ROADEX
Implementing Accessibility

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NIINISALO AND IVALO TRACTION DEMONSTRATION PROJECTS, FINLAND

A Report on a Demonstration of Tyre Pressure Control on Timber Haulage Vehicles travelling on Slippery Surfaces and a Snowy Hillside

ABSTRACT

The European Union ROADEX Project 1998 – 2012 was a trans-national roads co-operation that aimed at developing ways for interactive and innovative management of low volume roads across the European Northern Periphery. Its main goals were to facilitate co-operation and research into the common problems of constructing and maintaining low volume roads in harsh climates.

This report gives a summary of two local demonstrations of the benefits of the use of tyre pressure control (TPC) on timber haulage vehicles on a slippery surface and snowy hillside in Finland. ROADEX has been a pioneer in the use TPC in the Northern Periphery and the demonstrations at Niinisalo and Ivalo aimed to show how decreasing tyre pressure from timber vehicles equipped with TPC helped drawbar pull and hence the applicability of the system for forest roads.

According to the results obtained in the Niinisalo tests, tyre pressure had hardly any influence on the traction of the truck on a homogenous surface. Calculations made using the data from the tests however showed that the tyre pressure may have a significant effect on traction when frictionally poor and good surfaces alternate.

According to the results from the comparable climbs in Ivalo tests, it seems that lowering tyre pressure did slightly improve the traction of the truck on the snowy road surface.

KEYWORDS
CTI, tyre pressure, icy surface, snowy hill, traction, low volume road, forest road, Northern Periphery

PREFACE

This is a final report from Task D2 of the ROADEX “Implementing Accessibility” project, a technical trans-national cooperation project between The Highland Council, Forestry Commission Scotland and the Western Isles Council from Scotland; The Northern Region of The Norwegian Public Roads Administration; The Northern Region of The Swedish Transport Administration and the Swedish Forest Agency; The Centre of Economic Development, Transport and the Environment of Finland; The Government of Greenland; The Icelandic Road Administration; and The National Roads Authority and The Department of Transport of Ireland.

The lead partner of the ROADEX “Implementing Accessibility” project was The Northern Region of The Swedish Transport Administration and the project consultant was Roadscanners Oy from Finland.

This report records a demonstration of the benefits of the use of tyre pressure control (TPC) on timber haulage vehicles on a slippery surface and snowy hillside in Finland. The works includes traction testing of a timber haulage vehicle with load cell measurement at Pohjois Satakunta’s test driving track in Niinisalo, (Kankaanpää), on a snowy hill test at Nokian Tyres testing center in Ivalo, interpretation and assessment of the measured data, and some conclusions.

The report was compiled by Nuutti Vuorimies and Heikki Luomala under the supervision of Pauli Kolisoja, all from the Laboratory of Earth and Foundations Structures at the Tampere University of Technology (TUT). Kauko Sahi from TUT assisted with the measurement system in Niinisalo. Antti Korpilahti from Metsäteho measured the wheel loads of the timber vehicle at Niinisalo. Jaakko Mäkinen from Pohjois Satakunta’s test driving track helped greatly at Niinisalo. Ari Siekkinen, Reima Hedemäki and Arto Sarajärvi from Metsähallitus organized the test at Ivalo, carried out the measurements and took the excellent photographs and video.

Grateful thanks are given to Jaakko Klemettilä of Kuljetusliike Veljekset Klemettilä Oy and Pentti Karvonen of P & A Trans Oy for their confidence to invest and operate trucks equipped with TCP.

Ron Munro from Munroconsult Ltd, Scotland checked the language. Mika Pyhähuhta of Laboratorio Uleåborg designed the graphic layout.

Special thanks are given to Ari Siekkinen from the Metsähallitus for supplying trucks. Without his enthusiastic attitude on the TPC (CTI) demonstration in Ivalo would have never been realised.

Finally, last but not least, the authors would like to thank the ROADEX IV Project Steering Committee for their guidance and encouragement during the work

The cover photograph was taken by Ari Siekkinen

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1. INTRODUCTION

1.1. THE ROADEX PROJECT

The ROADEX Project is a technical co-operation between road organisations across northern Europe that aims to share road related information and research between the partners. The project was started in 1998 as a 3 year pilot co-operation between the districts of Finland Lapland, Troms County of Norway, the Northern Region of Sweden and The Highland Council of Scotland and was subsequently followed and extended with a second project, ROADEX II, from 2002 to 2005, a third, ROADEX III from 2006 to 2007 and a fourth, ROADEX "Implementing Accessibility" from 2009 to 2012.

Figure 1.1 *The Northern Periphery Area and ROADEX Partners*

The Partners in the ROADEX "Implementing Accessibility" project comprised public road administrations and forestry organisations from across the European Northern Periphery. These were The Highland Council, Forestry Commission Scotland and the Western Isles Council from Scotland, The Northern Region of The Norwegian Public Roads Administration, The Northern Region of The Swedish Transport Administration and the Swedish Forest Agency, The Centre of Economic Development, Transport and the Environment of Finland, The Government of Greenland, The Icelandic Road Administration and The National Roads Authority and The Department of Transport of Ireland.

The aim of the project was to implement the road technologies developed by ROADEX on to the partner road networks to improve operational efficiency and save money. The lead partner for the project was The Swedish Transport Administration and the main project consultant was Roadscanners Oy of Finland.

The project was awarded NPP funding in September 2009 and held its first steering Committee meeting in Luleå, November 2009.

A main part of the project was a programme of 23 demonstration projects showcasing the ROADEX methods in the Local Partner areas supported by a new pan-regional "ROADEX Consultancy Service" and "Knowledge Centre". Three research tasks were also pursued as part of the project: D1 "Climate change and its consequences on the maintenance of low volume roads",

D2 “Road friendly vehicles & tyre pressure control” and D3 “Vibration in vehicles and humans due to road condition”. All of the reports are available on the ROADEX website at www.roadex.org.

1.2. TASK D2 ROAD FRIENDLY VEHICLES & TYRE PRESSURE CONTROL

ROADEX has been a pioneer in the use of ‘road friendly’ timber haulage vehicles and tyre pressure control (TPC) across the Northern Periphery. These technologies did not exist in Scotland or Finland before being introduced in ROADEX III and now numbers are growing in response to changing economic conditions and environmental considerations. This is particularly the case for weak public rural roads where public road organisations and forest agencies are coming under pressure to permit haulage along weak roads to support local communities. The ROADEX D2 demonstration projects aimed to demonstrate the operational, commercial & environmental benefits that can be gained in the use of road friendly vehicles on weak roads.

The series of tests at Kankaanpää and Ivalo in Finland were designed to demonstrate the benefits of TPC on the traction of timber trucks. The tests aimed to demonstrate the improvement in traction force on very slippery surfaces, such as ice, and the ability to climb steep hillsides when using timber vehicles equipped with TPC. The demonstrations were carried out at the Pohjois-Satakunta’s Test Driving Track (Pohjois-Satakunnan ajoharjoittelukeskus) in Niinisalo, Kankaanpää, and at the Nokian Tyres Testing Center, Ivalo. The timber haulage vehicles in the tests were arranged by Metsähallitus.

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2. NIINISALO

2.1. LOCATION AND THE TEST DRIVING TRACK

Pohjois-Satakunta's Test Driving Track is located in Niinisalo, Kankaanpää, about 100 km north–west from Tampere in Finland. The test driving track is designed for cars and heavy vehicles. Figure 2.1 shows the main parts of the track. The location of this test track was chosen due to its suitability for heavy vehicles, the availability of slippery sections, and its moderate distance from Tampere and the timber truck with TPC. The slippery section was made of metal plates and these were made slippery with white oil or water. The safety area was made of gravel.

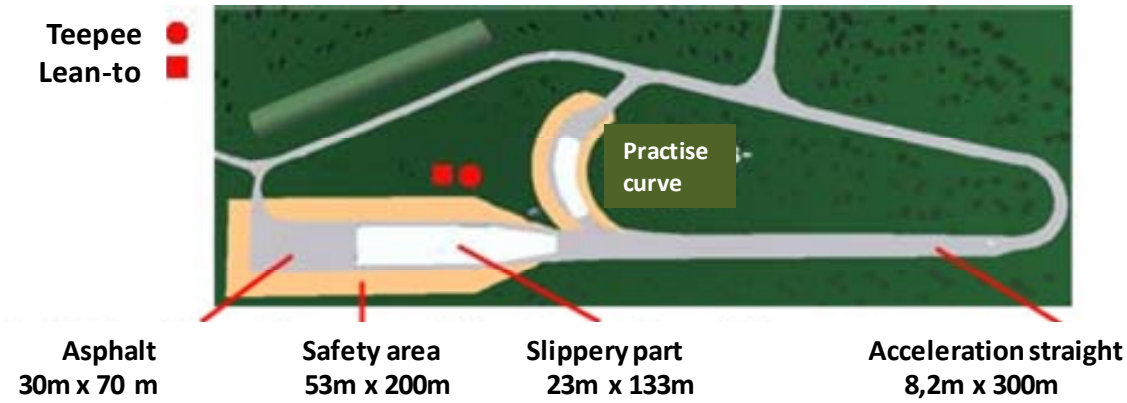

Figure 2.1 *Pohjois-Satakunta's Test Driving Track (PSAK 2011)*

2.2. THE TIMBER TRUCK AND WHEEL LOADS

The timber truck in the demonstration tests was owned by Kuljetusliike Veljekset Klemettilä Oy and equipped with a Syegon "Central Tire Inflation System" (CTIS). The truck had three axles and the trailer had four axles. The steering axle wheels were single wheels and the others were twin wheels. The truck had two driving axles on the same bogey. Figure 2.2 shows axles of the trailer and the bogey of the truck.

Figure 2.2 *The axles of the timber truck used in the demonstration tests.*

The truck was weighed loaded before the measurements, and weighed unloaded following the measurements with the empty truck. For the final measurements with full load the logs were loaded up as close to the original load of the truck as possible. The measurements were carried out on an even asphalt area in the test driving track. According to these measurements the total weight of the truck unloaded was 15,370 kg, and 28,140 kg loaded. The full trailer weighed 35,920 kg. The weight on driving axles was 20,640 kg when the truck was loaded, and 9,630 kg unloaded. Table 2.1 shows the measured wheel loads and axle loads of the truck.

Table 2.1 Wheel and axle loads of the truck. The trailer was loaded all the time.

axle and wheel type	Truck with timber load			Truck without the timber load		
	left side	right side	**axle load**	left side	right side	**Axle load**
1.single	3720	3780	**7500 kg**	2910	2830	**5740 kg**
2.twin	5100	5160	**10260 kg**	2320	2550	**4870 kg**
3.twin	5140	5240	**10380 kg**	2340	2420	**4760 kg**
4.twin	3720	3820	**7540 kg**			
5.twin	4240	4060	**8100 kg**			
6. twin	5320	5280	**10600 kg**			
7. twin	4600	4880	**9480 kg**			

Four different tyre pressure settings were used with the loaded truck, and three with the unloaded truck. The contact areas of the tyres with different three tyre pressures were measured for the loaded truck after the tests had been carried out. This was done using a large scale vernier caliper assuming the contact area to be rectangular. When the area of a twin tyre was measured only the outer wheel was measured and it was assumed that the inner wheel was similar to that of the outer wheel. The contact pressure of a tyre was calculated by dividing the weight on the wheel by the measured contact area. Table 2.2 shows the tyre pressures and calculated contact pressures for the wheels of the loaded truck.

Table 2.2.Tyre pressures and calculated contact area for the wheels of the loaded truck.

wheel type	Single	Twin	Twin
high pressure; kPa	**800**	**750**	**750**
contact pressure, right	491 kPa	398 kPa	403 kPa
contact pressure, left	465 kPa	396 kPa	416 kPa
gravel road pressure; kPa	**720**	**550**	**550**
contact pressure, right	not measured	not measured	not measured
contact pressure, left			
poor gravel road pressure; kPa	**650**	**450**	**450**
contact pressure, right	479 kPa	351 kPa	350 kPa
contact pressure, left	437 kPa	304 kPa	300 kPa
very low pressure; kPa	**450**	**220**	**220**
contact pressure, right	391 kPa	240 kPa	249 kPa
contact pressure, left	362 kPa	251 kPa	252 kPa

2.3. MEASUREMENT SYSTEM AND THE SURFACES OF THE TEST

2.3.1. Measurement system

One measurement load cell was installed between the truck and the drawbar of the trailer as shown in Figure 2.3. The load cell was connected to a fast measurement system by means of a cable. The measurement system included a data logger, signal amplifier and laptop computer, and was powered by an external battery. The loaded trailer was released from the brake and electric system of the truck so that the wheels of the trailer were locked and the trailer used as a counterweight. The trailer location was on a non-skid surface.

The measurement was started before the traction of the truck was slowly increased, and was stopped after the driving wheels started to slip for a moment. Thus it was possible to measure two values for traction force. The maximum value as the driving wheels start to slip (static friction) and the lower value as the wheels gave grip again (sliding friction). It was very important to have a good driver for these measurements as the looseness between the truck and the trailer had to be taken off very slowly to avoid peak tensile stresses being incurred from the moving truck.

Figure 2.3 *The load cell between the truck and the drawbar of the trailer.*

2.3.2. Surfaces of the test

The oil used on the metal plates was MERKUR WOP 240 PB white oil. This was spread on the metal plate around the driving wheels with a squeegee. Figure 2.4 shows how the squeegee was used to direct the oil to the correct place. Testing was started after all the full surface of the tyres had also been covered with oil. This ensured that oil was always present between the tyre and the metal plate.

Figure 2.4 *Spreading and directing the white oil under the wheels using the squeegee.*

The testing on gravel was carried out on the safety area which was visually assessed to be sufficiently homogenous for the tests. The gravel was well compacted and the friction was so high that the truck had to be unloaded to prevent damage being done to the transmission gear of the truck.

The metal plate was also used with water. A low lying area was identified on metal plates in the slippery area where enough water could gather and remain during the testing. The driving wheels were placed on this wet area so that the tyres were surrounded by water.

2.4. TRACTION MEASUREMENTS

2.4.1. Metal plate with white oil

The testing was started on the metal plate which was covered thinly with the white oil. Because the tyres were dry the oil quickly evaporated from the metal plate and the dry metal came in contact with the dry tyres as can be seen on the left side of Figure 2.5. The traction measured in the driving wheels with a tyre pressure of 750 kPa against the dry metal was about 140 kN. As more oil was added on to the metal plate the traction decreased greatly, even though the metal plate and tyres remained partly dry. At this point the tyre pressure was then first reduced to 450 kPa. When the tyres and the metal plates appeared to be covered in white oil the tyre pressure was further decreased to 220 kPa to start the comparable measurements. The photograph on the right side of Figure 2.5 shows the driving wheels fully covered with white oil.

Figure 2.5 *Left side: dry metal plate against the tyres. Right side: well oiled metal plate and tyres of the driving axles.*

When the tyres of the driving axles were well covered by the white oil, the traction of the truck was measured with four tyre pressures starting from the lowest tyre pressure of 220 kPa. Figure 2.6 shows the measured traction forces for the metal plate covered by the white oil for each of the tyre

pressures used. The highest line can be interpreted as presenting the highest achieved traction (maximum traction). The lower lines are the interpreted tractions at the time the driving wheels were slipping around and losing grip (static friction) and getting it again (sliding friction). The figure shows that there were no differences between the tyre pressures from 450 kPa to 750 kPa, and only a minor increase in the traction of the truck when the tyre pressure was set to 220 kPa. The marginally higher value with the lowest tyre pressure might have arisen from the polishing of the metal plate on the fringe of the footprints of the tyres.

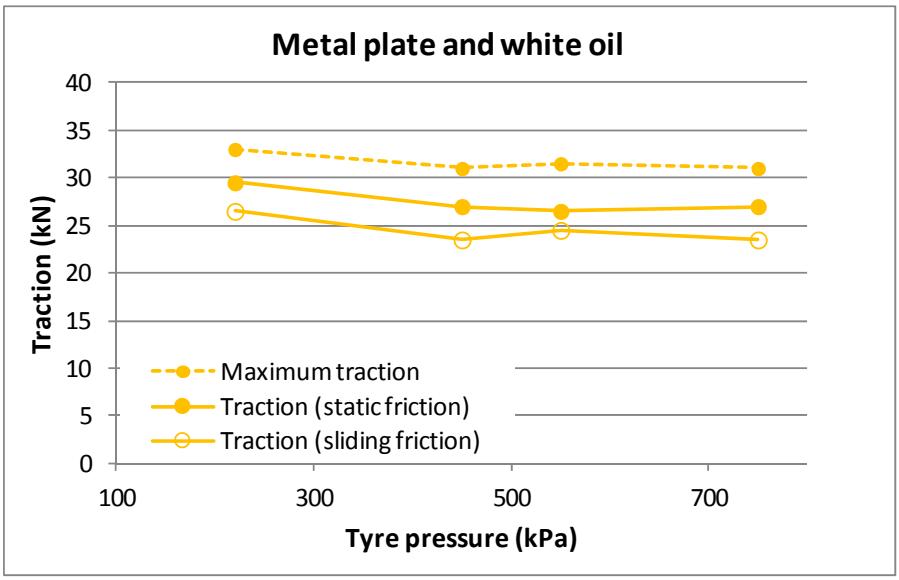

Figure 2.6 *Interpreted traction forces of the truck from the measurements on the metal plate covered by white oil.*

2.4.2. Gravel

The testing on the gravel surface was commenced using the loaded truck with high tyre pressure. The measured traction during this test was approximately 160 kN and because of this it was decided to unload the truck to avoid damage to its transmission. After each measurement of traction the truck was moved slightly to allow each new measurement to be commenced on a fresh gravel surface. Figure 2.7 shows footprints formed by the driving wheels on the gravel surface.

Figure 2.7 *Footprints of the driving wheels on the gravel surface after a traction test.*

The traction of the truck on the gravel surface was measured using three tyre pressures starting from the highest tyre pressure of 750 kPa. Figure 2.8 shows the measured tractions for each of the three tyre pressures used. The highest line can be interpreted as presenting the highest achieved traction (maximum traction). The lower lines are the interpreted tractions when the driving wheels were slipping around and losing grip (static friction), and getting it again (sliding friction). The figure shows that there were hardly any differences between the tyre pressures. The only measured difference was a marginally lower maximum traction when using the tyre pressure of 220 kPa.

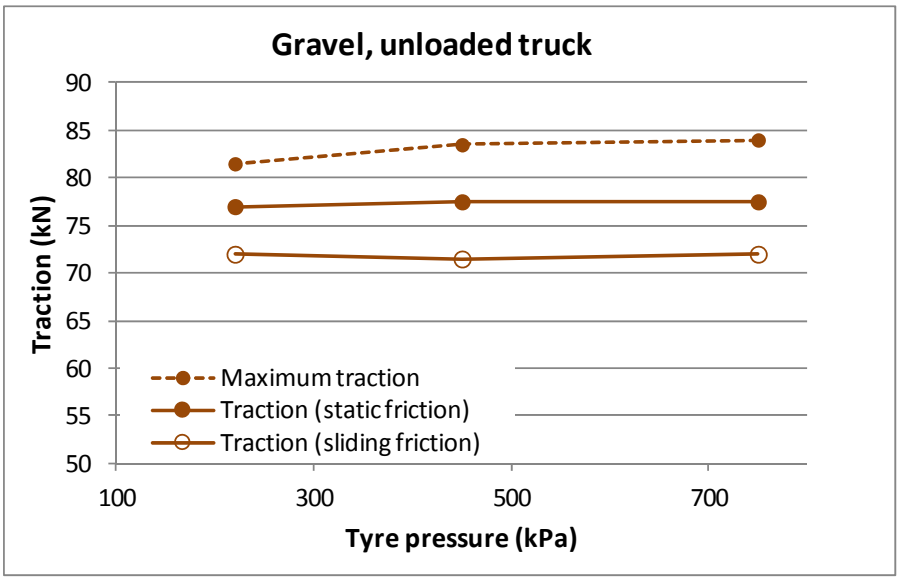

Figure 2.8 *Interpreted tractions of the truck from the measurements on the gravel surface.*

2.4.3. Metal plate with water

The first traction test on the water covered metal plate was with the truck unloaded. The measured traction was less than 20 kN, and it was decided to load the truck as close to the earlier loading as possible. Before reloading the logs the wheel loads were measured. Figure 2.9 shows the driving wheels slipping on the low lying area of the metal plates filled with water.

Figure 2.9 *Tyres of the driving wheels slipping on the low lying area of metal plates filled with water.*

The traction of the loaded truck was then measured with four tyre pressures starting from the lowest tyre pressure of 220 kPa. Figure 2.10 shows the measured tractions on the low lying area of the metal plates filled with water for each of the tyre pressures used. The highest line can be interpreted as presenting the highest achieved traction (maximum traction). The lower lines are interpreted tractions as the driving wheels slipping around and losing grip (static friction) and getting it back again (sliding friction). The figure shows that there were hardly any differences between the tyre pressures from 450 kPa to 750 kPa. When the tyre pressure was set to 220 kPa the measured traction was higher. This higher value with the lowest tyre pressure might have arisen from the polishing of the metal plate on the fringe of the footprints of the tyres. It would have been good to have had the lowest tyre pressure measured again at the close of the measurements but this was not done.

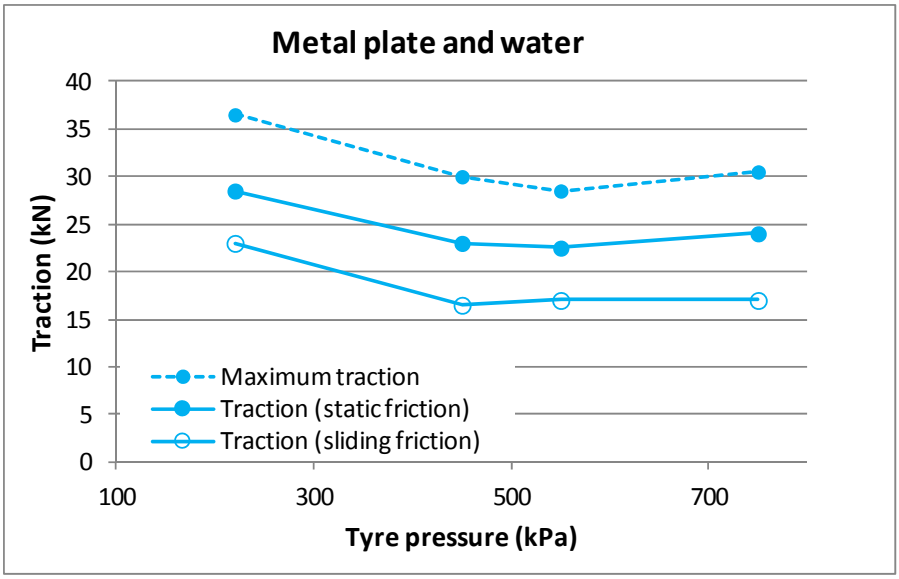

Figure 2.10 *Interpreted tractions of the truck from the measurements on the low lying area of metal plates filled by water.*

2.4.4. Summary and conclusions of the measurements in Niinisalo

Each traction test at Niinisalo was measured and interpreted individually. By this means, from one to seven usable measured values were obtained for each of the combinations of tyre pressure and surface. Figures 2.11 - 2.13 show these individual interpretations for (a) maximum traction, (b) traction as the driving wheels were slipping around and losing grip (static friction) and (c) getting traction back again (sliding friction). The surfaces and tyre pressures are presented in the order of the measurements. The number in the legend below the bars indicates the tyre pressure used. The legend also states if the truck was loaded on the gravel or unloaded. In all other cases the truck was loaded. The calculated values above the bars are the average values of the measurements rounded to the nearest 0.5 kN. These rounded values are used in Figures 2.6, 2.8 and 2.10.

Looking at the measured values of the 220 kPa tyre pressure on the metal plate with water on Figures 2.11 – 2.13 it is obvious that the traction was quite clearly decreasing after each pull, and that the last values were quite near the values measured for higher tyre pressures.

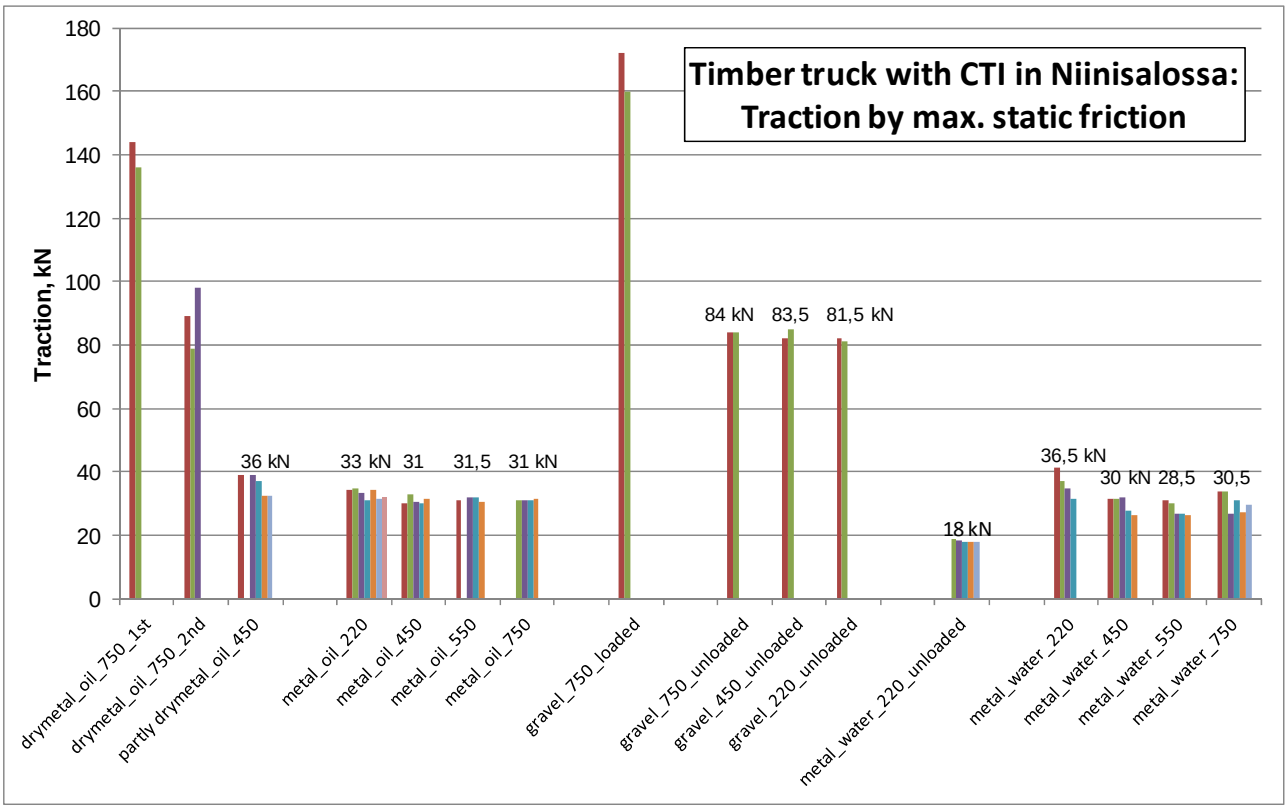

Figure 2.11 *Interpreted maximum tractions for each truck pull.*

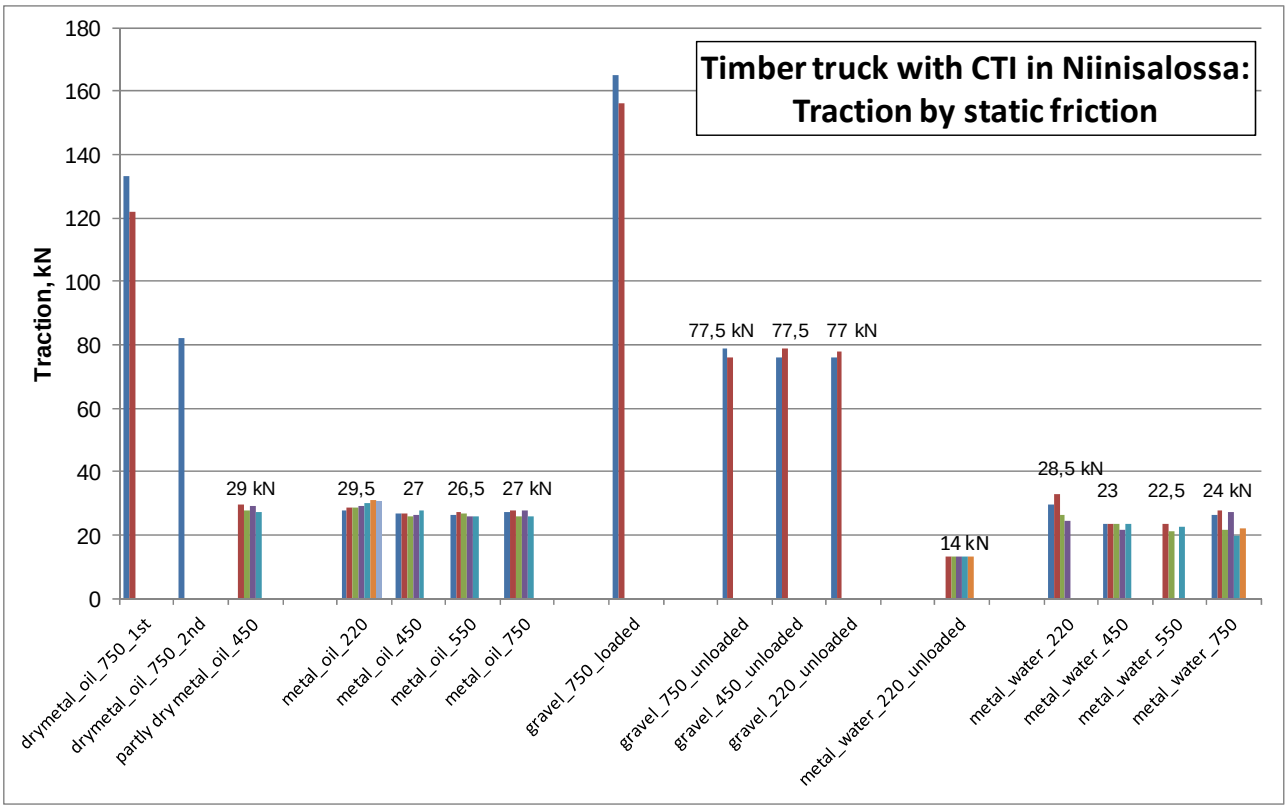

Figure 2.12 *Interpreted traction when the driving wheels were slipping around and losing grip (static friction) for each truck pull.*

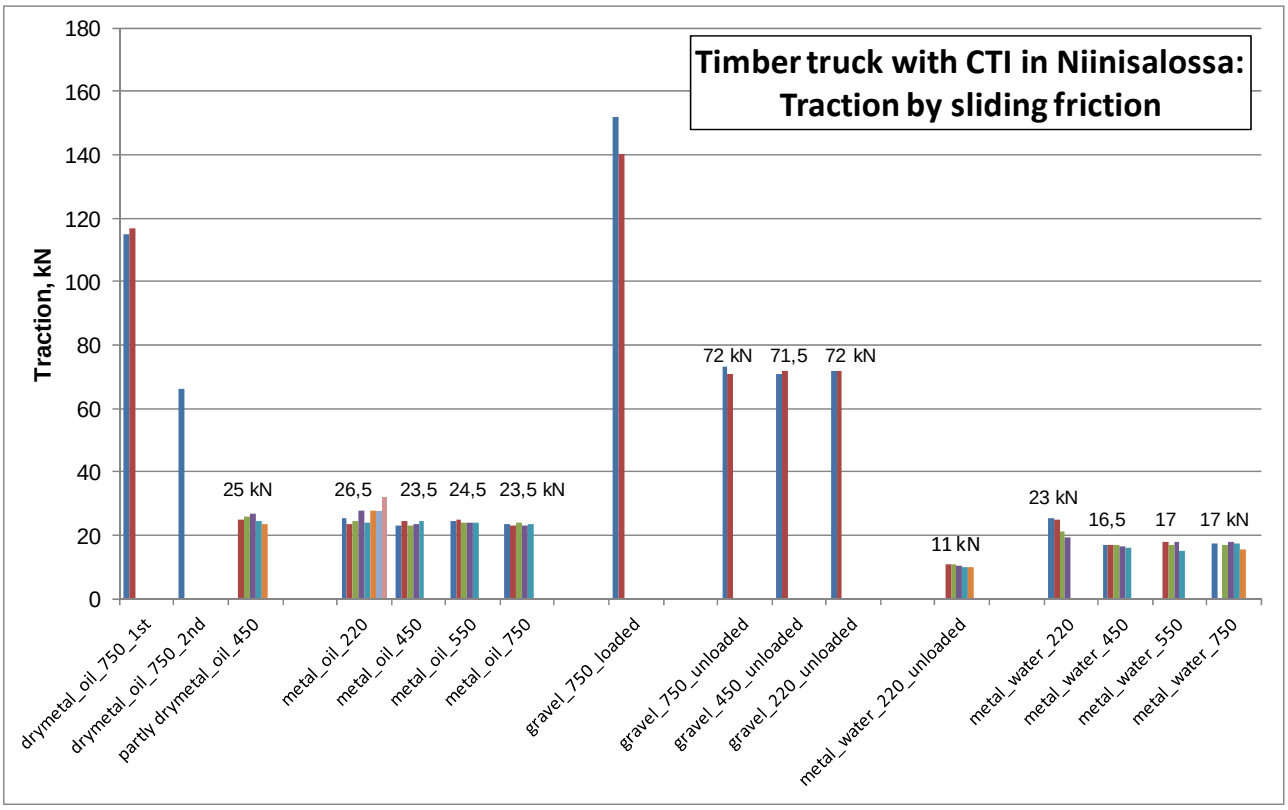

Figure 2.13 *Interpreted traction as the driving wheels were slipping around and getting grip back again (sliding friction)) for each truck pull.*

According to these measurements the traction of a truck on a homogenous surface appears to be uncorrelated to tyre pressure. This can be explained by the fact that as the tyre pressure decreases and the tyre footprint increases the vertical load remains the same for the driving wheels. Thus only the friction between the tyres and the road surface has an influence on the measured traction. The calculated frictions in the truck pulls between the tyres and the slippery metal were approximately 0.15-0.10, and between the tyres and gravel surfaces about 0.85-0.75.

Tyre pressure may however have a large influence on traction if the surface under wheels changes strongly. For example, Figure 2.14 shows the combined tyre areas of the driving wheels of the loaded truck used in Niinisalo. If we assume, for example, that the road surface changes from gravel to ice under the driving wheels after every 0.1 m, 0.2 m or 0.3 m as shown in Figure 2.15, and that we use a friction value of 0.15 for ice and 0.7 for gravel, the traction in relation to tyre pressures for the load used in Niinisalo test can be summarised as in Figure 2.16. The dashed lines show the calculated traction at the time tyre is completely on the first ice section (i.e. the rear edge of the tyre is at the start of the ice section), and the solid lines show the calculated traction as the tyre is completely on the first gravel section (i.e. the rear edge of the tyre is at the start of the gravel section). This figure shows that tyre pressure control has a great effect on traction as the slippery surface length increases. The biggest calculated difference between 220 kPa and 750 kPa was more than 30 kN.

Figure 2.17 shows the calculated traction for the proportion of ice under the tyres for the calculated tractions in Figure 2.16. This shows that the calculated traction is linearly related to the proportion of ice under the driving wheels, and not influenced by tyre pressure. So the benefit of the lower tyre pressure comes from the greater possibility of the tyres getting a good grip on the non-slippery surface, i.e. the larger contact area.

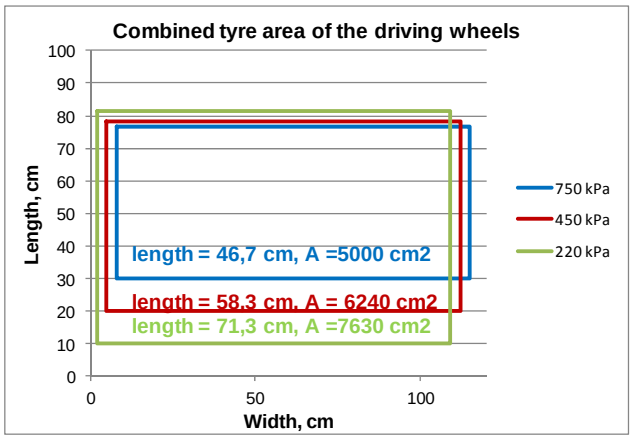

Figure 2.14 *Combined tyre area of driving wheels for the loaded truck used in Niinisalo.*

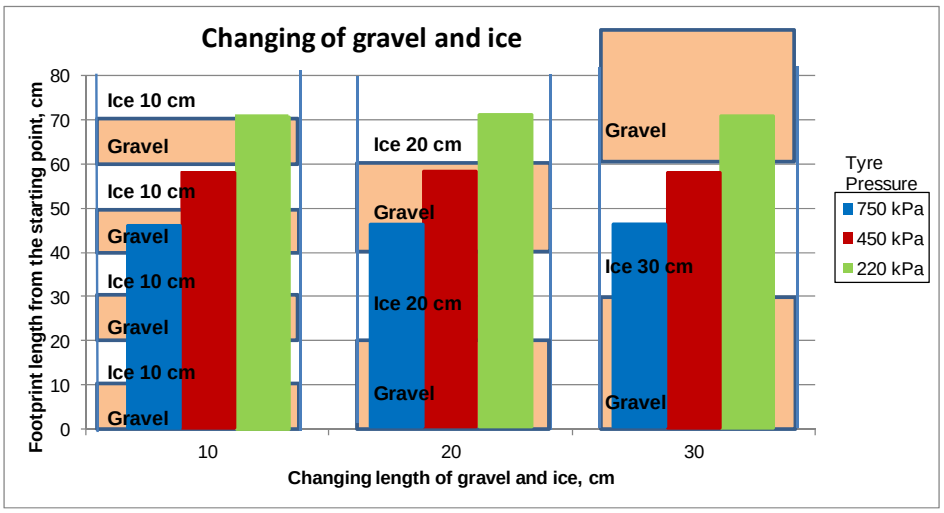

Figure 2.15 *Tyre contact lengths on the 0.1 m, 0.2 m and 0.3 m gravel and ice areas. The blue, red and green columns show the combined tyre lengths of the driving wheels.*

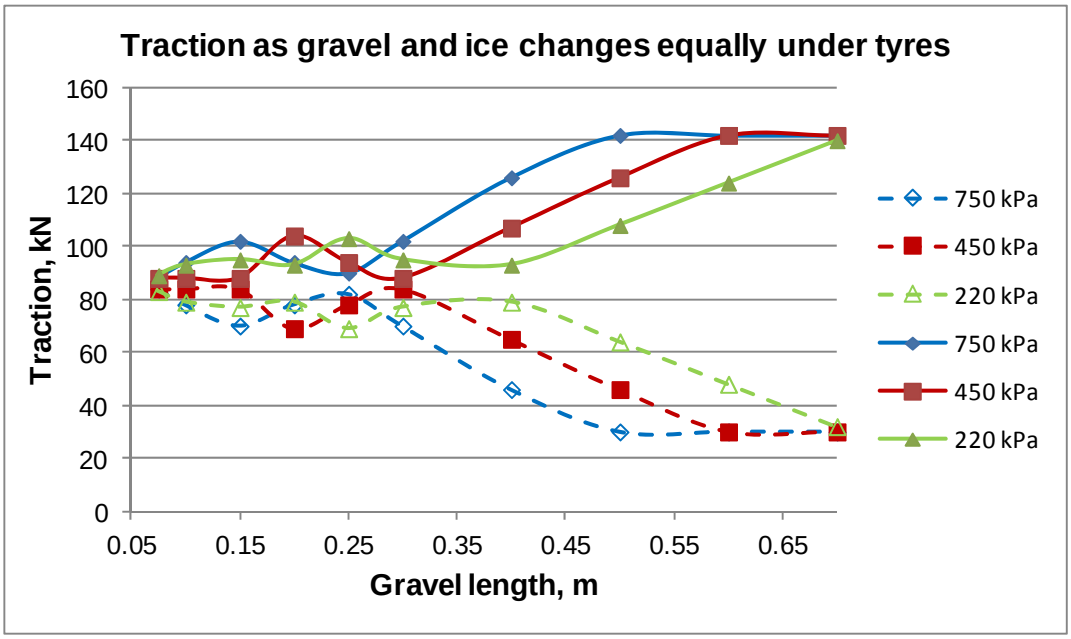

Figure 2.16 *Calculated traction as a function of the gravel surface length before it changes to an ice surface. The dashed lines show the calculated traction at the time tyre is completely on the first ice section (rear edge of tyre at the start of the ice section), and the solid lines show the calculated traction as the tyre is completely on the first gravel section (rear edge of the tyre at the start of the gravel section).*

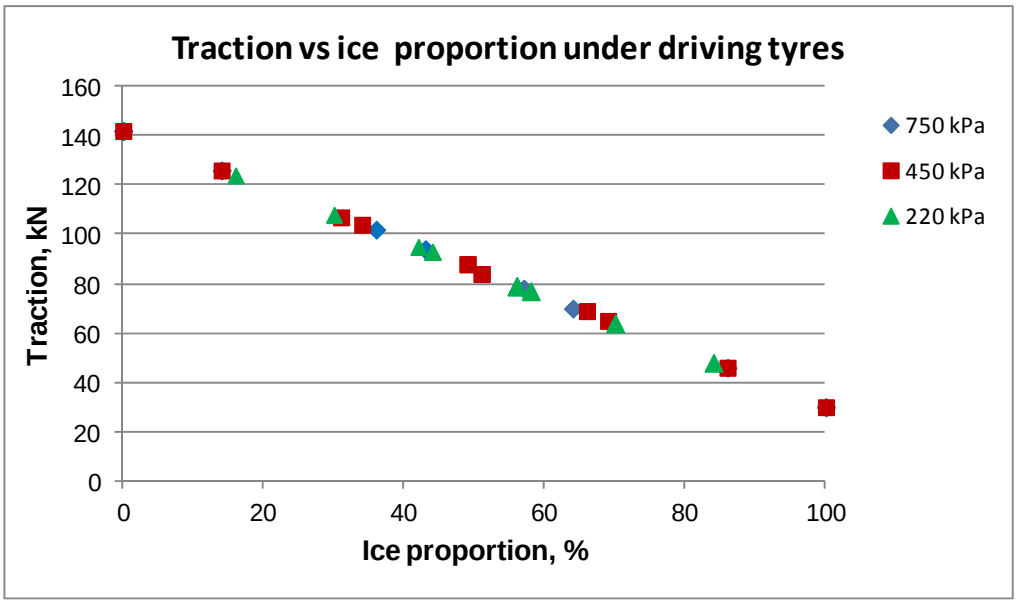

Figure 2.17 *Calculated tractions in Figure 2.14 as a function of the ice proportion under the driving wheels.*

According to the measurements in Niinisalo, tyre pressure has hardly any influence on the traction generated by a truck on a homogenous hard surface. As the tests were done on a surface the rolling resistance of the trailer and penetration of the tyres into the soil did not have an influence on the measured tractions. The calculations did however show that tyre pressure may have big effect on traction when frictionally poor and good surfaces alternate.

3. IVALO HILL TEST

3.1. LOCATION OF THE HILL TEST TRACK

The Nokian Tyres Ivalo Testing Center is located in Ivalo, near to Lake Inari in northern Lapland. The hill test demonstration at the Center was carried out on 20nd of January 2012. The straight track on the hill side was selected for the demonstration as it was almost 12 metres wide. The fringes of the track were however somewhat softer than the central part. Measurements were taken using a distance-meter with angle correction with maximum distance 500 m. The measured distances and the inclination of the snowy track are given in Figure 3.1. Figure 3.2 shows the track from the cabin of the truck at a point where the inclination was about 10 %. The traffic signs in Figure 3.2 were about 150 m from the starting point of the climb, and about 50 m before the inclination changed to 17 %. Figure 3.3 shows the track from the opposite direction. The truck in the photograph is at the point where the inclination of 17 % started. During the test the local temperature was about -10°C.

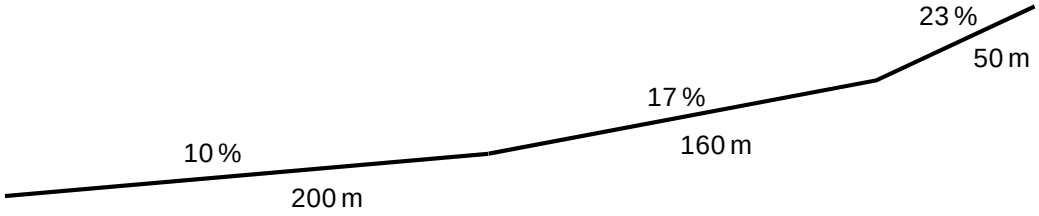

Figure 3.1 *the inclination of the snowy hill test track.*

Figure 3.2 *The hill test track as seen from the cabin of the timber truck*

Figure 3.3 *The hill test track as seen from almost 400 m from the starting point of the climbing (inclination 23 %). (photograph A. Siekkinen)*

3.2. THE TIMBER TRUCK AND THE TYRE PRESSURES

The timber truck used in the demonstrations in Ivalo was owned by P & A Trans Oy, part of the Qteam® company network, and was equipped with a system of “Tireboss” tyre pressure control. The truck had three axles and the trailer had four axles. The steering axle wheels were single wheels and the others were twin wheels. The truck had two driving axles on the same bogey. The hill test was executed using four different tyre pressure settings. The tyre pressure of the trailer was a constant 848 kPa “winter setting”. The tyre pressure settings used in the tests are summarised in Table 3.1.

Table 3.1 Tyre pressures and calculated contact area for the wheels of the loaded truck.

Pressure setting	Description	Steering tyres	Driving tyres	Trailer
5	Paved road, loaded	848 kPa	800 kPa	848 kPa
3	Poor forest road, loaded	448 kPa	352 kPa	848 kPa
6	Sticking setting	448 kPa	221 kPa	848 kPa
7	Only pressure of driving wheels reduced	848 kPa	352 kPa	848 kPa

3.3. TESTING

The climbing test on the hill test track was planned to be carried out in the same fashion for every test. First gear was used throughout, with maximum revolutions limited to 1500 rpm. Driving speed was 8 – 10 km/h. The climbing test was terminated when the wheels started to slip, at which point the driver applied the brake to prevent the truck sliding downhill again. The position that the truck had reached was marked and thereafter the driver reversed the truck downhill to the start or the next run.

The first three climbing runs were able to be carried out on a track surface practically undisturbed by heavy vehicles. The fourth climbing test was carried out on a slightly different surface as the left side tyres were on a surface which was estimated to be slightly softer than the central part of the track. The fifth climb was again on the central part of the track as the driver tried to find the best driving line between the earlier drive paths. The sixth climb was executed on the central part of the track and as the driving wheels came on to the earlier polished surface the wheels skidded. A summary of the climbing runs is given below, listing the driving distance in the order that they were carried out:

1) 370 m (pressure setting 5, full)
2) 380 m (pressure setting 3, low)
3) 379 - 380 m (pressure setting 6, lowest)
4) 375 m (pressure setting 7, low in driving wheels)
5) 375 m (pressure setting 5, full)
6) 370 m (pressure setting 7, low in driving wheels)

A video of the tests revealed that a lump of snow moved along the trailer ahead of the left tyre of the fourth axle in the third climbing run. This lump of snow interfered with the test results, but it is difficult to estimate its effect in metres. Figure 3.4 shows the lump of snow ahead the left tyre of fourth axle on the critical part of climb. On the other runs the lump of snow did not happen.

Figure 3.4 *Lump of snow ahead the left tyre of the fourth axle in the third climb. (photograph from a video by A. Sarajärvi)*

Six test climbs were completed in total: climbs (1) and (2) took place on an undisturbed track surface, (3) could have travelled further but was affected by the lump of snow, (4) was partly on a slightly different road surface, (5) was hopefully on an undisturbed track surface, and (6) ended on a section of polished track by earlier climbing runs. The distances achieved in each climb are shown in Figure 3.5. From these it seems that the lowering of the tyre pressure did improve traction of the truck on the snowy road surface slightly, but it has to be remembered that there were only a few comparable climbs from which to draw conclusions.

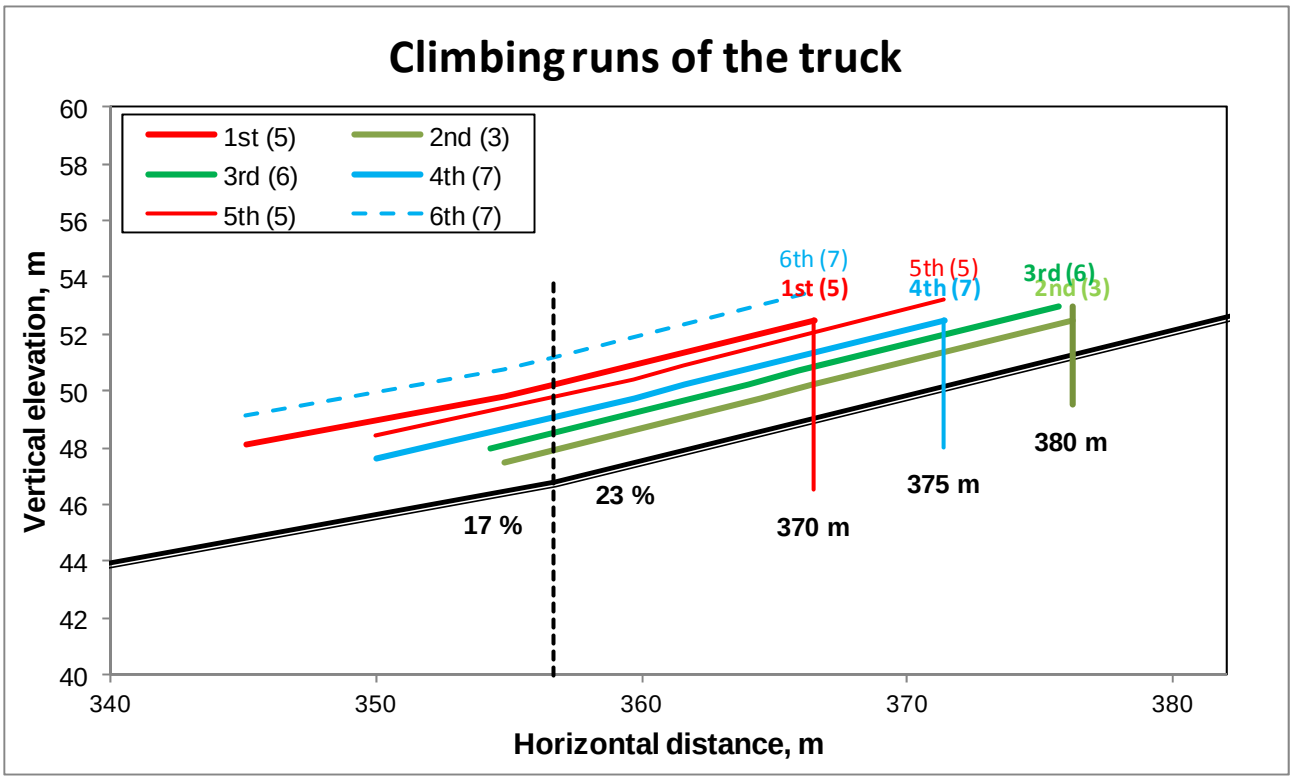

Figure 3.3 *The distances achieved in the hill test. The red colour is full pressure, the green colour is low pressure and also the lowest tyre pressure setting, and the blue colour is low pressure in the driving wheels alone.*

The traction needed for climbing a certain inclination can be estimated by dividing the axle load into its parallel and perpendicular components to the road surface. Table 3.1 shows the traction needed to continue climbing axle by axle, as the inclination is changing from 17 % to 23 %. The axle weights used in the calculation have been taken from the truck used in the Niinisalo test, presented in Table 2.1. Figure 3.3 shows that the truck achieving a distance of 370 m had all driving wheels on the 23 % inclination, but that the trailer was on the 17 % inclination. In this case it could be supposed that the traction was between 121 and 125 kN. The trucks that achieved a distance of 380 m probably had all axles, except the rear axle, on the 23 % inclination. In this case the traction was estimated between 135 and 140 kPa. This indicated that the additional 10 metres distance achieved, when the tyre pressure of the truck was decreased from highway setting to lowest setting, gave an increase in traction of between 10 and 20 kN (11 - 16 %).

Table 3.1 Calculated tractions by axle needed for the truck to climb on an inclination of 23 %. The axle loads used in the calculations are presented in Table 2.1.

Axles	0	1	2	3	4	5	6	7
Traction, kN	105	109	115	121	125	129	135	141

4. SUMMARY OF THE TESTS

This report summarises the results of two traction demonstrations of timber trucks with tyre pressure control (TPC, also referred to as CTI) in Finland. One test was carried out on the Pohjois-Satakunta's test driving track designed for cars and heavy vehicles that permitted slippery driving. The other was executed on the hill test track of Nokian Tyres' Ivalo Testing Center on a snowy track.

According to the results obtained in the Niinisalo tests, tyre pressure had hardly any influence on the traction of the truck on a homogenous hard surface. The tests however were carried out on a hard surface where the rolling resistance of the trailer, or the tyres penetration into driving surface, did not have an influence on the test results. Calculations made using the data from the tests however showed that the tyre pressure may have significant effect on traction when frictionally poor and good surfaces alternate.

According to the results from the Ivalo tests, it seems that lowering tyre pressure did improve the traction of the truck on the snowy road surface, but it has to be remembered that there were only a few comparable climbs in the series of tests from which to draw conclusions.

REFERENCES

PSAK 2011 available at http://www.psak.net/?page_id=3 (taken 10.8.2011)

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