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Contents

Performance evaluation of heavy-duty vehicles equipped with automatic transmissions in forestry transportation

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Abstract

This study is a continuation of the work done by FPInnovations – Feric (Carme 2005) and aimed to provide more information to the forestry transportation sector on the influence of automatic transmissions on operational performance of Class 8 trucks. The results of this study indicate that automatic transmissions can minimize the influence of the driver's shifting ability on fuel efficiency.

Keywords:

Automatic transmission, Chip-haul, Log-haul, Long-haul fuel consumption test, Long-term operational observation.

Introduction

As the truck driver pool changes, fleets are turning to automatic[1] and automated[2] transmissions as a means to attract new drivers. The market share of heavy-duty vehicles with automatic transmissions increased from less than 5% in 1996 to 18% in 2001 (Kilcarr 2002). For automated transmissions, Arvin Meritor estimated the total market share at 10% and Eaton Corporation at 14% (Gelinas 2007). However, many experts believe that in the Class 8 long-haul segment, the market share for automatic and automated transmissions will be eventually limited to a maximum of 30% because of the additional costs involved, which range between $4,000 and $10,000 (Kilcarr 2006). In Canada, Quebec has the greatest number of users of this technology (NRCAN 2001 and the updated information provided by Allison Transmission).

This study aimed to evaluate the influence of automatic transmissions on fuel consumption by comparing them with standard manual transmissions. Two methods have been used: a long-haul fuel consumption test and a long-term operational observation. The long-term operational observation was performed with three different groups of Class 8 vehicles, monitored during normal operations. Each group was composed of one manual transmission vehicle and one automatic transmission vehicle. Two groups were involved in on- and off-highway

1. A transmission offering a range of torque multiplication or a continuously variable ratio, with automatic gear selection and providing an uninterrupted torque during shifting.
2. A constant mesh transmission with gear selection done automatically. This type of transmission was not evaluated during this study.

logging operations in Quebec, the first one in the Abitibi-Temiscamingue region and the second one in Saguenay-Lac-St-Jean region. The third group, based in the Quebec City region, was involved in on-highway chip transport.

Methodology

Long-haul fuel consumption test

The purpose of the long-haul test was to evaluate the influence of the transmission on driver performance during the day, using an automatic transmission vehicle as test vehicle and a manual transmission vehicle as control vehicle. The long-haul fuel-consumption followed the SAE J1321 (SAE International 1986) procedure. For the purpose of the test, each truck was equipped with a temporary portable fuel tank to measure fuel used by weighing the tank before and after the test. The baseline test, performed in the first part of the day, was followed by a final test performed in the second part of the day. For both baseline and final tests, the trucks drove the test route several times until it was statistically established that the results were repeatable, and the representative result was the ratio between the average fuel consumed by the test truck and the average fuel consumed by the control truck (T/C ratio). The results of the complete test trial consisted of the percentage difference between the final ratio and baseline ratio.

The test route was 66.4 km long and had one traffic light and two stop signs. Grade ranged from - 20% to + 20%, and elevation from 198 m to 269 m. These characteristics were representative of actual operations.

Long-term operational observation

The long-term operational observation aimed to measure the impact on fuel consumption under actual operating conditions. This was achieved by comparing the performances of test vehicles equipped with automatic transmissions with those of control vehicles equipped with manual transmissions. The vehicles were equipped with onboard computers that collected and stored data from the engine's electronic control module (ECM). ECM calibration was periodically checked.

Table 1 presents the specifications of the vehicles used in this study.

Table 1. Vehicle specifications

Group	Transport	Vehicle	Make	Year	Engine	Transmission	Trailer
1	Log-haul	Test	Freightliner LLC	2005	DD 60	Automatic Allison HD 4560	Manac Forestier
		Control	Freightliner LLC	2005	CAT C15	Manual Fuller 18 spd	Manac Forestier
2	Log-haul	Test	Western Star	2004	DD 60	Automatic Allison HD 4560	Manac Forestier
		Control	Freightliner LLC	2006	DD 60	Manual Fuller 18 spd	Manac Forestier
3	Chip-haul	Test	Western Star	2006	CAT C15	Automatic Allison HD 4560	Fericar
		Control	Peterbilt 387	2006	CAT C15	Manual Fuller 18 spd	Fericar

Results

Long-haul test results

Table 2 presents the results of the long-haul test performed with the vehicles from the first group.

Between the baseline and final trials, there was degradation in driver performance with the manual transmission truck, caused by increased driver fatigue, which resulted in 2.9% deterioration in fuel efficiency.

Long-term operational observation results

The results of the operational observations consist of the percentage difference between the fuel consumption of the test vehicles and the fuel consumption of the control vehicles. Table 3 presents the fuel consumption data for the three groups of vehicles. There was no significant difference in fuel consumption between the performance of automatic transmissions and manual transmissions vehicles.

Table 2. Long-haul test results

	Test vehicle	Control vehicle
Transmission	Automatic	Manual
Base average consumed fuel (kg)	31.41	31.35
Final average consumed fuel (kg)	31.28	32.16
Difference between final and base fuel consumtion (%)	-0.41	2.58
Base average T/C ratio	1.002	
Final average T/C ratio	0.973	
Fuel consumption difference (%)	2.93	
Average test run time (min)	49:56	50:50

Table 3. Long-term operational observation: fuel consumption comparison

Group		1	2	3
Type of transport		Log-haul	Log-haul	Chip-haul
Period of observation (months)		16	6	8
Average fuel consumption (L/100 km)	- Manual	80.21	79.33	55.50
	- Automatic	80.55	79.86	55.40
Difference (%)		-0.42	-0.66	0.19

Figure 1 presents the comparison of engine speeds (RPM) and Table 4 the comparison of driving errors for the first group of vehicles. It can be observed that the automatic transmission vehicle spent less time out of green band (optimum engine speed range for fuel efficiency: 1200 to 1600 RPM). It also had far less harsh braking (deceleration greater than 5 km/h/s) and harsh acceleration (acceleration greater than 3 km/h/s). Excessive idle (idling when engine temperature is greater than 30°C and PTO is not engaged) and over-revving (when engine speed is greater than 1800 RPM with engine temperature greater than 30°C) were sensibly equal.

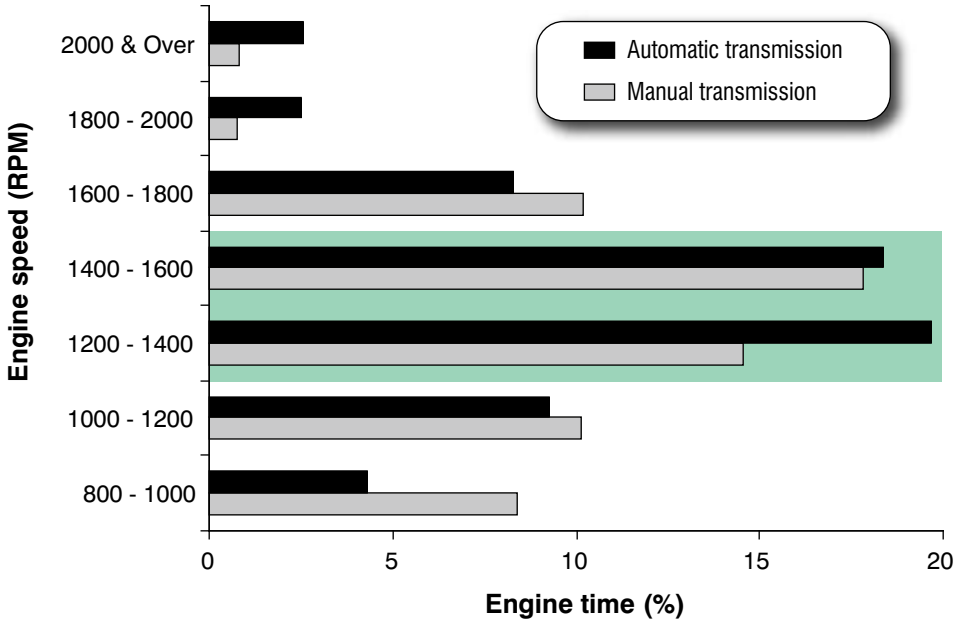

Figure 1. Comparison of engine speeds (RPM) for first group of vehicles.

Table 4. Comparison of vehicle driving errors for first group of vehicles (percentage of total engine time)

	Test vehicle	Control vehicle
Transmission	Automatic	Manual
Over-revving	13.37	11.72
Harsh braking	0.05	2.23
Harsh acceleration	0.23	4.18
Excessive idling	20.40	19.73
Out of green band	41.51	47.89

Discussions

Long-haul fuel consumption test

The results of the long-haul test indicate that the driver of the automatic transmission truck showed almost unchanged driving behaviour, as seen in his fuel consumption constant performance, practically unmodified between the base and final trial (a small improvement of 0.4%, see Table 2).

The driver of the manual transmission truck showed degradation in driving performance in the second part of the day (during the final trial, i.e. the last three runs). Between his baseline and final trials, there was an increase of 2.6% in fuel consumption, which translates in a total 2.9% increase in fuel consumption when compared with the driving performance of the automatic transmission truck during the day. Considering that the two trucks had almost the same fuel consumption in the base trial (see Table 2), the differences in the final trial can be explained by the increased fatigue of the driver of the manual transmission truck.

With respect to the time to complete the test runs, the manual transmission truck was on average slightly less than one minute slower than the automatic truck.

Long-term operational observation

The results of the operational observations show no significant difference in fuel consumption between the performance of automatic transmissions and manual transmissions. The small differences shown in Table 3 are well within the error that can be expected from a long-term operational test.

The data analysis shows that the automatic transmission vehicle overrevved more than the manual transmission vehicle. It should be noted that the two trucks had the same rear-end ratio (5.38), thus this difference was not caused by the rear axle specification, but it gives the impression that the engine is not working in the green band. In fact, except for these short peaks in engine speed during shifting, the engine was working in the green band.

Table 4 shows that the automatic transmission had far less harsh braking and acceleration and spent less time out of green band (optimum RPM range for fuel efficiency). The RPM profile comparison presented in Figure 1 also shows that the engine of the vehicle equipped with the automatic transmission worked longer in the green band.

This is consistent with the key advantage of an automatic transmission: it does not have to interrupt the power curve to make shift changes, which results in greater productivity for the vehicle. Power has to "drop out" when a manual or automated transmission shifts, but with an automatic transmission, the power remains smooth throughout. This benefit is very advantageous, particularly for traction in on/off road applications, as well for the steady operation of all types of trucks in start-and-stop traffic (Cullen 2007).

One possibility for further optimizing the use of engines, already explored by FPInnovations – Feric, is to install a transmission adaptive system. An electronic control triggers the automatic transmission to convert to an economy shift pattern when the truck is empty, and a performance shift pattern when it is loaded. FPInnovations – Feric's test using the in-service fleet fuel data, provided by onboard computers and confirmed by company fuel records, indicated the automatic transmission truck had an overall 4.6% fuel improvement compared with the manual transmission truck (Surcel et al. 2007).

Conclusions

The results of the long-haul tests show that automatic transmissions can eliminate driver-shifting ability as a factor in fuel efficiency and reduce the impact of driver fatigue. The results of operational observations show that there was no significant difference in fuel consumption between the performance of an automatic transmission vehicle and that of a manual transmission vehicle.

Automatic and automated transmissions reduce driver fatigue by allowing drivers to concentrate on operating the vehicle safely, particularly in difficult road conditions.

Further long-term evaluations and more fuel consumption tests are required to statistically confirm these results. Although no abnormal conditions were recorded, other aspects will need to be evaluated, such as the impacts on tire and brake wear and on vehicle maintenance.

Implementation

- Cooperate with automatic transmission OEM to bring creative approaches to the forestry transportation market.
- Provide support to forestry trucks fleets and owners in developing truck specifications.
- Provide training support to forestry trucks drivers on operating automatic transmission vehicles.

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