Research on an Air Lubricated Snow Plow

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The development of high speed guided ground transport systems has been carried out in North America and elsewhere for over a decade. For these systems to be applied in temperate zones that experience snowfalls, some improvements in dealing with snow will have to be made if the high speed systems are to be used advantageously in winter as well as in summer. Investigations have been conducted on unconventional methods of removing snow from a substrate. One of the methods investigated was a means of reducing the dynamic friction of snow on a snow plow blade. Air is supplied to the surface of a blade to provide a lubricating film.

In another presentation the subject of snow accumulations on possible high speed transportation system tracks is discussed (1). This work on snow accumulations resulted in the Low Temperature Laboratory at NRC reviewing the then current situation on snow clearing as it applied to airport runways, highways and railways. At a time when research and development organizations in the transport field were looking at guided ground transportation based on either air cushion or magnetic levitation technologies it appeared that high speed snow removal was 100 km/h (60 mph) providing the snow accumulation did not exceed 2.5 to 5 cm (1 or possibly 2 in.). On airports the clearing of runways was in fact more likely to be carried out at 25 km/h (15 mph) by the multiple vehicle system where the limitation was dictated by the speed and capacity of snow blowers fed by snow plows operated ahead and in parallel (2). On railways the equipment currently in service has in some cases been in use for 50 to 60 years and no major advances have been made in railway snow removal equipment in that period of time with the only change being the provision of diesel locomotives in place of the older steam locomotives. In a storm during February 1978 a snow plow powered by two diesel locomotives was caught in snow drifts near Gull Lake, Saskatchewan and eventually had to be dug out by construction equipment. In the meantime one of the transcontinental lines was out of service.

It should be noted that the various railways have tried a number of different schemes for snow removal including the use of jet engine exhausts to clear snow from the right-of-way. This latter method was observed to remove ballast as well as snow under some conditions. Some improvements have been made in North America in equipment for snow removal from tracks in limited areas such as yards and terminals. However, nothing is known to exist in North America comparable to the so-called "snow trains" designed to clear out snow from yards and terminals in Moscow and other Russian metropolitan centers (3).

Considering the average speed of vehicles on the various transportation systems there is doubt regarding the necessity for higher speed snow removal equipment. On roads and highways the presence of other vehicles will always be a limiting factor. On railways the speed limits in various sections are limited by curves, superelevation and the quality of the roadbed. The removal of snow from airport runways could be accomplished more rapidly by either higher speed equipment or the provision of more equipment. However, in any case there is an economic limit that also must be taken into consideration. Thus, at the present time with existing transportation systems there does not appear to be any necessity for considering snow removal equipment with higher vehicle speeds. If high speed guided ground transport becomes a reality from the current developments then systems will be available with vehicle speeds in the 250 to 300 kilometre per hour range. In order for these high speed systems to operate in the temperature zones that experience winter snows, either prevention of accumulation or removal of snow must be considered.

The prevention of snowfall accumulation by the classical method of snow melting is a possible solution for high speed guideways. In an area such as Buffalo, N. Y. an input in the order of 1070 kilocalories/h m^2 (400 BTU/hr. ft^2) is required for snow melting (4). For the upper surface of the box beam design track originally proposed by British Tracked Hovercraft a thermal input of approximately 1.6×10^6 kilocalories/h/km (1×10^7 BTU/hr/mile) of track would be required. The high speed systems have been designed primarily for intercity traffic and one of the routes considered in Canada has been between Toronto and Montreal. For the thermal protection of a single track between these two centers a power input of approximately 1×10^9 watts is required. In view of the rising cost of energy there is little doubt that other more energy-conserving means must

be considered.

The removal of snow from the guideways of high speed transportation systems by conventional or modified snow plows should not involve any great problems if current snow removal speeds are acceptable. The application of snow removal vehicles limited to say 100 km/h (60 mph) on tracks designed for vehicles with speeds 3 times faster would cause severe interference with normal traffic except in instances of low density applications. It would be desirable if the operating vehicles were capable of snow removal simultaneously during normal operation. As an example considering the box beam track a 2.5 cm (1 in.) snowfall accumulation at a density of 0.16 (10 lb/ft^3) would result in approximately 5,700 kg of snow/km of track (20,000 lb of snow per track mile). At a vehicle velocity of 90 m (300 ft) per second a snow removal rate of 1,800,000 kg/h (2000 tons/hr would be required. Snow blowers for use on airport runways exist with capacities up to this range; however, these vehicles are designed for low speed operation. They are indicative that snow removal rates of this order can be realized with sufficient energy input.

Unconventional Snow Removal

In order to study various possible methods of snow removal a simple test facility was installed at the Helicopter Icing Research location adjacent to the Ottawa Uplands Airport. In the design of this research set-up it was decided to use a standard gage steel rail track to guide the propulsion vehicle and the experimental equipment. This method would allow for longitudinal guidance while simultaneously maintaining good vertical alignment. For the initial phase of the work, i.e. the low speed preliminary evaluation of various concepts, a 90 meter (300 ft) long track was installed of which 54 meters (180 ft) were of conventional construction with wooden ties and a ballast roadbed. The central section of the track included a concrete pad 36 meters (120 ft) long mounted between the steel rails and elevated above the rail head. The steel rails and the concrete pad are mounted on continuous steel beams supported on concrete columns. In the central section the test track is elevated approximately 1.2 meters (4 ft) above the surrounding terrain. Figure 1 shows the track under construction.

Standard railway maintenance-of-way vehicles were purchased as a propulsion vehicle and a vehicle for mounting research equipment. The propulsion vehicle is powered by a gasoline engine and drives the rear wheels through a multi-speed transmission and a differential rear axle. The research equipment vehicle is a standard four-wheel flat top car used to carry maintenance-of-way tools and equipment in normal use. It was modified and strengthened to a limited extent prior to use for mounting research equipment.

One of the developers of tracked air cushion vehicles had assumed that the frequent operation of these vehicles would remove snow as it accumulated on the track surfaces, and therefore a major build-up of snow would not occur except during periods without normal traffic. It was decided to investigate this supposition as one aspect of the research on unconventional methods of removing snow.

The first equipment placed on the research vehicle was a centrifugal fan powered by a 50 HP 3-phase electrical motor. A trailing cable supplied power to the motor from a track-side power terminal. The centrifugal fan had a maximum flow capacity of 340 m^3/min (12,000 cfm) of air and a maximum discharge head of 45 cm (18 in.) water column. Inlet shutter control is available to control the output of the fan. The discharge from the fan was directed through an elbow and a three-channel diffuser into a rectangular plenum. From the plenum air could be directed through nozzles to impinge on the concrete track surfaces. The first nozzle tested was a forward facing full width slit representing the discharge from the clearance between a hovercraft skirt and a substrate. Within the speed limits of this vehicle, allowing for acceleration and braking on this length of track, the nozzle cleared dry snow accumulations well but failed to clear heavy cohesive and adhesive snow formations. A number of different nozzle designs were investigated on this vehicle and track with varying degrees of success. None removed the snow cleanly from the concrete substrate if the snow deposit was highly adhesive or if some freezing and sintering had taken place between accumulation and attempted removal.

During the tests on the snow removal air nozzles it was noted that the snow once removed from the surface was moved horizontally considerable distances. This observation ultimately led to the development of the horizontal air curtain for railway switch protection, thus this research work had an unexpected spin-off.

In the operation of hovercraft the supporting air provides almost frictionless motion for the vehicle. After it was displayed that the escaping air from an air cushion would not remove snow in all instances from a substrate, consideration was given to the inversion of the air cushion principle as a means of aiding in snow removal. Since air provides a low friction for movement of the ACV, might it not also provide low friction for snow removal? In the mechanical removal of snow from a substrate by a plow the forces involved include detachment of the snow from the substrate and the friction force of the snow moving across the blade. It was thought possible to reduce the friction force on the plow blade if a film of air could be supplied and maintained on the surface of the blade. The air would act as a supporting and lubricating film for the snow moving across this surface in a manner similar to its application on hovercraft. It was considered desirable that the air flow should be directed to assist the preferred directional flow of the snow in preference to using an air flow perpendicular to the plow surface, i.e. one that would be supporting only.

Air Lubricated Snow Plows

In order to investigate this concept it was decided to purchase a small standard cylindrical design snow plow and modify the blade surface to provide the air-lubricated feature. A commercial snow plow, intended for use on smaller vehicles such as a pick-up truck, was procured. To provide air to a blade surface it proved to be simpler to mount a false blade surface in front of the existing blade. The false blade surface was made of aluminum especially perforated and oriented to give directional flow to the supply air. The aluminum sheet was attached to the standard blade by multiple zig-zag truss members. Together with end and bottom pieces, this assembly formed a plenum for the air which was supplied from the fan outlet by a number of flexible hoses. Figure 2 shows material being perforated for construction of an air lubricated snow plow, while Figure 3 shows the

Figure 1. Experimental track under construction.

Figure 2. Preparing perforated material for an air lubricated snow plow blade.

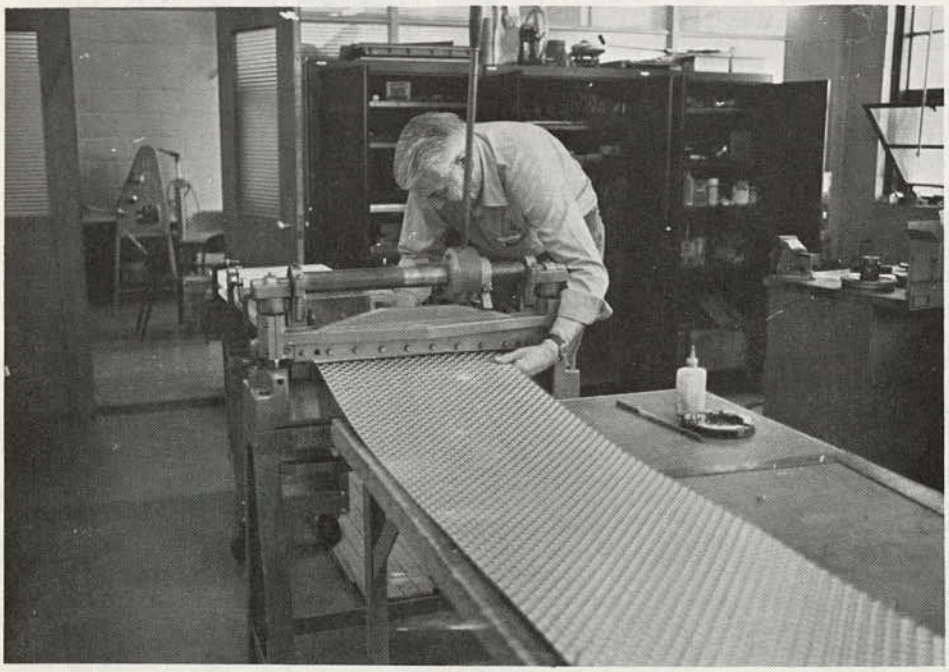

Figure 3. MK 1 air lubricated snow plow ready for tests.

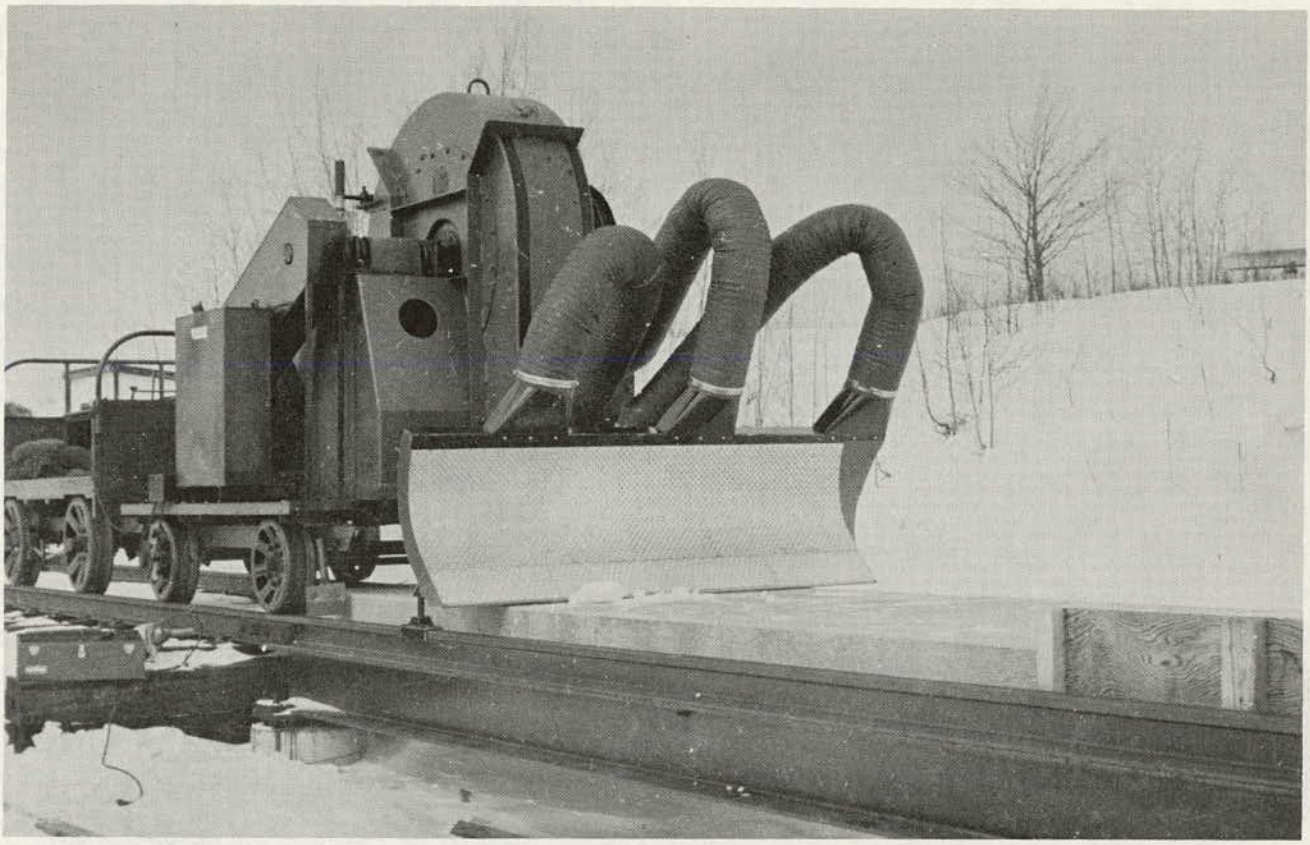

Figure 4. MK 1 air lubricated snow plow at approximately 15 km/h.

Figure 5. MK 2 air lubricated snow plow on the experimental track.

Figure 6. MK 2 air lubricated snow plow in road service.

completed MK 1 plow mounted on the experimental vehicle ready for tests.

The first few tests with this plow showed two things rather dramatically, i.e. air provides a virtually frictionless surface and without friction the snow flow is uncontrollable. The next figure displays what happens when this snow plow blade lubricated with air hits a snow accumulation of approximately 5 cm (a few inches) at a speed less than 16 km/h (10 mph), see Figure 4. Various tests were conducted for one winter season with the MK 1 design using either freshly fallen snow, recast snow or manufactured and recast snow.

After the observation of the snow explosions resulting from the air lubricated simple blade hitting a snow accumulation, consideration was then given to how a blade might be designed to take advantage of the air lubrication and still provide directional control of the flowing snow. A number of design concepts were considered, and of these one was selected for the next construction. The MK 2 was designed to give some directional control by partial containment coupled with air lubrication. This air lubricated snow plow contained a much larger perforated blade surface of a somewhat modified hole design. The outlet area of the perforated surface was designed to take the maximum available output from the centrifugal fan. It should be noted that this fan had been changed from electrical motor to diesel-engine powered to eliminate the trailing cable and allow for ultimate use elsewhere.

The MK 2 was mounted on the experimental vehicle and a series of tests have been conducted during two winter seasons. This air lubricated snow plow has provided the directional control desired while taking advantage of the low friction feature. At low vehicle speed it provides high cast distances due to the high velocity of the exit air.

The initial tests of this snow plow blade on a standard vehicle and a roadway have been conducted during the past winter. Figure 5 shows the vehicle installation while Figure 6 shows the air lubricated plow in experimental service.

We have proven that the concept of air lubrication can be applied to a snow plow blade. It will take further development and evaluation of this principle to deterfine its possible merits for either high speed snow removal or improved snow plow efficiency at existing speeds.

References

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