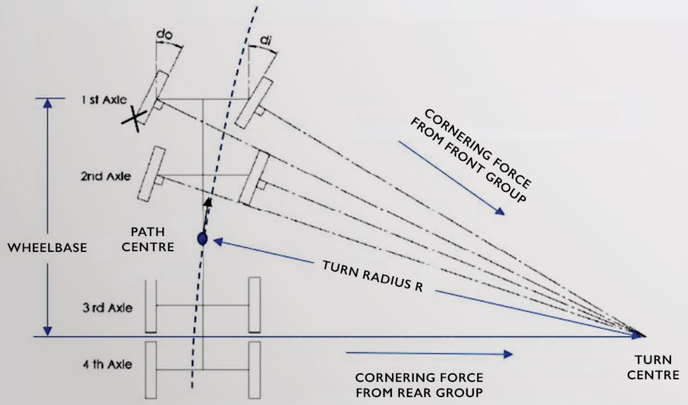
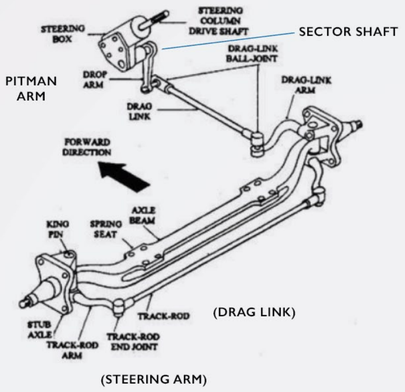
Steering basics

I recently investigated a front wheel separation. The separation was the result of a unitised bearing failure. There was evidence of front wheel misalignment. This investigation prompted me to consider the engineering 'basics' for steering axles and wheels. This article describes them.

The condition of the Steering Mechanism is crucially important for long and safe truck-life. The illustration shows the basic components. A great guide to condition inspection for the steering joints and pivots is in the NHVR's Heavy Vehicle Inspection Manual – Section 4. For example, when a front-axle wheel is lifted and rocked, the maximum acceptable back-and-forth horizontal movement at the tyre tread is 3mm. This movement could be due to bearing wear or kingpin wear. If an excessive movement exists, the bearings need to be slightly preloaded to determine whether the movement is reduced. If not, a worn kingpin is indicated. A preventative maintenance strategy is sensible for the steering mechanism. The frequency of replacements will again depend upon the levels of loading and the harshness of the road conditions that the mechanism experiences.

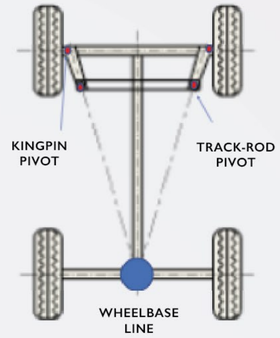
The turning geometry for a four-axle truck is shown below. All four steering wheels need to have different angles to point to the turn centre. This is the 'Ackerman' geometry. The steering mechanism design is supposed to achieve it. When the truck is moved in a low-speed turn with radius R, one point on it will be the path centre. This point is determined by the 'battle' of tyre forces. The front tyres push the front to the right whereas the rear tyres resist being turned, and they cause the rear of the truck to move left. This moment of forces causes the truck to rotate around the path centre. The path centre should be near to the centre of mass. The minimum turning circuit that can be achieved depends upon the maximum wheel-cut angles and the length of the truck. Wheel-cut angles are limited by stops that are adjustable, but they are needed to stop the wheel contacting the chassis rails to avoid tyre damage. Australian Design Rule 43/04, clause 5 specifies that the turning circle of a truck be no more than 25m. This circle is measured by making a complete circular turn and measuring the diameter across the turning circle that is traced by the outer edge of the outer front tyre (identified by the cross). Because the path centre depends upon load, the turning circle has a minor dependence on load.





(STEERING ARM)

A simple check on the Ackerman steering geometry can be done visually when all steerable wheels are straight ahead. Using a straight edge, a line through the centre bottom of the kingpin and track rod joint should intersect the centre-line of the truck at the wheel-base line. For a bogie rear axle group, the sight line will be projected just to the outside of the centre of the differential on the front drive axle. If the wheelbase of the truck is altered, the steering mechanism may need to be altered. For a longer wheelbase, replacement track rods (steering arms) are needed that move the track rod end-joints outwards so that the sight line still intersects the centre line of the truck at the wheelbase line. If this is not done, front axle tyre wear will increase, and the truck steering will be 'heavy'.



When the truck travels around a corner at speed, the lateral forces generated by the tyres must increase to provide the centripetal acceleration (cornering forces) necessary for the truck to stay on course. The lateral tyre forces are generated when the tyres point at a different angle to the direction of travel, which is arrowed at the *Path Centre* in the illustration.

The steerable wheels have steering angles that are positive with respect to the direction of travel and the rear wheels have negative angles. The net effect is that the tyres generate different cornering force pointing inwards and cause the vehicle to rotate around the *Path Centre*. The desired situation is called **Neutral Steer**, when the cornering force necessary to hold the road is provided by the axle groups in proportion to the weight carried by that group. If the vehicle exhibits **Understeer**, the front group steering angles need to be greater than those of the rear group and for **Oversteer** it is vice-versa. The usability of the steering system then depends upon design factors (geometry) and tyre quality (sidewall stiffness and tread depth) and on the load distribution on the truck (balance of load between the axle groups).

There is not much point in getting the wheel alignment checked on your truck if the bearings, joints and bushes are worn!

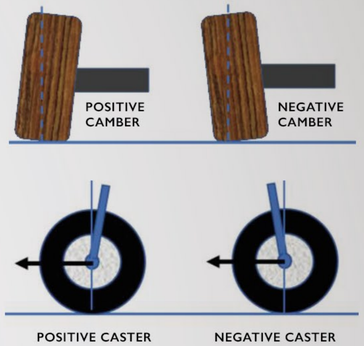
Assuming they are in good condition, there are three elements to front axle group alignment, which are: Camber, Caster and Toe.

Camber

Camber concerns the angle that the wheel plane makes with the roadway as shown below. For trucks, camber mainly affects tyre wear. Because roads are never flat and because the engine operation twists the chassis at the front of the truck, it can be advantageous to set the camber on each side by cold-bending the steering axles. There is some controversy about the best settings. Different values are proposed by axle benders for different states and regions! The bend must be outside the spring seat as otherwise the springs are twisted. Left wheel camber might be ¼ to 1½°. Right wheel camber is lower.

Caster

Caster is the angle between the kingpin axis (the steering axis) and a vertical axis when the steerable wheel is viewed from the side. Caster affects road tracking. Negative caster makes the steering light and prone to wandering. Positive caster makes the steering heavier and centrering. Typically, trucks have 3½ - 4½° of positive caster. Caster is adjusted by putting wedges between the suspension springs and the spring seat on the axle to rotate the axle away from horizontal.



Toe

Toe concerns the direction of the tyre with respect to the centre line of the vehicle when the steering wheel is in the straight-ahead position. It is crucial for good tyre wear that a neutral toe exists under driving conditions. Toe can be affected by suspension movement and therefore load level. Excessive toe-in or -out results in wandering steer when the road friction is uneven on the two sides. Toe is adjusted at the track road end. If the spring is not tightly clamped to the axle, axle movement can occur, which causes toe. Offset steering can also occur. It is undesirable because the driver must correct the direction with the steering wheel continually.

Note that rear axle group misalignment will tend to 'steer' the truck. Not all problems are at the front steering group.

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