A New Support Structure for **Independent Wheel Suspensions in Heavy-Duty Trucks**

Thyssen-Krupp Automotive Systems in Essen has presented an all-new support structure for independent suspensions in heavy-duty trucks. The system features innovative solutions for suspension mountings, frame structures and steering. It will improve handling characteristics and ride comfort and as well allow for future engine generations and emission demands.

1 Introduction

Whereas an independent suspension has been available for the steered wheels of buses and light trucks for some time now, the transfer to heavy-duty trucks has posed a serious challenge. On one hand, the system has to deal with high axle loads, and on the other there is little room for its installation as a result of the front-mounted engine. However, advantages associated with the independent suspension (suspension comfort, improved steering behaviour, modular design) generally justify the development of such new support frame concepts.

Ever since trucks have been manufactured, their support structure primarily consists of two side members (most commonly C-shaped). Although such a ladder frame will leave sufficient room for adding various types of vehicle bodies and any form of rigid axle arrangement, it is not optimal for load bearing and it requires additional structural components for independent wheel suspensions.

To solve this problem, Thyssen-Krupp Automotive Systems has come up with an innovative concept whose starting point is an optimized topology within the vehicle's front end packaging space. Another factor that influenced the endeavour to find optimal load paths for different load levels was the desire to improve partner protection during crash (front underrun protection).

2 Requirements for Future Truck Chassis

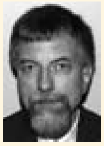
Future generations of commercial vehicles will have to meet several requirements that affect the design to various degrees. Among the objectives that commercial vehicle manufacturers continuously strive to achieve are the improvement of handling behaviour and the enhancement of ride comfort. Major aims in this regard are the reduction of body roll and pitch. Another challenge is to create more room for the engine and the power train, which is particularly important for enabling diesel engines to meet future emission requirements. The main features of an efficient design are compact arrangement, modular construction, and preassembled modules. An optional aspect that may have to be considered is the use of alternative steering systems. Generally, requirements to be met include a correspondingly large steering angle and a small turning circle.

3 Advantages of the Double Wishbone Axle

Thyssen-Krupp Automotive Systems has used double wishbones for the new steering axle with independent suspension. The wheel location is governed by the wheel knuckle, which is connected to the vehicle frame by means of an upper and lower control arm, **Figure 1**. In this design, wheel travel has been limited to a range from +100 mm to -100 mm, which is regarded to be sufficient for the needs of the mass market trailer tractor. The advantages of this type of axle are obvious, since it allows kinematic properties to be optimally set and makes it possible to transmit forces between the wheels and the frame along favourable load paths.

It was decided to separate suspension and damping elements in order to get a more effective use of space and improve the load distribution. Because such axles generally have ball-joint connections to the wheel knuckle, the number of components can be reduced. A particular design aim in this system is to keep the control arms as short as possible in order to provide more room for the drive-train and to reduce the vehicle weight.

Author



Dr.-Ing. Dirk Ziesing is responsible for CAE coordination at Thyssen-Krupp Automotive Systems in Essen (Germany).

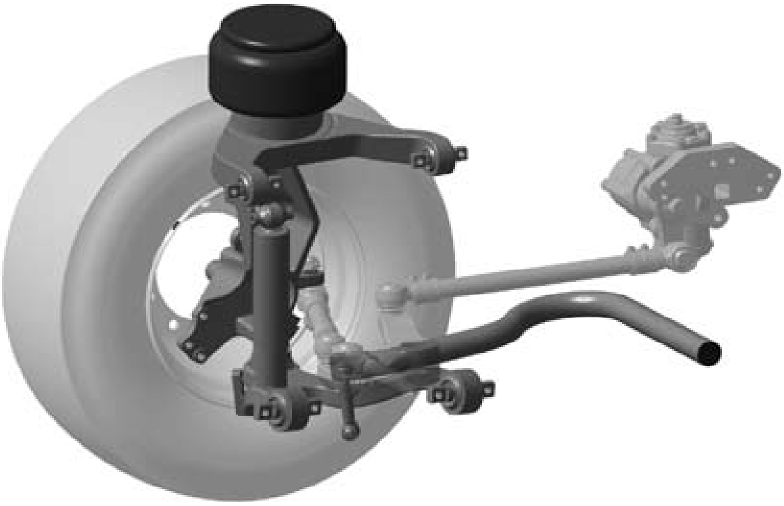


Figure 1: Independent wheel suspension with double wishbone design

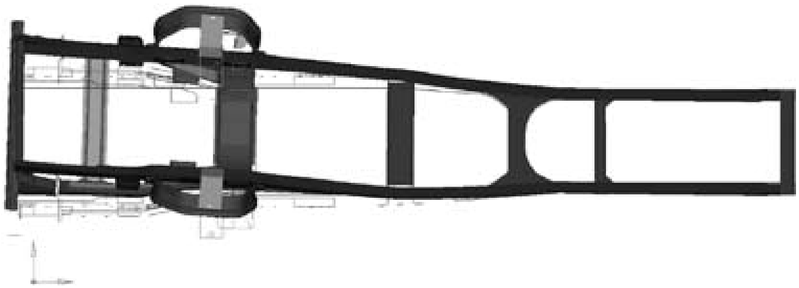


Figure 2: Deformation analysis in order to evaluate structural stiffness

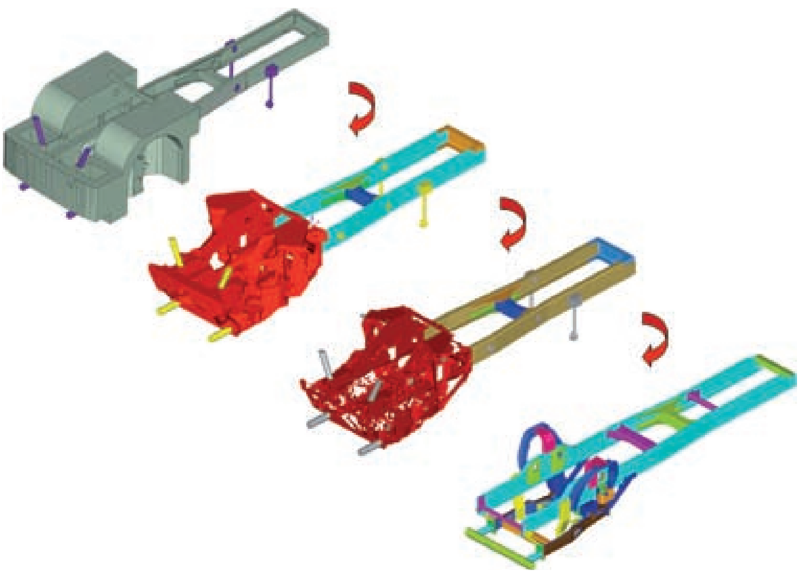


Figure 3: Topology optimisation steps – from the package to a design ready for manufacture

4 Requirements of the Support System

It is assumed that the investigated front axle has a load of 8 t. This results in the following conditions for the arrangement of the components: the static wheel load is around 40 kN. Setting the dynamic magnification factor to 2.5, the corresponding vertical load is 100 kN. The forces from transverse impacts are similar in magnitude, at about 80 kN. Finally, if a braking torque of 30 kNm is to be achieved, the longitudinal force at the wheel contact area, with a tire radius of 0.5 m, will be 60 kN in the direction of travel. Naturally, this demands a corresponding friction coefficient in relation to the wheel load in order to transfer the given horizontal force from the tires to the road surface.

Besides this basic concept of load requirements, the vehicle structure must also meet certain stiffness targets to ensure that internal deformation of the supporting frame has no negative effects on the vehicle's handling. In this case, both transverse and torsional stiffness are common parameters. To determine their values for means of comparison, the frame is fixed at the rear, while the front is loaded with standard loads, **Figure 2**.

In addition, since 2003, EU laws require that newly registered trucks offer a front underrun protection. This protective system is designed to prevent trucks from rolling over passenger cars following a frontal collision. The regulation applies to vehicles over 7.5 t GVW, which means that it does not affect delivery trucks below this weight. In addition, more than 15 % of heavy-duty trucks are subject to a special exemption for off-road vehicles, allowing them to dispense with any protective measures for road traffic. To achieve this protective standard, the following requirements must be met: a horizontal force of up to 160 kN is applied at predefined points at a height of up to 445 mm above the road surface. When this force is applied, the penetration must be limited to a depth of 400 mm.

This defines, however, only a geometrical limit. In addition to the minimum legal requirements, it is desirable that the front of the truck presents energy-absorbing structural sections. With regard to the costs, these deformation elements should be easily replaceable and feature a defined interface to the main structure, which must remain free of damage up to a predefined crash level. Thyssen-Krupp Umformtechnik has gained considerable expertise in the development of so-called crash boxes, which are easy to incorporate into the new axle system concept.

5 Topology Optimisation within the Available Packaging Space

The design measures are restricted to the front end of the vehicle. That means this study does not extend to the tractor's rear frame around the king pin and the driven rear axle. The first task was to create a model of the available packaging space, while taking the geometrical situation into account. This 3D model was meshed by means of solid finite elements and subjected to an optimisation process using special software. In a number of steps, this process reduced the structure to the regions required for transmission of the forces, **Figure 3**. Non-load-bearing areas were detected with the help of a notional density graduation. The result is a skeletal residual structure, shown in **Figure 4**.

6 Transfer of the Optimal Structure to a Sheet Metal Design

Large-scale downstream operations and interpretations of the results are required to transfer the optimised solid model into a design suitable for manufacturing from sheet metal and profiles.

Even with the computer capacities available today, there are still limits to how far the meshing fineness can be carried. It is therefore unavoidable that the result will have a substantial layer thickness even in the minimised structural areas. This is in contrast to shell struc-

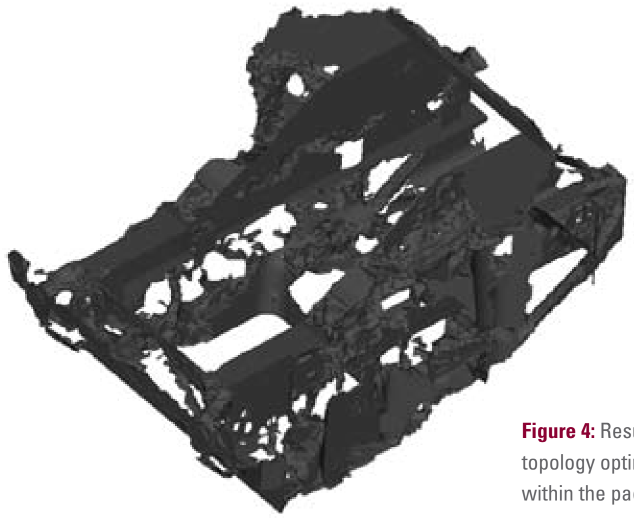


Figure 4: Result of the topology optimisation within the package space

tures, in which the thickness of the surface elements is negligible, compared to the length of the edges.

As soon as a welded or bolted design has been created suitable for manufacture, it can be fine-tuned through a parameterised optimisation of individual sheet thicknesses. It is during this phase when the expertise of Thyssen-Krupp Steel comes into play. Whereas a traditional ladder frame for trucks is made of conventional steel grades, the use of new high-strength grades, offered by Thyssen-Krupp Steel, makes it possible to further reduce the weight of the support structure.

An evaluation of the final sheet structure of several axle projects for passenger cars shows that the results are 90 % in agreement with those of the three-dimensional structures considered to be optimal.

The concept created in this manner features several innovations that set the support structure apart from previous truck frame designs. The lower structural section is a major part of the overall system. The specified height for applying the passenger car crash loads results in a load path that must be suitably transferred to the main frame. If the crash box is connected to the longitudinal member in the classical way there inevitably exists a corresponding lever creating a considerable bending moment. On the other hand, the effectiveness of the Thyssen-Krupp solution is comprehensible. The pronounced lower substructure is connected to the main structure at several points. This results in distributing the force to be transferred and makes it possible to reduce the weight of the individual connecting elements.

By the way, the distinction of primary and secondary load paths in particular for crash design is to be found in passenger cars, too, if a part of the forces is assigned to the doors, for example.

7 Business Opportunities

The system's modular design and the reduction of the number of variants and components create potential savings that make it interesting for commercial vehicle manufacturers. Considerable business opportunities are also created by the foreseeable tightening of the emission regulations for commercial vehicles and the associated requirements with respect to packaging space. Series produced heavy-duty trucks with independent suspension are currently not available on the market. However, for the reasons given above, it is only a question of time until such systems are at least introduced for front axles.

A life-size model of the structure was first presented in 2006 at the International Truck Show in Hanover, **Figure 5**, where it met with a great response from trade visitors. Furthermore, this concept has been presented in June 2007 during the Trucknology Forum at MAN Nutzfahrzeuge in Munich and it has been published in the VDI report no. 1986. ■

Figure 5: Truck show model of the structure featuring the independent wheel suspension