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Evaluation of a tridem drive tractor with a long log B-train

Abstract

B-train truck configurations exhibit superior dynamic performance when compared to most other log hauling combinations, and long log B-trains have similar productivity compared to other long log configurations with comparable axle arrangements. Despite these advantages, long log B-trains can find themselves traction-limited in some forest operations. To address this shortcoming, the Forest Engineering Research Institute of Canada (FERIC) undertook a short-term, in-service evaluation of a long log B-train in combination with a tridem drive tractor. The evaluation included a dynamic performance analysis through computer simulation, the modification of an existing B-train trailer from five axles to four, and monitoring its in-service performance with a log haul fleet. This report discusses the findings of this evaluation and makes recommendations based on observations from the field trial.

Keywords

Long log B-train, Tridem axle group, Vehicle dynamics, Traction, Performance, Logging trucks.

Author
Colin Blair,
Western Division

Introduction

B-trains have been shown to exhibit superior dynamic performance compared to other heavy haul configurations (Ervin and Guy 1996). FERIC evaluated the use of the B-train configuration for long log transportation and found it to be as dynamically stable and productive as other long log configurations (Blair 2001). During the course of this initial work, the long log B-train configuration was also found to be traction-limited in some forest operations. To alleviate this, it was proposed to use a tridem drive tractor to tow a four-axle B-train. This configuration (Figure 1) would maintain the 8 axles of a super B-train but would move the tridem axle group from the lead trailer to the drive group of the tractor. This would result in more weight on the drive axles and therefore improved tractive ability. Maintaining 8 axles is desirable as this would allow a maximum gross combination weight (GCW) of 62 500 kg[1] without adversely affecting the tare weight.

Figure 1. Tridem tractor/8-axle B-train.

The evaluation of the tridem tractor/long log B-train took place in the fall of 2000 with the cooperation of Alberta Transportation and Alberta-Pacific Forest Industries Inc.

[1] As of April 1, 2001 the GCW was increased to 63 500 kg. All references to the GCW in this report remain at 62 500 kg which was in effect at the time of this study. See Implementation for information on how the increase in GCW may affect the results.

Sun Trucking Ltd. provided the tridem drive tractor and Homestead Holdings Ltd. supplied the long log B-train trailers. Funding assistance was provided by Alberta Economic Development.

Objective

The objective of this project was to evaluate a tridem tractor/8-axle B-train for hauling long logs through the following study tasks:

- Estimate the dynamic performance of a tridem tractor/long log B-train using the University of Victoria/National Research Council of Canada (UVic/NRC) yaw/roll computer model.
- Modify an existing set of long log B-train trailers to be towed by a tridem drive tractor by removing one axle on the lead trailer, and adjusting both bunk positions for correct load distribution for legal axle weights.
- Place the tridem tractor/long log B-train into service with an active haul fleet and monitor its performance with regards to handling, delivered payload, and ease of loading and unloading.
- Use the UVic/NRC yaw/roll computer model to optimize the dimensions for a tridem tractor/long log B-train based on observations from the in-service evaluation.

Figure 2. Tandem tractor/long log B-train configuration.

Study methods

The first step in the evaluation was to estimate the dynamic performance of the tridem tractor/long log B-train using the UVic/NRC yaw/roll log truck model developed in the Western Log Truck Configurations Study (Parker and Amlin 1998). The NRC had previously reviewed the computer model and found it to be appropriate for modelling the performance of long log B-train configurations, including tridem tractor/long log B-trains (Billing and Preston-Thomas 2000). The computer model predicts the dynamic performance of a configuration based on nine performance measures, and was used to compare the dynamic performance of the tridem tractor/long log B-train to both a short log B-train and a tandem tractor/long log B-train. These vehicle dynamic comparisons were conducted according to the weight and dimension regulations of Alberta (Province of Alberta 1998) with the configurations loaded to Alberta maximum legal weights. The results were calculated using a range of block load densities[2] (340 kg/m^3 to 555 kg/m^3) that is representative of the Alberta forest resource.

It was desirable to undertake the short-term, in-service evaluation without incurring the costs of designing and building trailers specifically for a tridem tractor/long log B-train. Therefore, an existing set of long log B-train trailers was modified from the earlier study (Figure 2). The modifications included removing the front axle on the lead trailer (converting to a tandem group from a tridem group) and adjusting the bunk positions on

[2] Block load density is calculated from payload weight and block volume (including air voids, which typically make up 40% of the volume).

Forest Engineering Research Institute of Canada (FERIC)

Find us online! www.feric.ca

Eastern Division and Head Office
580 boul. St-Jean
Pointe-Claire, QC, H9R 3J9
(514) 694-1140
(514) 694-4351
admin@mtl.feric.ca

Western Division
2601 East Mall
Vancouver, BC, V6T 1Z4
(604) 228-1555
(604) 228-0999
admin@vcr.feric.ca

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both the lead and rear trailers to allow for the correct weight distribution for legal axle weights. The front axle on the lead trailer was removed to allow for the minimum inter-axle group spacing, as well as to reduce the tare weight of the configuration (any more than 8 axles is redundant in terms of GCW per Alberta Transportation regulations). The maximum GCW of 62 500 kg is achieved by having 6500 kg on the steer axle, 22 000 kg on the drive axles and 17 000 kg on each tandem group. Shifting the weight from the lead trailer axle group onto the drive group was also needed to realize the improvement in tractive ability.

Once the trailers were modified, they were transported to Boyle, Alberta and put into service with the Alberta-Pacific log haul fleet. The configuration was evaluated for its handling, delivered payload, and ease of loading and unloading by having FERIC personnel along for each trip during an eight-day trial. In addition, discussions with the driver, loader/crane operators and woodlands supervisors were held to determine the merits of the configuration.

After the field trial was completed, the UVic/NRC yaw/roll model was re-visited to optimize the dimensions of the configuration based on the in-service evaluation. The optimized dimensions were associated with bunk locations and the wheelbase of both the lead and rear trailers. This optimization was performed without compromising the inter-axle spacing, and within the overall maximum length regulation (30.5 m) for log trucks in Alberta.

Results and discussion

The results comparing the dynamic performance of the tridem tractor/long log B-train, the short log B-train (baseline reference for comparison), and the tandem tractor/long log B-train are summarized in Table 1, with each loaded to the maximum Alberta legal weights. These results show that the tridem tractor/long log B-train compares favourably to the other B-train configurations. Similar to both the short log B-train and the tandem tractor/long log B-train, the tridem tractor/long log B-train meets the performance standards for the critical measures of static rollover threshold and load transfer ratio, indicating a stable configuration. It fails to meet the performance standards for the less critical measure of high speed off-tracking which is typical of B-train configurations. As well, its performance is marginal in terms of the lateral friction utilization measure. Despite these two factors, the tridem tractor/long log B-train exhibited good overall dynamic performance.

Table 1. Dynamic performance of log haul B-trains (legal weights)

Performance measure	Pass criteria	Short log B-train	Tandem tractor/ long log B-train	Tridem tractor/ long log B-train
Gross combination weight (kg)		62 500	62 500	62 500
Understeer coefficient	>-4.51	-2.34–0.63	-0.49–0.84	2.09–0.27
Static rollover threshold (g)	>0.35	0.33*–0.40	0.39–0.47	0.35–0.42
Load tranfser ratio	<0.60	0.44–0.62*	0.37–0.47	0.37–0.48
Rearward amplification	<2.20	1.77–1.84	1.64–1.69	1.50–1.53
Friction demand	<0.10	0.11*	0.13*	0.03–0.04
Lateral friction utilization	<0.80	0.56–0.57	0.56–0.57	0.82*–0.83*
Low speed off-tracking (m)	<6.00	4.90–4.94	4.64–4.65	5.22
High speed off-tracking (m)	<0.46	0.59*–0.64*	0.57*–0.62*	0.53*–0.56*
Transient off-tracking (m)	<0.80	0.57–0.68	0.49–0.55	0.45–0.52

* Indicates performance standard not met.

The modifications to an existing set of 5-axle long log B-train trailers were performed in the fall of 2000. The front axle of the lead trailer was removed, the front bunk was moved approximately 0.5 m forward of its normal position, and the rear bunk was moved about 0.2 m rearward of its normal position. This resulted in weight reductions at the lead trailer axle group and an increase in weight on the drive axles of the tractor (the tridem group). The dimensions of the reconfigured tridem tractor/long log B-train can be seen in Figure 3.

The in-service trial was conducted over an eight-day period from October 23 to 30, 2000 with the Alberta-Pacific log haul fleet. Like the tandem tractor/long log B-train, this configuration tows the lead trailer while carrying the rear trailer when returning empty to the loading site. At the loading site, the log loader lifts the rear trailer off the lead and then couples them together. Once the trailers are connected, the truck driver reverses the configuration to ensure that the sliding pin is at its rearmost position. This ensures enough free slide distance to allow for pin travel during turns, and permits the trailers to align themselves when the configuration pulls away from the loading site. Further details on these features are discussed in a previous FERIC report (Blair 2001).

Only nine loads of tree-length aspen were hauled with the tridem tractor/long log B-train during the trial. Bunk scales were used to determine the axle weights when loading the configuration. The configuration's tare weight was 23 400 kg and its average delivered payload was 33 200 kg. The maximum legal payload was 39 100 kg at the time of the study. The difference between the maximum and delivered payloads was due to the lead trailer axle group reaching its legal weight limit before all of the other axle groups because the logs were too short. The average log length encountered during the trial was about 14 m while the bunk spacing was 11.5 m. As a result, it was difficult to achieve the front and rear load overhangs necessary to achieve full loading on the other axle groups.

During the evaluation, several attempts were made to shorten the inter-bunk spacing to allow the configuration to haul shorter logs. This simply added weight to the tandem group on the lead trailer, while both the drive axles and rear trailer axles remained underloaded. Increasing the bunk spacing would have relieved this problem, but the available logs were too short to span the longer inter-bunk spacing, making it difficult to achieve maximum legal axle weights at the tractor and rear trailer. Box loading of the logs (i.e., mixing butts and tops) was used in an attempt to achieve legal axle weights. While this improved the axle weights, the effectiveness was limited because the short logs did not provide a stable base between the bunks, which in turn limited the achievable front and rear load overhangs.

While box loading the tridem tractor/long log B-train improved the weight distribution and axle weights, it created difficulties for unloading with Alberta-Pacific's portal crane (Figure 4). These difficulties resulted from removing the load in two portions, which

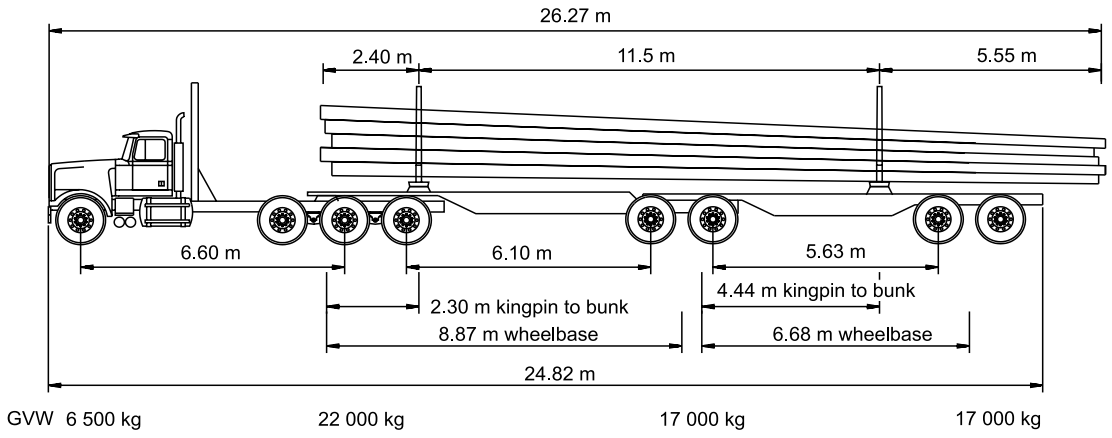

Figure 3. Dimensions of trial configuration.

increased the potential for logs slipping through the grapple and falling to the ground. This was a function of the rated size of the crane (about 30 000 kg). If the crane could grasp the entire load in one grapple or if a butt-and-top loader was used, these unloading difficulties would be alleviated.

Based on discussions with the driver, loader and crane operators and woodlands supervisors, the tridem tractor/long log B-train handled and operated similar to other long log configurations. Despite having increased off-tracking characteristics from a longer wheelbase, the trial configuration negotiated the block roads without incident. The cornering performance of long log B-trains was previously found to be within the Alberta intersection design standards (Blair 2001). It was agreed that the tridem drive provided improved traction over the tandem tractor.

The difficulty with achieving legal axle weights and maximum payloads was because of short logs and because the wheelbases of the reconfigured trailers were not ideal for working with a tridem drive tractor. Furthermore, the tridem tractor/long log B-train had a high tare weight (23 400 kg) compared to other long log configurations. The tare weight of a tandem tractor/tandem jeep/tandem pole trailer is about 18 000 kg, while the tare weight for a tandem tractor/long log B-train is about 21 400 kg. The higher tare weight limited the maximum payload, but there may be opportunities to reduce the tare weight of both the tractor and the trailers if they are specifically built for a tridem drive tractor. The test configuration had long inter-axle spacings that could be reduced, resulting in a reduction in the tare weight. This would improve the productivity of the configuration and make it a more attractive alternative to existing long log configurations. For example, the B-train can be more productive at Alberta legal weights with 62 500 kg GCW compared to the tandem axle jeep/tandem pole trailer at 56 500 kg GCW.

Figure 4. Crane unloading the tridem tractor/long log B-train.

After the field trial was completed, the UVic/NRC yaw/roll model was re-applied in an attempt to optimize the dimensions of a tridem tractor/long log B-train based on the field trial experience. The primary goal of this optimization was to reduce the inter-bunk spacing, which would allow more variability in the log length that could be transported by the configuration. This optimized configuration is illustrated in Figure 5. It has a shorter wheelbase for both the lead and rear trailers, while respecting the minimum legal inter-axle spacings of 5.5 m

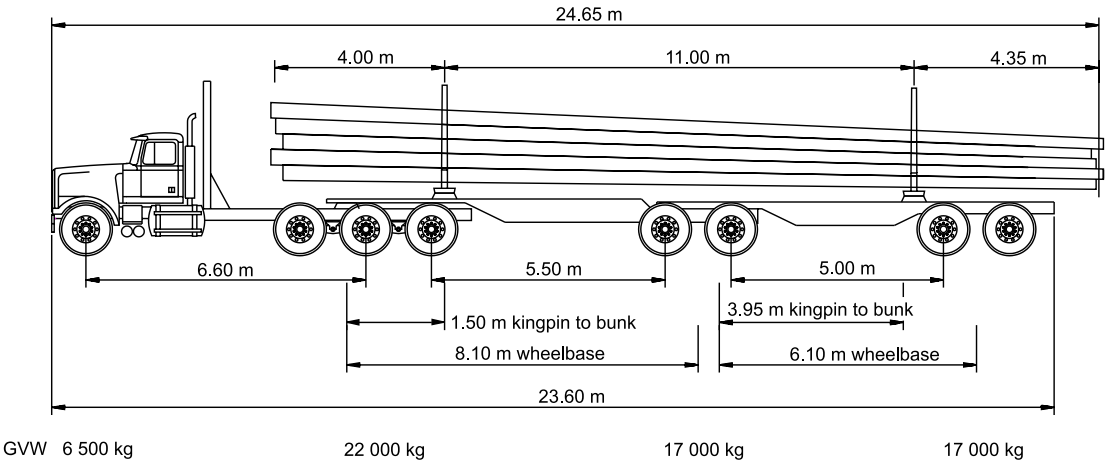

Figure 5. Dimensions of optimized configuration.

for tridem-to-tandem and 5.0 m for tandem-to-tandem. The resulting inter-bunk spacing was 11.0 m, which is 0.5 m shorter than the field trial configuration of 11.5 m.

This optimized configuration was evaluated by computer simulation, as shown in Table 2, and was found to exhibit acceptable dynamic performance similar to the other B-train configurations. Based on the Alberta regulations for long log B-trains, this optimized configuration would be acceptable with a rear overhang (measured from the centre of the last axle) of 6.0 m and a maximum overall length of 30.5 m. As well, it would be able to haul shorter logs and have better off-tracking characteristics than the configuration used in the field trials.

Conclusions

The tridem tractor/long log B-train fits within the Alberta log truck regulations with the following conditions: an overall length of 30.5 m, a rear overhang of 6.0 m, a front overhang of 4.0 m and a GCW limit of 62 500 kg (65 000 kg winter green route weight). General approval of this configuration is pending.

Dynamic simulations for the test vehicle indicated good dynamic performance, particularly for the critical measures of static rollover threshold and load transfer ratio. These performance results were similar to those of both the short log B-train and the tandem tractor/long log B-train. Therefore, it is recommended that the tridem tractor/long log B-train be approved for use on the Alberta road system.

From the truck driver's perspective, the tridem tractor/long log B-train handled similar to other B-train and long log configurations. The tridem drive also alleviates most traction limitations encountered by tandem drive tractors in the Alberta forest industry.

The majority of the difficulties encountered during the field trial can be attributed to the available logs being too short, or the inter-bunk spacing being too long. Had the logs been longer than 15 m, the tridem tractor/long log B-train would have achieved legal axle weights and performed well. However, as short, tree-length wood is a reality, the usefulness of the configuration as used for the field trial will be limited. However, an optimized trailer arrangement for use with a tridem drive tractor can be achieved by shortening the trailer wheelbases of both trailers. This would effectively reduce the inter-bunk spacing and in turn alleviate some problems with respect to short, tree-length wood.

Table 2. Predicted dynamic performance for optimized long log B-train

Performance measure	Pass criteria	Short log B-train	Tridem tractor/ long log B-train	Optimized tridem tractor/ long log B-train
Gross combination weight (kg)		62 500	62 500	62 500
Understeer coefficient	>-4.51	-2.34–0.63	2.09–0.27	2.61–3.15
Static rollover threshold (g)	>0.35	0.33*–0.40	0.35–0.42	0.39–0.48
Load tranfser ratio	<0.60	0.44–0.62*	0.37–0.48	0.37–0.48
Rearward amplification	<2.20	1.77–1.84	1.50–1.53	1.71–1.77
Friction demand	<0.10	0.11*	0.03–0.04	0.04–0.05
Lateral friction utilization	<0.80	0.56–0.57	0.82*–0.83*	0.75–0.76
Low speed off-tracking (m)	<6.00	4.90–4.94	5.22	4.82–4.84
High speed off-tracking (m)	<0.46	0.59*–0.64*	0.53*–0.56*	0.54*–0.59*
Transient off-tracking (m)	<0.80	0.57–0.68	0.45–0.52	0.47–0.55

* Indicates performance standard not met.

The tare weight of the trial configuration (23 400 kg) limited the maximum payload to 39 100 kg. This is not much greater than other existing long log configurations with fewer axles. Optimally designed trailers as described above may yield reduced tare weights.

Implementation

Alberta Transportation has allowed the general operation of tandem tractor/long log B-trains on public roads and reviewed the tridem drive tractors with conventional B-trains. Therefore, approval is expected for tridem tractor/long log B-train configurations. The higher legal GCW of B-trains provide better productivity compared to other long log configurations, so operations that have a large portion of their haul during the summer months would be ideal candidates for these configurations. The proportion of winter and summer haul will directly affect whether the long log B-train has an advantage over other configurations.

The tridem drive tractor with an optimized long log B-train is a configuration that would work well where the majority of logs are over 15 m in length. The long logs will enable the configuration to get the necessary front and rear overhangs to achieve legal axle weights on the drive group and the rear trailer axle group, while not overloading the lead trailer axle group. In addition, it is advisable to box load the tridem tractor/long log B-train to get good weight distribution, although this may cause off-loading and mill handling difficulties.

Although this study used the maximum B-train GCW allowance of 62 500 kg, the Alberta government increased this to 63 500 kg as of April 1, 2001. A benefit of this increase in GCW allowance is that the ownership costs decrease as productivity increases. The cornering performance of the configuration will not change because the length dimension regulations have not changed. In terms of dynamic performance, the static rollover threshold would be expected to decrease and the load transfer ratio would be expected to increase, but neither should fail to meet the performance standard. Similar to other B-train configurations, this configuration would not be expected to meet the performance measure for high speed off-tracking.

Both the tandem and tridem tractor/long log B-trains have distinct advantages. The primary advantage of the tandem drive tractor version is that the weight capacity of the lead trailer's tridem axle group can shorten the inter-bunk spacing and accommodate shorter logs. The tridem drive tractor version has greater mobility than the tandem drive configuration.

A "clean-sheet" approach to the B-train trailer design is recommended when a tridem drive tractor is under consideration. This would enhance performance characteristics and reduce tare weight beyond that experienced in this trial.

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