Stronger, Smaller, Smoother: A Design Engineer's Guide to Braided Wire for Medical Devices

Braided wire reinforcement gives a catheter or sheath its pushability, torque transmission, kink resistance, and burst strength. The braid is the structural skeleton inside an otherwise compliant polymer tube, and its behavior follows from the wire that feeds it. As interventional devices push toward smaller diameters and robotic platforms load cables beyond what conventional materials survive, the wire has to deliver more strength, fatigue life, and dimensional precision in less space.

That performance comes from a stack of choices made upstream of the braider: alloy and condition, round or flat cross section, spooling format, and surface finish. Small early choices decide what the finished device can do.

How properties impact performance

A braid's mechanical behavior follows from three properties of the strand: tensile strength, elongation, and modulus of elasticity. Yield strength matters too, particularly when a designer wants to specify the load at which permanent deformation begins rather than the load at which the strand fails outright.

- Tensile strength governs how much load a wire can carry before fracture, which in a braid translates to burst pressure and crush resistance.
- Elongation governs how much strain the wire can tolerate before failing, which affects how the braid behaves under flexure and how forgiving it is to handle.
- Modulus determines stiffness at a given diameter, which ultimately drives torque transmission for the assembly and gives an indicator of how well the device will navigate around tortuous paths.

The catch is that these properties trade off against each other. Increasing tensile strength through cold work generally reduces elongation. A designer who wants both has to look at where the choice of alloy and processing route can shift the curve, not slide along it.

Geometry — picks per inch, wire count, lay angle, and carrier load — determines how effectively the wire's strength, stiffness, and elongation translate into device performance. The braid can amplify or compromise those properties, but it cannot exceed the limits of the underlying wire. The material sets the performance envelope; the geometry determines how much of it the design can capture.

Round wire and the conditions ladder

For stainless steel round wire, the design choice begins with alloy and ends with condition.

Braided medical devices are most often built from 302, 304V, 304LV, or 316LVM. 304V dominates guidewire, braid, and coil work; the electric-arc melt followed by vacuum arc remelt strips out the inclusions that would otherwise seed fatigue cracks at fine wire diameters. 316LVM, low in carbon and vacuum melted, takes its place in long-dwell applications where corrosion resistance and biocompatibility outrank torque response, which is why it shows up in implantable coils and intravascular stents. ASTM A313 is the specification most designers work from — it covers cold-drawn stainless spring wire and tabulates tensile strength against diameter, class, and temper, which is the data needed to size a strand without guessing.

Condition refers to how much the wire has been cold-worked. From most to least processed, the conditions form a ladder: ultra strength, hyten, ultra spring, spring, hard, and annealed. As a designer moves down that ladder, tensile strength falls and elongation rises. Annealed material across the available alloys typically delivers about 586 to 896 MPa [85 to 130 ksi] tensile, with finer diameters running higher within that band. Spring temper for 304V and 302 follows the values in ASTM A313.

For 316LVM and 304LV, the maximum tensile capability is 1,862 MPa [270 ksi] and 2,137 MPa [310 ksi], respectively, with both decreasing as size increases. Hyten, available in 304V to 0.762 mm [0.030 in], runs from 3,034 MPa [440 ksi] nominal in fine wire down to 2,275 MPa [330 ksi] nominal at the larger sizes.

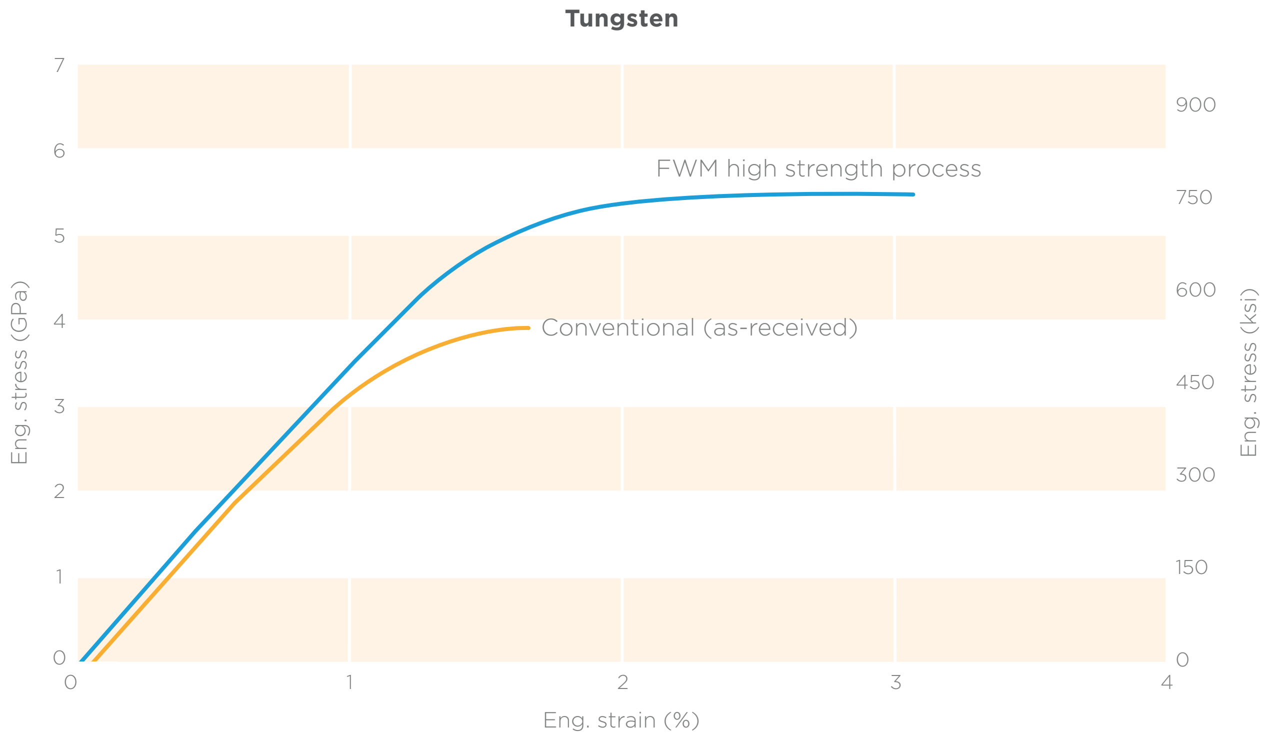
Smaller diameters allow higher tensile values within a given condition because the cumulative cold work is greater. The published values are also not the only options; if a project calls for a tensile target between two listed conditions, we can typically advise an intermediate processing route.

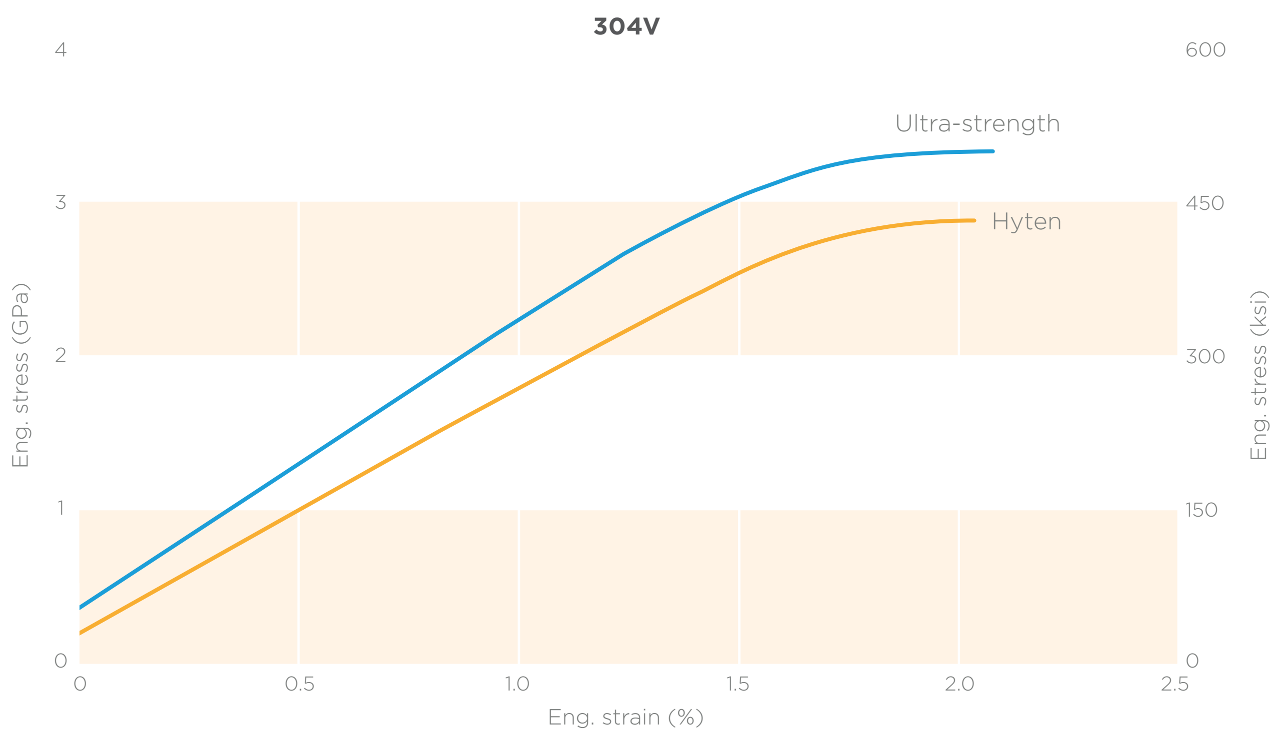
Pushing past the ladder: Ultra-strength conditions

The newest rung on that ladder, ultra strength, exists because conventional cold-worked wire reaches its limits as designers push toward smaller and more demanding devices. The two materials currently produced in this condition are 304V stainless steel and pure tungsten, and each one addresses a different design challenge.

Tungsten in ultra-strength condition is available from 0.0127 to 0.0254 mm [0.0005 to 0.001 in], with tensile strengths of 4,482 MPa [650 ksi] and higher depending on diameter. At 12.7 microns, or half a thousandth of an inch, the strand approaches about 6,895 MPa [1,000,000 psi], which is the highest tensile value reported for commercially pure tungsten in any published source. Elongation at these sizes runs 2–4%.

Strength performance





In braid construction, tungsten's modulus is roughly double that of 304V, producing a stiffer, more rigid construction with better kink resistance, increased column strength, and superior torque transmission. Conventionally processed tungsten carries a low yield strain limit; as little as 0.1% strain can deform a catheter. Ultra-strength tungsten shifts this balance of properties. It retains the high modulus advantage while approaching the strain behavior of stainless steel. Compared to conventionally processed tungsten at 0.0254 mm [0.001 in], ultra-strength tungsten achieves a nearly 40% increase in yield strain limit, improving kink resistance and enabling better manipulation through tortuous pathways where deformation might otherwise occur.

Tensile strength alone does not capture what a designer gets from this material. The area under the stress-strain curve, which defines the wire's toughness, is roughly three times that of conventionally processed tungsten of the same diameter. Toughness is the property that matters when a strand has to absorb a transient load, such as a snag, sudden tension excursion, or impact, without breaking. In surgical robotics, where a tendon-style drive cable cycles millions of times under load, the higher toughness translates directly to longer cycle life.

Ultra-strength **304V**, available from 0.0127 to 0.1524 mm [0.0005 to 0.006 in], reaches 3,241 to 3,447 MPa [470 to 500 ksi] while holding elongation near 2%. The jump over hyten 304V, the previous strongest condition, is on the order of 207 to 345 MPa [30 to 50 ksi]. The tensile increase is less dramatic than the tungsten case, but the practical effect is similar. A stronger strand at the same diameter lets designers thin the braid and gain inside-diameter clearance, or hold the diameter and gain burst capacity and torque. The same condition strengthens strands and braids built from those wires, including high helical-strength constructions used for tube-like reinforcements.

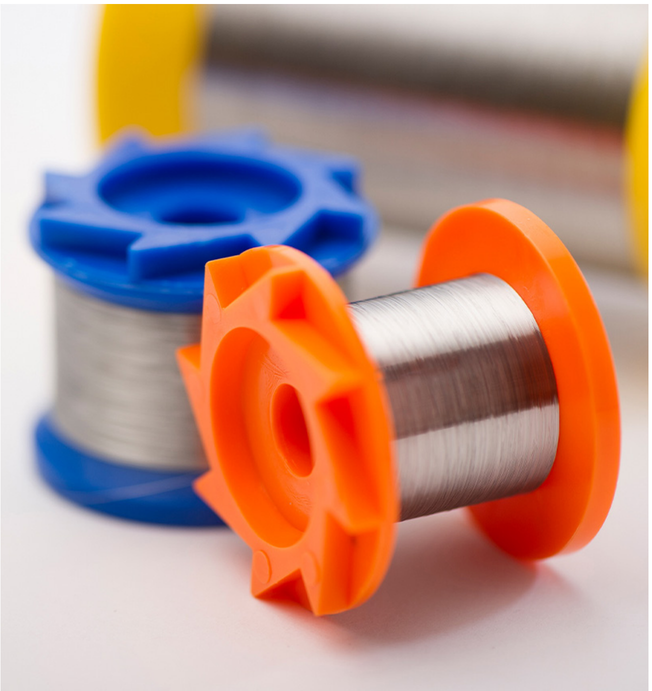
Ultra-strength conditions cost more than hyten. However, the right comparison is not ultra-strength against hyten at the same diameter, but rather ultra-strength at a smaller diameter against hyten at the original size. Smaller wire at a higher tensile may be the key to replacing a previously larger wire to downsize a device to reach further into the body, or upsize a device inner diameter while maintaining acceptable strength.

Multi-end spooling: The hidden complexity upstream of the braider

A braider runs only as well as its bobbins feed it. For fine-diameter constructions where dozens of strands have to track at consistent tension across long runs, multi-end spooling — placing several wires on a single bobbin — is often the only practical approach. Modern fine-wire shops can run up to nine ends on a single spool.

The bobbin choice depends on diameter and braid platform. For wires roughly 0.0254 to 0.0762 mm [0.001 to 0.003 in], Steeger-style bobbins are typical. For 0.0762 to 0.2032 mm [0.003 to 0.008 in], Wardwell- or New England-style bobbins are more common. Within the Steeger family, three bobbin types cover most of the fine-wire range and trade off footage capacity against spooling robustness.

The Endura® bobbin, a 45-degree-flange design, gives the most forgiving payoff and can reduce snag for rolled flat wire, but it is rarely recommended above three ends or much above 0.0762 mm [0.003 in]. The medium-hub bobbin holds the most footage and is the right choice when braider uptime matters most. The large hub holds less footage but offers the most repeatable spool integrity.



When specifying bobbin footage, the goal is to balance uptime against material risk. In general, the lowest footage that maintains acceptable braider efficiency is preferred. Larger bobbins reduce changeovers but increase material loss when a break occurs.

Three handling considerations deserve attention before any first build:

- **Tension matching.** A multi-end spool must be wound at slightly higher tension than the braiding tension. If the wires are wound looser than they will be braided, the strands dig into lower layers on the bobbin and contribute to breakages during the run. We need to know the planned braiding tension or the spring combination on the carrier to calculate a theoretical winding tension that matches.
- **Tension consistency.** The wires on a multi-end bobbin must all have the same length on each strand, otherwise known as being "in wrap." If a single wire loses a wrap during a stoppage and the others do not, the affected wire pulls at a different rate, and crossovers and breakages follow. When attempting to recover a bobbin after a braider break, verifying the bobbin is "in wrap" is the first step.
- **Catenary sag.** Under slight tension, one or two wires on a multi-end spool may droop more than the others. The droop comes from the spooling process, but braiding tension can compensate either by increasing or decreasing it. More ends and larger wire sizes make catenary sag more pronounced. The fix is rarely on the braider; it lives in the dialog with the wire supplier before the first run.

The pattern across all three is that multi-end success depends on collaboration before the first build, not troubleshooting after it.

Geometry as a design variable

A round wire is typically the default, but a flat wire changes what the braid can do. For a given amount of metal in the cross section, flat wire reduces the wall the braid contributes at wire crossing points, which lets designers preserve the inside diameter while shrinking the outer profile. The trade-offs run in several directions. Flat wire alters torque transmission, kink resistance, and bending response in ways that depend on aspect ratio, edge geometry, and how the strand sits in the braid. Unlike round wire, where one dimension defines the cross section, flat wire's performance is sensitive to the rolling process that produced it.

Two production routes, rolling and drawing, yield flat wire. Drawn flat wire, made by pulling round wire through shaped dies, has historically held tighter tolerances on width and thickness. Advances in rolling have closed most of that gap, and modern rolled flat wire is dimensionally competitive with drawn material across a wider range of alloys.

The size envelope for rolled flat wire runs from 0.0127 by 0.0381 mm [0.0005 by 0.0015 in] at the small end to 1.27 by 2.032 mm [0.050 by 0.080 in] at the large end. Above 2.032 mm [0.080 in] the product is classified as a rolled strip and runs on different equipment. Width-to-thickness ratio runs from 2:1 to 10:1. At the lower end of that range, when the cross section approaches square, cast and camber become harder to control and the strand can spool unexpectedly because it has no preferred axis. Standard tolerance is plus or minus 10%. Tight tolerance is plus or minus 5%, with the tightest production capability at plus or minus 0.00508 mm [0.0002 in] on thickness and plus or minus 0.00762 mm [0.0003 in] on width.

Ultra-strength flat wire is in development. Rolling a round wire into a flat cross section adds cold work but also relaxes some of the strength of the incoming material. From a 3,447 MPa [500 ksi] round-wire input, the rolled product typically gives back about 345 MPa [50 ksi], landing in the 3,034 to 3,172 MPa [440 to 460 ksi] range. The size envelope under trial spans roughly 0.0127 by 0.0635 mm [0.0005 by 0.0025 in] up to 0.0762 by 0.2286 mm [0.003 by 0.009 in].

The development trajectory matters because ultra-strength flat wire stacks two design wins: the cross-sectional efficiency of the flat profile and the load-bearing capability of an ultra-strength condition.

Surface finish as the underrated lever

Surface finish on flat wire is where coating adhesion, friction during decoring, and braid appearance get decided. Three standard finishes are produced, including bright, semi-bright, and rough rolled:

- Bright runs typically below 1 microinch Ra and always under 2 Ra.
- Semi-bright runs 2 to 5 Ra.
- Rough rolled runs above 5 Ra.

Surface roughness is not a free parameter; it varies with wire size and width-to-thickness ratio, and below roughly 0.0508 by 0.127 mm [0.002 by 0.005 in] the texture begins to overpower the wire size, which makes semi-bright and rough rolled less practical at the smallest dimensions.

The choice between bright and semi-bright often comes down to coating. Bright looks cleanest, but if the device will be coated with an opaque film, that visual finish becomes invisible after assembly. Semi-bright is more consistent across a production run, easier to manufacture, and gives coatings something to grip. For coated devices it is frequently the better engineering choice.

Rough rolled extends that logic. It maximizes coating adhesion through valley-and-ridge surface features. Beyond the production limit of rolling, wet blasting can push roughness above 10 Ra with a more uniform surface than rolling can produce, though equipment capacity for wet-blasted product is currently limited.

Rougher surfaces correlate with slightly better camber on flat wire. The difference is small, but for designs where camber affects payoff or braid uniformity, the rougher finish is not a trade-off against geometric quality.

A more advanced option is the hybrid surface, currently produced as a trial. The two faces of a flat strand are rolled with different rolls. One face is semi-bright or rougher, and the other is bright. The application logic is mechanical. The rough face goes outward to grip the coating; the bright face goes inward to reduce friction against the mandrel during decoring. For coiled and braided designs that fight friction during removal of the forming mandrel, hybrid finish offers a way to get coating adhesion without paying for it on the inside. Trial sizes match the standard rolled flat-wire range.

Building on the right foundation

Braid performance is not determined by any single variable. It results from a series of decisions that begin with alloy selection and extend through surface finish. The right combination for a 0.0254 mm [0.001 in] braided guide catheter is often very different from that of a 0.127 mm [0.005 in] robotic cable. Because these choices influence everything that follows, the decisions made before tooling is committed often have the greatest impact:

- Alloy and condition, because they set the tensile-elongation envelope.
- Round vs. flat geometry, because it sets the wall-thickness budget.
- Spooling format and bobbin type, because they govern braider yield.
- Surface finish, because it governs coating adhesion and decoring friction.

Of those, the ultra-strength conditions are the levers most likely to change a device's feasibility envelope. A higher-tensile, higher-toughness wire at smaller diameters that were previously unbuildable opens space for designs — e.g., sub-3-French neurovascular catheters, robotic cables with longer cycle life, guidewires that can cross harder occlusions — that the conventional conditions cannot support. Ultra-strength flat wire and hybrid surfaces extend the same logic, increasing capability in less space.

The work that remains is to make those calls with full visibility into the trade-offs, and to bring the wire supplier in early enough to match the wire to the design rather than the other way around.

The most effective braid designs begin with the right foundation. Fort Wayne Metals works with device designers early in the development process to evaluate material, geometry, and manufacturing options that influence pushability, torque response, kink resistance, and profile. If you are designing a new device or optimizing an existing one, our technical experts can help you navigate the trade-offs and select the right wire solution for your application.

To learn more, visit fwmetals.com