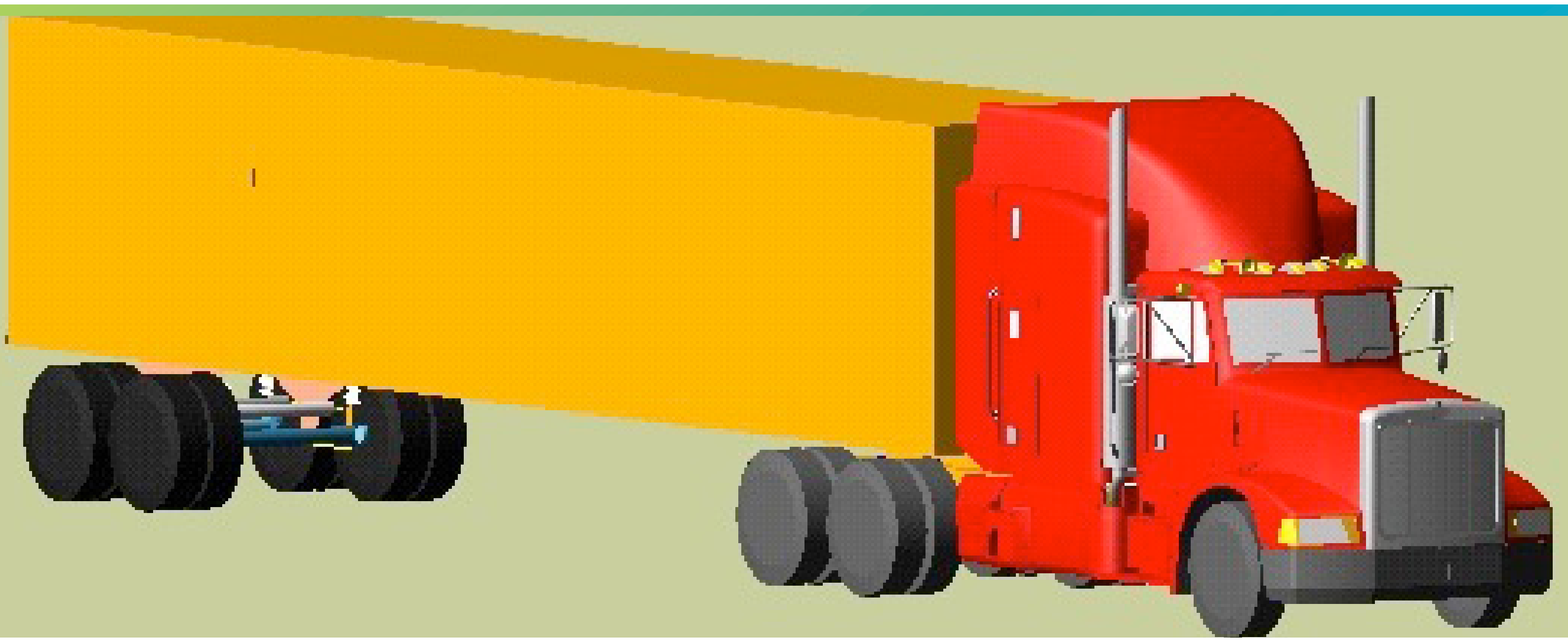
Case study

Meritor

Adams used to simulate new control strategy that reduces truck stopping distance by over 30%



Leveraging Adams-Controls Integration to provide virtual testing of the new braking algorithms used in the ABS system.

Regulators are continually increasing the performance standards required of automobile manufacturers. An example is FMVSS 105 and 121 which define the performance of braking systems and are intended to ensure safe braking performance under normal and emergency conditions for heavy trucks and trailers. A typical change in these regulations is to reduce the distance required to stop the truck under emergency conditions. This can be achieved by designing bigger, heavier, more expensive brakes. Ragnar Ledesma, Principal Engineer for Meritor, took a different approach by addressing the algorithms used to control anti-lock braking systems used in nearly all medium- and heavy-duty trucks.

ABS systems are based on the mu-slip curve which defines the relationship between longitudinal tire slip and braking torque. The point in the mu-slip curve where maximum braking torque occurs varies from tire to tire but typically is in the area of 10% to 15% tire slip. As the pressure exerted by the brakes increases, tire slip increases past this optimal point and the available braking torque is reduced. The purpose of the ABS

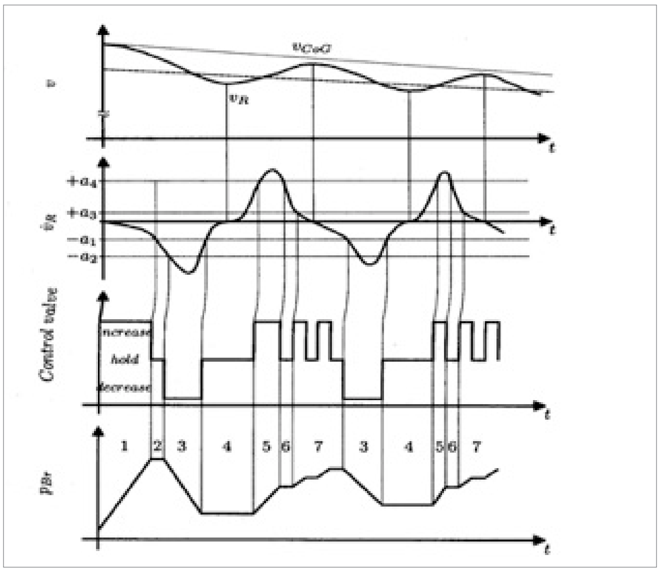


Figure 1: Panic stop with conventional ABS: 1) top graph shows angular velocity of the wheel 2) second from top graph shows first derivative of top graph – angular acceleration of wheel 3) third from top shows control state – increase, hold or decrease 4) fourth from top shows brake pressure at master cylinder

system is to keep the braking pressure from increasing substantially past the point at which maximum braking torque occurs. Besides increasing braking torque, ABS systems also enable the tires to continue to roll which helps the driver maintain steering capability.

ABS systems typically estimate longitudinal tire slip by comparing the velocity of each individual wheel to the velocity of the vehicle. The velocity of each wheel can be easily measured with a sensor. The velocity of the vehicle cannot be directly measured so a reference velocity that serves as an estimate of the vehicle velocity is calculated by an algorithm that uses as input the speed of each individual wheel as well as other factors such as steering wheel angle, yaw rate and whether the car is in the braking or accelerating mode. The current generation of anti-lock braking systems are limited by the fact that they utilize discrete control systems with only three states – increase pressure, reduce pressure and hold pressure constant. This limits their ability to maximize braking torque during the entire braking event with the result that the tire slip ratio undergoes considerable fluctuations above and below the optimal value.

Challenge

Ragnar Ledesma, Principal Engineer for Meritor, had the idea of using a more sophisticated sliding mode control, also known as a variable structure control, to continuously control the brake pressure applied to each wheel with the goal of maintaining longitudinal slip very closely to the optimal value throughout the entire braking event. He developed a decentralized strategy that controls the brake torque in each wheel independently of the other wheels, decoupling the vehicle into separate subsystems. Each subsystem has only one control input variable (brake torque), based on one controlled variable, the tire slip ratio. The other states of the system include the tire braking force, the wheel angular velocity and the spindle fore-aft velocity.

An estimate of the braking force is required to compute the equivalent control torque. This is obtained by using an adaptive nonlinear observer. This is a set of differential equations set up to emulate a specified plant, in order to obtain estimates for the state variables of the system, given measured time histories of plant inputs and outputs. In order to evaluate and demonstrate the effectiveness of this approach, Ledesma faced the challenge of accurately simulating the operation of the control system and the vehicle during a braking event.

Solution

Ledesma made the decision to use Adams because Meritor uses Adams on a regular basis to simulate a wide range application involving vehicle handling and stability, ride performance and prediction of dynamic loads on suspension components and axles. “We use Adams as our primary multibody simulation tool because it has demonstrated the ability to simulate a wide range of very complicated applications with a high level of accuracy,” Ledesma said. “Adams provided virtual testing of the new braking algorithm on a vehicle system-level model, making it possible to evaluate its performance without expensive prototype iterations.” 1D simulation software was used to model the control system and this software was integrated with Adams.

The Adams Controls module was used to couple the truck model to the ABS controls system. Meritor did not have a perpetual Adams Controls license and used MSC One, MSC software’s token-based licensing system. MSC One provided Meritor with the flexibility to use any Adams module or other MSC product without the need to purchase individual licenses. It enables on demand usage of infrequently used modules such as Adams Controls required for one-off applications such as validation of controls systems. For Meritor, accessing the controls module via the token pool was a more cost-effective alternative to maintaining an individual license.

Figure 2: Evaluate the performance of Antilock-Braking Systems (ABS) using Adams

Key highlights:
Product: Adams
Industry: Automotive
Benefits:
Leveraged Adams-Controls Integration to provide virtual testing of the new braking algorithms used in the ABS system
Achieved a reduction in truck stopping distance by over 30% using current disc braking systems
Evaluated the truck braking performance without many expensive prototypes iterations
On-demand access to the Adams Controls module via the MSC One token licensing system

To evaluate the new control concept, Ledesma modeled a loaded tractor-semi-trailer with a total gross vehicle weight of 76,500 lbf undergoing a panic stop from 60 mph. Direct meas-urements are performed within the simulation for the wheel angular velocities and spindle fore-aft acceleration at each wheel end. The spindle acceleration signals are numerically inte-grated to estimate the spindle fore-aft velocity. The simulation assumes that the brake sys-tems can deliver the required brake torque.

The peak values of the required brake torque are: 12,000 N-m at 55 mph for the front axle, 20,000 N-m at 55 mph for the tandem drive axles, and 14,600 N-m at 55 mph for the trailer tandem axles. Current disk and drum brakes can meet these torque requirements.

Results/benefits

The simulation showed the proposed control system brings the vehicle to a complete stop in less than 4 seconds in a stopping distance of 177 feet (54 meters),

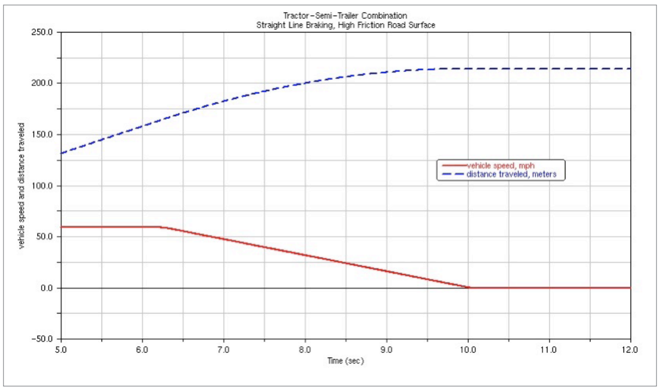


Figure 3: Wheel angular velocities in panic stop from 60 mph

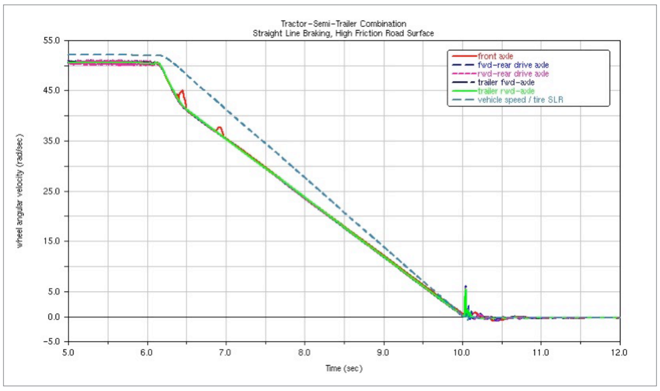


Figure 4: Vehicle speed and distance traveled, panic stop from 60 mph

demonstrating a way to meet the requirements of a tougher regulation without major changes to braking hardware. The results show a nearly constant deceleration response at the driver seat as opposed to the cyclical response with conventional ABS braking. The explanation for the improved performance is explained by the simulation results. The wheel angular velocities and tire slip ratios do not fluctuate from their desired values; hence the new ABS control system can sustain maximum braking forces almost over the entire braking cycle.

About Meritor

Meritor is a leading global supplier of drivetrain, mobility, braking and aftermarket solutions for commercial vehicle and industrial markets. The company's Commercial Truck & Industrial group supplies drivetrain systems and components including axles, drivelines, braking and suspension systems, primarily for medium- and heavy-duty trucks in North America, South America and Europe. The Aftermarket & Trailer group supplies new and remanufactured axles, brakes, suspensions, transmissions and components for aftermarket customers.

Hexagon is a global leader in sensor, software and autonomous solutions. We are putting data to work to boost efficiency, productivity, and quality across industrial, manufacturing, infrastructure, safety, and mobility applications.

Our technologies are shaping urban and production ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

MSC Software, part of Hexagon's Manufacturing Intelligence division, is one of the ten original software companies and a global leader in helping product manufacturers to advance their engineering methods with simulation software and services. Learn more at mscsoftware.com. Hexagon's Manufacturing Intelligence division provides solutions that utilise data from design and engineering, production and metrology to make manufacturing smarter.

Learn more about Hexagon (Nasdaq Stockholm: HEXA B) at hexagon.com and follow us @HexagonAB.