Experimental Development of New Small-sized Snow Vehicles for Forestry

By

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山林用小型雪上車両の開発

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Abstract

The authors developed different four small-sized vehicles traveling freely on soft and deep snow for the forest work, especially cutting and logging. The tests were carried out for three years from 1983 to 1985 at Moshiri district, Uryu Experiment Forest, Hokkaido University. The results showed the practical vehicles could be obtained by several improvements of commercial vehicles, keeping the speed of over 4 km/hr, the climbing-up angle of over 20 degrees, and the turning radius of below 5 meters. The specifications possessed of these traveling powers were: crawler type driving device giving about 0.1 kg/cm^2 of average ground pressure, about 1.5 meters of ground contact length, and articulated steering device, which became pretty expensive, priced at 1,000 to 1,500 thousand yen. Meanwhile, the vehicle used only for riding of forest laborers, and provided with a clutch-and-brake type device capable of a small turning radius, was thought to be priced at 500 to 1,000 thousand yen. Besides all the vehicles could be utilized for supplemental skidding by the dragging-out installation of the winch wire.

Key words: Small-sized snow vehicle, Ground pressure, Turning radius, Crawler type driving device, Clutch-and-brake type.

Introduction

The forest floor is usually covered with deep snow for four to six months every year in the mountains of Hokkaido. Cutting and logging forest trees in this season, the fellers must walk to the marked trees in the snow deeper than their knees with such heavy tools as a chain saw and the attachments as well as the fuel and grease. Accordingly, they exhaust often their stamina before working, and spend much their duty time for traveling. It has long been desired for the

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foresters concerned that the obstacles would be removed from the points of labor intensity and productivity.

The authors have studied and reported on the development of new vehicles usable for the cutting and logging in the mountains covered with soft and deep snow for a long time.[2~9] In this paper are summarized the recent results studied from 1983 to 1985.

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I. Past Studies

Since 1983 the authors have studied the theme of "the adaptation of small-sized vehicles for dragging-out the winch wire in the tractor skidding", which is practiced by human power. As the work is hard especially on soft and deep snow, the laborers are exausted. In order to avoid this hard work, the authors applied a conventional skidding vehicle for the dragging-out.

Firstly, they began to improve the vehicle so as to run about on soft and deep snow at will. The results of the study on "the development of a skidding vehicle with an electric chain saw and a generator" earlier reported,[8] showed that the caterpillar device with a low ground pressure was the best under such conditions from the points of both function and price. This was a small-sized skidding vehicle having an average ground pressure of 0.15 kg/cm^2 with crawlers attached on both sides of the body, in which the traveling device was operated by a clutch-and-brake type.

However, the vehicle being turned on soft and deep snow, the change induced by one operation of the clutch-and-brake was very small, owing to the compression resistance caused by the snow beside the crawlers. Therefore, it took 10 meters or often more than 20 meters of the turning radius for a 180-degree turn by a forward gear. It must be inconvenient that the vehicle operated with a large turning radius is used on the snow for the works especially in the forest of a high tree density. The authors have recently progressed the study on the development of a more suitable snow vehicle, taking notice of it.

II. Experiments

1. Examination on turning method

The authors examined different steering device to develope the small-sized vehicle turnable with a small radius. They aimed first at a turning type of a four-wheel drive vehicle with an articulated steering device, which was proved to show a small turning radius on sand. It would be expected that the vehicle could be easily turned on soft and deep snow, if the average ground pressure was decreased to about 0.15 kg/cm^2 by replacing wheels with crawlers. The authors purchased a small-sized four-wheel drive vehicle with the articulated steering device and changed the wheels to the crawlers by equipping its attachment, since the crawler type one had not been marketed. The crawler type vehicle provided for dragging-out the wire with a small power winch was named Test Model No. 1, as shown in Photo 1. The crawlers slided before and behind to some extent centering around the starting wheel axle in response to the rugged surface, and also the front and rear wheel axles individually slided right and left to some extent. Accordingly, the vehicle could be always maintained in the most stable situation on the snow, when the slope was not so steep.

2. Examination on ground pressure

The authors inferred that the vehicle with an extremely low ground pressure could be turned with a small turning radius even if it was deviced with a clutch-and-brake type, when they observed a large crawler type snow car with a low ground pressure to turn without trouble on soft and deep snow. To confirm this fact, the authors purchased a small-sized vehicle with less than 0.1 kg/cm^2 of an average ground pressure among the ones deviced with an ordinary two-crawler driving system and a clutch-and-brake turning type. The vehicle provided for the forest work with a small winch was named Test Model No. 2, as shown in Photo 2.

The authors, meanwhile, examined a new skidding vehicle with a generator for an electric chain saw, to compare the performance test on soft and deep snow, together with the above-mentioned. This was named Test Model No. 3, as shown in Photo 3.

Furthermore, the authors developed a two-crawler type snow vehicle taking the place of a laborers' walk in 1985 and named Test Model No. 4, as shown in Photo 4. The specifications of all the Models are described in Table 1.

The tests were carried out at Moshiri district in Uryu Experiment Forest, Hokkaido University, in the winter from 1983 to 1985, widely known as one of the coldest and heaviest snow regions in Hokkaido. The location is shown in Fig. 1.

Table 1. Main specifications of Test Models

Model No.	1	2	3	4
Length (mm)	3,430	2,500	2,650	2,410
Width (mm)	1,320	1,460	1,550	1,500
Height (mm)	1,880	1,030	1,650	1,305
Weight (kg)*	1,197	653	1,730	518
Track shoe width (mm)	280	300	330	500
Contact length (mm)	736×2	1,350	1,388	1,713
Engine power (HP)	12	8	15	10

* Including one operator (weight 55 kg).

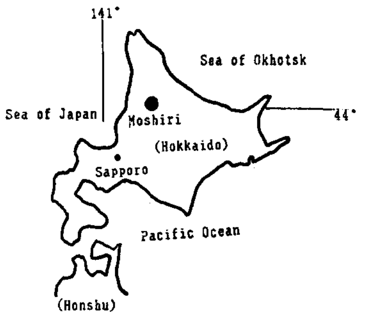

Fig. 1. Location of the test (Moshiri district in Uryu Exp. For.).

III. Results and Discussion

1. Study in the first year (1983)

It is well known that the traveling power of a crawler type vehicle varies with the properties of snow; namely on the inadhesive and granulated snow the power is decreased, while on the wet and compressed snow it is increased. At the Moshiri district fallen snow keeps usually granulated from the beginning of January to the end of February. Toward the middle of March, the snow becomes adhesive from the upmost layer which is easily compressed and fixed. On the contrary, in the lower layers the snow is gradually hardened by the own weight. Under such conditions the crawler type snow vehicle can travel, turn, or climb up easily on the gentle slope through a low sinking of the body, compared with the previous months.

Since the timber production is generally practiced from January to February in Hokkaido, the tests should be done in this period to develope the new snow vehicle usuable for the winter timber production. Owing to the structural trouble of the vehicles, however, the tests of all the vehicles (Test Models No. 1, 2 and 3) could not help being practiced in the middle of March, 1983. The results are shown in Table 2. So far as the turning performance is taken as an index of minimum turning radius on fresh snow, no difference is indicated among the three except that the trace of Model No. 1 is nearly circular, while that of the others is irregularly polygonal near elliptical. This indicates that the articulated steering device is superior to the clutch-and-brake device for the safety of driving on the snow.

Table 2. Results of test in 1983

Model No.	1		2	3
Average ground pressure (kg/cm^2)	Front crawler	0.214		
	Rear crawler	0.077	0.081	0.189
	Mean	0.145		
Coefficient in position of gravitational center*	0.735		0.582	0.710
Critical climbing-up angle on fresh snow (degrees)	22		19	19
Minimum turning radius on fresh snow (m)	3.9		4.0	4.4
Depth of rut at turning (cm)	18		22	26

* Value dividing the length from the rear crawler to gravitational center by contact length.

2. Study in the second year (1984)

The test was carried out with Model No. 2 and Model No. 3 in the end of February, 1984, because of some damage of No. 1. In order to clarify the effect of the ground pressure and the position of gravitational center on the traveling power, Model No. 2 was more lowered in the average ground pressure and shifted

Table 3. Results of test in 1984

Model No.	2	3
Average ground pressure (kg/cm^2)	0.073	0.189
Coefficient in position of gravitational center	0.633	0.710
Critical climbing-up angle on fresh snow (degrees)	19	19
Depth of rut at climbing-up (cm)	16	20

more forwards in the gravitational center by removal of the bed than those in 1983. The results are shown in Table 3.

Since the authors have noticed that the ground pressure of Model No. 2 is remarkably lower than that of No. 3, they expected Model No. 2 was higher in the critical climbing-up angle than No. 3 on fresh fallen snow. However, less difference was given between the two, as similarly as the tests carried out in March, 1983, when the snow traveling was proved to be most advantageous. The reason might be: Owing to the ground pressures considerably lower than a general value, the difference of the two in the critical angle was not shown by the structure of snow layer.

As shown in Table 3, 19 degrees of the critical angle given by Models No. 2 and 3 is sufficient for the forest work on the snow.

3. Study in the third year (1985)

Most serious hindrance of forestry in winter is a snow walk, as reported on "the mechanization of timber production in winter" by then Chief of Operation Division, Obihiro Regional Forest Office.[10] The development of a snow scooter must be one of the solutions, by which the efficiency is naturally elevated. It is also possible that the utilization copes with the advance of the laborer's age, now confronted as a problem of forestry in Japan, and that a new system of timber production in winter is introduced by several machines powered with the engine of the scooter. And it might be suggested that a new era comes in the forestry under such circumstances through the solution. The vehicle developed by the authors is thought to have the same way as the snow scooter demanded in the report. In 1985 they studied under the theme of "the development of a small-sized vehicle traveling freely in sloped forest covered with soft and deep snow". The vehicle is an ordinary two-crawler type with an extremely lowered average ground pressure (Photo 4). The characteristic is: the width of track shoe and ground contact length are approached to the maximum in the range functioned. Accordingly, with the lowest ground pressure obtained the largest climbing-up angle could be exhibited among all the developed vehicles, tested from February 27 to March 2, 1985 at the Moshiri district. The results are described in Table 4, together with the other Models. The angle ranges between 24 and 29 degrees on fresh snow, which seems sufficient in the climbing-up performance as the snow scooter. The minimum turning radius of Model No. 4 can compare with that of the others, except Model No. 1, operated with a clutch-and-brake device.

Table 4. Results of test in 1985

Model No.	1	2	3	4
Weight (kg)	1,197	593	1,730	518
Contact length (mm)	736×2	1,350	1,390	1,710
Average ground pressure (kg/cm²)	0.145	0.073	0.189	0.030
Coefficient in position of gravitational center	0.735	0.633	0.710	0.675
Critical climbing-up angle on fresh snow (degrees)	22–24	20–21	14–18	24–29
The average angle (degrees)	23	21	16	26
Depth of rut at climbing-up (cm)	17–20	14–21	20–24	10–15
The average depth (cm)	19	18	22	12
Minimum turning radius of fresh snow (m)	3.8	6.4	5.1	5.3
Maximum traveling speed on fresh snow (km/hr)	4.76	4.05	4.41	10.00
Maximum traveling speed on compressed snow (km/hr)	8.00	7.23	9.45	12.63

4. Summary of the three-year studies

Based on the tests of the four vehicles used for the three years, the authors would investigate the availability with traveling powers such as speed, turning radius, and climbing-up angle. The powers of the snow vehicles vary generally with the snow states which are changed by the climatic condition of each year, but are most influenced by the passage in snow-cover period.

1) Speed: The maximum speed of each vehicle traveling on fresh snow ranges between 4 km/hr of Model No. 2 and 10 km/hr of No. 4. As the walking speed of man is approximately below 1 km/hr on the fresh snow, those obtained by the vehicles may be useful, being equal to the speed of man walking on the road. The forest laborers can reach the destination without physical exhaustion.

2) Critical climbing-up angle: The critical angle of each vehicle climbing up on the fresh snow ranges between 14 degrees of Model No. 3 and 29 degrees of No. 4, and exceeds all 20 degrees except that of Model No. 3. The fact that the forests below 400-meter altitude at sea level are usually dealt with the management in Hokkaido, where the area of the slopes less than 15 and 20 degrees is occupied at 57% and 68%, respectively,[1)] means Models No. 1, 2 and 4 can be effectively utilized for the forestry in winter.

3) Minimum turning radius: The minimum turning radius on the fresh snow ranges between 3.8 meters of Model No. 1 and 6.4 meters of No. 4. Traveling among the trees in the forest, the snow vehicle is naturally needed in the radius as small as possible. As calculated from tree density, the interval of three, four and five meters between trees gives the density of 1,111, 400 and 100 stems per hactare, respectively. When the vehicle travels freely in the forest in winter the practical turning radius is desirable at below 5 meters.

4) Snow state: The influence of the snow state on the traveling power of

Table 5. Results of traveling powers by each Model and respective time tested

	Model No.	Mar. 17–18, 1983	Feb. 27–Mar. 2, 1984
Critical climbing-up angle on fresh snow (degrees)	1	22	23
	2	19	19
	3	19	16
	4	—	26
Minimum turning radius on fresh snow (m)	1	3.9	3.8
	2	4.0	6.4
	3	4.4	5.1
	4	—	5.3

the vehicles was investigated according to the time testing the critical climbing-up angle and the turning radius. Table 5 shows the angle and radius obtained by each vehicle and respective time tested. By the time, the two performances of Models No. 1, 2 and 3 are different; namely, No. 1 is not so changed in the climbing-up angle and turning radius, and No. 2 is remarkably changed in the turning radius, while No. 3 is changed in both of them. Generally speaking, the turning radius is influenced by the snow state, giving the large values in the end of February when the adhesion of the snow is low.

Conclusion

The powers requested for the snow vehicles are to travel on the fresh snow in the period of January and February at over 4 km/hr of the speed, over 20 degrees of the climbing-up angle and below 5 meters of the turning radius. It is concluded such vehicles would be possible, if those are equipped with a crawler type driving device providing $0.1\pm0.05\,kg/cm^2$ of the average ground pressure, 1.5 ± 0.1 meters of the ground contact length, and the articulated steering device. The price should be less than a million yen, but it may probably exceed (1,000 to 1,500 thousand yen) on account of the articulated steering device which must be provided with four crawlers.

Hereafter, the authors want to progress following study: Model No. 1 of the articulated steering device should be developed to use for a multipurpose forest work vehicle on the snow, provided with seats for two or more laborers, and equipped with an electric chain saw and a simple skidder together with a generator and a powered winch. Model No. 4 should be developed to use mainly for a snow scooter in the forest provided with seats for one or two laborers, so that the low price (500 to 1,000 thousand yen) and the mobility are expected.

The authors would, furthermore, investigated in detail the relationship between the snow state and the traveling power of the vehicle.

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要　　約

積雪期に伐出作業に従事する作業員は，積雪上を徒歩で移動させられる事が多い。1月から2月にかけての軟らかな深い積雪上を，チェンソー等の器具を携行して，雪に埋まりながら歩行することは，作業員にとって大きな労働負担となっている。このことは労働生産性向上の面からも大きな障害となっている。

これらを解決する方法の一つとして，作業員を高速で移動させる車両の開発を進めることにした。この車両は，軟らかな深い積雪上を自由に走行できる性能を有する必要がある。そのため筆者等は，1983年から1985年の3ヵ年間に実用規模の供試車両を試作して，それらの走行性能を検討した結果，一定の成果と方向を見い出した。

その結果，実用的な走行性能は新雪上を走行速度4 km/h以上，登坂角が20度以上，旋回半径が5 m以内と考えることができる。この走行性能を具備する車両の主要諸元は，クローラ駆動式走行装置を備え，平均接地圧が0.1 kg/cm² 前後，接地長が1.5 m前後で，操向装置は車体屈折式であることを明らかにした。しかし車体屈折式は，車両価格が高価になる欠点がある。

この研究から，作業員の移動だけの「雪上スクーター」的な車両には，クラッチ・アンド・ブレーキ式の操向装置で，車両価格 50～100 万円で実用車の作製が可能であり，また旋回性能が優れている車体屈折式車両は，車両価格が 100～150 万円となるが，この車両には作業員の移動の他に集材機能を具備させ，価格面の不利を補う「雪上林内作業車」として実用化の可能性があることを明らかにした。

Photographs of snow vehicles

Photo 1. Test Model No. 1 (left).

Photo 2. Test Model No. 2.

Photo 3. Test Model No. 3 (left).

Photo 4. Test Model No. 4 (front).