This month we consider 'bump steer': what it is, how to assess it and how to deal with it. **Paul Deslandes** *describes the phenomenon, the construction of a cheap gauge and methods to measure and correct it. You'll need a little school maths and some patience, but following Paul's example will help you understand what is happening. Obviously, some of the various suspension variables interract, for example camber and toe (as in, toe-in -out or neutral) and we'll look at these later, since gaining an overview of these will give you more confidence to explore them.*

BUMP STEER

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 more in-depth treatises on bump steer and, indeed, the whole subject of suspension design and adjustment, you can refer to the sources acknowledged over the page.

So why write about it again?

Fairly early in my Seven ownership I had an instructor-induced 'off' at Castle Combe's Quarry Corner involving a convergence with the tyre wall at high speed. The result was a bent de Dion tube and steering rack, wishbones etc... There was a fair amount of work to be done and I was away a lot of the time, so 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 quick-rack 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, more 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 various 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 wouldn't change and would remain pointing at precisely the same angle. Under these conditions the car's directional stability is not disturbed by bumps in the road – ie: 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 and 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 deflect in opposite directions, so more-or-less cancelling out the overall effect.

Nevertheless, this results in 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 rounding 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 Sevens out there that have never been right. Apparently, over the years, there have been a variety of Seven 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.

And then, of course, a great number of different people have built, rebuilt, altered, modified and repaired Sevens over the years...

In the case of my car, and that of at least one other owner I know of, the quick-rack 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.

The remedy is, in principle, 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 quick-rack or wide-track 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-in (or out) as well.

Left:
Paul's bump steer gauge in position against a front wheel. It's entirely mechanical, by the way: the battery is merely doing duty as a dead weight to keep the gauge in place.

Below:
The set-up ready to commence measurement, with the car raised to allow bump and droop to be effected by means of the trolley jack. *See text for details of the labelled features.*

With a little care and an understanding of what is actually being measured, accuracy can be achieved with simple and modest equipment

Equipment required

Apart from a level floor to work on, a trolley jack and some suitable blocks to raise the car on (*see Measurement procedure*) and a supply of patience, you'll need a few items to hand:

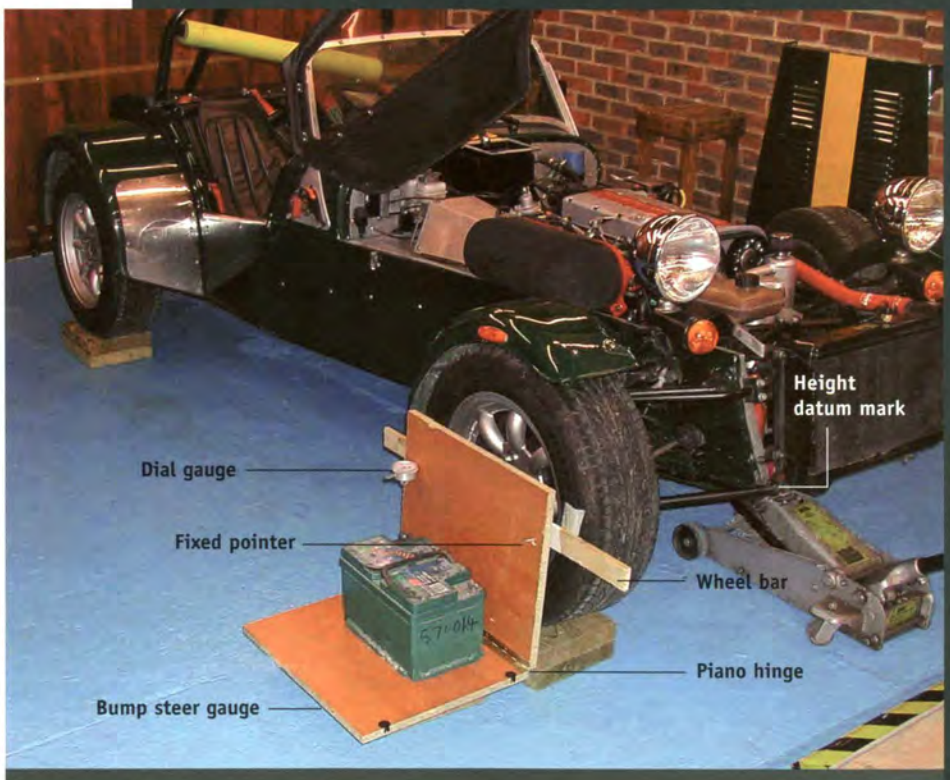
- Bump steer gauge and wheel bar (*making such a device for yourself is described elsewhere in this feature*)
- 0 – 10mm dial gauge
- Steel tape-measure marked in mm
- 7/32" Allen key to remove lower shock/wishbone bolt
- Some 30mm x 75mm shims made from 2mm and 1mm aluminium sheet, with two 6.5mm holes drilled at 2" centres
- Replacement (four of them) 1/4" UNF bolts, nyloc nuts and washers for the rack clamps if originals are too short after shimming up rack.
  (Note, *6mm bolts will fit but are slightly thinner than the original UNFs and should not be used unless absolutely unavoidable*)

The following, not actually needed for adjusting the bump steer, will need to be considered when re-setting things afterwards:

- Camber gauge, if you want to check castor and camber
- Toe gauge

We'll move on to camber and toe and means of measuring them next time, including a camber gauge you can make for yourself.

Continued overleaf >



Making your own bump steer gauge

There are two types of bump steer 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 a 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, fix 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, castor, camber, bump steer (rack height) and, finally, toe. In fact ride height, castor 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 rebound 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 wooden blocks under each wheel. I used 12″ offcuts from some 9″ x 2″ 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 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 unit out of the way and secure it so it doesn'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 a easy but 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 Bump steer 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 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 (half-way through the dial's range). The upper hinged face of the Bump steer 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's spring. If you use a piece of wood as the wheel bar, unless it's 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 10 mm increments, noting the reading on the dial gauge at each 10 mm point until you reach 50 mm. Now jack up the car, again noting the readings at each 10 mm interval and return to the datum height position, checking that the readings are the same as on the way down to 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 (or 'steer') 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 carefully 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. But first, how to alter the rack height...

Adjusting rack height

Due to the lack of the lower half of the clamps on my car, mentioned earlier, previous 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 could be done with some strong, drilled steel plates and bolts to squeeze the rack mounting plate back into shape, rather than beating it to death with a mallet 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 6 mm 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 Microsoft Excel.

If you need additional shims, then 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 2 mm or 1 mm 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 unnecessary flexing of the UJ adding stiffness to the steering.

5: Tighten the four rack clamp bolts to the recommended 5 – 8 lbft. This repeated procedure is made slightly easier if, **during the measurement and adjustment process only**, you use plain ¼" UNF nuts rather than Nylocs 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 procedure described previously; then repeat again with thicker shims, and so an as required, recording the measurements as you go.

Suspension height and wheel deflection
for each shim thickness

	Suspension height	Dial gauge readings			
		0mm (no shims)	4mm	8mm	etc
bump	250 mm	-0.52	-0.31	-0.08	
	260 mm	-0.39	-0.24	-0.06	
	270 mm	-0.29	-0.18	-0.05	
	280 mm	-0.20	-0.11	-0.02	
	290 mm	-0.09	-0.05	0.00	
	300 mm (datum)	0.00	0.00	0.00	
droop	310 mm	0.08	0.04	0.01	
	320 mm	0.16	0.09	0.02	
	330 mm	0.26	0.14	0.04	
	340 mm	0.36	0.20	0.06	
	350 mm	0.47	0.26	0.07	
	360 mm	0.57	0.32	0.10	

Plotting the results

Make a table of suspension height and wheel deflection for each shim thickness, such as that above. (*Note: the effect is usually referred to as 'Bump steer' whether it occurs in bump or droop.*)

You can now convert the suspension height change into bump and droop and the dial gauge readings into angular change (using the formula below) – this is not strictly necessary but does lead to a clearer plot:

Bump angle (*in degrees*) =

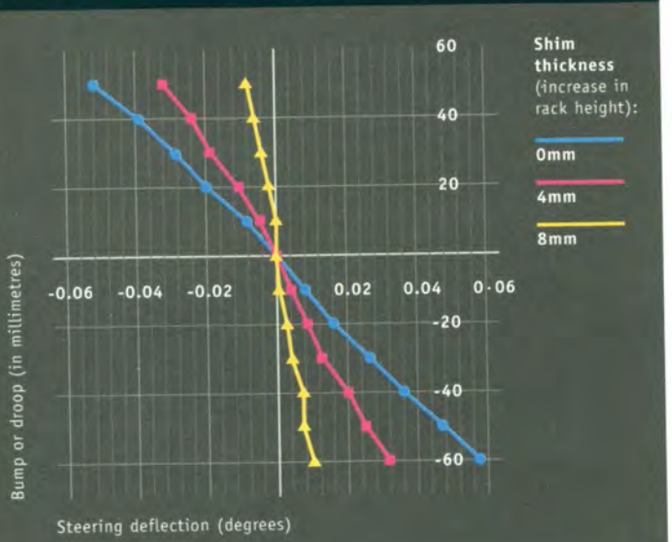
(180 ÷ Pi) x atan (dial gauge change ÷ wheel diameter)

You can then use the results to create charts, such as those shown here. In 'Wheel deflection versus wheel travel' (above right) the idea is to get the plot as close to vertical, over the whole of the suspension travel, as possible.

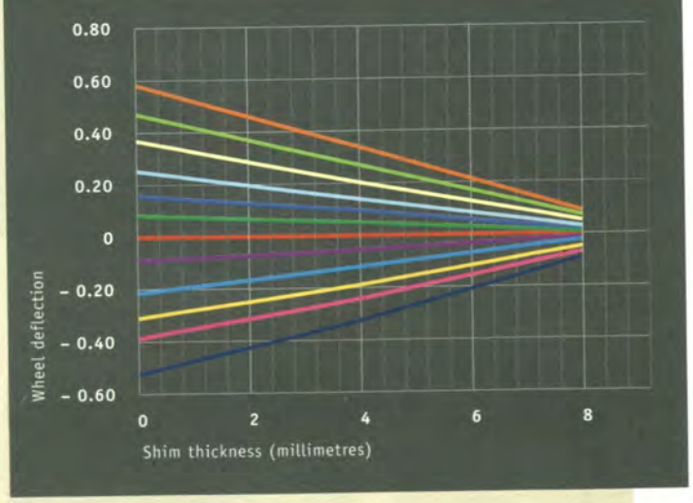
In my case, the yellow line was achieved with 8 mm shims and adding one additional 1 mm was near enough spot-on.

Do remember, the data and charts shown here are examples from Paul's car and the actual figures may bear no relation to you own situation. Don't be unduly deterred by the graphs (or the very idea of them!) – you can begin to get a understanding of what's going on from the raw measurements in the table. The graphs, though, make any improvements (or otherwise) altogether more obvious.

Wheel deflection versus suspension travel
for different shim thicknesses



Shim thickness against wheel deflection for contant suspension travel
the lines converge at the correct final shim thickness



Completing 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 will avoid 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 UJ 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 (which we discuss later).

Other observations

If you have one of the earlier 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, (that is, the rack ends are equidistant from the steering arms). You should also scribe, or otherwise, make some accurate rack location marks to make sure 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 (ie: 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 Seven 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. ■

© Paul Deslandes, 12th December 2005

References

- A brief, but splendid explanation of the phenomenon, by Club member Roger Swift, can be found at *http://7faq.com/owbase/ow.asp?BumpSteer*
- How to make your car handle *by* Fred Puhn (*HP Books*)
- Competition car suspension *by* Allan Staniforth (*Haynes*)
- Another Staniforth title, the more general Race and rally car sourcebook is, if it can still be found, very good read.