FPInnovations®

Comparative Test of the Energy Efficiency of Three Different Bulldozer Models

Advantage Report Vol. 15 No. 3 March 2014

by:

Michel Schinck, Senior Technician, Transportation and Energy

FPInnovations is a not-for-profit world leader that specializes in the creation of scientific solutions in support of the Canadian forest sector's global competitiveness and responds to the priority needs of its industry members and government partners. It is ideally positioned to perform research, innovate, and deliver state-of-the-art solutions for every area of the sector's value chain, from forest operations to consumer and industrial products. FPInnovations' staff numbers more than 525. Its R&D laboratories are located in Québec City, Ottawa, Montréal, Thunder Bay, Hinton and Vancouver, and it has technology transfer offices across Canada. For more information about FPInnovations, visit: www.fpinnovations.ca.

Follow us on:

Advantage Report - Vol.15 No 3

ABSTRACT

Tests were conducted comparing three different bulldozer models to determine their fuel efficiency: a fully mechanical Caterpillar D7R, a hydrostatic drive John Deere 950J and an electric drive Caterpillar D7E. The tests were conducted under controlled conditions and fuel consumption was measured using the gravimetric method. The results showed that both the hydrostatic and electric bulldozers showed considerable savings compared to the mechanical bulldozer.

ACKNOWLEDGEMENTS

This study was funded within the scope of the contribution agreement between FPInnovations and Natural Resources Canada. The authors also wish to thank J.D. Irving Limited, which provided them with the equipment used for the tests as well as the support staff.

CONTACT

Michel Schinck
Senior Technician
Transport and Energy
(514) 782-4503
michel.schinck@fpinnovations.ca

INTRODUCTION

Over the past few years, the constant rise in the price of fuel has prompted the development of new technologies to reduce fuel consumption. To address this concern heavy equipment manufacturers have been introducing new models integrating technologies, such as the diesel-electric hybrid suggesting improved fuel efficiency. In order to validate these claims FPInnovations has developed a methodology aimed at conducting controlled tests to measure fuel consumption. Tests were conducted on three different models of bulldozers of the same power class in order to compare their fuel consumption and energy efficiency. The evaluation of these three bulldozers was carried out on a controlled test track where standardized working conditions were reproduced. This report presents the findings of these tests conducted in Chipman, New Brunswick, in cooperation with J.D. Irving Limited. The test had three main objectives: 1) develop a standardized procedure to measure the fuel consumption of the bulldozers in a controlled environment; 2) compare the fuel consumption of three different models (drive trains) of bulldozers (electric, hydrostatic and standard) for a typical work cycle; and 3) quantify the variation in fuel consumption resulting from the differences between the engine/drive train technologies of the test machines.

METHODOLOGY

To ensure repeatability of these tests, a standardized course and work sequence was established. The work sequence represented the usual work done by this type of equipment. The test site was set up at a former open-pit coal mine located near Chipman, New Brunswick. The test track measured approximately 250 metres in length and one complete test sequence consisted of 8 return trips, for a total distance of 2.1 km of travel. Each sequence, which lasted approximately 1 hour, included 24 minutes of engine idling.

The work sequence was composed of the following specific tasks:

- Travelling a predetermined distance with or without a load
- Raising and lowering the blade

Four of the eight trips were carried out without a load and involved travel in both forward and reverse directions, while the others involved towing a load of approximately 7500 kg (Figure 1). Each bulldozer model under study had to carry out three repetitions of the test procedure, following the pre-determined work sequence.. Fuel consumption was measured at the end of each test procedure.

Depending on the work being carried out, this type of equipment uses two very distinct operating speeds during normal operations. Thus two standardized travelling speeds were established for the tests. This can have an impact on the fuel consumption of the equipment, as the John Deere 950J and Caterpillar D7R maintain a constant engine speed and vary their travelling speed by means of drivetrain controls. However, in the case of the Caterpillar D7E, the engine speed varies according to the travelling speed.

Figure 1. Load used for the tests

Fuel consumption measurement

The fuel consumption was measured gravimetrically for these tests. Each piece of equipment was equipped with an auxiliary fuel tank which was connected to the engine. In order to ensure that the only source of fuel came from the auxiliary tank, the original fuel lines were disconnected. To determine fuel consumption, the tanks were weighed before and after each test in order to calculate the weight of the fuel consumed. The fuel volume was then calculated using fuel density, determined by means of a hydrometer.

Figure 2. Portable fuel tank behind the D7R (left) and on the certified scale (right)

Models tested

Table 1 presents the features of the test equipment:

Table 1. Features of the bulldozers tested

Make	Caterpillar	John Deere	Caterpillar
Model	D7R	950J	D7E
Net power	230 hp (171.5 kW) @ 2100 RPM	247 hp (184 kW) @ 1600 RPM	235 hp (175 kW) @ 1700 RPM
Engine	10.8 L CAT	10.5 L Liebherr	9.3 L CAT
Emission standard	Tier 3	Tier 3	Interim Tier 4
Year	2004	2008	2011
Weight	24.962 kg	25.565 kg	25.700 kg
Drive	Mechanical	Hydrostatic	Electric

Figure 3 shows the three bulldozers that were tested. The D7R operates with a fully mechanical driveline. This system, introduced on the market by Caterpillar in 1978, is powered by a traditional mechanical planetary transmission.

The John Deere 950J bulldozer is powered by a variable speed, dual-path hydrostatic drivetrain. Each path is powered by a variable-displacement pump and motor combination.

The D7E bulldozer uses a diesel engine that drives a powerful generator to run two electric motors that are directly connected to the final drive system. The electric drive system is designed to use a diesel engine with a capacity that is slightly less than the conventional D7R unit (9.3-L capacity as compared to 10.8 L for the D7R). The electric drive system makes it possible to use a narrower engine speed range, i.e., between 1500 RPM and 1800 RPM instead of 1600 RPM and 2200 RPM for the conventional D7R system. The effect of using this narrower and especially lower engine speed range makes fuel savings possible. The D7E also reduces the number of moving parts by 60 % by eliminating mechanical components in conventional drives, and hydraulic components in hydrostatic drives..

It should be noted that FPInnovations has compared these machines and categorized them as comparable products based on the fact that net engine power and weight are similar. The tests were conducted with bulldozers that were equipped with different accessories (winch, ripper, etc.); however, they weren't used during the tests.

In addition, the three bulldozers were equipped with tracks of standard width and service and were therefore comparable. From an operational standpoint, these three pieces of equipment were used to carry out similar tasks.

Figure 3. The three bulldozers being tested: Top, the Caterpillar D7R (2004); bottom left, the John Deere 950J (2008); bottom right, the Caterpillar D7E (2011).

RESULTS

Table 2 presents a summary of the test results. Note that the tests varied between 49 and 65 minutes in length and fuel consumption ranged from 12.54 to 27.14 L. These results clearly show the D7R has the highest rate of fuel consumption among the three bulldozers.

For tests where three repetitions were carried out, the difference in time between repetitions of the same tests was less than 1.5%, with the exception of the high speed tests with the D7E. Moreover, we note that the standard deviations are low, showing that the results of the tests were successfully repeated.

Table 2. Fuel consumption data for high and low travell speed tests

Speed	Bull-dozer	No. of repetitions	Average time (min.)	Average volume (L)	Average L/km	Standard deviation (L/km)	Average L/hr	Standard deviation (L/hr)
Low	JD950	3	64.97	16.17	7.70	0.13	14.93	0.23
	D7E	3	61.29	12.65	6.02	0.05	12.38	0.10
	D7R	1	63.18	27.14	12.92	-	25.78	-
High	JD950	2	51.28	14.17	6.75	0.04	16.58	0.27
	D7E	3	50.54	13.51	6.43	0.06	16.05	0.61
	D7R	3	49.22	18.16	8.65	0.01	22.14	0.15

Note: Time constraints limited the number of tests carried out on certain equipment.

Table 3 compares the variation in fuel consumption of each bulldozer between high speed and low speed tests. From the standpoint of L/hr, the JD950 and D7E consume more at high speed, whereas the opposite holds true for the D7R. However, in considering L/km, which represents the amount of fuel consumed for the work carried out (energy intensity), we note that the D950 and D7R are more efficient at high speed, while the D7E is slightly less so.

The results show that in the case of the JD950 and D7R, the fuel consumption is higher at a low speed than at a high speed to perform the same work cycle. This is due to the fact that the same work cycle is carried out more quickly at a high speed, therefore reducing the total operating time as well as the fuel consumption. Technically speaking, this result can be explained by the fact that the JD950 and D7R maintain a constant engine speed (RPM) and their travelling speed is controlled by the drivetrain, which is not the case for the D7E, whose engine speed (RPM) varies to meet the required load (travelling speed).

Table 3. Comparison of the variation in fuel consumption between low and high speeds

Bulldozer	Difference (low- high speeds)			
	L/hr	%	L/km	%
JD950	- 1.7	- 10%	1.0	14%
D7E	- 3.7	- 23%	- 0.4	- 6%
D7R	3.6	16%	4.3	49%

Table 4 presents the comparison between the various pieces of equipment, at the two reference speeds. In comparing the fuel consumption of the three bulldozers for the same high speed, we note that the D7R consumes 5.6 L/hr more than the JD950 and 6.1 L/hr more than the D7E, thereby allowing for fuel savings of 25% and 28% respectively.

The energy intensity (L/km) savings of the JD950 and D7E, as compared to the D7R, are also noteworthy: At a low speed, the D7E showed significant savings compared to the JD950 during our tests. At a high speed, the difference was less significant (approximately 5% reduction in L/km).

Table 4. Comparison of the variation in fuel consumption between bulldozers

Speed	Comparison	Difference			
		L/hr	%	L/km	%
Low	JD950 vs D7R	-10.9	-42%	-5.2	-40%
	D7E vs D7R	-13.4	-52%	-6.9	-53%
	JD950 vs D7E	2.6	21%	1.7	28%
High	JD950 vs D7R	-5.6	-25%	-1.9	-22%
	D7E vs D7R	-6.1	-28%	-2.2	-26%
	JD950 vs D7E	0.5	3%	0.3	5%

CONCLUSION

The tests conducted show that the D7E and JD950 models consume considerably less energy than the D7R. However, given the specific features of each of the bulldozers tested, one model may be more appropriate to carry out certain specific tasks, depending on the operating conditions.

The results of this study provide unbiased information on fuel consumption. This information may prove useful to help quantify potential savings and to facilitate the decision-making process in renewing a fleet of bulldozers; however, these tests were conducted on a test track, following a standardized methodology to make it possible to reproduce a sequence of operations similar to the work carried out by bulldozers. The results obtained may vary if they are compared to fuel consumption data measured under operating conditions over a long period of time.

FPInnovations®

Head Office

Pointe-Claire
570, Saint-Jean Blvd
Pointe-Claire, QC
Canada H9R 3J9
T 514 630-4100

Vancouver
2665 East Mall
Vancouver, BC.
Canada V6T 1Z4
T 604 224-3221

Québec
319, rue Franquet
Québec, QC
Canada G1P 4R4
T 418 659-2647

OUR NAME IS INNOVATION