# A question of force

Let's consider the forces that are necessary for a two-trailer combination to safely go around a curve. The tyres on each group resist the destabilising outwards forces, which increase with the weight of the vehicle and the sharpness of the corner. The speed is the most significant factor because the destabilising forces increase with the square of the speed – a 10 per cent increase in speed results in a 21 per cent increase in the destabilising force. Each axle group resists the destabilising forces by generating turning forces (F in the diagram). The trailer pushes the back of the truck outwards, which, unless the drive-axle tyres are up to it, will result in jack knifing. The further the trailer coupling is located from the turn centre, the greater the potential for jack-knife. In Figure 1, the total sprung weight of the truck is $W_{truck}$ and the total sprung weight of the trailer is $W_{trailer.}$

If the tyres cannot produce the forces that are needed to resist the outwards destabilising forces, then the vehicle will leave the road. Therefore, the truck will follow the curve unless an axle group reaches its tyre limits. If the steer axle cannot provide the necessary fore (F1), the vehicle will under steer, and the truck will steer outwards. If the drive group cannot provide the necessary force (F2), the vehicle will jack-knife. If the dolly group cannot provide the necessary force (F3) then the trailer jack-knifes. If the rear-trailer group cannot provide the necessary force (F4), then the trailer will swing out. Of these four events the least desirable are truck jack-knife and trailer jack-knife because they occur very fast and are uncontrollable. The maximum forces the tyres can produce depend upon the weight on the tyre and of course on the tyre tread and construction. My next two articles will be about tyre performance, but for now I want to consider the forces on the couplings.

The semi-trailer (Figure 2) imposes an average load on the fifth wheel of $W_{trailer}$ x (S-C) / S. Of this, the load that gets transferred to the steer axle is $W_{trailer}$ x L x (S-C) / (S x wb).

Example: $W_{trailer}$ = 30 t, S = 10m, C = 7m. Coupling load = 9t. For a truck wheelbase of 4.5 m and a lead L = 0.1 m, the additional average weight on the steer axle is 9 t x 0.1 / 4.5 = 200kg.

During heavy braking, an additional weight transfer occurs. If the height of the trailer load centre above the axles is 1.5 m, then for a severe brake application (with a deceleration of say 0.35 g), the additional load on the fifth wheel is about 1.6 t. The vertical load rating of the fifth wheel should be well above the maximum load that can occur. A safety factor of at least 2 is sensible so the fifth wheel vertical rating in this example of 20 t is acceptable.

The minimum horizontal rating of the fifth wheel (or any other coupling that doesn't take a vertical load on the coupling mechanism) is: Minimum D-value = 9.8061 x $W_{truck}$ x $W_{trailers}$ / ($W_{truck}$ + $W_{trailers}$).

Example: The truck weight is taken to be the laden weight. For example, allowing for the imposed load on the truck of say $W_{truck}$ = 20t and $W_{trailer}$ = 30t, the minimum D-value is 118kN.

Additionally, the coupling transmits the cornering force $F_{d,}$ which depends upon the turn radius R, weights and dimensions.

For a truck that pulls a centre-axle trailer (Figure 3), the average vertical coupling force is $W_{trailer}$ x (C-X)/C. For example, if C = 6m, X = 5m and $W_{trailer}$ = 20t, than the vertical coupling load is 3.33t. As a guide, the vertical load on the coupling should be in the range 5 – 10% of the total trailer weight. This gives acceptable road handling performance. The load should be slightly in front of the centre-line of the trailer axle group. The weight on the coupling should not exceed 10 % of the maximum trailer weight (ATM) and no more than 1 tonne. The vertical load on the coupling causes the load on the steer axle to be reduced. The weight taken off the steer axle is $W_{trailer}$ x Y x (C-X)/(C x wb). So, if Y= 1.5 m and wb = 4.5 m, the weight taken off the steer axle by the trailer drawbar weight is: 3.33 t x 1.5 / 4.5 = 1.11 t. Such a weight reduction will cause the steering to feel light. During heavy braking additional weight goes onto the coupling. The higher the height of the load centre on the trailer, the more will the steer axle be unloaded. Therefore, it is important the Y dimension should be kept as small as possible to minimize this.

Light steering results in understeer. There is no design rule that limits the weight that can be taken off the steer axle by a cantilever load. As a guide the weight of a dog- or pig-trailer should be less that the weight of the truck. The basis of this is that the trailer should not excerpt excessive dynamic force Fd onto the truck. For a centre-axle trailer (or any trailer that imposes a vertical load onto the trailer) the minimum D-value is: Minimum D-value for a centre-axle trailer = 9.8061 x $W_{truck}$ x $G_{trailer}$ / ($W_{truck}$ + $G_{trailer}$). $G_{trailer}$ is the centre-axle group load rating.

The coupling regulations (such as ECE Regulation 55) also require a coupling for a centre-axle trailer to have a minimum vertical load rating (which is called the V-value). The minimum V-value required is: Minimum V-value for a centre-axle trailer = a $G_{trailer}$ x Z2 / C2. a = 1.8 for an air-bag suspension and a = 2.4 for a spring suspension.

Coupling suppliers in Australia will declare a D-value for each coupling. Couplings that experience a load onto the 'pulling element' should have a declared V-value. Coupling suppliers should prove the declared D- and V-value ratings by fatigue tests. Additionally, a fifth wheel will have a declared S-value, which is the load rating of the coupling plate. Because this load is not imposed on the jaws, the fifth wheel will not have a declared V-value.

Couplings that have approved status have a valid Component Reference Number (CRN) that is issued by the Federal Department of Infrastructure and Transport. Policy is that a CRN can be issued for the coupling and for the assembly of a fifth wheel mounted onto a turntable. A CRN will not be issued for the turntable only. Coupling suppliers should be able to advise operators about the maximum truck and trailer weights that a coupling can be used for. The rating plate on the coupling will usually only state the D-value (and V-value if applicable).

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**Figure 1**

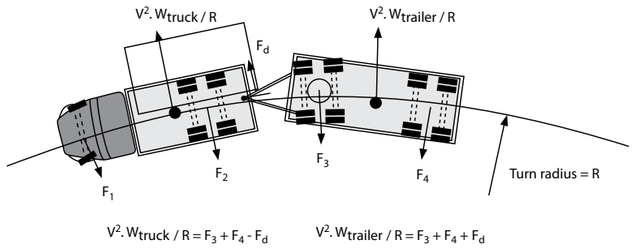


**Figure 2**

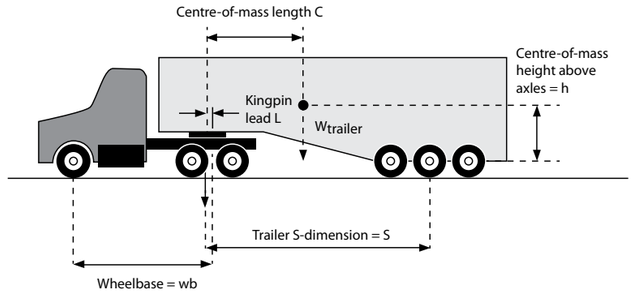


**Figure 3**