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Automation of Snowplow

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ABSTRACT

With the increase in traffic volume in recent years, the snowplow operators have to constantly monitor the surrounding conditions and passing vehicles, and take extreme care and precautions during work. For using the rotary snowplow, which has various operating levers, technique and experience of a high level are required. In addition, extreme care and precautions must be taken to ensure safe operations. Also, a high level of accuracy (detailed) is demanded by local citizens and drivers during the snowplowing operations. We have developed snowplowing equipment incorporated with automatic control functions for the snow throwing system and the drive system. The objective is to improve the operability, snowplowing ability, accuracy, and safety of the rotary snowplow.

We have developed automatic systems for XY control, concentration control, linear motion control and pattern control in chute operations for snow throwing, and driving control for steering operations. We have examined these systems in detail.

We have verified that these systems give comparatively good accuracy.

1. Design Conditions for Development of the Equipment

The conditions for the design of the equipment are given below.

1. 1 Model of the Base Machine

A two stage, 200 PS class of rotary snowplow, widely sold in the market, was taken as the model.

1. 2 Restrictions imposed on the Base Machine

We have given priority to manual operability, considering safety aspects.

2. Automation of Snow Throwing Operation

2. 1 Rotary snowplows currently used

The position for throwing snow in the rotary snowplow is decided mostly from the shape of the snow throwing device, such as the direction of the chute and the opening and closing of the chute cap. However, as shown in Fig. 1, the lever operation for swiveling the chute is rotation by a circular shift of the lever, with the chute at the center. The lever operation for opening and closing the chute cap is a linear shift in a radial direction from the front end of the chute. Therefore, the operations are complex and do not allow the operator to work with ease. Also, a high degree of technique and practice is necessary to throw the snow at the targeted position, because snow flies out in a parabolic curve.

Furthermore, more than two levers must be operated simultaneously for changing the dropping position of snow, such as operating the lever for swiveling the chute and another lever for opening / closing the chute cap. This has the disadvantage of

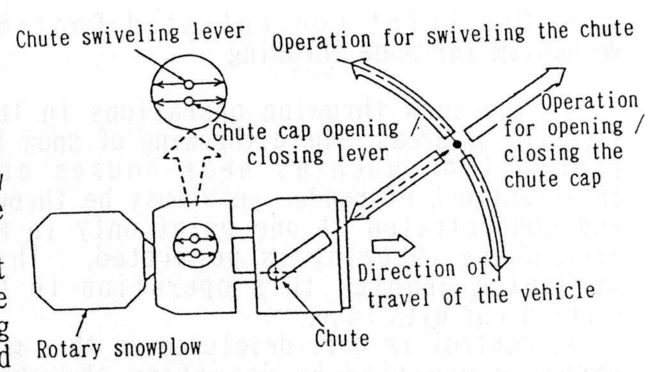


Fig. 1 Sketch of Snow Throwing Operations

leading to errors in operation during an emergency.

To cope with the current problems of rotary snowplows mentioned above, we have developed automatic control systems for simplifying the throwing of snow and for improving safety. These systems are described below.

2.2 XY Control Mechanism for Throwing Snow

This mechanism moves the throwing position in a straight line from the current throwing position toward the target position in the front-rear (Y) direction of the vehicle, the left-right (X) direction of the vehicle, and in arbitrary combinations of these directions. It is fitted so that the operator can operate it with ease.

The input operations are by one of the two devices installed in the driver's chamber, shown below. (Photograph 1)

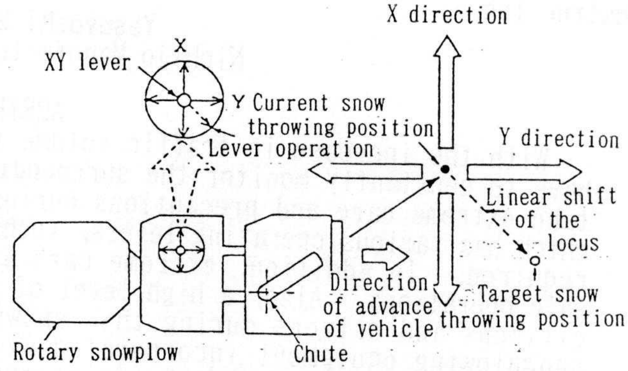
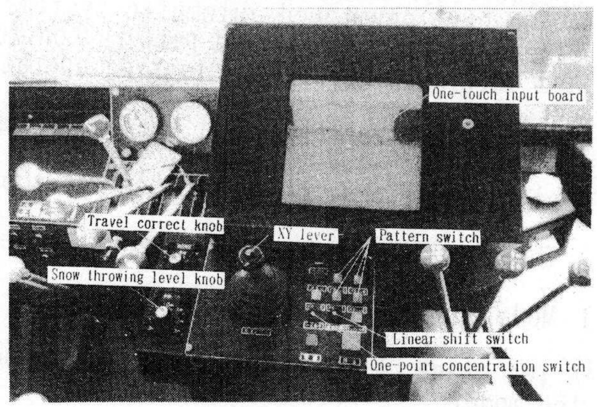


Fig. 2 Sketch of XY Control Mechanism



Photograph 1. Automatic Operating Units

2.2.1 XY Control Lever

The XY control lever (joystick type) is designed so that by merely inclining the lever in the direction of the target point, the throwing position will shift to the target position from the current throwing position.

2.2.2 One-Touch Input Board

The input board consists of a touch panel and a display board indicating the snow throwing position. This board is a direct input device. It is designed so that you can change the snow throwing position to the desired position by touching the surface of the panel with your finger.

The current snow throwing position and the snow throwing position input by the operator are displayed by LED (Light Emitting Diodes) installed beneath the transparent touch panel. The control range is 20 m in the up / down / right / left directions. There are 41 ×41 LED. Each LED shows the throwing distance at 1 m intervals.

There are various sensors in the control device mentioned above. The sensors detect the chute cap opening or closing amount, chute swiveling degree, chute contraction amount and blower rpm. The control device (computer) calculates the parameters. The signals of the control device drive the hydraulic equipment and control the snow throwing position.

2.3 One-Point Concentrated Control Mechanism for Snow Throwing

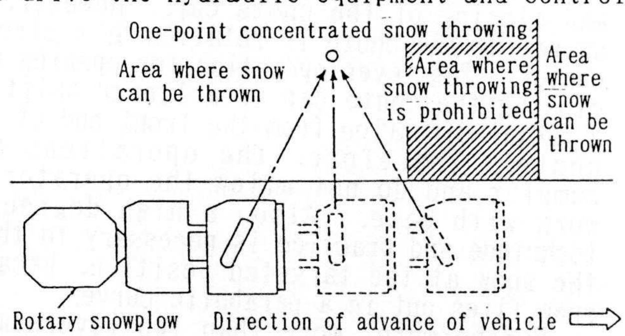


Fig. 3 Sketch of One-point Concentrated

During snow throwing operations in the vicinity of areas where throwing of snow is prohibited, such as near houses and intersections of roads, snow must be thrown and concentrated at one point only in an area where throwing is permitted. This mechanism enables this operation to be carried out with ease.

XY control is well developed in this mechanism. It automatically controls the snow throwing position by detecting the chute cap opening and closing degree, chute swiveling amount, chute contraction amount, blower rpm, direction of advance of the rotary snowplow, distance and steering angle.

When the operator presses the control switch, the snow throwing position at the specified instant of time is saved in memory. The mechanism concentrates the throwing of snow at one point, even if the vehicle is moved or steered.

2.4 Linear Shift Control Mechanism for Snow Throwing

If the direction of advance of the vehicle, the snow dropping position and the targeted shift line is set at the start, this mechanism controls the snow throwing and dropping position in a straight line, even if the direction of the vehicle is changed for avoiding obstacles or for removing snow on the vehicle parking strip. It can move the snow throwing position in a straight line, even if the vehicle is moved or steered.

The method of control utilized here is by finding the shift of center of gravity of the vehicle in the direction of motion of the vehicle. The vehicle refracting angle detection sensor and the data of travel pulses for the direction of advance of the vehicle at particular instants of time are used for control.

When the operator presses the control switch, the specified snow dropping line saved in memory. The mechanism moves the snow throwing position in a straight line, even if the vehicle is moved or steered. (Fig. 4)

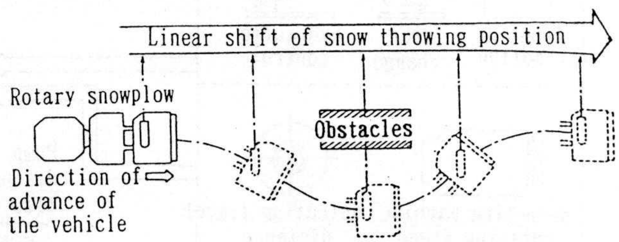


Fig. 4 Sketch of Linear Shift Control

2.5 Pattern Control Mechanism for Throwing Snow

Patterns of the changes in throwing positions in a fixed snow removal space are created. The data of a series of changes in throwing positions in this space is related to the travel distance data and saved in the computer beforehand. This control mechanism automatically changes the snow throwing position corresponding to the travel during the snow throwing work.

The data saved beforehand in the computer is the travel distance data and the X, Y direction data of the throwing positions.

The mechanism reads the X, Y direction data of the first throwing position. It converts this data to throwing distance and chute swiveling angle data. It assigns this data to the chute opening and closing operation and the chute swiveling operation. Therefore, it controls all operations up to the targeted snow throwing position.

Subsequently, it reads the travel distance data until the next operation is performed. It repeatedly compares this data with the travel pulse input data. When the data coincide, it reads the data of the X, Y direction of the next throwing position. The control mechanism repeats the cap opening / closing operations and control operations of the chute swivel similarly. (Fig. 5)

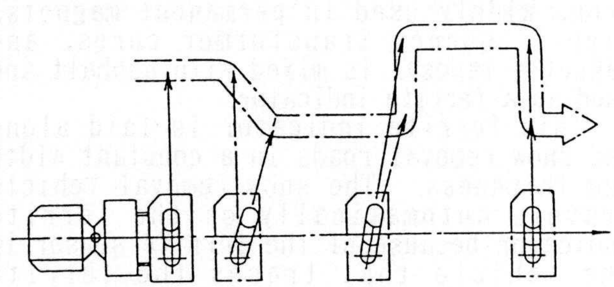


Fig. 5 Sketch of Pattern Control

2.6 Configuration of Automatic Control Equipment for Snow Throwing

The automatic control equipment consists of the operating input unit, the control input unit, the arithmetic control unit and the control output unit.

The operating input unit consists of the position feedback sensor, the ferrite sensor and the numeric data input sensor. The control input unit consists of the XY control lever, the touch panel, the one-point concentration start switch, the linear shift control start switch and the pattern control start switch. The arithmetic control unit consists of a Z80 series CPU board computer and the output display unit with LED display equipment. The control output unit consists of two types of hydraulic valves.

Fig. 6 shows the configuration sketch of the automatic control equipment.

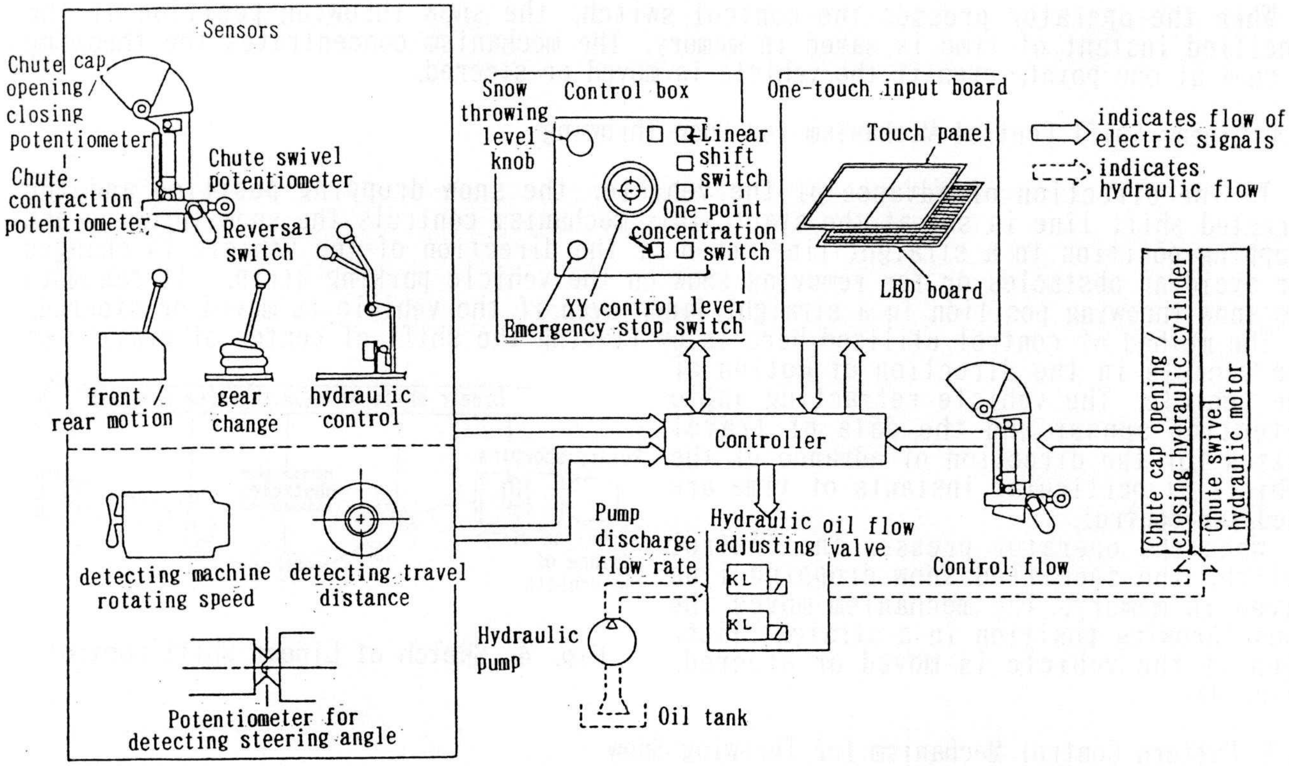


Fig. 6 Configuration Sketch of the Automatic Control Equipment

3. Automatic Travel Mechanism

This mechanism automatically controls the steering operation, using an induction system. In the ferrite induction system, reproductive ferrite, an industrial waste (This is a ferromagnetic material. It is the main component in the oxidization of iron, widely used in permanent magnets, high frequency transformer cores, and magnetic tapes), is mixed with asphalt and used as a ferrite indicator.

This ferrite indicator is laid along the snow removal roads in a constant width and thickness. The snow removal vehicle travels automatically on the ferrite indicator because of the ferrite sensor in the vehicle that traces the ferrite indicator. (Fig. 7)

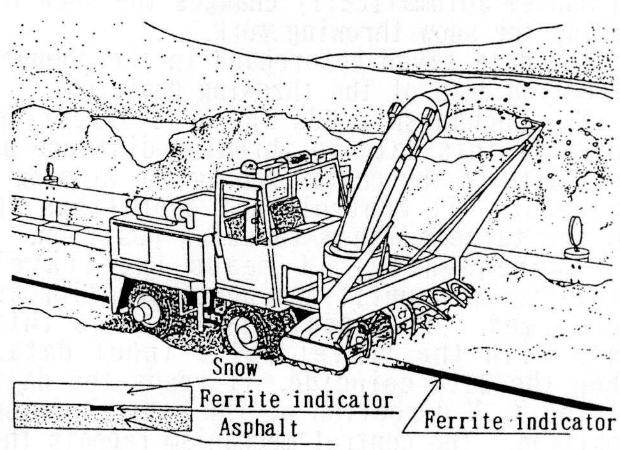


Fig. 7 Automatic Travel Mechanism

3.1 Characteristics of Automatic Control Equipment for Travel

(1) There is a selector switch on the operating panel that enables easy automatic control by hand operations. Also, the pilot lamp indicates the position of the vehicle with respect to the ferrite indicator in real time.

(2) Even during automatic travel, if the steering wheel is operated, the automatic steering control is canceled and the operator can change the direction of motion at his will. This ensures safety.

(3) Accurate steering control is enabled by installing a steering angle detection sensor in the steering unit and using feedback control. Also, an electromagnetic proportional flow control valve is used in the hydraulic unit of the steering mechanism. This valve enables smooth steering control.

(4) The operator of the snow removal vehicle does not have to concentrate fully on the steering operations. The operator can now concentrate on the working environment and the snow throwing location. He can throw the snow accurately at the desired location.
(5) By combining this control and the automation of snow throwing operation mentioned before, automatic driving in a specified space and a more efficient snow throwing operation have become possible. (Fig. 8)

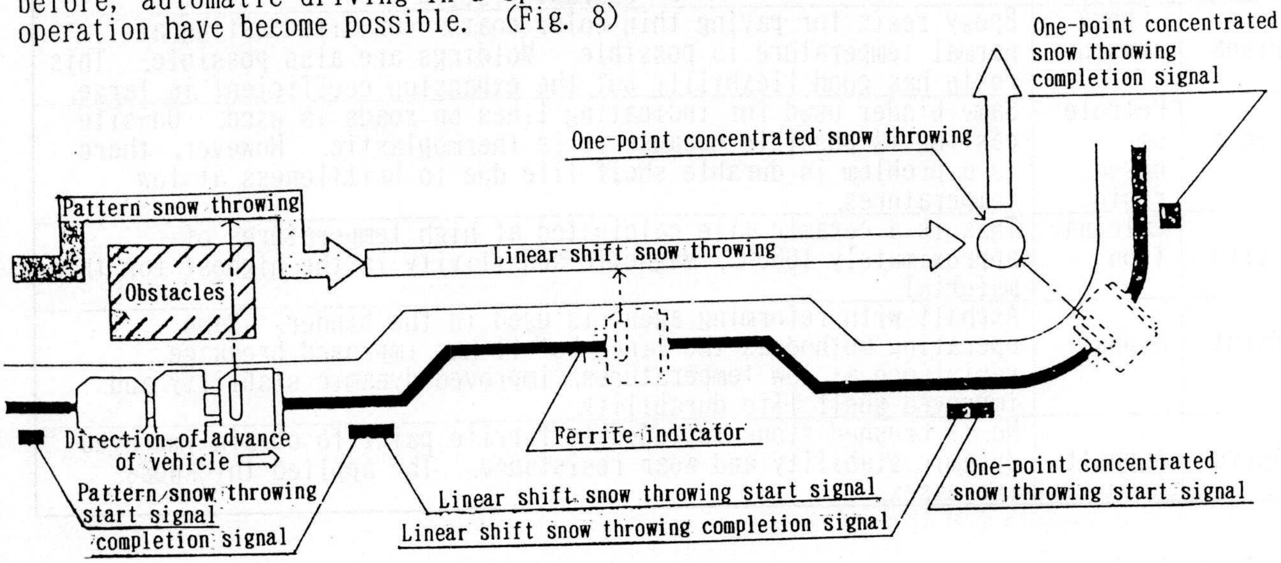


Fig. 8 Combination with the Automation of Snow Throwing Operation

3.2 Configuration of Automatic Control Equipment for Travel

The automatic control equipment consists of the steering operation unit, the operation panel (operating unit and display unit), the control unit, the hydraulic unit, the ferrite sensor unit, and the steering actuator unit.

The steering operation unit consists of the steering wheel and the potentiometer. The control unit consists of a Z80 series CPU board computer.

The ferrite sensor unit consists of the transmitter, the transmitting coil and the ferrite sensor.

The steering actuator unit consists of the steering cylinder and the potentiometer. Fig. 9 shows the configuration sketch of the automatic control equipment.

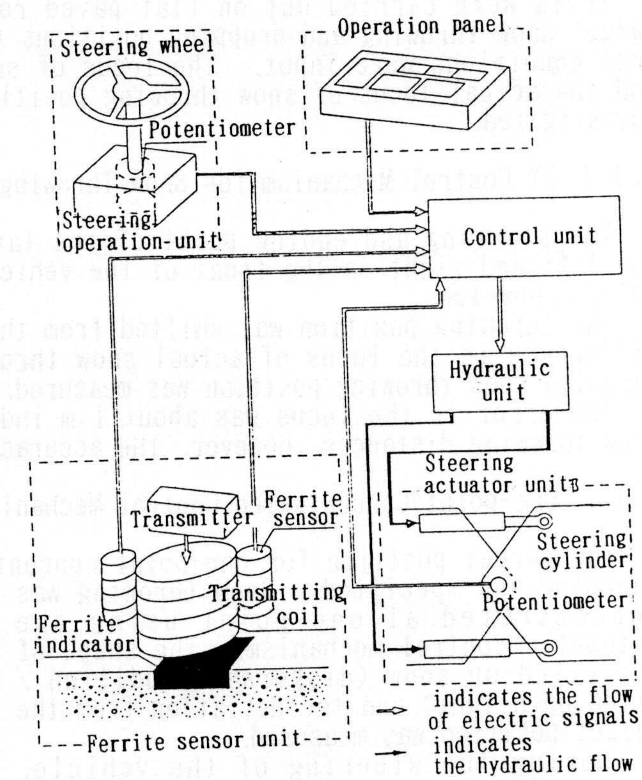


Fig. 9 Configuration Sketch of Automatic Control Equipment

3.3 Ferrite Indicator

Table 1 shows the types of ferrite indicator.

Table 1. Characteristics of Ferrite Material

Type	Binder	Characteristics
Plank	Epoxy resin	Epoxy resin for paving thin color coats. On-site casting at normal temperature is possible. Moldings are also possible. This resin has good flexbility but the expansion coefficient is large.
Liner	Petrole-um based resin	Same binder used for indicating lines on roads is used. On-site casting is possible because it is thermoplastic. However, there is a problem in durable shelf life due to brittleness at low temperatures.
Tile	Calcina-tion	This is a ceramic tile calcinated at high temperatures of approximately 1000℃. Magnetic sensitivity is the highest for this material.
Paint	Asphalt	Asphalt with reforming agent is used in the binder. Same operating method as the liner but it has improved breakage resistance at low temperatures, improved dynamic stability and improved shelf life durability.
Asryu	Asphalt	No. 7 crushed stone is added to ferrite paint to obtain improved dynamic stability and wear resistance. The applied thickness increases.

4. Test Results

4.1 Automation of Snow Throwing Operation

Tests were carried out on flat paved roads with natural snow accumulation. The target snow throwing and dropping positions (simulated command values) set with various test conditions were input. The locus of snow throwing targets in the command values and the actual locus of snow throwing positions were compared and the differences were investigated.

4.1.1 XY Control Mechanism for Snow Throwing

The starting and ending point of the targeted snow throwing position were set at the left and right on the front of the vehicle, and in the front-rear positions of the rotary snowplow.

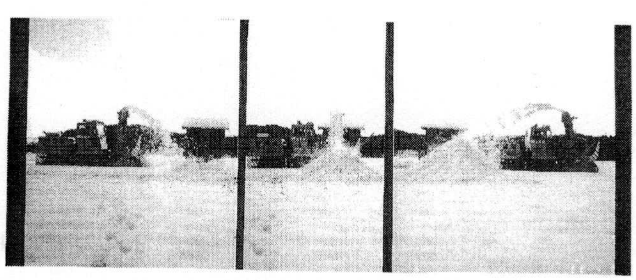
The throwing position was shifted from the starting point to the ending point. The difference in the locus of actual snow throwing position on the snow surface and the targeted snow throwing position was measured.

The error in the locus was about 1 m indicating a satisfactory result. For large snow throwing distances, however, the accuracy deteriorated slightly.

4.1.2 One-point Concentrated Control Mechanism for Snow Throwing

The target position for one-point concentration was decided in front of the rotary snowplow and specified. Snow throwing was concentrated at one point using the automatic control mechanism. The shape of the piled-up snow (dispersed condition / piled up height) and the deviation from the target position was measured.

During the steering of the vehicle, tire slip occurred. This led to a deviation in control and deterioration in accuracy. The accuracy, however, was comparatively good. The test results are shown in Photograph 2.



Photograph 2. One-point Concentrated

4.1.3 Linear Shift Control Mechanism for Snow Throwing

Snow piled up in extended width on the left side was taken as a precondition. Driving patterns for removal of snow on the vehicle parking strip and for avoidance of obstacles were set. Linear shift was investigated.

Linear control was initiated. In the advancing status, the vehicle was steered. The deviation in the actual snow throwing position was measured at various points on a straight line drawn from the snow throwing point when control was initiated, in the direction of advance of the vehicle.

The results of the test indicated that the locus of turns of the vehicle coincided with the theoretical locus. The cap opening / closing position, chute swiveling angle and snow throwing position at the start of the test and the completion of the test coincided. (Photograph 3)

Photograph 3. Linear Shift Control

4.1.4 Pattern Control Mechanism for Snow Throwing

Two types of pattern data for control were kept ready. The snow throwing position at the start of chute operation and at the end of chute operation for each pattern were measured. Each point on the left and right sides of the direction of advance of the vehicle was measured. The positions were compared with the target positions.

The deviation at the completion of chute operation with respect to the direction of advance of the vehicle was 1.5 m for a shift distance of 9 m of the throwing position in a direction perpendicular to the vehicle. For a shift distance of 5 m, almost no deviation was observed. (Photograph 4)

Photograph 4. Pattern Control

4.2 Automation of Travel

4.2.1 Test within the Premises

The test was carried out by setting the ferrite indicator on a flat, paved road surface. Various travel loci were set as targets for the test conditions. The output of the ferrite sensor was continuously recorded. The actual locus of travel when the vehicle moved was on the outer side of the tire (left side, front and rear wheels). The locus was marked for each rotation and the distance from the indicator was measured.

The minimum radius of rotation was 7 m and the maximum refracting angle was 25 degrees. The height of the sensor with respect to the indicator was between 90 mm to 190 mm. (Photograph 5)

Photograph 5. Test within the Premises

4.2.2 On-site Tests

The ferrite indicator was placed on the National Road No. 49 (Niigata Work Office, Suibara Branch Work Office) for a distance of 100 m and actual load tests were carried out.

Tire slip occurred during the travel over pile up snow, but the accuracy was comparatively good. (Photograph 6)

Photograph 6. On-site Test Status

4.2.3 Wear Resistance and Fluidity Tests

Wear resistance and fluidity tests (spike labeling test, wheel tracking test) were carried out assuming 5 types of indicators installed on the road surface.

Tile proved to be the most satisfactory in wear resistance tests. Tile and plank were satisfactory in the fluidity tests. However, considering that these materials are to be used on roads, paint and asryu that have wear resistance and fluidity equivalent to paved asphalt (fine gap 20F), are appropriate materials.

Therefore, asryu was used on the site.

5. Conclusion

We have developed multi-functional automatic control equipment for the rotary snowplow that has particularly complex operations and operates in an environment where ordinary vehicles always ply.

The automatic mechanisms for snow throwing have been introduced within the jurisdiction. We will collect usage data, continue to make improvements in the machine and endeavor to make the machine more easy to operate in future. We wish to develop and realize robotization by incorporating automation of snow throwing operations.

With the automatic control equipment that we have developed this time, we anticipate that the rotary snowplow will demonstrate an improved performance on site and the burden of driving and controlling the snowplow will lighten significantly.

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