New Lightweight Structures for Advanced Automotive Vehicles - Safe and Modular

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Introduction

The next generations of vehicle designs should be developed aiming for individual mobility whilst also retaining safety, environmental friendliness, and affordability. An essential step for increasing the body's performance in terms of safety and weight is the combination of high-performance materials such as new steel grades or high-performance fibre composite materials with a vehicle architecture optimised for these materials. The basis of the work is the unique synthesis of research fields at the institute, which enables findings from research on alternative power trains to flow directly into novel lightweight and hybrid constructions.

Innovative vehicle structure in rib and space frame construction

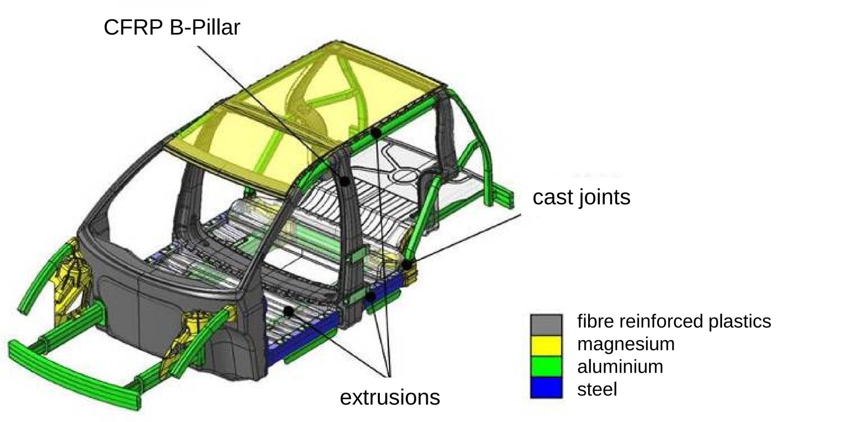

Figure 1: Material overview in the rib and space frame model

The rib and space frame construction (Figure 1) was devel-oped under the previously-mentioned objectives in line with other areas of technology, such as aeronautics. The area between the side members and the outer rocker panels incorporates energy absorbers for side impact and pole collision.

The advantages are:

- Alternative energy storage for natural gas or hydrogen can be arranged in an intrusion re-sistant area
- Modular area with standardised dimensions
- The centre of gravity can be lowered and weight distribution can be optimised

The rib's layout design and active principle

The starting point of the development was a mechanical basic principle in automotive con-struction (see Figure 2). In the event of a side impact:

- The rib´s ring structure in the base breaks open above a predefined force level.
- The intact lateral section of the B-rib rotates around a hinge joint.
- There are only minor intrusions at head and torso height.
- The space for the deployment of additional safety systems remains intact. [1]

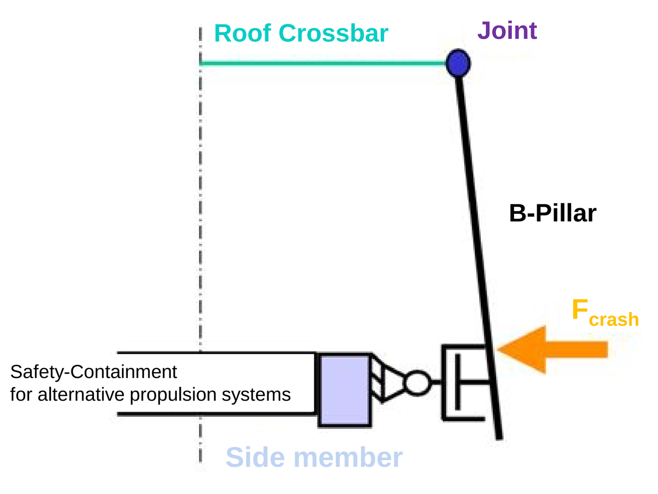

Figure 2: The rib's active mechanical principle and design

The construction method of the B-rib is an optimized three-layered structure (Figure 3) comprising an inner and an outer shell as well as an “omega” shaped profile for stabilizing the structure.

In addition, reinforcements and energy absorbers (crash cones) are located in the rib's lower area.

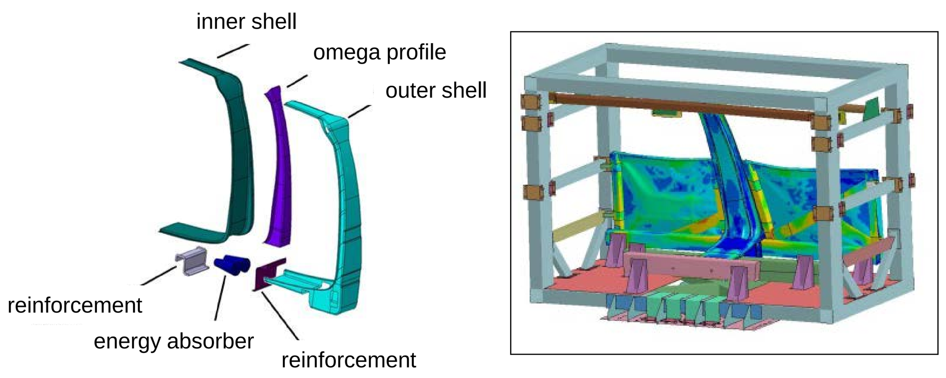

Figure 3: The rib's structure and it´s dynamic simulation

Validation of the rib prototype

Before the crash test, the structure's stiffness was tested. Furthermore, the positions identified in the simulation for the application of the strain gauge were also checked. For this purpose, different static load cases were examined (Figure 4).

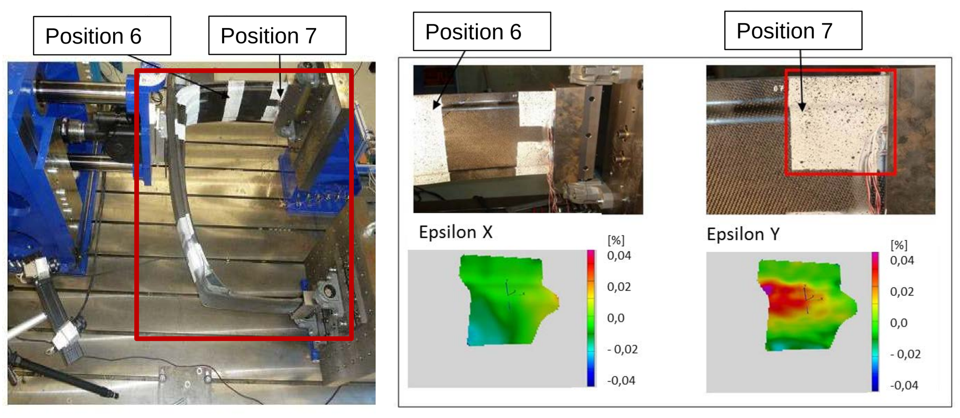

Figure 4: The rib's structure and it´s dynamic simulation

After conducting the static tests and application of the strain gauges, the rib was installed in a substitute structure representing a mid-sized vehicle. This structure is representing (Figure 5):

- the roof crossbar, rocker panel, side member and doors

with the performance (e.g. stiffness, strength) of the benchmark vehicle. Then the crash test was conducted in accordance to the American IIHS side impact. As the analysis of the strain gauges from the dynamic test shows, the area between positions 6 and 7 was the most heavily loaded, as was previously the case in the static investigation (see strain gauge DMS.E2 (E) and DMS.F2 (F) in Figure 5).

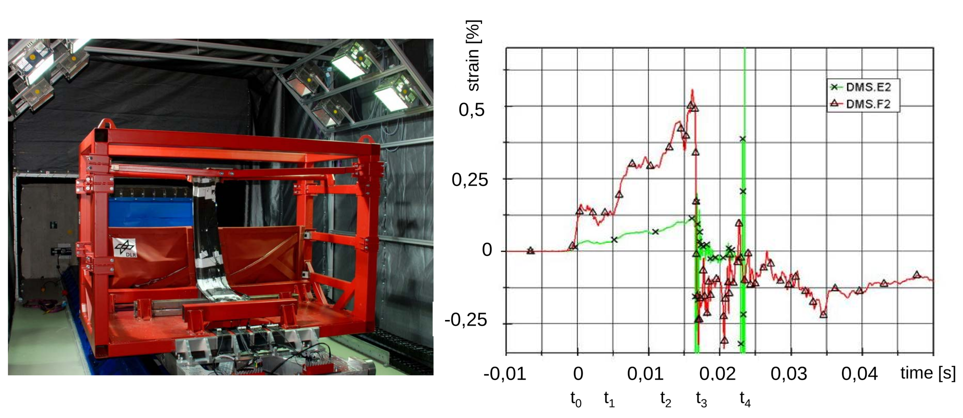

Figure 5: The structure on the dynamic-component test facility at the Institute and Selected strain gauge signals

The side-impact process can be divided into four phases here. At time t_0=0, the barrier impacts the doors causing the initial deformations and accel-erations of the free-standing test sled:

- t_1: deformation of the rib
- t_2: adhesive seam failure, which is why a slight strain-gauge relief occurs
- t_3: breakage of the inner shell, which is why strain gauges E and F are briefly relieved
- t_4: wedging of the broken shell and shearing off of strain gauge E

Safe and easy adaptable front end structure

Due to their modified package, alternative driven vehicle concepts increase the requirements on the design of vehicle front ends.
State-of-the-art passenger cars using a front structure design which is dominated from two longitudinal rails. Typically in an accident, a si-gnificant part of the kinetic energy of the vehicle will be absorbed by buckling of the longitudinal rails. Safety-relevant crash load cases are dec-isive for the design of front end structures. The front located propulsion units are integrated tightly into the structural behaviour [2].
A good structural behaviour independent of the particular type of propulsion would be beneficial. A further objective is simple adjustment of the re-quired energy absorption without major interven-tions into the basic structure.
A new type of energy-absorption mechanism in which energy is absorbed by the peeling of the outer skin of a telescopic tube has been devel-oped to achieve the objectives above. High spe-cific energy absorption of more than 40 kJ/kg [3] and near-ideal force-paths and trajectories char-acterize this mechanism. This principle was then integrated into a novel vehicle structure.

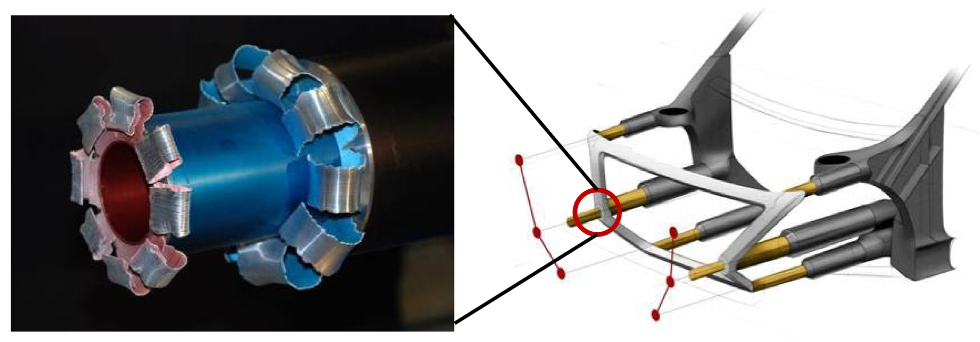

Figure 6: The rib's structure and it´s dynamic simulation

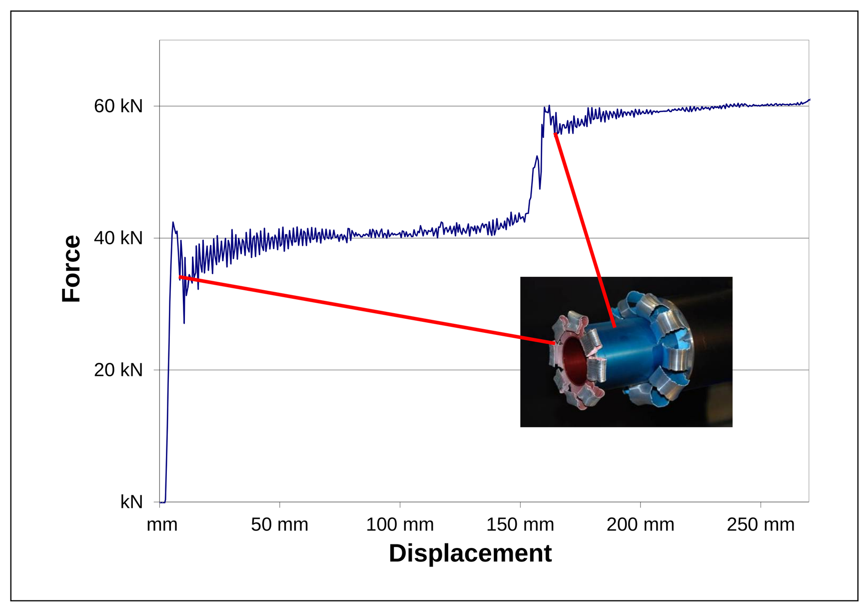

Figure 7: Force-displacement-curve of a telescopic absorber tube

Validation of the structural concept using simulation

Simulation and real crash tests of the tubes (Figure 7) and the front structure (Figure 8) have impressively shown the novel structure's potential (Figure 8).

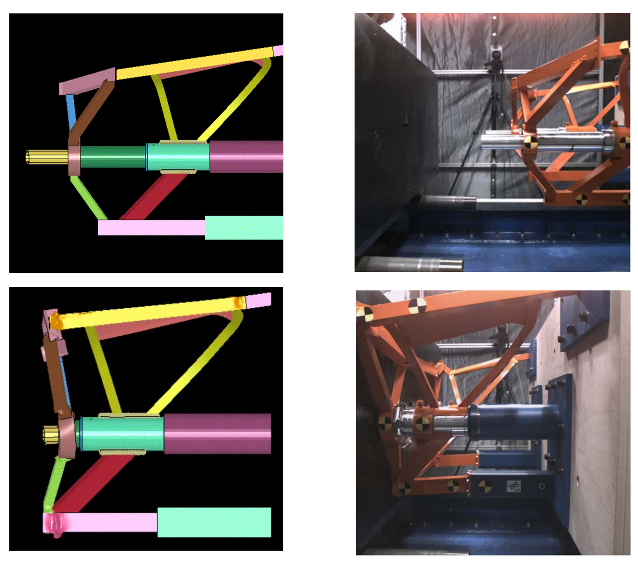

Figure 8: Comparison of crash behavior during simulation and testing (first row: before crash, second row: after crash)

The newly developed design offers not only struc-tural advantages but also weight savings of around 25 % compared to a conventional steel-body front end construction. The structure en-ables a construction with considerably improved safety versus conventional structures. This pro-perty can be used as advantage in vehicles with alternative power trains to circumvent cost-intensive adaptive developments and structural variations. The developed front end structure, which is validated through simulation and real crash tests, opens up the possibility of equipping both conventional vehicles, and those with alter-native power trains, without fundamental struc-tural changes.

[1] R. Schöll, H.E. Friedrich, Gu. Kopp, Ge. Kopp: Innovative Fahrzeugstruktur in Spant- und Space- Frame Bauweise, Sonderdruck aus ATZ Produktion Springer Automotive Media, 2008
[2] J. Hillmann, R. Cordes, S.Weyh, C.Krefter, J. Dickmann: Karosserie Perfektion in Anmutung und Leichtbau, Sonderausgabe ATZ/MTZ, April 2005
[3] Friedrich, Horst E. und Beeh, Elmar : Innovative Leichtbaukonzepte für die Vorderwagenstruktur. Vorderwagen und Front-End, München 2008

DLR Deutsches Zentrum für Luft- und Raumfahrt