The largest diesel electric mining truck currently in production, the Liebherr T 282 B

Designing Giants for Tough Work

Liebherr engineers rely on ANSYS structural simulation technology to develop giant diesel electric trucks designed to withstand harsh mining operations while providing maximum load capacity.

By Vladimir Pokras, Analysis and Simulation Manager, Liebherr Mining Equipment Co., Virginia, U.S.A.

Ultra-class mining trucks are designed to transport heavy loads of raw materials over spiraling roads from the world's largest open-pit mines, which can reach more than 600 meters into the earth. These huge vehicles have average load capacities of hundreds of tons, compared to typical construction-site haulers carrying 50 tons or less.

With fuel efficiency, hauling productivity and operating costs high on their list of priorities, mine operators are particularly drawn to trucks with electrically driven wheels powered by diesel generators, instead of mechanical powertrains with gearboxes and driveshafts. Diesel electric trucks typically are easier to operate, cost less to purchase and generally outperform mechanical trucks, especially on steep grades. They're also easier to repair and maintain, which is a real plus in remote mining locations where uptime is critical and work must be done on site.

Liebherr Mining Equipment Co. is a global leader in designing and manufacturing these durable monster trucks. The company's flagship is the T 282 B, the proven largest diesel electric mining truck currently in production. With a load capacity of 363 metric tonnes, the 7.8-meter-high behemoth is 15.3 meters long, runs on a set of six 4-meter tires, and is powered by a gigantic 3,650-horsepower diesel engine.

The payload to empty vehicle weight ratio is a very important characteristic for the giant trucks. The T 282 B, rated at 1.6, offers the best ratio in its size class. This is a distinct competitive advantage for a number of reasons: Lighter trucks can carry more payload without exceeding tire capacity; expensive tires each costing tens of thousands of dollars last

longer; and the trucks save on fuel on their empty return runs.

The engineering challenge is designing lightweight trucks strong enough to withstand harsh mining operating conditions. This is no easy feat, considering that mining trucks are some of the most abused vehicles in the world. Often, operators drive as fast as they can to haul as many loads as possible over huge boulders, deep craters, hip-deep mud and water-logged muck. Trucks are put to the test every hour of every day in conditions like this around the world, hauling coal in Indonesian rain forests, gold in Nevada deserts, copper ore in Chile, iron ore in South Africa, and oil sands in northern Canada.

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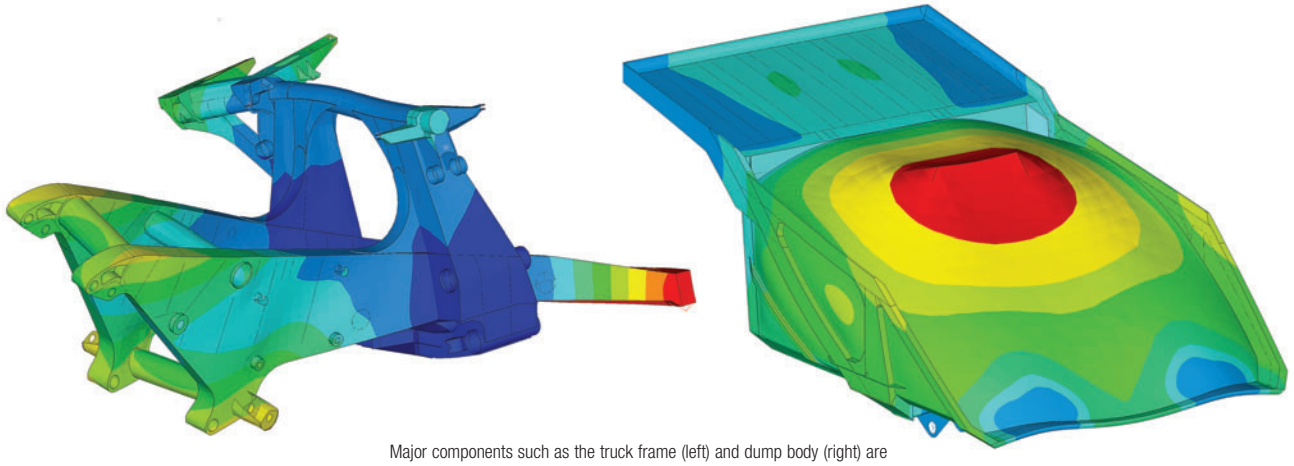
Considering the millions of dollars and months of work that would go into just one round of physical testing to ensure truck designs will withstand such punishment, Liebherr relies heavily on engineering analysis to design every one of its trucks. In particular, engineers create virtual vehicle models to predict truck behavior for a variety of load cases, including turning, hitting deep holes and bumps, and backing into barriers. When simulation indicates a potential trouble spot, it is then simple to modify the virtual model to explore alternatives and what-if scenarios that would be entirely impractical to study with physical mockups.

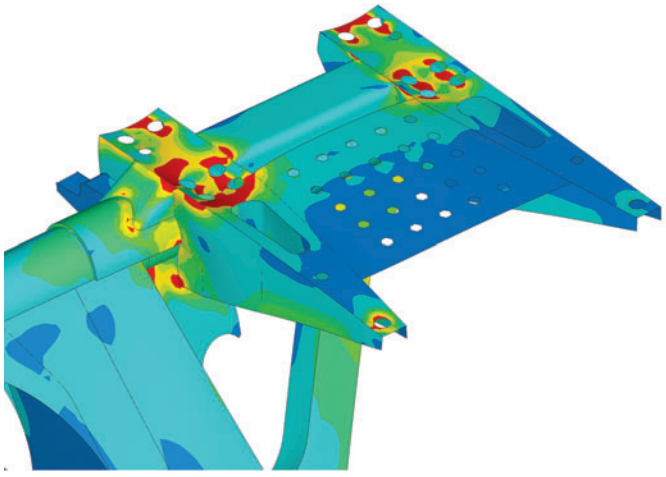
Engineers at Liebherr work to resolve problems and refine designs earlier in development and reduce the number of vehicle prototype test cycles. Currently, two or three physical mockups are needed for a typical new truck design — half the number built and tested 10 years ago. The aim is to perform simulations so accurately and in such great detail that only a single physical prototype would be needed to validate the mechanical and electrical design of the vehicle before production begins.

The key to this simulation-based design approach is the advanced analysis performed with ANSYS Mechanical software in calculating the stress, stiffness, deformation and natural frequencies of critical vehicle components and subsystems — especially in cases in which their flexibility and nonlinear behavior must be accurately characterized. Otherwise, modeling all parts as rigid members would lack sufficient accuracy for predicting real-world vehicle behavior in multibody virtual models.

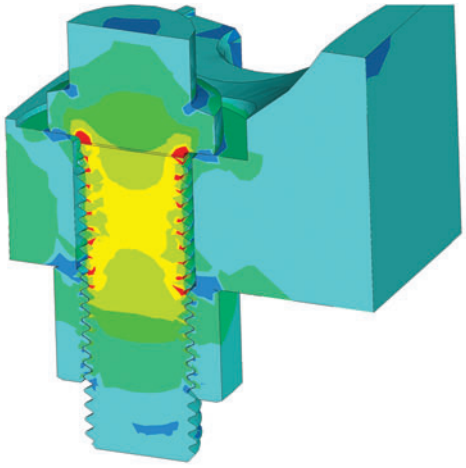
The Craig–Bampton method of representing flexible bodies in ANSYS Mechanical software works effectively for Liebherr engineers. In this technique, the mass and stiffness of parts are represented with generalized coordinates or mode shapes. This reduces the number of degrees of freedom in the analysis while providing accurate static and dynamic characteristics of the bodies. Representing components as flexible bodies is especially important for parts that must be analyzed undergoing relatively large deformations. Examples include the truck frame and superstructure



Major components such as the truck frame (left) and dump body (right) are represented as flexible bodies to study how they deflect under heavy loads.



Nonlinear stress analysis of the cab and support structure is critical for driver safety, such as in case of a serious accident, when the components must deform well beyond the material yield point.



Contact element and friction features, central to the analysis of the many bolted joints on the truck, are readily characterized in ANSYS Mechanical software through the use of pretension elements.

as they deflect under the forces experienced as the vehicle traverses rough terrain with heavy loads.

A very important capability of software from ANSYS is analysis of a variety of nonlinear materials. The operator's cab that incorporates a roll-over protective structure to provide safety for a driver in case of a serious accident must be able to deform well beyond the yield point to absorb the energy of impact. Therefore, advanced nonlinear material analysis is employed for its design.

The surface-to-surface contact element capability that automatically detects contact points between touching parts allows for different material behavior. Using contact elements with friction enables Liebherr engineers to calculate forces, for example, on the dump body from the interaction between the dump body and various payloads such as dirt, rocks or iron ore. Contact element and friction features are also central to the analysis of bolted joints, which are readily characterized in ANSYS Mechanical software through the use of pretension elements.

Using these capabilities, Liebherr engineers gain a detailed understanding of the behavior of vehicle parts and assemblies throughout the development cycle, before any hardware is built. Simulation gives engineers practical insight into the behavior and performance of the components, assemblies and full vehicle. The role of simulation at Liebherr has shifted from that of a verification tool at the end of design to an up-front development tool totally integrated into product development processes.

Certainly, mining trucks can be developed without using simulation. Other companies do it all the time and have been designing similar vehicles for decades. But the only way to design optimally strong and weight-efficient trucks is with advanced simulation tools like ANSYS Mechanical — tools that can help an organization maintain a leadership position in the highly competitive global mining equipment market. ■

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