Cold Regions Science and Technology 125 (2016) 65–71

Contents lists available at ScienceDirect

Cold Regions Science and Technology

journal homepage: www.elsevier.com/locate/coldregions

Prevention of icing with ground source heat pipe: A theoretical analysis for Turkey's climatic conditions

Ahmet Ozsoy [a,*], Ragip Yildirim [b]

[a] Suleyman Demirel University, Department of Energy Systems Engineering, Faculty of Technology, Isparta, Turkey
[b] Mehmet Akif Ersoy University, Bucak Emin Gulmez Technical Sciences Vocational School, Burdur, Turkey

ARTICLE INFO

Article history:
Received 13 March 2015
Received in revised form 1 February 2016
Accepted 7 February 2016
Available online 13 February 2016

Keywords:
Heat pipe
Thermosiphon
Ground source heat pipe
Icing
Icing prevention

ABSTRACT

The purpose of this study is to explore preventing icing by using the ground as a heat source at the appropriate region. The heat energy that can be transferred from ground to surface with an elbow heat pipe was analyzed. This study's variables are heat pipe diameter (10 to 50 mm), evaporator and condenser lengths (1 to 5 m), ground temperature (3 to 7 °C), air temperature (−2 to −10 °C) and wind velocity (3 to 10 m/s). It is calculated that the heat that can be transferred from ground changes in direct proportion to ground temperature, heat pipe diameter, and evaporator and condenser lengths. The protection area where the heat pipe can prevent icing depends on the heat transferred from the ground. When the heat pipe diameter is 25 mm, air temperature is −8 °C, ground temperature is 6 °C, wind velocity is 6 m/s and if the evaporator and condenser lengths are 1 m then the protection area is 2.7 m^2, if they are 5 m then the protection area is 14.2 m^2. The heat transfer from the ground surface to ambient increases with the increase of wind velocity and also with the decrease of air temperature. This increase of heat transfer decreases the protection area. In conclusion, the ground can be used to prevent icing as an energy source for heat pipes in Turkey's climatic conditions.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Snow and icing are widely seen in the eastern areas of Turkey in the winter season. Because of the snow and icing on bridges and highways traffic accidents can happen. There were 161,300 traffic accidents causing death or injuries in 2014. 34% of these accidents occurred in the winter months (November to March) (KGM, 2014). Snow and icing on surfaces cause great economic losses as well. Salt and chemicals are usually used for preventing snow or ice. Despite the good results from these techniques, environmental pollution, high cost and limited application conditions still exist.

Currently available technologies for internally heating bridge decks consist primarily of three types of systems: electrical, hydronic, and heat pipe. In the electrical system, heat is produced by a current flow in an insulated metallic cable mounted within a bridge deck. Typically, the cable is laid out in a corrugated pattern to provide uniform heat distribution across the surface. The cable transfers heat to the surrounding material when it warms up due to the passage of an electrical current. These heating cables have been used on projects that comprise pavements, sidewalks etc. On the other hand, the hydronic system produces its heat from the flow of a hot liquid instead of electricity. Usually, a continuous loop of a rigid or flexible pipe is used. Hot liquid is circulated through this closed-circuit loop by a pump. As the heat of the liquid decreases following heat transfer to the surrounding medium it returns to the heat source for reheating (Hoppe, 2000).

Some research projects were conducted on using alternative energy sources to eliminate icing or frost on roadways and bridges. The heat is provided by GSHP in order to prevent icing on pavements and bridges. Distribution of temperature on the ground has been studied by two colleagues (Balbay and Esen, 2013). Some researchers studied the process of snow melting on pavements through solar collection by experiments and numerical simulation (Chen et al., 2011). Someone else studied the de-icing process of concrete pavements with carbon fiber heating cables. With an input power of 1134 W/m^2, the temperature on the slab surface rises above 0 °C in 2.5 h at an approximate rate of 0.17 °C/min (Zhao et al., 2011).

11,200 heat pipes were used in order to prevent damage from frozen ground on the Alaska pipeline (Wu et al., 2010). For the purpose of maintaining the thermal stability of the underlying permafrost of the road, hairpin thermosiphons and air convection embankments are used (Xu and Goering, 2008).

The carbon fiber grille is located 5 cm below the pavement surface and the interval of heating wires is 10 cm to melt the snow on the airport surface in Beijing/China. When we obtained 350 W/m^2 energy, the temperature of the surface increased by 4.63 °C. 2.7 cm of snow on the surface melted in 2 h (Lai et al., 2014). The first heated bridge was built in Virginia/USA. In this study, 241 heat pipes were used with the aim of the prevention of icing for a total area of 567 m^2. Pipes were installed in the bridge surface with a 6.5% slope. R123, R134a, water

* Corresponding author. Tel.: +90 2462111401.
E-mail address: ahmetozsoy@sdu.edu.tr (A. Ozsoy).

http://dx.doi.org/10.1016/j.coldregions.2016.02.003
0165-232X/© 2016 Elsevier B.V. All rights reserved.

Table 1
Ground and air temperatures of some cities in Turkey.

	Ground temperature measured in long period (°C) (1 m depth)				Extreme minimum air temperatures measured in long period (°C)			
	Isparta	Ankara	Erzincan	Erzurum	Isparta	Ankara	Erzincan	Erzurum
October	19.7	19.8	19.3	14.4	6.6	7.3	5.9	1.4
November	14.8	14.9	14.2	9.5	2.4	2.5	0.7	−4.2
December	11.3	10.0	9.5	5.4	−0.3	−0.6	−3.6	−10.6
January	8.1	7.7	6.2	2.4	−1.9	−3.0	−6.8	−14.3
February	6.7	5.9	5.1	0.9	−1.3	−2.2	−5.3	−13.0
March	8.1	7.6	6.9	1.6	1.0	1.0	−0.5	−7.0

and ammonia were tested as working fluids and best outcome was from ammonia. 2460 W heat was provided from a heat pipe with ammonia as the working fluid (Hoppe, 2000).

Ice formation or accumulation of snow on bridges and highways can be prevented directly or indirectly by ground source heat pipe. Heat pipe (HP) is a heat transfer device that carries the heat with a phase change of working fluid from a high temperature medium to a low temperature medium. HP can carry the heat even when there is low temperature difference without needing additional energy. Basically, HP is vacuumed, sealed, and includes a working fluid that can boil at low temperatures and tube shaped passive heat transfer device. In the evaporator, the working fluid is evaporated with the transferred heat energy from the high temperature medium. In the condenser, saturated vapor condenses with heat rejection to the low temperature medium. The condensed working fluid returns to the evaporator by capillary forces in the porous wick structure or by gravity. This cycle repeats continuously and heat is transferred with a low amount of fluid (Peterson, 1994; Faghri, 1995).

In the HP different fluids that are suitable for the operation temperature can be used for transferring the heat. At this temperature the working fluids must be able to evaporate and condense. However, to select the working fluid taking only the operation temperature into account is not enough. Density, latent heat, surface tension and viscosity of the fluid should also be considered. A merit number that consists of all of these properties is defined and used in the selection of fluids (ESDU 80017, 2005).

If the heat pipe gets the heat from the ground, these kinds of devices are called Ground Source Heat Pipes (GSHP). GSHP can be used for various applications. These are; preserve the frozen soil and to prevent icing at roads, bridges, airfields, stadiums and pavements. Also for heating or cooling tunnels and petroleum pipelines (Hoppe, 2000; Lee et al., 1984; Yildirim, 2014).

Frozen soil is very sensitive to air temperature changes. Structures on frozen soil can be deformed and destroyed by ice melting in the soil. To prohibit that the temperature should be stabilized. For this purpose GSHP can be used. These heat pipes absorb the heat under the structure and release it to the atmosphere. In some cold regions there is permafrost with a railway built on it. If permafrost melts through climate change the railway can be damaged. To solve this problem, GSHP is recommended (Bayasan et al., 2006; Anna, 2014; Long Jin et al., 2014).

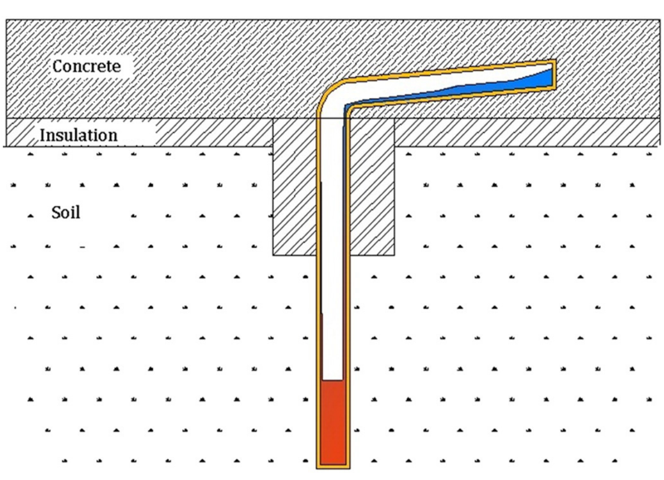

Fig. 1. Schematic view of the heat pipe inside the ground.

To prevent icing on a surface, CO_2 heat pipes and heat pump systems are used together. Heat pipes are placed 5 cm under the surface, horizontal to the surface and vertical to the ground at 60 cm intervals. In winter temperature at 2 m depth of soil changes between 8.8 °C and 13.8 °C. When the air temperature is between −6.7 °C and −1.7 °C, the measured snow melt rate is 0.6–1.25 cm per hour. For another study, when ammonia or Freon is used as the working fluid, ice formation was prevented in an area of 984 m^2 area 177 36 m length heat pipes (Yu et al., 2014). In northern countries, HP is used for carrying geothermal energy to fight icing. Because geothermal resources can get frozen at low temperatures, they cannot be used directly for de-icing. For this purpose heat pipes that use ammonia as working fluid are preferred (Swanson, 1980).

GSHP could also be used at metro stations. Intensively working underground trains produce large amounts of heat during their movements. Moreover, crowds as well as air conditioning and lighting systems at stations also produce large amounts of heat so tunnel temperatures increase. With this temperature increase the efficiency of cooling systems decreases. Soil temperature around the tunnel is almost constant throughout the year at about 15 °C. In summer, the temperature of the tunnel is approximately 30 °C, sometime rising to 36 °C. GSHP can be used for cooling the tunnel in summer and heating in winter (Ampofo et al., 2004; Thompson et al., 2007).

In this study, the aim was to prevent icing in places such as roads and airfields with the use of the ground as a heat source. For this purpose, the heat from the ground is transferred to the surface through an elbow type heat pipe that has ammonia as the working fluid. The system does not require any additional energy and the ground is an infinite source because it is always hotter than the air temperature. These advantages make the system more significant. Another important advantage of the recommended system is that the system does not require any maintenance and does not have operating costs after the initial investment. This is the first such study conducted under Turkey's climatic conditions.

2. Material and method

To prevent icing, surface temperature must be 0 °C or above. Energy carried by GSHP provides this necessary temperature on the surface. First the changes on the ground temperature are examined. A theoretical model is established for GSHP. Amount of heat transfer with GSHP was calculated according to this model. As a result, the protection area of GSHP was studied.

Because icing happens in winter, the heat pipe's working conditions were defined according to that season's ground and air temperatures. Eastern Anatolia is the coldest region of Turkey so ground temperatures are taken from that region. Ambient and ground temperatures are shown in Table 1 for some cities in Turkey. According to 2011 statistical

Download English Version:

https://daneshyari.com/en/article/6426625

Download Persian Version:

https://daneshyari.com/article/6426625

Daneshyari.com