Improving Fuel Efficiency by Measuring Rolling Resistance

What Was the Need?
The fuel consumption of vehicles is affected by numerous factors—from roadway friction and aerodynamics to engine thermodynamics and tire-pavement interaction. One important factor is rolling resistance, which consists primarily of the nonfrictional dissipation of energy as rubber tires undergo repeated cycles of deformation and recovery in response to the unevenness and roughness of roads.

Rolling resistance is also affected by the way pavements deflect in response to vehicle loads. It can be worsened by the vibration of the vehicle suspension as the tires bounce in reaction to pavement forces.

Rolling resistance is a factor in fuel consumption because it must be overcome for a vehicle to accelerate or maintain speed. MnDOT is interested in understanding the sources of rolling resistance since doing so can lead to more cost-effective pavement design and maintenance, permitting MnDOT to produce the kinds of pavement surfaces that lower operating costs while increasing safety and comfort. Fuel consumption of fleets can also be lowered, leading to lower costs and fewer environmental impacts.

What Was Our Goal?
The goal of this project was to determine how rolling resistance and other factors contribute to fuel consumption by heavy-duty trucks. This project also provides important data for MnDOT’s ongoing research into how pavement surface textures affect rolling resistance.

What Did We Do?
MnDOT partnered with FuelMiner, Inc., a company that has developed a mechanistic model based on physics and vehicle dynamics, to develop a more accurate method of predicting vehicle fuel use than current modeling approaches.

FuelMiner researchers conducted testing with a truck at MnROAD, MnDOT’s pavement research facility, as well as on two highway sections with distressed pavements: a 2-mile segment of Trunk Highway 66 near Good Thunder, Minnesota, and a 5-mile section of TH 10 near Sartell, Minnesota.

MnROAD testing was conducted on its mainline, a 3.5-mile section of Interstate 94 with more than 50 500-foot sections of different pavement designs, materials and surface textures. On TH 66 and TH 10, the same truck was driven at 55 mph and 64 mph, respectively. Accelerometers and other instruments onboard the truck collected data on more than 300 other parameters, such as torque, speed, rpm, transmission gear, instantaneous fuel consumption and ambient temperature. Researchers also collected environmental data, including temperature, wind speed and direction as well as road elevation and roughness data.

Researchers analyzed this data to estimate the relative contribution of rolling resistance and other factors to fuel consumption by using FuelMiner’s Time-Resolved Mechanistic Analysis of Vehicle Operating Costs. TRMA is a fully mechanistic model that allows re-
searchers to isolate the contribution of rolling resistance and other resistive forces acting on the vehicle, including aerodynamic drag, road grade and engine thermodynamics.

What Did We Learn?

Results showed that rolling resistance accounts for only 10 to 13 percent of vehicle fuel consumption. At 55 mph on TH 10, rolling resistance accounted for 11 percent of the test truck’s fuel consumption, and on TH 66, 13 percent. On MnROAD’s mainline cells, which consist of varying materials and designs, rolling resistance accounted for 10 percent of the test truck’s fuel consumption at 30 mph and 13 percent at 64 mph.

For each of the MnROAD mainline’s test cells, researchers provided a coefficient of rolling resistance, which is important data for MnDOT’s continuing research into the effects of pavement surface textures on rolling resistance. The coefficient of rolling resistance is the force needed to push a vehicle, per unit force of weight (assuming constant speed on a level surface, with no grade or air resistance). For MnROAD cells, this coefficient varied from 0.0044 to 0.0072 (the higher this value, the greater the rolling resistance due to pavement materials and texture). At an average vehicle speed of 55 mph, rolling resistance was 0.0072 on TH 66 and 0.0061 on TH 10.

Researchers also provided estimated fuel consumption for each MnROAD cell. At 30 mph, fuel consumption varied between 0.006 liters and 0.009 liters per cell, for an average consumption of 5 liters per 62 miles.

What’s Next?

The data from this research will help MnDOT continue to evaluate the effects of different pavement materials and surface textures on rolling resistance as well as the effect of rolling resistance and other factors on fuel consumption. Researchers will present the results of this study at the 2016 Transportation Research Board Annual Meeting and other conferences. They also had several recommendations for improving the experimental setup for future studies, including better synchronization of data from various instruments.