Strong Durable Bike Wheels

Everyone wants strong wheels that stay true and don't buckle. On top of that, they want them light and cheap. Well, the good news is that you actually can go a long ways towards getting this ideal wheel. This article aims to cover the basics of what you need to know to approach this, whether you want to make your own wheels, or whether you want to select parts for a wheel that someone else will build for you.

Almost everything I know about wheelbuilding comes from reading Jobst Brandt's book *The Bicycle Wheel*. If you want to be an expert in wheelbuilding, buy it and read it. This article has only a small amount of info that isn't contained in the book. My main purposes are to provide info on parts of wheels for people who want others to build their wheels, and to inspire people who are thinking of building their own wheels. Click here for a review of *The Bicycle Wheel*.

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What makes a strong wheel?

The strength of a wheel comes mostly from the spokes, and secondly from the rim. To have a strong, durable wheel, the quality of the wheelbuilding is far more important than the quality of the parts.

Most people seem to think that wheels fail in impacts because spokes break. In fact this isn't true. Most of the time when you have a buckled wheel, you'll find that despite the now potato-chip shape of your wheel, the spokes are all intact.

Wheels collapse when one of more of your spokes loses tension as a result of an impact. Obviously, the spokes that lose tension are the ones right at the point of impact. Then there's nothing supporting the rim, and it twists. The tighter your spokes are to begin with, the further they have to go before they lose tension. Thus a high-tension wheel is one that will resist impacts well.

And yes, spokes do break, but it's not usually as the result of an impact, typically they just break as you're rolling along. Spokes break as a result of fatigue. If your wheel is loose, then every time the wheel goes around, it flexes a tiny bit, and eventually it breaks. In fact spoke breakages are the most telling sign of wheels that don't have high enough tension. If your spokes are tight, the spoke doesn't move as the wheel turns, so they can last much longer. Thus a high-tension wheel is one that will last a long time with few spoke breakages.

The rim does contribute to the strength of the wheel, which is why rims for downhill mountain biking or expedition style touring are quite wide. However, they do this at the expense of quite a bit of weight. While you don't want a rim that's too wimpy for your intended use, the best way to increase the strength of your wheel is to increase the spoke count and make sure the spokes are about as tight as they can be.

Another thing that affects the strength of the wheel is the amount of dishing. This is mainly a problem with the rear wheel, although it is an issue with front wheels with disc brakes as well. On a normal front wheel, you have flanges equidistant from the center of the hub, and spokes go from these flanges to the rim. The spokes coming from each flange go at the same angle to the rim. On the other hand, consider a rear wheel. The right side of the hub has to have room for lots of sprockets, so the right side flange is much closer to the center than the left side flange. Thus if the rim is aligned with the center of the hub as it should be, the left side spokes will be more

slanted than the right side spokes (in some cases the right hand spokes are nearly vertical). Thus, in order to keep the rim in the center, the right hand spokes will have to be much tighter than the left hand spokes. When the wheelbuilder is tensioning the wheel, the right side spoke will reach their maximum tightness long before the left spokes will. It is the weakness of the less-tight left hand spokes that makes a highly dished wheel (one where the angle difference between the left and right spokes is great) less strong and less durable than a wheel with less dish.

In order to offset the growing numbers of cogs used in the rear wheel, the total width of hubs has been expanding. Fixed gear track hubs have an over-locknut (basically, the width of the space between the dropouts on the bike) width of 110mm. The old 5 and 6-speed screw-on hubs have a width of 126mm. Now hubs are usually 130mm wide for road use, 135mm wide for off-road or touring use, and 140mm to 160mm wide for tandems. The idea with the wider hubs is to put more distance between the right flange and the center of the hub, so that there still will be a decent slant to the right hand spokes. You can then move the left hand flange in a bit to try to make the angle more equal.

Ingredients

Hubs

At the center of it all is your hub. Almost all hubs have aluminum shells and flanges (the bits of the hub with spoke holes). First, it's lighter than steel. Second, the flanges deform a bit to support the spokes better. (This is why if you build a wheel using an old hub, you should look closely at the hub and lace it up the same way as it was used before.)

For the purposes of building a wheel, what you want are flanges that are going to support the spokes properly and aren't going to rip apart. To achieve this, the main thing to look for is a hub that's built via forging rather than being CNC machined. CNC machining allows the manufacturer to make all sorts of fancy shapes, but the result isn't as strong as an equivalent forged part.

In my opinion, there isn't much point in buying anything other than Shimano of Campagnolo hubs. They are good quality forged hubs and are good value for money. The only exception is if you want disc brakes. Shimano have gotten into the game only recently, and their offerings aren't as good as others yet. In particular they're quite a bit heavier than most other hubs. But given their track record, in a few years they'll have top-notch disc hubs.

Rims

Rims should be made of aluminum. Steel may last longer, since the sidewalls don't wear out under braking as with aluminum rims, but they are an absolute nightmare when it's wet. If you've got steel rims in the rain you're more likely to stop yourself by putting your foot down than by using the brakes. The only way to make steel rims work in the wet is to use leather brake blocks, which wear out very quickly. In addition, steel rims are heavier than aluminum ones. Wheels with alu rims also survive impacts better: they are less stiff than steel rims, so they bend a little bit under an impact, spreading the load to more spokes. This helps to prevent spokes from losing tension and collapsing the wheel.

Rims can vary in cross-section from a simple squared-U shape, to a multi-cavity box. In general, the bigger the cross-section, the more walls, and the thicker the walls are, the stronger the rim is. For most purposes, a narrowish (say 19 to 23mm width) single cavity (a simple box) rim will do fine. If you want something stronger you can get wider rims (for off-road and touring use) or deeper rims (for fast road use). The deep-section rims have the additional advantage of being a fair bit more aerodynamic than one with a more square profile.

Most better rims have steel eyelets lining the holes for the spokes. These distribute the stress of the spokes to a slightly larger section of the inner wall of the rim, making the rim less likely to crack. Some box-section rims have "double eyelets" which form a little cylinder in the cavity between the walls of the rim. This can help distribute stress from the spoke to the other wall of the cavity (the one nearer the tire) and also helps to prevent

your nipples from going wandering in the cavity while you're lacing up the wheel. Unfortunately, many rims are made with only single eyelets.

Rims are extruded as straight bits, then coiled up into circles, and then the ends of the hoops are joined together. The old way to put rims together was to simply line them up accurately, put a small insert in the cavity, and press the two ends of the rim together. The newer way to do this is to weld the ends together, and then machine the sidewalls so they are even. The benefits of the old system were simplicity. Sometimes there would be a slight misalignment at the join, and this would result in the join catching at your brakes. However, the braking quickly wore this smooth. The benefit of the new system is that it's nicer right out of the box: there is no unevenness at the join. In addition the little ridges left by the machining initially improves your braking performance, but this wears off quickly, leaving smooth aluminum. The drawback is that it's a more expensive process which leaves the walls thinner. Of course you can argue that the walls are designed thicker to start out with, so machining leaves them with the right wall thickness. But then this is a waste of materials, and you're likely to end up with a varying wall thickness.

What the pinned or welded-and-machined argument boils down to is the initial impression. Once your brakes have worn down the unevenness of the join or the little machined ridges, both rims perform the same, except that the walls of the machined rims may be thinner or even an uneven thickness. Welded-and-machined rims cost quite a bit more than the old pinned rims. Given a choice, I would buy pinned rims exclusively, but they are getting hard to find. I do sometimes manage to pick them up at bike rallies, and when I find them there they're generally dirt cheap.

Some rims meant to go into rear wheels have spoke holes that are offset to one side. The idea is that you build up the wheel with the spoke holes offset towards the non-drive (left) side of the rear wheel. This decreases the angle of the left spokes while increasing the angle of the right spokes. With more equal angles, they are more equal in tension as well, allowing the left hand spokes to be tighter when the wheel is tensioned up. This theoretically makes the wheel stronger, but there doesn't seem to be any proof that it works in practice. As for me, I'm convinced by the theory and tend to by asymmetric rear rims, unless I'm buying vintage pinned rims, which definitely don't come in asymmetric versions.

Rims can have several finishes put on them. Some finishes are strictly decorative, giving a nice color to the rim. Hard anodizing (Mavic calls this CD) is touted by rim manufacturers as something that makes the rim stronger or longer-lasting. However, it is best avoided. If the anodizing is on the sidewall of the rim, then it will make the sidewall last slightly longer: first the black stuff wears off the brake surface, and then the aluminum underneath starts to wear. So theoretically your sidewalls could last a bit longer. However, this coating wears off quickly, so this is of minimal benefit. Furthermore, the anodizing decreases braking power considerably. You'll be eager for that black stuff to wear off your rim as then your brakes will start to work again... In fact some rims are machined after anodizing so the rim starts off with a clean braking surface.

You might then think that once the sidewalls have been scraped clean by your brakes (or the machining) that you'll then have some protection from the bits of it still clinging to the spoke bed. However, this not only does no good, but can lead to premature failure of your rim. The anodized layer is hard and brittle. Rims do flex slightly as they go around, and the anodizing can crack. These cracks can then propagate into your rim, and then the spokes can rip out of their holes. I'm not sure how seriously to take this danger of cracking. After all, I've had some hard anodized Mavic MA40 rims for years and have had no problems with cracking, so it may do no harm to your wheels. But it certainly won't do any good either. If you really want black rims, go for a cosmetic anodizing instead.

A ceramic coating on your rims is a more useful thing. This coating takes ages to wear off, and in fact doesn't come off at all unless you nick it with a rock. Once it starts to come off it will gradually flake off, but even if you ride in a very rocky area you can still get greatly increased rim life. In addition, braking in the wet is improved. There are some downsides though. First, the cost. The ceramic coating can just about double the price. If you generally retire wheels due to trashing the rims rather than wearing them through, ceramic rims

will not be cost-effective. Second, the coating insulates the rim. Usually when you brake, the heat of braking goes into the rim where it is then dissipated. The ceramic layer prevents this, so all the heat stays in your brake blocks, and they can melt. You need to buy special brake pads for use with ceramic rims to prevent this. Third, although braking in the wet is better with ceramic rims, even with ceramic-specific pads it isn't quite as good in the dry as bare alu rims.

Spokes

Spokes are mostly made from steel. On very expensive wheels, you can get titanium, carbon fiber, or aluminum spokes, but steel is the standard choice for several reasons. First, steel is cheap. Second, it is strong and has good fatigue resistance. Third, it's easy to cut smooth, strong threads in it for the nipples.

So the main things you need to ask yourself is: what shape (profile), how many spokes, and what thickness? First, shape. Almost all spokes are round in cross section. If you want the wheels for time trialling or triathlon, where you'll be going very fast and aerodynamics are important, you can get ones that are a bit flattened in profile. However, if you get them too flattened, you won't fit them through the hole in the hub. You can get special hubs for this if you're desperate for very areo wheels.

Second, number. Low spoke count wheels are trendy nowadays. But let's face it: spokes really don't weigh all that much, and they are really what gives the wheel its strength. So you really gain very little by using few spokes. Consider, for example, Rolf wheels. They have very few spokes, but the rims have to be heavier in order to provide structure for the wheel in the large gap between spokes.

Still, if you're very light and ride only on the road you'll be putting less stress on your wheels than if you're heavy or ride off-road, so you can get away with fewer spokes. As a general guide: for road riding, 32 spokes make a good durable wheel, while if you're large, ride off-road, or go touring, 36 spokes is better. If you're light and want a light wheel, 28 spokes will do. 28 spokes is also fine for a racing wheel, where you're willing to trade off some strength for speed (reduced spoke count makes for reduced areo drag) and lightness. For off-road riding, the greater strength of MTB rims (their smaller diameter and wider profile) means that most people can get away with 32 spokes. Heavy people or people who want to carry a significant load off-road, dirt jumpers, or downhillers would be better off 36 spokes. Tandems generally need more than 36 spokes: 40 or 48 is the norm.

Third, thickness. Here, you not only have a choice of how thick you want the ends of the spoke to be, but also a choice of having spokes that are narrower in the middle. The spokes that are thinner in the middle are called double butted. Double butted spokes are definitely the way to go. They are slightly lighter than straight gauge spokes, but their main advantage is that they make a stronger wheel. The thinner middle section allows them to stretch a bit when the wheel is hit, spreading the load to neighboring spokes to help distribute the impact. This helps to prevents the elbow near the spokes head from flexing (which leads to fatigue and spoke breakage), and also takes the stress away from the rim wall near the nipples.

One of the most common myths about wheels is that double-butted spokes will make your wheels weaker. Where people get this idea from, I have no idea. Spokes almost never break in the middle, only at the ends (usually near the spoke head), so common sense should tell anyone that a wheel built from double-butted spokes will be at least as strong as one built from straight gauge spokes. In fact because of their greater elasticity, double-butted spokes result in a stronger wheel.

In general, the thicker the spoke is near the head, the stronger it will be. However since spokes mainly fail from fatigue (see above, under What makes a strong wheel?) if the wheel is built well, this does not make a big difference. So don't go thinking that to have strong wheels, you need to have super-thick spokes. In fact you'd be better off by having more thinner spokes to distribute the load better.

I tend to use 14/15/14 gauge (2mm/1.8mm/2mm) DT stainless steel spokes in all my wheels, mainly because that's what the local bike shop stocks. I wouldn't hesitate to use 15/16/15 gauge (1.8mm/1.6mm/1.8mm) spokes if they were as easy to come by. You can also get spokes that are drastically thinner in the middle than they are at the edges, such as DT's Revolution spokes, which are 14/17/14 or 15/17/15 gauge. I wouldn't use these

because it's hard to prevent spoke windup (twisting of spokes) with these spokes as they have so little torsional rigidity. However, if you're getting the wheels built by someone else, use them by all means as long as you don't mind the extra cost.

Nipples

With nipples there's much less choice. You get nickel-plated brass ones, or aluminum ones. The brass ones are stronger, and the brass helps to lubricate the threads a little. (However, this alone is usually not sufficient, so it's best to put some grease or oil on the threads of your spokes before putting on the nipples to make sure they don't bind when the tension is getting high.) The alu are lighter, but in most people's opinion there is not enough of a weight savings to make up for their shortcomings. Serious wheelbuilders use brass nipples.

Tools for the DIY approach

First and foremost you need a spoke wrench. The best one you can get without paying a fortune is the Spokey. It's a cheerful plastic disc with nipple-gripping bit on one side. The advantages of the Spokey are that the textured disc is easy to hold and gives you lots of leverage, it grips the nipple well, and it's inexpensive. Just make sure you get the right size for the nipples you use.

While it's possible to build a wheel without a wheel truing stand (using your brake blocks to tell you when the wheel is out of true) the task is made immensely easier with the use of a proper stand. You need to look for several things. First, it's useful if the feelers for the left and right sides of the rim can be moved independently, so you can choose which bumps to take care of first. Second, you need a gauge that goes up against the edges of the rim so you can check radial trueness.

I've used two truing stands. I wasn't pleased at all the the TACX Scorpio. The feelers didn't move independently. One knob moved them both in or out, and you had very little fine control over this movement. In addition it had nothing to help you with radial trueness. The Minoura Workman Pro I now own is much better. The feelers are simple screws, so you can move them independently and have fine control over how close they are to the rim, and there's a little movable plate for radial trueness. My only complaint is that the plastic bit that holds the feelers and the plate has cracked. I haven't been abusing it, so this suggests that it isn't very durable. It still hasn't broken though. Regular Performance catalog shoppers should note that the Minoura Workman Pro is exactly the same as the Performance Spin Doctor Truing Stand.

Finally, you need a dishing tool to make sure that the rim is centered between in the middle of the hub. These are pretty basic and all are similar. I have one by Minoura, but I'm sure any would do.

Building a wheel

Lacing

Making a wheel from the constituent parts has basically two phases. First, you put everything together. This is called lacing. I've done this enough times that it's pretty automatic, but there's no point in me typing it all out, as others have described it so well already. See Part II of Jobst Brandt's book *The Bicycle Wheel*, which has excellent illustrations. Or see Sheldon Brown's wheelbuilding pages. I'll only mention here that you should thoroughly grease the spoke threads before you start. That makes them easy to turn in the nipples and allows you to get the needed tension.

Tensioning and truing

Once you've laced the wheel up, screw all spokes in until the threads of the spokes just disappear into the nipple. Then shove the thing on your wheel truing stand and get tightening.

Basically, the idea is to bring up the tension of the wheel while maintaining lateral trueness (lack of side to side wiggles), radial trueness (even distance of rim to hub) and dishing (equal distance from rim to locknut on both sides of wheel). For the first, you have the feelers feeling the sides of your rim to tell you when they're out of true. For the second, any decent truing stand will have a bar that you put next to the rim, and where it scrapes,

that part is further from the hub. For dishing, you have your dishing tool, which is basically an arch with feet on the ends of the arch (you put that on the rim) and a feeler hanging down from the top of the arch. You adjust the feeler so that it just hits the locknut on one side of the wheel, and hopefully it just hits the locknut on the other side.

If the thing is out of true laterally, what I do is try to bring up the tension at the same time as I'm truing, by finding a place where the rim is out of true, and finding a looser spoke opposite the bulgy side (find looser spoke by plucking), and tightening that until it's roughly the same tension as the spokes near it. If there isn't a looser spoke, I tighten up two or three of the spokes a bit (half turn maybe) to bring up the tension.

If the thing is out of true radially, I tighten a few spokes near the bulge about a half turn, and ones next to those about a 1/4 turn, tightening spokes on both sides of the wheel. (Again my goal is to increase tension as I'm doing my truing).

If the thing is dished wrong, set up the feeler on the dishing tool so that it hits the locknut on one side, but has a gap between feeler and locknut on the other side. (Only do the dishing bit when the rim is laterally true; if you have side-to-side bulges you get different results depending on where you put the dishing tool on the rim.) Say we're looking at the wheel so that the gap side is on the right. Now, your goal is to bring the rim further to the left to try to close up that gap. What you need to do is tighten the spokes on the left (non-gap) side. Don't tighten too much at once here. Maybe 1/2 (or even 1/4, if the gap isn't too big) turn per spoke on the left hand side. This will bring the rim slightly closer to the left, giving a small gap on the left side, and making the gap on the right side smaller. Hopefully the gaps are now the same size, and when you realign your feeler, you'll get it just touching the locknut on both sides.

Your goal is to get a wheel that's true in all three senses, and tensioned enough. "Enough" is hard to gauge when you're starting out, but a rough rule of thumb is that the nipples should be quite hard to turn when you're finished. If you've managed to get all three aspects true but the wheel isn't to a high enough tension, then tighten all spokes about 1/2 turn, and retrue. Repeat until done.

When you're tightening (or even loosening spokes), turn the spoke a bit past the amount you're trying to tighten (or loosen) then back off. So if you want to tighten by 1/2 turn, then tighten by 3/4 turn, then loosen 1/4 turn. This helps prevent spoke windup (twisting of spokes). Unfortunately, despite your best efforts, you can end up with windup. This is the method I use to let the spokes unwind. Put a magazine on the floor and pull the quick release skewer out of the hub. Put on end of the hub on the magazine, and put your hands on two opposite places on the rim, then lean your weight on your hands. This releases the tension on the lower spokes just beneath your hands and lets them unwind if they've got wound up, making a pinging sound. Go around the rim this way, then turn over and repeat. You'll then have to put the wheel back on the truing stand to make sure this hasn't made the wheel go out of whack. If you've gotten spoke windup and you don't do this, you'll hear the pinging noises when you go to ride your bike with your new wheel.

Stress relieving

Once you've got your wheel all tight and true, you want to stress relieve it. This relieves minute stresses that may have built up in the spokes. Again, see *The Bicycle Wheel* or Sheldon Brown's wheelbuilding pages for info on how to do this.

Further reading

Other wheel-related stuff here

- Wheelbuilding tips
- Finding inner peace through wheelbuilding
- This wheel is made of memories

- Review of Jobst Brandt's book *The Bicycle Wheel*

Wheel-related stuff elsewhere

- Wheelbuilding the BikIndex Way
- Wheelbuilding by Sheldon Brown
- Spoke Length Calculator

If you want someone else to do it for you

I can recommend Roger Musson of Wheelpro. Unfortunately he only does MTB wheels.
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