

Design and Preliminary Experiment of Portable Device for Melting Thin Ice on The Highway Road

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Abstract: Removal of thin ice and accumulated snow on the highway road snow is agent problem to be solved in the southern China. We proposed a heating method to remove the thin ice and snow on the highway road. Theoretical analysis was conducted to prove the feasibility by burning diesel oil for heating. The ice and snow are effectively melted with little diesel oil. A heating device model was proposed accordingly. The specific 3D structure was designed according to the presented proposal. To verify the ice melting capacity of the device, a preliminary experiment melting ice is conducted. Experimental result shows that the ice was quickly melted with low consumption of the fuel. With further optimization of device structure, a portable device for removal of thin ice and snow on the highway road will have a wide range of applications in southern China.

1. Introduction

Highway road has become one of the key factors for the economic development. To ensure that traffic flows freely and safely is one of the key economic and social issues for the consideration of highway construction and operation. About three-fifths of the highway will be frozen in the winter in China. The ice on the road has become the white killer on the highway road [1]. The ice will lead to the speed limit for the vehicles. The driving speed is only about 50% of the slippery road surface due to lack of good roads. For the frozen roads are easy to make cars brake failure causing traffic accidents occurring frequently. Smooth traffic and road safety can't be guaranteed any more. Every year, traffic accidents with several vehicles and even dozens of cars collision on the way from head to end are occurred only due to the ice on the road. Snow and ice will cause serious highway road closures and traffic gridlock which gives great inconvenience to the passenger and freight transport [2]. Direct and indirect economic loss is immeasurable. The deck with many roads meeting together is called the highway traffic throat. The deck is more easily frozen than other parts of the highway road due to deck completely exposed to the air. Meanwhile the deck general has the slope and steep bend. Many drivers drive from the snow and ice roads to icy bridge because of underestimation, and then can easily cause accidents and traffic congestion.

Removal of ice and snow is a problem which has been painstaking research. People have been thinking about the problem through human and social development. The task of removing ice and snow is different due to the different of the size snowfall, air temperature and geographical environment [3, 4]. The ice and snow on the highway road will seriously reduce the adhesion between tire and road which can easily lead to vehicle steering and brake failure, and then traffic safety problems occur [5]. Therefore how to effectively remove the ice and snow became a very important problem to be solved. Traditional mechanical ice and snow removal equipment does very well for



removal of thick ice and snow, but really does nothing for thin ice and snow on the highway road. What's more, the large shovel de-icer has great applicant limitations in the corners and narrow sections of highway road. Currently, the large fuel consumption, high cost and low clean rate of the equipment is not suitable for China's national conditions. Deicing salt spreader can lower the freezing point and has a good effect to remove the thin ice and snow on the highway road. However it requires special large sprinkle for the high energy consumption. There are also some limitations for using of inorganic salts. Ice melting agents will pollute the environment, salinize soil, and corrode roads and bridges for a long-term use of chlorine salt melting agent. It will cause irreversible damage for durability of the highway road. Aiming at the problem of removing thin ice and snow on the highway road in the southern China, a heating method of removal pavement ice and snow was present and its feasibility has been verified by the theoretical analysis. Considering the portability and efficiency, a simple heating device with simplicity has been designed. The good de-icing effect has displayed through preliminary experiment test.

2. Theoretical Analysis

Road heating de-icing method mainly relies on the heat generated by fuel to melt the thin ice on the road. Considering the most common fuels are diesel oil, gasoline, etc.. Theoretical calculation is conducted based on the combustion value of the fuel, the heat transfer efficiency, the amount of the heat for melting ice and snow. It is assumed the calculation is analyzed under the same conditions with the same quality of fuel oil. Supposing the fuel quality is m , fuel combustion value is r , fuel heat conversion efficiency is η , the amount of heat for melting thin ice is λ , the average temperature of the thin ice is t , ice thickness is h , and the pavement width of the road is b .

If ice temperature was raised t °C to 0°C, the requirement amount of the heat is R_1 . According to the relevant definition of specific heat capacity, R_1 can be represented by the following formula:

$$R_1 = c_{ice} m_{ice} (0 - t) \quad (1)$$

Where c_{ice} is the specific heat capacity of the ice, m_{ice} is the ice quality. Similarly, the heat R_2 for changing the ice to water can be expressed as:

$$R_2 = \lambda m_{ice} \quad (2)$$

Therefore, when the thin ice temperature is t and the quality of ice is m_{ice} , the effective amount of the heat R provided by the fuel can be written as:

$$R = R_1 + R_2 = m_{ice} (\lambda - c_{ice} t) \quad (3)$$

The useful delivery of heat R from fuel with the quality of m can be expressed as:

$$R = mr\eta \quad (4)$$

So the effective ice quality m_{ice} of the melted ice by the fuel is:

$$m_{ice} = \frac{mr\eta}{\lambda - c_{ice} t} \quad (5)$$

When the ice thickness is h and the width of pavement road is b , the deicing effective length l is shown as follows:

$$l = \frac{m_{ice}}{\rho_{ice} hb} = \frac{mr\eta}{\rho_{ice} hb(\lambda - c_{ice} t)} \quad (6)$$

For southern China, the temperature is generally not very low and the thickness of the ice on the highway road is about a few millimeters. Therefore assuming ice thickness h is 2mm, the temperature t is -5°C, pavement width b is 3m, the quality m of the fuel is set to 5kg, and the fuel heat conversion efficiency η is 80%. While the density of the ice ρ_{ice} is 0.9×10^3 kg/m³, the ice specific heat capacity c_{ice} is 2.1×10^3 J/kg°C, and ice melting heat in the stand atmospheric pressure is 3.35×10^5 J/kg. For the two common fuels, the fuel value of gasoline r is 4.3×10^7 J/kg and diesel oil r is 4.6×10^7 J/kg. According to equation (6), the effective removal ice length l for the road by 5kg gasoline and diesel fuel of de-icing

are 94.7m and 101.4m, respectively. The calculation shows that the efficiency of use of fuel oil to remove the ice is very high, and as long as sufficient rapid combustion of the fuel can achieve the ice can be quickly removed. Compared with the gasoline, the diesel fuel value is high and more effective de-icing area can be achieved. So in subsequent study the heating deicing apparatus mainly uses diesel oil.

3. Ice Heating Model

Taking into account the characteristics of the thin ice on highway road in the southern China, the structure of the device should be simple and easy to carry. The system structure adopts the fuel heater to melt the ice. Combustion of diesel fuel heater generates heat, and then the fan to send warm air to the highway road. Fuel heater machine has the characteristics with light weight, flexibility, small size, high wind power, safety and reliable less electricity. Currently, the technology of fuel heater machine is mature, but fuel heater machine used for deicing is reported.

According to the actual needs and market research, a specific structure of the heating device to remove the thin ice has been designed as shown in Figure 1. The system consists of the burner, blower, control system (including controllers, temperature sensors and room temperature controllers, etc.), fuel supply system, shroud and mobile platform and other components. The burner fires the pressurized oil from supply system and provides the amount of heat need for melting ice. Blower is a major part for the heating system, and it provides enough oxygen needed for combustion and is also responsible for transferring the heat to the highway pavement to make ice melt. Fuel oil supply system satisfies the requirement for the burning oil, and meanwhile filters out the impurities in the fuel. The control system controls the temperature of the heater to send the appropriate hot air, and automatically protected in the event of overheating or failure to ensure the safety of the heater. The shroud can prevent diffusion of heat to improve the effect of melting ice. Mobile platform bears the weight of fan heaters and other components. There are two driven ways by the use of artificial or cars, which gives ease of operation concrete construction operations.

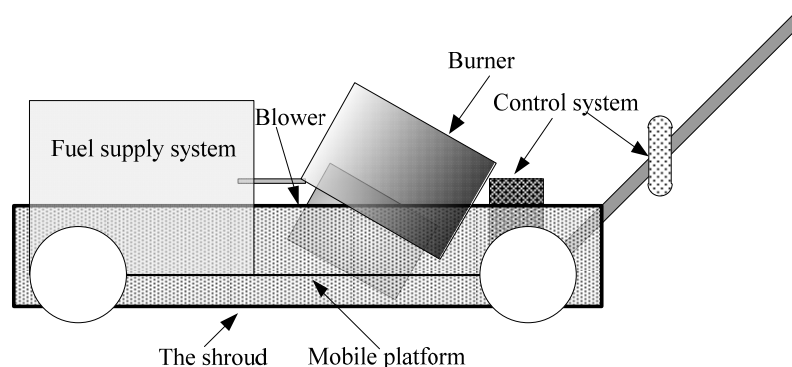


Fig.1 Schematic road heating deicing device

4. 3D Structural Design

3D structure of the heating device was optimistically designed by using Solidworks. The design result and specific physical device are shown in Figure 2. Blower and burner is an integrated structure, and the power supply depends on a battery and inverter to provide the alternating current. The shroud consists of three layers. The outermost layer called structure layer is thin alloy material. The middle layer is insulation material, and will prevent heat loss through the shield. The innermost layer is a high radiation layer with high emissivity, and the heat reflected by radiation will strengthen removing the ice. By pushing mobile platform the ice on the road can be heated and melted. The device is very simple, lightweight, high deicing efficiency, and adapt to road area that large-scale de-icing machine is

not easy to carry out deicing (such as bridge, tunnel, mountain trails, curved channel, etc.). Sustained oil supply can greatly increase its de-icing area.

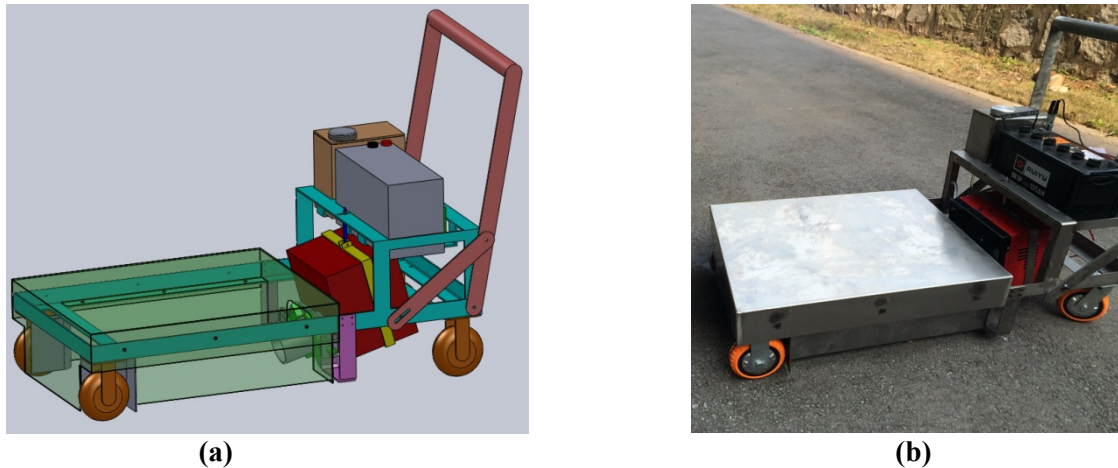


Fig. 2 The device (a) Three-dimensional design result (b) Physical device

5. Preliminary Experiment

To verify ice-melting effect of the apparatus, preliminary experiment was conducted. The relationship between the time required for melting a given amount of ice and the consumption of fuel was analyzed. Test materials are ice and diesel oil. Ice was prepared by an ordinary refrigerator and the weight was measured before the experiment, while diesel oil type is No.0 purchased from an ordinary gas station. The experiment process is shown in figure 3.

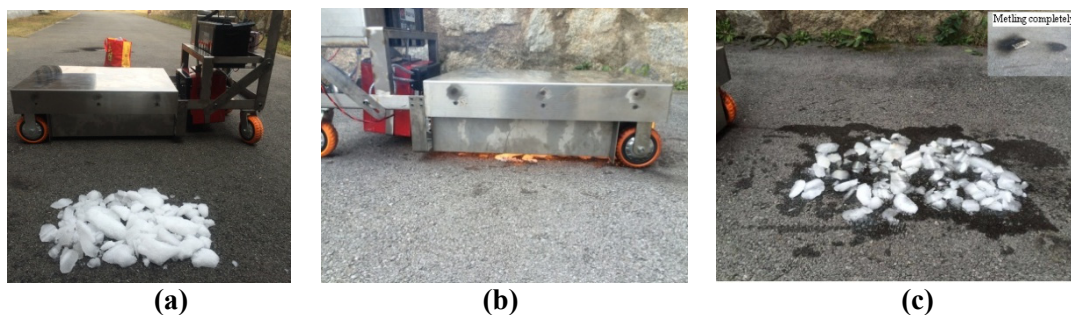


Fig. 3 Experiment process (a) Before ice melting (b) Ice melting (c) After ice melting

Experiment result shows that the consumption of oil is about 120ml and the use of time is 86 seconds when the 3kg of ice was completely melted. It demonstrates that the device has the ability to quickly and efficiently melt the ice while consumption of the fuel is very low.

6. Conclusions

This paper presents a heating method for de-icing. The heating effect of de-icing was analyzed theoretically, and calculation result shows the heat from the diesel oil can receive an efficient deicing effect. Specific structural design was achieved according to the presented proposal. Preliminary experiment result indicates that the device has very good effect with high deicing efficiency and low fuel consumption.

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