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WELCOME

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. This newsletter is a free service intended to benefit racers and enthusiasts by offering useful insights into chassis engineering and answers to questions. Readers may mail questions to: 155 Wankel Dr., Kannapolis, NC 28083-8200; submit questions by phone at 704-933-8876; or submit questions by e-mail to: mortiz49@earthlink.net. Readers are invited to subscribe to this newsletter by e-mail. Just e-mail me and request to be added to the list.

TWIST BEAMS AND JOINTED DE DION TUBES

Continuing on the topic of beam axles, there was an interesting de Dion axle design produced by the Rover Car Company. It appears it was originally invented by Stewert Tresilian for Armstrong Siddeley. The design featured a pair of fixed length half-shafts taking drive from the differential to the hubs. The half-shafts located the hubs transversely and were responsible for a small amount of track width change as they moved through their fixed radius arcs.

The hubs were joined by a beam axle that passed to the rear of the differential, behind the rear wheel axis. The beam axle was split into two portions in such a way that each portion could rotate relative to each other. A joint between the two portions could accommodate this and was also able to accommodate some plunge (transverse movement) so that the beam axle did not fight the half-shafts. There were trailing arms from the car body to the hubs.

Where is the roll centre? It appears that the roll centre is located at the centre of the differential although it can move about a little. Is this correct? If so, I think this position is somewhat higher than ideal.

Loading the differential with lateral forces is not necessarily ideal either (although many manufacturers have successfully accomplished it). The approach requires large stiff bearings in the differential housing and the method of locating the differential to the vehicle body becomes an interesting design issue (usually needing a sub-frame). All told this is an expensive solution.

Despite the roll centre being non-ideal (a bit of a pain to locate on a drawing board for some wheel articulations and difficult to place in the most advantageous location) there is an interesting and desirable effect with this suspension system. In roll it appears that the wheels do not lose camber as the vehicle body rolls outward. They do not adopt disadvantageous camber angles but relative to the vehicle body they gain camber with roll so that they stay perpendicular to the road surface. This seems to be because the split beam axle can twist at the sliding joint.

Even a normal beam axle allows the wheels to tilt outwards with roll. There is a contribution from tyre deflection and axle roll (tyres and axle are a spring mass system and there is deflection). With the Rover this can be allowed for and tuned out I think. It seems this is due to the beam axle passing behind the rear wheel axis. Am I correct?

What is the relationship between the trailing arm length, wheel camber in roll and beam axle longitudinal position?

How can I lower the roll centre with this suspension? It would be better to have some freedom about where the roll centre can be located. What is wanted is a way to take the lateral loading through a link or linkage instead of the half-shafts and differential unit. If this could be done, then the issues pertaining to mounting and locating the differential with precision would be eliminated. Also there wouldn't be such a need for such large bearings etc. in the differential housing.

Do you have any comments on this?

In related investigation I've looked at the torsion beam or twist beam axle used at the rear of many fwd cars. At first they seem to be a bit of a cheap mess but there is more to it than that rather cursory view. They are a clever and subtle design when considered in depth. And there are plenty of new applications yet to be addressed. For example, the torsion beam lends itself to being used as a variant of the de Dion system and being employed at the rear of a rwd car. As far as I know this has not been done. Are you aware of any?

There are many fwd cars with the torsion beam axle but in every case the beam axle is placed ahead of the rear wheel axis line. This means the wheels will roll outwards from a turn in the same sense as the vehicle body does. So they lose camber with body roll. Surely it would be beneficial to place the torsion beam well behind the wheel axis? If this were accomplished wouldn't it achieve the same effect as the Rover two piece axle? That is, matters could be arranged so the wheels remained perpendicular to the road regardless of body roll.

Certainly it is true with both beam axles and independent suspension that there is roll due to tire deflection, and that the camber recovery with this component is zero. This also happens with no suspension, as on a go-kart. The magnitude of the effect varies with tire selection and pressure. Consequently, we cannot predict it just by knowing the suspension geometry. Merely to keep the complexity of the discussion manageable, I generally discuss camber recovery as if the tires were rigid. That way, we can discuss properties of the linkage in isolation.

But of course, ignoring tire deflection doesn't make it any less real. Not only would we like to be able to compensate for camber change due to tire deflection, we would like to tilt the wheels into the turn slightly with roll, because they make greatest cornering force that way.

There is no free lunch here, however. There is no way for a passive suspension system to distinguish between suspension roll (oppositional motion within a front or rear wheel pair) due to sprung mass roll, and suspension roll due to road irregularities. Reducing camber change in the former case inescapably increases it in the latter case. With independent suspension, to obtain better camber recovery in sprung mass roll, we must accept more camber change both in ride and in suspension roll motion resulting from road irregularities. With a beam axle or de Dion system, we do not have the penalty in ride, but we still have it in roll. That is, to get more than 100% camber recovery in roll, we must increase the already considerable camber change over one-wheel bumps. That is what the Tresilian design does.

The twist beams used in front-drive cars typically play the tradeoff the other way, and accept poorer camber properties in sprung mass roll in exchange for better camber properties over bumps. Also, when the twist beam is further forward, the suspension's properties change less when the inside rear wheel lifts off the ground, as it commonly does in front-drive cars during limit cornering.

The idea of allowing the de Dion tube to twist in roll is not unique to the Tresilian design. The Mercedes-Benz W125 also had a de Dion tube that could twist freely, with the twist joint behind the differential, and simple trailing arms running forward from the hubs. The Mercedes design differed from the Rover in that the de Dion tube was not allowed to telescope. The halfshafts accommodated plunge instead. Lateral location was provided by a roller on the de Dion tube, running in a vertical slot cast and machined into the rear of the differential housing. Since this was a race car, and noise isolation was not a concern, the diff was mounted solidly to the frame. Lateral force was reacted through the differential housing, but not through the differential bearings.

We should note that thrust loads due to cornering force always have to be reacted through a bearing, one way or another. If we do not put the load through the diff bearings, the wheel bearings have to absorb it instead, and the wheel bearings are unsprung. Therefore, there may be a rational case for making the diff bearings a bit heavier if that allows us to reduce weight at the outboard ends of the de Dion tube.

Now, where is the roll center in a twist beam system? It is not at the height of whatever provides lateral location, except in the case where the twist beam is exactly in the axle plane (the vertical, transverse plane containing the wheel axis).

To locate the roll center on a drawing board, here's what we do: in a side view of the system, draw a vertical line from the center of the trailing arm pivot down to the ground. Insert or establish a point where this line meets the ground. We're going to call this point A.

Draw another vertical line from the wheel center to the ground, and also upward a ways from the wheel center. This represents the axle plane, in edge view.

Draw a third vertical line through the twist axis of the beam or deDion tube. This represents the twist axis plane (the vertical, transverse plane containing the twist axis), in edge view.

Now find the lateral force coupling point between the twist beam assembly and the sprung structure. Note that this is usually not the roll center, but it is a definable point. In a VW Rabbit/Golf rear suspension, it is the trailing arm pivot. In the Rover system, it is the diff axis, or more precisely the inboard U-joint center. In the Mercedes W125 system, it is the center of the roller. Draw a horizontal line from this coupling point to the axle plane. Insert a point at that intercept. We're going to call this point B.

Draw a line passing through points A and B, long enough so that it passes through the twist axis plane. Find the intersection of this line and the twist axis plane, and insert or define a point there. We're going to call this point C.

The height of point C is the roll center height. In the Mercedes or the Rover system, point C will be above point B. In the VW system, point C will be below point B.

The roll center is a modeling abstraction. It is the effective force coupling point for lateral forces passing between the two-wheel suspension system and the sprung structure. It is always considered to be in the axle plane. So, to complete our work on the drawing board, we construct a horizontal line from point C to the axle plane, and that intercept is our roll center.

If we want to be really rigorous, in a rolled condition the Rover design has slightly different anti-roll properties for the inside and outside wheels, and overall anti-roll depends on tire lateral force distribution, as with independent suspension. For most practical purposes, though, I think we can safely ignore this.

It would be possible to put the twist beam or de Dion tube ahead of the diff in a front-engine, rear-drive car, but there are some packaging issues. The beam or tube has to have enough room to go up and down without hitting the drive shaft.

It is also possible to have a lower roll center than in the Mercedes or Rover designs, while still having the tube or beam behind the diff, and still having greater than 100% camber recovery for the suspension component in cornering roll. All that is needed is a lower point B. This can be obtained with any of the known lateral locating devices. The roll center will still be somewhat above point B, assuming point B is above ground level. With a Mumford linkage, point B could be below any point on the linkage, and the roll center could then be as low as you'd probably want it.