crumple zone" that provides added protection for the vehicle occupants and the other parties involved in the accident.

Adaptive Protection

The restraint systems with two-stage driver and front passenger airbags have been enhanced. A headbag provides lateral protection for the head impact area. An additional thorax airbag in the seat backrest will protect the upper body in the event of a side impact.

The crash-responsive NECK-PRO head restraints now respond more quickly to support the driver and passenger in a rear-end collision, thus minimizing the risk of a whiplash injury [3]. Also fitted as standard is automatic child seat recognition. The ISOFIX child seat fastening system is available as an optional extra. During the development process for the new SL the requirements of Euro NCAP and other rating institutes as well as Mercedes-Benz internal requirements were taken into account. The basis for this is a new light-alloy bodyshell which is formed mainly by extruded sections and cast nodes made of aluminium. It facilitates a light yet stable cell compound for a highly rigid occupant cell. In conjunction with this the tail end and front are designed in such a way that in the event of an accident they can absorb high forces through deformation, thus considerably reducing the strain on the occupants in a crash in accordance with the principle of the crumple zone. The crash boxes behind the bumper trim and an exchangeable front module ensure that the damage sustained during a front impact at up to 15 km/h can be limited

Save and Rescue

The integrated safety concept from Mercedes-Benz also regards the phase after the accident has occurred. The new SL therefore integrates numerous post-crash measures. Depending on the type and severity of the accident, the doors can be automatically unlocked, the interior lights activated, and the side windows opened by 50 millimeters to provide better ventilation in the interior. In addition to this, the steering wheel can be slid upwards. The concept is completed by the Guidelines for Rescue Services and the rescue cards which can be downloaded from the internet free of charge and which can serve as a valuable support for fire brigades [3]. *Figure 2* shows the holistic “real-life safety concept” on the example of the new SL.

Figure2. Roadster specific “real life safety concept”

Simulations Reduce Numbers of Crash Tests

Crash testing plays a significant role in the development methods applied to optimize vehicle safety, whereby outlay to this end has increased considerably since the current SL was engineered for the global market with heightened rating and legislative requirements. In addition, Mercedes-Benz vehicles have to meet sophisticated internal safety standards. Had the development methods not been adapted accordingly, these requirements would have made it necessary to conduct three times the number of crash tests than were carried out for the predecessor model. By enhancing the crash test program with targeted CAE simulations, some 20 percent of the crash tests otherwise required did not have to be conducted. Before this "CAE offensive" could be leveraged, however, existing methods had to be augmented to accommodate the new lightweight construction of the SL. This investment already paid off in the optimized product quality that was achieved with the current SL, however .

Improved Safety with Lightweight Design

The SL is the first Mercedes-Benz model series after the SLS to integrate an all-aluminum body and is the first mass-production Mercedes employing this type of design (*Figure 3*). Making the entire bodyshell from aluminum reduces the weight of the cell by 24 percent as compared to the predecessor model, while CO_2 emissions are reduced by 15 percent when viewed across the entire life cycle (including the manufacturing phase) [4]. The design of the bodyshell takes into account all requirements pertaining to unit quantities, safety, noise, vibration, and harshness (NVH) characteristics, and cost effectiveness by employing an optimized mix of cast, extruded, and sheet metal parts made from aluminum. The aluminum bodyshell also offers improvements in safety. The underfloor, for example, comprises cast parts, hollow sections, and internal high-pressure forming parts [5]. This innovative, all-aluminum structure concept gives rise to a lightweight occupant cell with pronounced structural rigidity. Areas of the structure, which are exposed to specific strain, deviate from the all-aluminum construction**.** The A-pillars are one such area and combine steel with aluminum to provide the best protection possible in the event of an accident involving a rollover. Innovative safety systems also contribute to the lightweight design of the new SL. One example of this can be found in the pedestrian protection concept. In addition to passive measures such as the good deformation

characteristics of the engine hood and optimized foam material in the front bumper, an "active" engine hood is fitted that uses pyrotechnical actuators at the rear edge to raise the panel by 85 millimeters should a pedestrian impact occur [3]. This type of actuator benefits from its lower weight as compared to conventional mechanical actuators and shaves approximately 2 kilograms off of each vehicle – another example that lightweight design can go hand in hand with a high level of vehicle safety when an innovative strategy is employed.

Figure3. SL lightweight bodyshell

Modular Strategy

Mercedes-Benz Passenger Car Development pursues a single modular strategy via vehicle architectures that provide the basis for 90 standardized modules. This modular strategy was already applied to the new SL and its safety features in particular. The airbag and side protection components, for example, are shared with those of the SLK roadster. A key requirement in implementing this concept was to integrate standardized components in a manner that does not detract from any of the customer benefits the systems have to offer. The new SL not only features standardized components, but also standardized concepts. One of these concepts is the roll-over system, which uses protective cassettes that already have established a proven track record in other model series and reduce vehicle weight.

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