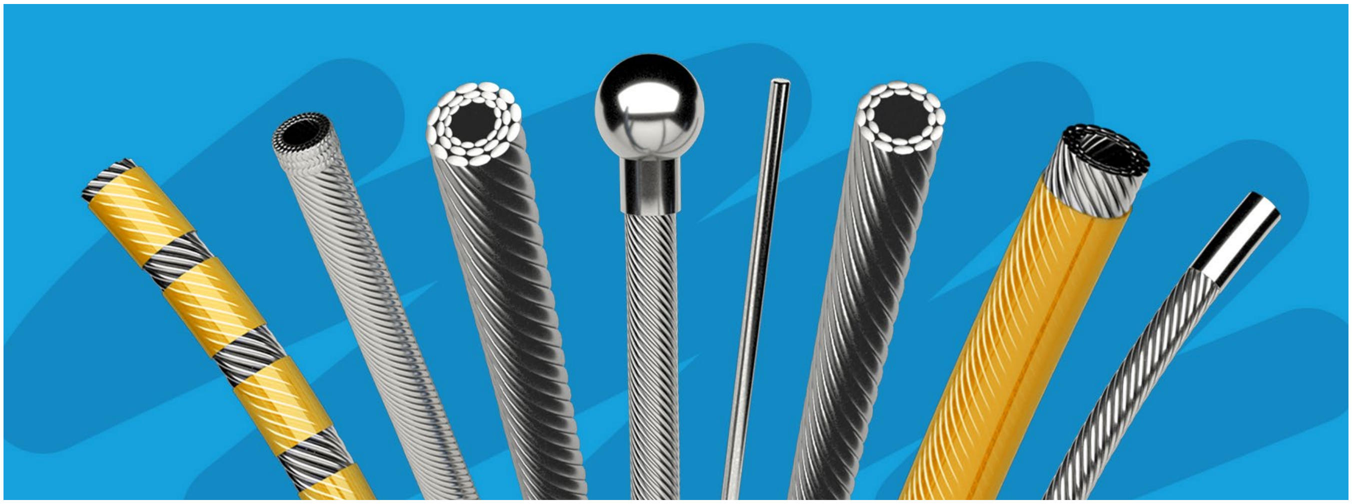


Exploring the Functionality and Applications of HHS® Tube

HHS® tube — a flexible, hollow, and multi-filar strand — is highly engineered wire wound in counter-rotating helices around an open central lumen. Pull on it and it resists stretching to the required force. Rotate one end and the other end transmits the required torque. Bend it through a tight curve and it follows the curvature without kinking. The innovative product behaves differently from traditional bulk metal tubes.

HHS® tube has been used in atherectomy and thrombectomy drive shafts, catheter bodies, chronic total occlusion (CTO) crossing devices, endoscope working channels, and laparoscopic instruments. These devices operate at the end of long, tortuous access paths, where the shaft must withstand a variety of forces and the open lumen must stay open.

The mechanical properties of HHS® tube can be tuned across a wide range by changing the construction. Flexibility, torque, tension, elongation, compression resistance, kink resistance, and rotational control all shift with the geometry, while the design preserves the open center. None of these properties are fixed, and device engineers can steer construction toward mechanical targets that traditional metal tubing cannot reach.

What HHS® tube is

HHS® tube consists of a set of round or flat metal filars helically wound in one or more layers around a vacant central axis. When more than one layer is used, the layers alternate direction — for example, left-hand, right-hand, left-hand — so they mechanically resist each other's tendency to unwind under load. That counter-winding contributes to multi-layer HHS® tube's torque response. Rotation applied at one end can be customized to translate into rotation at the other with little windup.

Generally, single-layer constructions are the least flexible and the most rigid in torsion. Adding a second layer decreases torque response and increases flexibility. Triple layer constructions further decrease torque response and further increase flexibility. Filar shape is another variable. A flat-wire construction, made by rolling the filars to a rectangular cross-section before stranding, is able to be manufactured with a thinner wall thickness ratio than round wire constructions. Flat wire constructions are an option for those design windows in which round wire constructions are not manufacturable or there is a high torque output required.

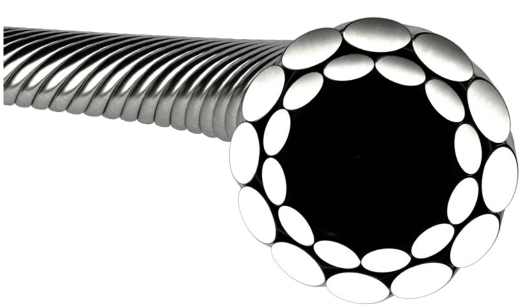
The seven design parameters

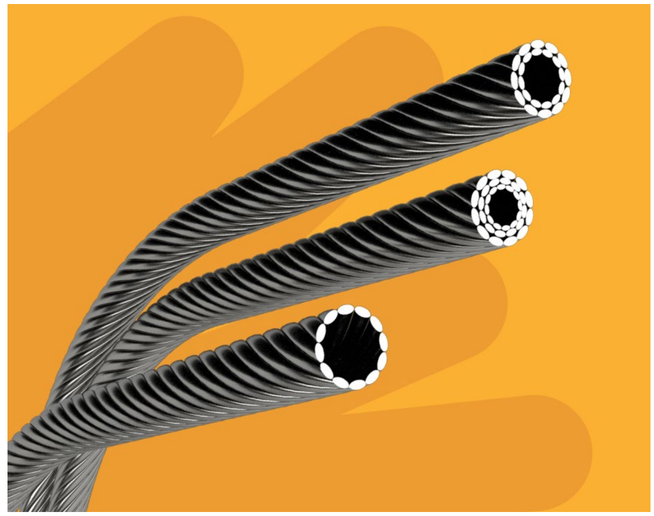
Seven construction parameters define HHS® tube and together determine its mechanical behavior:

- Inside diameter ranges from 0.0762 mm [0.003 in] at the small end to 2.2098 mm [0.087 in] at the large end
- Outside diameter ranges from 0.127 mm to 4.064 mm [0.005 in to 0.160 in]
- Pitch, defined as the helical angle of the filars relative to the tube axis, can run up to around 70 degrees depending on construction
- Filar count tops out at 18 per layer
- Layers can be one, two, or three
- Filar cross-section is round or flat
- The direction of lay can be left or right, with multilayer constructions alternating direction layer to layer

Each of these parameters balances against the others within the same design window. For example, increasing filar count at a fixed outside diameter will decrease flexibility. Pitch angle changes the leverage between rotational input and translational response, with longer lays producing more pushability and shorter lays producing more flexibility. Shape, layer count, lay angle, and lay direction adjust how that response is distributed among flexibility, torque transmission, and elongation resistance.

In practice, engineers do not specify HHS® tube by picking one number. They specify a target behavior — e.g., torque ratio, minimum bend radius, maximum elongation under a given axial load, or wall thickness budget — and derive the construction parameters from that envelope. When a target falls outside the standard ranges above, research and development activities may be considered to meet the application's needs.





The four standard alloys

Four alloys cover the majority of HHS® tube applications. Each brings a benefit depending on what is needed.

304V stainless steel is the most commonly used and cost-effective. It is the preferred alloy unless there is the need for corrosion resistance, fatigue life, or shape setting.

316LVM stainless steel concedes some strength for better ductility and corrosion resistance. The low-carbon, vacuum-melt designation makes it suitable for applications under sustained physiological exposure. It is also suitable for uses in which the device will see longer dwell times or aggressive saline environments.

35N LT™ alloy, a controlled-melt variant of the cobalt-nickel-chromium-molybdenum system covered by ASTM F562, is the choice when fatigue life is critical. Developed in the early 2000s and produced using a melt practice that eliminates titanium nitride inclusion-forming elements, 35N LT™ alloy achieves better fatigue performance over conventional MP35N® alloy. It has been found to be preferable when the device experiences high cycle counts under stress and strain. Typical applications include pacing leads, deflectable catheter shafts, and atherectomy drive shafts.

Nitinol is the choice for shape-set constructions. Wrought Nitinol under ASTM F2063 can be heat-set into a remembered geometry by holding the part in the desired form and exposing it to temperatures in the 410–440 °C [770–824 °F] range. The alloy then transitions to austenite at the austenite finish (Af) temperature, which for medical devices is typically set below body temperature so the part recovers its set shape at 37 °C [98.6 °F]. Shape-setting HHS® tube means the entire tubular structure can be locked into a curve, hook, or more complex distal geometry, which is useful for self-shaping access sheaths and deflectable catheter tips.

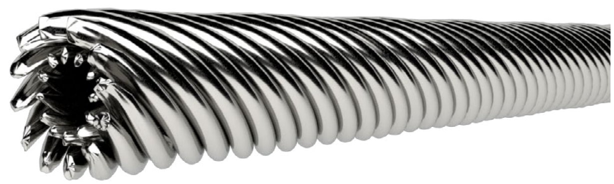
Other alloys can be substituted when an application requires it. The general rule is that if a filar can be drawn from a given alloy, it can usually be stranded into HHS® tube construction.

End finishing decisions

How HHS® tube is terminated is not a cosmetic question. The cut quality and end-fixation method determine how the device interfaces with the rest of the assembly and how the filars behave during shipping and handling.

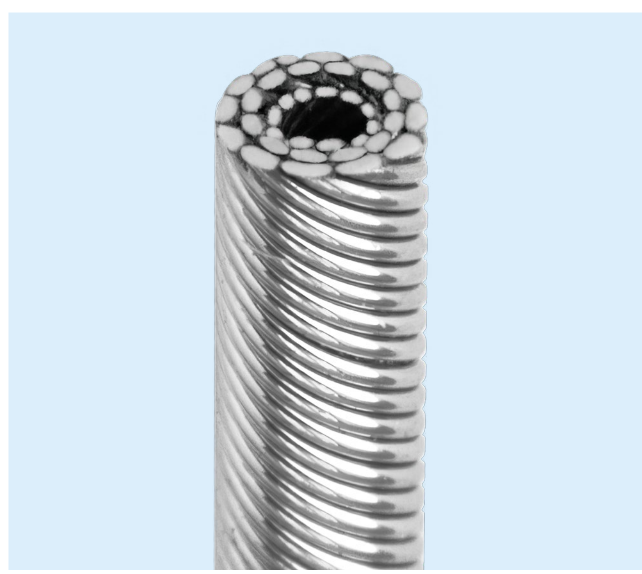
Two cutting methods are standard. Shear cutting produces a rough end with a wider length tolerance. It is fast and well-suited to high-volume production where the ends will be otherwise processed downstream. Shear-cut ends can shift filars during transit, so they are not the choice when the end face itself must remain dimensionally controlled.

Electrical discharge machining (EDM) cutting produces a square, burr-free face with much tighter length tolerance and high part-to-part repeatability. While the tradeoff is process time, EDM is the right choice when the end has to mate with a hub, fitting, or another tube without subsequent rework.



Welding adds a second decision. A band weld is a circumferential laser weld applied around the outside of the tube, fusing the filars to one another at the perimeter. Standard band welds are 0.508 mm ± 0.381 mm [0.020 in ± 0.015 in] long. They are cut with a wire EDM after welding to produce the final length and work well for customers who lack the assembly capability to manage filar shift in-house. A face weld is applied to the cut face of HHS® tube and is the preferred approach for dual- and triple-layer constructions, where layer shift — the relative axial movement of one layer against another — needs to be locked out before assembly. Single-layer tubes can also be face-welded when needed.

The end-finishing decision flows down from the next operation in the device build. A face-welded EDM-cut end goes straight into a hub bond with predictable geometry. A shear-cut, unwelded end is fine when the end will be otherwise captured.



Post-processing options

Several secondary operations modify the mechanical behavior of HHS® tube after it leaves the stranding line.

Rotary swaging compacts the outside diameter by passing the tube through a swage that radially compresses the filars against one another, closing interstitial gaps, flattening the contact between adjacent filars, and producing a smoother outer surface. The mechanical effect is increased stiffness, improved torque response, better compression resistance, and reduced filar mobility. The cost is flexibility, as swaged HHS® tube bends less freely than its unswaged counterpart at the same outer diameter. The amount of compaction is construction dependent. Swaging serves designs requiring more torque or compression than the as-stranded geometry delivers and can give up some flexibility in exchange.

Flat wire HHS® tube is a more recent development. Rolling the filars flat before stranding produces a tube with rectangular filar cross-sections that pack into a thinner wall and contact one another over a larger surface area. The result is high-torque performance at reduced wall thickness, with directional asymmetry and increased elongation resistance over equivalent round wire constructions.

Laser-welded assemblies allow multiple HHS® tube sections, hypotubes, fittings, or other components to be joined end-to-end. The key capability for device design is welding two HHS® tubes of different construction together. A single shaft can then carry a stiffer proximal section welded to a more flexible distal section, placing the mechanical-property transition exactly where the device needs it.

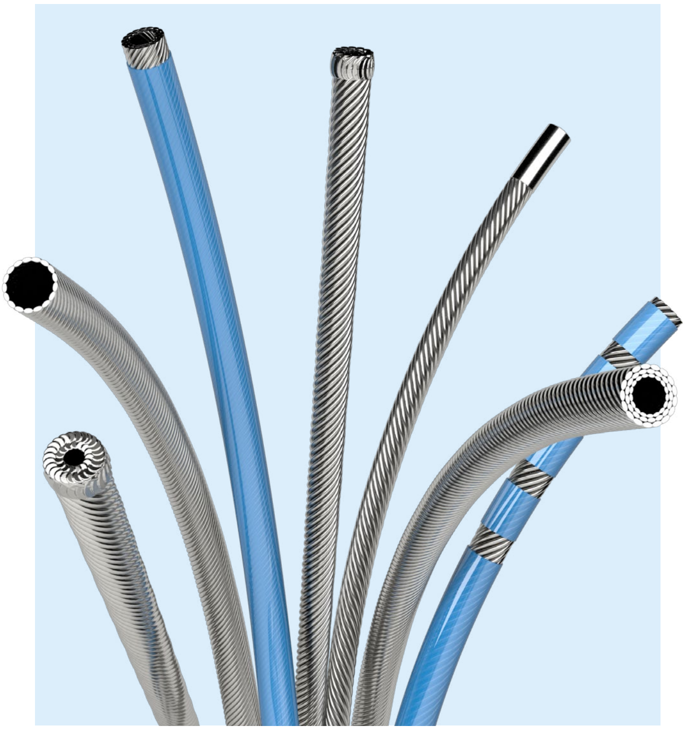
Coatings add a polymer surface to either the assembled tube or the individual filars before stranding. Polytetrafluoroethylene (PTFE) and ethylene Tetrafluoroethylene (ETFE) are the routine choices. PTFE provides lubricity and a degree of dielectric protection, while ETFE adds better abrasion and stress-crack resistance, with a continuous service temperature around 150 °C [302 °F] that survives downstream reflow operations. Other coatings, including nylon, silicone, and Pebax® reflow over the assembled HHS® tube, can be applied when the application demands specific surface properties. Coating individual filars before stranding produces a composite tube whose inter-filar friction, electrical isolation, and surface texture are all modified relative to a bare-metal tube.

Cleaning and passivation

Stainless-steel HHS® tube destined for medical applications receive routine in-process cleaning. When the device specification calls for it, additional passivation and ultrasonic cleaning are available. Nitric passivation is performed per ASTM A967, the standard specification for chemical passivation of stainless steel parts. The process dissolves free iron and contamination from the surface and restores the protective chromium-oxide layer required for corrosion performance in implantable and saline-exposed applications. Ultrasonic cleaning with a CIP-100-class alkaline solvent removes residues that simple rinsing leaves behind. Both steps are routine prerequisites for downstream sterilization and biocompatibility validation.

Construction as a design variable

For an engineer specifying HHS® tube, the mechanical envelope is set by inside and outside diameter, length, and bend radius. Within that envelope, the construction is chosen by balancing filar count, layer count, pitch, lay direction, and filar shape. The material is chosen by ranking strength against corrosion resistance against fatigue life against shape-set capability. End finishing is chosen by matching the next assembly operation. Post-processes are added where the as-stranded behavior falls short of the target.



The fastest way to compress that decision tree is to start from samples. More than 80 standard constructions are available for evaluation, with a subset shippable in one to three days through stocked sample channels. Putting representative HHS® tube under axial, torsional, and bending loads and then measuring actual torque ratio, bend radius, and elongation rather than estimating them is the most efficient path from envelope to specification.

The mechanical job has not changed. Devices still need to navigate, transmit, and deliver. The available structure has expanded.

If your device needs a shaft that flexes, torques, compresses, or holds an open lumen where conventional tubing falls short, put HHS® tube to the test. Contact us to discuss your project, request samples, or move straight to production. We'll help you find the right construction and get development moving faster.

To learn more, visit fwmetals.com