Bigger is better:
designing monster mining trucks

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ENGINEERING INNOVATION

Liebherr counts on LMS multibody and durability technology to design the world's largest diesel-electric mining trucks. Built to withstand the rigors of harsh mining conditions while providing maximum load capacity, these colossal giants not only dwarf conventional haulers, they out perform them as well.

Ultra-class mining trucks are BIG. Point. Average load capacities run to the hundreds of tons, an overwhelming number compared to a typical construction-site hauler carrying 50 tons or less. Hauling mega-loads of iron, copper, or gold ore, coal and other raw materials, these vehicles can travel up to 64 km/hr over flat terrain or spiral for miles up and down rough haul roads of the world's largest open-pit mines reaching depths more than 600 meters.

Demand for these commodities has risen sharply in recent years – as have prices – so mine operators have strong financial incentive to invest in new equipment to get precious metals and commodities out of the ground faster. Companies are particularly drawn to trucks with electrically-driven wheels powered by diesel generators instead of mechanical powertrains with gearboxes and driveshafts. Diesel-electric trucks are often easier to operate and they generally outperform mechanical trucks, especially on steep grades. They also are less expensive and easier to maintain so that in remote locations, Liebherr mining trucks are just where they need to be: in the mines and not in the repair shop.

With an empty weight 12% less than comparable mining trucks, the T282B has a competitive advantage since lighter trucks save on fuel on their empty return runs and significantly extend tire life – costing tens of thousands of dollars each.

The market for ultra-class diesel-electric trucks has been booming in recent years, with orders at the highest levels in decades. Liebherr Mining Equipment Co. – one of the global leaders in this growing market – reports that sales have increased 10 to 15 percent in each of the last five years. To keep pace, Liebherr recently added a third shift at its ten-acre factory in Newport News, Virginia.

Biggest of the big

Liebherr's flagship is the T282B, the world's largest diesel-electric truck currently in production. With a load capacity of 363 metric tonnes (equivalently to the weight of more than 210 minivans), the 7.8-meter-high behemoth is 15.3 meters long, runs on a set of six four-meter tires and is powered by a gigantic 3,650-horsepower diesel engine. "It's like driving a two-story house," said Liebherr Mining Equipment Analysis and Simulation Manager Dr. Vladimir Pokras.

One of the primary requirements when designing these giant machines is that total vehicle weight cannot exceed tire capacity. Every kilogram shaved from the vehicle structure can be added to the payload. The T282B is 12% lighter than other comparable mining trucks. This is a distinct competitive advantage since lighter trucks save on fuel on their empty return runs and significantly extend tire life. This is a major cost-saver considering that tires this size cost tens of thousands of dollars each.

Tire wear is also minimized by the kinematics of the Liebherr dual parallel control-arm arrangement and by a differential driving wheel control system that automatically adjusts the torque and speed of the traction motors when turning.

The most abused trucks in the world

The engineering challenge is integrating advanced features like the differential wheel control system into a lightweight truck strong enough to withstand the harsh mining operating conditions. As one could imagine, this is no easy feat.

Take the PT Kaltim Prima Coal mine in Indonesia, for example. Situated one degree north of the equator in a remote rainforest where hip-deep mud is common, this mine relies on more than thirty T282B trucks to get the job done. Likewise, Liebherr trucks can be found hard at work mining gold in Nevada, copper in Chile, coal in Australia and iron ore in South Africa.

"Mining trucks are some of the most abused vehicles in the world," said Dr. Pokras. "At many of these mines, operators drive as fast as they can over refrigerator-size boulders and holes as big as bathtubs to haul as many loads as possible."

Trucks are also put to work traversing layers of clay and water-logged peat – a cushioned terrain described as "like driving on a mattress" – to mine oil sands in northern Canada. Containing a thick form of petroleum that can be extracted and upgraded to useable products, oil sands are a hot commodity in light of rising crude oil prices and are estimated to represent as much as two-thirds of the world's total petroleum resource. At least 1.7 trillion barrels of petroleum are estimated to be in the Canadian Athabasca Oil Sands where Liebherr trucks are in increasingly heavy demand.

The critical role of multibody dynamics

Considering the millions of dollars and months of work that would go into just one round of physical testing, Liebherr relied heavily on engineering analysis to design the T282B to operate efficiently under such heavy-duty conditions. In particular, LMS multibody dynamics technology was used for full-vehicle simulations to study the truck's behavior on various terrains with a variety of load examples, including acceleration, braking, turns, bumps, holes, washboarding, up and down steep grades and bumping into rigid barriers.

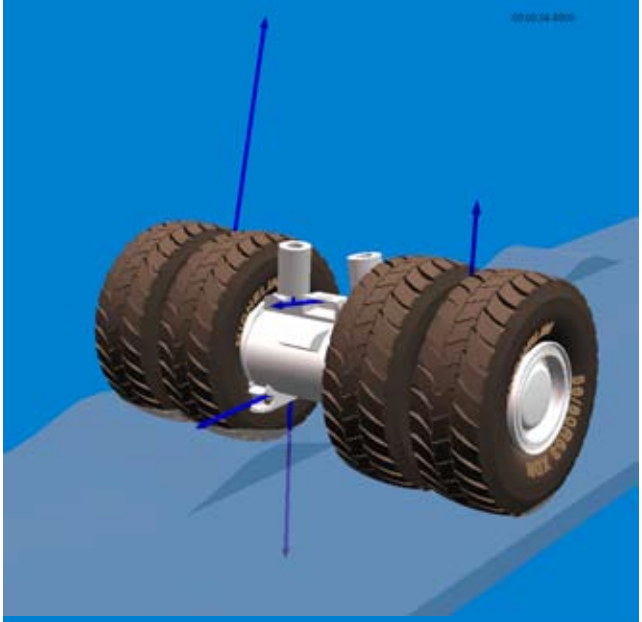
To refine the design as quickly and early as possible, multibody simulation models were created up front in the conceptual stage by the analysis and simulation group and modified as more information became available. Initial geometries of major truck parts and assemblies were estimated from preliminary solid models and pieced together as rigid bodies into a first-pass full-vehicle multibody model. Then, loads from a multibody simulation were generated for the structural group to perform finite-element analysis for computing stresses on the frame and other structural components; the mechanical group re-used these same loads to design the vehicle hydraulics, suspensions, the powertrain and other systems.

A central point to design a unified full-vehicle model

"In this way, LMS multibody dynamics serves as a central point where all the designs of individual major components and subsystems come together into a single unified full-vehicle model," Dr. Vladimir Pokras explained. As component and subsystem designs proceed, these engineering groups update their individual solid and finite-element models. The new information is imported into the multibody model where the analysis and simulation group can also add greater detail such as stiffness, damping and mass properties.

"Links with finite-element codes streamline the iterative process of updating LMS multibody dynamics models," noted Dr. Pokras. "With the ability to quickly enter additional details, we can generate new multibody models much more quickly and with fewer errors than building them from scratch each time. The capability to import finite-element models as flexible bodies in the LMS multibody solution is key to accurate full-vehicle simulation."

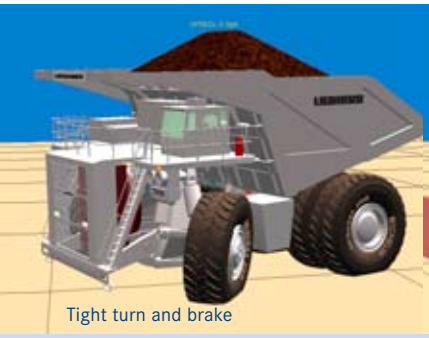
"The only way to design a market-leading, optimally weight-efficient truck is with advanced simulation tools like LMS durability and multibody software, tools that we not only should use, but must use. We can't maintain our market leadership any other way."

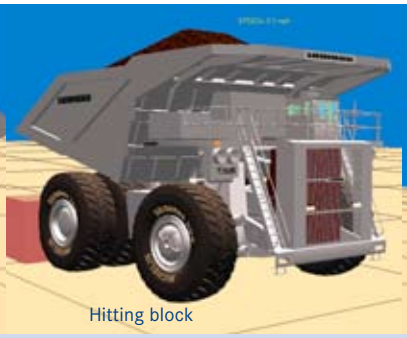


LMS multibody dynamics was particularly helpful in studying the behavior of many different alternatives in redesigning the T282B axle box to save weight and allow for easier service accessibility.

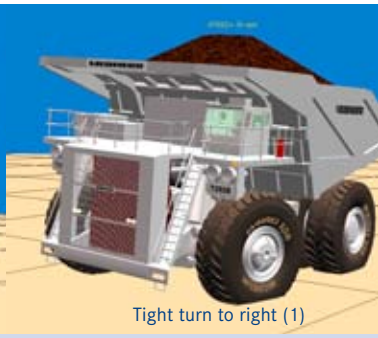
Major structural components throughout the vehicle such as the frame and dump body are modeled as flexible bodies to represent crucial bending and twisting during vehicle operation. The model incorporates over 70 different joints including rubber mounts, cylindrical and ball bearings, bolted joints, etc.

Analysts also used a wide range of other multibody elements in the detailed vehicle representation. Damping forces of suspension were represented by translational spring-damper-actuator elements. Expression force elements were used to simulate torque for brakes and electric motors, forces for steering and hoist cylinders, and spring forces in suspensions. Rotation stops that limit idler pivoting and dump-body pads were modeled with contact elements. Characteristics of electric


Tight turn and brake


Hitting block


Rear wheel in hole


Tight turn to right (1)

Liebherr analysts used LMS multibody dynamics in studying the behavior of the T282B truck for various load cases including turns, washboarding, braking, acceleration, backing into a barrier and running into holes.

motors, hydraulic pumps, oleo-pneumatic struts, tires, and other mechanical and electrical components were specified with curve elements.

Exploring "what if" scenarios

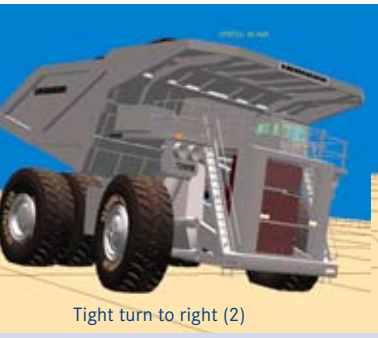
"The detailed multibody model created with the LMS software predicts vehicle behavior to a reasonable accuracy for a variety of load cases," Pokras stated. "The beauty of the approach is that when simulation indicates a potential trouble spot, it is really quite simple to modify the model to investigate other design options. In this way, LMS multibody dynamics lets us explore alternatives that would be entirely impractical to study with physical mock-ups." The multibody dynamics approach was especially helpful in studying many different "what-if' scenarios for the redesign of an axle box to save weight and allow for easier service accessibility.

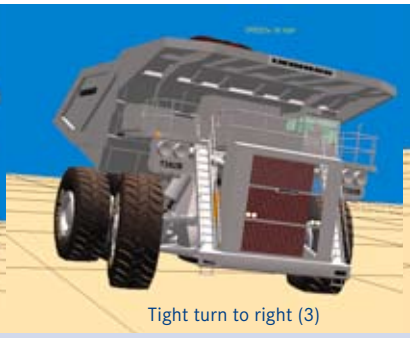
After a number of simulation iterations, multibody loads for the final design were entered into LMS durability software to determine the fatigue life of the critical structural components and assemblies such as the frame and axle box. Tight integration between LMS multibody and durability software enable fatigue life studies to be performed quickly and accurately, thus providing engineers valuable feedback for developing lightweight parts to withstand expected operational loads without under or over-designing them. The final step in the development cycle is prototype testing to validate the design before production begins.

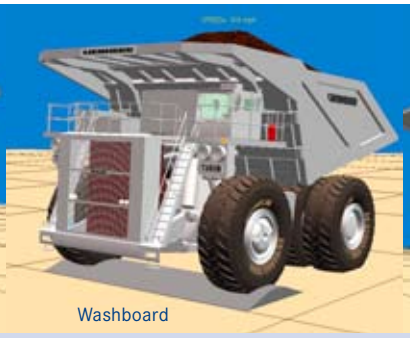
Maintaining mining market leadership

"Simulation gives engineers an insight into the behavior and performance of the components, assemblies and full vehicle that isn't practical otherwise," explained James Whitfield, Liebherr Mining Equipment General Manager of Research and Development. He notes that 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 that is now totally integrated into day-to-day engineering processes.

"It's not impossible to design mining trucks without using simulation – other companies do it all the time. But the only way to design a market-leading, optimally weight-efficient truck is with advanced simulation tools like LMS durability and multibody software, tools that we not only should use, but must use. We can't maintain our market leadership any other way." ■


Tight turn to right (2)


Tight turn to right (3)


Washboard


Front wheel in hole

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