

Roll-Coupling: Improving Vehicle Dynamic Stability

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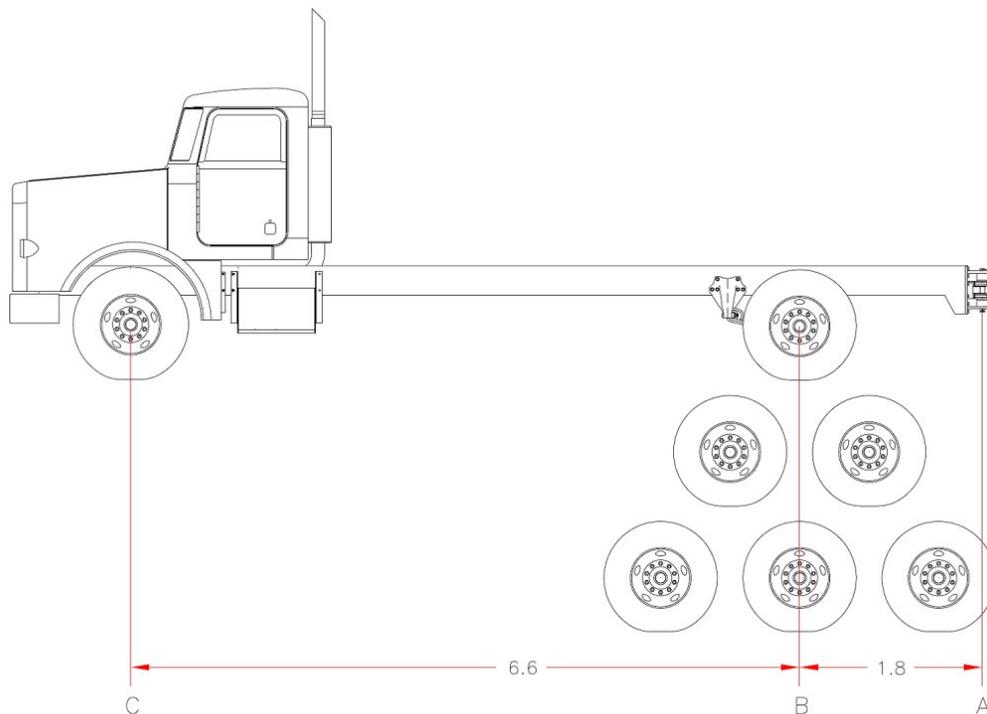
Measuring Vehicle Stability

The Transportation Association of Canada (TAC – formerly RTAC) measures vehicle performance and sets minimum standards for commercial vehicles operating on public roads in Canada. This document focuses on critical TAC standards relating to the stability of vehicles with rear-mounted hitches operating on public highways in Canada and around the world.

Hitch Offset

The TAC hitch offset limit is 1.8 m for rear-mounted hitches measured from the hitch Yaw axis (center of the pintle) to the turning center of a vehicle (i.e. the center (B) of the driving axle group on the truck in Fig 1). A 1.8 m hitch offset is practical for single and tandem drive axle groups but too short for tridem groups.

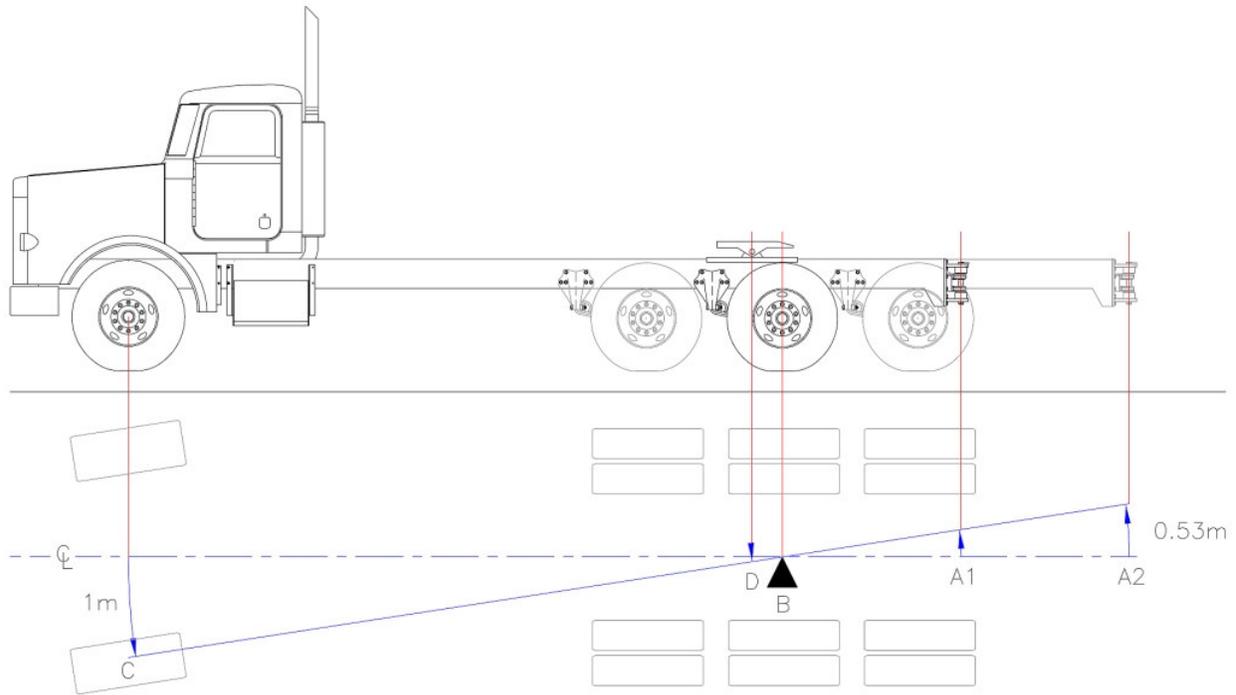
Fig. 1 – Hitch Offset Illustrated



The fundamental difference between tractors equipped with fifth wheel hitches and straight trucks equipped with rear-mounted hitches is the location of the coupler relative to the turning center of the vehicle. In Fig. 1 the rear mounted coupler is mounted at the TAC limit of 1.8 m (A) rearward of the vehicle turning center (B) on a vehicle with a 6.6 meter wheelbase measured from the steering axle (C).

Figure 2 illustrates the vehicle with a fifth wheel coupler installed slightly forward of the turning center in order to load the steering axle to capacity. The overlay illustrates the tri-drive configuration with a 3.5 m hitch offset distance to the rear-mounted coupler.

Fig. 2 – Hitch Locations



The rear-mounted hitches are located at 1.8 m (A1) and 3.5 m (A2) from the turning center (B) on a vehicle with a 6.6 m wheelbase. The yaw axis of the fifth wheel coupler is forward (D) of the turning center (B). When the truck driver steers the vehicle to the left, the front of a trailer coupled with the fifth wheel steers left however trailer drawbars coupled to rear-mounted hitches steer to the right. Trailer whipping oscillations (that can result in a rollover accident) increase as the hitch offset distance increases relative to a constant vehicle wheelbase and constant steering inputs by the truck driver. The first contributing factor to trailer dynamic instability is the location of the coupler on the vehicle towing the trailer. Other significant factors are axle spacing, trailer suspensions and frame stiffness as well as the location, weight and size of the load on the trailer and, to a large extent, the type of coupler being used.

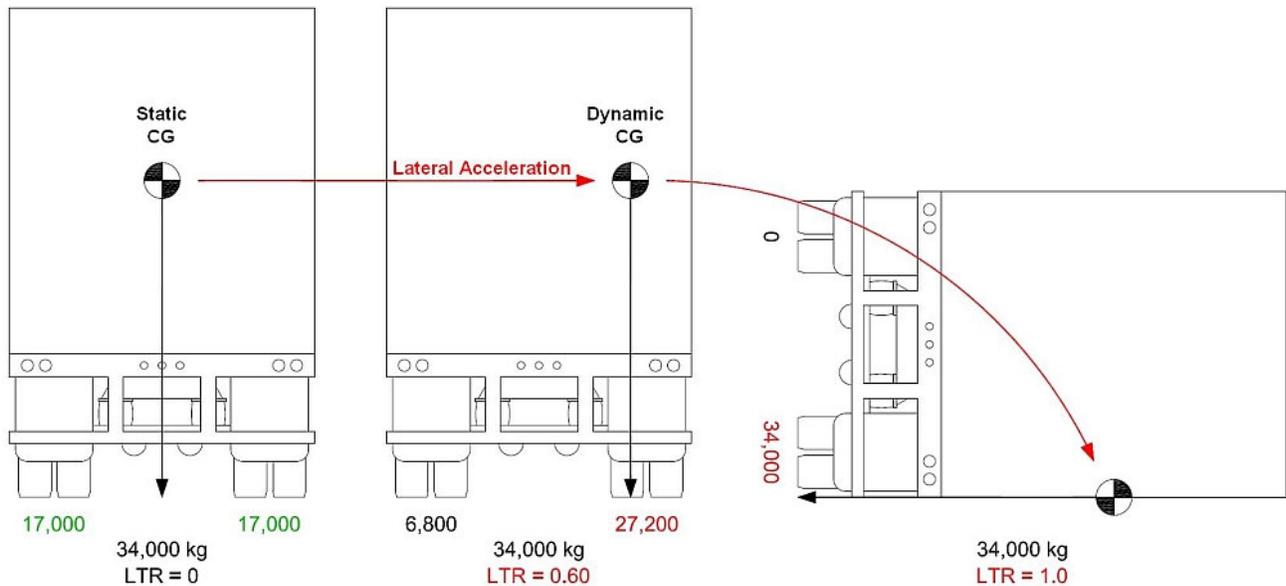
Load Transfer Ratio

The TAC performance measure for vehicle stability is Load Transfer Ratio (LTR).

“The Load Transfer Ratio performance measure is the fractional change in load between left- and right-hand side tires in an obstacle avoidance maneuver. The load transfer ratio should not exceed 0.60, which is equivalent to an 80% - 20% left-right division of wheel loads. This is a particularly significant performance measure for any vehicle with a high payload center of gravity, double and triple trailer combinations and truck-trailer combinations”

John R. Billing, Chuck P. Lam

Fig. 3 – LTR Illustrated



LTR measures the effect of lateral force overcoming gravitational force during a predictable maneuver around a pedestrian or automobile when a truck driver cannot stop a truck to avoid a collision. The dynamic center of gravity shifts laterally until eventually the vehicle rolls over. Operating any vehicle with a LTR in the range 0.60 – 1.0 on public highways is unacceptable because forces outside of the control of the driver can cause the vehicle to roll over. High speeds and off-centered loads significantly increase risk of roll-over accidents.

Unstable Vehicles

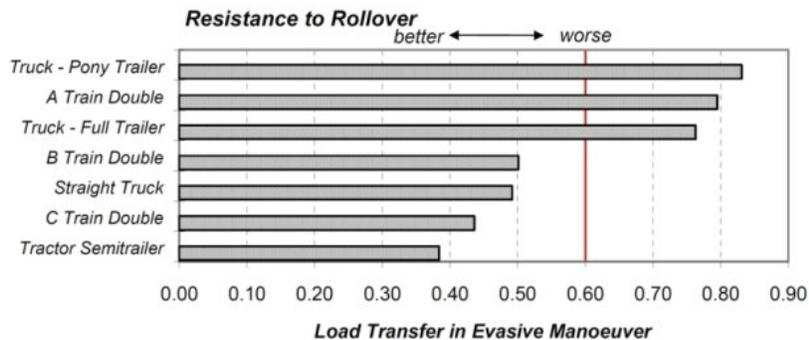
TAC identifies unstable vehicles operating in Canada below:

Graph 1

Stability and Handling - Comparison of Vehicles in the Current Truck Fleet

The stability and handling characteristics of heavy truck configurations depend upon the actual dimensions of the vehicle, the axle weights and the type of payload. However, for the purposes of comparison, typical performance levels for seven basic configurations of vehicles commonly used within Canada are depicted in the charts which follow.

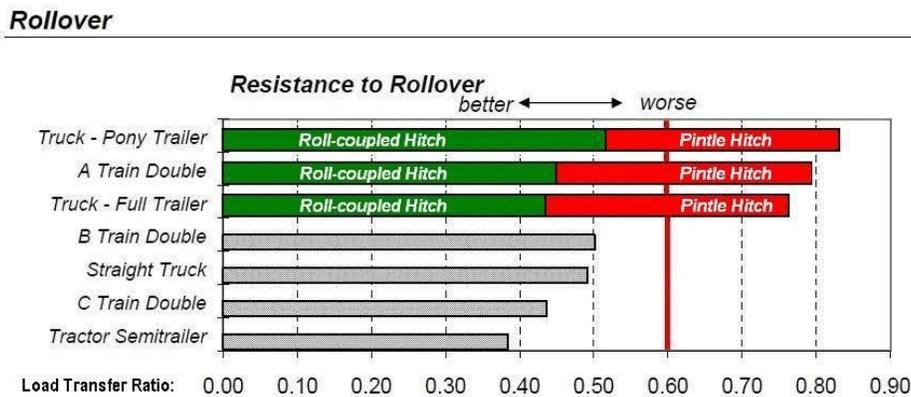
Rollover



John Pearson, P.Eng., TAC

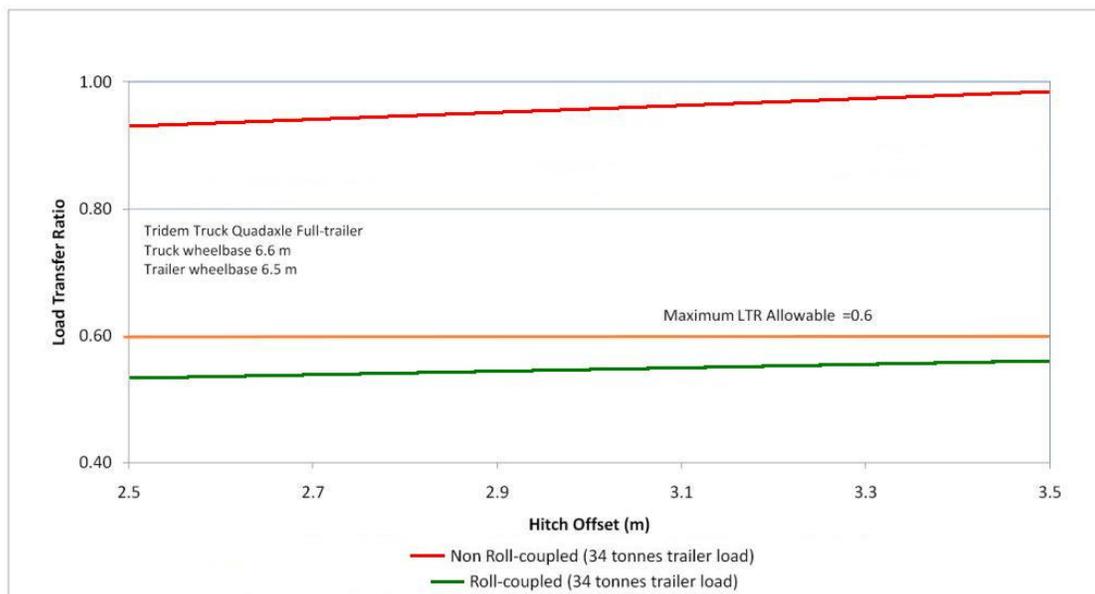
The vehicles in Graph 1 can be separated into two groups separated by the red line marking the 0.60 load transfer ratio limit. The stable vehicles are all roll-coupled and the unstable vehicles all use rear-mounted single oscillating pintle hitches (not roll-coupled). Graph 2 illustrates how roll-coupling improves the stability of otherwise unstable vehicles:

Graph 2 – The Effect of Roll-Coupling on Vehicle Stability



The reader will recall from page one that the TAC limit for hitch offset is 1.8 meters and that vehicles with tridem axle groups cannot meet the standard. The hitch offset standard was developed for vehicles that use pintle hitches; roll-coupling improves the safety performance of vehicles with longer hitch offsets up to 3.5 meters:

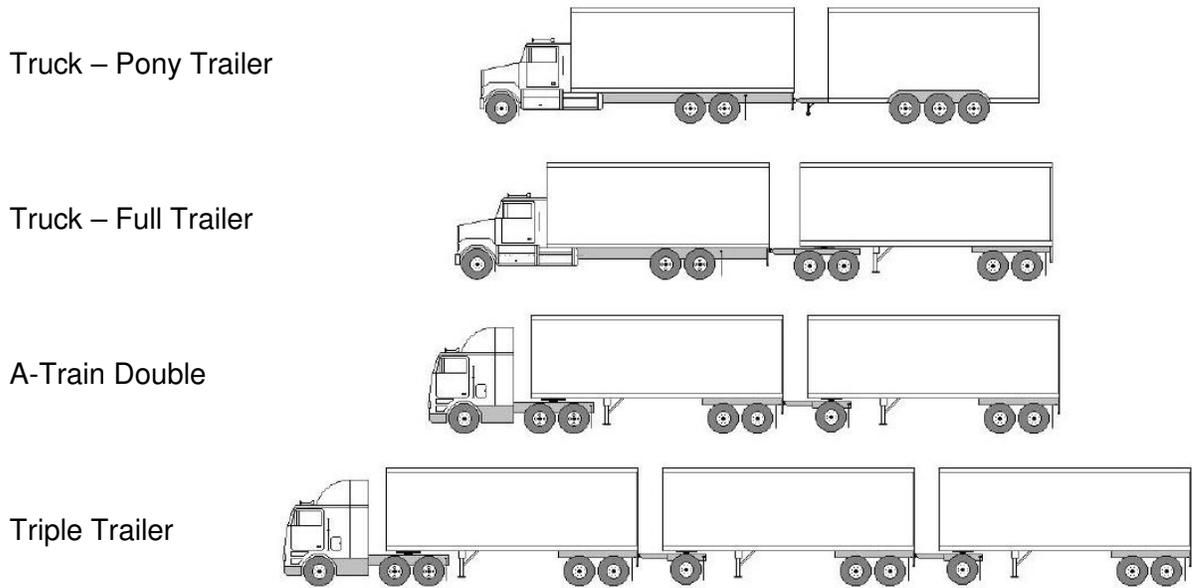
Graph 3 – The Effect of Roll-Coupling and Hitch Offset on Vehicle Stability



Séamus Parker, P.Eng., FPInnovations

The Canadian combination vehicles known to be unstable are straight trucks pulling pony trailers and full trailers, A-train doubles and triple trailers. The stability of other Long Combination Vehicles (LCVs) improves when using roll-coupled converter dollies. Figure 4 illustrates the basic configurations as they are named in Canada.

Fig. 4 – Unstable Vehicles Illustrated

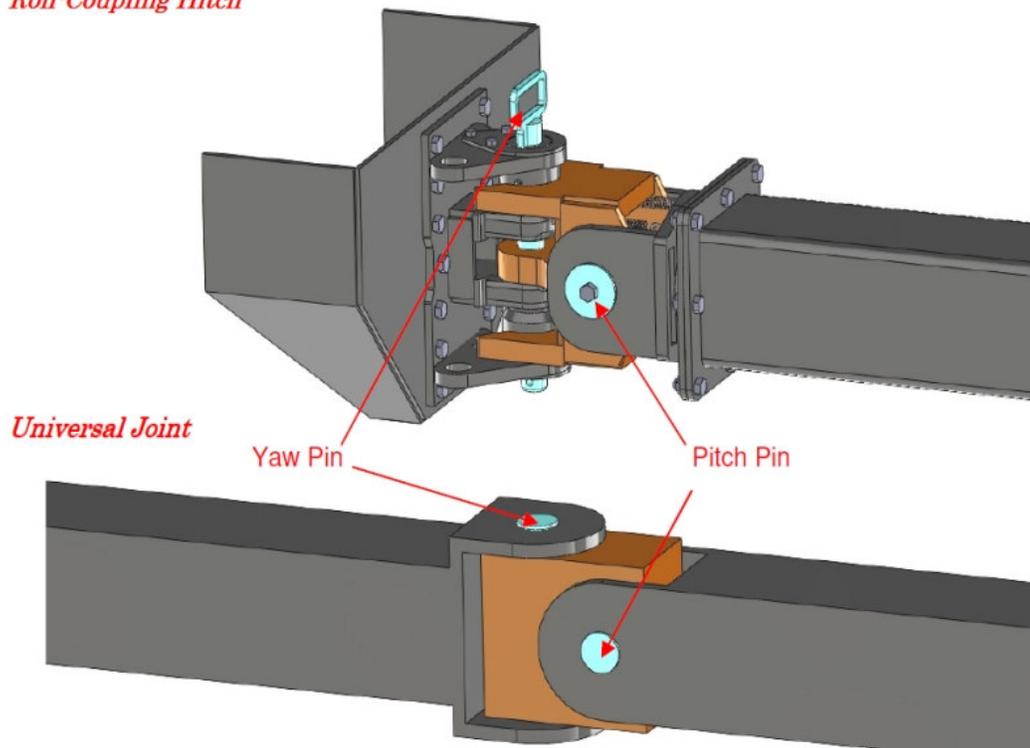


Roll-Coupling

Roll-coupling hardware replicates the performance of a universal joint that is fixed to the tow vehicle on one end. It prevents the trailer from rolling over without restricting the range of motion around the Yaw (turning corners) and Pitch (driving over bumps) axis.

Fig. 5 – Roll-Coupling Hardware

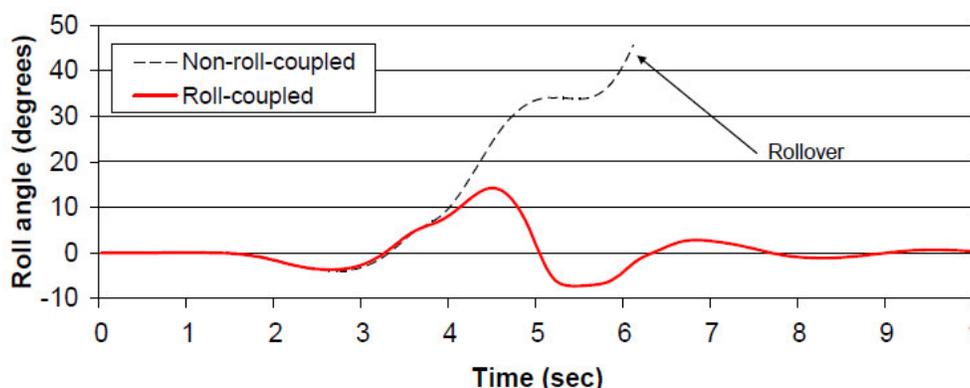
Roll-Coupling Hitch



Roll-coupling enables the transfer of roll stability from one vehicle to the other; this can prevent a roll-over event from occurring. During the onset of a trailer roll-over, the driver feels the truck responding to torsional loading conducted from the trailer via the roll-coupling hitch. With this advanced warning, the driver can take remedial action to prevent an accident from occurring and drive accordingly.

Roll-coupling balances opposing roll forces. When a truck and trailer(s) travel across uneven terrain (like a railway track crossing the road diagonally) or the truck driver is performing an avoidance maneuver or simply changing lanes, the truck and trailer(s) are out of phase with each other. Roll coupling uses left-side lateral acceleration force to counter right-side lateral acceleration force and vice-versa as the vehicle proceeds through the maneuver.

Graph 4 – The Effect of Roll-coupling in a Severe Lane Change Maneuver
(Quadaxle Full Trailer Carrying 34,000 kg)



“The benefits of roll-coupling are most dramatically illustrated in a severe lane change maneuver (0.2 g at truck, 100 km/h, 3 second period) with a 34,000 kg load. The graph shows the inherent risks of allowing full axle capacity weights with a non-roll-coupled unit and shows that full axle loads can be safely negotiated through this severe lane change maneuver when roll-coupling is present.”

*Séamus Parker, James Sinnott
FPInnovations - Feric*

Benefits of Roll-Coupling

Loads on pony trailers, full trailers and A-trains are capped below full axle load limits in Canada and hitch offset limits prevent many trucks from pulling trailers in Canada. Wolf Trailer Company is working with TAC and Provincial Governments in Canada to safely improve productivity with roll-coupling to solve both problems.

The demand for goods transported by trucks competing with passenger automobiles for road space on public highways is increasing all around the world. Roll-coupling can be used to improve safety and reduce traffic congestion for everyone using public highways, productivity and profitability for the trucking industry and to reduce fuel consumption and harmful environmental impacts in every country in the world.