Reduced Engine RPM and Energy Intensity for Log Loaders in Northern Alberta

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ABSTRACT

This study focused on the energy intensity of four loaders loading and unloading logging trucks in a Northern Alberta forest operation. The study also measured the productivity and fuel consumption of one loader at two reduced engine RPM settings in order to determine the optimum machine setting for lower energy intensity.

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BACKGROUND

To understand the total cost of a harvesting operation, it is essential to document the fuel consumption and productivity of all the forest machines used in the operation. Documenting fuel consumption and productivity for loaders in order to calculate energy intensity, or litres of fuel per cubic metre or tonne of wood, can aid in an understanding of the factors that increase fuel consumption. This in turn, can help in an assessment of productivity gains from technological and operational improvements. Energy intensity may also be used to estimate carbon emissions and how they can be reduced through the adoption of new machine technologies and operating techniques, and to educate machine operators and site supervisors about best work practices. This trial measured the fuel consumption of two loaders that loaded trucks at roadside in the cutblock and two loaders that unloaded trucks at a storage yard. The trial also included a detailed study of fuel consumption and productivity for one of the loaders when it unloaded trucks at normal and lower-than-normal power settings.

OBJECTIVES

The trial had the following objectives:

1. To measure the fuel consumption and productivity of two loaders loading logging trucks at the roadside in harvested blocks and two loaders unloading logging trucks at a log storage yard
2. To evaluate the energy intensity of a loader unloading trucks at three power settings (engine speed or RPM) that could be chosen by the operator—full power, economy, and below economy

SITE CONDITIONS

The study site was located north of the town of Wabasca, Alberta, and was conducted from mid-December 2015 to the end of January 2016. Two loaders were observed loading trucks at the cutblocks from decks of logs at the roadside. Another two loaders were observed unloading trucks at a log storage yard. Daily temperatures ranged from –7°C to 8°C. The machine specifications are shown in Table 1.

Table 1. Machine specifications

	John Deer 3554	Komatsu 300LL	Komatsu 300LL	Tigercat 875
Model year	2005	2008	2011	2013
Site	Roadside at cutblock	Log yard	Log yard	Roadside at cutblock
Operating hours	17 500	18 484	17 011	15 100

METHODOLOGY

Shift-level fuel consumption was monitored with Fill-Rite flow meters fitted to the portable tanks mounted in the backs of the equipment operators' pickup trucks. The meters were calibrated according to the manufacturer's instructions, and have a ±2% margin of error. The operators were instructed to record the volume of fuel dispensed in a written daily log. Some operators' logs were incomplete, and therefore their machines have been excluded from some of the results presented in the report. Machine hours were tracked with the machine-hour meter and a MultiDAT data logger that records the "shift-level" time when the ignition is turned on.

Fuel consumption is much higher when a loader is working than when it is idling, and therefore the data logger, which is equipped with a motion sensor, was used to differentiate between working and engine idling time. Shift-level fuel consumption that combined working and idling time was calculated from December 17, 2015, to January 27, 2016. The productivity of the loading and unloading of the logging trucks was measured with detailed timing and truck scale weights converted to volume (in cubic metres).

A separate detailed time study was performed on the 2011 Komatsu 300LL loader at the log yard, where fuel consumption and productivity were measured for three different operator-selectable power settings. Before each trial, the machine was fully warmed up; then each power setting was measured for a three- to four-hour period on the same day. Since the loader did not have a tachometer, engine RPM was not known, but measurements were taken at three different power settings: full power, economy, and below economy setting (an arbitrary setting, not indicated with a marking on the throttle control). The total amount of fuel consumed to unload the trucks was recorded for each of the power settings. The fuel measurements were made by a gravimetric process in which three 20-L jerry cans were filled and weighed before and after each fill-up to more accurately measure, than is possible with a Fill-Rite meter, the fuel used during each of the three trials. After each trial, the operator was interviewed about the performance and overall effectiveness of the machine.

Fuel density was tested with an API hydrometer, and temperature was corrected to 15.6°C.

RESULTS

By means of an API hydrometer, the fuel density was calculated to be 0.845 kg per litre, which is high for a sample of winter diesel fuel in northern Alberta. It would be expected that winter conditions, with winter-blend diesel, which has a lower calorific power than summer blends, and longer machine warm-up cycles for gear lubricant, hydraulic fluid, and engine oil, will increase fuel consumption significantly. That should be taken into account when using these results to estimate what fuel consumption would be for similar machines in the summer operating season.

Loader productivity and fuel consumption

Table 2 shows that the two loaders loading trucks at roadside had productivities of 74 and 114 m^3 per productive machine hour (PMH) respectively and that the two loaders unloading trucks at the log yard had productivities of 58 and 108 m^3 per PMH respectively. As was expected, long delays between loading or unloading greatly reduced the overall shift-level productivity.

Shift-level fuel data was collected from December 17, 2015, to January 28, 2016, from written records kept by the operator. The fuel consumption of the John Deere when loading at roadside was calculated at 24.2 L per hour. The fuel consumption of the 2011 Komatsu unloading trucks at the log yard was calculated to be 21.5 L per hour. Also presented in Table 2 is the fuel consumption for each productive machine hour, which excludes stops of 15 minutes and longer; that is useful information for determining the effect of greater machine utilization. Fuel data records for the Tigercat 875 and the 2008 Komatsu loader were not available.

Table 2. Loader productivity, fuel consumption, and energy intensity by machine model

	John Deere 3554	Komatsu PC 300LL	Komatsu 300LL	Tigercat 875
Model year	2005	2008	2011	2013
Activity	Loading trucks	Unloading trucks	Unloading trucks	Loading trucks
Productivity (m^3/h)	55.0	83.3	38.7	84.5
Productivity (m^3/PMH[a])	73.8	107.7	58.3	114.1
Fuel consumption (L/h)	24.2	n/a	21.5	n/a
Fuel consumption (L/PMH)	30.9	n/a	32.0	n/a
Energy intensity (L/m^3)	0.419	n/a	0.549	n/a

[a] Productive machine hours (PMH) excludes stops of 15 minutes and longer

Reduced power setting study

A reduced power setting study was performed on the 2011 Komatsu 300LL Loader. Several operating parameters, such as percentage of time spent idling; overall fuel consumption, and productivity, are shown in Table 3 to give a more complete picture of each trial. Table 3 also shows the energy intensity (in litres per cubic metre) for each power setting. The productivity (tree volume unloaded per working hour) became lower and lower as the power setting was reduced from full to economy and then to below economy, with the difference between full and economy setting being negligible. Therefore, energy intensity is a better measure in this instance. The economy setting was 30% more efficient than the full power setting, on an energy intensity basis, which is quite remarkable. The reason is that the power setting engages the accumulator pumps and hydraulic system in anticipation of work—to boost productivity—but with the disadvantage that fuel consumption increased during the time, which was considerable, when the engine was idling. Even though productivity was lowest at the below-economy setting, energy intensity was higher than at the full-power setting, a finding which shows that the engine was operating less efficiently.

Table 3. Fuel consumption, productivity, and energy intensity at three power settings

Power setting	Time idle	L / h	Productivity (m^3/h)	Energy intensity (L/m^3)	Difference in energy intensity
Full	54%	15.0	113.7	0.122	
Economy	54%	10.4	112.1	0.085	–30%
Below economy	62%	12.8	76.7	0.128	6%

DISCUSSION

In order to reduce non-productive machine time spent idling, effective sequencing of trucks for both loading and unloading is crucial. Although fuel consumption during idling is a small portion of that used during work, excessive engine idling is a waste of fuel that should be avoided whenever possible. The reduced-power study showed that a reduction in power using the economy setting lowers productivity below the full power setting by only an insignificant amount, but improves energy intensity by 30%. Therefore, when operators are waiting for trucks to load or unload, it is imperative that they place the throttle in the economy position if it is not feasible to actually shut the machine off. However, reducing power below the economy setting actually increases the energy intensity by 51% with a loss in productivity of 32%, which is unacceptable. The operator said performance at the economy setting was slightly lower, but once he had made some minor adjustments in machine operation, he found that the machine's performance was adequate and effective for the given task. However, he considered that performance at the below-economy setting was not adequate for effective work and would limit his ability to accomplish daily tasks. He thought he could operate the machine on the economy setting as long as there were no trucks waiting in line to be loaded, in which case the full power setting should be used to meet the perceived need for increased productivity.

CONCLUSIONS AND IMPLEMENTATION

Shift-level fuel consumption for the John Deere and 2011 Komatsu loaders ranged from 21.5 to 24.2 L per operating hour and from 30.9 and 32.0 L per PMH. The reduced-power study with the 2011 Komatsu found that the full-power setting had a statistically insignificant higher productivity than the economy setting but that fuel consumption was considerably higher. Those findings demonstrate that the economy setting should be used when productivity is not the top priority, which would be the majority of time, since loaders as observed in this operation have low utilization (a necessary evil when the goal is to optimize the more expensive, trucking phase). Full power should be used whenever fuel economy is less important, such as when trucks are waiting to be unloaded. The below-economy power setting, which had the highest energy intensity and the lowest productivity, did not appear to have any obvious work advantages for unloading trucks.

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