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A DYNAMIC EVALUATION OF TRUCK/FULL TRAILERS FOR HAULING LOGS

SESSION: VEHICLE SIZE AND WEIGHT ISSUES

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Abstract

In the province of British Columbia in western Canada, the use of truck/full trailer configurations has increased in recent years for hauling short logs. The popularity of this configuration arises from the compact design of the trailer which allows it to be stowed on the truck while not hauling logs, thereby improving its maneuverability and mobility on narrow and steep forest roads. The forest industry has expressed a strong interest in using a tridem drive truck in combination with full trailers in order to improve the configuration's productivity and off-road mobility. On behalf of the forest industry, the Forest Engineering Research Institute of Canada (FERIC) conducted a dynamic evaluation using computer simulations of three truck/full trailer configurations: a tandem drive truck coupled with an existing triaxle full trailer, a tridem drive truck coupled with an existing triaxle trailer, and a tridem drive truck coupled with an optimized trailer. This paper summarizes the results of this evaluation, and discusses implementation options.

1. INTRODUCTION

Since 1989, the Forest Engineering Research Institute of Canada (FERIC) has investigated the potential of tridem drive tractors for log-hauling on behalf of the forest industry. This research has demonstrated that tridem drive tractors relative to tandem drive tractors have improved tractive capability (Amlin, Klawer, Hart, 1995), and in general are more dynamically stable (Parker, Amlin, 1998). However, the steering performance of these units was a concern but research has shown that when properly configured, steering performance is acceptable (Parker, Amlin, Hart, 1998). The majority of the research to date has focused on tridem tractors in combination with pole trailers, and based on this research, both Alberta and British Columbia have drafted specific policies and regulations, which govern the use of tridem tractors for log-hauling. In Alberta, semi-trailers and pole trailers are permitted to be used with tridem tractors, while in BC only pole trailers are allowed at this time

Since 1995, FERIC has cooperated with Alberta Infrastructure (formerly Alberta Transportation and Utilities) and the Alberta forest industry in the testing and evaluation of two additional configurations for hauling short logs (tridem tractor/B-train, tridem truck/ quadaxle full trailer). Initially, these configurations were evaluated using the University of Michigan Transportation Research Institute's (UMTRI) yaw/roll model prior to obtaining approval from Alberta Infrastructure to conduct operational trials of these units. In both cases, the tridem drive unit exhibited superior dynamic performance relative to the existing tandem drive unit (El-Gindy, 1995; Parker, 1996).

In recent years, the proportion of the harvest hauled as short logs has increased significantly in BC, and the forest industry has expressed a strong interest in developing a tridem drive configuration which could be used for hauling short logs as well as long logs, and could be easily converted between uses. Similar configurations using tandem drive trucks have been used by the industry for many years and the improved traction and payload offered by tridem drives would provide a productivity improvement. The configuration felt to best meet these requirements is the tridem tractor(truck)/triaxle trailer (Figure 1). The trailer can be easily stowed on the truck when not hauling logs, thereby improving its maneuverability and mobility on narrow and steep forest roads. This same configuration has recently been permitted by Alberta Infrastructure for hauling long logs on a trial basis in Drayton Valley, Alberta. Prior to obtaining approval to operate and test the proposed configuration in BC, the Insurance Corporation of British Columbia (ICBC), stipulated that a dynamic assessment be conducted for the proposed configuration. This paper presents the summarized results of the dynamic assessment submitted to ICBC (Parker, 1999) for the short log configuration only.

1.1. Objective

- To determine critical dimensions and weights which will ensure the safe operation of the short log configuration by using computer simulations.

2. METHODOLOGY

Computer simulations were performed using the UMTRI yaw/roll model for the proposed tridem truck with an optimized triaxle trailer as well as an existing triaxle trailer and compared with an existing tandem truck coupled with an existing triaxle trailer. This comparison was conducted since the tandem truck/triaxle trailer is an existing approved configuration used for hauling short logs, and will likely be replaced in many operations by the proposed tridem truck/triaxle trailer. Each configuration was evaluated at three log lengths (5.18 m, 6.55 m, and 8.08 m), with an inside bunk width of 2.31 m and at a load density of 520 kg/m^3 (refer to Figure 2 for configuration details). At the shortest log length (5.18 m), the maximum allowable load height of 4.15 m was reached before maximum axle group weights could be achieved. A trailer wheelbase of 4.6 m (180") was used for the existing trailers since this is the most common triaxle trailer wheelbase currently in use in BC.

These configurations were evaluated according to the ICBC proposal making and approval process, which includes the evaluation of 11 performance measures. Most of these performance measures were developed during the Transportation Association of Canada (TAC) weights and dimensions study (Ervin, Guy, 1986), with others developed by the National Research Council of Canada (NRC) (El-Gindy, 1992). One of the NRC performance measures, lateral friction utilization was modified by evaluating this measure on a low friction surface, which FERIC has previously used to evaluate steering performance (Parker, Amlin, Hart, 1998). For the purposes of this paper only the following four performance measures are presented:

2.1. Static Rollover Threshold

The static rollover threshold (SRT) is the level of steady lateral acceleration beyond which the configuration rolls over. The measure is expressed as the lateral acceleration (in g's) at which all wheels on one side, except the steer axle, lift off the ground. Configuration performance is considered satisfactory if the static rollover threshold is greater than or equal to 0.35 g. This performance measure is determined during a ramp steer manoeuvre (ramp steer rate of 2 deg/sec at steering wheel) at a forward velocity of 100 km/h.. This slow ramp steer input results in a mild quasi spiral path trajectory that is essentially free of transient disturbances. Normally the SRT is determined experimentally using a tilt table device.

2.2. Load Transfer Ratio

The load transfer ratio is defined as the ratio of the absolute value of the difference between the sum of right wheel loads and the sum of the left wheel loads, to the sum of all the wheel loads. The front steering axle is usually excluded from the calculations because of its relatively high roll compliance. The recommended maximum value of load transfer ratio is 0.6. This measure is evaluated during a rapid high-speed path-change manoeuvre conducted at 100 km/h, yielding a lateral acceleration amplitude at the centre of truck mass of 0.15 g within a time period of 3 seconds.

2.3. Lateral Friction Utilization

Lateral friction utilization is a measure proposed by NRC to characterize the highest level of the lateral friction utilization at the steering axle (El-Gindy, 1992). Lateral friction utilization is defined as the ratio of the sum of lateral forces to the vertical load, and the peak tire/road coefficient of adhesion. The tires of a steering axle that achieves a lateral friction level of 1 are said to be saturated. The recommended maximum level of lateral friction utilization is 0.80. This performance measure is evaluated in a 90-degree turn at a vehicle speed of 8.25 km/h. During the manoeuvre, the centre of the front steer axle tracks an arc with a 12.8-m radius (14-m at outside steer tire). FERIC modified this performance measure by evaluating the performance measure on a low friction surface (coefficient of adhesion = 0.2), rather than a high friction surface. This is a more conservative approach since steering performance is most challenged under winter road conditions.

2.4. Low-Speed Offtracking

Offtracking is measured as the maximum lateral displacement of the centre-line of the last axle on the vehicle from the path taken by the centre of the steer axle. The recommended maximum level of low-speed offtracking is 6.0 m. This is evaluated at a vehicle speed of 8.25 km/h using a tight-turn manoeuvre with a 12.8 m turning radius (measured to the centre of front steer axle).

3. RESULTS AND DISCUSSION

3.1. Static Rollover Threshold

The tandem truck configuration exhibited improved stability relative to the tridem truck configuration (Figure 3), due to the lower payload and lower centre of gravity height. However, the rollover stability of the tridem truck configuration met the TAC/NRC performance standard of 0.35 g's for all log lengths. There was little difference in performance between the tridem truck configurations. In all three cases examined the truck was the least stable unit of this configuration rolling over before the trailer. The tridem truck's increased payload was compensated to some degree by the improved roll resistance provided by an extra axle and wide track drive axles (2.6 m overall width).

The stability performance would likely be unchanged if a quadaxle trailer were to be used in place of the triaxle trailer, as the truck is the more unstable of the two units. Quadaxle trailers typically have longer wheelbases which allow for the placement of an additional bundle on the trailer thereby lowering centre of gravity height. This together with the increased roll stiffness provided by the extra axle would more than compensate for the increased payload of this trailer. The greatest challenges for the quadaxle trailer are stowing the trailer on the truck in the unloaded mode and meeting the current configuration length limit of 23 m. In Alberta, two tridem truck/quadaxle full trailers are currently under test, where the maximum configuration length limit is 25 m.

3.2. Load Transfer Ratio

Both tandem truck and tridem truck configurations failed to meet the TAC performance standard at all log lengths for load transfer ratio (Figure 4). However the tridem truck configurations' load transfer was reduced, particularly when coupled with an optimized trailer relative to the tandem truck configuration, where the load transfer ratio approached 1 when loaded with low density logs. This indicates that under some conditions, the tandem truck would be very close to rolling over during an evasive manoeuvre. The results illustrate that by replacing existing tandem trucks with tridem trucks will improve dynamic performance, with performance further much improved when coupled with optimized trailers.

The adoption of the proposed configuration could be a gradual process where initially existing triaxle trailers could be allowed. Following a specified date all tridem truck/triaxle trailers should be coupled with optimized trailers. In order to meet the TAC performance standard, the roll coupling between the truck and trailer will need to be increased or payloads reduced. Since a reduction in payload is undesirable, alternative hitch designs should be investigated which provide increased roll coupling. Another means of improving dynamic performance would be to further increase drawbar length, increasing the maximum overall length from the current 23 m to 25 m (current maximum overall length for B-Trains). It is possible that the use of a quadaxle trailer would enable the TAC performance standard to be met due to the longer trailer wheelbase, the net lowering of cg height resulting from the placement of an additional bundle, and the increased roll stiffness provided by the additional axle. Therefore the tridem truck/quadaxle trailer should also be considered as a potential configuration, and should be investigated.

3.3. Lateral Friction Utilization

The tandem truck configuration exhibited superior performance relative to the tridem truck configuration in terms of low-speed lateral friction utilization on a low friction surface (Figure 5). The tridem truck configurations exhibited lateral friction utilization very close to the performance limit of 0.8. Previous research has shown that truck parameters are the most critical to ensuring acceptable steering performance. Steering performance is improved at increased truck wheelbases, decreased drive group spreads, and an increased proportion of the load carried by the steering axle. The tridem truck's performance was obtained with 6500 kg on the steering axle, which should be the minimum steering axle load to ensure acceptable steering performance.

3.4. Low-Speed Offtracking

All configurations easily met the TAC performance standard for low-speed offtracking (Figure 6). The tridem truck configuration coupled with an optimized trailer has an increased level of offtracking relative to the tandem truck configuration due to its longer overall length. In discussions with stakeholders, this performance measure was of greatest interest. Most stakeholders felt that the configuration should have the same off-highway maneuverability as existing configurations and were concerned that the low-speed offtracking was increased by 0.9 m for the optimized trailer. In order to achieve good dynamic performance in the short log mode, the hitch offset needs to be minimized, and the trailer wheelbase and drawbar length need to be maximized, which results in decreased maneuverability. This problem could be addressed with either a sliding hitch position or sliding drawbar or a combination of both. The hitch offset could be maximized and drawbar length minimized for increased off-highway maneuverability. Before going onto the highway, the hitch offset could be reduced and the drawbar lengthened to ensure good dynamic performance. In order for the proposed optimized trailer to be loaded on a truck, the tailframe will likely need to be extended, and the drawbar will need to be folded and placed so that it will not project above the maximum allowable height. Discussions with manufacturers indicate that these options are all possible to add to their product designs.

4. CONCLUSIONS

1. In general, deficiencies in dynamic performance that were identified for this configuration resulted from the coupling arrangement between the truck and trailer. Performance was marginally improved when a tridem drive truck was used in place of a tandem drive truck, and performance was further improved when trailer parameters were optimized.

2. The tridem truck coupled with an optimized trailer exhibited improved dynamic performance relative to the tridem truck coupled with an existing trailer for load transfer ratio. However low-speed offtracking was increased by 0.9 m due to the longer overall configuration length.

5. RECOMMENDATIONS

1 Investigate hitch designs, which will dampen the rearward amplification between truck and trailer for the short log configuration, such as improved roll-coupling and therefore improve this configuration's dynamic stability performance.

2. To ensure acceptable lateral friction utilization on low friction surfaces, maintain a minimum steering axle load of 6500 kg while loaded. Where possible maximize the steering axle load above this minimum recommendation.

3. The tridem truck /quadaxle full trailer configuration should also be investigated in terms of regulatory considerations.

6. REFERENCES

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7. ACKNOWLEDGMENTS

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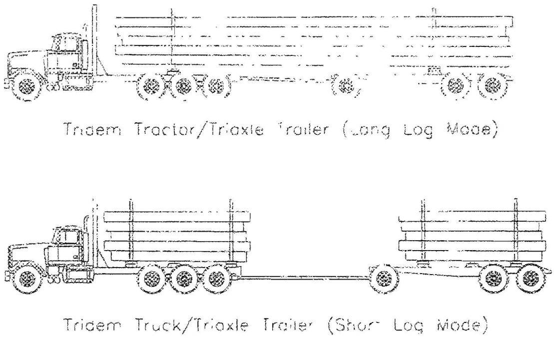
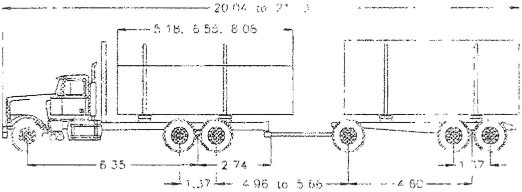
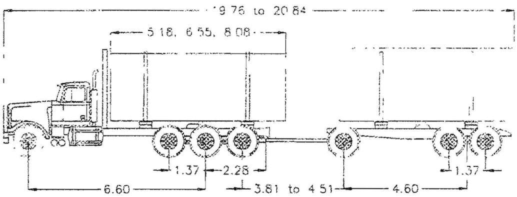


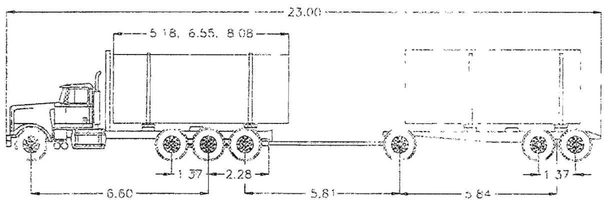
Figure 1. Proposed configurations



LOADS (KG)	5500 5500	17000 17000	9100 7680	7000 13960	6.55 m and 8.08 m logs 5.18 m logs
SUSPENSION TYPE	SPRING	RUBBER BLOCK	SPRING	WALKING BEAM	



LOADS (KG)	6500 5815	23600 21600	9100 7680	17000 13960	6.55 m and 8.08 m logs 5.18 m logs
SUSPENSION TYPE	SPRING	AIR	SPRING	WALKING BEAM	



LOADS (KG)	6500 5815	23600 21600	9100 7680	17000 13960	6.55 m and 8.08 m logs 5.18 m logs
SUSPENSION TYPE	SPRING	AIR	SPRING	WALKING BEAM	

Figure 2. Configuration details.

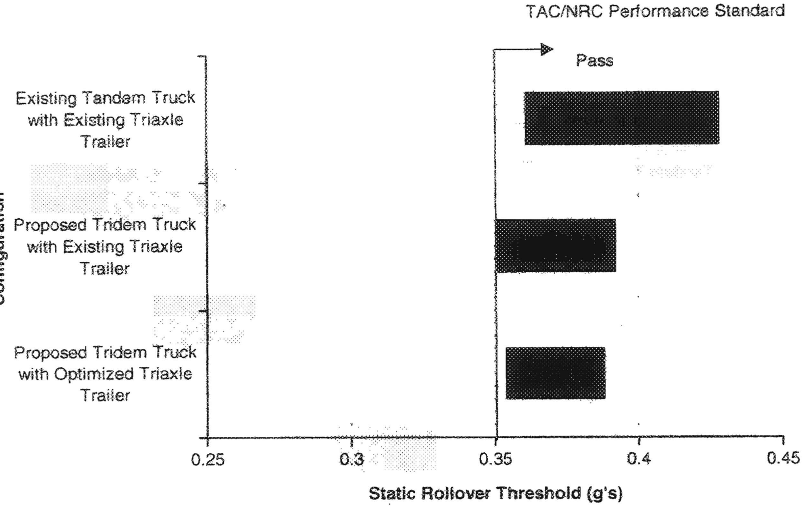


Figure 3. Static rollover threshold of short log configurations.

Note: Bars represent range of performance predicted from computer simulations

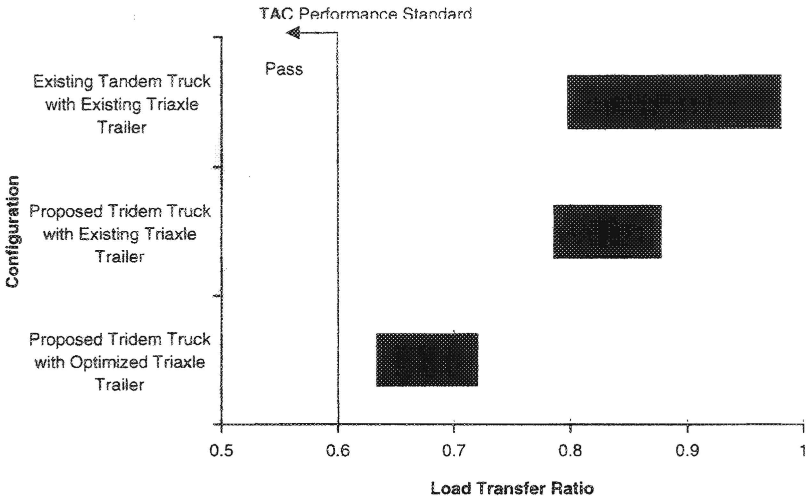


Figure 4. Load transfer ratio of short log configurations.

Note: Bars represent range of performance predicted from computer simulations

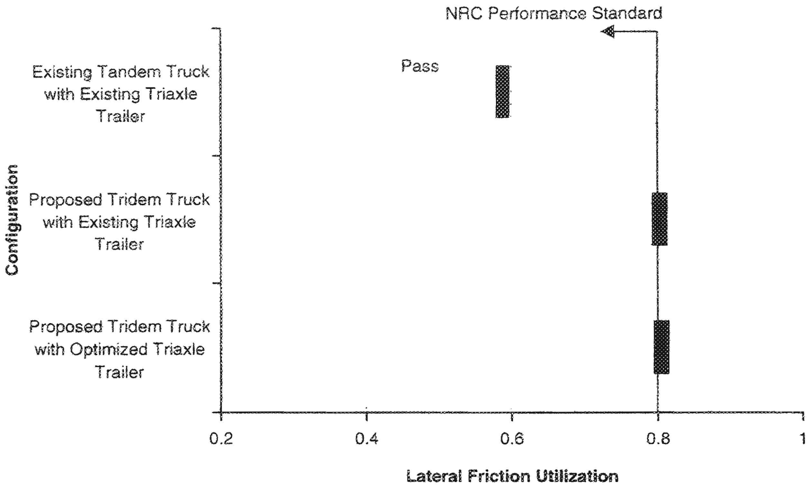


Figure 5. Lateral friction utilization of short log configurations.

Note: Bars represent range of performance predicted from computer simulations

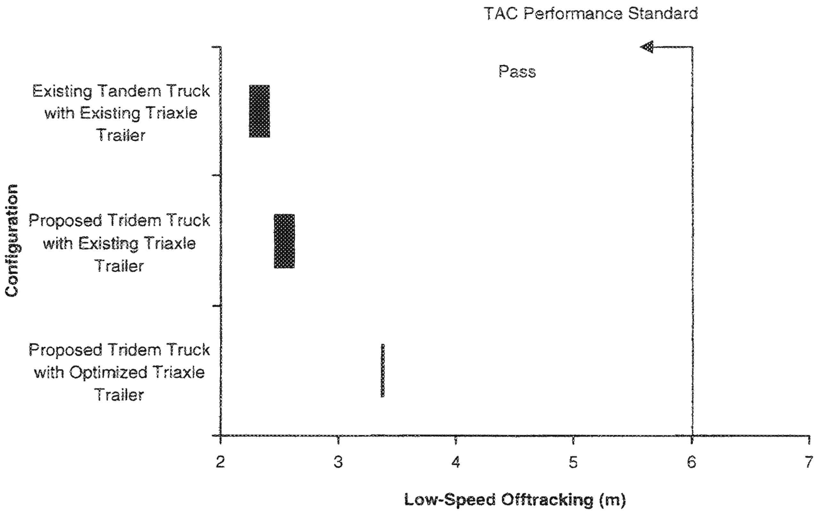


Figure 6. Low-speed offtracking of short log configurations.

Note: Bars represent range of performance predicted from computer simulations