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Thermal modeling of railroad with installed snow melting system

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ABSTRACT

Light rail transit (LRT) vehicles that employ electric power supply systems along the running rails may be forced to suspend operations when snow or ice freezes on the collector shoe. The presence of snow on the collector shoe causes loss of power supply to the train unless the power supply system has a melting system with sufficient heating capacity to melt the snow. A general solution to prevent ice formation on railroad systems is to preliminarily operate a heating system in the running rail and guide rail based on weather forecasts. However, excessive pre-heating increases electricity costs and reduces the durability of the concrete running rail by subjecting it to persistent thermal stresses, which in turn leads to increased maintenance costs.

To minimize electric power consumption and maintain stable train operations, a reliable standard for the operation time of the electric pre-heating system must be established. In this study, we analyzed the operational conditions and impact of snow melting systems on the running rail and power supply rail (guide rail) of an LRT system, considering its reliable and safe operations in cold and snowy weather. We performed experiments at the LRT facilities in Uijeongbu, Korea, to analyze the time required to pre-heat the running rail and guide rail. In addition, we numerically analyzed the time by using modeling techniques with ANSYS, considering various weather conditions such as ambient temperature, wind speed, and humidity.

The numerical modeling results were verified by comparing them with experimental results. We analyzed the operating time for the snow melting system to minimize electric power consumption and maintain stable train operations.

1. Introduction

Public railway transportation in modern cities often comprises branch lines that do not have significant passenger loads and are not economically beneficial. On such lines, employing light rail transit (LRT) systems instead of heavy trains as the optimum vehicle type is preferable. The transport capacity of LRT systems lies between that of buses and typical metro rail systems. LRT systems are less noisy, have lower CO_2 emissions than buses, and are as fast and punctual as trains. Furthermore, LRT systems reduce construction and infrastructural costs.

LRT systems have different infrastructural and operational components as compared with conventional trains because the operational targets are different. For example, unlike typical railway vehicles that use overhead catenary systems for electric power supply requirements, LRT systems use power supply rails (guide rails) that are constructed near the running rails (Fig. 1).

Consequently, one disadvantage of LRT systems is that their operations can be influenced by weather conditions. For example, freezing of the running rail leads to unstable operations of the rubber tires. In the worst-case scenario, train operations must be suspended because ice formation on the guide rail creates a gap between the power supply rail and collector shoe.

This problem is typically solved by installing a snow melting system in the running rail and guide rail. Snow melting systems have been extensively used to melt snow on pavements; here, the conventional methods employ water heating systems that use either solar energy or waste heat from industries, electric heating systems, or chemical salt. The use of chemical salt, however, is prohibited today because it leads to environmental pollution and corrosion of structures. LRT systems employ electric heating systems to make use of a pre-existing electric power supply system for train operations. Electric heating systems can quickly respond to the melting of snow in snowy weather.

However, electric heating systems are economically inefficient and consume enormous amounts of electric power. Therefore, a reliable standard for the operation time of the electric heating system must be developed to minimize the consumption of electric power and maintain stable train operations.

2. Background and scope of work

The LRT vehicle of concern, which is used in Uijeongbu, Korea, is the Model VAL208 developed by Siemens. This automated guideway transit

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Fig. 1. Operational system of a light rail transit (LRT) vehicle.

(AGT) vehicle with rubber tires is automatically guided along a “guideway” without a driver. This LRT vehicle adopts a “sideway guidance” scheme, in which the guiding wheels run along a guide rail that is installed alongside the running rail (Fig. 2). The guide rail is also used to supply power to the vehicle through the collector shoe of the train.

Unless a proper heating system is employed in the running rail and guide rail under cold or snowy weather conditions, ice formation may cause problems in train operations including its suspension. If the heating capacity of the melting system is inadequate, the snow, slush, or ice on the running rails can spread during vehicle operation, stick to the neighboring guide rail, and freeze. This phenomenon causes a gap to form between the guide rail and collector shoe of the vehicle; consequently, the vehicle is disconnected from the power supply (Fig. 3).

A direct solution to remove snow from the running rail is to install a snow-removing brush at the front of the vehicle (see Fig. 4). However, this makes it impossible to couple trains. Moreover, identifying obstacles on the running rail becomes difficult.

A general solution to prevent ice formation on railroad systems is to preliminarily operate a heating system in the running rail and guide rail before actual snowfall on the basis of weather forecasts for when snowing is expected to occur. However, excessive pre-heating increases electricity costs and reduces the durability of the concrete running rail by subjecting it to persistent thermal stresses, which in turn increases maintenance costs.

An operator could make use of preliminary operation standards for the heating system, such as the time required to raise it to a certain temperature, to prevent excessive consumption of electricity and guarantee stable train operations. However, interest in typical snow melting systems has mostly been concerned with melting accumulated snow rather than operating the heating system to prevent snow accumulation.

To predict the operation time for the heating system to melt accumulated snow, a thermal analysis of the running system by considering the melting of accumulated snow is essential.

Snow melting is a complex process that includes phase changes due to heat transfer, and numerous studies with numerical and experimental analyses have been conducted thus far. Chapman (1952) presented equations for the heating requirements of a snow-melting system considering energy losses, and Chapman and Katunich (1956) proposed theoretical equations for the design outputs of melting system facilities.

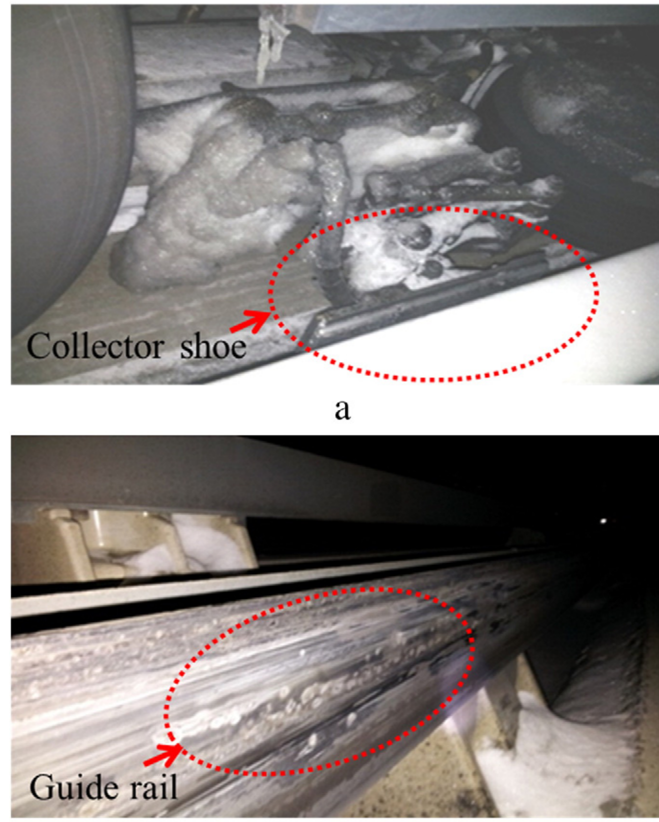

Fig. 3. Freezing at (a) collector shoe and (b) guide rail.

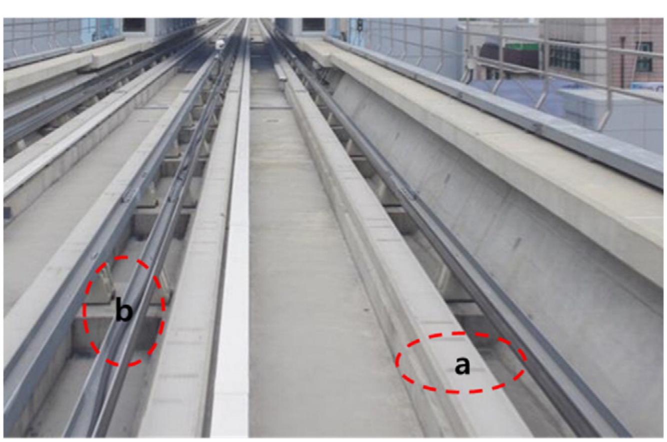

Fig. 2. (a) Running rail and (b) guide rail in an LRT system.

Fig. 4. Train nose with snow-removing brush.