

The story of your wheels

Handbuilt wheels - a process where the human still beats the machine. Here's an account of how your wheels were built with the greatest of care and precision. Wheel building is a craft that I love and I'm delighted to share some of the details that go into making your wheels the very best they can be...

“Measure twice, cut once”

Precision in building begins with precision in measurement. To build wheels most accurately, we need the following key measurements:

Rim

- **Effective Rim Diameter (ERD)**



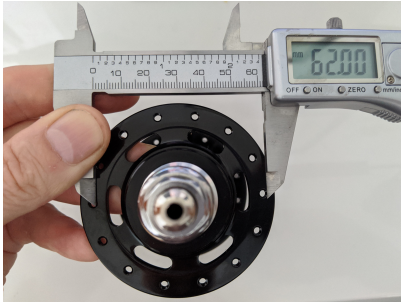
I always measure this myself, as manufacturers measure in different ways, and to different standards of precision. It is one of the most critical measurements, as it has an almost 1:1 effect on spoke length. I measure with the nipples (and washers if appropriate) that I will use - that's the best and most accurate way. Over time I have built up a library of experience and knowledge as to ERDs - but I always measure for the individual rims I will use. Every rim is (subtly) different (extrusion dies wear for aluminium rims, resin thickness may vary for carbon).

- **Spoke Hole Offset**

Manufacturers' measurements can be trusted for spoke hole offset for asymmetric rims.

Hub

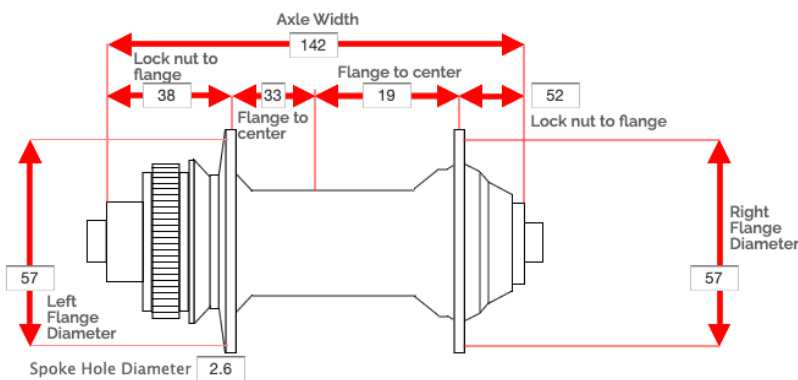
- **Flange Pitch Circle Diameter (PCD - left and right)**



Manufacturer supplied - checked with Vernier callipers for unknown / new hubs (where dimensions are not available).

- **Centre to Flange Offset (left and right)**

Again, often widely available or published by manufacturers, but for unknown / new hubs I measure using a specialist hub measuring device from iGaging.



Spoke length calculation

$$Spoke\ length = \sqrt{R^2 + H^2 + F^2 - 2RH \cos\left(\frac{4\pi \cdot X}{h}\right)} - \frac{d}{2}$$

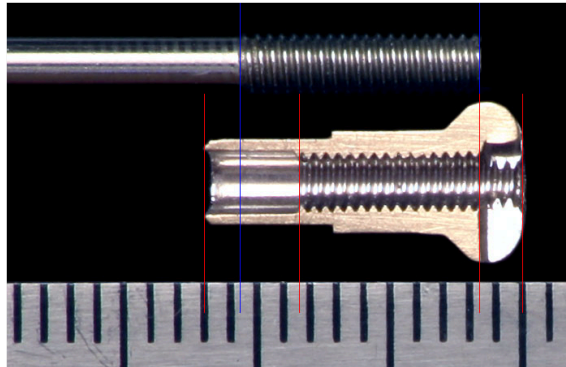
(where: R = Rim radius (half the ERD), H = Hub flange radius, F = Hub flange offset, X = Spoke cross pattern, h = Number of spokes, d = Diameter of hub spoke hole)

Spoke length calculation is basic trigonometry, and I use online calculators using the above formula to determine the correct length spokes. It is important to use a calculator that uses the ERD consistently with how it has been measured for a given rim.

The calculator I use and recommend is

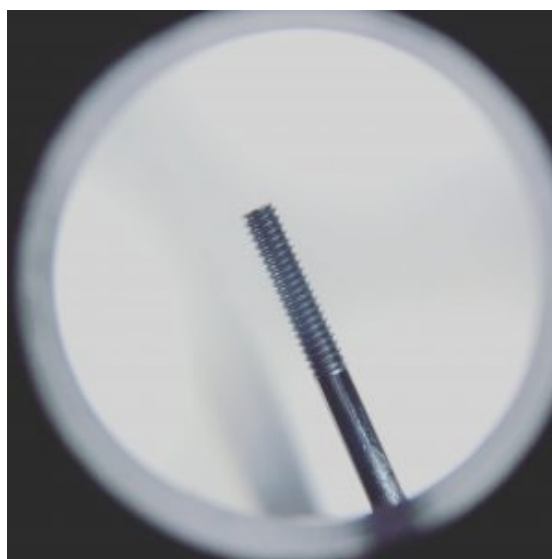
<https://www.kstoerz.com/freespoke/>

which bases calculations on an ERD derived from a perfectly positioned 12mm spoke (spoke end flush with screwdriver slot in spoke - a position which gives suitable thread engagement and room for adjustment), as below:



Spoke cutting and threading

Commonly, spokes are available in 2mm increments, which sometimes results in compromise (for example - we calculate 291mm, should we choose 290mm or 292mm?). Whilst it is possible to build perfectly acceptable wheels with compromises like this, I prefer to cut spokes precisely to length using the Morizumi Spoke Cutting and Threading machine. With this machine I can cut to a precision of 0.5mm and roll threads of the highest quality. This puts me in complete control of the process, and is part of a total commitment to quality.



Thread preparation

There are various methods of lubricating spoke threads. The best offer some form of lubrication plus subsequent gentle locking. The most traditional is linseed oil, which lubricates very nicely - it is sufficiently viscous to seep into the threads. As linseed oil dries it polymerises, which provides a gentle thread locking property. I am a big fan of traditional wheel building, and linseed oil is a very good choice. I also use "WheelFanatyk Spoke Fix", imported from the USA. This is a teflon-rich liquid adhesive sealant, which cures onto clean threads and provides low-friction building, and excellent anti-vibration qualities. When I use this, spokes are cleaned in turpentine (non-polar solvent) and then in isopropyl alcohol (polar solvent). I leave Spoke Fix to cure overnight to ensure best adhesion. **No thread compound is a substitute for spoke tension** - it is an additional protection, and the primary resistance to loosening is suitably high tension from the building process.

Spoke tension calibration

Every spoke batch is subtly different. Small variations in dimensions make a difference to measurement of tension. For example - Sapim CX Ray are notionally 0.9mm, but often present as 0.92mm - significant, as stiffness is proportional to the cube of thickness. To make sure that I can achieve the precise tension I require, I measure sample spokes from the batch I am using for each build. This is the only way to be sure of accurate tension measurement.



I use a custom built Tension Calibration device from GRS Engineering, who specialise in high end tooling for bicycle wheel building. This allows me to put a calibrated known load on spoke samples, and then measure what the reading will be on a spoke tension meter for that tension.

Lacing

I generally build using traditional 2x or 3x patterns as these provide the strongest, most reliable wheels. Radial lacing is an option for some low spoke-count front hubs, and sometimes for the rear non-drive side.

Setting spoke lines

Newly-laced spokes need appropriate correction of the lines they take from the hub flange to the rim to prevent excessive flex and movement at the spoke elbow. This is achieved in two ways: 1) with a gentle tap from a plastic headed hammer on the “elbows out” spokes, and 2) gentle leverage with an Engineer’s Punch of the “elbows in” spokes.

Truing and tensioning

As you can see, the real work of wheel building comes after thorough and careful preparation. When we true and tension a wheel, we adjust in the following dimensions:

Radial - the roundness of the wheel

Lateral - the side to side straightness of the rim

Dish (centre position) - the position of the rim relative to the axle lock nuts

I aim for a precision of $\pm 0.1\text{mm}$ lateral, $\pm 0.2\text{mm}$ radial, and $\pm 0.05\text{mm}$ dish. Often the rim join presents a small radial “hop” where it has been welded or pinned (it is virtually impossible to prevent this). This will not be noticeable in use. I build to extremely precise standards - often in excess of the precision for frame dropouts or tyre production! There’s sometimes a confusion once a tyre is fitted - “*I can see a wobble*”. Rest assured, this is natural variation in tyre material and production.



Spoke tension is added gradually, and “stress relief” is carried out constantly during the process. Guitar players will know that when you change the strings on a guitar, it’s useful to give them a good stretch and then re-tune, as otherwise we’ll encounter the stretch when we start playing, and need to re-tune immediately. That’s essentially what we are doing when we stress relieve the

spokes in a wheel - we stretch them and put them under higher tension than they will encounter in use, and then readjust, to reduce the risk of de-tensioning later, as well as making sure all the components bed in together in preparation for a lifetime of trouble-free use.

Keeping the tension even whilst forming a perfectly true wheel is the real art of wheel building. Even tension means that spokes will share the loads of the wheel in motion best, and no one spoke / set of spokes will “work” (as a wheel turns, spokes undergo a cycle of decompression as they pass the bottom of the rotation) more than others. I keep the tension even by monitoring it constantly throughout the process, and making all adjustments holistically (i.e. in consideration of the three dimensions of trueness and of the relative tensions of the spoke set - all of the variables are related). This is careful, patient work that should not be rushed.

Avoiding spoke twist

As spoke tensions rise, there is a natural tendency for spokes to twist with nipple rotation rather than rotate freely and tighten. There are a couple of notable ways of dealing with this - over tightening and then backing off $\frac{1}{8}$ of a turn with the spoke key is one common way. With bladed spokes the spoke is held in the correct orientation with a special tool, and I have also invested in a somewhat rarer tool that achieves the same for conventional round spokes. This is the Specialized Roval Twist Resist Spoke Hold Tool, which I use in the final stage of building with round spokes, when it is hardest to prevent spoke twist, and adjustments are very fine ($<\frac{1}{8}$ turn of spoke key), so the “over turn and back off” technique is not suitable.

Tension measurement

I use two of the highest quality devices available for measuring spoke tension. Both work on the same principle - measuring deflection under load.



Centrimaster Tension Meter



Wheel Fanatyk Tension Meter

The Centrimaster tool is a high precision analogue tool from Germany which I have found to be incredibly accurate, and the Wheel Fanatyk tension meter is an industry classic, based on an original design from Jobst Brandt (engineer and author of the definitive book “The Bicycle Wheel”). Both are calibrated and supplied with reliable charts of the readings for different spokes,

but as I have described above, I double check this for every spoke batch. I use two different meters as a “belt and braces” approach, no room for doubt.

Post build checks and recording

Final checks of all the measures of trueness, final checks of tension. Clean rim and hubs. Each build is then recorded in the wheellab.cc “Big Black Book of Builds”!

And, rest...

This could be superstition, but I was taught to let wheels rest overnight. That way they get a change of temperature, a chance to settle. Then - check them again, clean, and prepare for despatch.

Finally

Enjoy your new wheels - they have been built with the greatest care and love, and I hope they serve you well!

Further recommended reading

Jobst Brandt - “The Bicycle Wheel”
Roger Musson - “Professional Wheel Building 7th Edition”
Gerd Schraner - “The Art of Wheelbuilding”
David CR Hunt - “Professional Wheel Building - The Manual”

Image credits

Page 1 ERD - <https://www.prowheelbuilder.com/spokelengthcalculator>

Page 2 Hub dimensions - <https://www.prowheelbuilder.com/spokelengthcalculator>

Page 2 Formula - Roger Musson <https://www.wheelpro.co.uk/support/spoke-length-calculators/>

Page 3 Spoke cut through - Karl Stoerzinger <https://www.kstoerz.com/freespoke/tech-threadengagement.php>

All others my own.