

# Smooth rides for faster and safer construction vehicles

Timoney Technology uses LMS Virtual.Lab Motion to design independent suspensions that boost the productivity of construction trucks by up to 50%



Using LMS Virtual.Lab Motion multibody simulation, Tier One supplier Timoney Technology designs independent suspensions that boost the productivity of off-highway construction trucks by as much as 50%. Their innovative suspension concept enables the vehicles to travel at greater speeds on rough terrain without exceeding government standards for driver vibration. Engineers use Virtual.Lab to “drive” simulation models over virtual terrain and to quickly determine ride and handling behavior early in development. Doing so, they can accurately predict loads and vibration throughout the vehicle, find the root cause of problems, and iteratively tune the suspension for a smoother ride on uneven surfaces. In this way, the software has a strategic business role by enabling Timoney to leverage increased hauler productivity as a powerful market differentiator in a highly competitive market.

On construction sites, off-road trucks usually cannot drive at maximum speeds on extremely rugged surfaces, because drivers are exposed to excessive shock and vibration. At issue is what occupational safety experts call whole body vibration (WBV): lateral and vertical forces that jostle drivers as the vehicle bounces over bumps, ruts and other irregularities of the terrain.

WBV is not only uncomfortable but has serious work-related health risks such as lower back pain and spinal degeneration, and it contributes to an injury rate that authorities say is 40 percent higher for construction workers than for private industry as a whole. For these reasons a European Community directive mandates that the overall vibration dose to a vehicle operator cannot exceed a given level for an eight-hour day. The Human Vibration Directive 2002/44/EC of the European Community that took effect in 2005 established single-action limits of 0.5 m/s<sup>2</sup> and absolute limits of 1.15 m/s<sup>2</sup>. These limits are being enacted into law with strict enforcement by inspectors. Levels of driver acceleration and ride indices are also defined by ISO 2631.

### Traversing rough terrain at higher speeds

So when Timoney Technology ([www.timoneygroup.com](http://www.timoneygroup.com)) says their patented suspension can smooth out the ride of off-road vehicles allowing them to

run significantly faster while staying under these vibration limits, truck manufacturers pay close attention – wanting to edge out competitors in the high-stakes \$81 billion world heavy construction equipment market. By decoupling the effect of asymmetrical wheel loading, the Timoney double-wishbone independent suspension reduces the driver’s upper-body lateral acceleration and vertical acceleration at the seat.

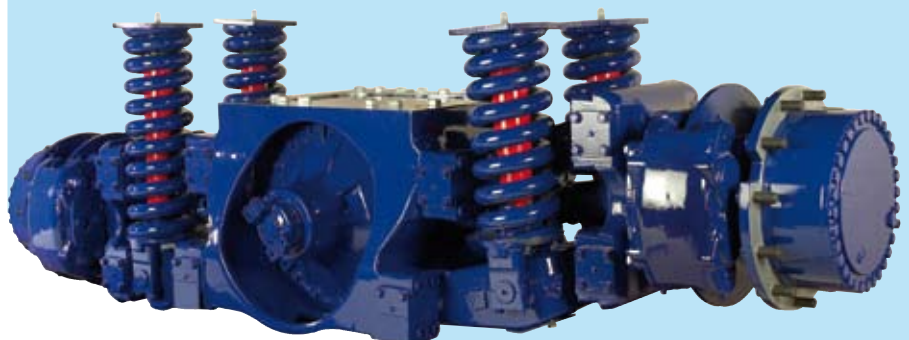
“Smoothing the ride allows vehicles to negotiate rough terrain while maintaining traction on all wheels at speeds two to three times faster than those achieved with conventional beam-axle systems,” says Timoney CEO Shane O’Neill. “We use this compelling productivity message as a market differentiator in

building a highly successful business providing considerable brand value to our customers.”

Timoney developed the world’s first independent suspension for airport rescue fire fighting trucks in the 1970s. In the decades that followed, emergency, fire fighting and rescue vehicles continued to be a major business segment for Timoney, and the company has gained worldwide recognition in leading the evolution of independent suspensions for off-highway construction vehicles. Timoney’s 87150 Series suspension, for example, was rated as one of SAE’s Off-Highway Engineering magazine’s Top 20 Products when it was introduced.

**“LMS Virtual.Lab has a strategic role in enabling Timoney to provide its customers with some of the best suspension systems in the world for a broad range of off-road vehicles.”**

**John Nolan, Engineering Director at Timoney**



Timoney independent suspension has long-travel coil springs and hydrostrut dampers on each front wheel to isolate ground forces, thus minimizing vehicle roll and driver vibration.

Timoney engineers have become particularly adept at developing independent suspensions for smoothing the ride of articulated dump trucks (ADTs), a relatively new class of hauler particularly susceptible to WBV because they operate mainly in mucky, muddy, rocky, hilly, bumpy terrain that would bring conventional dump trucks to a standstill. Because of their versatility, the use of ADTs has grown significantly since they were first introduced in the mid-1960s.

Recognizing the large potential of providing smoother rides in this burgeoning market, Timoney designed the first truly full independent suspension system for ADTs and now attributes a significant portion of its business to this market segment. O’Neill estimates that half the company’s revenue could conceivably come from construction equipment business within ten years.

### Custom engineering complex suspensions

“Leveraging these market opportunities requires the ability to develop suspensions for some of the most complex haulers in the world,” O’Neill explains. He notes that in contrast to rigid-frame haulers, ADTs are hinged between the cab and the dump box with a universal joint that allows the front and rear frames to rotate longitudinally about one another while traversing extremely uneven terrain and making 450 turns. Also, whereas most other construction haulers are two-wheel drive and some are four-wheel drive, only the ADT is six-wheel.

Because of these complexities, most of Timoney’s independent suspensions for ADTs are exhaustively custom-engineered for each vehicle model, with engineers tuning the high-quality suspensions for specific applications. In this effort, LMS Virtual.Lab Motion multibody simulation enables engineers to use simulation models in predicting vehicle dynamic ride and handling characteristics for designing its suspension systems. Engineering Director John Nolan explains that the simulation tool predicts vibration over various terrain conditions as well as the dynamic behavior of suspension

systems and full vehicles for J-turns and other maneuvers. “In this way, the software accurately determines critical loads, accelerations and motion paths of components in the form of quantitative plots as well as animations that provide valuable insight into the overall dynamic behavior of the vehicle and suspension,” says Nolan.

He notes that considerable work with LMS Virtual.Lab Motion is involved in determining how best to isolate the severe loading on the wheels, because each must be dealt with separately considering the overall ride and handling of the vehicle. Another complication is packaging the suspension to fit within the compact size of the ADT – usually only 2.5 meters wide – not much more than a passenger car.

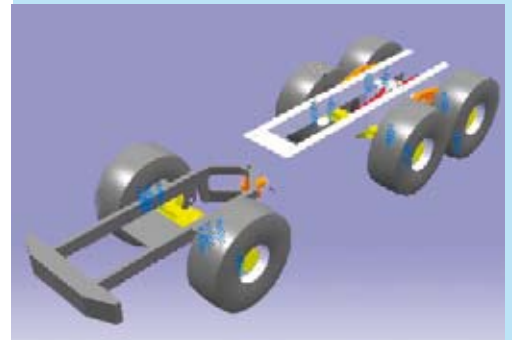
“Making the necessary tradeoff decisions between ride, handling, packaging and cost in a timely manner for such complex designs is certainly no easy task for ADTs, which is why most of our competitors shy away from the ADT market,” says Nolan. “By utilizing LMS Virtual.Lab Motion, we can account for all these factors, performing cross-attribute optimizations and assessing multiple design alternatives with fast iterative simulations that accurately predict dynamic motion and internal loads. The software is ideally suited to address the many complex issues of reducing WBV in construction equipment. Combined with the specialized expertise of the engineers at our company, LMS Virtual.Lab has a strategic role in enabling Timoney to provide its customers with some of the best suspension systems in the world for a broad range of off-road vehicles.”

### Technology in action

In one recent project, Engineering Designer and Analyst Shaun McFadden used LMS Virtual.Lab Motion in developing an independent double-wishbone suspension to replace a leading-arm suspension for a 30-ton ADT hauler. An initial LMS Virtual.Lab model was created to represent the existing hauler. The dump body was modeled as a rigid body connected to other components by joint elements to model ball and pin joints, by bushing elements to model rubber pads, and by



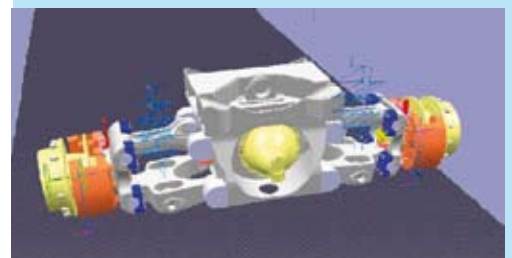
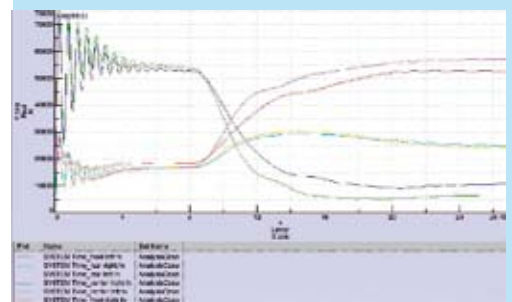
Six-wheel drive and good maneuverability enable articulated dump trucks (ADTs) to haul heavy loads over extremely uneven terrain.



Timoney engineers modeled and integrated independent suspensions to accurately predict the behavior of the dump truck under actual construction job-site conditions.



LMS Virtual.Lab allowed the simulation model to be “driven” over virtual terrain surfaces at various speeds to determine driver vibration levels defined by ISO 2631.



LMS Virtual.Lab Motion animations combined with output plots of key parameters proved to be a powerful way of showing customers problems and solutions.

translational spring-damper-actuators to model damping of struts and hydraulic cylinders. Contact elements were utilized to model axle rotation stops. Based on data provided by the tire manufacturer, complex tire elements were used for computing forces generated by each pneumatic tire as it rolls along the terrain.

“Solid elements are on par with most CAD programs in defining complex part geometries. The software clearly shows what inputs are needed in accurately representing parameters such as mass, stiffness and friction for the various components. A design tree displayed to the side indicates at a glance the relation of components and subassemblies to one another,” says McFadden. “With these capabilities, I can quickly and easily build multibody models in LMS Virtual.Lab that closely determine how an actual vehicle behaves under real-world operating conditions.”

Next, he wrote a Matlab program representing each of three types of road surfaces generally encountered by ADTs in completing a round-trip haul cycle between the loading and dumping points on typical construction sites. Each surface type was characterized by a root mean square (rms) of high and low points in the terrain:

- Light-duty applications traveling over a relatively well-maintained dirt road that is typical for earthmoving and stockpile jobs.
- Medium-duty applications over sections of haul roads, gravel tracks and quarry floor surfaces representative of road-building, construction and open-pit mining.
- Heavy-duty applications representing continuous use of short, poorly maintained haul roads with high rolling resistance and poor traction surfaces that often generate high impact loads.

## Quick design iterations

Terrain surface representations were entered onto an Excel spreadsheet and easily imported to the simulation model using the spline function of LMS Virtual.Lab, with automatic features handling the data transfer and no further actions required by the user. The simulation model was then “driven” over these virtual surfaces at various speeds, with the software calculating driver accelerations defined by ISO 2631. Validation features comparing the simulation with physical test results enabled McFadden to quickly verify that the virtual model accurately predicted real-world accelerations experienced by the driver over similar courses.

“The ability of LMS Virtual.Lab Motion to present output data in so many ways – particularly the animations – was valuable for us in understanding the



Equipped with a Timoney independent suspension axle system, a race truck made by Dutch manufacturer Ginaf competes in the annual Dakar rally off-road endurance race.

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**Shaun McFadden, Engineering Designer and Analyst at Timoney**

behavior of the original truck design and in identifying the root cause of vibration,” he says. “The leading-arm beam axle suspension had high roll stiffness, which caused large lateral accelerations on the driver seated high up in the vehicle. Clearly, this level of WBV severely limited the speed the operator could safely drive over rough terrain.” To provide more compliance in the roll direction and effectively isolate the vehicle from ground forces, the leading-arm suspension was replaced by an independent double-wishbone suspension design in the virtual vehicle model and the simulation reran to determine the maximum speed the vehicle could travel without exceeding ISO 2631 ride index of 0.8 m/s<sup>2</sup>.

Several design iterations were required in exploring various alternatives for spring and damper size and stiffness until maximum suspension performance was achieved. “We went through these iterations very quickly with LMS Virtual.Lab Motion,” he explains. “We only had to enter different parameters to change the model, with the software automatically accounting for the modifications throughout the entire process. Moreover, only a single physical prototype cycle was needed to demonstrate to the customer that our final product design matched that of the simulation prediction.”

### **The bottom line: boosting productivity by up to 50%**

Based on the increase in maximum allowable speed determined with LMS Virtual.Lab, the productivity of the ADT with the Timoney independent suspension was shown to increase as much as 50% overall across the three types of applications in round-trip haul cycles – a productivity gain that far

outweighs the slightly higher cost of the independent suspension.

“Throughout the process of developing the suspension, LMS Virtual.Lab Motion was indispensable in pinpointing the root cause of vibration problems in the old suspension and in quickly guiding us toward the best design for the new independent suspension,” says McFadden. More broadly, the ability of LMS technology in providing fast, accurate results enabled us to respond quickly to the customer. Animations in particular were a powerful means of visually demonstrating the performance improvement of the new versus old suspension and in providing convincing proof of a significant productivity increase. In that sense, LMS Virtual.Lab Motion is as much an essential component in our corporate business strategy as it is our product development processes.

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