

Peter Eland's web pages

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Tricycle steering geometry - instructions

How to design a steering linkage

Spreadsheets

These instructions should apply to pretty much any modern spreadsheet program. The sheets were originally written on Excel 5, but work fine with many different programs. If you don't have Excel, don't buy it: instead use free, open-source software like OpenOffice.org.

- You don't even have to know how to use a spreadsheet. All you have to know is that a spreadsheet is a sort of grid, and the spacs in the grid are referred to as cells. They are identified from the letters which run across the top, and the numbers which run down. So cell B3, for example, is two along, three down.
- To change the value in a cell, click once on it with the mouse, and type the new number. Press enter.
- If ever you get a cell full of #####, that means there's not enough room to display the number. Move your mouse to the top of the grid, onto the row of column labels (A, B, C etc), and move it until it's over the edge of the column you want. You can then drag the column wider.
- Unless your screen is particularly tiny, you shouldn't need to scroll down or anything - all you need is visible on the screen when you start the program up. All the gubbins further down is stuff I used in the calculations, and of not much interest to most end users.
- All the units I used are mm, but there should be no problems if you decide to work in inches.
- The graph, which shows the model of your linkage, should be 'square' - in other words, the tick marks on the vertical and horizontal axes should appear the same distance apart on the screen (they're 100mm apart 'to scale'). To adjust this, click once on the graph and drag (with the mouse) one of the black 'control points' which appear on the graph's boundary.

Design

So, to start the design.

1. **First, you need to enter some figures which you'll have set already as part of your wider design process.**
 1. First, the wheelbase. Change the number in cell C26 to however long your wheelbase will be.
 2. Next, the centre-line to kingpin dimension, figure a on the diagram. This is the distance from the centreline of the trike to one kingpin, or in other

words, half the distance between the two kingpins (the point which the wheels pivot around). Put this value in cell C20.

3. Then, estimate the distance you'll have between the kingpins and the centre of the front tyres - this will be about half the width of your hubs, plus a bit to leave room for pivots etc. If your kingpins are inclined, as they might be to achieve centre-point steering, it's anybody's guess what value you should use. This value doesn't affect the steering anyway - it's just useful to see where the wheels end up at extreme turn angles, so you can avoid them hitting the seat etc. This value goes in cell C27, labelled 'Front wheel offset'.
4. You can also enter now the handlebar length (C30) and the rear wheel offset (C31) and wheel size (C28). Again, these have no effect on the steering geometry. The handlebar length lets you see where the ends move to at extremes of the steering. For USS designs it'd probably be about 400mm long, for joystick designs you could just leave it as 0. The rear wheel offset has no effect on steering geometry, it's just there to keep Windcheetah fans happy (or anyone with an offset rear wheel), so you can see on the graph what it looks like.

2. Now, time to start changing things which define how the trike steers. Refer to the diagram to see what the various dimensions refer to. Here's a few notes about the various variables:

1. C21 Steering arm length b: This is the arm which projects from the kingpin, and it would have a rod end (aka track joint) on the end. Positive values project out towards the rear wheel, negative values project towards the front (like on the Greenspeed - see below). Bear in mind that the smaller you make this length, the higher the forces on your linkage, and hence the stronger you'll have to build it. The smallest value I've seen commercially is on the S-327, at about 40mm, and they've used some fairly mighty aluminium track rods.
2. C22 Steering arm initial angle c1: This is how you make the steering arms point inwards, the classic way to achieve Ackermann geometry. You'll adjust this later to fine-tune the steering, so just leave it at, say, 75 for now.
3. C23 Handlebar pivot offset d. Not surprisingly, this defines the position of the pivot for the handlebar assembly. I've assumed you want to keep it on the centreline of the trike. Use this number to move it forward or back - negative values work fine, BTW. Depending on the rest of the design of your trike, there may be restraints on where you can put this pivot, and whatever you do it'll have a big effect on where the ends of the handlebars end up (unless you're using an extra linkage!).
4. C24 Handlebar initial angle e1 I hope this is self-explanatory - the bigger the angle, the further apart the two pivot points on the handlebar assy are placed. 0 works fine if you want them together, like on say the Windcheetah. Negative values cross the track rods over.
5. C25 Handlebar arm length f This is the distance from the main handlebar pivot to each of the pivots for the track rods. Increase it to get more steering movement from less handlebar motion, or vice versa.
6. C29 Handlebar offset This is the distance from the midpoint of the handlebat to the main handlebar pivot. If you increase too much, you'll find the ends of the handlebar swing in and hit seats etc much faster than if you'd kept it small.
7. Right! You should now have a first-attempt setup. You'll have noticed the graph updating itself as you entered each new value. Now have a

play changing the value of h (cell C33). This just changes the angle of steering shown on the graph. Try figures in the range plus or minus 20 first, then see how large an angle you can make the thing turn. When you reach the limit some lines might disappear or flip round.

Optimising

Now, time to optimise the linkage, and to compare it to the Ackermann ideal.

1. You'll see on the right-hand side of the screen a few columns of figures. The three columns under the heading 'ideal Ackermann' list respectively the radius at which you're turning, and the ideal angle for left and then right wheels at this radius.
2. The next column uses your geometry to work out the angle of the right-hand wheel (as you look at the screen), when the left-hand wheel is turned to the Ackermann-ideal angle for that turn radius. If the constraints of your geometry mean that it can't manage a turn down to 2m radius, that number will disappear into an error message.
3. The 'error' column simply looks at the difference between the ideal value and the one achieved with your geometry, and expresses the error as a percentage. Plus indicates 'under-ackermann', minus indicates 'over'ackermann'. Read about the ins and outs of Ackermann elsewhere! Generally, if you get within a few percent, it won't make much difference.

So, all you do now is change the figures for your geometry until you get nice low percentage errors, and have a linkage you can build as well. Enjoy!

Oh yes, a couple more useful things:

- The track rod length is shown at C38 - it's calculated from other things you've entered, so don't try changing it. Also, rows 45 to 62 give you the coordinates of all the points at any angle h (C33). That can be useful when looking at clearances with wheels, handlebars etc.
- Another thing to watch, BTW, is that the track rods and the steering arms don't get too close to being in line - if they are, the linkage isn't keeping things very firmly in position, and it's easy for the steering to 'flip' right round, unless you have some sort of 'bump stop' or something. The geometry which the spreadsheet starts up with is not ideal in this respect! You have been warned.

Finally

Finally, people keep pointing out that this is a purely 2-dimensional analysis. If you start inclining kingpins (e.g. for centre-point steering) or handlebar axis or the like you'll introduce distortions. True. But the maths involved in getting all that sorted makes my head hurt. So live with the approximation. Or build a 3D design tool yourself!

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