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RESEARCH
SERVICES SECTION

TECHNICAL SUMMARY

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PROJECT COST:
$140,000

Because the measurement system's small wheel is set at an angle, it receives a lateral force corresponding to the road's surface friction.

Using Real-Time Road Condition Measurements for Automated Winter Road Maintenance

What Was the Need?

The specific winter maintenance measures (such as plowing or applying liquid deicing agents, salt blends or sand) that are most appropriate for a particular section of road will depend on the road's precise condition. Since not applying enough deicing material will leave the road unsafe, snowplow operators typically use more than is actually necessary, resulting in wasted resources and highway runoff that pollutes the surrounding environment.

Numerous highway agencies have come to regard surface friction measurements (specifically, tire-road friction coefficient readings) as a useful basis for optimizing deicing material application. While several systems have been developed to take these measurements from a moving vehicle, they all have serious limitations. Many can only take readings when the vehicle is changing speed or direction. Others, like the Norsemeter, a currently available commercial system that uses a redundant wheel to measure surface friction, require a dedicated operator and an actuator to skid the wheel on the roadway at timed intervals.

Mn/DOT wanted a more practical system that would use surface friction readings to automatically adjust a snowplow's chemical applications to the right level for each section of roadway.

What Was Our Goal?

The purpose of this research was to develop and test a tire-road friction coefficient measurement system that:

- Attaches to standard winter maintenance vehicles.
- Takes real-time surface friction readings even when the vehicle is proceeding in a straight line at a steady speed.
- Is durable, with few moving parts.
- Provides more accurate measurements than previous systems using innovative signal processing algorithms to filter out "noise," vibrations and the influence of vehicle maneuvers.
- Automatically and efficiently controls the administration of deicing materials.

What Did We Do?

Investigators developed a system that, like the Norsemeter, uses a small wheel to take measurements but also employs a key innovation. Past systems required the wheel to skid to some degree, whether through moving it in and out of contact with the pavement or through changing its velocity. With the new system, the added wheel is set at an angle of about 5 degrees to the traveling direction of the snowplow. This angle produces a continuous lateral force on the tire whenever the vehicle is moving forward; this force is used to estimate the friction coefficient.

A prototype of this system was attached to a snowplow along with computerized data acquisition, signal processing and real-time control systems. Researchers interfaced friction measurements as well as pavement temperature measurements to FORCE America deicing material applicators, allowing for automated control of these applicators to

continued

"The best part about this technology is that we can reduce the amount of salt and chemicals that are applied to roadways during the winter without compromising safety."

–Rajesh Rajamani,
Professor, University of Minnesota Department of Mechanical Engineering

"The real-time filtering algorithms developed for this system are highly effective in removing noise, which makes it possible to quickly identify changes in the friction coefficient."

–Farideh Amiri,
Senior Engineer, Mn/DOT

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The new measurement system can be fitted on full-size snowplows and delivers real-time surface friction readings to an automatic control system that dispenses deicing chemicals.

optimize treatments to the condition of the road surface in accordance with the guidelines provided in the Minnesota snowplow operators' field handbook.

The system was subjected to a variety of tests to evaluate its performance when accelerating, decelerating and steering, and also when transitioning at various speeds between dry asphalt and ice. Researchers also evaluated the efficiency of the automated applicator and tested the data-filtering algorithms developed to ignore the noise resulting from the roughness of the road surface.

As another possible method to measure tire deflection, researchers also considered piezoelectric sensors, which generate a small electrical charge when subjected to force.

What Did We Learn?

This project successfully delivered and documented the desired real-time autonomous winter road maintenance system. Reading continuous lateral force on an additional wheel in real time was found to be highly effective for accurately estimating the friction coefficient as road conditions changed from dry to icy or snowy conditions.

The wheel was subject to excessive noise resulting from the roughness of the road surface, but the real-time filtering algorithms developed for removing this noise—especially at very low frequencies (less than 1 hertz)—were very effective. Another challenge was how to compensate for the effect of driver steering on the lateral forces measured by the system's wheel. This study produced a filtering algorithm that addressed this problem when used with a lateral accelerometer on the wheel.

The piezoelectric sensors did not provide reliable estimates of the friction coefficient. Additional work needs to be done before piezoelectric sensors can be used as another method for estimating friction coefficient.

What's Next?

The results of the tests conducted during this project were promising enough that Mn/DOT is moving this innovative winter maintenance technology toward field tests. The system may be rolled out for use on Minnesota highways pending the outcome of a follow-up study, currently in progress, to determine how accurately the system detects smaller patches of ice and snow, and whether the current automatic control system is the most effective way to deliver salt or chemicals to these patches.

This Technical Summary pertains to Report 2007-37, "Automated Winter Road Maintenance Using Road Surface Condition Measurements," published September 2007. The full report can be accessed at http://www.lrrb.org/PDF/200737.pdf.