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# Evaluation of wide-base tires for off-road applications

Advantage Report Vol. 15 No. 6 December 2014

**By:**

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Advantage Report – Vol. 15 No. 6
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## ACKNOWLEDGEMENTS

This project was financially supported by the FPInnovations / Natural Resources Canada Contribution Agreement.

The authors would like to thank the following persons and their organizations for their contributions to this study: Roy Dondale, Geoff Will, Mike Larmand, Bruce Perrin, and Paul Simon of Excel Transportation Inc.; and Charles Buhr of Michelin North America (Canada) Inc.

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**Keywords**

Wide-base tires, dual tires, 11R24.5, fuel consumption, off-road, off-highway, forest industry, logging trucks, biomass, chip trucks, 455/55 R22.5 X One, fuel efficiency.

**Abstract**

Wide-base tires are used by many freight companies for on-highway transport. These tires have lower rolling resistance than dual-tire assemblies, which can improve the vehicle combination's fuel efficiency. Although these benefits are well-documented for highway use, the suitability of wide-base tires for off-highway use is generally unknown. FPInnovations, Michelin North America (Canada) Inc., and Excel Transportation Inc. equipped two tractor–semi-trailer combinations with wide-base tires. These trucks haul wood biomass from in-woods grinding operations in the Prince George area of British Columbia. The performance of the vehicles with wide-base tires was monitored, and fuel consumption tests were done. This report contains the results of the investigation.

## INTRODUCTION

Wide-base tires cost less, weigh less, and have lower rolling resistance than the conventional duals they replace. These advantages have been proven for on-highway applications. On-track fuel-consumption tests performed by FPInnovations found up to 9.7% improvement in fuel economy for a tractor-trailer combination equipped with wide-base tires (Surcel 2007). In-service testing of wide-base tires conducted by FPInnovations showed a 5.1% improvement in fuel economy compared to duals (Surcel and Jokai 2010).

Michelin has expanded its line of wide-base tires to include tires that are suitable for both on- and off-road applications. According to Michelin, the X One XZY 3 On/Off Road wide-base tire is an all-position radial tire that is designed for weight and fuel savings in on- and off-highway operation.

There has not been much experience with these tires in applications that operate both on- and off-highway. FPInnovations, in partnership with Michelin North America (Canada) Inc. and Excel Transportation Inc., evaluated wide-base tires in forestry operations that included both on- and off-highway travel. Two tandem-drive tractors coupled to tridem semi-trailers were evaluated in service, and controlled fuel-consumption tests were conducted. The areas of particular interest were fuel consumption and tire suitability for an off-road environment.

## OBJECTIVES

This project had the following objectives:

- Determine the effect that single wide-base tires have on fuel consumption in on- and off-highway transport.
- Evaluate the durability and puncture resistance of wide-base tires in an off-road application on a long-term use basis (one year).
- Determine the operational suitability of the wide-base tires for off-highway applications.

## METHODOLOGY

The test vehicles were 2004 Peterbilt PB378 tractors powered by Caterpillar C-13 435 hp (324 kW) engines connected to 53-foot tridem semi-trailers (pictured in **Figure 1**). All the tractors had identical specifications. These trucks serve in-woods grinders, transporting woody biomass from the bush to processing plants in the Prince George area, where wood pellets and other bio-products are manufactured. The in-service evaluation used two test vehicles and two control vehicles. For the test vehicles, both the tractors and trailers were equipped with wide-base tires (445/55R22.5 X One XDN2 on the drive and 455/55 R22.5 X One XZY on the trailer) and their performance was compared to that of two trucks with the conventional dual tires (11R 22.5 XZA3 or XZA-1 on the drive and 255/70 R22.5 XZE on the trailer). The wide-base tires required the use of two-inch offset rims to meet the mandatory minimum for track width.


**Figure 1. Test truck with wide-base tires on drive and trailer axles.**

## In-service evaluation

To determine the reliability of the tire technology, its performance over time was evaluated and any maintenance and repairs were recorded.

Researchers rode along on a number of trips to obtain the drivers' opinions about the vehicles' operation with wide-base tires. The chief topics of discussion were the suitability of wide-base tires for off-road operations, traction in mud and snow, puncture resistance, and vehicle stability.

## Fuel consumption

### *In-service fuel-consumption monitoring*

The procedure for comparing the in-service fuel consumption was based on FPInnovations' *Long-term Operational Observation Handbook* (FPInnovations 2008). This procedure establishes a baseline fuel-consumption ratio between the control and test vehicles in an unmodified state. Changes are then made to the test vehicle, and monitoring is continued. Any difference in the fuel consumption ratios between the baseline and test stages must be due to the change, which in this case was the change from dual to wide-base tires.

### *Controlled fuel-consumption tests*

Controlled fuel consumption tests were done based on the SAE J1321 Joint TMC/SAE Fuel Consumption Test Procedure – Type II (SAE International 1986). The test compared the fuel consumption of the test vehicle operating under two different conditions – with dual tires and then with wide-base tires – to that of a control vehicle. A minimum of three test runs were made for each the baseline and the test conditions. The test trucks were equipped with the standard dual tires for the baseline tests and with wide-base tires for the test phase. Any differences in the fuel consumption ratios between the baseline and test phases were due to the change made to the test vehicle, namely the change from dual tires to wide-base tires.

Fuel consumption was measured gravimetrically by installing external fuel tanks on each of the trucks. The trucks' fuel systems were modified by plumbing both the supply and return fuel lines into the portable tanks, as shown in **Figure 2**.

**Figure 2. Portable tank installed on a test truck.**

The tanks were weighed before and after each run to determine the mass of fuel consumed. The gravimetric method is preferred to the volumetric method because it does not require temperature correction.[1]

[1] As the trucks travel the test route, a portion of the fuel that is supplied to the engine is returned to the tank through the return line. This return fuel is warmer than the supply fuel, and as a result, the density of the fuel changes, making consumption measurements based on volume inaccurate without a correction for temperature.

The trucks were loaded to full capacity, and in all cases they reached their volumetric capacity before reaching the maximum legal axle weights. Since the wide-base tires are lighter than the duals they replaced, the loads were adjusted to make the payloads the same for both the baseline and test phases. **Table 1** compares the weight of the wide-base tires to the dual-tire assemblies they replaced.

**Table 1. Weight of wide-base and dual tires compared**

| Location | Tire type | Tire and rim weight (kg) | Number of tires on truck and trailer | Total weight (kg) | Difference (kg) |
|---|---|---|---|---|---|
| Drive | X One | 125 | 4 | 500 | 147 |
| | 11R22.5 | 81 | 8 | 647 | |
| Trailer | X One | 125 | 6 | 750 | 19 |
| | 255/70R22.5 | 64 | 12 | 769 | |

***Test site***

The route, referred to as the Hoodoo-Teardrop Loop, is north of Prince George. It is 47.4 km long, and the trucks took, on average, an hour to complete the circuit. The route consisted mostly of gravel roads with a 7 km section of pavement. The gravel section, which ranged in quality from a main line to a spur road, is representative of the roads that forestry trucks normally operate on. A map of the route is shown in **Figure 3**.

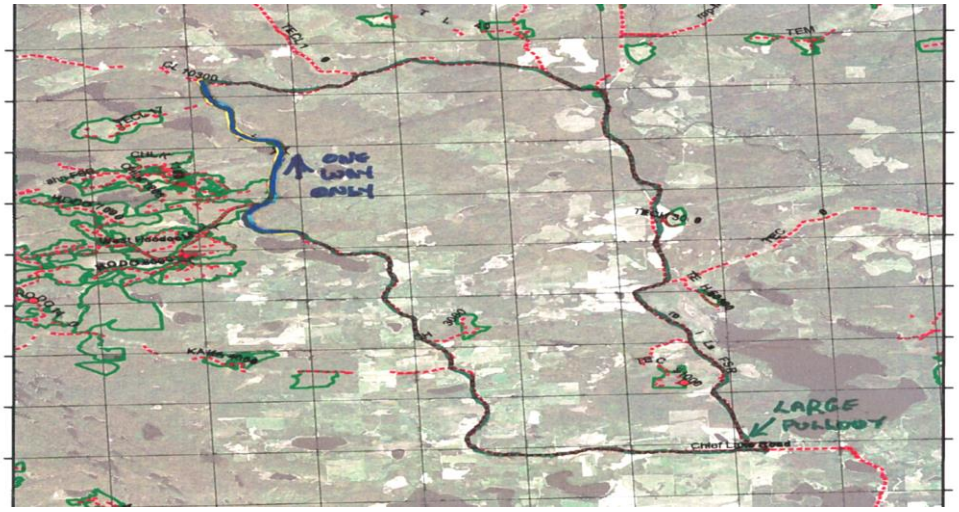


**Figure 3. The Hoodoo-Teardrop Loop test route.**

The same drivers were used for all the tests; they were instructed to drive as they normally would during their daily duties. The goal was to produce repeatable results and minimize the influence the driver has on the results. Each day before the start of testing, the vehicles travelled to the test route; that drive which took about 40 minutes was considered to be the warm-up cycle that allowed the engine and drive train to reach operating temperatures.

# RESULTS AND DISCUSSION

## Fuel consumption

### *In-service fuel-consumption monitoring*

The baseline period for the in-service fuel-consumption monitoring was from March to October 2011, and the test period with wide-base tires was from November 2011 to January 2012. Excel's fuel-management system tracked fuel consumption with onboard computers and tank fill data. However for truck T4, data for the baseline period was not available and therefore in-service fuel consumption for this vehicle is not presented. **Table 2** shows the difference in fuel consumption for truck 225 when operating with dual tires compared to wide-base tires.

**Table 2. Long-term operational observations and results**

| Vehicle | Baseline period | | | | Test period | | | | Fuel improvement (%) |
|---|---|---|---|---|---|---|---|---|---|
| | Days | Distance (km) | Fuel consumption (L/100km) | T/C ratio | Days | Distance (km) | Fuel consumption (L/100km) | T/C ratio | |
| 225 (T) | 144 | 54 286 | 59.38 | 1.05 | 51 | 18 452 | 60.40 | 1.03 | **2** |
| 232 (C) | 134 | 50 355 | 56.64 | | 68 | 25 093 | 58.79 | | |

When operating with wide-base tires, truck 225 used, on average, 2% less fuel than it did with dual tires. It must also be noted that these trucks are driven by a number of different drivers, and they may not have been hauling from the same location; both those factors can influence fuel consumption. The controlled fuel-consumption tests were intended to remove some of these variables.

### *Controlled fuel-consumption tests*

The baseline stage, with the test trucks operating on dual tires, was conducted on October 15, 2011. The first test phase was conducted the following week, on October 22, with one truck equipped with X One XDN2 tires on the drives and X One XZY 3 tires on the trailer, while the other truck had X One XZY 3 tires on just the trailer. Further testing was done on November 12, and for these tests both test vehicles had the Michelin X One XZY 3 for trailer tires and X One XDN2 for drive tires.

**Figure 4** shows the trailer tires installed for the baseline stage on the test vehicle trailer, and **Figure 5** shows the wide-base tires installed on the same trailer for the test stage.

**Figure 4. Tires installed for the baseline stage on the trailer axles of the test truck.**

**Figure 5. Tires installed for the test stage on the trailer axles of the test truck.**

**Table** 3 shows the difference in fuel consumption for both test vehicles.

**Table 3. Summary of test results for wide-base tire tests**

| Condition | Average reduction in fuel consumption (%) |
|---|---|
| Wide-base tires on trailer only | 3.23 |
| Wide-base tires on drives and trailer | 4.61 |

When the test tractor-trailer combination was equipped with wide-base tires on the trailer only, the combination used 3.23% less fuel than it did with dual tires. For the two test combinations with wide-base tires on both the tractor and the trailer (**Figure 6**), the average reduction in fuel consumption was 4.61%.


**Figure 6. Control and test vehicles T4 and T5.**

## Operational and maintenance events

### *Driver feedback*

The investigators took trips in both trucks that were operating with the wide-base tires. The drivers made the following comments:

- Rocks getting stuck between the dual tires was no longer a problem.
- Highways that have large numbers of heavy trucks tend to develop ruts where the dual tires track. Since the tires generally track in the same places, the ruts in the pavement are in the shape of two dual tires, with a slight hump in the middle, where the gap is between the duals. Since wide-base

tires tend to drive right over the hump, in slippery road conditions the trailer tires tend to drift at high speeds. This is not a problem during good road conditions.

- When tire chains are used on dual tires, there are two sets of cross links, one for each tire. The cross links are staggered so that at least one set is always touching the road. However, the drivers reported that with the wide-base tires, there is only one set of cross links and sometimes none are touching the road. For wide-base tires, the distance between cross links should be less to ensure at least one set is always in contact with the road.
- Both drivers commented that they had no issues with the trailers using wide-base tires. However, they felt that the drive tires did not provide the same traction as the duals they were previously using. Part of the reason may be due to the fact that wide-base tires make unique ruts and therefore tend to plow through ruts created by dual tires, which translates to more drag. They also commented that the drive-tire tread patterns used for this trial may not be aggressive enough for off-road use. **Figure 7** compares the tread patterns of the wide-base tires and dual tires.

**Figure 7. Drive tire tread patterns: wide-base tires (left) and dual tires (right).**

The tread design of the dual tires appears to be more aggressive than that of the wide-base tires. This may be part of the reason the drivers felt they had less traction with the wide-base tires.

### *Tire repairs and maintenance*

During the first six months of operation with the wide-base tires, the following few incidents required tires to be repaired or replaced:

***Trucks with wide-base tires:***

- Truck T5 – Pipe penetrated the face of tire; ruined tire had to be replaced.
- Trailer T43 – Tire was run flat; tire was ruined and needed replacing.
- Truck T4 – Two flats, one needing a section repair; the other was a normal flat repair.

***Truck with dual tires:***

- Truck T2 – Flat tire on control truck that required a service call.

Those incidents are considered to be normal for forest operating conditions and not to be related to the use of single tires or to be indicative of a less resistant tire. The small sample size and short duration does not permit any solid conclusions to be drawn about the durability or maintenance of wide-base tires.

### *Reduced axle weight capacity*

In British Columbia and all other provinces except Ontario and Quebec, a tandem axle group with dual tires may carry 17.0 t, whereas the same axle group with wide-base tires is reduced to 15.5 t. In Ontario and Quebec, tandem axle groups equipped with single tires are permitted to carry the same weight as axle groups equipped with duals.

For this test, the reduction in capacity did not affect payloads because the trucks, which were carrying biomass from stands killed by mountain pine beetles, would reach their volume capacity before their weight capacity. However, as operations move to greener stands, this reduced weight capacity may limit the size of the payload.

### *Removal of wide-base tires*

In July and August 2012, Excel decided to remove the wide-base tires from both of their test trucks and replace them with dual-tire assemblies. Excel gave the following reasons for the removal:

- Due to the conditions the trucks were working in, Excel thought it was better to replace the wide-base tires with duals to improve the tractive ability of the combination.
- The road which the trucks were operating on had heavy logging-truck and industrial traffic. If a truck with wide-base tires had a flat, it might block all traffic on the road until repairs could be made. With dual tires the truck could safely limp to a pull-out.
- The trailers that Excel had previously been using were replaced with higher capacity trailers, capable of carrying larger payloads. The wide-base tires did not fit on these new trailers.

## CONCLUSIONS

Fuel consumption tests found that when the dual tire assemblies on the trailer were replaced with wide-base tires, the combination used 3.2% less fuel. When dual tires were replaced with wide-base tires on both the tractor and trailer, fuel consumption was reduced by an average of 4.6% for the two test trucks. In-service fuel consumption monitoring found when both the tractor and trailer dual tires were replaced with wide-base tires, fuel consumption was reduced by 2.0%.

Operationally the wide-base tires performed well; the main problem reported by the drivers was reduced traction, which may be due to the less aggressive tread design of the wide-base tires compared to the dual tires they had been using before. Another problem was that the wide-base tires did not fit on the new higher-capacity trailers. For those reasons, Excel replaced the wide-base tires with dual-tire assemblies on both test trucks.

## RECOMMENDATIONS

In some provinces, the maximum axle weight allowance is lower with wide-base tires, thereby resulting in smaller payloads. Provincial regulations on wide-base tires and axle weight capacity should be consulted before switching to wide-base tires. The test drivers said they did not have the same traction with the wide-base tires as with dual tires. If in the future, wide-base tires with a more aggressive tread pattern become available, they should be re-evaluated for off-road use.

## DISCLAIMER

The results refer only to the vehicles and technology tested according to the procedure and conditions described in this report. FPInnovations cannot guarantee the reproducibility of these results in other operating conditions.

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