

Using Reduced Tire Pressure for Improved Gradeability – A Proof of Concept Trial

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ABSTRACT - Pope & Talbot Ltd., Arrow Lakes Timber Division, Nakusp, B.C. having no alternative options constructed a forest road with adverse haul grades up to 16%, to access a harvesting area. The company did not know the exact limitations of the adverse haul grade, but it did plan to use highway sized loads on this off-highway haul, thus sacrificing some productivity. When the road was completed and the right-of-way wood was to be hauled, it was found that the self-loading log trucks were unable to climb the grade without the assistance of a skidder despite the reduced load size. Since the road was intended for long term access and no alternate route was possible, Pope & Talbot sought the advice of the Forest Engineering Research Institute of Canada (FERIC) on safe and economic alternatives to improve log truck gradeability on the adverse road section. Based on a theoretical analysis of tractive ability, a field trial was conducted in October 2000 to demonstrate log truck gradeability improvement resulting from tire pressure reduction.

Keywords: Gradeability, Tire pressure, Logging trucks, Performance

INTRODUCTION

A major consideration in forest road construction and log hauling operations in B.C.'s interior is vehicle gradeability. This is the maximum grade that a vehicle can climb while maintaining adequate control (Anderson *et al.* 1987). A log truck's gradeability is affected by many factors including configuration, tire pressure, gross combination weight, surface condition and road alignment. Maneuvering around curves results in reduced gradeability due to the additional resistive forces encountered while cornering.

Pope & Talbot Ltd., Arrow Lakes Timber Division, Nakusp, B.C. constructed a forest road with adverse haul grades up to 16% over a horizontal distance of approximately 1.5 km, to access a difficult harvesting area with no alternate route. The haul cycle in this operating area is relatively short and takes place entirely off-highway with maximum travel speeds of 60 km/h. The B.C. Ministry of Forests agreed to appraise this cutting permit as a highway rather than an off-highway haul to recognize the limitations of the grade. When the harvested wood was to be hauled, the loaded self-loading log trucks were unable to climb the grade without the assistance of a grapple skidder, which would increase the haul cost considerably. Since the road was intended for long-term access and there was no alternate route, Pope & Talbot asked FERIC to investigate safe and economic alternatives to improve log truck gradeability on its adverse road section.

In October 2000, the Forest Engineering Research Institute of Canada (FERIC) performed a theoretical analysis and devised a field trial to determine the degree of gradeability improvement available with reduced drive-axle tire pressure for the loaded log trucks in this particular case. Previous traction trials conducted by FERIC and others indicated that as tire pressure is reduced the footprint lengthens, increasing the tire contact area which improves the drive tire traction and truck gradeability (Bassel and Raybould 1992; Bradley 1993, 1996; Keller 1993). This report presents the results of the analysis and field trial.

OBJECTIVES

The objectives of this study were to:

- Predict the tire pressures needed to allow Pope & Talbot's trucks to haul, unassisted, at least typical highway-size payloads (34 000 kg) on adverse grades up to 16%.
- Validate the tractive analysis theory on an actual hauling trial.

METHODOLOGY

FERIC used a computer model to determine the gradeability of the single axle jeep/tandem pole trailer configuration (i.e., the configuration used in this study), which has a gross combination weight of 52 200 kg (Figure 1) when loaded to maximum highway-legal weights. This model was developed by FERIC, based on methodology described by Sessions *et al.* (1986) and Goldsack (1988), to estimate the gradeability of various log truck configurations. The model was also used to predict the gradeability of the log truck under various road conditions, including mud, snow, and hard-packed gravel. These results were validated with data from previous trials and experimental data (Bradley 1991), and provided accurate gradeability predictions for a variety of tire inflation pressures. Based on the modelling results and discussions with Pope & Talbot staff, a field study was conducted to demonstrate the effectiveness of reduced drive axle tire pressures for tractive improvement on the problematic road section.

Three practical options are available to manipulate truck tire pressure for operational improvement: central tire inflation (CTI) systems, airing stations, and the use of constant reduced pressures.

CTI systems permit drivers to vary tire inflation pressures in response to changing operating conditions while the vehicle is moving. With CTI, drivers can deflate the tires for road sections with high tractive requirements (i.e., adverse grade) and inflate when travelling at higher speeds.

One alternative to CTI is to locate a remote airing station just prior to high-speed road sections (i.e., highways). Drivers would deflate the tires when leaving the highway on the empty portion of the duty cycle or just prior to negotiating an adverse road section. Although this airing station option could be an economic alternative to CTI for intermittent use, it will increase cycle times to allow for the inflation and deflation stops.

A third option is to operate tires at constant reduced pressures where circumstances permit. Constant reduced pressure is a viable option if loaded log trucks operate at low speeds throughout the duty cycle (i.e., less than 60 km/h).

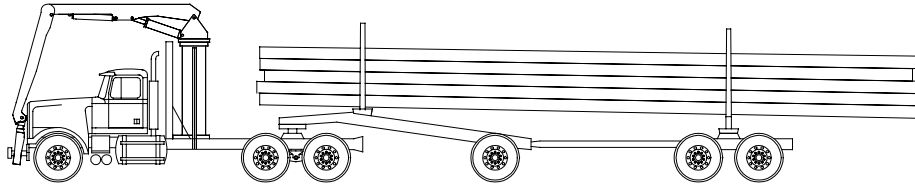


Figure 1. Typical configuration used by Pope & Talbot to load and transport right-of-way logs – Self-loading single axle jeep/tandem pole trailer.

Since the trial at Nakusp was exclusively off-highway at travel speeds less than 60 km/h, the option of constant reduced pressures appeared the most cost-effective. Published tables relating load and maximum travel speeds indicated that a constant reduced pressure of 410 kPa (60 psi) was suitable for the most demanding portion of this particular haul, namely the loaded portion (Tire and Rim Association 1999); once set, this pressure was more than adequate for the empty part of the duty cycle.

RESULTS AND DISCUSSION

Figure 2 illustrates the gradeability improvements predicted by the theoretical model at various tire inflation levels for a single axle jeep/tandem pole trailer. The 1.5 km long grade of the trial road section at Nakusp was not perfectly aligned, and concerns were expressed regarding the influence of cornering while ascending the grade. The figure also shows the gradeability predicted by the model for the same configuration at high tire pressure, while maneuvering around a 25-m-radius curve (assuming no super-elevation). The grade that the configuration could negotiate decreased from 14 to 9% as a result of cornering (at 0.3 coefficient of friction). The model also predicted that the cornering gradeability would increase proportionally as tire pressures are reduced.

Figure 2 also shows the effect of road surface condition (coefficient of friction) on gradeability. Coefficients of friction ranged from approximately 0.3 for loose gravel and mud to 0.6 for hard-packed gravel (McNally 1975). As the road condition improved, the coefficient of friction increased, and gradeability improved. The results of the modelling process indicated that at reduced pressures, these trucks could negotiate the existing grade under full loads without assistance under the expected range of summer coefficients of friction (0.3–0.6). It is doubtful that the trucks could safely negotiate the adverse grade under poorer (winter) conditions (<0.3).

The trial haul was entirely off-highway, which involved travelling empty to the loading site. The trucks then loaded and climbed the steep, adverse grade. After climbing the adverse grade, the grades were flat to favourable to the weigh scale and log dump. Based on this duty cycle, the limiting tire pressure condition occurred when the trucks were loaded and travelling along the flatter grades. This condition (fully loaded at 60 km/h) was then used to determine the optimized

tire pressure for the drive tires. This pressure was determined to be 410 kPa, and offered the greatest improvement in tractive ability and truck gradeability. Pressures of the drive tires were lowered from 690 to 410 kPa and no incremental tire pressures were applied to the trucks while they attempted to climb the adverse grade. By decreasing the tire pressure, the average length of the tire footprint increased from 28 to 38 cm. The trucks with reduced pressures on their drive tires immediately benefited from the increased tire footprint and were able to climb the hill unassisted, while trucks operating at normal, high tire pressure (690 kPa) needed an assist vehicle for every load.

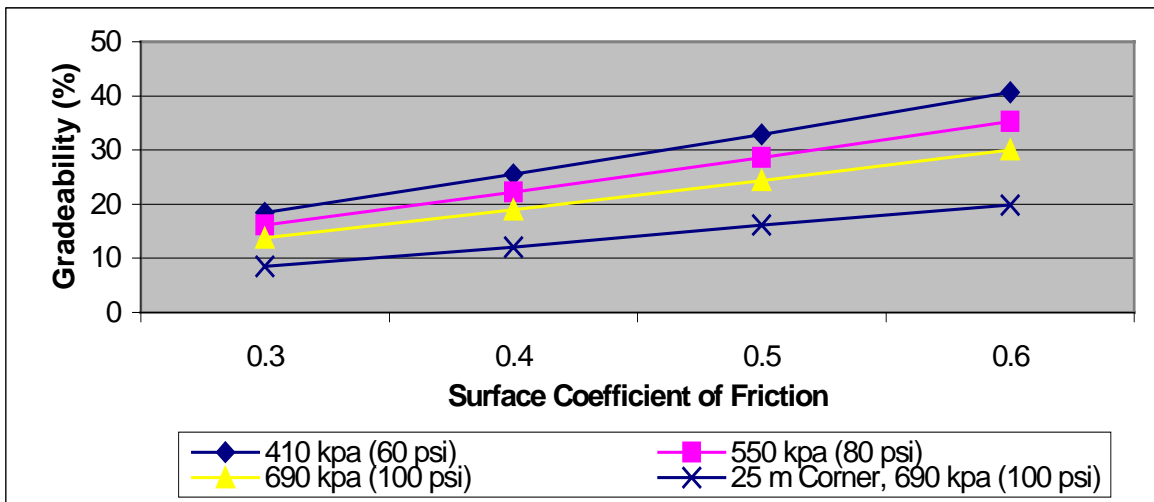


Figure 2. Predicted gradeability of a single axle jeep/tandem pole trailer.

This tractive improvement offered benefits to Pope & Talbot in four ways:

- Cycle times for trucks improved by an estimated 3% through elimination of hook-up and unhook times with an assist vehicle.
- Grading requirements were reduced for adverse haul sections. The savings will vary depending on the volume of wood hauled and the number of loads hauled over this specific section.
- Assist vehicle costs were eliminated.
- There was reduced risk to operators and equipment.

Table 1 shows the magnitude of expected savings to be \$1.88/m³ for this specific haul (Blair 1999). The savings by eliminating the assist vehicle is only an estimation and will differ depending on the nature of the contract with the assist vehicle owner and the amount of wood hauled.

CONCLUSIONS

Through the use of reduced pressure on the drive tires, improved gradeability allowed loaded (highway sized) logging trucks to ascend a steep grade that was otherwise only negotiable with an assist vehicle. In Pope & Talbot's situation, using constant reduced pressures of 410 kPa on

the drive tires was an effective and inexpensive means of improving gradeability. In addition, it created an estimated savings for this scenario of \$1.88/m³ of wood hauled.

Table 1. Projected savings with reduced drive axle pressures (Canadian \$).

	Conventional Pressure	Reduced Pressure	Savings
	(\$/m ³)	(\$/m ³)	(\$/m ³)
Hauling	6.74	6.54	0.20
Grading	0.75	0.56	0.19
Assist Vehicle	1.49	0.00	1.49
Total	8.98	7.10	1.88

IMPLEMENTATION

Based on the results of modelling and the field trial, Pope & Talbot and other similar operations may consider using the constant reduced pressure option to overcome tractive limitations on challenging haul routes. If routes with gradeability challenges also include high-speed sections, the use of an airing station or CTI-equipped log trucks are other options.

With the use of reduced tire pressures, the probability of drive tire slip is reduced, and more torque can be applied to the road for traction. Therefore, drivers and/or mechanics should examine drive trains and related components closely to ensure that partially failed or fatigued drive line components are replaced prior to applying reduced tire pressure strategies.

ACKNOWLEDGEMENTS

The authors would like to thank Mike Webster of Pope & Talbot Ltd., Nakusp, B.C. as well as Thomas Winters and the drivers of Swan Lake Log Sort, Vernon, B.C. for their cooperation during the field trial.

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