DEVELOPMENT OF SNOW REMOVAL MACHINERY IN HOKKAIDO

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1. Summary

As snow removal from roads is now mainly conducted by machinery, it is necessary to improve operation speed and efficiency, raise the level of work execution and ensure safety as basic elements for snow removal machinery. Due to the ban on studded tires to solve the dust pollution problem and other conditions in recent years, it has become necessary to improve road surface management, take anti-freezing measures especially for slippery road surfaces, and improve snow removal machinery to deal with the use of studless tires. Measures are also required to meet a variety of needs concerning improvements in efficiency of snow removal operations for arterial high-standard highways and other high-speed traffic facilities, as well as simplification and automatization of operations to compensate for the shortage of experienced operators.

This is a report on (1) high-speed snow removal trucks, rotary snowplows and snow removing wheel-type loaders, (2) single-lane loading-type rotary snowplows and (3) air-type snow removal trucks (for suspension bridge), which were developed by the Hokkaido Regional Development Bureau to deal with the above circumstances. It also explains the current status of mechanical snow removal.

2. Introduction

The entire area of Hokkaido belongs to a cold, snowy region. Having the large urban area of “Sapporo” in this region with heavy snow, the prefecture is in a very severe condition that is unique to the world.

To deal with such regional characteristics, the Hokkaido Regional Development Bureau has been playing a leading role in the technical development of snow removal machinery to improve efficiency of snow removal on roads through the management of national highways.

3. Hokkaido weather characteristics

Hokkaido, in which a highly decentralized society is formed, has a population of 5.69 million, most of which is concentrated in major cities such as Sapporo (1.82 million), Asahikawa (360,000) and Hakodate (290,000).

The mean temperature in winter is under 0℃ in most major Hokkaido cities, while it is below -5℃ in Asahikawa. Snowfalls are observed on more than 70 days on the Pacific side with relatively little snow and over 120 days on the more snowy Sea of Japan side. The maximum snow depth is 100 cm in Sapporo and 94 cm in Asahikawa (Figure 1).

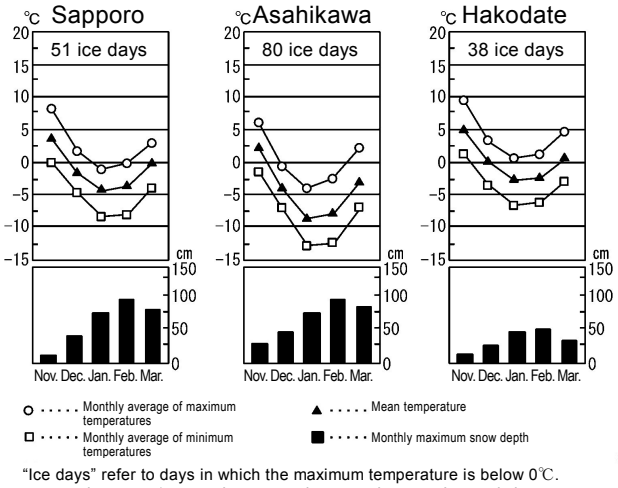

Figure 1 Winter climate in major cities

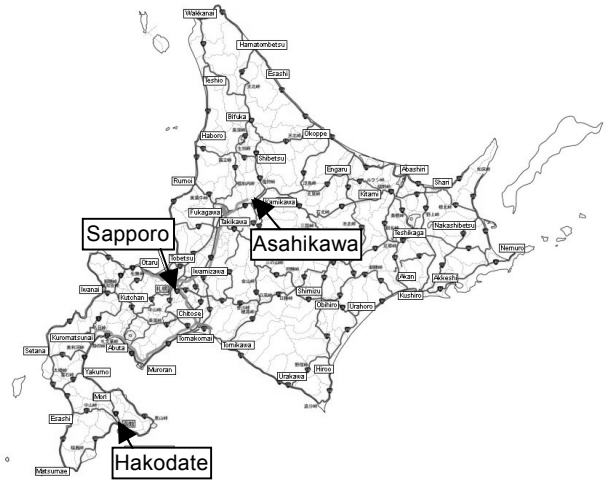

Figure 2 Snow removal routes on national highways

4. Current status of mechanical snow removal

As of April 1, 2000, the total road length in Hokkaido was 87,212 km, out of which 450 km consisted of national expressways, 6,400 km were national highways (including arterial high-standard highways, Figure 2), 11,651 km were prefectural roads and 68,711 km were municipal roads.

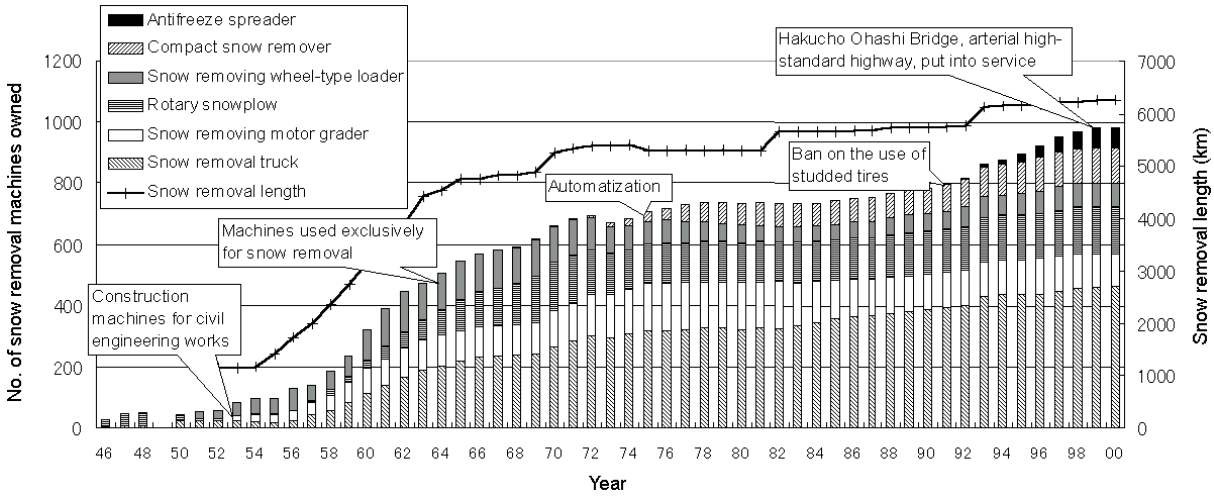

Figure 3 Changes in snow removal length and number of snow removal machines owned by Hokkaido Regional Development Bureau

Mechanized snow removal in Hokkaido began in 1945. Snow removal was first conducted on 55 km of national highways. With an increase in the length of snow to be removed, the number of snow removal machines owned by the Bureau has increased from 29 to 983 (Figure 3). While construction machinery for civil engineering works was used for snow removal around 1955, it was replaced by machinery exclusively for snow removal by 1965 and automatization was introduced around 1975. Performance of machinery has been improved with an increase in unit power.

Because studless tires were introduced in 1990, the Bureau's attention has recently been focused on snow removal machinery with higher snow removal accuracy. It has also taken measures for conducting meticulous transportation and disposal of snow to secure lanes in urban areas and remove ice from shoulders, as well as measures against slippery road surfaces.

From the breakdown of snow removal machinery owned by the Hokkaido Regional Development Bureau in 2000 (Table 1), it can be seen that snow removal machines have been introduced to suit the long inter-city distances characteristic of Hokkaido. For example, snow removal trucks with a high driving speed and large snow removal capacity account for 50% of the total (Figure 4).

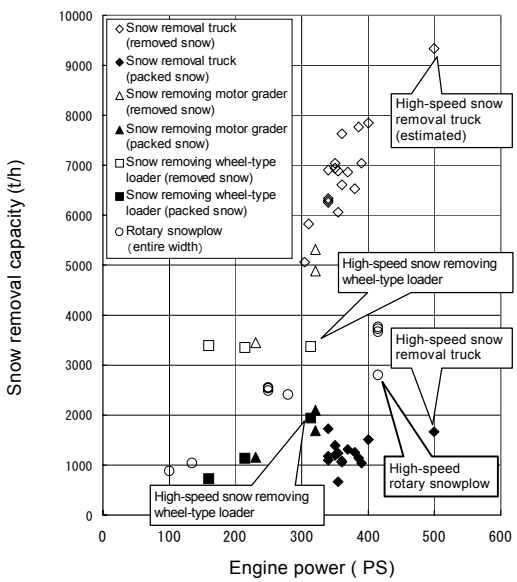

Figure 4 Capacity of snow removal machinery

Snow removal sections and methods of major snow removal machinery in use are classified by machine type as follows. (Table 2)

Table 1 No. of snow removal machines owned in 2000 (Hokkaido Regional Development Bureau)

Snow removal truck		Snow removing motor grader		Rotary snowplow		Snow removing wheel-type loader	Compact snow remover		Antifreeze spreader		Total
7t	10t	4.0m	High-speed grading	200PS	400PS	13tU	R&B	R	4.0m^3	2.5m^3	
96	366	65	45	90	62	77	110	4	26	42	983

Table 2 Outline of snow removal machinery

Snow removal section	Snow removal machinery		Snow removal devices etc.	Remarks
Roadway	Plow system	Snow removal truck	One-way snowplow and road surface grader	One-way snowplow: removal of fresh snow Road surface grader: removal of packed snow Side wing: snow removal for widening roads, snow removal on sidewalks Mackley: scraping snow out
			One-way snowplow, road surface grader and side wing	
			One-way snowplow, road surface grader and Mackley	
			One-way snowplow, road surface grader, side wing and Mackley	
		Snow removing motor grader	Road surface grader	
			Road surface grader and side wing	
		Snow removing wheel-type loader	Blade capable of holding snow	
	Rotary system	Rotary snowplow	400 PS	Snow removal for widening roads
			200 PS	Snow removal for widening roads, transport and disposal of snow
			Single-lane loading type	Transport and disposal of snow
Sidewalk	Compact snow remover		100 PS, for both rotary- and blade-types	
Frozen road surface	Antifreeze spreader		2.5m^3, 4.0m^3	Devices also available
	Rough grooving device		Equipped on snow removal trucks, snow removing motor graders, etc.	

5. Problems of mechanical snow removal and technical development

Ensuring safe and reliable road traffic throughout the year is the most important issue in Hokkaido, as people lead social lives and conduct economic activities under severe weather conditions with snow and extreme cold in winter. In recent years, greater emphasis has been placed on management of national highways, which account for the main part of major roads, due to the arrival of the aging society, demand for round-the-clock emergency services and traffic congestion in urban areas. Diverse measures are also required in snow removal technology, such as extension of arterial high-standard highways for high-speed traffic, coping with trends toward highly information-oriented society, cost reductions and dealing with changing social needs concerning environmental issues. Specific measures include the following:

(1) Improvements in speed and efficiency of snow removal operations to cope with high-speed traffic
(2) Consolidation of frozen road surface measures and development of anti-freezing technology
(3) Snow removal technology to promote urban environmental improvements, such as safety problems of sidewalks and intersections
(4) Snow removal technology taking exhaust gas, noise and other environmental issues into account
(5) Snow removal technology in response to highly-advanced information-intensive society
(6) Automatization to realize improved safety and efficiency

Under such circumstances, the Hokkaido Regional Development Bureau has promoted many technical development projects and put the results into practical use. The following are some case examples of such technical development:

5-1 Speeding-up of snow removal machinery

Improvements in highway networks have progressed in recent years, and the speed limit for ordinary vehicles on arterial high-standard highways is currently 70–100 km/h. As the age of high-speed traffic is approaching, demands concerning snow removal machinery, such as improvements in speed and efficiency of snow removal operations, are becoming increasingly diverse.

The Hokkaido Regional Development Bureau is therefore developing high-speed snow removal machines and putting them into practical use for faster and more efficient snow removal operations.

(1) Development of high-speed snow removal trucks

While snow removal in Hokkaido is mainly accomplished by snow removal trucks at present, the Bureau has addressed the development of a high-speed one to realize quick, safe and stable snow removal (Photo 1, Table 3).

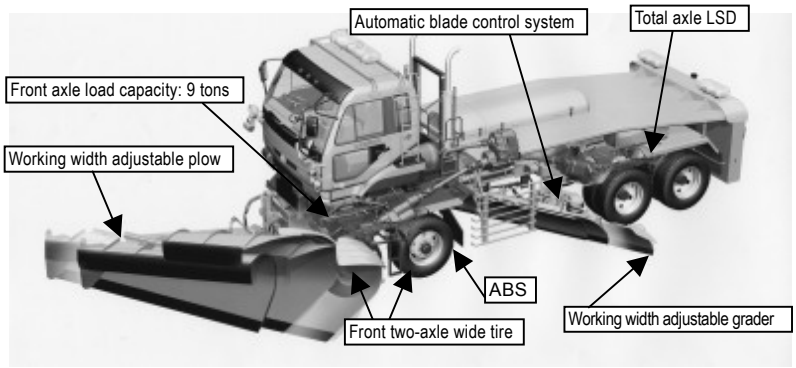

Photo 1 High-speed snow removal truck

This truck is characterized by the use of two drive axles in both front and rear wheels of the vehicle that minimizes the effects of side forces as well as increased engine power to ensure stable high-speed snow removal operations. Operation efficiency has also been improved through the introduction of a wider snow removal device. By developing this truck, removal of fresh snow at a speed of approximately 70 km/h has become possible. Reduction of operating costs by the increased snow removal width is also expected (Figure 5).

Table 3 Specifications of snow removal trucks

Standard			High-speed type	Conventional type
Performance	Snow removal width (snowplow)		4.5-3.2m	2.9m
	Surface grading width		4.5-3.1m	2.9m
	Max. speed		100km/h	80km/h
	Min. turning radius		11.8m	10.6m
Item	Total length		11.98m	11.97m
	Total width		3.2m	3.1m
	Total height		3.75m	3.7m
	Total vehicle weight		24,950kg	18,715kg
	Vehicle weight	Front axle weight	12,160kg	5,970kg
		Rear axle weight	12,680kg	12.580kg
Engine			367kw(500ps)	256kw(350ps)
Travel device		Model	Full time 8x8	Part time 6x6
		Controller	ABS,LSD	None
Equipped tire		Type	Studless tire	Studded tire
		Front axle	365/70R22.5	315/80R22.5
		Rear axle	12R22.5-16PR	12R22.5-16PR
Snow removal device		Plow	Width changeable one-way	Width fixed one-way
		Surface grader	Automatic control-type	None
Front obstacle detector			Millimeter wave radar-type	None

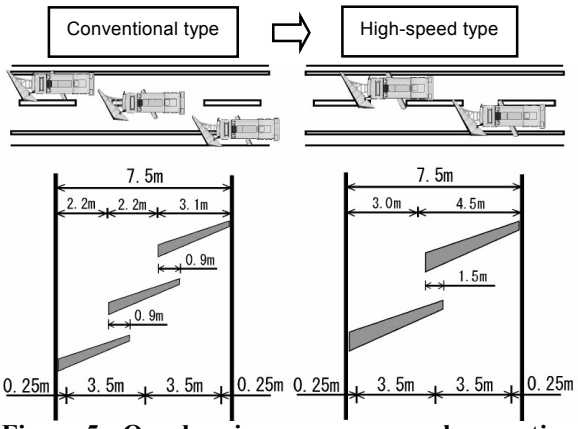

Figure 5 Overlapping snow removal operation using snow removal trucks

(2) Development of high-speed rotary snowplows

Although rotary snowplows have been introduced for suburban routes and snowy mountainous areas mainly for removing snow to widen roads, they may disrupt the traffic of ordinary vehicles due to their low-speed operation.

A high-speed rotary snowplow was therefore developed and introduced in 1992, in order to increase snow removal and driving speeds and reduce the vehicle width (Photo 2, Table 4).

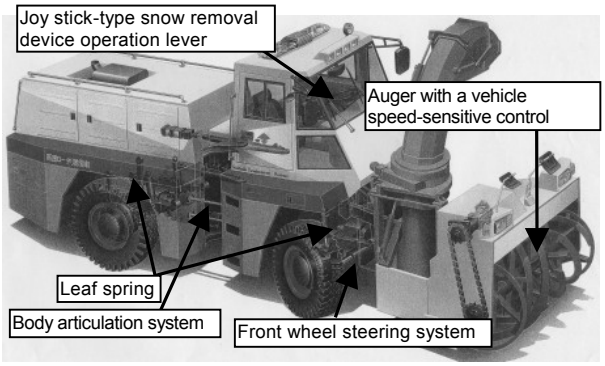

Photo 2 High-speed rotary snowplow

Table 4 Specifications of rotary snowplows

Standard			High-speed type	Conventional type
Performance	Max. snow removal volume		2,800t/h	3,000t/h
	Max. snow removal speed		20km/h	13km/h
	Max. speed		70km/h	40km/h
	Max. snow removal width		2.4m	2.6m
	Mini. turning radius	Articulated body	7.5m	7.1m
		Front wheel steering	10.5m	
Item	Total length		8.24m	8.27m
	Total width		2.40m	2.60m
	Total height		3.67m	3.49m
	Total vehicle weight		17,410kg	15,865kg
Engine			305kw(415ps)	301kw(410ps)
Travel device			Front/rear wheel driving-type	Front/rear wheel driving-type
Steering system		When operating	Articulated body	Articulated body
		When driving	Front wheel steering	
Suspension system			Front/rear leaf springs	Rear leaf springs only
Snow removal device		Model	Two-stage	Two-stage
		Auger drive	Vehicle speed sensitive (hydraulic)	Coupled with a blower (mechanical)
		Chute control	Joy stick lever	Multiple hydraulic switch lever

By applying an auger device with a traffic-speed sensitive control and the wheel steering method with a center pin lock function, snow removal speed increased from 12 or 13 to 20 km/h and the driving speed increased from 30 to 70 km/h. It has also become possible to ease the traffic congestion from ordinary vehicles and improve safety during snow removal operations by reducing the vehicle width from 260 to 240 cm.

Photo 3 Conventional operation levers

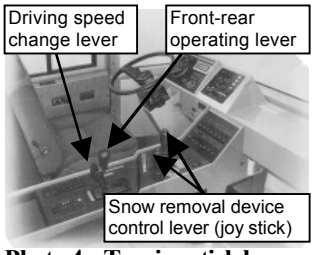

Photo 4 Two joy stick levers

The operational environment during high-speed operations has also been improved by

installing a suspension system (Photo 2) and a functional concentration of operation levers for the snow removal device (Photos 3 and 4).

(3) Development of high-speed snow removing wheel-type loaders

Snow removing wheel-type loaders are mainly used for posttreatment of primary snow removal at intersections and other sections, and snow removal at special sections, such as ramps of arterial high-standard highways. The slow driving speed of the loaders to operation sites tends to delay their work compared with other works and obstruct traffic.

A high-speed snow removing wheel-type loader was therefore developed and introduced in 1995, in order to increase the driving speed and improve the snow removal capacity (Photo 5, Table 5).

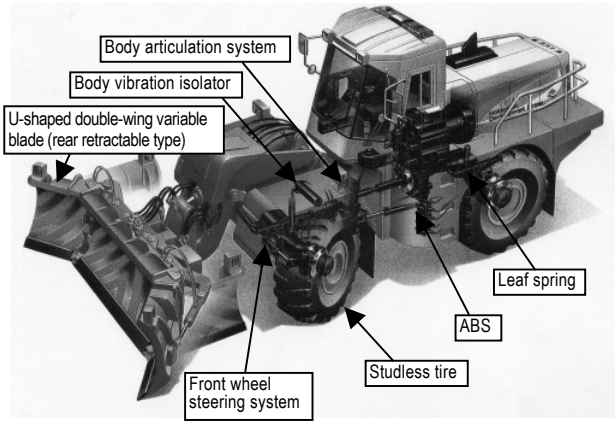

Photo 5 High-speed snow removing wheel-type loader

Table 5 Specifications of snow removing wheel-type loaders

Standard			High-speed type	Conventional type
Performance	Max. speed		70km/h	37km/h
	Min. turning radius	Articulated body	5.42m	5.22m
		Front wheel steering	9.36m	
	Blade holding volume		6.4m^3	3.5m^3
Item	Total length		7.88m	7.58m
	Total width		3.94m	3.7m
	Total height		3.50m	3.55m
	Total vehicle weight		16,710kg	14,300kg
Engine			230kw(314ps)	128kw(175ps)
Travel device		Model	Front/rear wheel driving-type	Front/rear wheel driving-type
		Control unit	ABS	None
Steering system		When operating	Articulated body	Articulated body
		When driving	Front wheel steering	
Tires equipped			Studless tire	Studded tire
			20.5-25-12PR	20.5-25-12PR
Suspension system			Leaf spring	None
Body vibration isolator			Dynamic damper	None
Snow removal device (U-shaped double-wing variable blade)			Rear retractable type	Front retractable type

By adopting the wheel steering method using the center pin lock function and developing studless tires exclusively for the loader, the driving speed has increased from 30 to 70 km/h. The snow holding capacity has been increased by 30% by widening the U-shaped double-wing variable blades to improve removal operation efficiency. The operator's environment during high-speed operation has also been improved by introducing a suspension system, a dynamic damper, etc.

5-2 Development of a single-lane loading-type rotary snowplow

Rotary snowplows which are mainly introduced for urban areas are used for snow removal to widen roads and transport and dispose of snow. Because the snow transport and disposal operation requires a width of over 5 meters for the parallel loading method (Photo 6) using the combination of a rotary snowplow and a dump truck, it causes traffic congestion in urban areas. A single-lane loading-type rotary snowplow has therefore been developed and introduced to operate in the minimum number of lanes by straight-line loading (Photo 7, Table 6).

This rotary snowplow has a snow removal device equipped with a belt conveyer-type loading

Photo 6 Parallel loading method

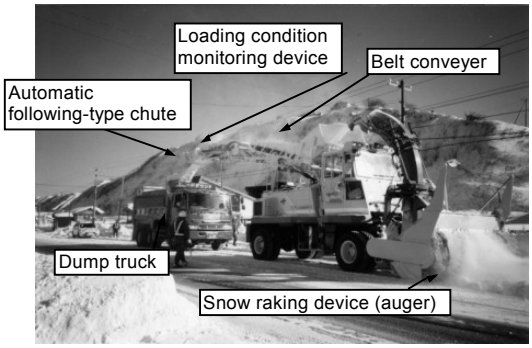

Photo 7 Single-lane loading type and dump truck

device, an automatic tracking-type discharge chute and a device to confirm loading conditions, to enable safe and reliable loading to a dump truck following behind. Operation on a single lane has thus become possible and traffic obstacles have been reduced considerably.

Table 6 Specifications of single-lane loading type

Performance	Max. handling capacity	730m³/h
	Max. snow removal width	2.6m
	Front height of the snow removal system	1.53m
	Max. speed	40km/h
Item	Total length (driving position)	9.87m
	Total width (driving position)	2.6m
	Total height (driving position)	3.76m
	Total vehicle weight	17,900kg
Engine		161kw(220ps)
Travel device	Model	Hydraulic all-wheel-drive
	Steering	Hydraulic body articulation
Snow removal device	Model	Two-stage type
	Auger	2.376 x 1.2m
Loading system	Model	Belt conveyer type
	Conveyance size	0.9 (width) x 7.1 (distance) m
	Conveyance speed	230m/min
	Chute	With automatic following function
Loading condition	Confirmation device	TV camera (indoor)
Confirmation device	Monitoring device	TV monitor

5-3 Development of an air-type snow removal truck (for suspension bridge)

Hakucho Ohashi Bridge, which opened in 1997, is 1,380 meters long and is the largest suspension bridge in a cold, snowy region of Japan (Photo 8). Because the bridge site is in an area of strong winds in winter, fairings projecting 4.5 meters from the outer side of the railings are installed from both sides of the road to ensure wind-resistance of the bridge (Figure 6).

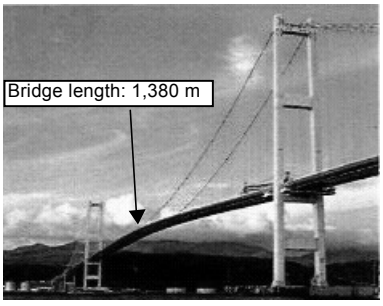

Photo 8 Hakucho Ohashi Bridge

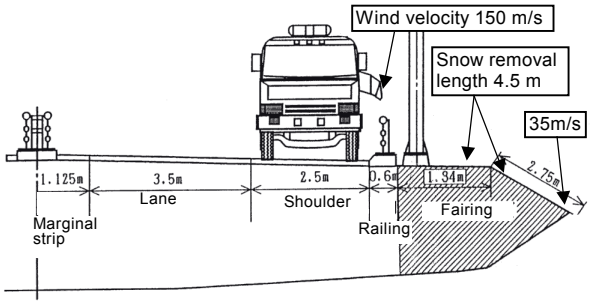

Figure 6 Fairing and air-type snow removal truck

Because the function of the fairings deteriorates when a large amount of snow accumulates on them and there is danger of masses of snow and ice falling to the ship route below the center of the bridge, prompt snow removal is essential.

Because snow removal on fairings equipped with hunger ropes and lighting poles was difficult with conventional snow removal vehicles, however, manual operation that involves danger had to be conducted. An air-type snow removal truck has therefore been developed to realize mechanized snow removal (Photo 9, Table 7).

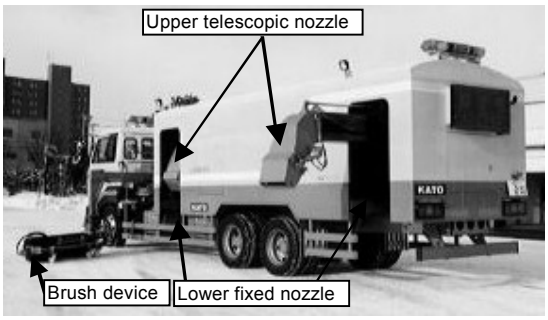

Photo 9 Air type

Table 7 Specifications of air-type

Performance	Max. snow removal width	Air	4.59m(left side)
		Brush	1.65m(left side)
	Snow removal speed		2km/h
	Nozzle (discharge opening)	Max. wind velocity	150m/min
		Max. wind volume	500m³/s(1 unit)
Item	Total length		11.05m
	Total width		2.49m
	Total height		3.57m
	Total vehicle weight		19,525kg
Travel device	Two front-axle and four double rear-axle driving		
Engine	When operating		257kw(350ps)
	When driving		305kw(415ps)
Blower	Model		Turbo fan-type
	Quantity		2 units
Nozzle device			4 units
Brush device	Size		ø0.45 x 1.65m
	Material		Polypropylene
	Amount of buckling		Max. 4.2 m

This truck has a mechanism to remove snow by shooting air from upper and lower nozzles installed on the front and back of the left-hand side of the vehicle at a maximum wind velocity of 150 m/s. It is also equipped with a brush device to remove adhered snow. This has enabled snow removal on the entire route in 90 minutes. The state of the actual operation is shown in Photos 10 and 11.

Photo 10 Air type

Photo 11 Brush type

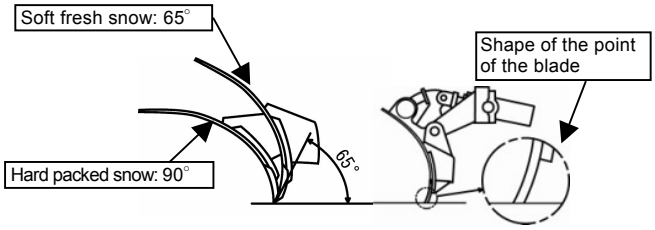

Figure 7 Cutting angle and point of the blade of the grader

5-4 Automatization of snow removal machinery (development of an automatic blade controller for snow removal trucks)

The grader of a snow removal truck is the main device used for grading of road surfaces with packed snow. When operating this grader, the operator changes the cutting angle using the empirical rule to obtain a blade linear load to suit the hardness of snow on the road surface (Figure 7). The operation requires advanced skill because the abrasion angle must also be adjusted by fine-tuning the angle of the blade tip during cutting. An automatic controller has therefore been developed so that inexperienced operators can operate the device without difficulty (Photo 12).

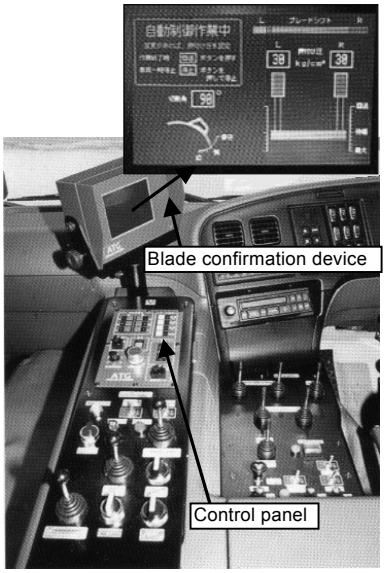

Photo 12 Automatic blade control panel

This device has four modes of blade linear load and cutting angle (compacted snow 1, 2 and 3 and fresh snow) and is automated to enable operation using switches from the driver's seat. The abrasion angle of the point of the blade is also automated.

The number of lever operations, which used to be over 200 per hour, could therefore be reduced to one tenth, and it has become possible for inexperienced operators to conduct advanced operations of a grader.

6. Current development of snow removal machinery

The following are development projects of snow removal machinery which are currently under way:

(1) Site-specific snow removal machinery and establishment of operation methods

Site-specific snow removal, such as at crosswalk terminus areas, must be conducted within a limited time frame between the completion of snow removal on roadways and the commuting time. Most of such operations are currently conducted manually (Photo 13). Technical examination has therefore been promoted to eliminate hard manual labor and realize safe and fast operation using snow removal machines (equipment) designed for crosswalk terminus areas.

Photo 13 Manual snow removal at a pedestrian crossing

Photo 14 Measurement of road surface skid resistance coefficient

(2) Simplification of operation

To compensate for the increasing lack of skill of experienced operators, new technologies to recognize road conditions have been developed for safer operation of snow removal machinery. Such technologies include measurement of the road surface skid resistance coefficient using a non-contact sensor (Photo 14) and a device to detect people, structures and obstacles during snowfalls and other poor visibility conditions (Figure 8).

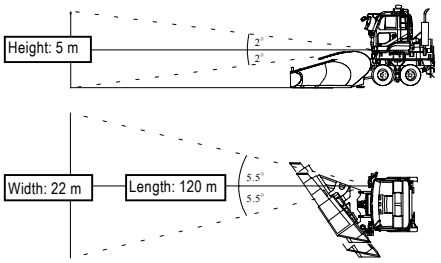

Figure 8 Front obstacle detector

(3) Advanced operation management system for snow removal machine operation

Snow removal machine operation is currently managed by installing an operation recording device. This device will be further improved in the future to realize an advanced system to conduct efficient and fast snow removal on roads by incorporating snow removal information, as well as road surface and weather conditions (Figure 9).

Other technical development projects are also promoted for examination of environment-friendly snow melting and disposal technology and the introduction of compact snow removers using natural gas.

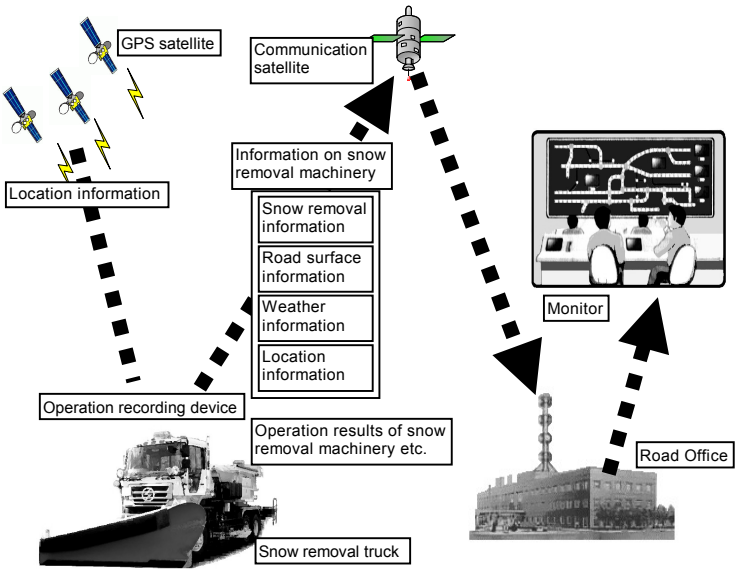

Figure 9 Advanced management of snow removal machine operation

7. Conclusion

Securing road traffic in winter is an important issue to support safe and comfortable lives in snowy Hokkaido and promote exchanges between regions. Mechanized snow removal plays a central role in securing winter road traffic, and its position is expected to remain in the 21st century. The keys to future prosperity of the snowy region, therefore, include improvements in snow removal machinery, such as an increase in speed, labor reduction and improved operability, as well as establishment of an advanced and efficient operation system.

This report therefore presented snow removal machines which have recently been developed and put into practical use. It also described technical development projects that are currently under way. The authors wish to contribute to the development of cold, snowy regions through such technical advancements.

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