SPOKE WHEEL BUILDING & TRUING

by Mark Barnes

IF YOUR BIKE has spoke wheels, then you need to know how to maintain, repair and true them, it's as simple as that. This article will cover the basics as illustrated with a dirt bike wheel, but the same principles apply to street hardware. Note that we're using a tube-type rim because most spoke wheels are like that. Less common tubeless spoke-wheel applications, like those on the BMW GS, the Aprilia Capo Nord and various trails bikes, look a little different, but the fundamentals are identical.

Second, you need a way to get your bike's wheels up off the ground, at least one end at a time. If you're changing components, the wheels obviously must be removed. But if you're just giving your wheels a truing tune-up, they can stay on the bike.

Third, you've got to have some way of measuring very small deviations in the radial and lateral movement of a turning rim. Professional truing stands allow for rotation of a wheel's hub in a fixed plane, and include an adjustable armature for mounting a runout gauge or for using as a static indicator all by itself. However, these professional grade tools are rather expensive (from around $200 to upwards of $600), and you can probably improvise something adequate for a whole lot less (see sidebar).

A fourth necessity, one that isn't particularly expensive, is a quality spoke wrench. Throw out that pot-metal piece of junk that came in your bike's tool kit—it'll do more harm than good. Spoke nipples are small but require significant torque. And if it's a dirt bike you're working on, the nipples you'll be twisting are probably made of soft, easily deformed aluminum, and they may resist turning due to corrosion or excessive tension. Either way, a precise, tight-fitting match between the wrench and nipple is absolutely necessary to avoid rounding off and ruining the nipple's flats and crushing it against the spoke threads. You can usually pick up a much better-fitting version at your local motorcycle shop for under ten bucks. But know the exact size you need, as there are half a dozen in common use.

Finally, because the procedures involved are extremely repetitious; use tiny increments of adjustment; and require a meticulously systematic approach, you will need above-average patience and a setting in which you can concentrate for an extended period of time.

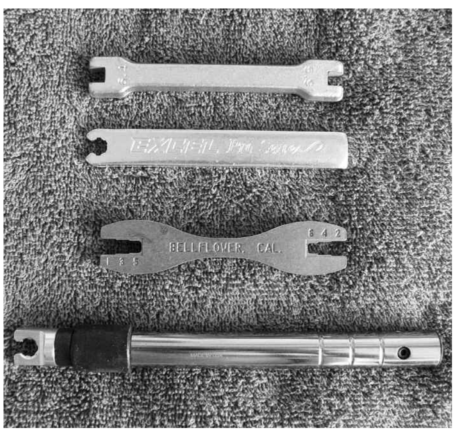
Starting From Scratch

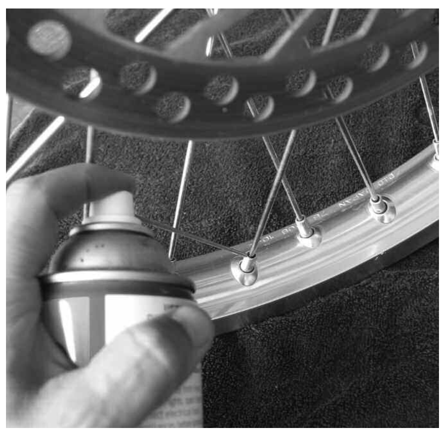
If you're replacing only a bent rim plus a broken spoke or two, begin by taping the spoke overlaps together to keep everything in alignment. However, if major disassembly is your plan, and you are replacing your hub, perhaps a full set of spokes and/or rim without altering the original spoke pattern, you should begin by studying your wheel's layout before taking anything apart. Spokes are rarely identical; often with four distinct configurations per wheel, some with the heads angled differently because they are positioned inside or outside a flange and therefore slightly different in length as well, and/or the hub flanges are different sizes or configurations, necessitating perhaps two more different lengths and angles. The distance from the head to the bend is known as the throat length, which varies depending on the thickness of the flange.

Notice, too, how the spokes leave the hub in different directions; which row of hub holes points its spokes clockwise, and which counter-clockwise? Look to see where the spokes cross one another, and how many make up a repeating pattern (the most common arrangement is a sequence of four, comprised of one inner and one outer from each hub flange). If you have a digital camera, take several pictures from different angles for quick reference later. Or, make yourself a sketch. Spending a few extra minutes at the beginning may save you much frustration later. And if you're building a wheel with all new aftermarket components, you may be given a completely different spoke pattern from your bike's original design, so consult your supplier for instructions. If you're only replacing spokes, you can ensure the reproduction of the existing configuration by simply replacing each one you remove before removing the next one.

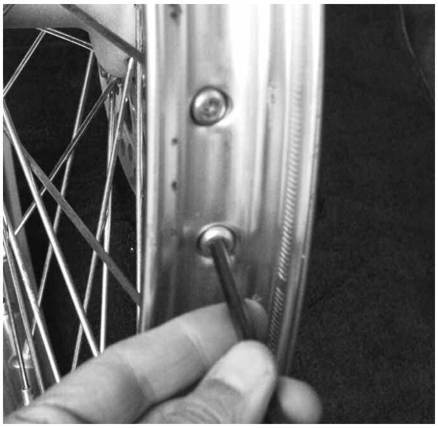
In the example shown, we're keeping the stock hub, and installing aftermarket stainless steel spokes and an aluminum alloy rim, all made by Excel. The goal was increased strength, so the replacement pieces are sturdier than stock (however, the weight difference in this particular application is negligible). And while you can't appreciate it in black-and-white photos, the new rim is also flashier, with a deep gold anodized finish. Also, we chose Excel's "spline drive" nipples, which provide a stronger surface for wrenching than conventional square nipples, and they're made from steel instead of aluminum.

The trickiest part is getting everything in place without scratching your new rim. Start by placing your disassembled hub flat in the center of the rim. Hubs with large off-





Left: The stock wheel prior to disassembly. Note that the nipples have Allen heads at their ends, accessible only with the tire and tube removed, but some will have slots for conventional screwdrivers instead. Center: Choose your weapon. From top: Stock tool kit spoke wrench, spline drive wrench included with new spline-drive spokes; the multi-size spoke wrench from Rowe, which covers all six common nipple sizes; Fasst Company's spoke *torque* wrench, with spline drive head. Right: A little penetrating lubrication can make nipple removal a painless process. Now there's a thought!

Left: A perfect fit between spoke wrench and nipple makes the job easy and…(Center) prevents this from happening. Not only is this nipple rounded, it's also become crushed against the spoke threads, making it doubly difficult to remove. Right: Once loosened "topside" with a wrench, nipples can be unscrewed easily from the other side.

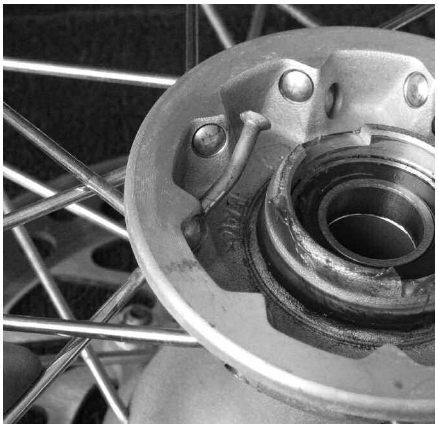
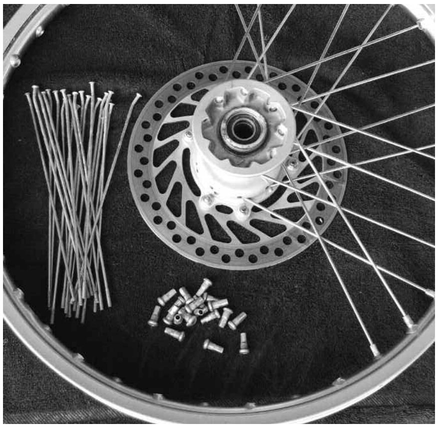
sets may require special measures, such as setting the rim on a couple two-by-fours in order to get its centerline at the midpoint between the two hub flanges. You'll be lacing one hub flange completely before turning everything over. Thread the first spoke through its hole in the hub, and then insert its threaded end into the rim, taking care to chose a hole angled upward (toward the side of the hub you're currently working on). If you're working on a very fancy wheel, the rim for which has holes cut at more than two angles (left and right), you'll need to make sure that the spoke's entry angle matches the rim hole's angle precisely. (You can check this by simply inserting a pencil through the hole and confirming that the spoke lines up with it.) Now, after putting a drop of lubricant on the threads to inhibit corrosion, screw a nipple onto the spoke tip—but only a couple turns. This keeps the spoke from falling back out of the rim, but leaves you maximum room to push the rim away from the hub in other directions to give subsequent spokes the clearance they need for easy insertion.

On the wheel shown, we found it worked best to do all the outer spokes (those furthest from the axial centerline) first, and then insert the inner ones. This may be different on your wheel, depending upon the spoke pattern and clearances. You may have discerned the easiest sequence during the disassembly process, or you may have to do some trial-and-error testing at this stage. The main point here is that you should not have to struggle to get all the spokes in place. If you find yourself tempted to force a spoke into position by bowing it or its neighbor, there's almost certainly a better way. Remove a few and try a different order. Be sure to leave the correct number of holes on the wheel open between spokes as you insert them.

Once all the spokes are in place on one hub flange, turn the wheel over and repeat the process on the other side, and when you complete this phase of the job, give yourself a pat on the back; the (relatively) hard part is over. You now have a floppy, jangly thing with a roughly circular shape that will soon become an amazingly sturdy and geometrically precise piece of hardware.

Circular Logic

Chances are, the rim you're working with is currently very close to perfectly round. Your job is to keep it that way while tightening all those spokes, any one of which is capable of distorting your rim's shape in either of two dimensions. You see, spokes are incredibly strong devices. Their real strength is in the form of pulling (tension), rather than pushing (compression), even though that may run contrary to intuition. Spokes do not support the hub from underneath so much as suspend it from above. Think about it. Which would be stronger, a single spoke extending from the hub downward to the rim, or that same spoke extending upward? Would it be easier to bend the spoke below or tear the spoke above? Now it's obvious, right? Tremendous tension can be brought to bear on the rim by tightening spokes, enough to deform a very strong loop of steel or alloy into a wobbly potato chip shape. You can avoid this painfully embarrassing fate if you heed our advice.

Left: Notice how the inner row of spokes on the far flange point clockwise, while the outer row points counter-clockwise. Also, see how their heads are recessed in the near side of this hub. Center: The partially installed spoke illustrates its specific features: The "head," "throat length" (distance it passes through the flange) and "angle" to match the direction to the rim. Right: The old wheel, half-way disassembled.

Left: The new pieces, left, are visibly more substantial than the stockers they replace. (Don't be fooled by the narrower threaded section on the Excel spoke; its shaft is thicker than OEM.) Right: The first row of new spokes, with nipples loosely attached. Right: Notice the even spacing along the rim.

Start by getting all the nipples equally snug. Again, you may have to figure out what's possible by trial-and-error. On our example, we found we could get all the nipples tightened to the last visible thread on each spoke before any significant tension was applied to the rim. We arrived at this knowledge by meticulously tightening every spoke on the wheel the same number of turns, time after time. Time consuming, yes, but ultimately it saved time because we didn't end up with one side of the rim pulled in closer to the hub than the other side before we even started the truing process. Remember, the definition of a circle is a line with all points equidistant from a central point and lying in the same plane. It's better to avoid pulling the wheel out of round from the beginning, instead of correcting deviations afterwards.

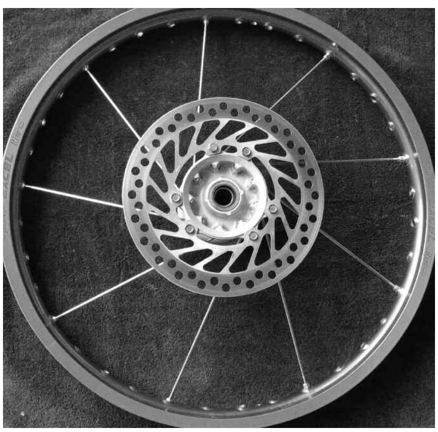
Now, with all the nipples threaded the same distance up on the spokes, the wheel will be much closer to rigid, but there should still be no tension among the spokes. When you lift it up, it should hold its shape, but still jingle just a tiny bit. However, you may notice that—even with all the nipples perfectly the same on their respective spokes, some are closer to the rim than others. This may be because of variations in spoke length or their placement radially on the hub. For example, if all the outer spokes (furthest from the axial centerline) are also a little closer to the edge of the hub's flange, they will protrude further through the wheel unless they compensate for this difference in hub mounting position by being slightly shorter than the inner spokes. If you find such a discrepancy between spoke subgroups, carefully adjust the looser ones in small increments, just as you did with all the spokes at the start of this tightening process, until they have just as little slack as the spokes that were initially closer to snug.

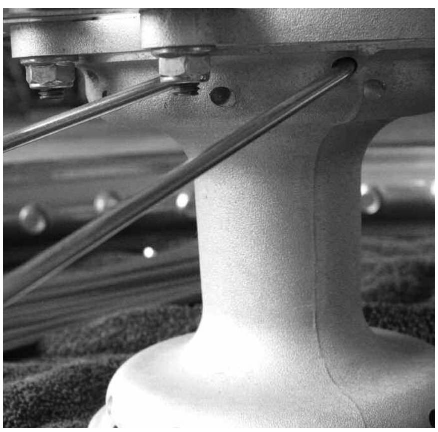
NOTE: Those of you who are only performing a tune-up on your wheels, rather than building them, should join us here. Because spokes will tend to loosen over the miles, you should try to identify the loosest spokes by spinning the wheel and bouceing a wrench off the spokes. The loose spokes emit a dull "dead" sound when tapped, while those that are still tight emit a bright "ping." To get all the nipples close to snug before precise truing, snug the loose spokes first.

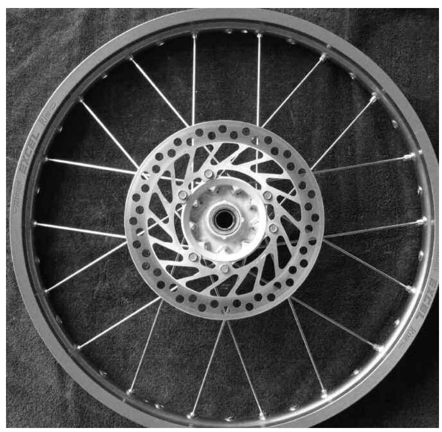
If you decided to spring for a truing stand, position your wheel in it now. If you are using a different method, secure the wheel on its axle (or axle-substitute) and set up your runout detector (dial gauge or pointer armature) to check radial runout (distance from the hub center to the outside edge of the rim). Next, check the lateral runout, (side-to-side deviation). If your spokes are all evenly snug (but not floppy), this will tell you if your rim is way out of true, all on its own. A new rim should be nearly perfect, and small deviations in a used rim may be correctable during the truing process.

Now The Fun Begins

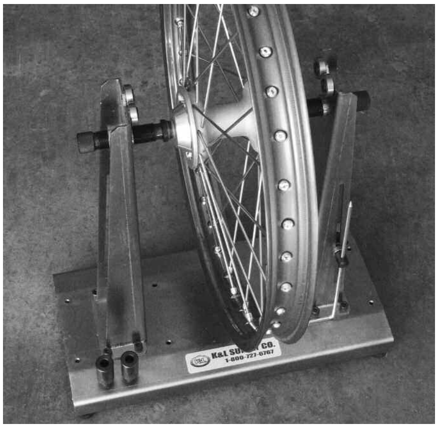
We'll address radial runout first. With your detector in position for this measurement, determine where the rim is furthest away from the hub. This will be the "high" zone if your detector is at the top of your wheel or the "low" zone if it's at the bottom. You'll need to tighten the spokes in that zone to pull the rim there closer to the hub. Start with a spoke in the middle of the

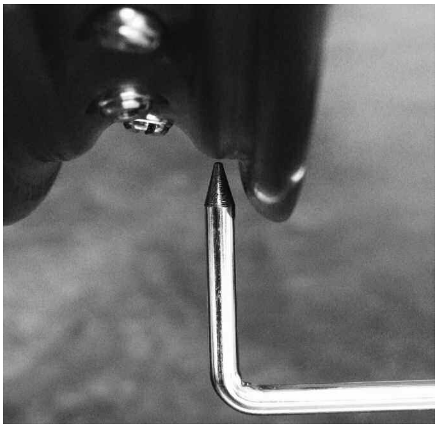






Left: One row of spokes finished. The wheel begins to take shape. Center: Detail of the spokes leaving the hub. Notice how the holes point only partway toward the spoke's target on the rim; the spoke's bend (right at the hole's edge) completes the necessary angle. Right: Halfway done; here's the wheel with one side (flange) of the hub laced.





Left: This truing stand from K & L Supply is a good value; it can be used as a balance stand as well. Notice the armature stored on the right-side support. Center: Here the armature is set to radial runout. Notice that the reading is taken from a horizontal surface on the rim, rather than at the edge of the flange. This keeps variations in flange shape out of the equation. Right: The armature has been set to measure lateral runout. Notice that the reading is taken at the base of the rim flange to minimize the effect of irregularities in the flange's shape.

offending zone and tighten it in a small increment, such as a half-turn. Tighten the next spoke on both sides of it slightly less, maybe a third of a turn. Tighten the next spokes away even less, perhaps a quarter-turn. Finally, tighten the next spokes out (now three spokes away from the first) an even smaller fraction of a turn. This method distributes the influence of your efforts evenly, so that it doesn't change the lateral runout, instead of causing an acutely focused shift that is likely to create other irregularities and send you chasing your tail in an endless series of corrections. Next, find the "low" spot and reduce spoke tension in a similar pattern.

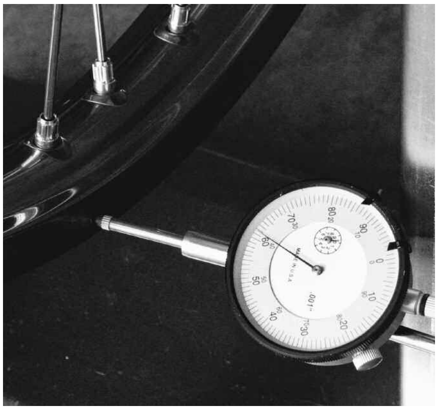
This is the kind of thing you will develop an efficiency-boosting feel for with practice. But novices should make small adjustments, even though that may mean making a lot of them. It will still take far less time to do it right the first time—gradually—than to get into—and then back out of—a cycle of overtightening/overcorrections.

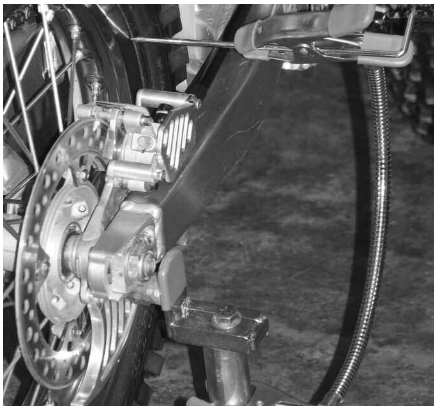
Now recheck the radial runout. Is it still within your margin for error? If not, repeat the previous steps and check it again. Keep doing this until your wheel shows less radial deviation than two millimeters.

Now, it's time to switch the angle of attack, although the battle tactics remain the same. Set your runout detector to check the lateral deviation and rotate your wheel to find the place where it is furthest from the axial centerline. For the sake of simplicity, we'll call that the lateral "high" zone, and in this example let's say you've found it on the *right* side of your rim right next to the rim lock hole. To pull it back toward the center, you'll need to tighten the spokes on the *left* side in that zone while loosening the spokes on the *right* side. Start with the left spoke closest to the middle of the high zone, and tighten it a small amount. Proceed to its next left neighbors on both sides, and tighten them a little less. Continue to spread your influence to the outer edges of the high zone, reducing the amount of rotation as you get further away from the middle, and tightening only the spokes on the left side. Repeat the same technique while loosening the right side spokes.

Recheck the lateral runout. Next, determine the lateral "low" zone (the *right* side) and make the necessary adjustment, by loosening in the same way. Repeat this process until the rim has less lateral deviation than two millimeters. Note that it's possible by making all adjustments to only one side (for instance, always tightening the left side, rather than tighening/loosening) to make your wheel perfectly even in the left-right dimension, but with the rim centerline *offset* laterally to one side of the hub's axial centerline.

For more precision in achieving this alignment of centerlines, depending on how your wheel is mounted for this operation, you may be able to flip it around in your wheelstand or take measurements on both sides from positions exactly the same distance from the hub's centerline; a straightedge laid across the flanges might allow this. Note, however, that all *hubs* are not necessarily symmetrical in their axial





Left: Here, a dial caliper is set to measure left-right runout. Center: During the truing process, each spoke is turned only a small amount at a time. Many tiny adjustments get the job done more quickly than larger moves that upset the wheel's shape elsewhere, or set up a cycle of overcorrections that deforms the rim. Right: This simple yet effective truing setup required only a pair of clamps connected by an articulated stalk, about five bucks at a local hardware store. One end grabs the rear workstand, the other end holds a piece of metal stock up next to the rim.

dimension to the chassis centerline (perhaps to accommodate a sprocket or rotor mount), although a correctly aligned *rim* will be, which is really what matters. If you have any doubts about your own wheels, before dismounting them, find a way to measure their left/right distances to fork legs or swingarm sides in order to duplicate the precise arrangement.

Once the wheel runs true laterally, you should recheck the radial runout, and if you make radial adjustments, you should recheck the lateral runout once again. Eventually, you'll have a nice round wheel with most or all of its spokes holding some reasonable amount of tension. At this point, none of the spokes should be very tight. However, check each and every one to make sure none have any actual slack. If you find one that does, gently tighten its nipple until it is snug against the rim.

Gettin' Tight, Truly

Okay, now you've got a wheel that's true, but you've still got to tighten all its spokes to make it strong. Doing so incorrectly could very easily undo all your careful work up to this point, so if your patience is wearing thin, this is a good time to take a break. Come back to the job when you can focus comfortably for another stretch of time.

Choose a unique spot on the rim, such as the valve stem hole, and decide on a direction to rotate the wheel. Call the first spoke you come to number one, the next number two, etc. until you've come to the end of the repeating pattern of spokes in your wheel. In the vast majority of cases, this will be a total of four spokes, as mentioned earlier, so that's what we'll use for our example here. Tighten spoke number one a small amount, such as a half-turn. Count three spokes in your chosen direction of rotation. Now tighten this spoke, which will be spoke number four in the first series, the same amount you tightened number one. Now count three more spokes. This will be spoke number three in the second series. Tighten it the same amount you tightened the others. Count three more spokes. This will be spoke number two in the third series. Tighten it the same amount. Keep doing every third spoke until you've gone all the way around the wheel three times. Keep track of that place-keeper you chose at the beginning, and advance your starting point one spoke at the conclusion of each revolution. If you look closely, you'll see that this method distributes the impact of your efforts as evenly as possible across all four types of spokes—left, right, inner, and outer. This minimizes the possibility of distortion in any particular direction, averaging out any errors that get produced along the way.

Time to check runout again. Correct any unacceptable deviations by the same methods outlined earlier, doing radial adjustments first and then tweaking whatever lateral problems still remain. When the wheel is once again true in both dimensions, perform another round of tightening using the every-third-spoke method, but tightening less, perhaps a quarter-turn. Then recheck runout and adjust as necessary. Continue to repeat these steps with smaller adjustments until all the spokes are truly tight, with the wheel remaining true. How tight? Unless you're using one of the trick "clicker" spoke-torque-wrenches, it's about as tight as you can make it without stripping the nipples. To make sure you have equal torque on all the spokes, you can also check your spokes the old-fashioned way—by ear. Just as a guitar or piano string produces a higher pitch when pulled tighter (and struck), a spoke's tension will be revealed in the sound it makes when tapped by another metallic object. Spokes with inadequate tension will make a relatively lower-pitched, short-lived note, while those with adequate tension will create a relatively higher-pitched ring of longer duration. It's not necessary for all the spokes to emit exactly the same sound—you're not tuning a piano. But they should all "ping" instead of "twang." Simply spin the wheel, bounce your wrench off spokes and listen for the shift in tone.

What if a correction needs to be made in the direction of spokes that are already plenty tight? Remember that each spoke pulls against two sets of opposing spokes—those on the opposite side of the wheel radially, and those on the opposite side of the rim laterally. Corrections can be made by tightening combined with loosening the opposing spokes, keeping all spokes involved within the optimal range of tension.

With all spokes tight and your rim running true, your naked wheel is ready for tire mounting, unless you notice any spokes sticking out beyond the outside edge of their nipples. Carefully grind any protruders down so they pose no threat to your delicate inner-tube. We recommend a double strip of duct tape to replace the standard rubber-band-like rim strap. Torn to width and rubbed down tightly against the rim, it can slow the release of air from a punctured tube through spoke holes enough to let you stop safely.

Spokes can loosen over time. Although there are conflicting opinions about whether or not a correctly assembled/torqued wire wheel actually "settles in" (soon requiring some touch-up retorquing of the spokes), don't be surprised if your brand-new bike's wheels fail inspection right off the showroom floor. We've found some very loose spokes on factory fresh machinery. Loose spokes make it easier for other spokes to come loose and because they no longer share the load equally, increase the potential for wheel failure; that's a bad thing. So check spoke tension regularly, especially on off-road machines. Inspection and correction of runout is easiest to do at tire-change time—by yourself if you change your own tires or by shop personnel if you don't. You may even discover that proper spoke tension and wheel true solves an elusive vibration or handling problem. But, it will certainly help prevent wheel failure, just as keeping your tires properly inflated makes them better able to handle the stresses to which they're subjected.

Spoke wheels can be things of great strength and beauty, but keeping them that way requires occasional maintenance. Proceeding slowly and carefully through the procedures in this article will yield a true wheel in the shortest possible time. Rushing or attempting to resort to brute force will make for a nightmare of oscillating errors, and produce a disfigured rim that's obvious from ten yards away.

Sources

Buchanan's Spoke and Rims—(626) 969-4655; www.buchananspokes.com

Excel—www.rk-excel.co.jp/english

Fasst—(562) 601-8119; www.FasstCo.com

Hallcraft's—(940) 668-0771; www.hallcrafts.com

K&L Supply—(800) 727-6767; www.klsupply.com

Landmark Manufacturing—(800) 497-0312; www.landmarkmfg.com

Pit Posse—(866) 447-6773; www.pitposse.com

Pro-Wheel—(360) 435-8139; www.prowheelracing.com

Rad Manufacturing—(435) 574-2537; www.radmfg.com

Rowe—(805) 349-8243; www.roweusa.com

Spoke Wheel Specialties—(888) 334-4575

LUBRICATION AND MAINTENANCE WORK - WHEELS

Checking the spoke tension and rim run-out

- Spoke nipple: 5 Nm
- maximum radial/lateral run-out of the rim (without tires): 1.2 mm
- maximum radial/lateral run-out of the rim (with tires): front 2.3 mm, rear 2.5 mm

Checking the chain and chain guides for wear, force fit and tension.

NOTE:
- Replacing the drive elements: see Chapter 10.
- Checking and adjusting the chain tension: see Owner's Manual

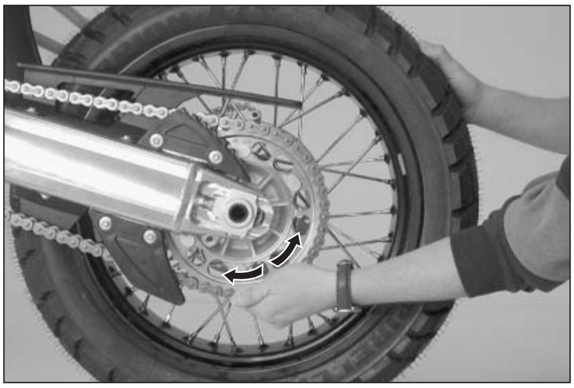
Checking the nuts/bolts on the engine sprocket and the rear sprocket for the securing agent and a tight fit

NOTE: check the nuts/bolts listed below with a torque wrench. If a nut secured with Loctite 243 is not tightened to the specified torque (if it can easily be screwed in further), remove, clean, secure with Loctite 243 and tighten to the correct torque.

Hexagon nuts on the rear sprocket bolts: Loctite 243 + 50 Nm
Hexagon nut on the engine sprocket: Loctite 243 + 100 Nm + sheet retainer

Checking the wheel bearing and jerk damper for clearance

- To check the wheel bearing: jack up the motorcycle, lifting the wheel to be inspected off the ground. Try to tilt the wheel to each side. You should not feel any clearance. If you feel any wheel bearing clearance, replace the wheel bearings (see Chapter 10).



- To check the jerk damper: hold the rear wheel while you try to move the rear sprocket back and forth in the running direction.

NOTE: the transmission should be switched to neutral.
Maximum clearance: 5 mm (measured on the outside of the rear sprocket)

To replace, see Owner's Manual.