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CENTRAL TYRE INFLATION THE UNITED STATES AND NEW ZEALAND EXPERIENCE

Gareth Jones/Mark Smith

Figure 1 - The New Zealand prototype CTI system fitted on the logging truck

ABSTRACT

A brief summary of tests conducted in the United States of America to examine the benefits of operating trucks at low tyre pressures is presented. A central tyre inflation (CTI) system was designed and built in New Zealand and installed on a logging truck which operated in Kinleith Forest. Experience with this New Zealand system is outlined and recommendations for future CTI systems are given.

INTRODUCTION

The performance of logging trucks on forest roads is partially governed by the condition of the road. When road conditions become unfavourable to truck travel, productivity and truck life decrease. Central Tyre Inflation (CTI) is a design concept that has the potential to reduce the damage to forestry roads and improve the gradeability of logging trucks on these roads. If this potential can be realised, then, CTI will reduce the cost of log transport.

Tests conducted in the United States (Refs. 1-3) have indicated that lower tyre pressures and the resulting greater tyre contact area results in:

- greater traction and truck gradeability on unsealed roads
- reduced road damage and reduced construction requirements due to the lower unit pressure exerted on the road surface
- greatly improved ride quality and driver comfort.

Potential cost savings for the New Zealand logging industry from increased road grades, reduced road construction and maintenance could total several million dollars annually (Ref. 4).

In addition there is some evidence that low pressure tyres may actually heal road damage caused by high pressure tyres. Reduced vibration transmitted to the truck from the road may also reduce truck maintenance.

This report backgrounds the experience the United States logging industry has had with CTI and summarises the New Zealand experience with a prototype CTI system.

ACKNOWLEDGEMENTS

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WHAT IS CENTRAL TYRE INFLATION ?

CTI systems allow the driver of a heavy vehicle to inflate or deflate the vehicle tyres while in motion. This is usually accomplished by an electronically controlled pneumatic system using the vehicles existing air compressor.

Using CTI systems, a vehicle can be operated with tyre pressures appropriate to the road surface, road condition, vehicle speed and the load carried. For high speed highway running, the tyres can be operated at the normal high pressures to minimise rolling resistance. On low standard and unsealed roads, where travel speeds are generally lower, the tyre pressures may be reduced to increase the tyre footprint on the road, as shown in Figure 2.

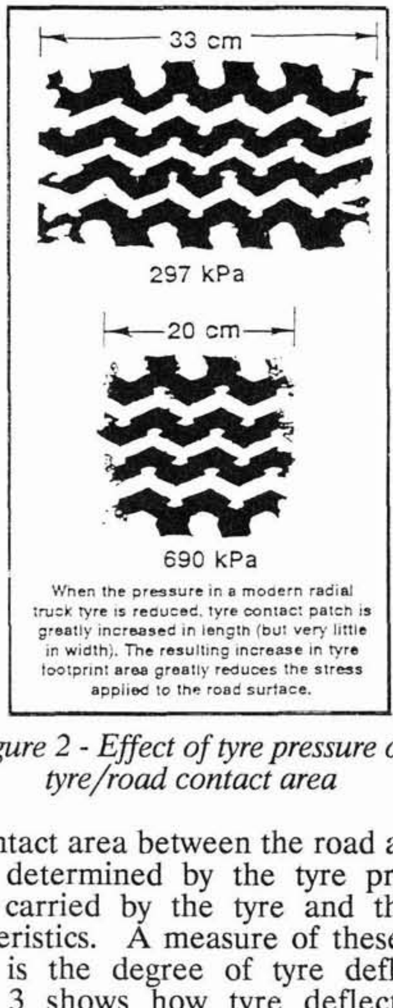

Figure 2 - Effect of tyre pressure on tyre/road contact area

The contact area between the road and the tyre is determined by the tyre pressure, weight carried by the tyre and the tyre characteristics. A measure of these three factors is the degree of tyre deflection. Figure 3 shows how tyre deflection is defined. A typical relationship between tyre pressure and tyre deflection is shown in Figure 4. In CTI trials in the United States, a tyre deflection of 20% has generally been taken as the standard for low pressure off-highway operation.

CTI TESTING IN THE UNITED STATES

The United States Department of Agriculture Forest Service (USFS) have been investigating the effect of variable tyre pressures through CTI for a number of years and have conducted many field trials. The results of these trials are summarised under the various areas affected by CTI operation.

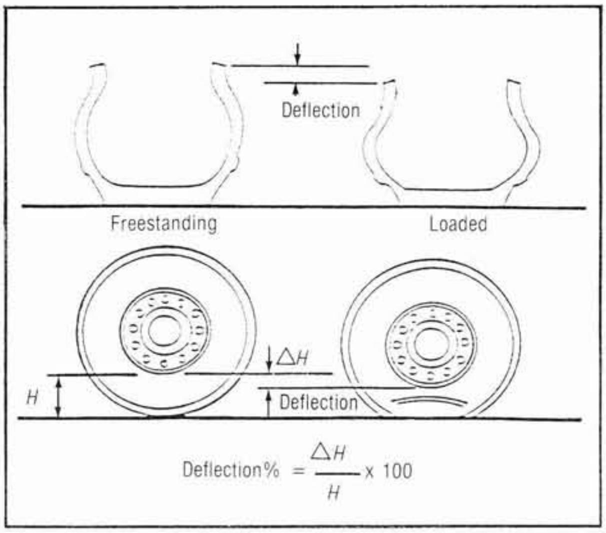

Figure 3 - Measurement of tyre deflection

Traction and Gradeability

Drawbar pull tests were conducted with a loaded ten wheel logging truck as part of a CTI test program by the Engineering Research Laboratory in Auburn, Alabama (Ref.1). A load cell was connected between the truck and a forwarder to measure the drawbar pull of the truck. At a slow steady speed the pull was slowly increased until 100% slip of the truck's driving tyres occurred. Tests were conducted at three different tyre pressures of 690 kPa (100 psi), 450 kPa (65 psi) and 205 kPa (30 psi), which gave corresponding tyre deflections of 10%, 20% and 30%.

On a sandy surface a 34% increase in pull was measured at tyre pressures of 450 kPa (65 psi) relative to the pull at tyre pressures of 690 kPa (100 psi). On a saturated clay soil, the increase in pull was 17% for the same tyre pressure change. On both the soils, no significant increase in pull was observed by decreasing the tyre pressures from 450 kPa (65 psi) to 205 kPa (30 psi).

These drawbar pull tests indicate that the increased traction of tyres at low pressures will vary according to the road conditions.

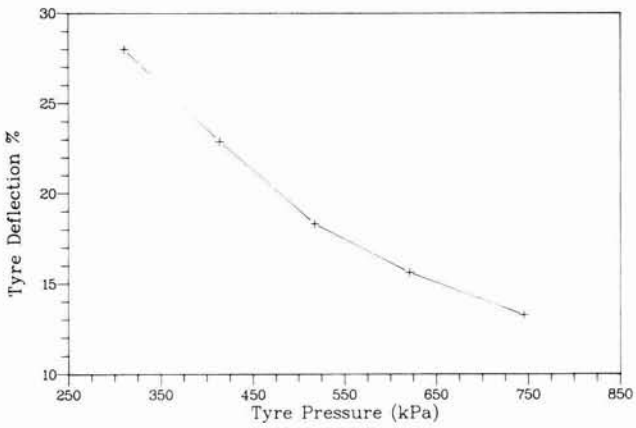

Figure 4 - Typical relationship between tyre pressure and deflection for 11R22.5 tyres on the driving axles of a New Zealand logging truck loaded to 57 tonne gross

Many other field tests in the USFS test programme have qualitatively shown the increased traction of low pressure tyres (Ref.1).

Road Maintenance and Construction

The larger footprint of a tyre at low pressure spreads the load on the road surface over a greater area. This can lead to lower road maintenance requirements and may permit lower standards of road construction. Both of these factors can produce significant roading cost savings.

In the USFS tests in Auburn a three mile section of good quality unsurfaced road was divided into three sections. Two fully loaded ten wheel logging trucks were driven backwards and forwards along this road, with each road section being subjected to truck operation at one tyre pressure. The tyre pressures were set to give tyre deflections of 10%, 20% and 30%. Each section of the road was subjected to 268 passes loaded and 90 unloaded.

At the end of the test, the high pressure section of the road had failed and become impassable. The two lower pressure sections showed very little wear and were in as good condition as when the test had started. At the end of the tests additional passes with tyre pressures of 310 kPa (45 psi) were made over the passable sections of the road damaged by the high pressure tyres. The low pressure tyres produced a pneumatic roller effect that smoothed out the rutted areas and improved the road surface.

Tests were also run in Boise, Idaho on the Moore Creek Timber Sale using eighteen wheel logging trucks over eleven miles of both dirt and gravel roads (Ref. 1). Tyre pressures were set to give 21% deflection in both the loaded and unloaded state. In these tests some minor rutting was experienced in extremely wet spots, but these never became more than 100mm deep. Road maintenance was dramatically reduced relative to the previous year when continual road maintenance was required due to ruts up to 400mm in depth.

At the Prong Flight Timber Sale in 1987 all the logging trucks were fitted with CTI (Ref.2). The trucks were operated at tyre pressures ranging from 175 kPa (25 psi) for unloaded travel to a maximum of 550 kPa (80 psi) when loaded. At tyre pressures of 415 kPa (60 psi) the road wear was described as "surprisingly little" (relative to previous operation in this area at 550 kPa). Some corrugation did occur on the steeper sections of the road in the empty haul direction. There was only a small difference in road condition between operation at tyre pressures of 415 kPa and operation at lower pressures. There was no corrugation on the empty haul grades at the lowest pressures. At 550 kPa the road developed ruts and potholes that necessitated grading after only two weeks' operation. The travel empty route was not graded even though it had developed corrugations, and when low pressure tyres were operated over this section of road, it returned to a smooth flat surface.

There have been other tests which have produced similar results. It is clear from these trials that lower road maintenance costs can be attained by operating tyres at lower tyre pressures. With lower tyre pressures placing less demand on the road surface, lower construction standards for forestry roads are possible.

Fuel Consumption

On sealed roads tyre rolling resistance is known to increase as tyre pressures decrease. In USFS tests at the Nevada Automotive Test Centre (NATC) two eighteen wheel logging trucks were operated in adjacent lanes of a specially constructed test track (Ref. 1). The track was comprised of sections of gravel, thin chip seal and thin asphalt, and included sections with potholes and corrugations built in. A series of tests was conducted which involved 2150 passes over the test track, with one truck operating at 620 kPa (90 psi) tyre pressures and the other at tyre pressures to give 21% deflection. Approximately half of these passes over the test track were with the trucks fully loaded and for the rest of the test the trucks were unladen. The testing program also included 5800 miles of highway running with both trucks at 620 kPa. At the conclusion of testing, the difference in fuel consumption was a 3% advantage to the truck that operated with the high pressures on the test track. The fuel consumption penalty of operating at low tyre pressures off-highway will vary according to the particular road conditions and so must be determined for the specific conditions of interest.

Tyre Life and Wear

A major concern for the truck contractor when considering adopting a CTI system is whether the tyre life will be reduced. The USFS tests provide an indication of how tyre life and wear are affected by low pressure operation.

In the NATC tests, a 15% wear advantage was observed for the low pressure CTI truck. No significant damage was detected in X-rays. No tyre failures occurred during this test, but the number of cuts and "chunk-outs" in the high pressure tyres were two to three times the number for the low pressure tyres.

In concurrent NATC tests, tyres on a 5-ton army truck were operated over a shrapnel course. The shrapnel was reset after every five passes to ensure that the tyres experienced the same degree of harshness. Tyres operated at 450 kPa (65 psi) experienced four punctures at the end of fifteen passes. Tyres operated at 138 kPa (20 psi) experienced three punctures after 125 passes.

A test by Goodyear Tire Company on over 400 truck tyres under a variety of conditions is probably the most conclusive to date (Ref. 3). CTI and standard trucks were paired and operated together over the test period. Goodyear's tests showed no significant difference in tyre wear between the paired trucks. While no tyres have run full life under low pressures using CTI, to date there have been no problems with recapping CTI tyres. Bandag Corporation who have been a major cooperator in the USFS programme has not detected any problems and some tyres have been recapped two to three times.

These test results indicate that there is not a great deal of difference in tyre wear or life in off-highway operation between tyres run at "normal" highway pressures (approximately 10% deflection) and tyres run at a deflection of 20%. In very rough conditions where a lot of tyre damage is normally experienced, the tyre damage may be reduced with low pressure operation.

Driver Comfort

In all USFS tests the truck drivers have reported a much better ride with the low pressure tyres. This is especially so for the unloaded travel. Accelerometer measurements in the cab of trucks involved in the NATC tests showed impacts two to ten times higher for the high pressure truck in off-highway operation.

Truck Maintenance

In the NATC tests the maintenance costs for the truck run at highway pressures were eight times higher than the truck running the low tyre pressures. These test results cannot be taken as conclusive as there is no way of proving that the trucks (or the various individual parts of the trucks) were in an identical condition to start with. It has not been shown that the parts on the high tyre pressure truck failed as a result of greater vibration and shock loading. However, it is obvious from the accelerometer measurements taken during these tests that lower tyre pressures greatly reduce the transmitted shocks to the vehicle, which must reduce part failure and truck maintenance in the long term.

Tests have been conducted to investigate the peak torque loading on the drive train of a CTI equipped truck climbing steep adverse grades (Ref. 5). The dynamic drive shaft torque was measured at various tyre deflections. The results show that the average torque required to sustain a steady climb is independent of tyre deflection, but with increasing deflection the peak torques produced as the tyre slips and grabs are reduced. This indicates that increasing tyre deflection for truck operation on steep adverse grades will decrease wear of drive train components.

NEW ZEALAND SYSTEM DEVELOPMENT

Background

Interest in CTI developments overseas and the benefits for logging trucks prompted LIRA to set up a CTI system for evaluation in New Zealand. CTI technology is commercially available for fitting to logging trucks. Several United States companies supply retrofit kits containing the control system (both electronic and mechanical components). It was decided to commission a New Zealand designed and built system which would be easily serviceable by local agents and be commercially available should it succeed.

Design and Installation

The CTI system was developed for LIRA by National Fluid Power of Auckland. An 8x4 logging truck with a self loading crane was fitted with the test system.

Air was supplied to all twenty tyres of the truck via externally fitted rotary air couplings (Figure 5). The steering tyres were plumbed on a separate system from the drive tyres and trailer tyres allowing different pressure settings. Solenoid valves mounted on the trucks chassis enabled individual wheel sets to be isolated in the event of a leak or puncture. Heavy duty hydraulic fittings were used for the system wherever possible to minimise repairs and maintenance.

The truck was initially fitted with a manual control system which allowed the tyres to be inflated or deflated to the desired pressure. The operator could read the pressure of the front and rear tyres directly from two pressure gauges mounted in the cab.

Figure 5 - Air supply hoses and rotary couplings on the drive tyres

An automatic control system was later fitted allowing the driver to adjust the tyre pressures at the touch of a button. Three predetermined pressure settings were allocated "high", "medium" and "low" buttons on the controller. When a button was pushed, this instructed the computer to adjust the tyre pressure automatically to the predetermined level and then sustain that pressure. The steering tyres were set to a pressure slightly higher than drive axle and trailer tyres.

The automatic control system was powered from the 12 volt supply on the truck and the truck's compressor supplied the air for inflating the tyres. Four extra twenty litre air tanks were fitted to the cab guard of the truck. Two were used to provide a reservoir of high pressure air to assist inflation of the tyres, and two were used as static tanks to measure the system pressure.

It took 300 man hours to fit the system. Complicated wiring, pipe layouts and the housing of all the electronic equipment contributed to this lengthy fitting time. The flexible hosing network was fabricated and installed on site as were many other components. Fitting times could be substantially reduced if the same design and layout was used and most parts were prefabricated.

EXPERIENCE WITH THE PROTOTYPE

As with any prototype development, problems are to be expected. This section outlines the experience gained with the system and some of the problems encountered. A high degree of maintenance was required on the system and a good range of spare parts (e.g. air hose joiners) needed to be carried at all times. Flat tyres occurred frequently during the first few months of operation and many repairs were necessary. The removal of the system from the steering and trailer axles reduced the amount of maintenance required.

Improved Traction

On several occasions during the trial period in Kinleith Forest, the truck operator was able to utilise improved gradeability when operating lower pressure tyres. By lowering the tyre pressures, the truck was able to negotiate slopes and muddy spur roads previously impassable at normal highway pressures. LIRO has conducted gradeability tests with the truck on different surfaces to quantify increased traction. The results will be presented in a later report.

Air Supply

The system was initially fitted to all twenty tyres and took up to 45 minutes to inflate from 310 kPa (45 psi) to 745 kPa (108 psi). The auxiliary air reservoirs provided a surge of high pressure air but a large volume of air still had to be made up by the truck compressor.

It was decided that for practical use inflating and deflating all the tyres was too time consuming. This led to the removal of the system from the steering and trailer axles leaving only the eight drive axle tyres connected to the CTI system. The system now takes 17.5 minutes to inflate the drive tyres from 310 kPa (45 psi) to 690 kPa (100 psi) and 8 minutes to deflate from 690 kPa to 310 kPa. This long time to deflate is caused by the flow restrictions of the tyre valves and the solenoid valves.

Solenoid Valves

Dirt and contaminants in the air and from external sources lodged in the seals of the solenoid valves caused them to leak. Filtering of the air supply was unchanged from the truck's standard system. The solenoid valves were subjected to very harsh conditions being located directly above the wheels and unprotected from dirt and water. Several solenoid valves had to be repaired after being damaged in operation.

Automatic Controller

The automatic controller took several months before it was operational. After many changes to the system a new controller was assembled and reprogrammed which rectified the problems. During this period, the operator was reluctant to use the manual system as it was found to be easy to forget the tyres were deflating and not realise until they were at very low pressure.

Punctures and Air Leaks

In the event of a puncture, all the tyres connected to the CTI system would go flat if the system was not switched off to close all the solenoid valves. As both tyres in a set of duals were connected to a common rotary coupling by a small flexible braided hose, even with the solenoid valves closed, both tyres in a pair of duals deflated when one punctured. If the braided hose could be quickly disconnected, only the punctured tyre deflated. Because of the restricted access, it was an extremely difficult job to detach (or attach) the braided air supply hose to the valve stem of the inside tyre.

Small leaks in the system would deflate tyre sets if the truck was idle for long periods. This caused delays while the tyres were reinflated.

Small plastic hoses near the exhaust manifold melted and insulation had to be provided to protect them.

External Hoses

Damage to the external hoses was caused by rubbing on the wheel rims which wore through the protective rubber and steel braiding on the hose. The steel braiding though not infallible was effective at reducing a lot of damage and subsequent leaks. The external hoses were also exposed to damage from logs hitting them during loading but this seldom happened. If an external air hose was damaged causing it to leak, a situation similar to that of a puncture arose, requiring the system to be switched off.

Over-Width

The rotary couplings mounted in the centre of the wheel hub protrude enough to exceed the allowable 2.5m width of the truck. This is acceptable on private roads but the Ministry of Transport prohibits over-width vehicles on public roads. Over-width permits can be obtained from the Ministry of Transport in certain situations.

These problems are not insurmountable but they indicate the need for careful thought and planning in design, installation and operation of a CTI system.

RECOMMENDATIONS FOR FUTURE SYSTEMS

- Due to the harsh environment that the equipment operates in, it should be robustly constructed using heavy duty components. Parts like solenoid valves should be well protected from dirt, water and impacts if possible.

- Valve stem extensions would make attaching and detaching supply hoses easier.

- Some overseas systems have a larger compressor fitted to reduce inflation time. A large compressor would be recommended on any system which inflates more than eight tyres, especially if frequent pressure adjustments were to be made.

- Another useful feature would be a dump valve to enable quick deflation of the tyres.

- The use of internal axle seals for the supply of air to the tyres would eliminate the problem of damage to the external hoses. The internal supply systems are, however, more expensive and not currently available for retrofitting.

- The ability to deflate the tyres to 170 kPa (25 psi) can be useful in situations where the truck is stuck and needs maximum traction.

- Future systems should aim to minimise the inflate/deflate time.

CONCLUSIONS

The USFS CTI test programme has shown a number of advantages are associated with operating trucks with low tyre pressures on unsealed forest roads. The traction and gradeability of trucks is significantly increased at low tyre pressure while road damage is reduced. These tests have also shown that a fuel consumption penalty is to be expected. Tyre life has been shown to be approximately the same at low pressures, provided the speed of the truck is limited. Increased driver comfort at low tyre pressures was found in all USFS tests.

Experience with the New Zealand designed and built CTI system has shown the technology to be workable but prone to air leaks. Extensive inflation/deflation times can be expected with a standard truck air compressor and tyre valves if the system is fitted to all tyres. Improved CTI system control and monitoring is important if the technology is to become a feature on logging trucks in New Zealand.

A CTI system can be a useful tool for the truck driver to use in off-highway situations when the road surface is sub-standard or the truck becomes stuck. By deflating the tyres, the truck may have enough extra traction to travel in conditions normally not attempted or to pull clear on its own when stuck.

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Information regarding the availability of commercial CTI systems can be obtained from LIRO.

For further information, contact:

N.Z. LOGGING INDUSTRY RESEARCH ASSOC. INC.
P.O. Box 147,
ROTORUA, NEW ZEALAND.

Fax: 0 7 346-2886 *Telephone 0 7 348-7168*