Measurement of Wheel Force for Durability Analysis at Daimler Truck

Durability Analysis

At the EVZ, the development and testing center at Daimler Truck in Wörth (Germany), new trucks are being developed to production readiness. Twelve years ago, the decision was made to measure the forces interacting between ground and wheel with wheel force transducers, and three years ago the Kistler KiRoad Performance system was introduced. During the testdrive, the forces and torques acting on the rotating wheel in the X-, Y- and Z-axes are precisely measured and acquired. At the same time, measurements are carried out with CSM measurement technology on up to 200 analog channels in order to be able to analyze the mechanical loads in the components. With the KiRoad Performance Gateway developed by CSM, the measurement data from the various systems can be synchronously acquired and evaluated.

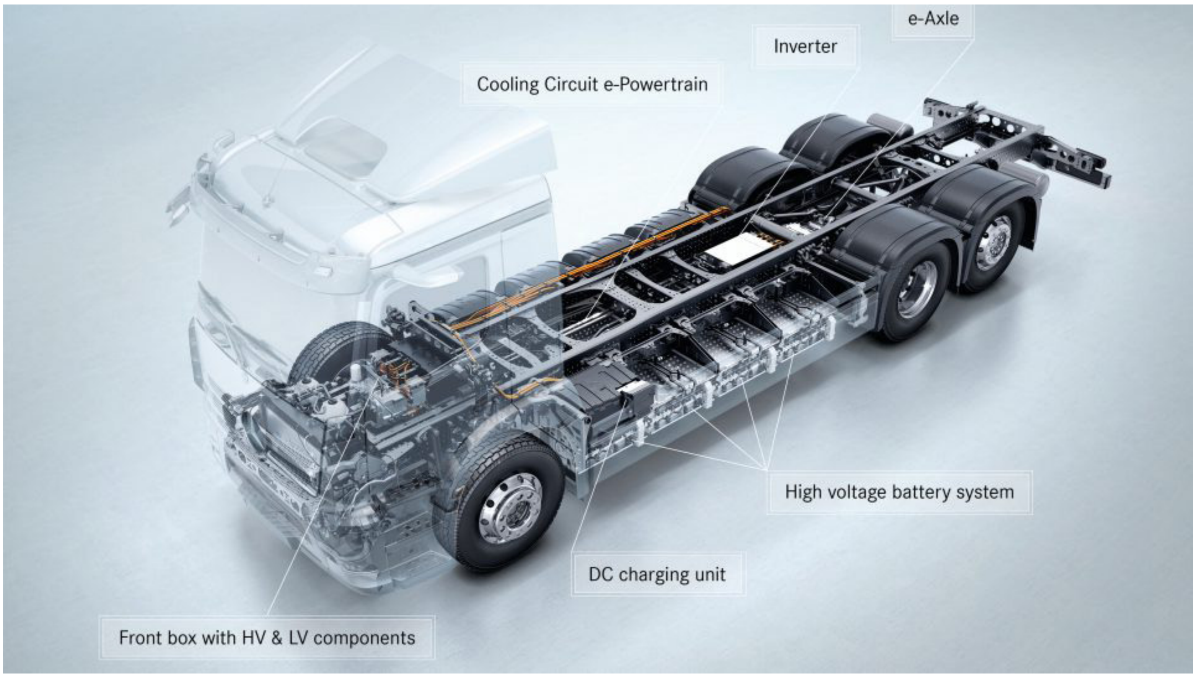

Fig. 1: eActros design: The high-voltage battery systems are installed between the front and first rear axle. The first rear axle forms the e-axle construction with two electric motors and auxiliary units.

Background

The mobility of the future and renewable energies to replace the combustion engines are the automotive industry's current preoccupations. Daimler's first fully electric truck, the eActros, was launched in 2021. Their plan: further battery-electric vehicles are to be developed and launched on the market as quickly as possible. The eActros will be used to expand the experience gathered to date. Philipp Benz, Test Engineer for Vehicle Testing and Durability at Daimler Truck, explains:

"Our aim now is to understand in depth what is happening in the vehicle. We're trying to capture the loads that are acting on the vehicle, over the entire vehicle life cycle."

This includes normal loads on public roads, such as potholes, but also special maneuvers, such as maneuvering, loading or tipping operations when unloading bulk materials. This causes forces to act via the wheels on the axle and into the vehicle frame, the effects of which must be acquired and evaluated. On the test track for durability testing in Wörth, the service life of many hundreds of thousands of kilometers can be simulated in a compressed time. Particularly severe loads such as railway thresholds, potholes and washboard surfaces are also available here, so that reproducible worst-case track profiles can be created. They serve as a reference for a wide range of performance and durability analyses.

Measurements are made with strain gauges, wire-draw displacement transducers, laser sensors and accelerometers on the axle to see how it moves in three dimensions. For this purpose, all movements, vibrations and accelerations are characterized and, in addition, the strains, bends, compressions and torsions in the components are verified in order to make a determination about the structural strength.

Challenge

A challenge arises from the E-axle design (Fig. 2) and the associated arrangement of the individual components. A flanged cast housing is attached to the E-axle, onto which various components are assembled. These include oil pumps and heat exchangers as well as the two electric motors. In addition, there are the high-voltage cables for the electrical connections.

In a conventional truck, the combustion engine sits at the front of the vehicle and power is transmitted to the rear axle along the length of the vehicle via a driveshaft. In the electric eActros model, there is no longer any space for the drive shaft, as the battery modules are placed in this installation space. The electric motors are therefore integrated directly into the axle. Compared to the normal axle, the E-axle has a different weight and a different center of gravity.

"We need to examine exactly what this means for the vibration behavior of the entire axle and how it affects driving."

Philipp Benz.

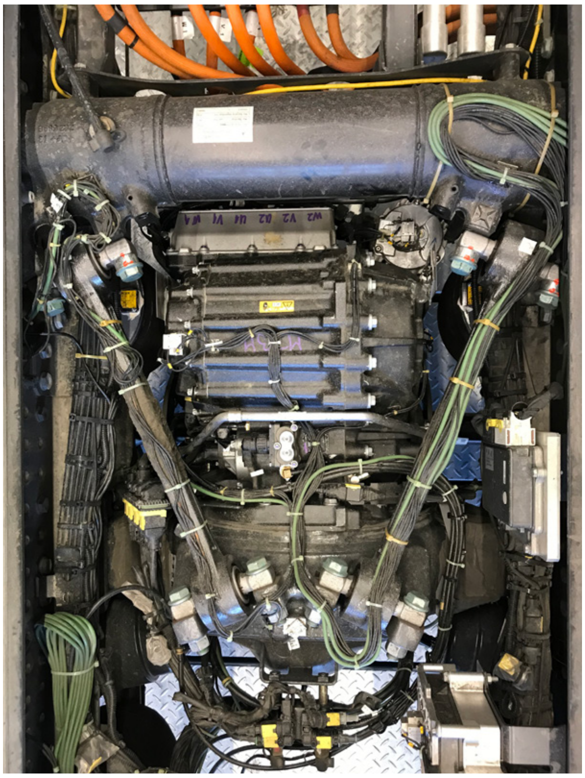

Fig. 2: E-axle with the electric motors; on the left and right of it, the air bellows under the frame longitudinal member.

The measurement data obtained must be precisely synchronized to allow interpretation of the measured loads. For example, this is the only way to determine the correlation between an occurring wheel load and the resulting deflection.

To achieve this, the acquisition of measurement data from the Kistler RoaDyn wheel force transducers (Fig. 6) and the analog CSM measurement technology in the vehicle must be precisely synchronized in timing.

"We therefore approached to CSM to develop a solution."

Philipp Benz

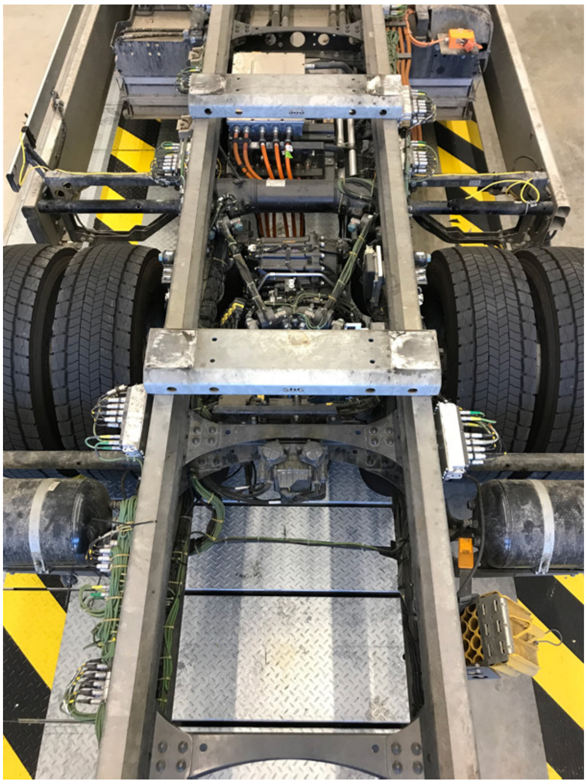

Fig. 3: eActros E-axle from above with applied measuring sensors: The CSM measuring modules are attached to the side of the vehicle frame. Due to their robust design, they can be installed within the construction.

Fig. 4: Lasers are used to check whether collisions can occur between air bellows and the cast housing of the E-axle.

The CSM Measurement Solution

For simultaneous acquisition of the signals from the Kistler wheel force transducers and the analog sensor signals, CSM developed the KiRoad Performance Gateway. The Kistler KiRoad Performance electronic unit is connected to this and, in parallel, the CSM ECAT measurement modules for all analog channels required for the measurement campaign.

The KiRoad Performance Gateway synchronizes the clock supplied by the KiRoad measurement system with all other connected analog channels. This means both the measured values of the CSM EtherCAT measurement technology and those of the Kistler KiRoad system are acquired simultaneously. They can thus be compared directly on the DAQ computer and analysis software, Vector CANape or vMeasure. In addition, KiRoad Performance measurement data is now available PTP synchronously according to IEEE 1588.

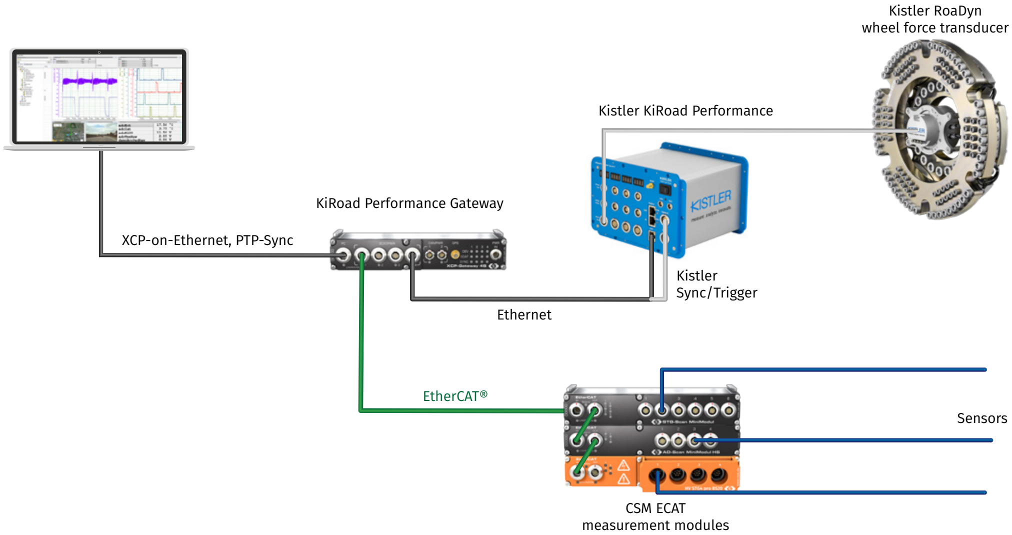

Fig. 5: The CSM KiRoad Performance Gateway sends acquired measurement data to the measurement computer. The measurement data of the wheel sensors are acquired with the Kistler KiRoad Performance. Synchronously, the measurement data from strain gage and acceleration sensors via CSM ECAT measurement modules.

KiRoad Performance

The compact KiRoad Performance electronics unit is used for the supply, configuration, signal processing and data output of up to four RoaDyn wheel force transducers, for rotating or stationary applications. It processes the raw signals from the measuring cells in a crosstalk- and lever arm-compensated manner and ensures the highest possible accuracy of the measurement results. These data are provided in digital and analog form.

If another KiRoad electronic unit is connected, up to four additional RoaDyn wheel force transducers can be included in the measurement. The CSM KiRoad Performance Gateway supports this linkage as an option.

Fig. 6: RoaDyn measuring wheel on the E-axle for measuring the three-dimensional wheel forces (Fx, Fy, Fz) of +- 180 kN and torques (Mx, My Mz) of +-50kNm.

A measurement campaign has a scope of at least 115 analog channels.

"We were concerned about collisions between the air bellows and the cast housing of the E-axle. To clear up these concerns, we had to verify that the distance was sufficient for all extreme cases, even with the largest lateral forces. For example, when we drive the electric motors under full load for minutes at a time on a winding mountain road, where the road surface is also very poor and has many potholes."

Philipp Benz

Fig. 7 shows the transverse force on the wheel and the transverse displacement of the axle, which was measured using a laser sensor, during a figure-eight run. The graph shows a clear correlation between the transverse displacement of the axle and the transverse force of the Kistler measuring wheels. The measurement thus allows estimates to be made of how the transverse displacement of the axle, and thus the clearance to neighboring components, shifts when the transverse forces change as a result of adjusted general conditions.

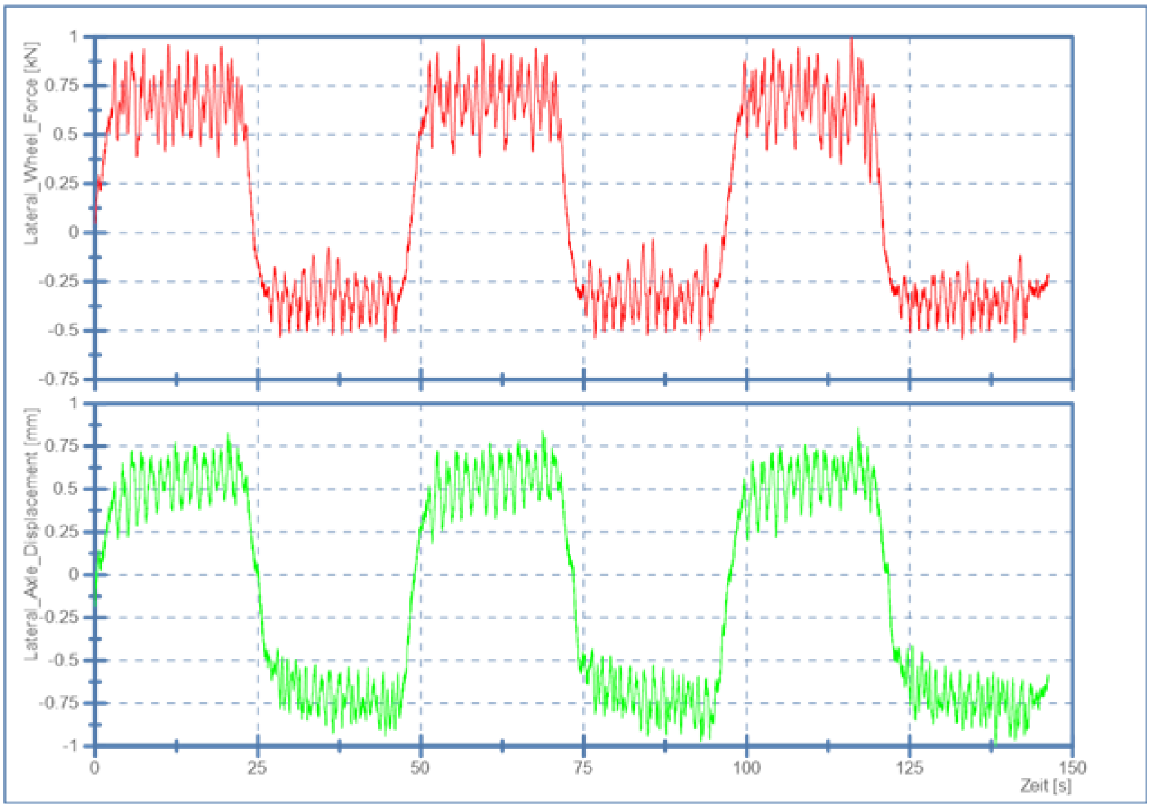

Fig. 7: The measurement result of the laser measurement shows a correlation between the transverse travel of the axle and the applied transverse force on the wheel

Thanks to the measurement solution developed by CSM, it was thus possible to ensure that the transverse travel of the E-axle remains small enough, even with the highest transverse forces, so that there is no collision with neighboring components.

Durability tests for components are carried out on test rigs using the road and bad road data recorded in the road test. For example, on axle test rigs, including all axle-guiding components (chassis). With the help of the recorded wheel force measurement data, the test rig is set up to travel hundreds of thousands of kilometers in fast motion.

The characteristic force input must be precisely adjusted on the test rig with the aid of wheel force measurement so that the force inputs correspond to the recorded path data. Then the axle can be loaded in exactly the same way as on the test track itself.

In order to quickly verify special requirements for durability or to specifically identify weak points, wheel force measurements and strain measurements must also be performed synchronously here.

Several test can be performed more quickly on the test rigs, with the same loads as on the road, even if there is not yet a finished test vehicle. It is then possible to investigate very quickly on new components exactly which wheel forces and moments represent particular loads that affect structural strength. In the future, measurements are planned on tandem axles, on which measurements will be made with up to 250 analog channels.

"Further on, we also have tipper trucks with four axles. Two KiRoads are then coupled together there."

Philipp Benz

Benefits

A single module integrates Kistler wheel force measurement into CSM measurement technology. This enables durability analyses to be performed more quickly and precise because the data correlation of mechanical load measurements and wheel force measurements is synchronized with high precision.

Measurements on electric vehicles where sensors are placed in a high-voltage environment, such as inside the battery assembly, and wheel force measurements can be carried out simultaneously. This makes it possible, for example, to investigate the force and momentum inputs of bad roads and their effects on HV batteries.

Elaborate improvement installations obtained from simulations can also be validated very accurately after installation. For example, tests for wheel imbalance excitation, brake friction excitation or vibration excitation on roads and test rigs.

Other applications, such as tests on vehicle dynamics, measurement of the exact longitudinal and lateral dynamics or the braking distance are possible.

Featured Products

KiRoad Performance Gateway

The KiRoad Performance Gateway is used for synchronous data acquisition from Kistler KiRoad measurement wheels and CSM ECAT measurement modules. This enables the simultaneous analysis of mechanical loads in vehicle wheels as well as other measured values on other components. This gateway was designed specifically for this application.

Complete solutions from a single source:

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