

Predicting Snowmobile Speed from Visible Locked-Track and Rolldown Marks in Groomed/Packed Snow Conditions

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ABSTRACT

The ability to accurately calculate a snowmobile's speed based on measured track marks in the snow is important when assessing a snowmobile accident. The characteristics and length of visible snowmobile track marks were documented for 41 locked-track braking tests and 38 rolldown tests using four modern snowmobiles on a groomed/packed snow surface. The documented track mark lengths were used to quantify the uncertainty associated with using track mark length to estimate initial speed. Regression models were developed for both data sets. The regression model of the locked-track tests revealed that using an average deceleration of 0.36g over the length of the locked track mark provides a good estimate of the best-fit line through the data, with the upper and lower 95th percentile prediction interval bounds best represented by using deceleration rates of 0.23g and 0.52g respectively. For the rolldown tests, using an average deceleration of 0.23g over the length of the measured rolldown mark provides a good estimate of the best-fit line through the data, with the upper and lower bounds of the 95th percentile prediction interval best represented by using deceleration rates of 0.13g and 0.40g respectively. For our locked-track braking tests, we also calculated a 0.38 ± 0.19 s delay between initial brake application and track lock. The results of this study will allow investigators to quantify the accuracy of their calculated speeds using measured track mark lengths on similar snow conditions.

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INTRODUCTION

Calculating a road vehicle's speed based on skid distance is commonplace in collision reconstruction. The same principles apply to snowmobiles, although there are two important differences: track marks in the snow must be interpreted correctly and deceleration rates appropriate for snowmobiles and snow must be used.

Snowmobile tracks leave different marks in the snow depending on whether they are accelerating, traveling a constant speed, rolling down or braking with the tracks locked. Distinguishing between these different types of track marks is key in analyzing snowmobile dynamics, yet techniques for interpreting track mark characteristics are limited in the available scientific literature. Stevenson [1] photographically illustrated the difference between a rolldown track mark and a locked track mark in the snow, but provided no detailed description of distinguishing features.

Deceleration rates for snowmobiles have been studied in different snow conditions and under different braking conditions [1,2,3,4]. These studies have reported locked-track deceleration rates of 0.38g to 0.46g on 2.5 to 5 cm (1 to 2 in) of hard-packed snow [1], 0.32g to 0.43g on groomed snow [2,3], and 0.39g to 0.58g on flat packed snow [4]. Rolldown deceleration rates varied from 0.11g to 0.25g and have in some cases been shown to vary with initial speed [3,4,5]. These deceleration values can be used to estimate a range of

pre-braking or pre-rolldown speeds of a snowmobile based on the length of a track mark, although the uncertainty associated with these estimates is often not reported.

In this study we examine some key features of snowmobile track marks generated during locked-track and rolldown tests of four snowmobiles. We also use the length of the track marks measured during these snowmobile tests to quantify the uncertainty associated with using track mark length to estimate initial snowmobile speed. The test data used in this study was previously acquired during testing conducted in 2010 [3].

METHODS

Snowmobiles

In the prior tests [3], four stock (unmodified) snowmobiles were tested (Table 1, Figure 1). Each snowmobile was equipped with its original equipment manufacturer (OEM) non-studded track. All four snowmobiles were short-track sleds with track lengths of 307 cm. Both Ski-Doo snowmobiles were purchased used and were serviced by a snowmobile mechanic prior to testing. Both Yamaha snowmobiles were borrowed from a driver training facility where they received ongoing maintenance. Fuel level was maintained between half and full during all tests.



Instrumentation

A DL2 Data Logger (Race Technology, Nottingham, England) mounted to the rear of the snowmobile was used to log onboard global positioning system (GPS) and 3-axis accelerometer data. Brake-line pressure transducers (Sensotec LM/2345-12, 20.7MPa, Columbus, OH) were installed at the master cylinder located on the left handlebar. GPS data were acquired at 20Hz and accelerometer, pressure, brake light voltage and running light voltage were acquired at 100Hz using the DL2's data acquisition system. The OEM track speed sensors on the Ski-Doo snowmobiles were also recorded by the DL2 to monitor track rotation and lockup. On the Yamaha snowmobiles, track rotation and lockup were recorded using a video camera (Aiptek Pocket DV5800, Irvine, CA) oriented so that the brake light and track were both visible. Video data was recorded at 30 fps and the video was synchronized with the DL2 data using the time of brake light activation. The snowmobiles were operated by a certified snowmobile instructor (Canada Safety Council) with 40 years of experience. His mass, including clothing, was 92 kg.

Table 1. Description of Snowmobiles Tested.

Code	Year	Make	Model	Engine	Power* (hp/ kW)	Dry Weight (kg)	Track Width (mm)	Track Lug Height (mm)
S6	2004	Ski-Doo	MXZ	600 cc, 2-stroke	115/86	211	381	25
S8	2003	Ski-Doo	MXZ	800cc, 2-stroke	135/101	206	381	25
Y1	2009	Yamaha	RS Vector	1000cc, 4-stroke	120/89	253	381	25
Y5	2009	Yamaha	Phazer RTX	500 cc, 4-stroke	80/60	222	356	32

* Power estimated from exemplar dynamometer reports from Dynotech Research.



Figure 1. Test Snowmobiles.

Test Site

The tests were conducted in rural Ontario over three consecutive days in February 2010. The test area had a small constant slope for which the data was corrected. The test surface varied between freshly groomed to traveled groomed snow. A grooming tractor (Pisten Bully 200 Edge) was used to replicate freshly groomed trail conditions before both the morning and afternoon test sessions. The snow surface was monitored over the three test days using the International Classification for Seasonal Snow on the Ground (IACS, 2009). Atmospheric conditions were recorded with a portable weather station (Tycon TP1080WC, Draper, UT). Air temperature remained below freezing, except for one afternoon, where it reached a maximum of 2.9°C. Snow surface temperatures during testing varied between -7 °C and -0.4 °C. Throughout testing, the surface snow was “moist” (it had a tendency to stick together when crushed), although no water was visible, even under a magnifying glass. The hardness of the groomed snow was very soft, as defined by the International Classification for Seasonal Snow “hand test” method. Snow grains that were not broken during grooming were generally large rounded particles ≥ 0.25 mm. There was some snow precipitation during testing which was typically in the form of stellar dendrites and plates.

Test Procedure

The operator accelerated the snowmobiles to various target speeds and then either rapidly and maximally applied the brake lever until the snowmobile came to a complete stop (locked-track braking tests) or released the throttle and allowed the snowmobile to coast to rest (rolldown tests). After each test the visible mark left by the decelerating snowmobile (either a locked-track mark or a rolldown mark) was measured using an open framed surveyor tape (Figure 2) and its nature/pattern was recorded. Test order was pseudo randomized across the three days to minimize the effect of changes in environmental and surface conditions. All deceleration tests were repeated four times for each test condition and snowmobile. Due to some missing mark length measurements, the final dataset consisted of 41 locked-track braking tests and 38 rolldown tests.

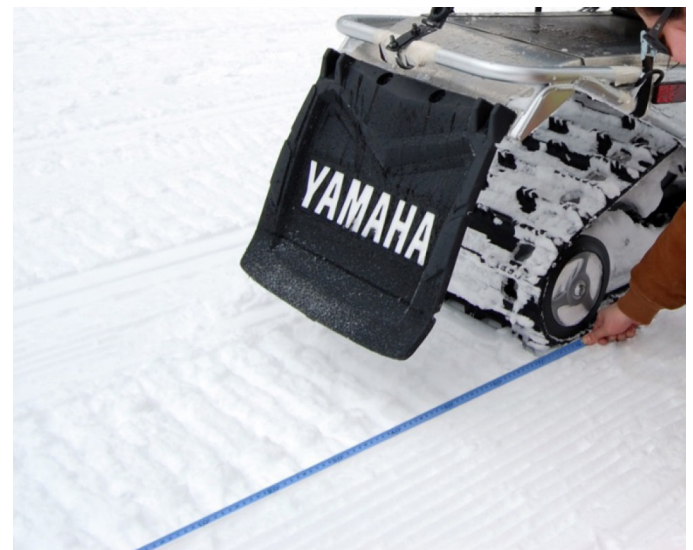


Figure 2. Measuring the rolldown mark length.