SIMPLE METHOD TO ESTIMATE SURFACE SNOW DENSITY

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ABSTRACT: In winter, trains have accreted snow on its bodies and these accreted snow cause damages to railway equipment. To decrease such damages, we are developing a method to estimate snow accretion amount on the train from meteorological conditions along the railway. The amount of flying up snow from snowy railway track affects snow accretion to train bogies. Such snow flying up amount is influenced by snow properties on the track and running speed. The snow properties are influenced by meteorological conditions. Therefore, in this study, we have developed a surface snow density estimation model. The model can calculate the change of snow density after snow fall from snow melt amount of the surface layer which can be obtained from solar radiation and temperature. Comparing observed surface snow density and calculated values of the model, it was found that the calculation result well represents the change of snow density of the surface layer.

KEYWORDS: surface snow density, snow melt, snow accretion, train

1. INTRODUCTION

When train car runs over snowy track, snow on the track fly up and the flying up snow particles accrete to underfloor equipment and bogies of the train (snow accretion). These accreted snow drops off in warm area, and cause damage to railway equipment on the track and car bodies. To prevent these damages, snow removal work is carried out at some stations in winter season. In order to efficiently perform such snow removal work, it is necessary to estimate the amount of snow accretion from weather information. We try to develop estimation method of snow accretion amount. In this study, we first describe a method to easily estimate the snow density on the track which greatly affects the snow flying up amount.

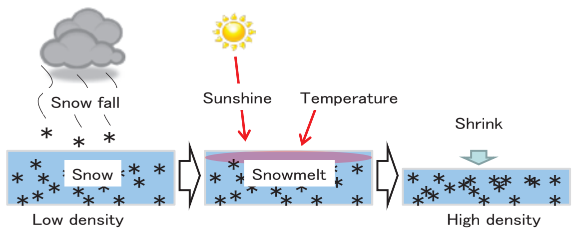

Figure 1: Images of increasing snow density.

2. SURFACEW SNOW DENSITY ESTIMATION MODEL

The amount of snow flying up is large immediately after new snowfall because the bonding force between snow particles is weak. On the other hand, time has elapsed after the snowfall under sunshine and warm temperature, the snow density increases due to melting snow and sintering, etc, and then the bonding strength of snow particles at surface layer increases (Figure 1) , and it is considered that the amount of snow flying up decreases.

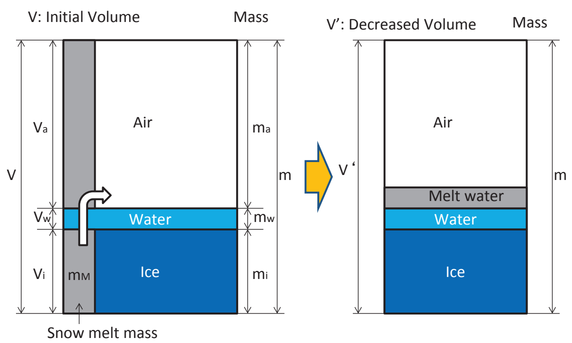

Figure 2: Concept of surface snow density estimation model in snow composition diagram.

In our surface snow density estimation model, it is assumed that snow particles on the surface layer will melt due to solar radiation and temperature after snowfall and then the snow density of the surface layer will increase. We think that the unit volume of snow is divided into the composition of ice, water, and voids. Melting occurs at the ice part, so the change of the mass of the ice that affects the density change. Assuming that the melted ice is filled in the void during snow melt occurrence (Figure 2). So total mass does not change but the volume decreases. Therefore, if

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the density before snowmelt is ρs and the density after snow melting is ρs1, the density increase due to snow melting isexpressed by equation (1).

$$\rho_{s1} = \frac{m}{V'} = \rho_s \left(\frac{\rho_d \times V}{\rho_d \times V - m_M}\right) \qquad (1)$$

Here, ρ_d is dry snow density (kg/m^3), V is volume (m^3) and m_M is snow melt mass (kg).

In order to calculate the surface snow density by the estimation model, it is necessary to know the mass of snow melt. Snow melt mass is obtained by equation (2).

$$m_M = M \times 10^{-3} \times \rho_w \qquad (2)$$

Here, ρ_w is water density (kg/m^3) and M is snow melt amount (mm).

The amount of surface snow melt can be obtained by the heat balance method, but many parameters are necessary for calculation. However, in the railway field, calculations applicable to a wide area at short time intervals are required with less weather information. Konya et al. reported a model to estimate hourly snowmelt amount at snow surface from solar radiation and temperature (equation (3)). Therefore, we use Konya's simple snow melt model for our model.

$$M = aK_d + bT_a + c \qquad (3)$$

Here, K_s is solar radiation (W/m^2) and T_a is temperature (°C). Coefficients a, b, and c are determined by multiple regression analysis with observation values.

3. VALIDATION OF SURFACE SNOW DENSITY ESTIMATION MODEL

We observed the time change of the snow density of 2cm of snow surface layer at the Shiozawa snow testing station of Railway Technical Research Institute (Niigata prefecture, Japan) and the model was verified by comparing the estimated snow density and the observed snow density.

Snow density increased with time after snowfall under solar radiation and temperature change. It was found that the change of the calculation value well represents the change of snow density of the surface layer. As a result, it was shown that the snow density can be estimated by appropriately giving coefficients for estimating the snow melting amount.

4. CONCLUSION

To decrease snow accretion damages, we are developing a method to estimate snow accretion amount on the train from meteorological conditions along the railway. In this study, we have developed a surface snow density estimation model. The model can calculate the change of snow density after snow fall from snow melt amount of the surface layer which can be obtained from solar radiation and temperature. Comparing observed surface snow density and estimated values of the model, it was found that the calculation result of the model well represents the change of snow density of the surface layer.

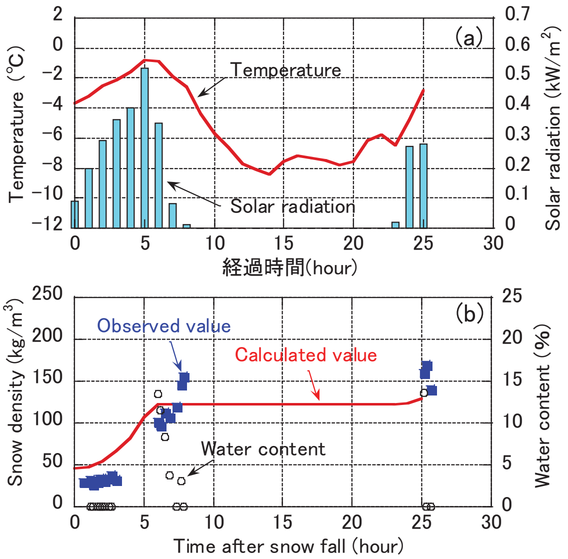

Figure 3: Comparison of observed value of surface snow density with calculated value by the model.

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