Opel Speedster/VX220 Bumpsteer

February 2014

Introduction

Bumpsteer is the tendency of the wheels to change toe when in bump or droop. This is not a bad thing, it can be used to improve the handling of the car. Lotus documented the bumpsteer in the rear very well, but for the front, there is not much information available. That's the reason why I started doing some measurements. The information below is a result of that.

I will not go into the topic of what bumpsteer setting is best, optimal etc. That will differ from car to car and from driver to driver. I'm also not experienced enough to say what works under what conditions and what doesn't. Both for the rear and for the front Lotus must have had a reason to set the bumpsteer to what it is, as it's quite easy to change it.

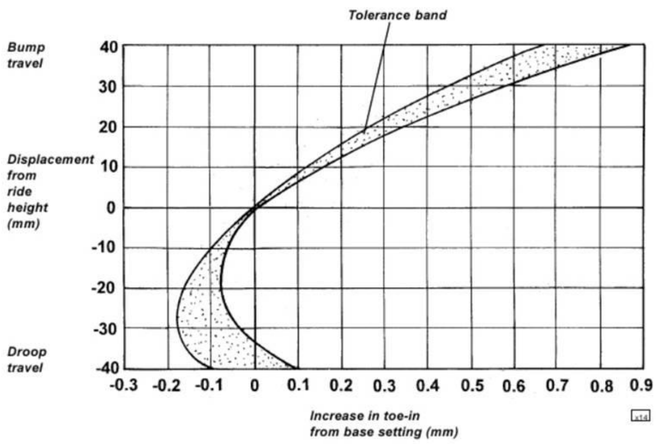
One other thing to consider is that bumpsteer has different effects under different conditions. Hitting a bump causes immediate toe change and back again with the car going back to normal ride height. But unless the geometry is different left/right, the amount and direction of the change is the same for both wheels. So you might experience some feedback in the steering wheel, but no dramatic steering effect. Again, only if the geometry is the same.

Under braking, both wheels at the front go into bump, but in a more gradual way than when actually hitting a bump. Again the amount and direction of the change is the same for both wheels, but any difference will be more noticeable, simply because there is more time for any effects to get noticeable.

The most challenging situation is cornering, as one side is in bump and the other in droop. The correct term is rollsteer. The toe change between wheels is now really different, with one wheel for example toeing in and the other out. Beware that the bumpsteer curve with the wheels at an angle will be different, as the geometry of the pivot points changes. I just don't have enough experience to say if this is a noticeable effect or not.

Bumpsteer curves

The VX220 has unequal length non-parallel (almost parallel) wishbones with a toe link at the rear and a track rod connected to the steering arm at the front. The wishbone pivot points determine caster and king pin inclination. The wishbones and the toe link/track rod all move in different arcs and this is what causes the toe change under bump and droop. The change of toe in bump and droop is represented by a curve, the bumpsteer curve. I will follow the same format as Lotus used for the Elise rear curve: x-axis is toe change with toe-in positive. y-Axis is ride height with bump positive. Origin on the x-axis is where the curve crosses the axis. Beware that toe normally is set to toe-in (rear) and a little toe-out (front), which means that for absolute values you have to shift the origin to the actual toe setting. Origin on the y-axis is static ride height, in my case 115 mm front, 125 mm rear. To use the curves for your car/ride height:

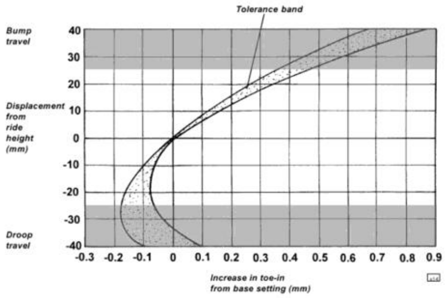


- my effective front wheel radius: 305 mm (215/15 R18, radius: 314 mm)
- my effective rear wheel radius: 310 mm (235/40 R18, radius: 322 mm)

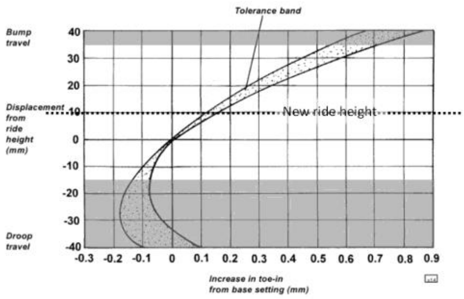
Effective meaning the actual radius as measured from the centre of the hub to the ground with the tires compressed by the weight of the car. In case of front wheels with an effective radius of say 300 mm, the actual ride height changes from 115 to 110 mm, but the origin on the y-axis remains the same. If with those wheels the actual ride height is not 110 but 120 mm, the new origin on the y-axis will be at -10 mm.

Changing the bumpsteer curve can only be done by changing the suspension geometry. That can be done in many ways, but in practice with the VX220 it means changing the vertical position of the pivot points of the toe link or track rod. Beware that bumpsteer is a subtle thing and we're talking about millimetres or fractions of millimetres at the upright or steering arm. A change of a couple of mm in vertical position of a toe link or track rod pivot point will have a significant impact on the bumpsteer curve.

Also important to realize is that in practice the suspension will only move through a part of the bumpsteer curve; an interval around the static ride height. How wide that interval is will mostly depend on spring rates, assuming that the dampers have the correct length and that at static ride height you're not close to one of the limits of travel. When you change static ride height, you move that interval to a different place in the curve. When you assume one inch of suspension travel at the upright each way, the part of the curve you're interested in is in the white area as indicated in the picture on the right. At this ride height (standard ride height, or 140 mm in the rear), you see that going into bump, the toe-in increases almost in a linear way. In droop, the toe decreases, but the effect is very small. Beware that the curve shows toe change. At static ride height, toe-in is usually around 3 mm at the rear. You see from this curve that the toe change due to bumpsteer is not big and certainly never big enough to go from absolute toe-in to toe-out.



Now lowering the car 10 mm means another part of the curve is important. The interval changes with ride height and you have to deal with another part of the curve. With this curve, lowering the car is not much of an issue. At least not for bumpsteer. The relevant part of the curve doesn't change much.



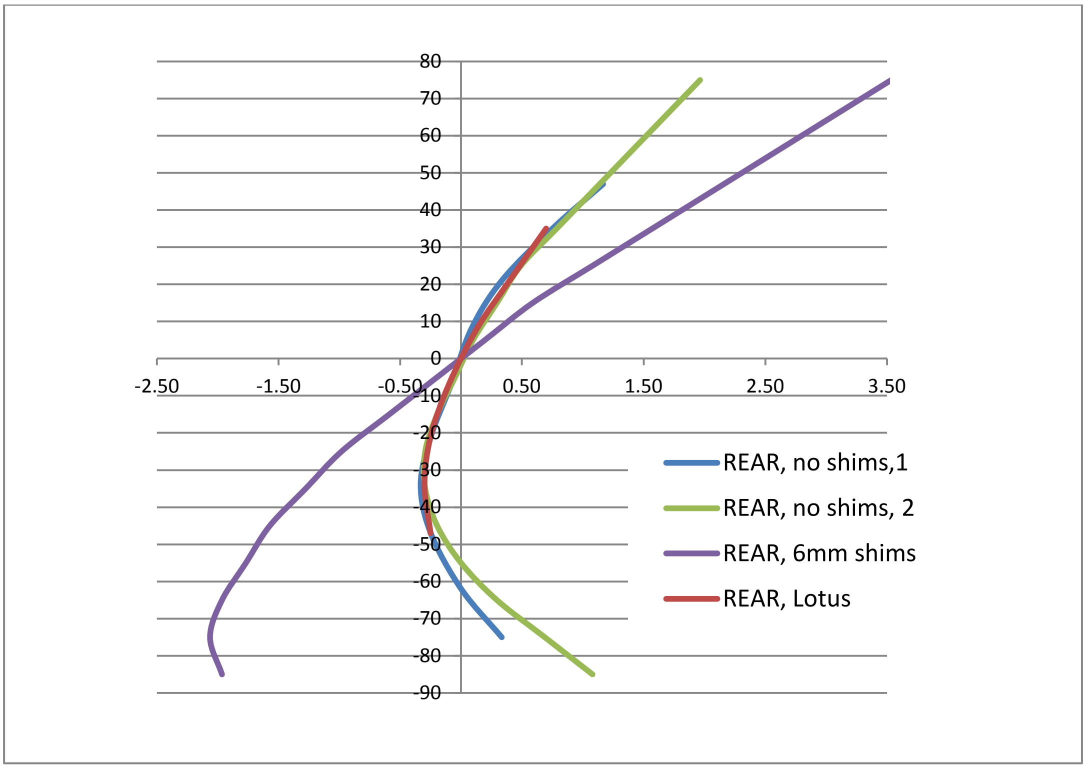
Measurement set up

All measurements done on a NA Opel Speedster (nr. 2904).
To measure the change in toe, I put the car on blocks, removed the damper and the ARB at the front and used a scissor jack to move the upright. A block with a combined laser and level was bolted to the upright with the laser bouncing off a mirror to compensate for side way movement of the upright (as the target is moving with the upright). All measurements were done at least twice going both up and down. At the front special care was taken to not move the steering wheel.

The laser bouncing off the mirror doubles the distance between the laser and the target so that even small toe changes are easy to measure. I actually used this set up as I was expecting to see small changes. To get a better idea of the set up see picture above. Laser bounces off the mirror to hit the target mounted in the centre of the hub. The upright is moved up and down and the mm horizontal change at the target measured. To get from the measured mm change to mm change at the rim, the correction factor is two times the distance from the laser to the target, divided by the rim diameter (495 mm in my case as I have 18" rims). If you have smaller rims, you could compensate for that, but the compensation factor is small (18/17 or 18/16). TBH, I should have done this in degrees to make it rim diameter independent, but mm is just easier.

Rear Bumpsteer

I have the Elise shop toe link kit installed without any shims. Comparing the bumpsteer curves, it looks like the measured results are in-line with the curve that Lotus published. To see how things would change, I moved the upright pivot point down using three 2 mm thick rings, for a total of 6 mm. The pivot point of the toe link at the chassis side coincides with the pivot point of the lower wishbone.

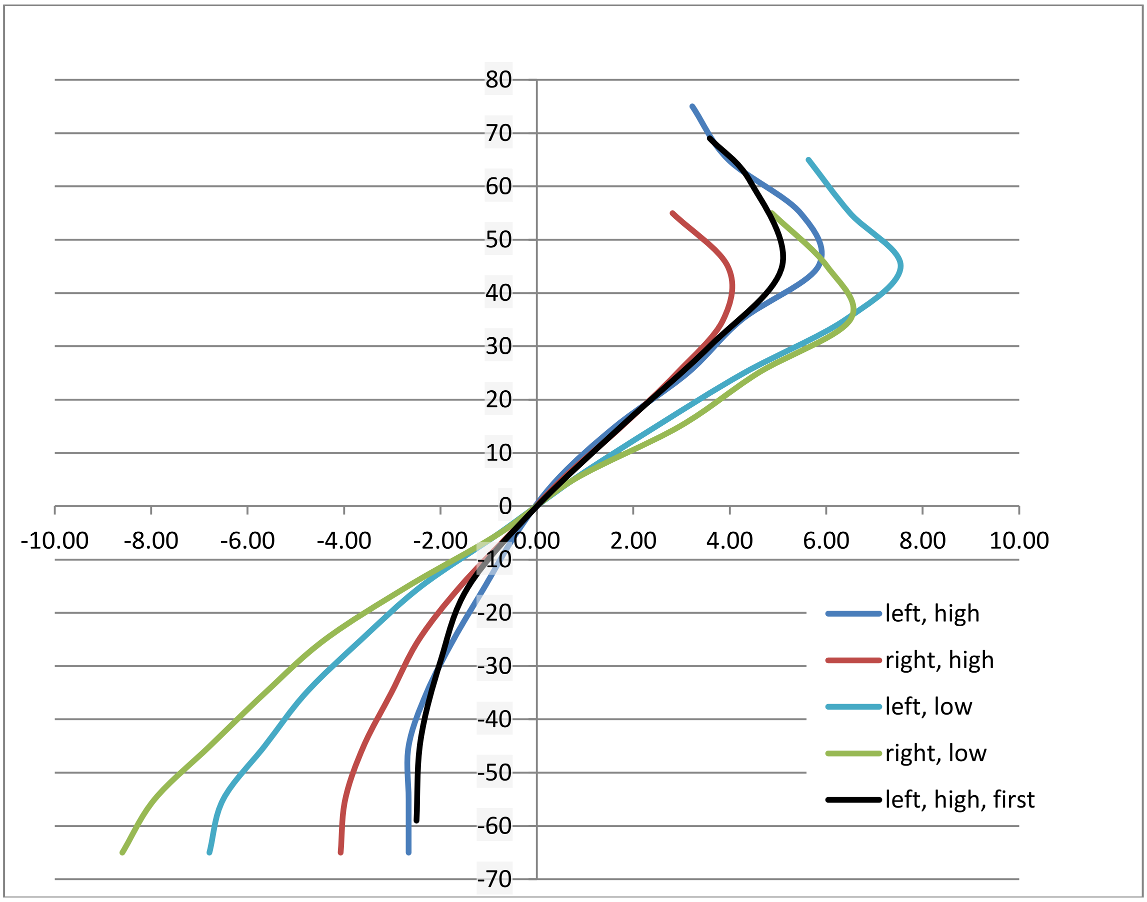


REAR, no shims, 1: first measurement
REAR, no shims, 2: second measurement, other day, just to see if I could reproduce results. This measurement should actually be a little better as I measured the vertical movement of the upright in a different way, which also explains the difference you see at higher droop values
REAR, 6mm shims: with three 2 mm thick rings as shims
REAR, Lotus: as published by Lotus

A curve with for example a 3 mm shim will be between the no shims and the 6 mm shims. By shimming, you increase the amount of bumpsteer and start exaggerating the effect that the Lotus engineers are going for. It would have been very easy to get no bumpsteer at all. You do that by moving the toe link pivot point at the upright up a few mm to coincide with the lower wishbone pivot point. Clearly that is not what the Lotus engineers wanted. Total bumpsteer is small in the non-shimmed case, it’s less than 1 mm change over a range of one inch bump-droop. With 6 mm shims, it’s about 2.5 times as much over the same range.

Front Bumpsteer

I expected this to be less than the rear. Based on the little you can find about it. Turns out it's a lot more. Because I was surprised by the result, I measured both left and right side and also the left side two different days using a different laser and a different set up to measure ride heights. I also measured with the steering rack in the lower and upper position (5 notch and 10 notch riser plates, the 10 notch raises the rack with about 8 mm). Results:



Left, high: left side, 10 notch riser plate
Right, high: right side, 10 notch riser plate
Left, low: left side, 5 notch riser plate
Right, low: right side, 5 notch riser plate
Left, high, first: first measurement, different day, different set up. Added to check consistency

You see that raising the rack reduces the amount of bumpsteer. Around 115 mm ride height and 1 inch bump and droop, with the 5 notch plate you have about 9 mm change. With the 10 notch plate, that's reduced to about 5 mm. Quite a change. You can also see that the effect on bumpsteer is not that different from 115 mm to 140 mm ride height. Also at 140 mm, if you want to reduce bumpsteer, you should use the 10 notch plate.

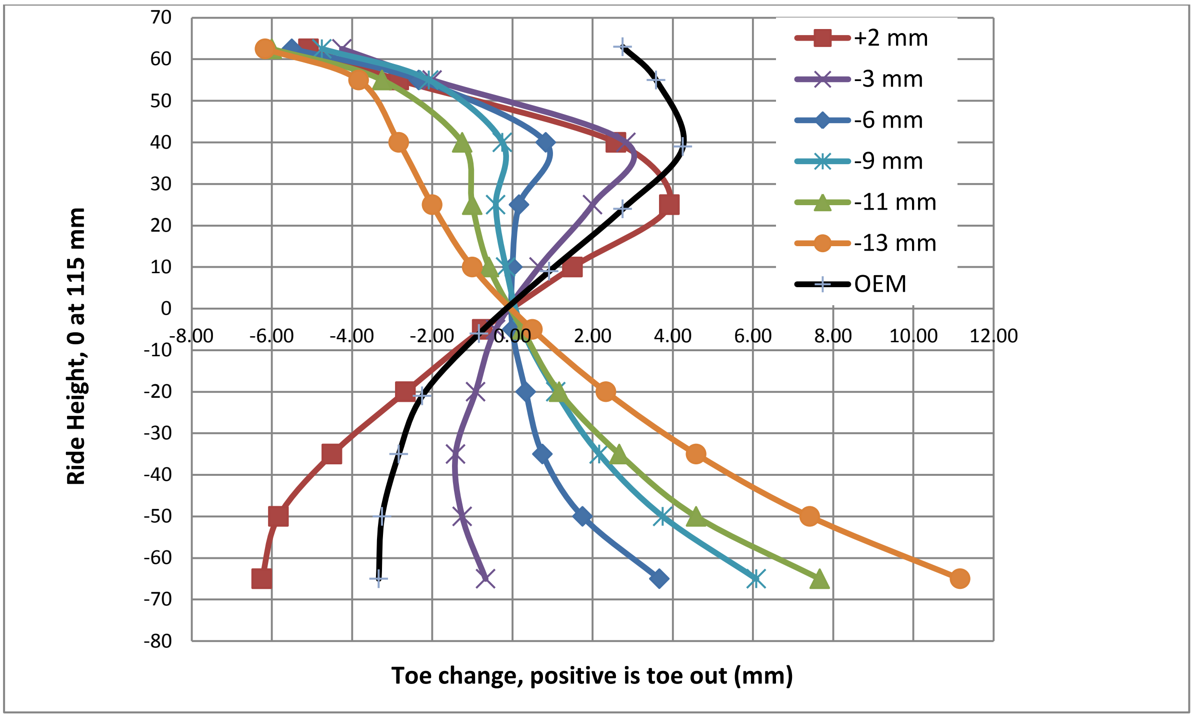
What you also see is that it looks like the right side of my car is about 10 mm different from the left side. This is consistent with the damper settings. On the right side the damper ring for setting the ride height is higher up than on the left side. I've tried to find what's causing this, but can't figure it out. Everything is straight, there is virtually no play. So after much looking and measuring I still have no idea what's causing this. Seems excessive for production variation, but given the way these cars are built, it might be the case.

As you can't raise the rack any higher than with the 10 notch plate (perhaps it's possible, I didn't check. The plates are only there for indexing. The chassis actually has a slot, so it might be possible to raise the rack a little more), the only other easy way to modify bumpsteer is by lowering the pivot point at the steering arm. Just like raising the rack, this brings the track rod more in-line with the upper wishbone pivots thus decreasing bumpsteer.

To be able to measure the effects of lowering the steering arm pivot point, I had to make up my own adjustable 'steering arm'. The slots allow me to move the pivot point up 3 mm and down about 20 mm with regards to the standard steering arm. More than enough as it turns out.

Although I made it from pretty solid material, what happened is that at maximum bump, the track rod hit the plate that holds the track rod end. After seeing the curves and wondering about how they converged, I had a look at the plate and found a sizeable dent in it. So measurements at high bump values are not valid.

Results



The numbers indicate the height of the pivot point with regards to the OEM steering arm. So -3 mm means 3 mm lower. OEM is OEM height of the pivot point. The rack is raised, using the 10 notch riser plates. Beware that at higher bump values the track rod started to hit the adjustable steering arm, forcing it down. This causes all the curves to convert to one point.

As you can see, you can change the bumpsteer curve to do whatever you like by raising or lowering the track rod pivot point. You can even completely reverse it. Lowering it by 6 mm will reduce it to almost nothing. This might be a bad idea however in the sense that just one mm might reverse the curve and lead to complete different and unwanted behaviour.

It seems that I'm not the only one who found this and that there are several sources for steering arms that are actually lowered a couple of mm. In Germany some people found the same and made a modified steering arm available on a commercial basis. Not available anymore however. In the US Sector111 sells the V2arms and Elise Parts sells one that you can shim to set your own bumpsteer curve.

Conclusions

Rear: no real surprises, as it's well documented. I always wondered what would actually happen with shimming and now at least I know, it will increase the effect that was aimed for with the OEM setting. It also looks like the rear is not very sensitive to changing ride height, at least not for toe. Toe change going from 140 mm to 125 mm is less than 0.5 mm.

Front: things get more interesting. Going from 140 mm to 115 mm ride height and with the standard (at least for the NA) 5 notch riser plate, toe changes with more than 3 mm. It's always stated that these cars are very sensitive to toe in the front and it should be a little out (like 0.5 mm). But you actually get 0.5 mm toe change with 5 mm change in ride height. I always wondered about the statement that you should geo with the car loaded as it is usually driven. It seems that makes perfect sense. Just taking a passenger with you will change the toe considerably.

Somehow I don't like that. To me it seems the car is too sensitive to ride height changes that way. This is not based on any facts that I have, only on the fact that most literature tells you to minimize bumpsteer, especially at the front. Again, the OEM bumpsteer characteristic must be there for a reason, as it would have been quite easy to minimize the effect. It already gets less by using the 10 notch riser plate, but even in that case it's still pretty big. Personally I like to at least try a little less, which means lowering the pivot point of the track rod at the steering arm using a commercially available steering arm that allows for that.

Beware that I'm only looking at bumpsteer, not at other factors, like camber change or roll centre. These also change with changing ride height. The best solution for lowering the car is changing the position of the hub. That way the wishbone angles stay where they were always supposed to be. It's an expensive solution however.

Geo: because I was fooling around with ride heights and changing them all the time and was too lazy to properly set toe and camber every time, I have personal experience with some pretty drastic settings. At times I took the car for a spin and really wondered what the hell was happening. After checking toe and camber settings, it always turned out something was wrong. When these cars are properly set up and geo'd, they are very sweet to drive. When they're not, they can be a quite a handful.

Disclaimer

I've tried to be as accurate as possible with the equipment at hand, some of which I made just for this purpose. As I've seen significant differences from left to right on my own car, please do not use these results in an absolute way. The only proper way is to measure it yourself or go to a specialist who knows what he's doing.

Comments

Welcome on the www.vx220.org.uk forum, username alexb, or

www.speedsterclub.nl, username aboellaard