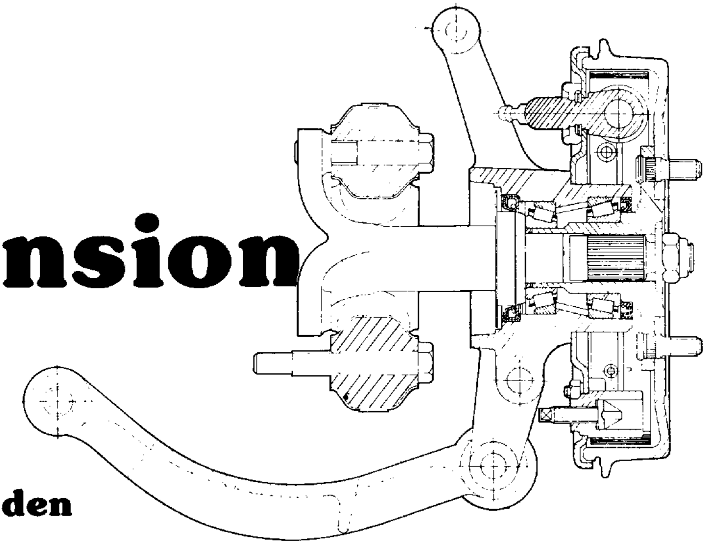
# Rear Suspension Talk



### C H Eickoff - Sweden

Another head scratching and thought provoking article from the pen of 'Power Curves and Differentials' fame, this time comparing Swing Axle and Rotoflex rear suspension systems.

*Brain in gear? Then into first....*

No car is better than its suspension system! Without it a car is just not a car and hence, accepting this premise, the beauty of the exterior and interior become relatively unimportant.

*So,*

*"JUST WHAT DO YOU KNOW ABOUT YOUR REAR AXLE?"*

During renovation jobs, I'm sure that many more Club members other than myself have asked themselves just why a particular part was made in such and such a way, or whether or not the design is truly definitive. Perhaps with some modification it could be designed better for improved performance and or for greater reliability? To this end, I have analysed the rear axle and suspension of 'our cars' and in doing so have been surprised about the design of some of the integral parts of the assembly. For why, read on.

Firstly, let's look at the original swing axle design employing a standard transverse leaf spring. For example, take the case of a saloon spring being made up of 11 leaves, each 45mm wide and 5.3mm thick with an associated spring constant of 38mm/kNewton, which in Imperial units means that the spring height is reduced by O.687in for every 100lb load added to the centre mounting point. Standing free and unloaded, the spring has an arch height of 165mm (6.5in). Hence in order to straighten the spring, a force of 4200Newtons (943lb load) needs to be applied. In this position, the stress in the spring amounts to 425N/sq mm . Although the quality of the steel is an unknown quantity, experience suggests that 650N/sq mm is the maximum repetitive stress value for the material. From a horizontal axle position, ie. zero degrees in the UJ, the axle is able to move 13 degrees down before it comes to rest against the chassis frame. Hence, in my opinion the spring stress rises over the maximum allowed by the time an 8 degree axle elevation occurs. The total axle angular movement, also here equivalent to the camber change, therefore amounts to 13+8=21 degrees. Incidentally, this figure has been confirmed previously in Turning Circle No.10, page 7.

These figures point to the main disadvantage of the swing axle system which is one of excessive camber change. This is most serious when the car is travelling on uneven roads where one wheel movement is different compared to the other as the rear axle drives the wheel which has the heaviest load at any particular moment. In contrast, an advantage of a swing axle suspension system apart from its low cost (an important consideration to all production engineers, and especially to Standard Triumph of the day -Ed) is that of its relatively low unsprung weight (ie. the mass of the car supported under movement including the weight of the wheel and tyre). Consequently, the tracking between the tyre and road surface is good. Unsprung masses for one side for both swing axle and rotoflex systems are given in table 1 below.

| Part | Whole Weight | Unspr.Wght -Swing Axle | -Rotoflex Axle |
|---|---|---|---|
| Leaf Spring | 14.05 Kg | 1.40 Kg | 1.40 Kg |
| Vertical Link | 1.28 | 1.28 | - |
| Hub Housing Incl. Bearing | 4.03 | - | 4.03 |
| Hub -Rotoflex Axle | 1.30 | - | 1.30 |
| Radius Arm Incl. Bracket | 0.655 | 0.33 | - |
| Radius Arm Adjustable | 0.955 | - | 0.48 |
| Swing Axle | 4.41 | 2.41 | - |
| Hub -Swing Axle | 0.915 | 0.915 | - |
| Back Plate | 0.92 | 0.92 | 0.92 |
| Brake Drum | 2.60 | 2.60 | 2.60 |
| Brake Shoes, Cyl. & Adj. | 0.80 | 0.80 | 0.80 |
| Outer Axle Shaft | 1.91 | - | 1.91 |
| Rotoflex Rubber Donut | 1.08 | - | 1.08 |
| Bolts for above | 0.54 | - | 0.54 |
| Inner Axle Shaft | 3.015 | - | 1.58 |
| Wishbone | 2.20 | - | 1.46 |
| Bolts, nuts | spec | 0.195 | 0.76 |
| Part of Shock Absorber | | 0.30 | 0.30 |
| | | 11.15 Kg | 19.16 Kg |
| Rim, steel 4½J | 6.35 Kg | | |
| Tyre | 7.65 Kg | | |

Table 1: Comparison of Swing Axle and Rotoflex Component Unsprung Weights

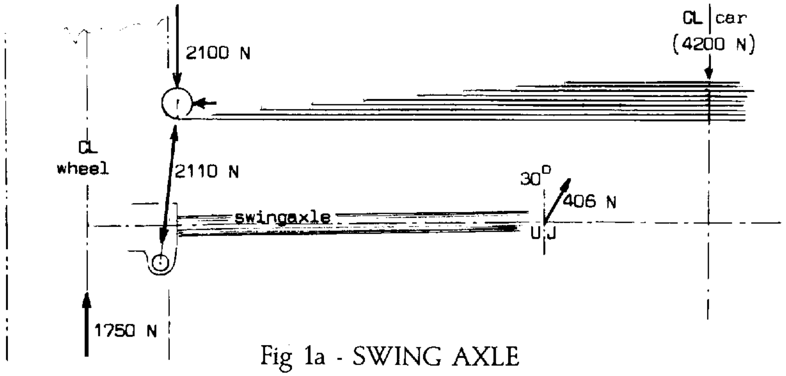


Fig 1a - SWING AXLE

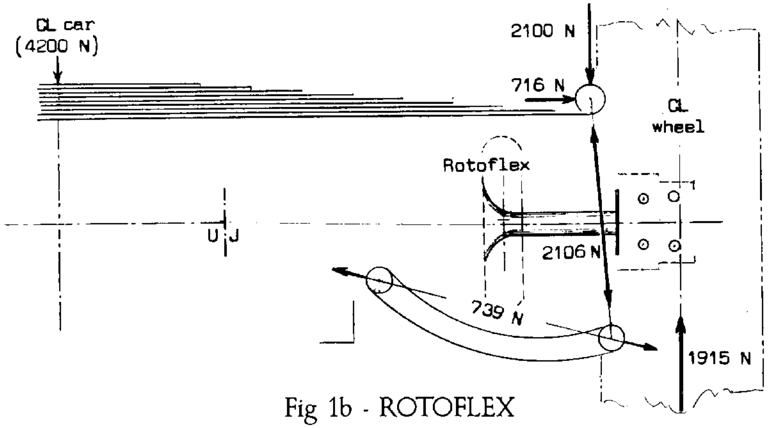


Fig 1b - ROTOFLEX

*Comparison of Swing Axle versus Rotoflex suspension systems. As shown and assuming the same spring is used for both, a greater wheel force is required to straighten the spring on a Rotoflex compared to a Swing Axle rear suspension due to the different 'lever arm' geometry involved.*

A comparison of swing axle verus rotoflex rear suspension systems is given in figures 1a/b. The measurements used being:

| | |
|---|---|
| Half length of leaf spring, straight | 523mm |
| Half track width | 609.5mm |
| Distance from car centre-line (CL) to UJ | 162mm |
| Swing axle length, UJ to wheel centre-line | 447.5mm |
| Rotoflex inner axle shaft length | 274mm |
| Distance from outer axle to wheel centre-line | 224mm |
| Wishbone angle for depressed straight leaf spring | 14.5° |

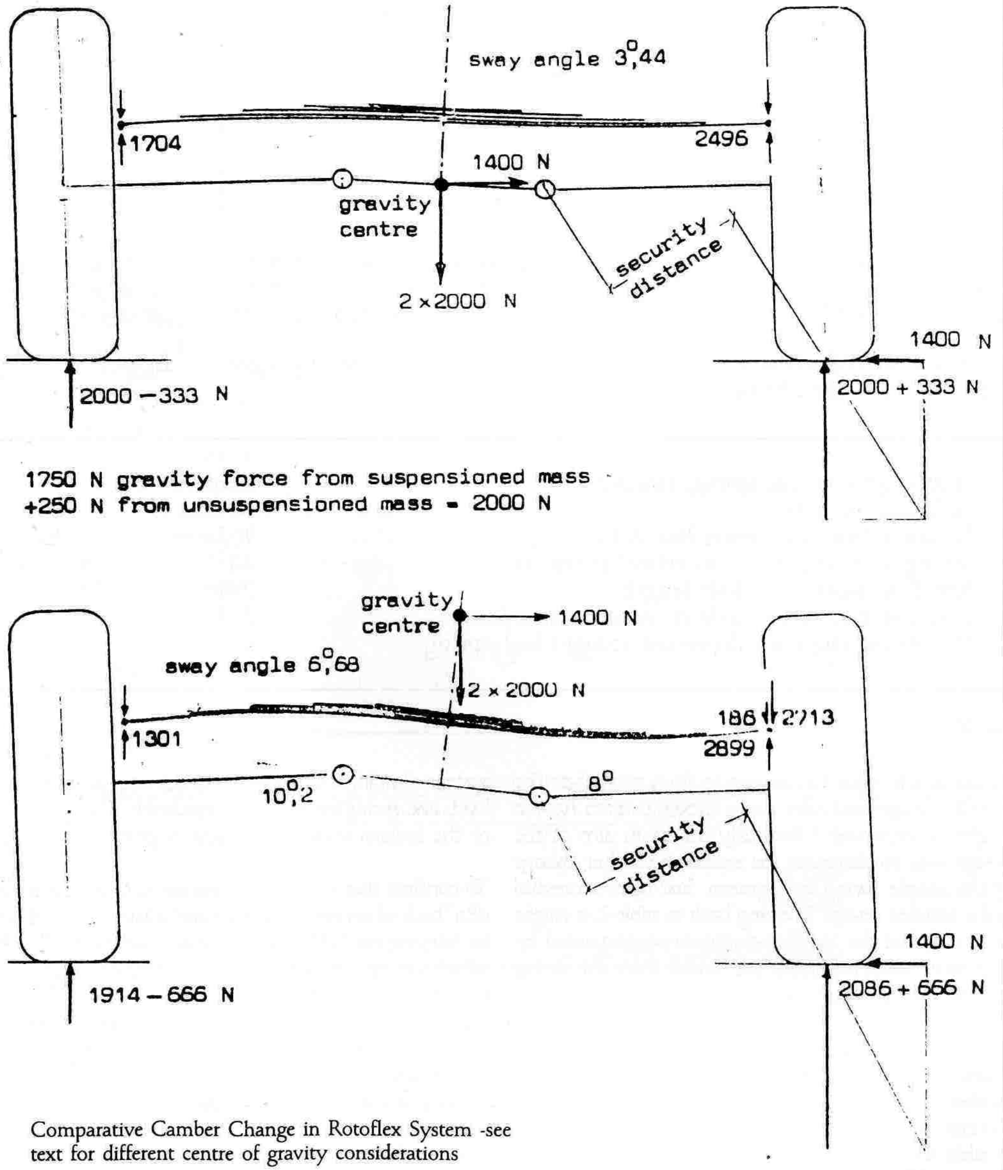
Table 2

In this article what I'm aiming to do is to analyse the rotoflex design and offer some thoughts as to how it might be improved. Obviously the main aim of the design was to eliminate the excessive camber change of the simple swing axle system. Just how successful is the rotoflex set-up? Looking back to table 1, it might be noted that the rotoflex design is accompanied by 8kg more unsprung mass per wheel than the swing axle design and that's a lot.

In the Turning Circle article referenced above, it was stated that moving to the rotoflex system reduced the camber change from 21 degrees to 7 degrees 21 minutes (60 minutes making 1 degree). That's not really true. Within the limit of the shock absorber, the 7 degree figure is OK, but compared with the movement up and down in the swing axle as giving 21 degrees camber change then the correct value for the Rotoflex system should be 10 degrees 20 minutes (comparable loads and spring forces being considered). The geometry of the system under movement is given in figure 2.

To confirm that my calculations are not just the result of a 'back of an envelope estimate', a friend helped out by bringing his GT6 around (chassis number KC77283) which we duly measured up. We can therefore establish that from the position of camber angle =0 degrees, 13mm of vertical wheel movement will give one degree camber change which corresponds to 10.5mm track divergence.

Looking at the system shows that the above suspension control can be done better. If the wishbone mounting point in the frame bracket is lowered by 60mm then the camber change over the same vertical wheel movement given previously can be reduced to 2.9 degrees. In the original design, a maximum axial offset i.e. an increase in the effective drive shaft length) of 6.6mm is taken up by the Rotoflex rubber. By lowering the lower wishbone mounting point, this offset can be reduced to 4.0mm. A comprimise leading to practically no axial displacement is possible if the wishbone mounting point is lowered by 44mm. The resulting camber change would then amount to 3.56 degrees, a fairly good value compared to the 10.33 degrees of the original set-up.



Comparative Camber Change in Rotoflex System -see text for different centre of gravity considerations

Fig 2.

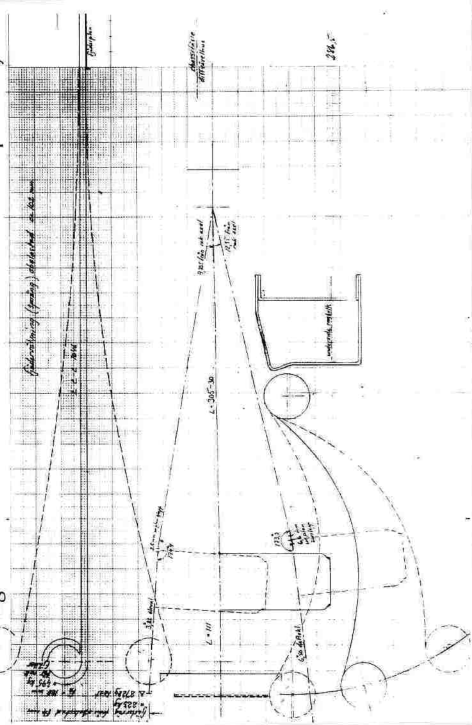


Fig.4 Limits of travel for a standard Rotoflex rear suspension system

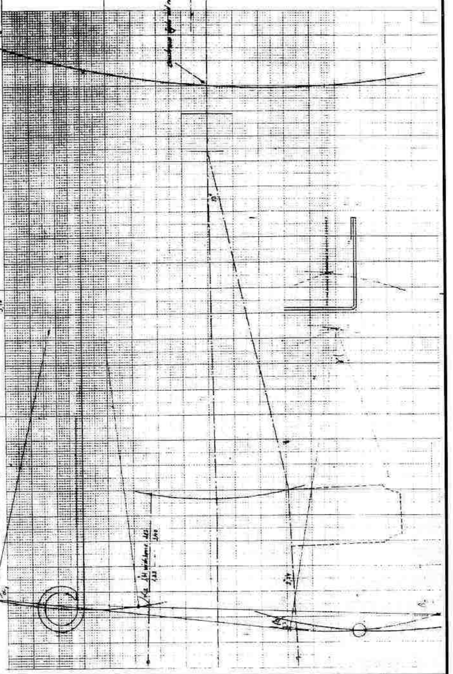


Fig.6 Limits of travel for a Rotoflex rear suspension system modified to give optimised drive shaft length stability :inner wishbone bracket lowered by 44mm giving a camber change of 3.56 degrees (cf. original 10.33 degrees) with a practically zero axial offset.

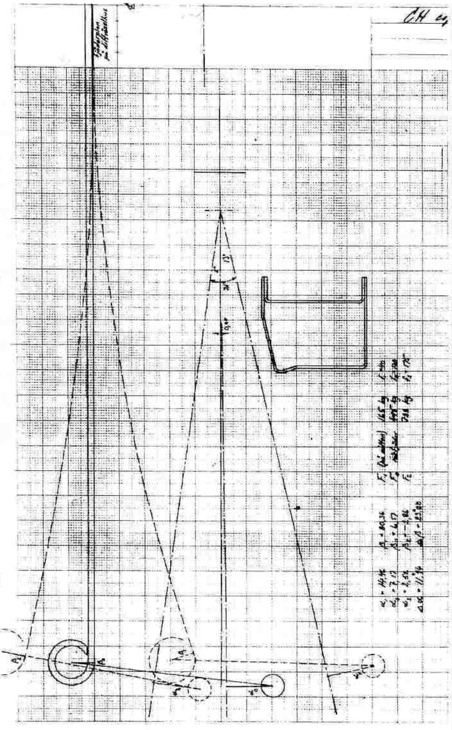


Fig.3 Limits of travel for the Swing Axle rear suspension system

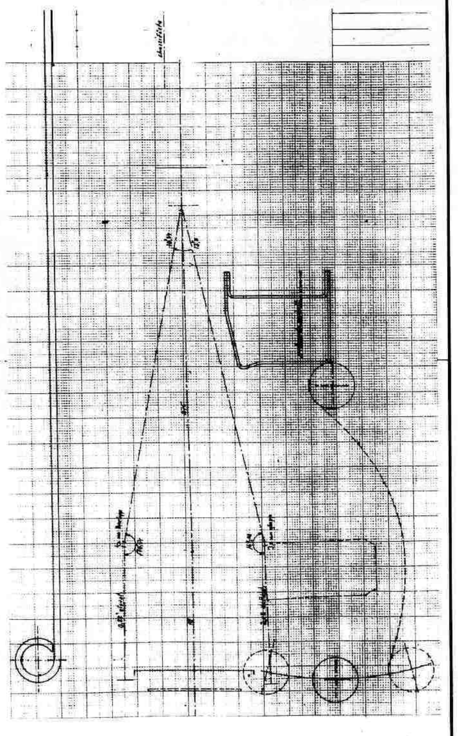


Fig.5 Limits of travel for a modified Rotoflex rear suspension system :inner wishbone bracket lowered by 60mm giving a camber change of 2.9 degrees (compared to the original 10.33 degrees) and an associated axial offset taken up in the rubber donut of 4.0mm (compared to the original maximum figure of 6.6mm).

## Universal Joint Considerations

The universal joint is also worth looking at. I think the size was selected for the first Herald having an engine giving a torque of about 75Nm (102lb.ft). In first gear, and assuming a back axle ratio of 4.55:1, the UJ has to transmit about thirteen times this amount to the wheels. The joint manufacturers specify that for a life of 2500 hours, only 350Nm can be transmitted at 350 rpm. Shocktorque is the limit for a sharp impulsive force and this is stated to be 1130Nm. Deformation comes at around 1800Nm. We might imagine that the Standard Triumph chassis designer knew that the joints could only have a long life with a careful, very smooth driver -no racing away at traffic lights! This is OK in some respects but not in others. From figure 1(a), it can be seen that a radial force acts on the UJ which it isn't designed to withstand ie. it can carry the dead weight from its own axle but no more. In 'our cars', the swing axle design causes the bearing cases in the UJ to be compressed continously with a 400 Newton force leading to the usual consequence of having to renew the UJ fairly regularly. With later cars with their larger, more powerful engines, it's litle wonder that UJs have a problematical life.

## Rotoflex Wheel Bearings

Let's now look at the wheel bearing within a Rotoflex driveshaft. The accompanying diagram (Figure.7) shows the layout with the very closely arranged roller bearings, hub and its fixture to the outer axle shaft.

A lateral pressure from fast cornering must be taken up in these two bearings and I will comment on the forces involved a little later on. The inner smaller bearing (LM67010-LM67048) is specified as being able to take a maximum dynamic force of 31,400 Newtons and a static force of 26,000 Newtons. Following this data, 3,500N will be the maximum static side force on the tyre. That means that if you overturn the car, leaving it standing with its whole weight on the wheels on one side, then the bearings in the rearaxle may be damaged. Perhaps not surprising really. Driving a Vitesse on two wheels is definitely not recommended!!

Following on, the hub detail supports the inner bearing race. The hub and axle are joined by the use of push fit splines, 12mm in length. The push fit is very strong as, with the difference in width between hub and axle diameters being 45 microns (ie. the drive shaft diameter is that much wider), a force of at least one ton is required to press the hub into position. This fact makes it impossible to adjust for correct bearing play. The hub will be expanded and the inner race of the inner bearing is immovably fixed on the hub surface. I have no solution to offer, except to carry out a radical redesign. The Triumph people tried to do it for the 2000 model, the play there can be reduced but not increased if necessary. On my own car I have reduced the 45 micron diameter difference to 15 micron.

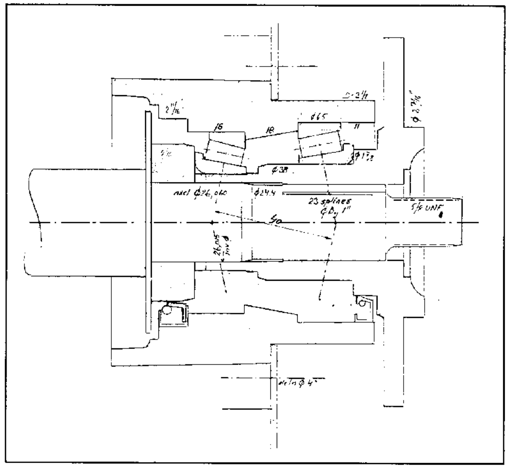


Fig 7.
Schematic of Rotoflex Rear Hub/Wheel Bearings Unit

## Nylon Suspension Bearings

Another item on the list for improvement is the nylon bearing between the wishbone and the vertical link: inexplicably named 'trunnion' in the spare parts list. Even, well greased, the bushes have a tendency to bind and it is not difficult to explain considering the different thermal expansion coefficients of polyamid versus steel:- (102 vs 11.5).10exp-6/Kelvin.

*(For general information, Kelvin is THE absolute temperature scale which defines absolute zero as its 'Zero degrees'. A difference in temperature of 1 Kelvin is however exactly the same as that of 1 degree Centigrade or Celsius. It's just that the Centigrade system has the freezing point of water as its 'Zero' which is equivalent to about plus 273 Kelvin -Ed)*

A 0.05mm play between bush and spacer tube is eliminated at a temperature of 23 degrees C less than the temperature at which it was put together so on a cold winter's day, binding is inevitable. The angle that the wishbone moves in the frame bracket is a little more than 30 degrees and the correspomding movement between the wishbone and the vertical link is less than 21 degrees so why aren't the Metalastic bushes used on the inner sleeves also used in the outer end of the wishbones? From the Metalastic catalogue, I've shown the data for the 13/1239 bush used, the ultra duty bush used in the leaf spring eye and also the bush used in the radius arms and front axle suspension.

| Part No. | A | B | C | D | Torsional | | | Axial | | | Radial | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **METALASTIC** | | | | | Rate | Max. Tque | Defln. | Rate | Max. Load | Defln. | Rate | Max. Load | Max. Defln. |
| | ins.dia. | ins.dia. | ins | ins | lb.ins /rad. | lb.ins. | deg. | lb.in. | lb. | ins. | lb./in. | lb. | ins. |
| 13/773 | .437 | 1.000 | 1.750 | 2.000 | 480 | 120 | 14 | 3,350 | 200 | .060 | 60,000 | 900 | .015 |
| 13/1309 | .375 | .812 | 1.125 | 1.437 | 225 | 55 | 14 | | | | 30,000 | 450 | .015 |
| 13/1239 | .500 | 1.000 | 1.375 | 1.750 | 500 | 125 | 14.5 | | | | 64,000 | 1,100 | .0173 |

The wishbone bush specified is used over the deflection limit as shown. Using the same bush in the outer end should not cause problems. The maximum radial load on the inner wishbone bush corresponds to 2800 Newton side force on the tyre and the deflection in the two outer bushes is then 0.2mm: nothing to speak about. I decided to use the bush mentioned. A longer bolt and two small levers to bring about a friction suface on both sides of the bush-tube was the only alteration needed. On this occasion I will emphasise the imperative necessity only to tighten up the bolts through the bushes in the middle position of the moving angle.

## Roll Angles

By cornering fast in a car having a swing axle rear suspension like the Triumph Herald, the risk is that the combined force arising from the horizontal friction force exerted between tyre and road (centripetal force) and that of the gravitational force acting through the wheel will result in a force with its direction passing under the universal joint (causing the dreaded tuck under). It is too complicated to illustrate all imaginable positions as load and hence initial axle angle, centripetal force and the height of the car's centre of gravity are all variables. I have therefore chosen one proposition with two centre of gravity heights.

Data as follows: a load on the rearend giving a straight leaf spring as mentioned before, a centripetal force 35% of the gravitational force and centre of gravity heights equal to or alternatively twice that of the height of the wheel centre above the road. Here we're assuming that only the outside wheel has friction against the road. For example, in a 29 metre radius corner, the centripetal force mentioned comes up at a speed of 10 m/s (22.4mph) or for a 182 metre radius corner at 25m/s. The two figures show the forces in action anf their effect on the 'sway' or roll angle. The fact is that a larger roll will give safer cornering!!! So what is the effect of an anti roll bar? On my Vitesse, I have a 17.5mm diameter bar and I have calculated its influence to 15% of all 'antisway' forces. By one degree side declination on the car, the stabiliser increases/reduces the front wheel pressure by 136N.

My conclusion is that with swing axles, it is better having no anti roll bar stabiliser on 'our cars'. An increase in roll from, for example, 2 to 2.35 degrees is difficult to feel, but smoother suspension in the front axle is perceptible. With a stabiliser, the front suspension is in reality not independent, without the torsion bar, shocks are not transmitted from side to side. There is some consolation in that the centripetal force, giving an axial pressure on the UJ in the rearaxle, increase the resulting force on its needle bearings very slight

However, in spite of all the critical judgments I've made....

I Like my Vitesse. ★