DEVELOPMENT OF AUTOMATIC CONTROL SYSTEM FOR SPREADING ANTIFREEZING AGENT

Akira Yamao
Tohoku Engineering Office, Tohoku Regional Deve lopment Bureau,
Ministry for Land, Infrastructure and Transport, Japan
3-6-1 Sakuragi, Tagajo-shi, Miyagi-ken 985-0842 Japan
TEL.:+81-22-365-8211/FAX:+81-22-365-5938
E-mail:yamao-a82ac@thr.mlit.go.jp

1. OUTLINE

It is very important to secure smooth and safe winter traffic conditions by implementing measures to prevent freezing of road surfaces in cold regions. Though various measures have been taken by road administrators in Japan, the most prevalent method has been to spread antifreezing agent over road surfaces. Since June 1990 when restrictions were imposed on the use of spiked tires, the amount of antifreezing agent utilized has continued to increase. However, the optimum amount of antifreezing agent to be spread has very much depended on the experiences and skill of field engineers and operators. In recent years, it has become increasingly difficult to secure skilled engineers and operators.

In view of such circumstances, the following targets in the development of the automatic spreading system were established.

(1) OPTIMUM SPREADING CONTROL OF ANTIFREEZING AGENT (point and volume control)

(2) AUTOMATION OF SPREADING OPERATION (one-man control system with shortage of skilled operators)

The automatic control system developed consists of the following three functions: 1) MEMOLIZING OF SPREADING CONDITIONS 2) DETECTION OF SPREADING LOCATIONS and 3) EVALUATION OF ROAD SURFACES. This system is able to perform the most ideal spreading operation by reducing manpower and operation costs through effective and efficient operation independent of skilled and experienced operators, and can evaluate preset data and make self-corrections in response to changing road conditions for each road section.

2. INTRODUCTION

At present, the following issues need to be resolved for snow removal machinery and operation in Japan.

- Measures to cope with the advancing age of operators and securement of new operators
- Proper road surface maintenance for spikeless tires
- Reliable local weather and road condition forecasting
- Simplification and automation of machine handling
- Cost reduction through higher productivity and increase in safety measures
- Improvement of cabin comfortability

Figs. 1 and 2 reflect the problem of the advancing age of operators and the increasing difficulty of securing skilled operators year by year.

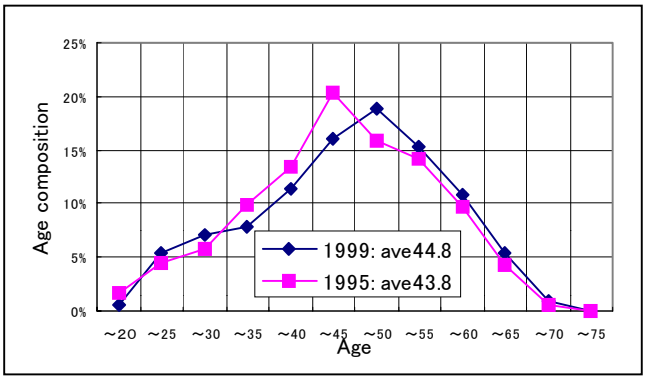

Fig.1 Operators' age distribution

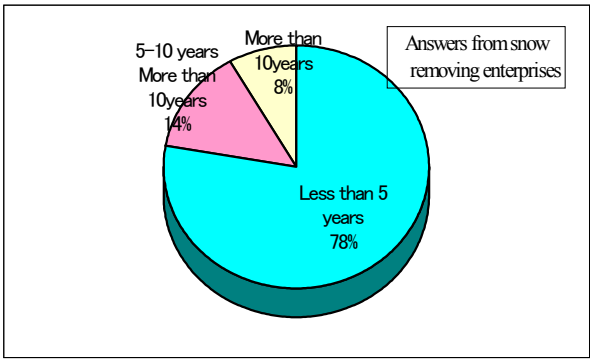

Fig.2 Forecasting difficulty of securing skilled operators

Among various measures for snow removal, the strong request by drivers for spreading of antifreezing agent on roads has resulted in an increase in volume and costs, thus emphasizing the need for more efficient operations. In the meantime, operations for optimum spreading and proper timing have depended almost entirely on the experience and skill of field engineers and operators.

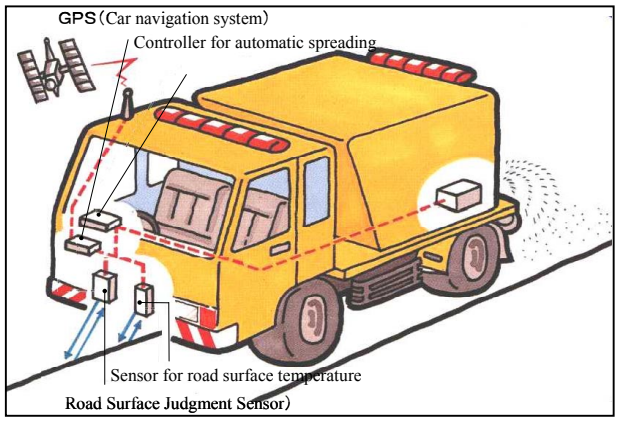

Fig.3 Image

At present, operations are carried out by tow persons i.e. one driver and one spreading operator. Thus, it is imperative that a one-man operation system be achieved to reduce spreading costs. We have therefore established the following targets to actualize an AUTOMATIC CONTROL SYSTEM FOR ANTIFREEZING AGENT SPREADING that would enable a spreading vehicle, on its own, to judge and determine various conditions necessary for spreading and automatically turn itself on or off accordingly.

(1) To actualize optimum spreading

Spreading proper amount to proper location by programming spreading conditions.

(2) To automate spreading operation

Actualizing a one-man operating system in response to the shortage of skilled operators and reduction of cost.

3. CONCEPT OF AUTOMATIC CONTROL SYSTEM

(1) Automatic spreading control system

Present operations can be categorized according to following three patterns.

① PREVENTION SPREADING
Spreading antifreezing agent to prevent road surfaces from freezing

② COUNTER-MEASURE SPREADING
Spreading antifreezing agent to thaw out frozen road surfaces

③ RE-FREEZING PREVENTION SPREADING
Additional spreading of antifreezing agent to prevent re-freezing resulting from a reduction in the effectiveness of agent

Road sections for spreading in high-traffic problem areas are determined by various factors such as weather conditions (e.g. windy areas), road topography (e.g. slopes), and conditions along roads (e.g. bus stops). Therefore, various spreading methods are applied in accordance with the actual conditions of road sections. In order to satisfy the requirements for such complicated spreading conditions, we developed a concept for programmed automatic spreading under preset conditions (spreading points, flow rates, etc.). The following functions were established for this automation system and the basic configuration of the automatic control system is shown in Fig. 4 and Fig. 5.

Functions for automation:

① Function to store memory of spreading conditions

② Function to detect spreading area

③ Function to detect road surface conditions;

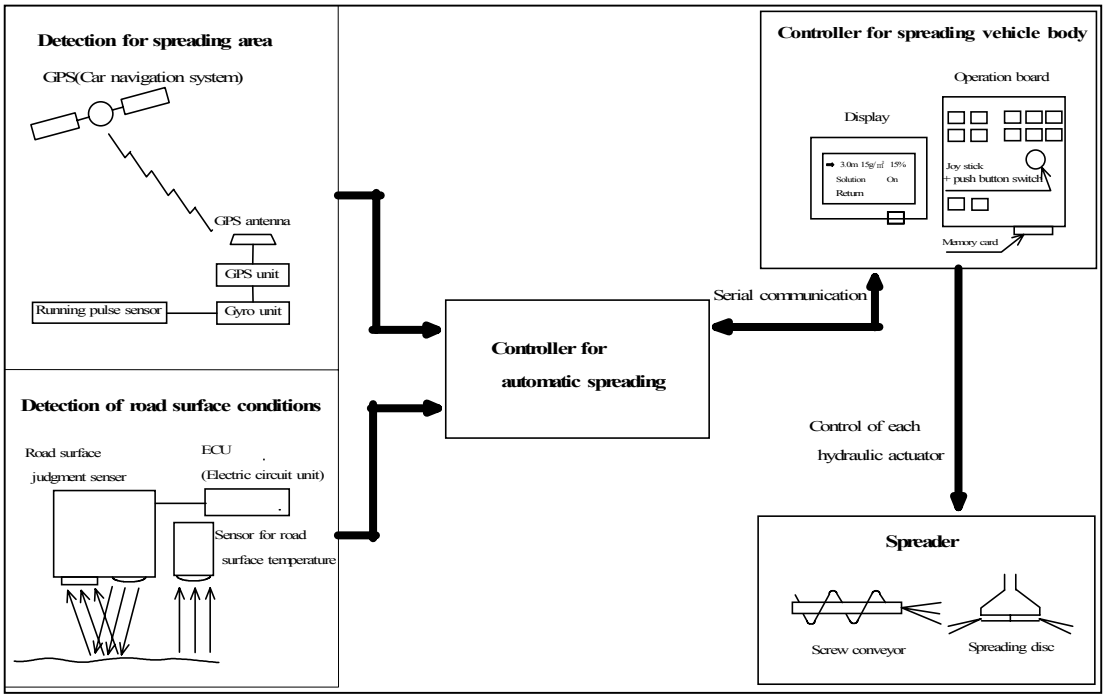

Fig.4 Configuration of automatic control system

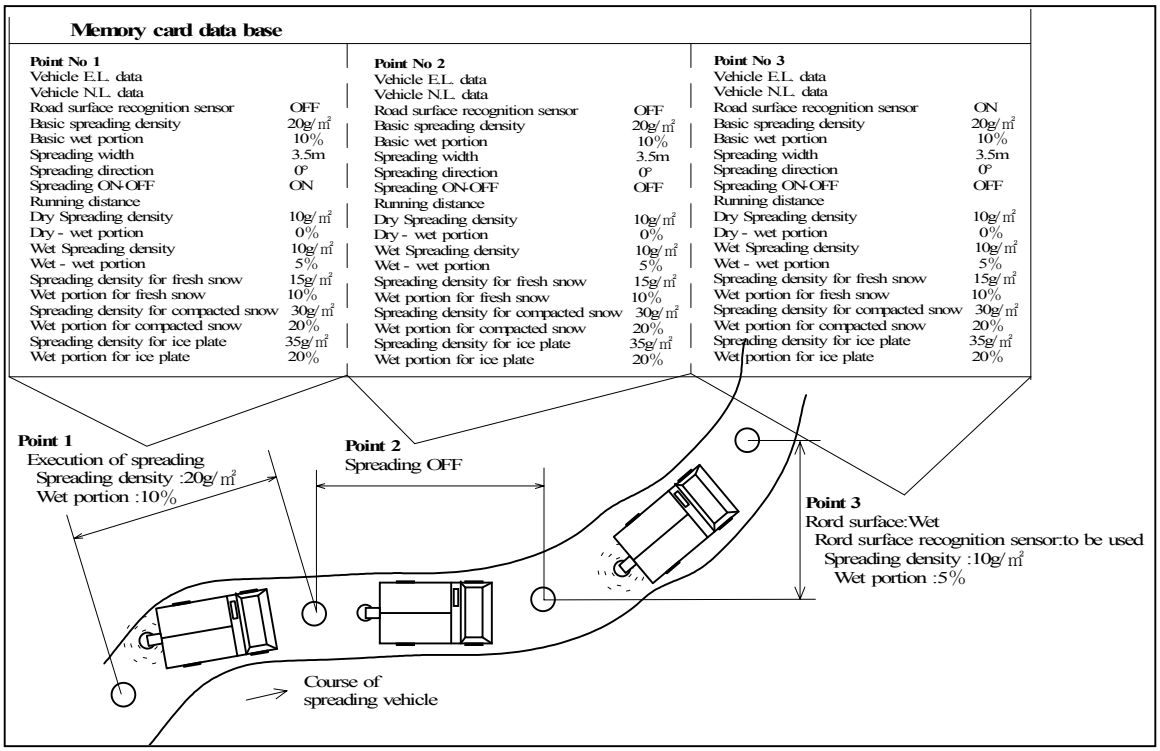

Fig.5 Example of Spreading by Automatic Control System

(2) Function to store memory of spreading conditions

This function is to memorize various spreading conditions such as spreading density and width that correspond to each spreading location of each spreading road sections. This function requires the following conditions.

- Capacity for easily removal and installation to/from the controller and personal computer for easy editing
- Capacity to input data from spreading locations by memorizing locations during actual operations
- Capacity to minimize physical effects such as trouble by vibration of the vehicle
- Capacity for sufficient memory

A memory card (PC card) was used to fulfill above conditions.

(3) Function to detect spreading area

This function is to automatically control the on-off action for spreading operations by the sensor for detecting location and memory data of spreading conditions.

This system is equipped with a commercial car navigation unit provided with D-GPS(Deferential GPS) to determine absolute positions of the vehicle together with map matching functions and an automatic spreading controller.

(4) Function to detect road surface conditions

This function is to evaluate road surface conditions by sensors while the vehicle is operating, and to select, from data memory, optimum spreading conditions such as spreading density.

This system consists of compact road surface evaluation sensors that are vehicle-mountable and of a non-contact type. They can instantly judge road conditions such as degree of dryness or wetness, whether the snow is fresh or compacted, and whether ice-plating has occurred while the vehicle is in operation.

To improve the accuracy of road surface evaluation, a non-contact type temperature sensor has been integrated into this system.

(5) Vehicle mounted with automatic control system

Vehicle mounted with automatic control system, sensors and other devices are shown below.

Photo 1 Antifreezing agent spreading vehicle mounted with automatic control system

Photo 2 Operation control panel (above) and road surface judgment sensors (below)

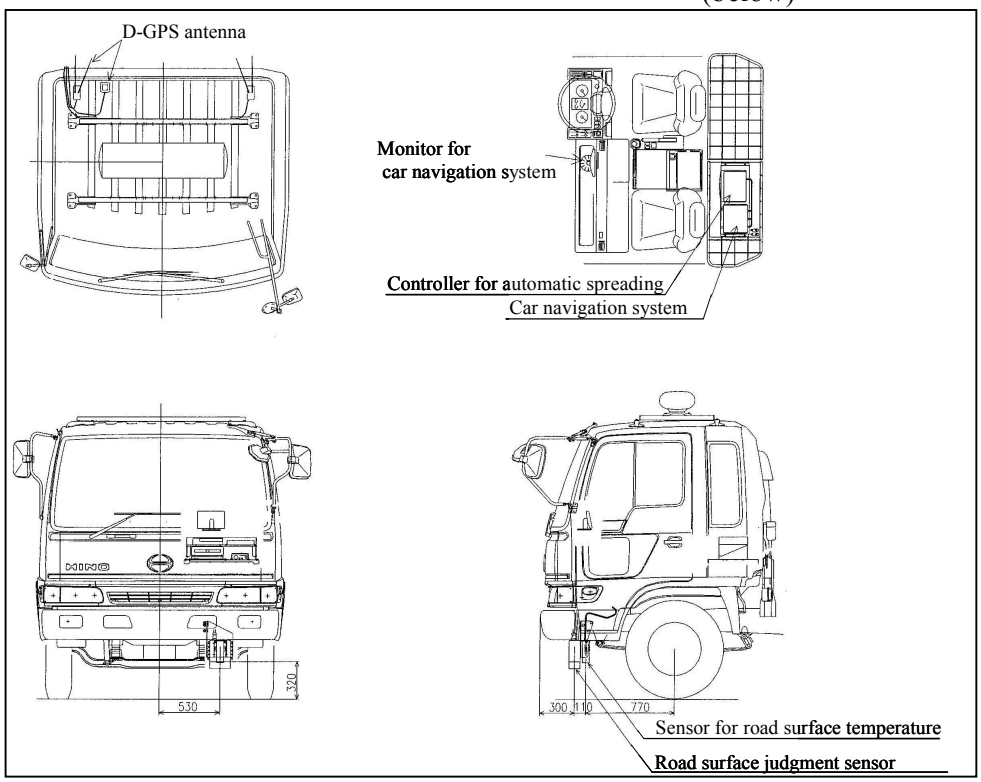

Fig. 6 Installation of automatic control system

4. TEST RESULTS

Field tests were carried out on the aforementioned vehicle mounted with automatic control system to test its effectiveness for all functions.

(1) Testing Effectiveness of Function for Detecting Spreading Area

The function for detecting the spreading area was confirmed by determining the difference in distance between the preset position and the actual position of the start while the vehicle was operating at 50 km/h. This operation was also conducted manually to compare the results between the two. Table 1 shows that the results are almost identical. Thereby, the effectiveness of the automatic spreading operation using the automatic control system could be confirmed.

Table 1 Comparison of automatic & manual spreading in position detection accuracy (displacement value)

Item	Distance difference from target position Average value 0m 50m 100m (Target position) 50km/h	Standard deviation	Max.value
Automatic spreading	Spreading area 0.6m (0.04 sec advanced)	8.1m	19.3m
Manual spreading	Spreading area 3.2m (0.23 sec advanced)	1.0m	2.4m

(2) Testing Effectiveness of Function for Evaluating Road Surface Conditions

This function was confirmed by evaluation of various road surface conditions through road surface sensors of vehicle operating at speeds of 20km/h and 40km/h.

Testing was carried out on road surface conditions that were continuously maintained under the equal test conditions uncontaminated by soil or sand. Table 2 shows results that confirmed the same accuracy with no difference in road surface evaluation between the different running speeds. Therefore, this road surface evaluation system by road surface detection sensors was confirmed to be effective for actual application.

The range of error for road surface temperature measurements was within the allowable limit with an average -0.6℃ with a maximum of -1.1℃ for actual application.

Table 2 Test result confirming accuracy of road conditions judgment

Road surface condition	Asphalt road	Concrete road
Dryness	100%	74%
Wetness	95%	73%
New Snow	63%	—
Compacted snow	100%	—
Ice-plated	98%	—

Since there are a variety of road surface conditions for actual applications, the following conditions were tested for accuracy of asphalt road surfaces:

- Dried surface: 74% accuracy for road surfaces contaminated by soil and sand
- Compacted snow surface: 51% accuracy for thin layer of compacted snow where original road surface can be seen through the snow, or where surface is soiled to gray or brown color

These result show that the accuracy of road surface evaluation is lower than the results shown in Table 2, thus reflecting a need for further improvement.

(3) Field Adaptability

Operators who participated in these tests concluded that this automated spreading system contributed to the efficacy of spreading operations for accurate and optimum spreading. Therefore, our preliminary pre-set target was achieved for the most part

The importance of adjusting programming to adapt to local conditions for actual applications was realized so that emphasis could be placed on preparation of various methods of application.

5. CONCLUSION

Tests have shown that the automatic control system will be able to effectively carry out optimum spreading of antifreezing agent through utilization of one-man operation of vehicles and contribute to minimizing spreading costs and relieve the shortage of skilled operators.

At present, there are 15 spreading vehicles equipped with the automatic control system, with plans for further expansion to eventually have full-scale application of this system.

We intend to make further improvements on the system by incorporating the comments and opinions of operators and eventually have this system used throughout the country.