Sorting out the GTD Suspension from Scratch

(with apologies for the title to Roy Smart!)

Introduction

When I read Roy's articles about building the 302, my first thought was that I wish I'd read it before I'd built mine! My next thought was to realise that I was in the early stages of doing something similar on the suspension of my car, and perhaps this might be useful to others who might benefit from my ab initio attempts to understand and improve the handling of my car.

Not that I claim to be an expert, far from it, but having read all the books I can lay my hands on, I am convinced that this is a subject which the professionals like to keep an air of mystery about . As a result of the reading, working on the actual suspension and a lot of head scratching, I think I am slowly beginning to understand at a pragmatic level what goes on, and its this learning process which I propose to describe. That's enough waffle, lets get started!

Background

First of all, I'm a member of the club under slightly false colours as my car is a GTD Lola T70. However, from a chassis point of view , it is closely related, and the suspension components are I believe, identical to the GT. 40. My T70 hadn't had as much development as the 40 because it has been made in far smaller quantities, (mine is virtually identical to the original "yellow peril") but the principle and most of the details will apply directly to the 40.

I built the car for number of reasons which will apply to many.

The first was that when I was a teenager, the T70 was the car of my dreams, so as a "grown up?" I still wanted one.

Secondly, I enjoy making things, but my job had evolved to the point where I was flying a desk, and the car was an interesting long term project to keep my hands busy and my mind sane? during the stresses of the recession .

Thirdly, I wanted to learn to drive really powerful car, not the mass produced stuff we all know.

I started the car in March 1990 and had it on the road with a small block Ford in 1993, but when the hardware to connect a small block Chevy became available, I built and installed one in the Lola. The extra oomph was too much for the Granada brakes ,so I fitted the Alcon front callipers. So now it was quick in a straight line, and stopped well, so I had the confidence to start pushing it on the track and had to deal with the wiggly bits, which brings us to the suspension and chassis.

The problem

Initially things went well but as I went quicker in the corners, it gradually became clear that the front was well behaved but at a certain cornering force, the rear stepped out suddenly leaving very little opportunity to catch it before it spun. The cornering speeds at which this happened were not that high, I was being overtaken by Golf GTi's etc. who could corner faster than I. I felt that this was wrong because :-

1) it offended my pride
2) a mid engine car with wishbone suspension should do better!

I initially though this was down to me and the way I was driving, was I trying hard enough?, was I doing something wrong?.

I tried to understand what was happening by reading up on suspension theory, the dynamics of cornering cars, etc. This didn't help as much as I'd hoped because there seemed to me to be a lot of ill defined jargon, and arbitrary assumptions concerning the readers knowledge which made the books difficult to apply to my situation.

As a result, I have made progress, not by applying the theory to the problem and solving it, but by practical work on the car trying to understand what it is doing in the corners.

This has helped me to understand at a pragmatic level what was happening, and basically in this series of articles I hope to explain in plain English what I have learned in a way which you may find helpful, or at least vaguely interesting.

A valuable input to this process has been the opinion of expert drivers such as Paul Radisich who have driven the car. Their input was combined with my lap times improving to a modest level and then not improving, (because if I went any quicker, I spun!)
If someone like Radisich says it "on a bit of a knife edge", it makes you think two things
1) its not just me
2) why is it twitchy on the limit?

I asked several professional drivers who had driven the car and they were fairly unanimous "the front is good, but the rear is poorly controlled, stiffen up the rear springs and roll bar".
I think the thinking was that the lack of rear grip compared with the front was due to lack of consistent contact of the tyres with the road.

In other words**, Oversteer** just means that the front grips better than the rear, so the rear tyres generate less corning force at a given angle to the direction of travel than the fronts, so they adopt a greater angle to the direction of travel (the tail starts to hang out) and eventually start to slide (spin) while the fronts carry on gripping.

Understeer is the opposite.

This also explains why I have spun a number (no I'm not saying how many) of times, and usually ended on the inside of the corner ,facing back the way I've just come. This is because the rear has come round and steered the front, still gripping well, so the car has turned a sharper corner than was intended.

Since I now understood that, the cure was either to reduce grip at the front (counter productive, it wouldn't spin, but would still corner slowly) or increase grip at the rear. The latter is obviously the way to go as maximising the cornering forces the car can develop will increase cornering speeds.

So I resolved to maximise grip at the rear, and then balance the car by adjusting the front grip as necessary.

Starting Work!
As winter was now approaching, I took the car off the road and put it up on axle stands to change springs, roll bars etc. as suggested.
One evening , I had the rear body off, so the rear suspension was exposed in all its glory, and had the wheels, springs and shocks off. I had a trolley jack under the rear upright to take the weight off the spring so I could remove it ,and had left it in a high position. I walked away from the car to the workbench to get a tool, and when I turned back to the car ,it was clear from the more distant viewpoint that the wheel was canted inwards at the top (negative camber, positive camber is the wheel leaning out).
I measured the camber angle, it was 6 1/2 degrees!, which is a lot with a 275 mm wide tyre!. At this point, I was sitting on the floor with the upright in front of me, and the removed wheel leaning against the car , to one side. I thought "if the wheel leans in that much in practice, it should show in the way the tyre has worn, so I turned my head to look at the wheel, and it was worn a lot more on one shoulder than the other, but it appeared to be the outside shoulder, not the inner you would expect from the wheel leaning in too much. That was that theory canned!
At this moment the wife came in with liquid refreshment, so I got up to take the drink, when I realised that I had turned the wheel round when I took it off, the inner shoulder **was** badly worn, so the car was running on the inner shoulder at some stage.

This raised the next question which was, what was the camber through the operating range of bump and droop of the suspension? I measured it next and the result was:-

This means that the tyre is working OK at nominal ride height (approx. 1 degree negative) but in a corner, as the car rolls outward the wheel is rolling inward even faster, so the contact patch of the tyre is getting smaller, when you need it most!

This seemed to me to explain why the car handled OK at moderate cornering forces, but gave up suddenly once roll angles became significant.

I decided at this stage, based on the above findings, plus what I had read, that a good initial and purely pragmatic objective would be to **keep the outside tyre flat on the road when cornering** so at least most of the tyre was working. (This is not a bad approximation for road tyres, but won't get the best from slicks etc.)

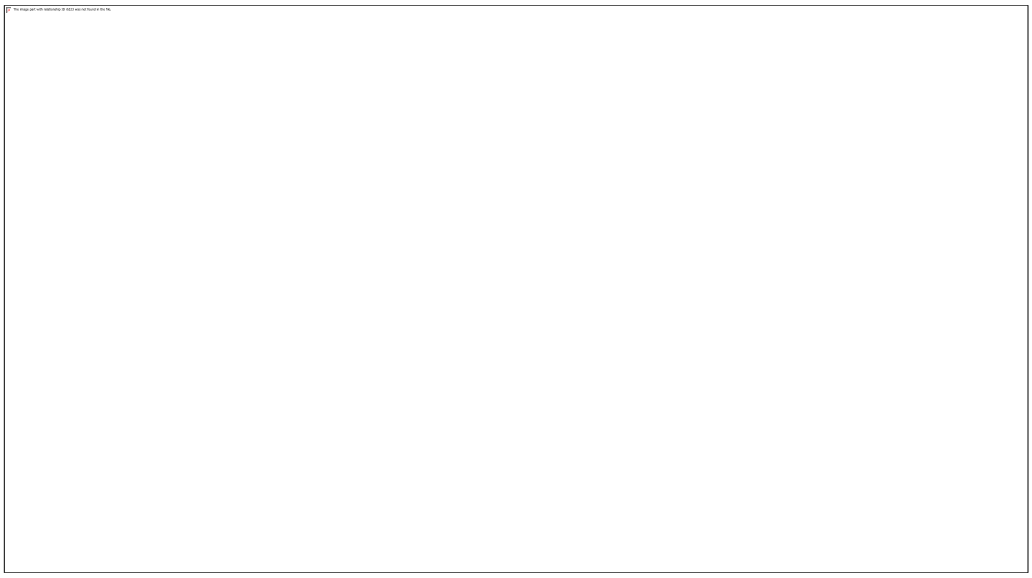
Having started this exercise because of the suggestion that the rear springs and roll bar needed stiffening, I now came to the conclusion that whilst the professional drivers assessment was that there was not enough rear grip, that the reason for this was not lack of control, but incorrect geometry, and that changing springs would not directly address the root cause of the problem. Stiffening the rear suspension would help by reducing roll angles, but on a road car , F1 levels of suspension stiffness is not a practical solution. Hence I decided to try to improve the geometry.

Having found this problem, I decided to check the front as well, by measuring the camber curve with the following result:-

This is better than the rear with less pronounced camber variation, but I needed to know what sort of angles the car adopted in corners. Fortunately I had a few still photos taken on the track which showed that I was getting at least 4 degrees of roll. It was also possible to see, once one knew what to look for, that the front outside wheel did not have enough camber to keep it flat to the road, and that the rear was leaning in at a pronounced angle, which confirmed that diagnosis that the rear camber went negative too fast, and the front , not fast enough to make the best use of the tyres.

I also found when I removed the front suspension, that the upper front wishbones appear to be handed, but that my car had two of the same type, so the upper front mounting brackets were fixed in quite different positions to get the castor the same on both sides!

For the sake of completeness, I also measured the rear toe in, and how it changed with the two alternative trailing arm pivot points. It is important to avoid toe out (positive numbers) when in bump on the rear, because this means that the rear wheel is trying to steer the rear of the car so as help the rear to run wide i.e. tighten the corner which means to introduce oversteer. On the other hand too much toe in means that the rear wheel in bump will try to cancel out the front wheel steering, and introduce understeer.



I decided that as I was going to lower the car a little, the upper mountings were OK, as a sensible objective was to try to have moderate and stable toe in over the usable suspension travel, especially in bump. In the lower position, the toe in is disappearing at large bump deflections.

One other observation was that when one just had the wishbones and uprights moving without springs and dampers, it was surprising how resistant to movement they were, in the direction you wanted them to move, and yet how squishy the whole thing was, especially when the moving parts were usually pulled out of the rubber bushes natural position in order to connect the components together, due to minor misalignments.

Next steps

I decided that the problems discussed above were likely to be substantial contributors to the problem I was having, so I resolved to modify the suspension to try to solve them as a first step, and then see how the car behaved.

So the list of actions was :-

1) Modify the rear suspension to reduce negative camber in bump

2) Modify the front suspension to increase negative camber in bump

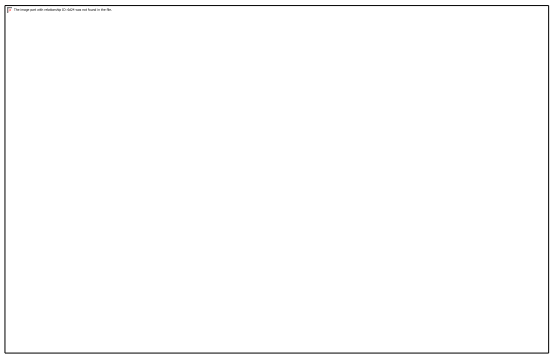
3) ensure that the suspension movement was free to do what I wanted, and not free to do anything else, by Rose jointing the whole thing.

4) lower slightly all round to reduce roll forces

Rear suspension Camber

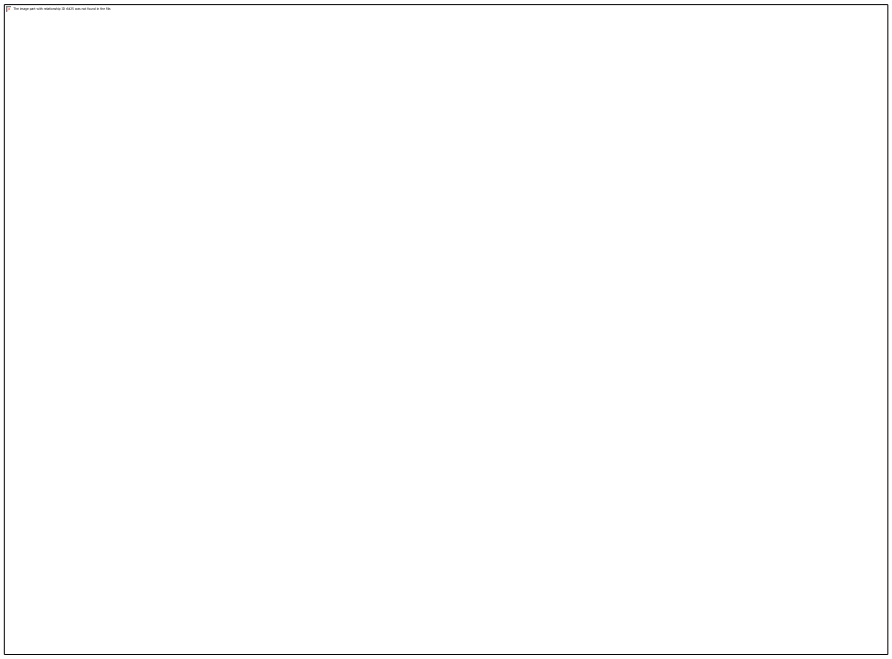
The non parallel, unequal length wishbone system is more or less universal in racing cars. typically the lower wishbone is longer than the upper, and is normally parallel to the ground at normal ride height. this means that when the wheel moves up and down,

the lower pivot of the upright is moving approximately vertically, with very little movement with respect to the centre line of the car.



The upper wishbone is normally shorter than the lower, and is pivoted so that the chassis end is lower than the top pivot of the upright. This means that in bump, as the top of the upright is moving up, the circular arc of movement about the chassis pivots pulls the top of the upright inwards, i.e., camber goes negative. Changes in length of the wishbones does very little, but moving the upper pivot strongly effects the rate at which the camber goes negative.

By jury rigging various lash up pivot points I obtained the following results.



The web mentioned on the graph is the one which braces the current upper wishbone mounting plate on the chassis to the rear chassis upright . As you can see, it got in the way and prevented me from trying intermediate positions

I came to the conclusion that a position between those above and below the web was about right, less than 2 degrees of camber change for the above position was too little, but 4 perhaps too much if I was going to change roll angles as well, so I decided that half the previous values was about right, and decided on about 3 to 3.5 degrees.

Now I can weld, sort of, but blobbing together a couple of bits of mild steel to make an unstressed bracket is one thing, welding critical stressed components like wishbones is another, so at this stage I decided to get the metal work done professionally. I removed the suspension components and took them away to get the mod's done and Rose joints fitted.

How it all worked out is the next thrilling episode.....!