

## Fifth wheelers & stability

**A**s more and more fifth-wheeler owners join the CMCA it seems timely to run another Tech Notes column relating to their on-road characteristics. In particular I am surprised that rarely do neither owners nor vendors of these vehicles mention what is probably the strongest case for their use: and that is their superior dynamic stability. The latter difference is so great that people are now querying why, this being so, were not all caravans built like this from the start?

Some were of course, but the answer is that originally there was less need. The issue relates more to changes in the design of towing vehicles rather than anything to do with trailers (the design of which remains almost Edwardian).

Early motor vehicles had little rear overhang (i.e., distance from rear axle to towing bracket). If there was much luggage, passengers would travel in the Royce, luggage would go with Jeeves in the Bentley. With cars like the T-model Ford, it was assumed owners were too poor to own luggage anyway. If there was luggage it was strapped to the running boards.

There being no luggage boot to speak of, there was no need for rear overhang so a trailer would be typically attached a bit over half a metre behind the rear axle. Engines were then mostly big lumps of cast iron with holes in various places for pistons and things so there was a lot of weight on the front wheels.

But two trends evolved: softer suspension; and largish rear luggage boots. The latter necessitated lengthy rear overhangs.

Now, trailers were attached at ever-increasing distances behind the rear axles – onto a towbar that had equally increasing up and down movement as a consequence of longer travel, softer rear springs. And often some sideways

movement as tyre sidewalls became more horizontally compliant.

So began an inherent effect. Any trailer so attached has an inherent tendency to pitch and snake. From the mid-1930s to this day, caravan magazines, and now websites, report jack-knifing and (not infrequently) overturning as a consequence.

Curiously, the physics of this has barely been investigated (my original paper on which this article is based is still the only literature – except for a heavily mathematical one published by the US military). Here, in hopefully less obscure terms, is what happens and why.

### Pitching

Push a child on a swing only a few times and let go, friction and wind forces will quickly slow that swing. But continue to give even a little push at the critical time and swing angle will increase. Once past a certain point, movement is difficult to stop. If pushing still continues, the swing may 'go over the top'.

This so-called 'positive feedback' does not just happen with swings. It is true of monetary economies, early Porsches and VW Beetles, sailing boats, and public address systems. Unless that disturbing impetus is negated (eg, a yacht turned into the wind, a PA system turned down) the effect rapidly escalates. This can spectacularly happen with caravans. Given ongoing 'pushes' from any number of causes, a trailer attached via an overhanging hitch may build up this movement. Unless resisted or damped, escalating pitching and snaking may overwhelm.

A pitching caravan pushes down on the rear overhang of its towing vehicle. This causes the front of that vehicle to lift. It's like pushing down on the handles



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of a wheelbarrow: the front wheel lifts. It makes no difference whether the wheelbarrow's legs are sprung, or are totally rigid – push down on the handles and the front end lifts. It is a simple lever effect.

This is exactly what happens when a caravan pitches: the down force on the overhung rear lifts the front of the towing vehicle. Stiffening the towing vehicle's rear suspension makes no difference. The effect is innate: it is that of a 'first class lever', originally described by Archimedes in 260 BC. Despite clear visual evidence to the contrary and readily demonstrated simply by standing on a tow bar, many caravanners and builders deny it exists!

*'Give me a lever and a place to stand,  
and I shall move the Earth'.*

Archimedes – 287-212 BC

## Snaking

Snaking is an ongoing lateral sway usually triggered by one trailer wheel encountering a dip or hump. This slightly slows that side of the 'van, causing it to skew. Much the same, only worse, can happen if one 'van wheel runs onto soft ground whilst the other remains on the bitumen (the suddenly increased drag brakes that wheel). Skewing is also initiated by wind gusts, including from passing trucks.

Things may get serious if pitching and snaking occur simultaneously, because pitching forces reduce the grip of the towing vehicle's front wheels, at the same time that snaking forces try to spin the vehicle.

If snaking forces exceed the grip of the towing vehicle's tyres, the rig will begin to jack-knife. The friction as the tyres slide sideways dissipates some of the snaking energy, but whether it is enough to prevent total jack-knifing is now in the hands of Archimedes, Sir Isaac Newton - and whichever gods look after rubber technology. This combination of events is the known cause of many caravan accidents, some of which happen on straight suburban roads.

## False Sense of Security

A major problem with convincing drivers there is a problem is that big end-heavy rigs seem exceptionally stable in normal circumstances. Their rigs behave like ocean-going tankers in calm seas and so strongly resist minor pitching and swaying that their owners may boast of the apparent stability. But these rigs can suddenly become an unstable nightmare if, for example, crossing a humpback bridge too fast – or cornering too fast on a bumpy and slippery road. Strong, cyclically gusting winds, or passing road trains too may induce seriously dangerous snaking.

Pitching and snaking forces are not linear. They increase by the square of the distance that any mass is in front of or behind the centre of mass (in practice the latter is a point a bit ahead of the axle/s. In plainer English that means that weight at the ends has very much greater adverse effect than weight near the middle.

Caravan builders know their products are less unstable if front-heavy and they usually have about 10% of the weight on the towbar. But when that caravan pitches, a 150 kg mass one metre away from the centre of mass pushes down with a force equivalent to 150 kg; if three metres away that 150-kg mass pushes down with a force equivalent to over a tonne.

Pitching forces can be partially counteracted by using a weight equalising hitch. This acts like a full-length semi-rigid beam that forms a single and common virtual chassis for both towing vehicle and trailer. The rig becomes the dynamic equivalent of an ultra-flexible three-axle truck. This reduces but cannot eliminate the full effects of pitching but it reduces them by a worthwhile amount.

Snaking pushes the rear overhang of the towing vehicle sideways. Because the force is applied behind the towing vehicle's centre of mass it attempts to spin that vehicle in the opposite direction, and around that centre of mass.

The build up of snaking energy can be resisted and partially absorbed by friction or cam mechanisms, but it must always be ultimately resisted by the grip of the towing vehicle's tyres (particularly front tyres) on the road. If that grip is lost, the vehicle is almost certain to jack-knife.

There is less cause for concern where light caravans are towed by heavier vehicles, but undesirable effects are inherent when a heavy trailer is attached by a towbar any appreciable distance behind the rear axle of a towing vehicle.

## The Fifth-Wheel Solution

The basic problem with caravan stability is thus not so much the caravan. It is rather that modern passenger vehicles, especially cars, have developed long overhangs. This introduces the lever effect that causes the problems: of undesirable forces that affect stability. The greater the overhang, the greater the problem. (The ultra-short overhang DS Citroen was a wonderful towing vehicle).

But if the trailer's weight is carried by a coupling located over the towing vehicle's rear axle, pitching and snaking forces are reacted by that axle and tyres alone. The front of the towing vehicle still lifts under acceleration but that is rarely an issue. The above configuration is dynamically stable.

But if the coupling is behind that axle, the dynamics are that of a conventional caravan. The argument is not whether it is stable or otherwise. It is inherently unstable. The only argument is 'by what degree'.

Will a millimetre or two rearward make any measurable or perceivable difference? Measurably? Certainly, given scales of adequate repeatability and resolution. Perceptibly? Probably not - except in an extreme situation.

There simply has to be a defined hitch location. The current two 'centimetres in front of the axle' makes good sense but an allowable tolerance of (say) minus one centimetre would allow for measurement discrepancies.

Whilst the CMCA's policy regarding hitch position is sometimes criticised, it is that positioning, and that positioning alone, that differentiates a fifth-wheeler from a conventional caravan hung onto an overhung hitch. This is not an argument such as 'how many hairs constitute a beard' – this is an issue of engineering absolutes.

There is no logical/engineering difference whatever between a caravan with a raised drawbar being attached onto the deck or chassis of a towing vehicle and behind its rear axle – and that caravan being hitched to the towbar of that same vehicle. In virtually every respect, both have 'caravan' not fifth-wheeler dynamics. But if (say) that modified Jayco pop-top is attached over the towing vehicle's rear axle it becomes, by definition, a 'fifth-wheeler'. Archimedes and Newton explained most of the above centuries ago. I've just attempted to put it into an RV context.

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