Measuring and Correcting Bump Steer on a Caterham 7 Using Cheap Home Made Gauges.

by Paul Deslandes

Introduction

The first thing to say is that none of the following is particularly original apart, possibly, from the use of the Excel plots of measured data to extrapolate to the correct final shim thickness. The information and underlying design of calibration gauges are unashamedly plagiarised from a variety of sources including Blatchat and authoritative books on the subject of suspension design and set-up. For far more in-depth treatise on bump steer and, indeed, the whole subject of suspension design and adjustment, you can refer to the books acknowledged at the end of this article.

So why write about it again?

Fairly early in my '7 ownership I had an instructor induced 'off' at Castle Coombe's Quarry corner involving a convergence with the tyre wall at high speed. The result was bent deDion tube and steering rack, wishbones etc. As there was a fair amount of work to be done and I was away a lot of the time, I left it to Arrowstar, whose trackday it was, to take the car away and repair it. Taking advantage of the situation I had a Quickrack fitted and, subsequently added a Caterham wide track front suspension kit. In spite of accurately setting up the suspension geometry in terms of camber and toe, the car had become very twitchy to drive so I recently decided to research possible causes. It became clear that incorrectly set rack height would cause bump steer and this could explain the symptoms I was experiencing.

I couldn't find all the information in one article and after I asked a couple of questions on the subject on Blatchat, a number of people expressed interest and wanted to know how it was done. So here goes.

What is Bump Steer?

When the suspension rises and falls as the car goes over undulations and bumps in the road, all the suspension components and linkages move to allow the tyre to follow the road surface. These include the top and bottom wishbones, the upright between them carrying the hub and road wheel, and the track rod connecting the end of the steering rack to the steering arm, in turn attached to the upright.

With a perfect set-up and the steering wheel held centrally, as the linkages move to follow a bump, the direction of the road wheel shouldn't change and should remain pointing at precisely the same angle. Under these conditions the car's directional stability is not disturbed by bumps in the road – i.e. no bump steer(ing). If, however, the set-up is less than perfect, bump induced vertical movement of the suspension components effectively moves the steering arm/track rod end's horizontal position in relation to the other suspension joints, causing the upright to turn one way or the other and hence steer that wheel. If only one wheel goes over a bump then only that wheel is affected and will cause the car to 'twitch' to one side. If both wheels go over the same bump the wheels will deflect in opposite directions, so more-or-less cancelling out the overall effect. Nevertheless this results is a twitchy car and less than perfect straight-line stability due to bump induced toe change.

Undesirable geometry change will also be induced as the nose dives when braking. Albeit the net affect is far more complex, when going round even a smooth bend the weight transfer onto the outer front wheel will compress the suspension – the equivalent of a long bump!

A first level check and an indication-only apart from experiencing a twitchy ride, is to look at the front of the car from ground level and check that the track rods are roughly parallel to the lower wishbones on their respective sides. If they're not or you have other clues (or you just want to have a go) then you have to measure what's going on.

So, what to do?

The good news is that the Caterham front suspension design allows the set-up to be adjusted for zero bump steer. The bad news from comments read and received is that there may be an awful lot of '7s out there that have never have been right.

Apparently over the years there have been a variety of '7 chassis designs with the rack mounting plate set at different heights. There may also have been a number of rack assemblies used with different rack and hence track rod lengths. All this leads to uncertainty as to what height any rack should be set in any chassis. In the case of my car and that of at least one rather well known other owner, the QuickRack had been fitted to the mounting plate using only the top halves of the mounting saddle clamps and with the flat machined surface of the rack directly in contact with the plate. The rack was therefore set at its lowest possible level and, it subsequently transpired, was more than 15mm out.

Fortunately the remedy is actually very simple in that all you have to do is adjust the rack height. But first you have to measure how far out it is and for this you need to make a simple bump steer gauge, clear some space in the garage and be prepared for some laborious and repetitive work. An assistant will make life easier but you can most certainly do it on your own.

If you are planning to upgrade to a QuickRack or widetrack suspension, now is a good time. Either of these upgrades will potentially throw out your bump steer and you will have to measure and reset camber and toe as well.

Equipment Required

- Bump Steer Gauge and wheel bar
- 0 – 10mm dial gauge
- Steel tape measure marked in mm
- 7/32" Allen Key to remove lower shock/wishbone bolt
- Some 30mm x 75mm shims made from 2mm and 1mm aluminium sheet, with two 6.5mm holes drilled at 2" centres
- Qty 4 of ¼" UNF bolts/nyloc nuts and washers if originals are too short after shimming up rack. Note, 6mm bolts will fit but are slightly thinner than the original ¼" UNFs and should not be used unless absolutely unavoidable.
- Toe Gauge
- Camber Gauge if you want to check caster and camber

Making Your Own Gauges

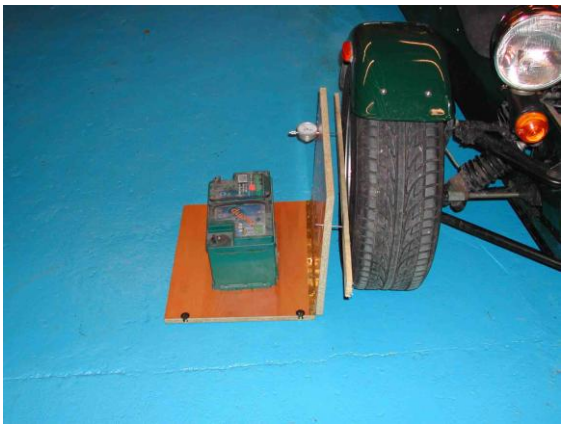
Camber gauge

A simple camber gauge is made using a metal or wooden bar with two styluses that touch either end of the vertical diameter of the wheel rim. One stylus is fixed and a known length from the vertical bar and the other adjustable. Using a spirit level to keep the bar vertical and adjusting one screw so that they both touch the rim, the difference in the distances of the top and bottom of the wheel rim to the vertical is measured to better than 1mm (distance 'd'). If the wheel diameter is distance 'W', the camber angle = arctan (d/W). For small angles Sin and Tan are equal to the angle in radians so camber in degrees = (180/Pi) x (d/W)

I used a piece of aluminium angle approximately 400mm long with two 6mm tapped holes separated by the wheel diameter. A 50mm long 6mm bolt is screwed through each hole, one locked with a lock nut and the other adjustable. A two-axis bubble spirit level was super-glued to the top to allow setting of the bar to the vertical.

Bump steer gauge

There are two types of bumpsteer gauge described in the literature and both work in a similar way, needing the suspension to move over its full travel whilst measuring wheel deflection. With the first type the wheel to be measured is set at a fixed height (on the floor or on blocks) and the chassis moved up and down. With the second the car is fixed and the wheel hub height moved. I chose the first method although I doubt there is much to choose between them.



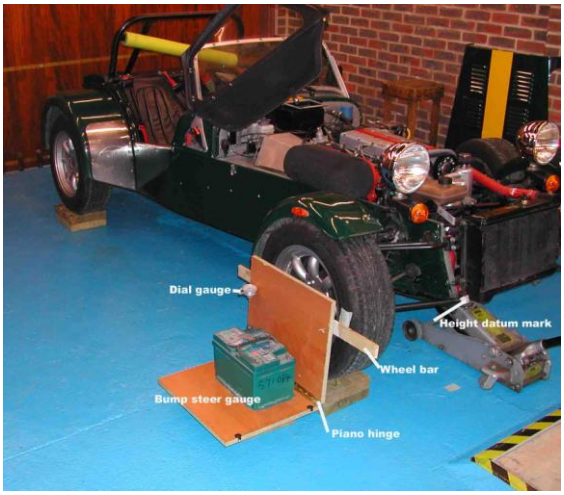
The gauge is made from two pieces of plywood or mdf etc, hinged together using a piano hinge along one edge. A fixed probe and the 0 – 10mm dial gauge are fitted through the board so that they touch the wheel rim at either end of the wheel's horizontal diameter. However, rather than relying on smooth contact with either the tyre or the wheel rim, stick a flat, smooth piece of wooden batten across the wheel with double sided tape and rest the gauge screw and dial gauge against it.

Measurement Procedure

The suspension set-up parameters all interact and they must be measured and adjusted in the right order which is:

Ride height, caster, camber, bump steer (rack height) and, finally, toe. In fact ride height, caster and camber do not interact too much but any change to the rack height and/or camber will seriously affect toe which must be checked after any other adjustments are made.

The following assumes that you have a reasonable amount of clear working space around the car and are on a level concrete floor.



1. Undo the front antiroll bar clamps to allow it to move freely and avoid unnecessarily stressing as one side of the front suspension goes from full droop to full bump during measurement.
2. Increase the ground clearance by raising the car off the ground by about 100mm. This can be done by putting two suitably large 50mm thick wood blocks under each wheel. I used 12" offcuts from some 9x2" roofing joists.
3. Make sure that the handbrake is firmly on and the car in gear so that it cannot roll off.
4. Mark a datum height point so that the chassis height to the ground can be readily measured. I marked a horizontal line on a piece of masking tape stuck to the head of the lower wishbone front mounting bolt.
5. Measure and note the height of the datum line above the ground.
6. Jack up the front of the car using the trolley jack so that both front wheels are clear of the blocks.
7. Remove the front wheel from the other side of the car from the side being measured.
8. On the side being measured, remove the lower shock absorber Allen screw and push the shock absorber/spring out of the way so they don't foul the wishbone as it goes up and down.
9. Lock the position of the steering rack so it can't move during measurement. I struggled to find an elegant way of doing this and ended up using a block of wood wedged between the far side spring and track rod. Be careful not to bend anything.
10. Place a double thickness of plastic sheet under the wheel to act as a bearing (a supermarket carrier bag does the job). This stops the wheel sticking as it swivels on the base and makes the measurements more repeatable.
11. Lower the car slowly so that the suspension rises to exactly the same level as 5. above and stop.
12. Fix the wheel bar horizontally across the middle of the wheel and place the BS gauge in position with the dial gauge and fixed pointer against the wheel bar. Place a heavy weight (an old battery or bricks are ideal) on the base of the BS gauge so it can't move and adjust the position so that the fixed pointer and dial gauge are against the bar with the dial gauge at about 50% full scale. The upper hinged face of the BS gauge should be at an angle to the vertical so that it remains resting against the wheel bar under its own weight and cannot be pushed away by the strength of the dial gauge spring. If you use a piece of wood as the wheel bar, unless its very smooth put some tape or other smooth finish where the fixed pointer and dial gauge touch the bar to avoid sticky movement.

13. Using the jack, slowly lower the front of the car (bump) in 10mm increments, noting the reading on the dial gauge at each 10mm point until you reach 50mm. Now jack up the car, again noting the readings at each 10mm interval and return to the datum height position, checking that the readings are the same as on the way down within 0.1 mm or so. If they are not then something is moving or sticking and the measurements won't be sufficiently accurate. Check that the rack is clamped and that the road wheel is free to turn on the supporting blocks and that nothing else is moving or stuck.
14. As above, now raise the front of the car (droop) noting the dial gauge readings as you go. In both cases its easier and more accurate if you stop at each point to take the readings, rather than on the fly.
15. Using Excel or a piece of graph paper, plot the dial gauge offset against height. If there is no bump steer there will have been no change in the dial gauge reading and the plot will be a straight line. Lucky you! Bolt the whole thing back together again, checking what you do, and enjoy your car.
16. Assuming you haven't been so lucky and have to make an adjustment, adjust the rack height by adding some shims and do the measuring process and plotting again.

Once you have taken two or three series of measurements, first with no shims and then with one or two under each clamp, you can plot a graph of the changes and this will show very closely what your total height adjustment and shim thickness needs to be.

Adjusting Rack Height

Due to the lack of the lower half of the clamps on my car, earlier tightening of the four bolts had distorted the plate around the holes. If the same has happened to your car it would be advisable to flatten out the plate before going any further. This should be done with some drilled strong steel plates and bolts to squeeze the rack mounting plate back into shape, rather than beating it to death and risk distorting it even more!

If your initial measurements indicated that the height is a long way out and you don't have the lower halves of the clamps fitted, these can be bought in pairs from Caterham Cars. They will raise the rack by about 6mm and, once fitted, the measurement should be repeated to see how far towards zero bump steer you have moved. Assuming you're going in the right direction and haven't gone too far, use these measurements as your 'zero shim' datum and plot them on your graph, either on paper or in Excel.

If you need additional shims proceed as follows:

1. Slacken the top steering column clamp by loosening the lock nut and backing off the Allen screw. If there is some clearance between the back of the steering wheel boss and the top bearing on the dash this may not strictly be necessary but it will reduce any risk of stressing these components.
2. Undo the four ¼" nuts and bolts holding the rack in place.
3. Insert a 2mm or 1mm shim under both clamps. At each stage you may want to use more than one at a time each side depending on how quickly you are converging on the correct height.
4. Make sure that the rack is rotated within the clamps correctly so that the pinion shaft attached to the steering column universal joint is in line with the steering column. This avoids any flexing of the U/J adding stiffness to the steering.
5. Tighten the four rack clamp bolts to the recommended 5 – 8 lbft. The procedure is made slightly easier if you use plain ¼" UNF nuts rather than Nylocs DURING THE ADJUSTMENT ONLY so that you can run them on and off by hand. They MUST be replaced by Nylocs once the job is finished and before the car is driven.
6. Re-measure the bump steer using the above procedure.

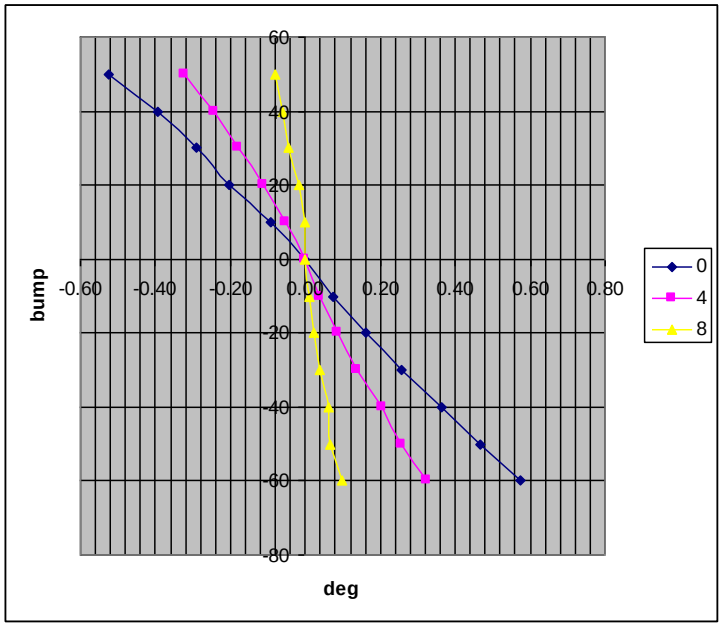
Plotting the Results

1. Tabulate suspension height and wheel deflection for each shim thickness.

	Dial Gauge Reading			
Suspension height mm	No shims (0mm)	4mm	8mm	etc
250 (bump)	-0.52	-0.32	-0.08	
260 "	-0.39	-0.24	-0.06	
270 "	-0.29	-0.18	-0.05	
280 "	-0.20	-0.11	-0.02	
290 "	-0.09	-0.05	0.00	
300 (datum)	0.00	0.00	0.00	
310 (droop)	0.08	0.04	0.01	
320 "	0.16	0.09	0.02	
330 "	0.26	0.14	0.04	
340 "	0.36	0.20	0.06	
	0.47	0.26	0.07	
	0.57	0.32	0.10	

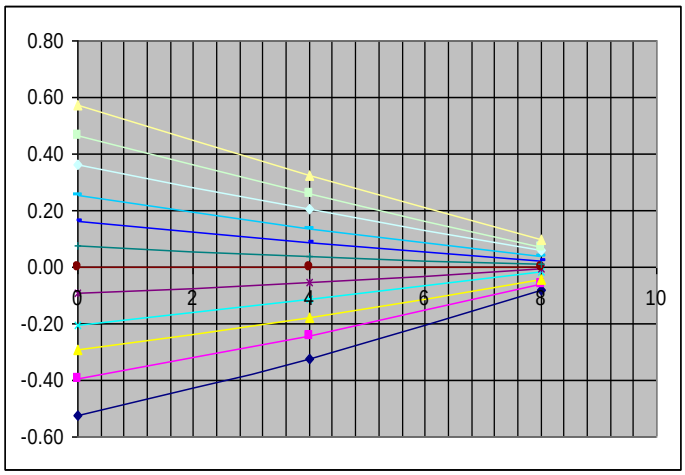
2. Convert suspension height change into bump and droop and the dial gauge reading into angular change. Not strictly necessary but leads to a clearer plot.

Bump angle (deg) = 180/Pi()*atan(dial gauge change/wheel diameter)



The idea is to get the plot as close to vertical over the whole of the suspension travel as possible. The yellow line was achieved with 8mm shims and adding one additional 1mm was near enough spot-on.

Suspension deflection (X axis) versus suspension travel (Y axis) for different shim thickness



Shim thickness (X axis) against wheel deflection (Y axis) for constant suspension travel. The lines converge at the correct final shim thickness.

Completion of the Job

1. Refit the Allen bolt securing the shock absorber to the outer joint of the lower wishbone. If not already done, slide out the inner aluminium sleeve from the shock absorber bottom metalastic bush, coat the sleeve and bolt liberally with Copperslip so that it works freely and you can get it out next time, reassemble and tighten. As always with suspension joints, only tighten once the joint is at its normal 'at rest' loaded position. This avoids any preloads to the bushes.
2. Tighten the rack clamp bolts to the specified tightness, checking that the rack is rotated to the correct angle. If the rack has been raised, check that the steering column and U/J are not snagging or rubbing against any hoses, cables, linkages or other components.
3. Adjust the gap between the back of the steering wheel and the dash to how you like it and retighten the top steering column clamp Allen screw and lock nut.
4. Refit the front antiroll bar if removed
5. Check everything for correct tightness including road wheel nuts.
6. Measure and adjust camber and toe angles.

Other Observations

If you have one of the standard non-Quick racks without machined recesses for the securing clamps, the rack is held laterally by locking screws through the clamps. Before starting any of the above procedure it is essential that you check that the rack is exactly central in the car, i.e. that the rack ends are equidistant from the steering arms. You should also scribe or otherwise make some accurate rack location marks to ensure that the rack is always correctly positioned each time you retighten the clamps.

If for some reason raising the rack height takes bump steer in the wrong direction, i.e. makes it worse rather than better, and you have no means of going any lower then you will need to refer to the Caterham factory for their comments.

Conclusions

I had always regarded driving my '7 as an exhilarating experience and have used it both for speed events and on the road. Even though I enjoyed taking it out I was aware that, given half a chance, the car was looking for an opportunity to take me into the nearest hedge or ditch.

Some local roads were always taken with caution in case the car got the better of me. Now, having corrected the bump steer, the whole set-up is a lot more benign and, frankly, enjoyable. So if yours scares you, give this a go.

REFERENCES

http://7faq.com/owbase/ow.asp?BumpSteer A good explanation of the phenomenon on BlatChat by Roger Swift

How To Make Your Car Handle by Fred Puhn – HP Books

Competition Car Suspension by Allan Staniforth – Haynes Publishing

BUMP STEER REVISITED

I wrote the original article about bump steer and how to measure and adjust about five years ago and, since then, have had numerous requests for copies via Blatchat

Usually once the rack height has been adjusted there is no more to be done and you can forget about it until, that is, you smash the car up and have to start all over again! Which is what happened to my car after a big 'off' at a French hillclimb – nothing to do with suspension adjustment, just over exuberance on a newly laid out hill and going too fast for the upcoming chicane.

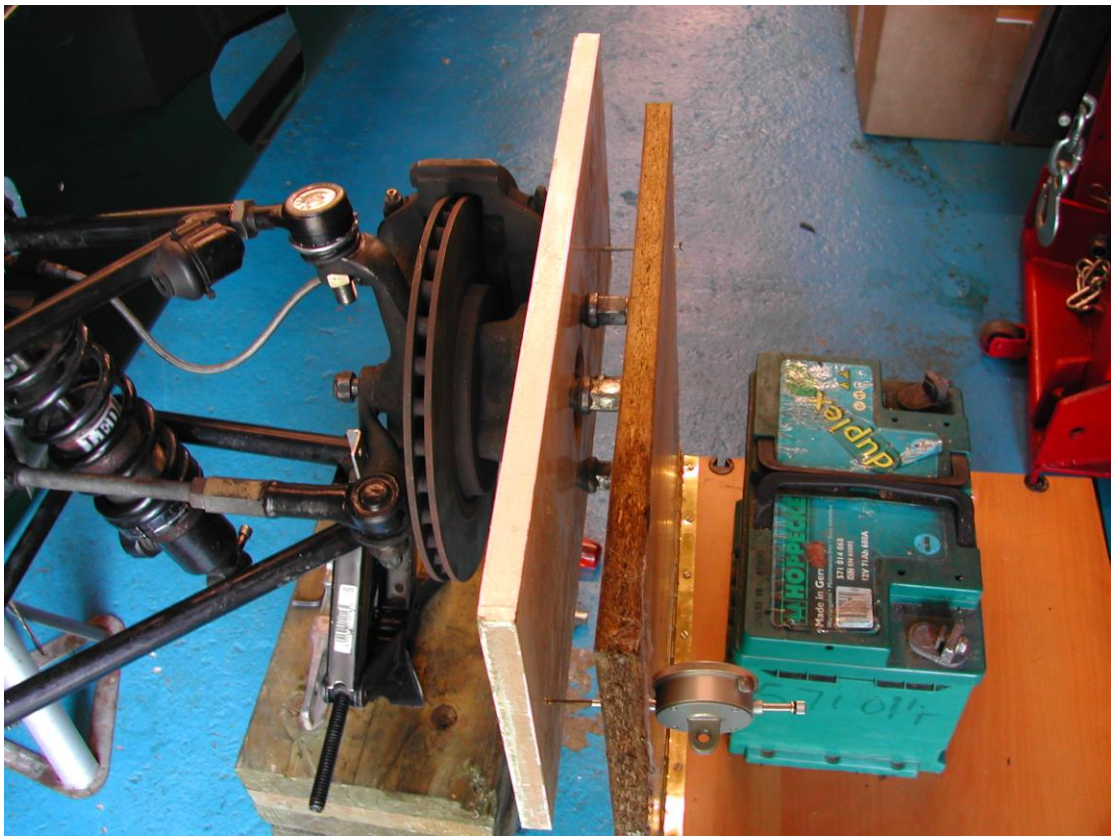
The car, which has widetrack suspension, was stripped out and hauled back at Arch Motors and it was obvious that the car would need a new long front and a total re-skin, plus a lot of other front and rear suspension components. But where there's damage there's also opportunity.

In this case, this was to replace the older front suspension pickup design for the newer improved layout. On the original the spring/damper unit top mount was shared with the top rear wishbone bolt whereas now they are separated and the pickups moved to improve anti-dive and reduce the falling spring rate problem that beset the wide track layout. This did mean that I needed a new set of bolts which are most easily obtained by buying the appropriate pack from Caterham Cars plus a couple of spacers for the shock and wishbone bushes which can easily be turned up on a lathe or bought from CC.

The change also meant that I had no idea how the bump steer was going to be affected with a different steering rack bridge height and changed suspension layout. I decided to use a slightly different method of measurement this time, moving the suspension up and down rather than the whole car as it was easier to do with the car in bits and up on axle stands. The results were quite different to before but again the rack needed to be raised about 8mm to minimise change of toe with rising and falling suspension, i.e. bumpsteer.

Fig 1. Wheel plate fitted to hub, showing pencilled horizontal lines 10mm apart.

The same bumpsteer gauge was used as before and, with the wheels off, I made a simple wheel plate against which to take the measurements. This needs to be reasonably stiff so it doesn't flex and I ended up with a piece of ½" thick board, 9" x 19". Four 13mm holes are drilled in a 3" sided square central to the board to match the wheel studs and a large central hole to clear the bearing cap. The measurement process is simplified if the board is marked with a series of longitudinal lines 10mm apart to act as the height change measurement scale. As the caster changes with suspension travel the hub rotates from the horizontal so a spirit level can be placed on the top edge of the wheel plate which can be turned at each position to keep it level. Take care not to turn the steering when doing this as it will invalidate your results. Ideally you should lock the steering whilst doing the job.



Having first removed the bottom shock absorber bolt so that it hangs free (take care that it doesn't damage the paint or bodywork) and remove the antiroll bar, adjust the gauge fixed pointer so that the dial gauge is somewhere in the middle of its range at the midpoint of the height adjustment. Then take a dial gauge reading. Using a jack to adjust the height, wind the suspension up (bump) in 10mm steps, carefully adjusting the wheel plate level, and take a dial gauge reading at each step from 0mm to 50mm up and then 50mm down the other way. The bottom of the gauge needs to be far enough away from the wheel plate for the vertical board weight to overcome the force of the dial gauge spring without dragging on the plate.

Plot the results and adjust the rack height in the same way as the original article.

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ANOTHER REVISIT FOLLOWING BLATCHAT READER FEEDBACK – FEB. 2015

For some reason when I wrote the original article I omitted any reference to the fact that raising the rack can allow the bellows to catch on the holes through the sideskin. In my case I now realise that I ignored the problem as it wasn't too bad and, as I rarely put the car on extreme lock, the bellows haven't suffered any premature wear, nor has the sideskin been damaged in any way.

The amount that needs to be removed and the profile of the enlarged opening will need to be determined by inspection but it shouldn't be more than a few millimetres that needs to be removed as the rack has only moved up 8 or 9 millimetres.

A good way of enlarging sideskin holes is to use a flap wheel on an electric drill or flexible drive although, in the case of the bellows, there might not be enough room to get in there unless the rack is eased out of the way. A Dremel with a little cylinder sanding drum would probably work just as well and it should be possible to pull the bellows sufficiently out of the way, maybe protected with a bit of card or tape. Cover the skin area with masking tape, mark out the shape that you want and gently remove metal using the sander. Go slowly so as not to overheat the local paint and generally cover everything nearby so that aluminium filings don't go everywhere.

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