WHEEL FANATYK

Dial SPOKE TENSIOMETER Owner's Manual

Port Hadlock, WA

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Spoke Tensiometer

Features

- Extra low spring force for highest accuracy
- Sealed, robust, SS spring (36cm wire length)
- Shock, dust, and water resistant
- Large dial
- Resolution: 0.005”/0.1mm
- Precision ball bearing spoke rollers
- Low friction Delrin® anvil
- Easy to handle and use
- Calibrated and serially numbered
- Lifetime recalibration privilege

Notes

Welcome:

You are using the most advanced and accurate spoke tensiometer available.

Spoke tension is the key to bicycle wheel integrity:

- Excess tension can damage carefully designed hubs and rims.
- Inadequate tension reduces wheel stability and stiffness.

The Wheel Fanatyk Spoke Tensiometer enables you to make fast, accurate measurements. A spoke is bent between three points with a constant, low force spring. The deflection, proportional to tension, is read by the digital indicator. Support bearings and a gauge probe approach from the same side of the spoke and the anvil depresses the spoke when released. Deflections rarely exceed 0.5mm. Unlike other tensiometers, this very low load barely affects the spoke's tension and minimizes the effect of mass and material stiffness.

The Wheel Fanatyk tensiometer is unique among commercial spoke tools because it does not measure across the spoke thickness, it only detects deflection. The many column conversion chart that accompanies all other tensiometers must subtract thickness in order to convert deflection to tension.

Any discrepancy between spoke thickness and the column expectation seriously interferes with accuracy. For example, a painted 14G spoke diameter can be as thick as 2.15mm due to its coating, causing a conventional tensiometer to read 20% too high.

The Wheel Fanatyk tool also subtracts spoke bend from the process (zeroing before each reading). Spoke paths are rarely dead straight, which will impact apparent tension if unaccounted.

Jobst Brandt, author of The Bicycle Wheel, created this ingenious design and we're proud to offer the finest version yet of his idea.

Feel free to ask questions and share your insights: info@wheelfanatyk.com.

Use

(1) Hold the tool in the palm of your hand as shown (**Fig 1**). Squeeze gently, compressing the hidden spring until the tool bottoms out. Now, the path is clear for a spoke.

(2) Without releasing your grip, set the tool on a spoke. The spoke should be touched in three points: by two bearings and the indicator's probe (**Fig 2**).

i. Place the tool on a section of spoke with constant diameter. With butted spokes, for example, position the tool on the thin center section, only.

ii. Center the tool between the rim and the spoke's first cross (or hub in the case of radial patterns).

iii. Note: On aerodynamic and oval spokes, place the tool perpendicular to the plane of the wheel.

Fig 1

Jobst * Stelvio Pass * 2008

Some History

Jobst Brandt designed this tensiometer around 1978, while he was an engineer with Hewlett-Packard in Palo Alto. He is the author of The Bicycle Wheel, a pioneering work that unraveled the mystery of tensioned bicycle wheels. Translated into five languages and reprinted numerous times, it remains the seminal work on the science of bicycle wheels.

Back then, we recognized his tensiometer as the best way to measure spoke tension. At Wheelsmith, we decided to create a less expensive tool because Jobst used a dial indicator, adding to the cost. In those days, appreciation for spoke tension numbers was yet to come. The Wheelsmith gauge introduced many builders to spoke tension management.

Both Jobst and I shared a commitment to demystify the bicycle wheel. It's with great satisfaction that Wheel Fanatyk now offers these updated versions of the iconic Jobst design.

For a thoughtful 5-part interview with Jobst by Ron George, check:

http://cozybeehive.blogspot.com/2010/03/learning-jobst-brandt-part-i.html

For my recollections, see:
http://www.wheelfanatyk.com/blog/the-force-who-rode/

Fig 2

(3) VERY IMPORTANT - PLEASE NOTICE!
While maintaining three point contact, still holding your grip, rotate the dial bezel until the needle reads zero. (**Fig 3**).

Fig 3

(4) While holding the tool in place:

i. Release your grip, so the anvil pushes and bends the spoke.

ii. Observe the reading of deflection, in hundredths of a millimeter. Ignore the small clock scale, it records multiple rotations of the large needle but this is not needed here.

(5) Refer to the tension chart (**pgs 7-8**) to learn what actual spoke tension corresponds to this reading. Find the deflection in the end column and follow across to see what actual force is present. Force is listed in kilograms (kgf). Locate your spoke's column (by thickness) in the chart.

(**5**) Finish every adjustment with an automatic slight turn in the reverse direction. With experience, you'll be able to feel twist through the nipple. For example, if you just finished a 1/4 turn tightening adjustment, give the nipple a slight (1/16 or so) reverse rotation at the finish. If that reverse movement is very easy, you can be sure it's powered by a wound up spoke. Once the twist is relieved, the nipple will quickly become harder to turn, your cue to stop. Safe crackers are not the only ones with sensitive fingers. Wheel builders can and need to develop the same detection skills.

Solutions

(1) Avoid dangerous situations, in so far as possible; examples: excess tension, aluminum nipples, and building dry. On the subject of tension, bear in mind that bicycle spokes were designed before super high tensions were possible. Rims of the past, wood in particular, could not support high tension.

Today's rims, aluminum and composite, are stiffer and high tension is standard. That doesn't change the fact that 100 kgf is probably the highest tension that spokes are meant to support. If you build with higher, and I regularly see 120-150 kgf, the spokes will be at their limit. If you do the stress calculations for the thread root on a spoke at 150 kgf you'll see the problem. IMHO, tensions greater than 100 kgf do not generally improve wheel performance.

(2) Fight friction and corrosion with thread compounds such as SpokePrep or equivalent. A good lubricant reduces both friction and corrosion. Use any oil that is not messy and you don't mind smelling. Olive oil is fine except it might attract ants if you park in the woods. In the past, many builders used linseed oil because it later hardens into a gummy glue which helps fight vibration induced loosening.

However, the wheel is not fully rideable until the oil is dry, and that might be an unacceptable (several day) period if the weather is cold.

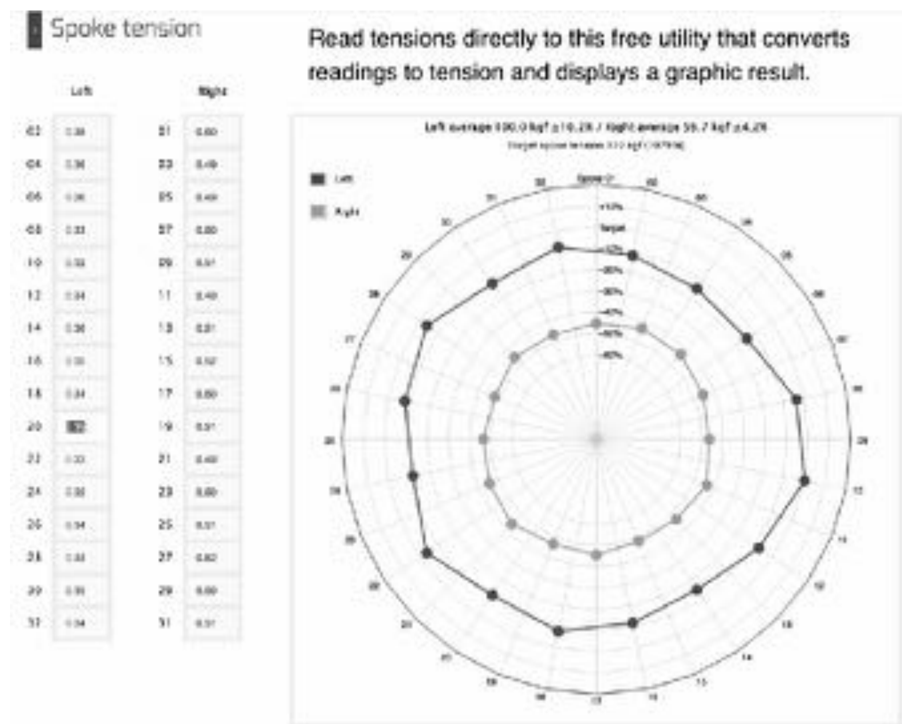
(3) Hold spokes still when they try to twist. A smooth jaw plier or a brake wire pulling tool are common solutions. Make sure your toolbox has one or both.

(4) When turning a nipple, hold its spoke gently with your left hand (if you're right handed). This way, you can feel a spoke twisting and compensate so your adjustment is accurate. When the adjustment is finished, return the spoke to its untwisted state. On bladed spokes, windup is easy to see; but not with round spokes. But it's easy to feel with your second hand.

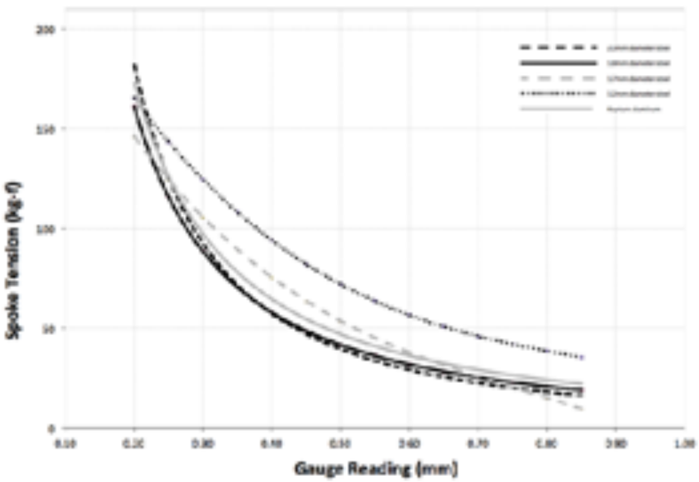
Data Out

To better understand and share the tensions in your wheels, consider recording them in the free utility available at SpokeService.ca. Enter the deflection for each spoke in their dedicated chart and you'll enjoy simultaneous conversion to actual tension and a radar chart for the entire wheel.

Consider printing this chart with notation for components used, date, and the rider.



Spoke Tension



What is the graph message?

Notice how close these various spokes read at tension. This tensiometer is exceptional in delivering very similar readings for different spoke types. This makes your job easier. For example, if you seek tension of 100kgf, you will have an easy time remembering that most standard steel spoke gauges read around 0.33mm on our tool.

Establishing true tension: a 3-step process

(1) Determine the spoke thickness where it is being measured. This is all that counts. It does not matter whether the spoke is bladed or butted. Thickness at measurement, and it must be constant, is the only consideration.

(2) Find your reading in the left hand column (see chart, pg 8) labeled "reading."

(3) Follow across to the column that matches your spoke. Here is your tension.

Most metal spokes (titanium, super aero blades, round aluminum, etc.) measure similarly with this tool.

Light spokes compound the problem. The torsional rigidity of a spoke varies with the 4th power of its diameter. That means small diameter changes make for huge differences in resistance to twisting. For example, a thin butted spoke may have a diameter of 1.5 mm. This is close to half the cross sectional area of a 14g spoke (1.77 vs. 3.14 sq mm). The thinner spoke will be 3X more torsionally flexible.

Under good conditions, spoke windup is not an obstacle because thread friction is normally quite low, only 2-4 in-lbs. Not enough torque to twist a spoke. However, lack of lube, corrosion, and aluminum nipples can create substantial thread friction.

Windup slows

Twisted spokes mess up a build. For example, if when you make a 1/4 turn adjustment (typical in high spec wheel building), the spoke twists 1/8 turn so the nipple only turns on the threads 1/8, you're 50% off. When centering a wheel (dishing), if some spokes are twisting, the outcome makes the wheel worse. It might require a 20 minute truing session to correct the damage. This one variable contributes heavily to the difficulty and time of building, ruining the ambitions of many beginners.

Windup damages

Twist also damages spoke material. The most vulnerable points are the stress risers created by threads and shape (butting and blading). If a spoke twists, the greatest damage will be done at the first thread and the transitions between larger and smaller diameter. Thin spokes are at risk of "necking" which is a plastic deformation when the metal stresses are near yield. A stretched spoke is much smaller diameter and doomed to fail.

Lastly, a wound up spoke will eventually unwind and a tell tale clicking, pinging noise may be heard. As these spoke are temporarily loosened during riding, they will untwist. Too often, this activity makes a straight wheel crooked. Unable (or unwilling) to control this twisting, some builders have devised schemes to release the windup before riding. Leaning on the wheel or, even, walking on it can permit the twisted spokes to become untwisted. But these procedures add time and often induce secondary damage that requires more truing.

V. Nipple lubrication

Why does it matter and what is the science behind this practice? What are the practical benefits and what are some effective means to lube nipples?

(1) Brass, the most common nipple material, has a self lubricating property and is remarkably smooth turning. This low coefficient of friction against steel and aluminum means that thread lubrication for building is of secondary importance.

(2) Corrosion resistance of brass is quite good, it is used for many nautical fittings. While not equivalent to stainless materials, this resistance makes lubrication less important.

Lubricating nipples should focus on the nipple to rim contact, not the threads. The former produces much more friction than the threads. Thread friction is, however, still important especially because it can cause a spoke to wind up. Wind up confuses the builder, masking the precise magnitudes of adjustments. It also stresses the spoke at the threads, a weakness best to avoid. Light oil is the best all around lubrication for these parts although I've heard builders use a grease stick on rims prior to building.

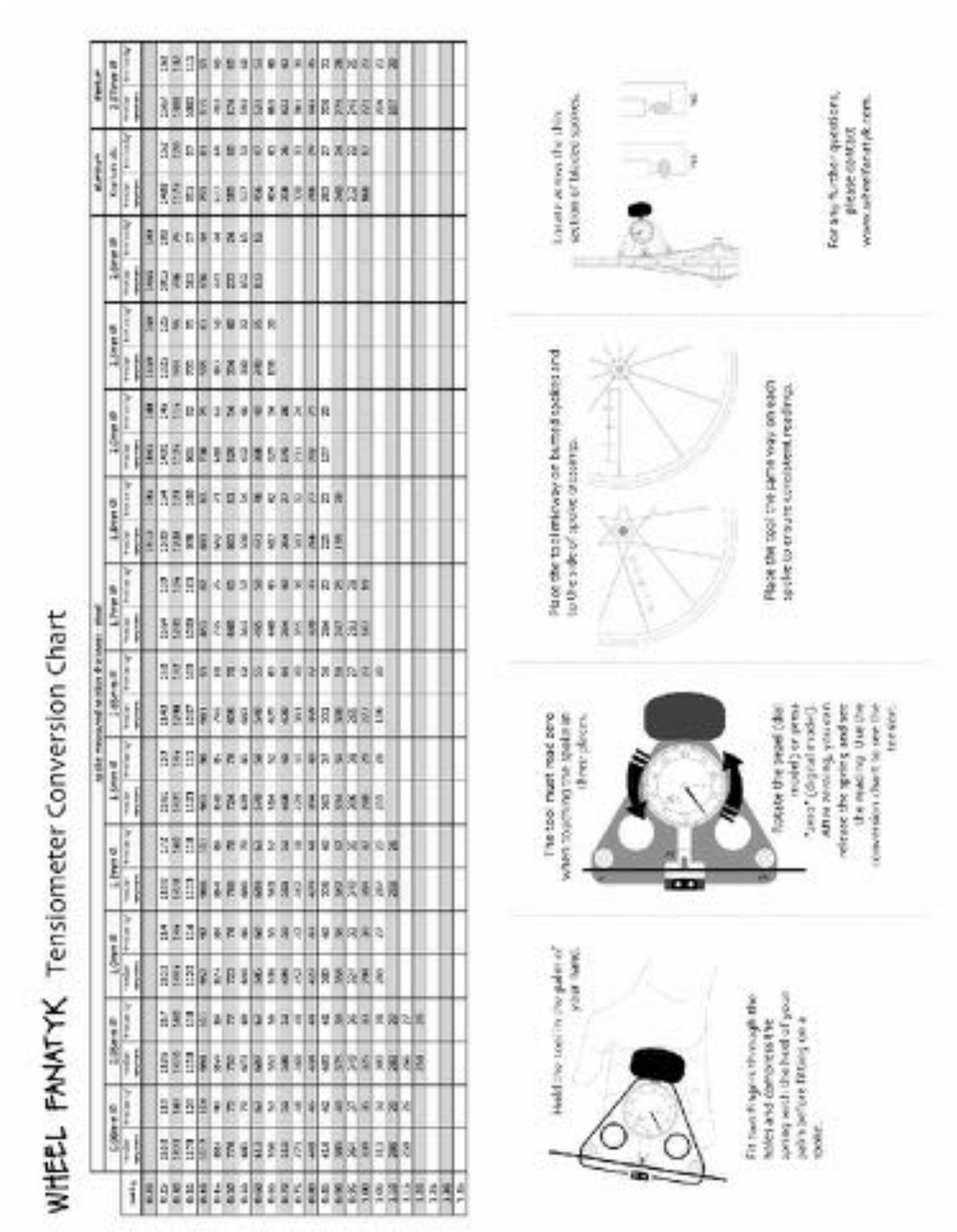
Many builders like coating spokes with a Teflon material like SpokePrep, that lubricates the threads and has other benefits.

VI. Stop Spoke Windup

Spoke wind up, twisting from end to end as the nipple is turned, is a serious menace to wheel building; blurring truing corrections and damaging a spoke at its weak points. Everyone deserves to understand the reasons why and how to stop it.

Windup hurts

The main reason is friction between nipple and spoke. You turn the nipple but does it advance on the threads or twist the spoke? With aluminum nipples, the friction coefficient is high (compared to brass, the traditional nipple material). Even with lubrication, the spoke still wants to twist.



Warranty

Maintenance

Inspect your tensiometer on a regular basis. Check parts for looseness, damage and wear before each use.

- Do not lubricate the gauge. Simply wipe it clean from time to time.
- Do not disassemble the gauge. Its construction is simple but disassembly may compromise its accuracy.
- Take care not to drop or damage the gauge.

Your Wheel Fanatyk Spoke Tensiometer is guaranteed against defects in materials and workmanship for a full year from date of purchase. The warranty does not cover damage due to misuse. At our discretion, Wheel Fanatyk will repair or replace the instrument if determined to be defective.

Not covered by warranty

1. Modification, neglect, or poor maintenance.
2. Damage from causes other than defects such as a user lack of skill or experience.
3. The finish or aesthetics of the instrument.
4. Normal wear from use.
5. Any labor cost associated with the repair, replacement or reassembly.

How to Stress Relieve

With a bicycle wire wheel, stress relieving can be done in two ways. First, as spokes are inserted into a given hub, you'll notice that they often don't exit the hub flange at exactly the correct angle. Tension of a finished wheel is enough to pull the spoke straight but it would have residual stress. It would secretly want to return to its pre tension shape. Each time tension was reduced, the spoke would tend to flex back to its original shape. This flexing would accelerate fatigue. The answer is to forcefully bend each spoke to the new shape PRIOR to tension. Even a bit of over bend is good. Then, with cycles of tension change during riding, the spokes will not be changing shape so much. That's stress relieving.

A second stress relieving opportunity exists after the wheel is at full tension. If you grab side-by-side parallel sets of spokes, one in each hand, and give a forceful squeeze, their tensions will be momentarily increased without damaging the wheel. Increasing spoke tension and then lowering it back has the wonderful effect of reducing trapped stress. Such stress relieved spokes have enhanced fatigue resistance. Every handbuilt wheel deserves this simple touch.

After a few such squeezes or with aero spokes, you'll begin wearing gloves.

Avoid Brutality

All too many pre stressing or stress relieving strategies are simply too rough. Pushing a wheel sideways with enough force to flex it is dangerous. It's easy to damage the structure since this is its weakest dimension. I've seen builders step on their wheels or drop them from heights. In skilled hands, such techniques might have benefit but they take unnecessary time and often cause damage that requires additional repair. Some of these procedures are born more of superstition than science.

Why Stress?

Two popular lines of thought underlie wheel stressing. First, spokes that wind up during tightening and truing should be unwound so the new wheel makes no noise if this unwinding occurs in initial riding. Unwinding spokes are also liable to make a wheel untrue and we want it to stay straight from new. In Tip No. 3, about spoke twisting, I recommend building in a way that leaves no residual windup. If you master such a technique, then there's no reason to pre-stress for spoke windup.

The second idea involves stretching the component parts. If some outside stress can provoke stretch or yielding in the hub, spokes, or rim that might occur later in the wheel's life, then it will be more stable and require fewer touchup's. This makes sense but is not too important as the changes within a wheel during use mostly involve periodic reductions in tension, not increases. So yielding in the future, except during a traumatic event, is not much of a threat.

The Science of Stress Relieving

Well then, what is a solid reason to "pre-stress" a wheel? Here we refer to material science and the well established practice of stress relieving. What a new wheel can really use is not, technically speaking, pre-stressing. It's stress relieving. Any assembled structure involves new forces within its component parts. These forces involve static loads but they also involve trapped stress. Sometimes this stress is beneficial but generally it will make the structure less stable and encourage fatigue failure.

A good example (thanks, Jobst) is the grappling hook used by an industrial crane or derrick. Such a hook is expected to carry huge loads without deforming or wearing out. When it's formed, a straight section of metal is bent into a "U," the shape of the eventual hook. However, if the U is over bent a bit and then pulled open to the desired geometry, pent up stress in the metal is relieved. Such a hook is more rugged than one simply bent to shape. The over bent, then opened hook is stress relieved.

Warranty Service

To obtain service under this warranty, original purchaser must send your tensiometer with (i) a full description, and (ii) proof of purchase to:

Wheel Fanatyk
111 Curtis St
Port Hadlock, WA 98339
USA

Whenever discussing your tensiometer with us, have your serial number handy. This unique, 8-digit number is etched into a stainless steel label on the instrument sliding bar (**Fig 6**).

Each Wheel Fanatyk tensiometer is individually checked for calibration.

If you are not the original owner, please know we want you to enjoy full function from your tool. Do not hesitate to contact us.

Fig 6

Absolute accuracy is listed at +/-10%.

Why

- While great care is taken in making spoke wire, it is not dimensionally consistent. For instance, butted spokes are made by swaging. The center section can vary by 5% as a consequence of the shaping process. Without exact dimensions, tension measurements will vary.
- Spoke path, from hub to rim, is not entirely straight. Due to lacing pattern and nipple angle, spokes often have a compound bend. This bend directly affects tension measurement. Moving a tension gauge over a spoke shows how the reading is affected.
- Gauge placement affects the reading. A spoke is stiffer at its ends. Center the gauge between the rim and the spoke's first cross (if any). Stay on a constant section of a butted or oval spoke.

How we minimize these factors

- This tool is extremely consistent from spoke to spoke. This "repeatability" is due to careful tolerances and a high quality digital indicator. This tool's repeatability is second to none.
- The tool uses a very low spring force. A strong spring, as used by other gauges, will be less accurate because:

  (i) The act of measuring can change the spoke's tension, and

  (ii) A strong spring involves the spoke material's bending stiffness, blurring tension detection.

One answer is to use a mild thread locking compound. Ideally, your choice provides both lubrication and thread locking action: the locking action to prevent vibration, the lubrication so future adjustments are easier. One complication: the spoke threads may need to be cleaned before applying such a treatment.

Gently crimping the nipple (experiment first on loose nipples and spokes) or using adhesives such as Loctite can provide the needed stability. Try the "after assembly" or "wicking" Loctite, such as 220 or 290 (almost too strong). Linseed oil on spoke threads or tubular rim cement leaking onto the nipple heads also limit wheel loosening but you will not find them in use these days in aviation, F1, or elsewhere that maximum performance is demanded.

III. Monitor tension

Spoke tension is one of the wheel's most elusive properties. As a wheel supports various loads its spokes are constantly changing tension to absorb, distribute, transfer, and just plain endure the forces of riding. The base tension with which a wheel is built has a strong effect on its ultimate strength and longevity. Just remember, more is not better. Generally speaking, high (but not excessive) and uniform tension serves a wheel best.

Now that tensiometers are commonplace, at least in bicycle shops, you can have your tensions measured. Don't leave such an important characteristic unsupervised.

IV. Prestressing

Wheel builders often try to "pre stress" their wheels as a last step in the building process. All builders, especially novice, are nervous, wanting the new wheel to be as good and stable as possible. Like the rituals that preceded hunting in earlier times, we want to stack the cards in our favor. After all, hunting was important, uncertain, required skill and luck, and was potentially dangerous. Sounds like bike riding. Consequently most wheel building methods involve some sort of stressing routine.

are "over-bent" compared to the hub fit, whose elbows are being opened out in the finished wheel, are more prone to fatigue failure. The secret is within the metal crystal structure, but well known to material science.

If a spoke does not fit a particular hub perfectly (i.e. does not lie flat against the flange and aim directly at the rim), it can be "set" during the building process. If the spokes are not set, then the spokes will be held in place (partially set) by tension alone. But they will not fully conform to the hub flange. With full tension, the spokes will be flat against the flange but as the wheel is ridden, normal fluctuations in spoke tension will cause the spokes to flex at the elbow. This will shorten their fatigue life, resulting in breakage.

To set spoke elbows, try the smooth shaft of a screwdriver in the opening between two crossed spokes against the edge of the flange, over the outside spoke, under the inside spoke. Gently lever down to set both inside and outside elbows at the same time. With practice, this process will take only a few seconds.

II. Prevent spoke loosening

Nipples can loosen from the vibration caused by regular hard riding. This is a more common problem with lighter rims, smaller and higher pressure tires, and rough roads or trails. Nipple loosening is an even more common problem in because the hollow section of modern rims prevents the inner tube or rim strip from pressing against the nipple head and holding it in place.

Building with high uniform spoke tension helps because any one spoke is less likely to reach very low tension during riding, and that is when loosening from vibration is most likely to occur. But this alone is not enough. If you imagine unwinding the threads inside the nipple you essentially have a long ramp at a slight angle. The tension on the spoke is constantly trying to pull the spoke down this ramp inside the nipple.

- This design enables the use of a single Tension Chart column for nearly all spokes.

More About Spoke Tension

- Remember that the tension gauge can also be used for comparative measurements. Consistency of tension within a wheel is as important as actual magnitude. When making spoke to spoke comparisons, it’s not necessary to consult the Tension Chart. Compare gauge readings from spoke to spoke to understand consistency.
- When the gauge is positioned, give it a bit of movement to make sure it’s fully seated. Don’t push the gauge into the spoke or the reading will be disturbed.
- If you have any doubts about accuracy, please return the gauge to Wheel Fanatyk. We can measure and verify its function. In general, it doesn’t need regular inspection or recalibration.

To speak in the most general terms, optimal wheel performance comes from high and uniform spoke tension. Always consult the manufacturer of a wheel component for advice on appropriate tension level.

Simple guidelines

- With high quality components, absolute spoke tension will often average 100 kgf. Individual spokes may vary between 60-120 kgf.
- Uniform tension of same-side spokes is more important to a well built wheel than perfect trueness. Thanks to a rim’s inherent stiffness and imperfections, a perfectly true wheel can contain spoke tension imbalances, especially in side by side pairs, which makes the wheel less stable in the future. It is often acceptable to trade perfect trueness for more consistent spoke tension to produce a more stable and lasting wheel.

- Rear wheels and disk brake wheels often have lower tension on one side. This is a consequence of hub spacing and wheel-dish.
- Inflated tires affect spoke tension. The tension of a road wheel, for instance, is reduced by 20% with tire inflation. This phenomenon is understood and normal.
- Thin spokes feel looser than thick ones, at the same tension, due to their lower bending stiffness. Don't let fingers mislead you: use a gauge to determine actual tension.
- Audible tone is proportional to tension, as with a stringed instrument. Plucking spokes to hear their tone gives a quick tension indication. Using your tensiometer and plucking will, with experience, calibrate your ear the same as musicians using tuning forks and pitch pipes. Some find banjo picks are better than fingernails for producing a clear tone.

Building Tips

1. Set spoke elbows

Spokes will give maximum service life and strength if the elbow is firmly set against the hub flange during building. If not, spokes may appear to "loosen up" and their fatigue life may decrease, resulting in premature breakage. When a spoke is set loosely into a hub, it should lie about 15º above the angle directly to the target rim hole. That's the amount that the spoke will need to be bent to conform to its position.

When designing a spoke there are two factors to consider: 1) strength, meaning reliability and fatigue life, and 2) hub fit. Unfortunately, some shapes that seem to improve hub fit can actually decrease strength and fatigue life. Therefore, there must be a compromise in the final spoke design to account for these two factors.

The spoke design is complicated by the fact that many hubs have different shapes and proportions. More importantly, even if all hubs were identical, there would still be two different ideal spoke shapes. The spoke whose elbow is on the inside of the flange would require a different shape from the spoke whose elbow is on the outside. The best compromise is a spoke whose elbow bend is "incomplete," creating the 15º angle mentioned above. This is best because spokes that