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(54) **Method and system for detecting freezing of a liquid on a road**

(57) A system (2) and a method are provided for detecting freezing of a liquid on a road utilizing a release of latent heat from the liquid. The system comprises a sensor for measuring a road temperature, and a processor connected to the sensor and adapted to monitor temperature changes over time as measured by the sensor. The sensor comprises a measuring element arranged above and at a distance from a road surface portion (10) to continuously measure a surface temperature over the road surface portion (10). The processor is adapted to determine the release of latent heat as an increase in the surface temperature corresponding to a differential quotient between the surface temperature and time and the differential quotient exceeding a threshold value.

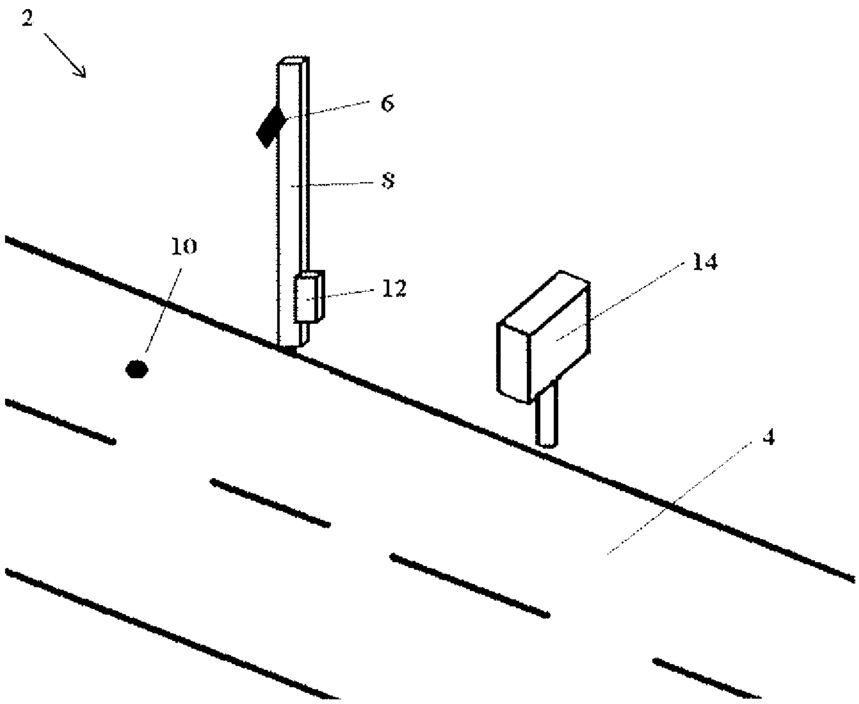

Fig. 1

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Description

TECHNICAL FIELD

[0001] The present invention relates to a system for detecting freezing of a liquid on a road utilizing a release of latent heat from the liquid according to the precharacterizing portion of claim 1. The invention also relates to a method of detecting freezing of a liquid on a road utilizing a release of latent heat from the liquid.

BACKGROUND

[0002] Two principles of thermodynamics are utilized in the present invention:

- The freezing process of water does not always begin when the temperature (T) sinks to the freezing point of the water (T_f). In practice the freezing seldom starts immediately when $T = T_f$. Instead the freezing of water often begins at a temperature significantly lower than the freezing point. This is the principle of super cooling.
- A large amount of heat energy is released when water freezes.

[0003] As the temperature of a wet road surface sinks below the freezing point an ice nucleus has to form in order for the freezing process to begin. Normally the water can form an ice molecule spontaneously which acts as a nucleus for the surrounding water to freeze, but it could also be a change in pressure caused by turbulence which initiates forming of a nucleus or a dust particle. As T gets much lower than T_f the non-frozen water becomes more unstable and a smaller disturbance will be sufficient to cause the water to freeze. When freezing does occur latent heat is released and the large heat flow released will cause a sudden increase in temperature until the temperature has reached the freezing point according to the equation:

$$\text{Water(liq)} \Rightarrow \text{Water(sol)} + 333\ \text{J/g}$$

[0004] The temperature will subsequently be equal to the freezing point as long as both water and ice are present.

[0005] The consideration of these two thermodynamic principles provides a model of the road surface temperature during the process of a liquid freezing thereon. The delayed nucleation leads to the water temporarily becoming super cooled but after the freezing process begins the temperature rises rapidly to the freezing point. Theoretically the water can reach a temperature colder than -40°C with a freezing point of 0°C. This is only possible in extremely pure and calm water under laboratory conditions. However, even on a road surface super cooling of several degrees have been observed.

[0006] Frozen liquid on a road surface is sometimes referred to as black ice. It is not actually black but transparent which makes it look black due to the asphalt. In comparison to frost or snow black ice is much harder to detect and looks much like a wet road. To know when and where black ice has formed is important information for both road users and maintenance personnel who may use chemicals, e.g. salt, to lower a freezing point temperature of liquid on a road surface and to avoid ice formation.

[0007] US 5416476 and US2002/0075141 disclose a system and an apparatus, respectively, which are vehicle mounted and measure a temperature of the road surface on which the respective vehicle travels. US ’476 and WO ’141 do not disclose detecting freezing of a liquid on a road surface.

[0008] US5313202 discloses a method and an apparatus for detecting icing on airfoils. Temperatures of different portions of an airfoil are measured. The temperatures of the different portions are compared and if a temperature difference is detected, ice accretion is to have been detected.

[0009] US 6456200 discloses a device for indicating ice formation on a surface. A temperature difference is measured by a sensor in the form of a Peltier element recessed into a road surface. A circular metal plate on an upper surface of the device is at the same level as the top of the road surface. The device may actively heat and melt an ice layer on the metal plate. No actual freezing point temperature is determined. WO03/044508 discloses an active pavement sensor module provided with a sample well, in which a Peltier cooler is arranged. Freezing of a liquid collected in the sample well is determined.

[0010] A system called Frensor ® developed by Saab/ Combitech/ Saab Technologies utilizes a Peltier element for active heating and cooling of a fluid collected in a recess of a road surface to determine a freezing point for the liquid in the recess. A sensor head is arranged at the bottom of the recess.

[0011] The three latter prior art technologies, as disclosed in US ’200 and WO ’508 and the Frensor ® system, operate utilizing a sensor in direct contact with liquid (or ice). Thus, heat transfer must take place between the liquid (or ice) and a respective sensor in order for a change in liquid temperature to be sensed by the respective sensor. Inherently these systems therefore affect the freezing process due to that a certain mass of the sensor has to adopt a temperature of the liquid (or ice). Further, these technologies operate intermittently since ice is melted and liquid is allowed to freeze again, respectively actively frozen again. Also, freezing of a liquid on the metal plate, respectively in the sample well or the recess, is not the same as detecting freezing on a road surface. Freezing conditions on the metal plate, in the sample well or in the recess differ from freezing conditions on a road surface. Thus, these technologies do not provide information about a liquid on an actual road surface, on which vehicles travel.

SUMMARY

[0012] An object of the present invention is to provide reliable information about freezing of a liquid on a road surface.

[0013] According to an aspect of the invention, the object is achieved by a system for detecting freezing of a liquid on a road utilizing a release of latent heat from the liquid. The system comprises a sensor for measuring a road temperature, and a processor connected to the sensor. The processor is adapted to monitor temperature changes over time as measured by the sensor. The sensor comprises a measuring element arranged above and at a distance from a road surface portion to continuously measure a surface temperature over the road surface portion. The processor is adapted to determine the release of latent heat as an increase in the surface temperature corresponding to a differential quotient between the surface temperature and time and the differential quotient exceeding a threshold value.

[0014] Since the measuring element is arranged above and at a distance from the road surface portion, reliable temperature measurements of the road surface are made and freezing of a liquid on the actual road surface is detected. The freezing of a liquid on an actual road surface covering is detected, i.e. not freezing of a liquid collected in a recess or freezing of a liquid on a metal plate. As a result, the above mentioned object is achieved in a simple and reliable manner.

[0015] According to example embodiments the road surface portion is situated in an area of a wheel track of the road. In this manner the measuring element may be directed at the road surface where vehicles travel and thus, freezing of a liquid on the road surface as such on which vehicles travel may thus be detected. A wheel track being a portion of the road where the right hand or left hand wheels of vehicles touch, and travel on, the road surface.

[0016] According to example embodiments the processor may be adapted to acknowledge the increase if the surface temperature or an ambient temperature is below a threshold temperature. In this manner sudden temperature increases, which occur at non-freezing temperatures are not recognized as freezing of a liquid.

[0017] According to example embodiments the processor may be adapted to determine whether the increase has a duration of at least a minimum time period. In this manner temperature increases due to e.g. passing vehicles are not recognized as freezing of a liquid.

[0018] According to example embodiments the processor is adapted to determine an actual freezing point temperature of a liquid on the road surface portion as dictated by present conditions influencing the liquid on the road surface portion. Knowledge of the freezing point temperature may be utilized for many purposes. For instance may the freezing point temperature be used for deciding whether chemical treatment of the road surface to lower the freezing point temperature, is required. For instance may the processor be adapted to determine the actual freezing point temperature as a temperature reached after the increase. The liquid will remain at essentially the freezing point temperature for a period of time after the increase.

[0019] According to example embodiments the measuring element may be an infrared thermometer. The infrared thermometer will provide contactless measurements of the surface temperature in a reliable and cost effective manner.

[0020] According to example embodiments there may be a cooling element arranged underneath at least part of said road surface portion and the processor may be connected with the cooling element for controlling the cooling element. In this manner the road surface portion may be actively cooled under control of the processor and thus the freezing point temperature of the liquid may be determined also when ambient temperatures are above the freezing point temperature of the liquid.

[0021] According to example embodiments the processor may be adapted to communicate the actual freezing point temperature to a recipient. Such recipient may be a road maintenance vehicle or a road information station. Other examples may be a public warning road sign or a road maintenance supervising station or a road vehicle.

[0022] According to an aspect of the invention there is a method of detecting freezing of a liquid on a road utilizing a release of latent heat from said liquid wherein:

- a road temperature is measured,
- changes in the road temperature are monitored over time,
- the road temperature is a surface temperature measured continuously over a road surface portion,
- the surface temperature is measured from above and at a distance from the road surface portion, and
- the release of latent heat is determined as an increase in the surface temperature corresponding to a differential quotient between the surface temperature and time and the differential quotient exceeding a threshold value.

[0023] According to example embodiments the increase may be acknowledged if the surface temperature or an ambient temperature is below a threshold temperature.

[0024] According to example embodiments the method may include determining whether the increase has a duration of at lest a minimum time period.

[0025] According to example embodiments the method may include determining an actual freezing point temperature of a liquid on the road surface portion as dictated by present conditions influencing the liquid on the road surface portion.

[0026] According to example embodiments the actual freezing point temperature may be determined as a temperature reached after the increase.

[0027] According to example embodiments the method may include that at least a part of the road surface portion is actively cooled.

[0028] Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. Those skilled in the art will realize that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the present invention, as defined by the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The various aspects of the invention, including its particular features and advantages, will be readily understood from the following detailed description and the accompanying drawings, in which:

Fig. 1 illustrates a system for detecting freezing of a liquid on a road surface according to example embodiments, and
Fig. 2 illustrates freezing of a liquid on a road surface portion.

DETAILED DESCRIPTION

[0030] The present invention will now be described more fully with reference to the accompanying drawings, in which example embodiments are shown. However, this invention should not be construed as limited to the embodiments set forth herein. Disclosed features of example embodiments may be combined as readily understood by one of ordinary skill in the art to which this invention belongs. Like numbers refer to like elements throughout.

[0031] As used herein, the term "comprising" or "comprises" is open-ended, and includes one or more stated features, elements, steps, components or functions but does not preclude the presence or addition of one or more other features, elements, steps, components, functions or groups thereof.

[0032] As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0033] As used herein, the common abbreviation "*e.g.*", which derives from the Latin phrase "exempli gratia," may be used to introduce or specify a general example or examples of a previously mentioned item, and is not intended to be limiting of such item. If used herein, the common abbreviation "*i.e.*", which derives from the Latin phrase "id est," may be used to specify a particular item from a more general recitation.

[0034] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0035] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0036] It will be understood that when an element is referred to as being "coupled" or "connected" to another element, it can be directly coupled or connected to the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly coupled" or "directly connected" to another element, there are no intervening elements present.

[0037] Well-known functions or constructions may not be described in detail for brevity and/or clarity.

[0038] Fig. 1 illustrates a system 2 for detecting freezing of a liquid on a road surface 4 according to example embodiments. The system comprises a sensor comprising a measuring element in the form of an infrared (IR) thermometer 6 arranged on a post 8 at a side of a road, the road surface 4 of which is to be monitored for freezing of liquid.

[0039] The liquid on the road surface 4 may be water or brine containing water and a chemical for treating the road to prevent freezing of water on the road surface, e.g. salt (NaCl). In case of only water on the road surface it is commonly known that the freezing point temperature of the water is 0° Celcius. However, on roads which during cold seasons are treated with chemicals to lower the freezing point temperature of the liquid on the road, the freezing point temperature is unknown in particular, if some time has passed since a road section was treated. By means of the system according to the present invention freezing of a liquid on the road surface 4 may be detected and according to some example embodiments the freezing point temperature may be determined.

[0040] The IR thermometer 6 is pointed at a road surface portion 10, such that the IR thermometer 6 may measure the temperature of the road surface portion 10 or a liquid covering at least partially the road surface portion 10. The road surface portion 10 may be situated in an area of the road where vehicles travel, such as a wheel track area. The road surface portion 10 may have an area of about 20 square centimetres, or may have a different area e.g. within the interval of 5 - 30 or 1 - 50 square centimetres. Too large an area may make it difficult to determine a sudden increase in liquid temperature.

[0041] The IR thermometer 6 is connected to a processor or data logger arranged in a box 12 on said post 8. The processor is adapted/programmed to utilize an algorithm for detecting freezing of a liquid on the road surface portion 10, see below. The processor may be connected to an active road sign 14, a warning sign which is lit when a freezing of a liquid (formation of ice) is detected by the system 2. The active road sign 14 may be positioned a distance ahead of the IR thermometer 6, e.g. 1 kilometre. The processor may alternatively or also be connected to a road maintenance supervising station, e.g. a centre from which road maintenance vehicles are directed. Such a supervising station may alternatively be a device mounted in a road maintenance vehicle. The processor may also be connected to a warning system, which alerts vehicle drivers e.g. via a GPS receiver about ice formation on relevant road sections. In an alternative embodiment the processor is arranged at a different location than the IR thermometer 6. In this case the box 12 may contain communication equipment for communicating temperature measurements from the IR thermometer 6 to the processor.

[0042] The processor may receive temperature reading from more than one measuring element. Either several IR thermometers 6 may be arrange on the post 8 and directed at different road surface portions at one site or measuring elements, e.g. IR thermometers at different sites send their temperature readings to a centrally arranged processor.

[0043] The system 2 may be installed as a part of an existing RWiS-station, (see below about RWiS-station). This may have the advantage that the same processor or data logger may be used for other RWiS functions and the system according to the present invention and that no new site needs to be prepared. The IR-thermometer feeds the data logger with a signal which is analyzed. In the case of an ice alarm a message is sent to a decision support system that maintenance personnel is using, together with traditional data such as wind, air temperature and humidity which are normally measured at an RWiS-station. The personnel may either receive a message of a freezing point temperature or an alarm of freezing, i.e. ice formation. The system 2 may alternative be installed separate from an existing RWiS-station.

[0044] Beneath the road surface portion 10 a cooling element may be arranged to actively cool the road surface portion 10 in order to determine a freezing point temperature of a liquid also when ambient temperature is above the freezing point temperature of the liquid. The cooling element is controlled by the processor.

[0045] Fig. 2 illustrates freezing of a liquid on a road surface portion. The graph shows how the temperature of the liquid, as measured by a measuring element arranged above the road surface, changes. At first the temperature falls gradually until it reaches - 2 degrees Celsius, at which point freezing of the liquid starts and its temperature increases rapidly to the present freezing point of the liquid, -0,5 degrees Celsius. The liquid remains at this temperature until all the liquid is frozen. Thereafter the temperature of the ice continues to fall.

[0046] Example embodiments of the system for detecting freezing comprises a contactless thermometer, e.g. an IR-thermometer (infrared thermometer), and a processor connected to the thermometer. The processor is programmed with a detector algorithm. The processor may comprise or may be connected to a memory. The memory may be utilized for storing e.g. measured road surface temperature values and calculation results as calculated utilizing e.g. the detector algorithm. The processor and memory may alternatively be called a data logger.

[0047] According to example embodiments the system may comprise a cooling element, e.g. a Peltier element thus forming an active system. The cooling element may be installed underneath the road surface in order to be able to cool the road surface above the cooling element. It is to be understood that "underneath the road surface" encompasses also the cooling element being embedded in a road surface covering (e.g. asphalt or tarmac) as long as the cooling element is covered by the road covering. The cooling element is connected to the processor and controlled by the processor. Thus, the processor may utilize the cooling element to cool the road surface above the cooling element to a temperature below its current temperature as dictated by ambient conditions. Thus, the freezing point temperature may be established even before it has been reached naturally. The processor may be programmed to cool the asphalt until liquid thereon is frozen, the actual moment of freezing may be detected by the IR-thermometer and a freezing point temperature may be calculated. This may provide determining of an actual freezing point temperature before the liquid on the asphalt naturally freezes. With the cooling element the system would be considered active in the sense that the cooling element actually freezes a liquid on part of the roads surface. If the cooling element is turned off the system would be considered passive and may detect ice that forms naturally and only calculate a freezing point temperature when freezing occurs. According to example embodiments, a passive system without the cooling element may provide sufficient information for many applications. The road surface needs not to be manipulated in this case.

[0048] According to example embodiments, the system could be integrated in or added to already existing measurement stations for roads, these are commonly called "Road Weather information Systems" (RWiS). At present an RWiS typically measures temperature and humidity but cannot indicate ice formation. Alternatively, the system for detecting freezing of a liquid may be arranged in a dedicated station in a fixed location at a road or a vehicle. In the latter case it is to be noted that, since detecting freezing of a liquid on a road surface according to the present invention has to be performed on a road surface portion, the vehicle must be standing still to utilize the detector algorithm.

[0049] A passive system may be upgraded to an active system by the addition of a cooling element. The IR-thermometer and the black ice detector algorithm are utilized in both the active and passive systems.

[0050] The IR-thermometer may have a time-resolution of 0,5 - 50 Hz, e.g. a time-resolution of 10 Hz may be used. It may be connectable to the data loggers of the RWiS-station where the black ice detector system may be integrated. Alternatively, a standalone system may be built with a data logger which exclusively handles the IR-thermometer. This may be useful if standalone systems will be installed closer than existing RWiS-stations, for example at bridges or other areas prone to ice formation.

[0051] The data logger with the algorithm software may be remote, i.e. the data logger is placed at a different location than the IR-thermometer. The main reason for using a data logger close to the IR-thermometer is that the continuous temperature measurements need not be communicated, instead the temperature measurements may be analyzed in place and signals to other locations or devices may be sent e.g. in case of detection of ice or to communicate freezing point temperature values. With sufficiently high data transfer rates a remote data logger may be realized.

[0052] According to example embodiments an IR-thermometer of brand Quixote Surface Patrol model 999J may be used. It operates well measuring form a static position.

[0053] The signal from the IR-thermometer is sent to a data logger where an algorithm is analyzing the signal in an on-line fashion. The IR-thermometer signal gets interpreted by a detector algorithm. The algorithm states a few conditions of the signal which may correspond to a freezing occasion. Preferably, the algorithm may be insensitive towards disturbances such as passing traffic. The basic foundation of the algorithm is the calculation of the differential quotient between the surface temperature and time, $\Delta T/\Delta t$. To exclude sudden disturbances in the temperature signal, such as traffic, to be interpreted as freezing, Δt is set to a constant value k_t (seconds) longer than the used time step, e.g. longer than 0.1 second in the case of temperature measurements at 10 Hz. The size of k_t is a question of optimization where too small values will trigger alarms for situations which are not related to the process of freezing. k_t may for instance be set to a value of 10 seconds or 20 seconds or even 90 seconds. Other values may also be used, e.g. during experiments a value of k_t = 30 seconds has shown good performance to detect ice with few false detections. A too large k_t would make the algorithm less sensitive towards changes and miss freezing occasions; hence k_t can be seen as a sensitivity parameter of the system.

[0054] The quotient is calculated for every step of the signal which means the algorithm is rerun ten times per second in the case of a 10 Hz signal being used. For the algorithm to detect a freezing occasion the differential quotient has to exceed a predefined threshold value, Td_{thr}. The foundational condition for freezing then becomes:

$$\frac{\Delta T}{\Delta t} > Td_{thr} \quad \leftrightarrow \quad \Delta T > k_t * Td_{thr}$$

[0055] A high threshold value may exclude most slow climatologically variance of the surface such as heating from sun radiation. The algorithm may also include a condition requiring a number, n, out of n + m calculated quotients to be above the threshold, Td_{thr} , to ensure that occasional incorrect temperature values do not influence the detection of ice forming on a road surface portion. Td_{thr} may be determined at a site of a system for detecting freezing or a fixed value may be set, e.g. at Td_{thr} = 1/60 °C/second. Other values of Td_{thr} may alternatively be used, e.g. within the interval 1/120 to 1/20 °C/second.

[0056] To avoid disturbances at higher temperatures to be falsely interpreted as freezing occasion the road surface temperature or ambient temperature may be required to be below a maximum value of T_{max} . T_{max} may for instance be 0.5 °C, 5 °C or 10 °C or any other suitable temperature, which gives:

$$IF \quad \Delta T > k_t * Td_{thr} \quad \text{AND} \quad T < T_{max} \quad \text{THEN} \quad [F] = \begin{bmatrix} F \\ t \end{bmatrix} \tag{1}$$

[0057] Where, [F] is a vector which saves the times of freezing occasions.

[0058] The algorithm described so far is for example enough, to direct information that ices has formed to active road signs or in other ways indicate that ice has formed. To provide information about a freezing point temperature of a liquid on a road surface, e.g. for maintenance personnel the system has to save the freezing point as well. Since the freezing point temperature (T_f) occurs after the freezing has started and while both liquid and solid liquid is present this will correspond to the highest temperature reached after the process of freezing has begun. The vector that was saved in equation (1) may then for example be expanded to:

$$[F] = \begin{bmatrix} F \\ t \quad T_f \end{bmatrix} \quad \text{were } T_f = \max(T(t-120):T(t+300)) \qquad (2)$$

[0059] In this example T_f will be the highest temperature reached 120 seconds before the freezing is recorded until 300 seconds after, the algorithm looks for the highest temperature instead of the momentary temperature. Other time limits than 120 seconds and 300 seconds may of course be used to define a interval, in which the highest T_f is recorded. For instance may the time limit before the freezing (sudden increase in surface temperature) be set to 0 minutes and the time limit after the freezing be chosen within the interval 20 - 180 seconds.

[0060] A freezing point temperature may alternatively be defined as a temperature within a temperature interval of a temperature reached at the end of the sudden increase in road temperature, e.g. an interval of 1 degree Celsius.

[0061] Equation (2) may be utilized in an active system with a cooling element. The system will then cool the road surface with the cooling element until it freezes. The freezing point temperature will be saved. The determined freezing point temperature may be utilized by maintenance personnel to evaluate if more brine is needed or if the last application is still effective. If ambient and/or road surface temperature gets close to the freezing point temperature the cooling element may be turned off in order to use the system in the same way as the passive system without the cooling element to detect freezing on the road surface caused by natural decrease in ambient temperature.

[0062] According to example embodiments a method of detecting freezing may be described using the following steps:

- Read an input value corresponding to the road surface temperature.
- Compare the value with the value recorded 30 seconds earlier.
- If the temperature has risen quickly (faster than Td_{thr}) and if the temperature is less than 0.5° then save the time as a freezing event.
- Search for the highest temperature a time interval before and after the freezing event.
- Record this temperature as the freezing point.

[0063] In case an active system is used, the cooling element may be activated several times per hour, e.g. 2-10 times/hour.

[0064] According to example embodiments, the system may comprise:

- An IR-thermometer
- The ice-detection algorithm
- A cooling element
- A processor or data logger for data processing running algorithm and sending out ice formation information, i,e, info to ice warning signs, road maintenance personnel, car navigators etc.

[0065] The cooling element may be a Peltier element in an aluminium cylinder. The element requires a voltage of 12V. The aluminium cylinder would be embedded in the road and connected to a power supply. An active system may detect freezing point temperatures at any time compared to a passive system where a freezing point may be calculated after a natural freezing event.

[0066] According to example embodiments a main application for the system may be to monitor a road network in order to detect ice formation and estimate at least one freezing point temperature. The system may either be integrated into one or more existing RWiS-stations or installed as stand-alone systems. Other applications may include ice detection on airport runways, the terms road, road surface and road surface portion are in this context interpreted to mean runway, runway surface and runway surface portion.

[0067] According to example embodiments the system may enable assessment of when and at what temperature freezing actually occurs. The system may consequently enable safer roads with fewer accidents. Moreover, the system may enable more efficient and optimized road maintenance as the results of road treatment with de- and anti-icing may be monitored if they have given any effect. This will result in less salt being used, less trucks deployed for road treatment and hence cost savings, environmental benefits and safer roads.

[0068] According to example embodiments, the increase in temperature may be used as an indicator of ice formation and hence enables detection of ice being formed, for example on a road. The phenomenon of the rising temperature of the freezing water-ice mixture may be measured with sufficiently high resolution. During field observations the increase in temperature has lasted for approximately 30-90 seconds. Thus, as a part of a criteria a duration of the increase may be selected e.g. to be 10, 20, 30 or 40 seconds. The temperature may be measured ten times every second in order to be sure to catch the rapid temperature changes. However, measuring temperature at a different frequency, e.g. 1 Hz or 3 Hz may be done. The measuring requires a thermometer of a kind which will not act resistive towards rapid changes of the surroundings, i.e. a classical thermometer probe will have a mass that needs to adapt to the surroundings in order to represent the true temperature. This effect will smoothen out rapid temperature changes. An IR-thermometer which measures infrared radiation of the road surface portion without any contact does not suffer from this effect. This non-contact method to measure temperature makes it possible to catch rapid changes in temperature. The concept of high-frequency measuring with a non-contact thermometer will make it possible to observe rapid changes in temperature that occur during freezing of a liquid on the road surface portion.

[0069] According to example embodiments, the proposed system may monitor the road surface portion and is able to detect rapid changes in temperature being indicative of a liquid freezing and hence ice formation. Consequently the proposed system may warn maintenance personnel and road users of slippery road conditions. To do this the high-frequency temperature signal may be analyzed by an algorithm in real time. The algorithm detects patterns in the temperature signal which may correspond to a freezing event and trigger an alarm when freezing occurs. The alarm may for instance contain three types of information: the time of the alarm, the location of the relevant IR-thermometer and the freezing point of the surface which corresponds to a temperature reached during the sequence of freezing.

[0070] Compared to existing technologies for detecting ice on a road surface the present system has an advantage of being simple and cheap. The passive version requires no modification or installations on the road surface, no traffic will be hindered and the IR-thermometer is small enough to not disturb road users. The present system may present a low-cost alternative which may be installed in many locations. If active road signs are used with the system, these signs may replace passive signs.

[0071] A commercially interesting application of example embodiments may be to install a large number of sensors in a road network of a country or a region of a country in order to inform road maintenance personnel of time and place for freezing events. The information may also include freezing point temperatures at different locations. Optionally detected ice formation may be output via active road signs.

[0072] Example embodiments may be combined as understood by a person skilled in the art. Even though the invention has been described with reference to example embodiments, many different alterations, modifications and the like will become apparent for those skilled in the art.

[0073] Therefore, it is to be understood that the foregoing is illustrative of various example embodiments and is not to be limited to the specific embodiments disclosed and that modifications to the disclosed embodiments, combinations of features of disclosed embodiments as well as other embodiments are intended to be included within the scope of the appended claims.

Claims

1. A system (2) for detecting freezing of a liquid on a road utilizing a release of latent heat from said liquid, the system comprising
   a sensor for measuring a road temperature, and
   a processor connected to said sensor and adapted to monitor temperature changes over time as measured by said sensor
   characterized in that
   said sensor comprises a measuring element arranged above and at a distance from a road surface portion (10) to continuously measure a surface temperature over said road surface portion (10), and
   wherein said processor is adapted to determine said release of latent heat as an increase in said surface temperature corresponding to a differential quotient between said surface temperature and time and said differential quotient exceeding a threshold value.

2. The system (2) according to claim 1, wherein said processor is adapted to acknowledge said increase if said surface temperature or an ambient temperature is below a threshold temperature.

3. The system (2) according to any one of claims 1 and 2, wherein said processor is adapted to determine whether said increase has a duration of at least a minimum time period.

4. The system (2) according to any one of the preceding claims, wherein said processor is adapted to determine an actual freezing point temperature of a liquid on said road surface portion (10) as dictated by present conditions influencing said liquid on said road surface portion (10).

5. The system (2) according to claim 4, wherein said processor is adapted to determine said actual freezing point temperature as a temperature reached after said increase.

6. The system according to any one of the preceding claims, wherein said measuring element is an infrared thermometer (6).

7. The system (2) according to any one of the preceding claims, wherein a cooling element is arranged underneath at least part of said road surface portion (10) and said processor is connected with said cooling element for controlling said cooling element.

8. The system (2) according to any one of claims 4 and 5, wherein said processor is adapted to communicate said actual freezing point temperature to a recipient.

9. The system (2) according to claim 8, wherein said recipient is one of a public warning road sign (14) or a road maintenance supervising station or a road vehicle.

10. A method of detecting freezing of a liquid on a road utilizing a release of latent heat from said liquid wherein:

    a road temperature is measured,
    changes in said road temperature are monitored over time,
    said road temperature is a surface temperature measured continuously over a road surface portion,
    said surface temperature is measured from above and at a distance from said road surface portion, and
    said release of latent heat is determined as an increase in said surface temperature corresponding to a differential quotient between said surface temperature and time and said differential quotient exceeding a threshold value.

11. The method according to claim 10, wherein:

    said increase is acknowledged if said surface temperature or an ambient temperature is below a threshold temperature.

12. The method according to any one of claims 10 and 11, wherein:

    it is determined whether said increase has a duration of at lest a minimum time period.

13. The method according to any one of claims 10 - 12, wherein:

    an actual freezing point temperature of a liquid on said road surface portion as dictated by present conditions influencing said liquid on said road surface portion is determined.

14. The method according to claim 13, wherein:

    said actual freezing point temperature is determined as a temperature reached after said increase.

15. The method according to any one of claim 10 - 14, wherein:

    at least a part of said road surface portion is actively cooled.

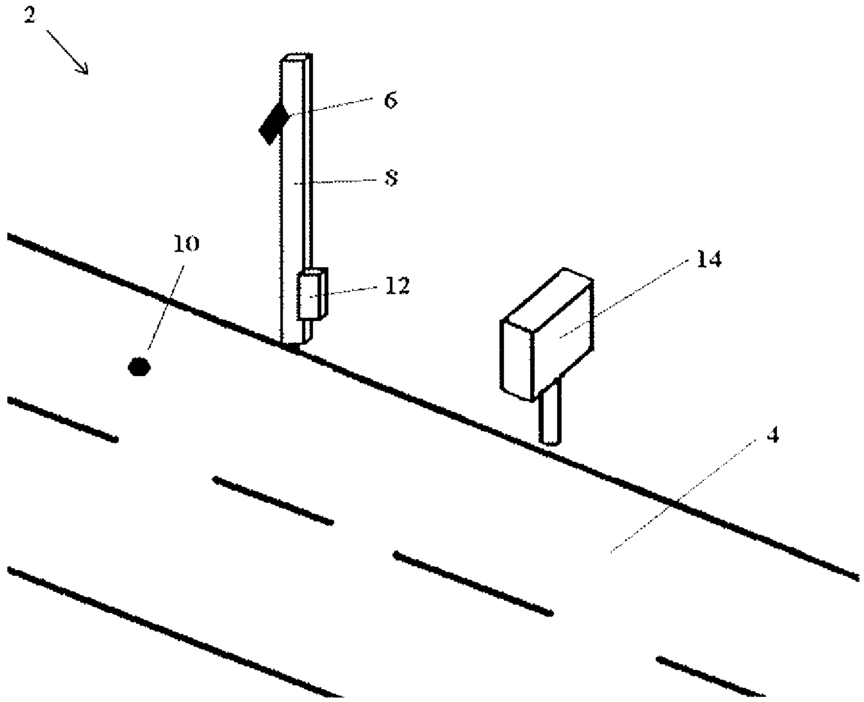
2
6
8
10
12
14
4

Fig. 1

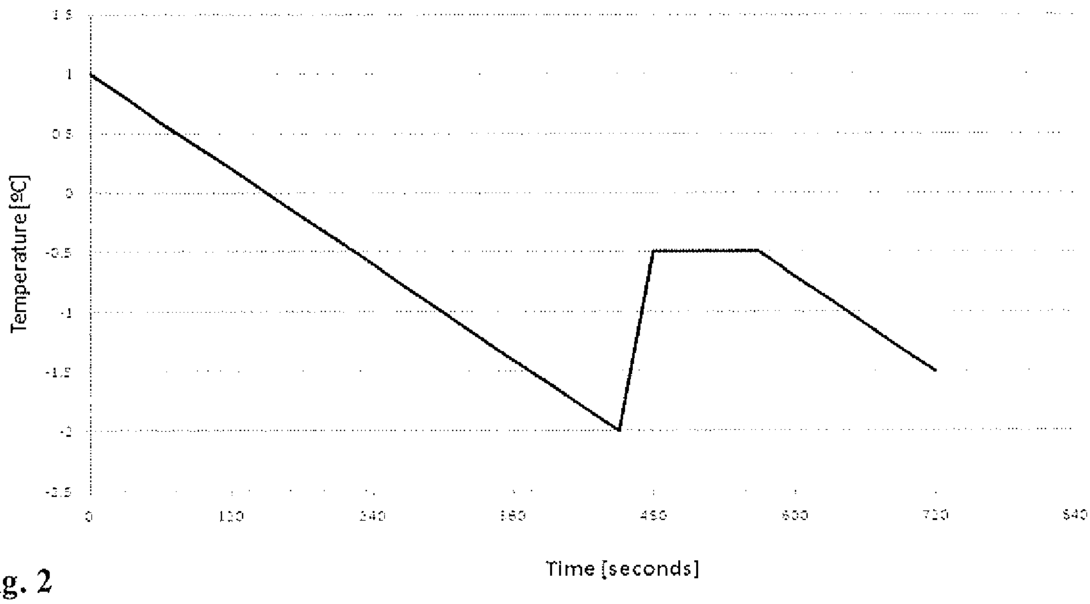
Temperature [ºC]
1
0.5
0
-0.5
-1
-1.5
-2
0
120
240
360
480
600
720
840
Time [seconds]

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 10 17 3604

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 313 202 A (HANSMAN JR ROBERT J [US] ET AL) 17 May 1994 (1994-05-17) * column 3, lines 14-64 * * column 6, lines 12-66 * * figures 1,2A,5A,5B * -----	1-15	INV. G08B19/02

TECHNICAL FIELDS SEARCHED (IPC)
G08B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 November 2010	Sgura, Salvatore

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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24-11-2010

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US 5313202 A	17-05-1994	NONE	

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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