BIRDS - Sensors for detection of ice formation and freezing point measurements

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Introduction

• Passive- and Active-BIRDS are two systems for the detection of ice formation and freezing point measurements on roads.

• The systems which are based on simple principles of thermodynamics use a combination of Infrared (IR) thermometers and signal processing.

• Both systems are being tested in field and have proven potential of being cost effective sensors for improving winter road maintenance and traffic safety.

• A patent for these systems is pending.

Methodology

The methodology is based on two basic principles of thermodynamics:

I. The freezing process of water does not always begin when the temperature sinks to its freezing point. Instead, the freezing often starts at a temperature significantly lower than the freezing point. This is the principle of super cooling.

II. A large amount of energy is released when water freezes.

Considering these two principles, the road surface temperature during freezing can be modeled. It includes a sudden rise in temperature during the freezing process and explains a very distinct temperature pattern visualized in Figure 1.

IR-thermometers can be used to detect sudden changes in temperature without being in contact with the surface. Combined with a detection algorithm, IR-thermometers can detect ice formation on roads. This principle has been used for the implementation of two detection systems, Passive- and Active-BIRDS.

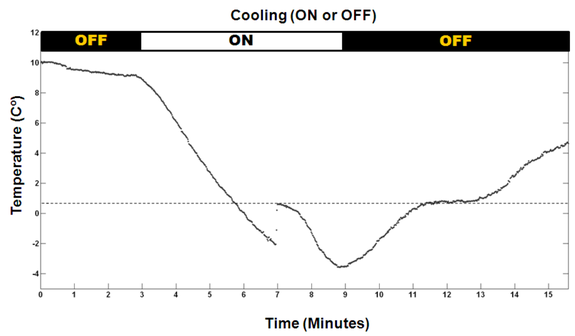

Figure 1: Temperature pattern during a freezing process produced with Active-BIRDS. Ice formation occurs at t = 7 min and is detected due to the distinct temperature pattern.

System Design

Passive-BIRDS

Passive Black Ice Infrared Detection System (Passive-BIRDS) consists of an IR-thermometer installed beside the road and is consequently non-intrusive. The IR-thermometer measures the temperature of a small section of the road surface at very high frequency. An ice detection algorithm is continuously interpreting the temperature signal to detect patterns typical for freezing events.

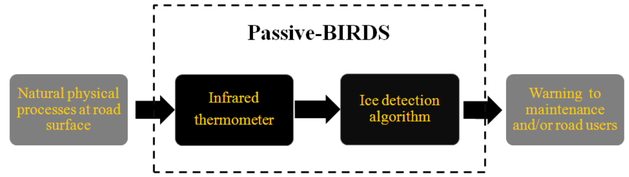

Figure 2: Schematic overview of the process chain involved in Passive-BIRDS

As the algorithm identifies ice formation, a warning can be send to road weather information systems (RWIS). The system is well suited for installment on road stretches with restrictions on installments of intrusive sensors in the road surface or which are difficult to shut off for traffic, such as bridges.

Active-BIRDS

Winter road maintenance personnel generally attempt to treat a road surface with deicing chemicals before freezing to avoid ice formation. If previous deicing applications are still efficient, the freezing point temperature will be lower than 0°C and a new application might not be needed.

Active-BIRDS is an extension of Passive-BIRDS with the addition of a cooling element installed in the road body.

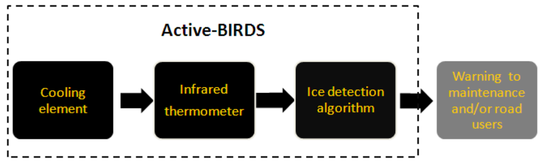

Figure 3: Schematic overview of the process chain involved in Active-BIRDS

The cooling element, which is covered with road surface, cyclically cools the road surface to try to cause a freezing event on the above road section.

The covered cooling element prevents problems that many other sensors have with wearing of the road and dirt. An IR-thermometer is installed at the side of the road pointing at the cooled area and detects the time and temperature when the freezing occurred.

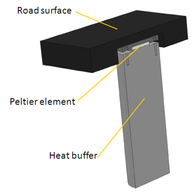

Figure 4: Cooling element used in Passive-BIRDS

Results from Trials

Passive-BIRDS was initially tested during the Winter of 2008-09 on a non-operated road stretch. During this period, three occasions of black-ice formation were confirmed by observations, all of them showed a detectable response in the temperature signal.

A prototype of Active-BIRDS has been built to make it possible to adjust and investigate the system in detail. The installed system is programmed to cool the road surface once every hour. Preliminary results show that the system is able to measure the road surface freezing point as well as give an indication of the amount of moisture at the surface.

Tests have shown that factors such as distance between the surface and the IR-thermometer, distance-to-spot ratio of the thermometers field of view and the angle towards the surface are fundamental in order to get a distinct signal response during ice formation.

Conclusions

• Both the passive and active systems have shown great potential of getting more valueable information out of RWIS.

• Hardware costs are low due to the use of a simple but robust measurement principle.

• Research and development is needed to optimize the hardware, the detection algorithm and to quantify different sources of disturbances to the systems.

• Passive-BIRDS can measure road surface temperature, detect ice formation and is suitible for installation on , e.g., bridges since it is non-intrusive.

• Active-BIRDS can measure the road surface freezing point with a sensor placed beside the road and a cooling element embedded in the road body. Under certain circumstances it can also be used to determine if the road surface is wet or dry.

• Both the passive and the active system are currently being tested in a real road environment to clarify all potential opportunities and weaknesses.

Figure 5: Test site with Passive-BIRDS installed

Acknowledgements

The authors would like to thank their colleagues at the Royal Institute of Technology and the University of Gothenburg. Special thanks to Professor Per-Erik Jansson, Hans Alter and Olle Wedin. The research has been funded by the Swedish National Road Administration through the Centre of Operation and Maintenance.