Direct low lateral slip roadgrip measurement compared with surface reflection of three laser beams

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ABSTRACT

Road grip on winter roads depend on many factors and different techniques are available to estimate available road grip. To ensure that entrepreneurs have successfully increased the road grip to an acceptable level both entrepreneurs and road keepers need tools to evaluate present road grip. Information about road grip can also be utilized directly in a vehicle if available, for systems such as ABS, traction control, etc. To evaluate a non-contact method based on three laser beams with different wavelength, it was mounted on a vehicle equipped with low lateral slip device measuring road grip. The wheel on the lateral slip device is angled ~1.5 degrees compared with the centreline of travel. A sensor in the hub measures forces acting on a standard winter tire; this is a quantification of road grip. The main objective of this work is to see how well road grip can be estimated with a low cost, non contact device made with laser beams in combination with a photodiode.

KEYWORDS

ROAD GRIP / IR-LASER / RT3 / REFLECTION / ICE / ROAD EYE

1. INTRODUCTION

The Swedish road administration sees a need to measure road grip to ensure safe driving conditions. The main goal is to reduce accidents resulting in personal injuries or even worse, fatalities. Other goals also includes reducing cost of transportation such as lost time due to delays, damages of vehicles, damages of properties surrounding the road system and time spent solving issues created due to accidents. The Swedish government has increased its attention on pollution arising from use of studded winter tires in densely trafficked and populated areas, in Gustafsson et al. [1], research show that levels of small particles increase dramatically with studded winter tires. This pollution problem has been addressed in Japan, however other issues arise from banning studded winter tires, see Takagi et al. [2]. The need to measure road grip will increase when the use of studded winter tires decreases due to new regulations in Sweden. Measuring road grip can be done by many different techniques, in Engström et al. [3], different equipments were tested. Results showed that equipments using low lateral slip with real studless winter tires have better roadgrip resolution than equipments utilizing high longitudinal slip with a Trelleborg industrial tire. The objective with this article is to investigate how IR-lasers combined with detectors relate to direct friction measurements with low lateral slip equipment on old polished ice. Old polished ice has been selected as it is a surface type that is available and has similarities with the most dangerous road surface types.

2. METHODOLOGY

For this article we use two devices to measure road grip, a RT3, measuring low lateral slip and a road eye, measuring reflection of laser beams. Data from each device were recorded through LabVIEW on a laptop PC. Connected between the PC and the measurement devices were two high speed serial RS-232 to USB converters. The main tests are performed on an ice surface on Lake Kakel located close to the car testing metropolis, Arjeplog in northern Sweden.

2.1. Low lateral slip device

The main device is an RT3 that use a Bridgestone Blizzak Nordic WN-01 tire, slightly angled to achieve low lateral slip, see Figure 1. In the hub of the device a load cell measures the lateral forces produced by the road grip between measuring tire and road surface. The Halliday friction number, HFN is proportional to the force measured by the load cell. The relation is Road grip = (511.5/81.76)*HFN, the unit is Newton's [N]. As an example 100 HFN = 625.6 N. Lateral forces depends on type of tire and tread depth on the tire. A linearization compensation map for each type of tire is programmed into the control module. This means that forces will increase as the tire wear down. The data logging are made with a 1 Hz frequency. Practically it means that one hundred readings are averaged and sent to the laptop PC through the RS-232 to USB converter.

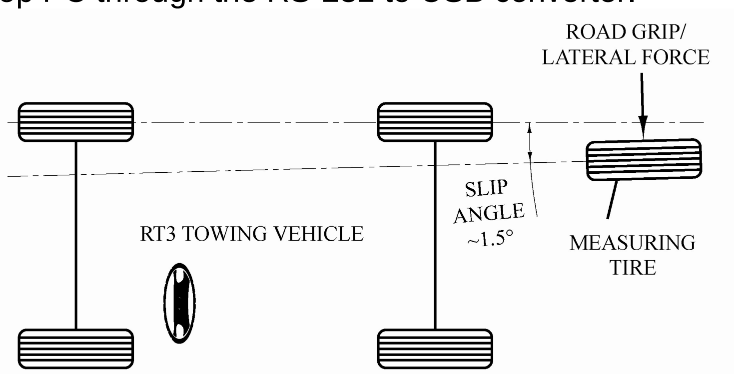

Figure 1 - Schematic layout of low lateral slip road grip measuring unit

2.2. Surface reflection of laser beams

The second device used is based on three laser beams for illumination and a photodiode for detection. The laser diodes emit coherent electromagnetic radiation with wavelengths 980 nm, 1323 nm and 1566 nm. The ratios between reflected radiations from the different laser wavelengths are used to determine what kind of surface the detector is pointing towards, See Casselgren et al. [4]. Graphs in Figure 2 show reflected intensity of four surfaces illuminate with halogen light continuous over the detectors spectrum. This version of the Road eye (Swedish Patent nr. 9904665-8), four different types of surface is detectable, dry asphalt, wet asphalt, ice and snow. Wavelengths have been selected through research on absorption characteristic of ice, water, snow covered asphalt and bare asphalt, see Casselgren et al. [5].

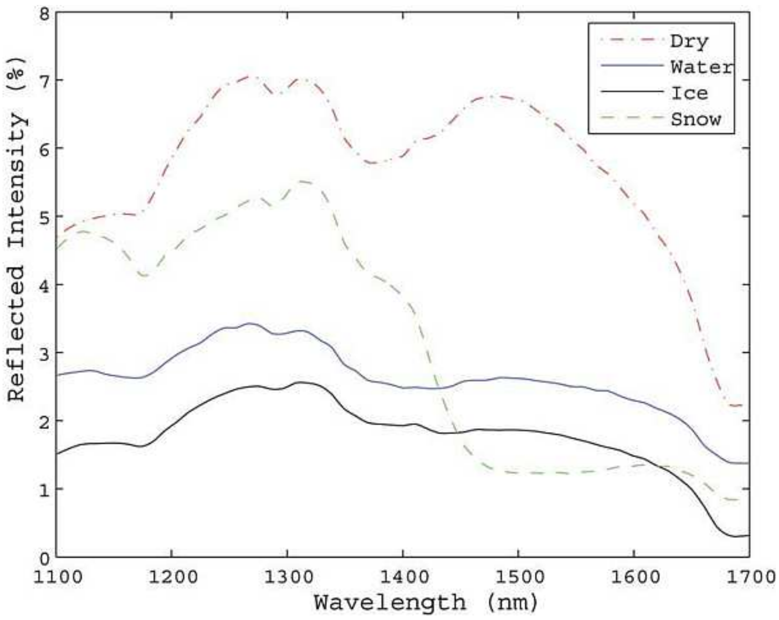

Figure 2 - Reflected Intensities for four surfaces when illuminated with a continuous spectrum from a halogen light source. Courtesy Casselgren et el. [4].

Research made by Casselgren et al. [6], showed that s-polarized illumination sources increased the detection capacity when combined with a polarize analyzer as detector. Lenses in front of the laser beams and the detector focus the measurement to a concentrated area. The measuring area is aimed in front of the longitudinal low slip wheel. The laser based detector and the longitudinal low slip device can be seen assembled on the towing vehicle in Figure 3.

Figure 3 - RT3 and Road eye on towing vehicle

2.3. Test track

The test track section with brushed old polished ice was roughly 100 m long and 10 m wide. It was located on a test area 1 km long and 80 m wide prepared with a grader blade equipped with system 2000 teeth. Polished ice is created with an ice machine that floods the ice with water and smoothens out the water with a thick cloth. The polished ice surface was several days old and debris and snow was brushed of before test begun.

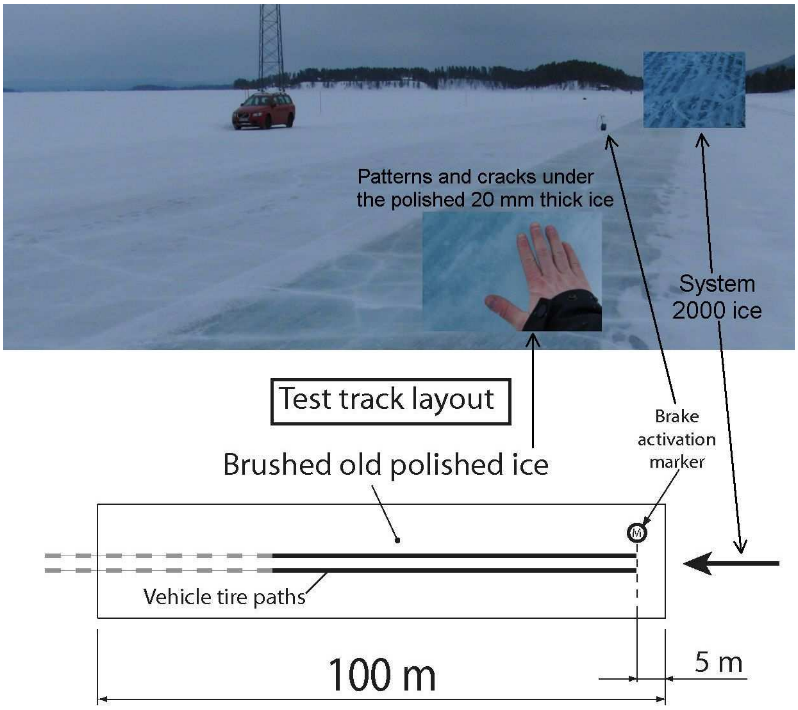

Figure 4 - Bottom, test track layout, pictures, with brushed old polished ice and system 2000 ice.

2.4. Test sequence

This test was performed in a steady stream of vehicles performing brake test on the brushed old polished ice surface. The towing vehicle was accelerated up to one of three measuring speeds, 30 km/h, 50 km/h or 70 km/h on the system 2000 ice before the brushed old polished ice. The measurement was initiated close to the start of the brushed old polished ice. Each test was performed three times for each speed. Tests were repeated several times each day.

2.5. Conditions during tests

Tests were conducted in February and March, 2009. Condition data were logged with a standard weather station, Oregon scientific WMR100N and a USB-502 relative humidity/temperature data logger, placed on the ice. The USB data logger was protected from direct sun light by a screen. Temperature and relative humidity data can be seen in Figure 5 and Figure 6

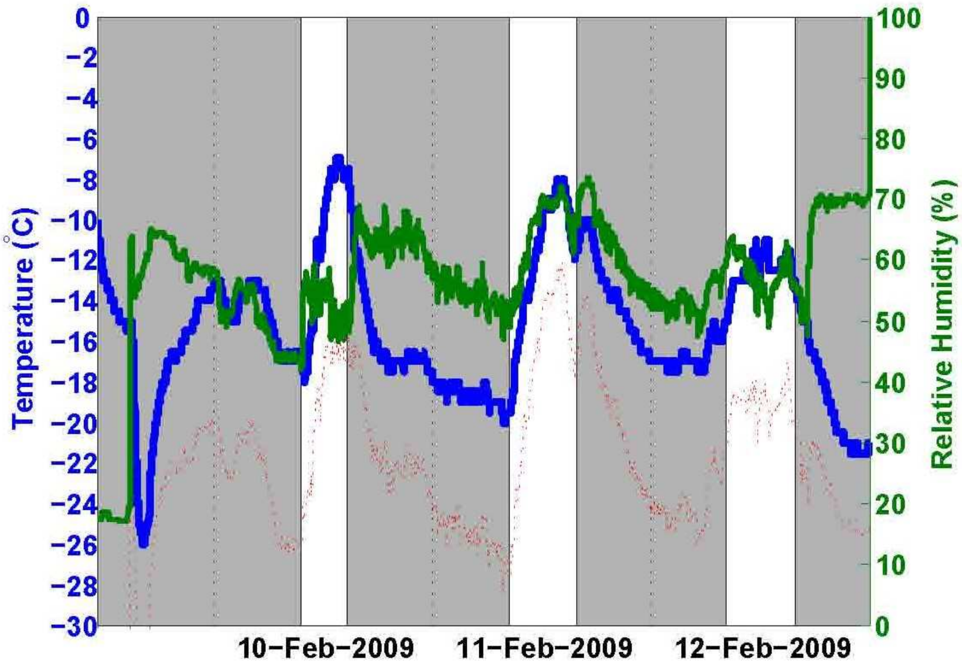

Figure 5 - Temperature and relative humidity chart from February 10 to February 12, 2009. White sections indicating active measurement.

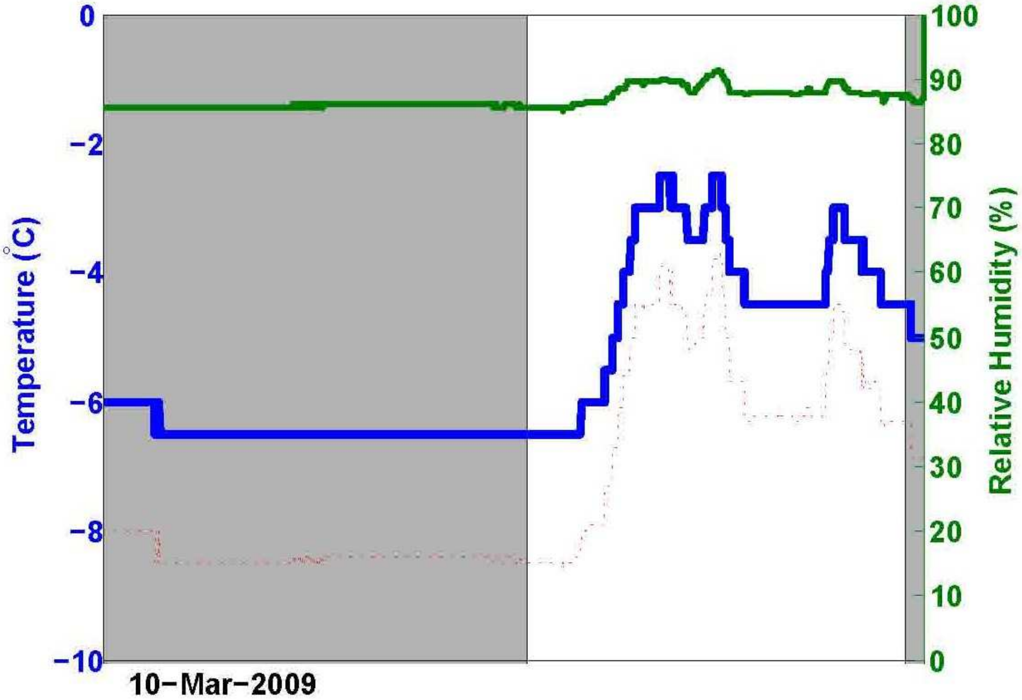

Figure 6 - Temperature and relative humidity chart from March 10, 2009.

2.6. Data Processing

In Figure 7 the left y-axis represent road grip measurements from the low lateral slip device, presented as Halliday Friction Number. On the right y-axis we find the calculated ratio between reflected intensities of wavelengths 1566 nm and 1323 nm, this is enough to distinguish between ice or snow.

Figure 7 illustrates a measurement made March 9, 2009 at 70 km/h. The towing vehicle leaves the first system 2000 surface and enters the old polished ice, HFN number decreases at the same time as the ratio from the reflection changes. At the end of the graphs we see how both the ratio of intensity and the HFN number increase back to similar values as the vehicle leaves the 100 m stretch of old polished ice.

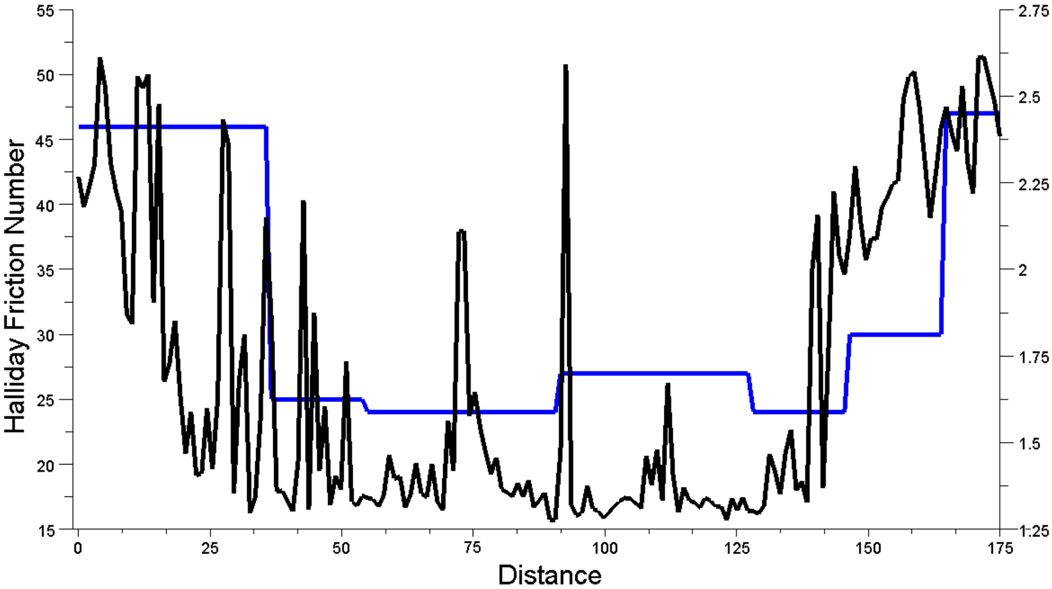

Figure 7 - Road grip, blue graph with 1 Hz sampling frequency, slower than the “reflective” ratio λ2/λ1, black fractious line.

3. MEASUREMENT RESULTS

In Figure 8 a), b) and c) we see that there is a patch in the beginning of the brushed old polished ice with lower road grip/HFN number than other sections of the brushed old polished ice. The reason for this is the stop distance tests that were performed parallel to our measurements. ABS systems often lock the wheels initially during a brake sequence, especially on a surface with this low road grip. This leads to a polished section where asperities are removed. The spikes in the intensity ratio are from accumulations of snow as there were some light snowfall on and off during these measurements. The snowfall also resulted in many corrupted measurements as the protective tube for the road eye was blocked with snow. The tube was cleaned frequently with a brush to enable measurements. Towards the end of the brushed old polished ice we see that both the HFN number and the intensity ration increase, this indicates that the road eye can detect changes in the surface characteristics.

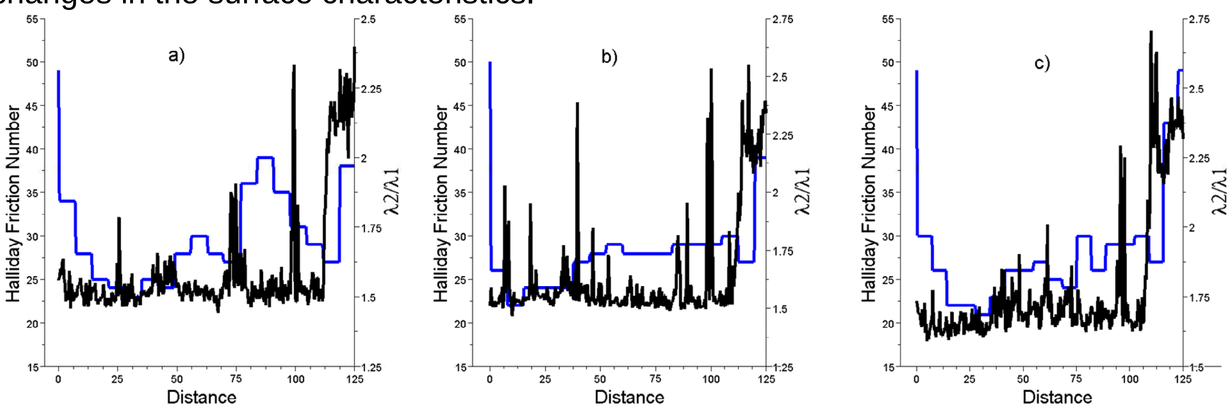

Figure 8 - HFN and intensity ratio for three consecutive measurements at 30 km/h. Measurements made March 09, 2009 between 11:14 and 11:19 AM. Temperature -5℃.

Figure 9 a), b) and c) represents measurements made at 50 km/h only minutes apart from the 30 km/h measurements in Figure 8. The difference is that the intensity ratio is much more instable. We also see that the signature of the HFN numbers changes slightly between each test run. The low initial road grip is always there as the ABS systems consistently polishes that section of the test track. Other low slip areas are moving around as the end of the stop distance tests with full ABS also produces locked wheel conditions. The stop distance tests were performed with the same test speeds resulting in different stop positions throughout the test.

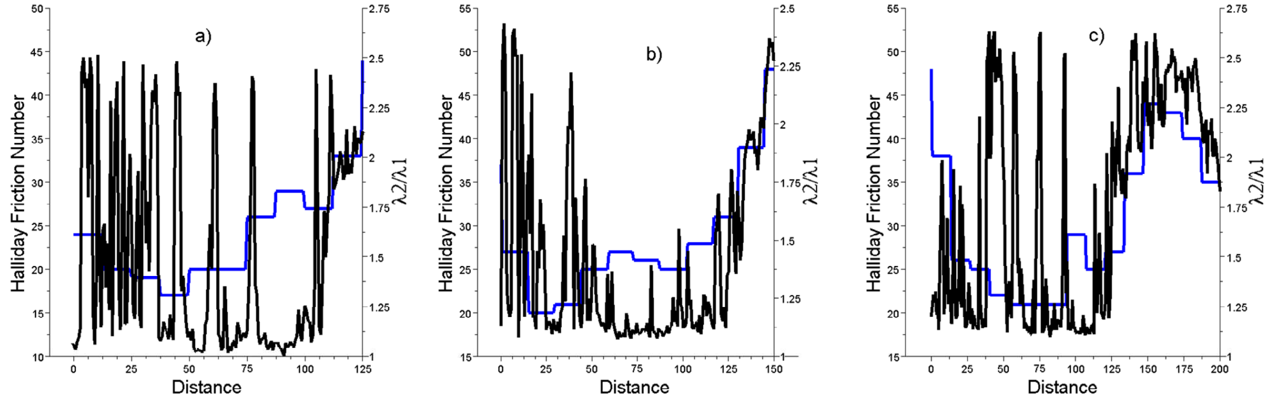

Figure 9 - HFN and intensity ratio for three consecutive measurements at 50 km/h. Measurements made March 09, 2009 between 10:58 and 11:01 AM. Temperature -5℃.

In Figure 10 b) and c) measurements were started a fraction earlier, this enable us to see that the intensity ratio fall slightly faster than HFN number due to higher sample rate and the fact that the measuring point is pointed about 1.2 m in front of the contact point between the low lateral slip device and the frozen lake surface.

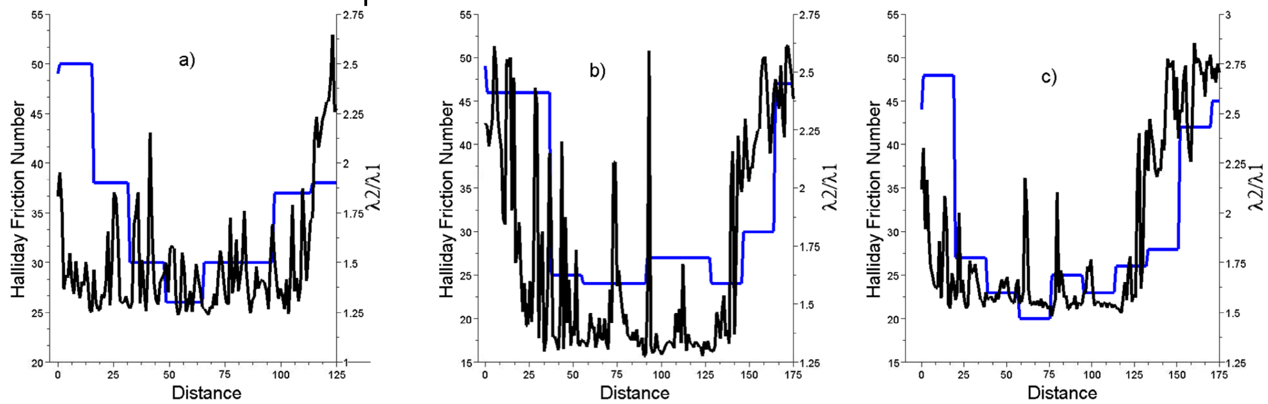

Figure 10 - HFN and intensity ratio for three consecutive measurements at 70 km/h. Measurements made March 09, 2009 between 11:03 and 11:07 AM. Temperature -5℃.

Figure 11 a), b) and c) represent a repeated measurement seen in Figure 8. We see on the blue graph representing HFN number, that road grip has stabilised through out the stretch of brushed old polished ice.

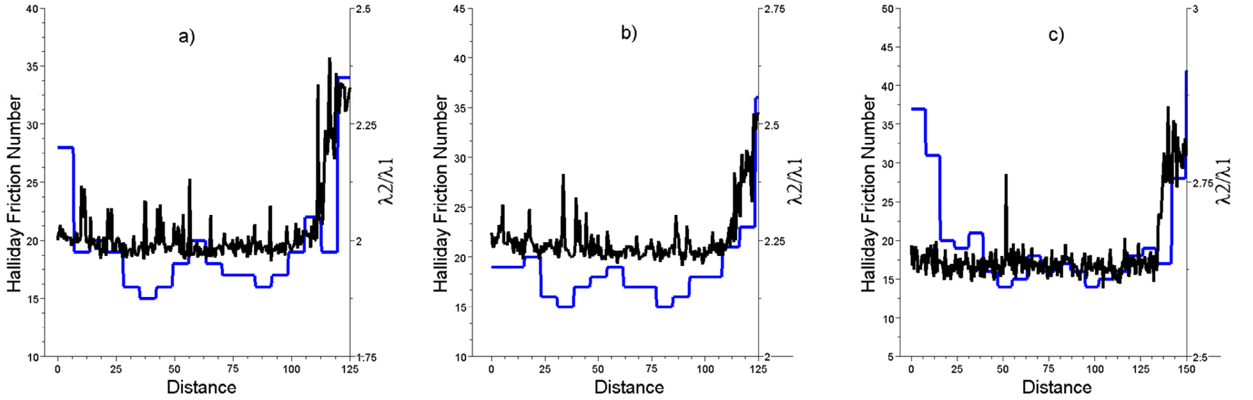

Figure 11 - HFN and intensity ratio for three consecutive measurements at 30 km/h. Measurements made March 09, 2009 between 04:00 and 04:03 PM. Temperature -5℃.

Figure 12 represents a measurement made roughly one month earlier during a roughly 9℃ colder period, we see that the HFN number are s ignificantly higher compared with the other measurements. Differences in intensity ratio are not as clear and less correlated with HFN numbers. We also see that differences in road grip are less depending on what surface the low lateral slip device are passing over.

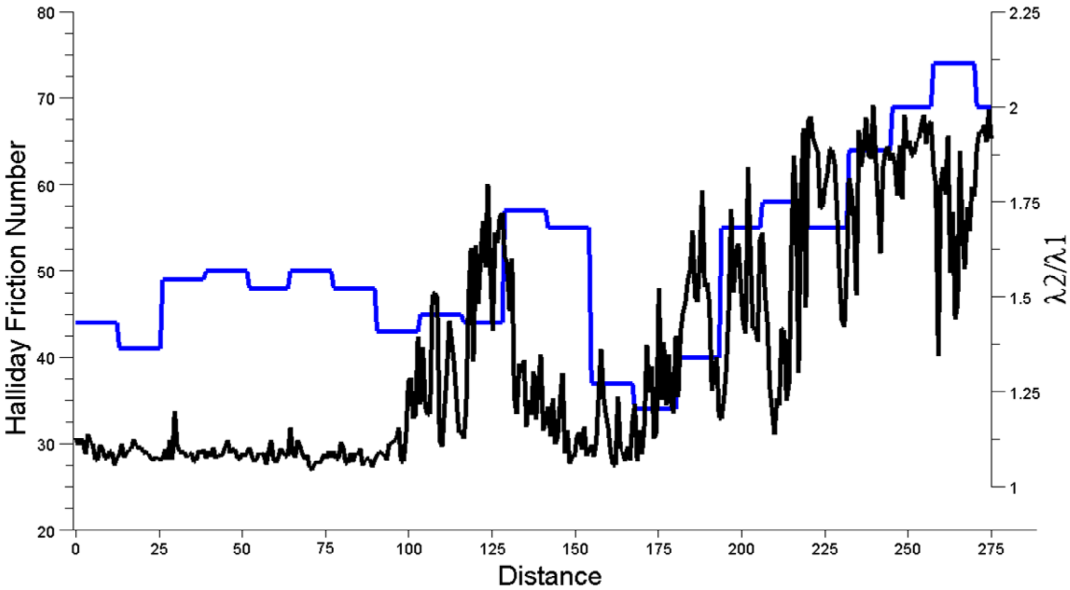

Figure 12 - HFN and intensity ratio measurement at 50 km/h. Measurement made February 13, 2009 at 09:50 AM. Temperature -14℃.

4. DISCUSSION

These first attempts to find lower cost methods are not encouraging, to correctly measure road grip one need a method that works in as many conditions as possible. We see in Figure 9 that the intensity ratio measurement method is easily disturbed by pollutions on the road surface that did not change the HFN number significantly. This will not stop these low cost detectors from entering the automotive market. Each sensor will add its information to the main control module to enable warnings and interactions to reach the driver of the vehicle. One of the main problems that we encountered during the use of road eye is pollution of the lenses and thus disabling the sensor.

5. FEATURE WORK

During the winter 2009/2010 we will measure with a new road grip device and the road eye, these measurements are going to form a base map of what signal one can expect from the road eye. With this map we might position fixed road eye cameras along roads and harvest road grip information to distribute to driver in the area.

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