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## Sorting out the GTD Suspension from Scratch, Part 3

### Anti Roll Bars - Part Two

Now imagine a neutrally handling car (i.e. the same level of grip at front and rear) in a corner on the absolute limit. If you could instantaneously add an Anti Roll Bar at, say the front, what would happen?

Because of the roll angle, the Anti-Roll bar would be under considerable load, so much of the remaining load on the inside front wheel would be transferred to the outside front wheel. The inside wheel is now loafing, under relatively little stress. The outside wheel, which was previously on the limit, is now over it and begins to slide at the front. The rear wheels are still OK since there is no Anti-Roll bar transferring load, so it continues to grip well. The result is, the front wheels can no longer generate as much in the way of cornering forces as they have lost grip, but the rears are still gripping, net result, the car tends to go straight on, in other words, understeer a la Mini.

In fact this is an over simplification, as the Anti-Roll bar would reduce the roll angle of the whole car since the total roll stiffness has been increased, and there is less weight transfer at the **rear** as a result of the **front** anti roll bar.

The inside rear would experience an increase in load due to the Front Anti-Roll bar and the outside rear a decrease in load. Hence the rear wheels actually share the load better and therefore are working better than without the front Anti-Roll bar.

The effect of the Front Anti-Roll bar is to transfer weight from the inside front to the outside front, but also transfer weight to the rear! This is the explanation for the pictures you may have seen of rear wheel drive cars (especially Porsche 911's) on the limit with the inside front wheel off the ground altogether, in this case obviously the whole weight of the car still has to be supported, but this is being done by only three wheels due to weight transfer. In the case of the Porsche, with the overhung weight of the engine at the rear, if rear grip is lost in a corner, inevitably the momentum of the

rearward weight will take over , so keeping rear grip is **VERY** important on the Porsche, and front grip is sacrificed by having low roll stiffness at the rear, and higher at the front.

With powerful mid engined cars there is another issue here. Unless you have a limited slip differential, the level of grip on the lightly loaded inside rear limits the power you can apply in a corner. Hence in this case it is desirable to optimise the front to rear grip balance in favour of good grip at the rear in order to be able to use power when cornering.

## **Chassis and Spring Stiffness**

The ideal situation to have with a car you wish to improve the handling of is that you can optimise the behaviour of the suspension at front and rear, without changes at one end affecting the other (except via the mechanisms described above, which requires a stiff chassis to provide a stable predictable platform), and then make fine adjustments with anti roll bars.

This is why chassis stiffness is so important in a racing car, without a stiff chassis, you can't play these games as the front and rear suspension will interact in a complex way due to the chassis twisting, and the effects of adjustment will be difficult if not impossible to predict.

It doesn't mean the car can't be made to handle well, but it will be much more matter of trial and error to get the overall behaviour of the car you want. An example of a less than ideal chassis from the stiffness point of view was the original rear engined Cooper Grand Prix car.

It broke many of the rules of chassis design, by joining load bearing tubes at the middle of their length instead of taking loads into triangulated stress points.

As a result, Willie Green in his book of classic car tests, describes the handling as "wilful" as it was in the habit of picking up wheels off the ground at inopportune moments, but the car got the job done!.

The stiffer the springs you want to use, the more important chassis stiffness is, because the higher the roll stiffness at each end, the bigger the loads put into the chassis by the suspension will be. In the ultimate situation, with very stiff springs, the suspension will not deflect and the compliance necessary to conform to the road surface will come from the chassis. Cars like the big racing Bentley's were designed to do this, and chassis flexibility was part of the handling package, but they did not use 35 profile tyres which had to be kept flat to the road!

A good rule of thumb is the chassis needs to be roughly 10 times stiffer than the springs for the effect of spring changes to be predictable. I hope to measure the torsional stiffness of the chassis soon when its off the road, but the general view is that the GTD design is OK, and capable of good handling and road holding but will begin to twist if racing springs are used, e.g. in the 500 lb./in region. Hence my approach of trying to get the suspension to keep the tyres flat to the road, and the movement supple to get good grip rather than solving the suspension geometry problems by restricting movement with stiff springs.

People seem to associate good handling and grip with stiff springs, but do you remember the little Lotus 25. It out handled everything in its day, because the novel monocoque chassis was so stiff, they could soften the springs compared with the similar

space frame Lotus 24 and hence keep the rubber in better contact with the road. With stiff springs the wheels bounce around and are in less good contact with the road.

I was pleased to see in a letter in the Xmas issue of the GTD magazine, that Tom Gollan had read episode one and wanted to know why chassis stiffness was important, I hope this helps Tom! I agree that stiffening springs willy nilly is not addressing the main issue.

### **Putting it all together**

Based on the above thinking, my approach has been

- 1) to stiffen the springs to the point where ride is still OK, just , for the road
- 2) control what is left of the roll with the roll bars and
- 3) make the suspension do the best job of dealing with the resulting degree of roll
- 4) fine adjustments in front to rear grip is then done with the anti roll bars with the emphasis on maintaining rear grip as far as possible, in order to retain traction.

The balance I have aimed for is a car which when cornered on the limit, but at constant speed, it understeers. This means that there is more grip at the rear than at the front, the front tyres therefore operate at a higher slip angle than the rears to generate the required cornering force. This can be achieved by a variety of set ups, the best would be that the front to rear weight distribution of the car, and the grip potential of the front and rear tyres are in such a proportion that the fronts are having to work a bit harder (at a greater slip angle than the rears). This is ideal because it means that all the available grip on all 4 wheels is used. This is better than deliberately forcing a car to understeer with a stiff front roll bar which brings about understeer by sacrificing grip on the inside front wheel, but is difficult to achieve.

So why does one want a car that understeers basically, surely the fastest cornering would be achieved by having maximum grip all round.?

I can give two reasons.

- 1) a car that is really neutral in grip balance between front and rear will be difficult to drive as it will reach the cornering limit at the front and the rear at similar speeds, and then will let go at both ends having given little indication of having been near the limit. In other words , it is difficult to drive, especially for the amateur driver.
- 2) a neutral handling car would corner faster, but only at constant speed in the corner. This is because if you apply any power at the rear, the rear tyres now have extra work to do, will adopt a higher slip angle, and the car will oversteer. By having the grip balance in favour of the rear, the maximum steady speed in a given corner will be slightly slower than for a neutral car, but the trade off is that we can get all that lovely grunt working on the exit from the corner, and actually reach a higher speed on

the straight. In low powered cars, a more neutral grip is the better choice, and there is not enough grunt to change speed in the corner much anyway, not a problem we have, thank god!

Since the grip of the rear tyres can be used in a corner for generating cornering forces, and acceleration, within the limit of the tyre, there is a trade off, the more grunt you want to use in the corner, the less is available for cornering, and the higher slip angles you will provoke.

But if the car basically understeers as per my proposal, this means that we have grip to spare at the rear, which we can use to apply some power without provoking high slip angles.

In other words, the car can be made to understeer, be neutral, or oversteer by controlling the amount of throttle applied, which controls the slip angle of the rear tyres by giving them more or less work to do.

This results in a car which gives a clear change in behaviour as the limit of grip is reached, and where it can be balanced in a corner by controlling the throttle. Bliss!!

That in a nutshell is why Anti-Roll bar's need to be adjustable

## **Results so far**

The process described in these three articles took place over most of last year's track day season, and it was late in the year before I got the whole package together. I had to change tyres as well because the old ones had worn asymmetrically because of the poor camber control, and I couldn't get the same sizes again as they had been discontinued, so I had to go up to 17" wheels as well, all of which took time (and some beer tokens!).

There was a couple of minor "settling down" track sessions before I got in one "all day" track day at Brands Hatch Grand Prix circuit. It was what my father calls "a wet day with no rain". Dingy, the occasional hint of damp/drizzle but the roads never got wet or bone dry either.

The car felt so different, much more secure at the rear, that it took me a while to explore the limits and in fact I'm sure that I was nowhere near the ragged edge as the car didn't hint at doing anything untoward even when provoked by my having to take avoiding action.

One of the things that really hacked me off was the way those bl\*\*dy "seven" things used to out corner me. Not any more. I was able to hold on to them in the corners for the first time, with the exception of one driven by Patrick Watts, which I wasn't too upset about in my first real session with the new suspension. I was able to hang on to them in the corners, and leave them, for dead on the straights, just as it should be.

On one occasion I was circulating on my own, trying to get used to the car, when I realised I was slowly catching a pair of race prepared Escort Cosworths who were having a bit of a dice. One then puled into the pits, so the other carried on and got his head down. I still gradually caught him, although he was clearly trying, and eventually I passed him in Surtees. I was fairly close along the Cooper straight, and the Escort lost the rear, not dramatically, but the tail hung out so far (too much boot too soon) that he lost a lot of momentum. I just tightened my line, and went past on the inside, outstanding!. I did the same to two Ferrari F40 road cars (one at a time!), holding a tighter line through Surtees, gradually pulling them in until we were dropping into Pilgrims Drop, when they reached peak revs and had to change up, whilst the Chevy was still pulling strongly, and took me past.

Its a nice feeling to hold your own with a £200,000 car in a car you have made , and developed yourself.

None of which is conclusive, but I am absolutely certain that I couldn't have done it with the car in its previous condition, and I think the result so far hint at the possibility of much more to come this year.

Some of you may have seen the car on Top Gear last October, at Oulton Park. Whilst there, Calum Lockie, an experienced racing driver who runs the Gold Track Club with Melindi Scott, drove the car.

This was with the old tyres still on the car, but with all the mods. The tyres were old, hard, and worn on the inner shoulder due to the excess negative camber in bump on the rear. Despite that Calum says that it was one of the best handling road cars he'd driven. At the time, we were overtaking a Lotus Esprit turbo 300 at Old Hall, round the outside !!, and the Lotus was trying.

So that's an encouraging data point to put with the Brands Hatch result. things came to a grinding halt, literally, at Donington a couple of weeks later as I sheared the first motion shaft in the gearbox.

I selected 5th going under the bridge on Starkeys straight, and when I put my foot down, there was no drive. I believe its failure was connected with the suspension mods, because before the mods, the grip on the rear was not that good, and if the engine and wheels disagreed about the speed, the wheels just chirped the problem away.

Now the tyres don't slip, so if the engine and wheels disagree,, the gearbox has to mediate, and is no longer strong enough. There was no point in just replacing the shaft, as there was nothing wrong with the old one, so a new one would also fail the same way, so that was me finished for the year, very frustrating as I wanted to get to grips with the new handling. Instead, I spent much time over the winter designing a new heavy duty one piece shaft for the Renault box, with some new gears and a higher ratio for first, and also dry sumping the engine to get rid of the oil surge problem brought on by the new higher level of cornering and braking forces. I'll let you know how the gearbox mods work out if Tony lets me, after this diatribe!.

## **Conclusion**

Overall, very encouraging so far. I have learned a great deal about practical suspension set up, some of which I hope I have communicated to you, and almost all of it applicable to the GTD 40.

I don't want to change anything else on the car until I have got to grips fully with what the car can do now, and develop my driving skills, which was one of the reasons for building the car. I will report progress at the end of this season so see how it worked out, see you on the track!.

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