Flexible Options with Flexible Shafts

Guido Broder and Michael Boehm

You need to transmit a rotary motion where no straight line is possible. Or, you need to allow for some uncontrollable misalignment. How about transmission taking place between moving components? What if you need to control something in hazardous locations where you cannot directly handle the application, such as high-temperature environments, under hazardous conditions or in clean room applications? Functionally designed flexible shafts can meet all these challenges (Fig. 1).

A flexible shaft is a very effective and cost-efficient way to transmit rotary motion, power or torque. Flexible shafts are made with wire spiraled tightly around a central wire. With each layer you increase the diameter of the shaft and with that the torque it can transmit. Compared to a pull cable or a wire rope, where a bundle of wires is twisted together, the flexible shaft is designed and made to transmit rotary power. Layers of wire spirals are wound in opposite directions to each other and will not twist open if turned (as a wire rope would do).

Figure 1 Flexible cables allow design freedoms that other solutions can't match.

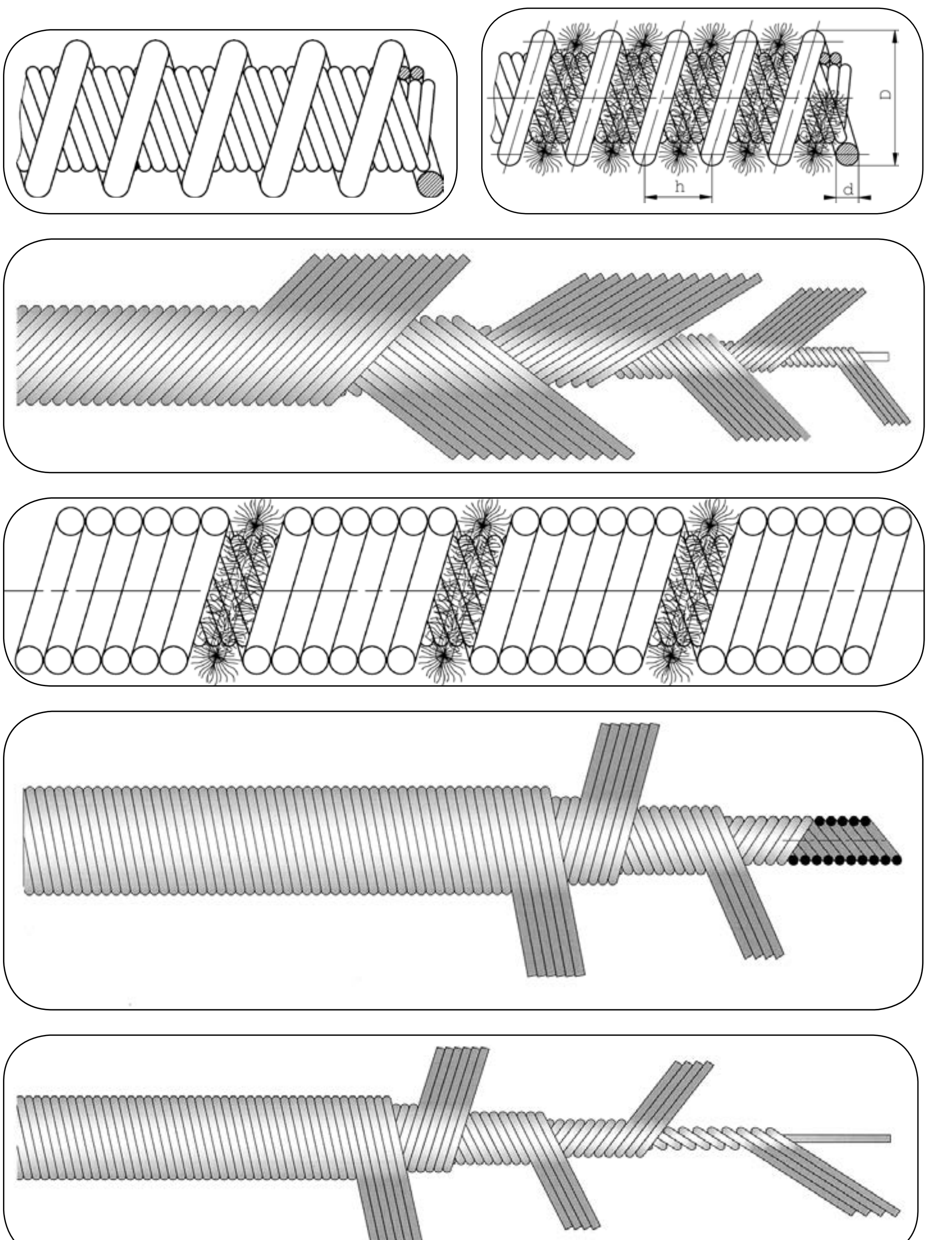

Figure 2 Different applications require different types of flexible cable.

Though it sounds like a very simple element, different applications require different designs, number of layers, number of wires, diameter and so on.

In flexible shaft design, it is important to know how much torque has to be transmitted, how small the minimum radius for the shaft has to be, what RPM is required, the environment the flexible shaft will work in and the preferred turning direction. Length is not critically important for the torque but plays a role in torsional deflection and has to be considered accordingly.

In flexible shaft design, unfortunately not all parameters can be stretched in all directions. For example, if more torque is required, the minimum radius goes down and with it the flexibility of the shaft. If the minimum radius can be reduced, the torsional deflection will go up, which for remote control cable is not a good thing.

Related to this basic "reality" of flexible shafts, two main design groups emerge. First there are torque-transmission shafts, mainly for higher speed, continuous speed, pure torque transmission applications like speedometer cable or shafts for drilling applications. Second are the torsion-stable flexible shafts for mechanically remote applications, with low speed and focus on low torsional deflection. An example is slide adjustments for stationary cutting machines. Also, there are special cables like flocked shafts, hollow shafts, shafts with helix wire and so on. Figure 1 shows some examples of special flexible shafts.

Direct influences on flexible shaft specifications are: the number of layers; the number of wires-per-layer; the diameter of the wire; the wire material (with higher or lesser carbon; different tensile strengths; different plating);and the manufacturing process (settings on the winding machines).

Considering influences related to shaft manufacturing processes, it has to be understood that winding is a high-speed process where gap settings will influence the flexibility of the shaft. The winding speed and the gaps must be uniform and controlled. Gap settings are a key parameter, but not the only one. There are others, like the tension of the wire, the quality of the spooled-wire package, the temperature of the operation and so on. Experienced producers effectively control their processes and assure highest quality flexible shafts, which in turn assures successful application.

Flexible Shaft Selection

The application will for the most part determine the design of the flexible shaft. First, consider the torque (or power) that needs to be transmitted; then the routing (defining minimum bending radius); the RPM (speed required); the torsional deflection (angle of deflection under load); and the environment.

Figure 3 shows the relationship of shaft diameter to what is roughly required to transmit a certain power (kW) under a given RPM.

As an example, for a 15 mm flexible shaft, you should consider 5 kW and 2,000 RPM. The chart assumes nearly straight conditions. The routing of the power transmission will determine the smallest radius of the system, and with that the friction or the loss of the system. A given flexible shaft has a minimum bending radius; below the minimum indicates permanent deformation (destruction) of the flexible shaft. A 3 mm shaft has a minimum bending radius of 80 mm; a 5 mm shaft 150 mm; a 7 mm shaft 210 mm; 10 mm is 300 mm; and 15 mm is 450 mm. If a system runs under minimum bending conditions, only 30 percent of the power will be transmitted;the rest is friction loss in the system radiated by heat (Fig. 4). This needs to be considered when choosing the diameter of the flexible shaft.

The degree of torsional deflection in a flexible shaft varies proportionally with the torque as well (Fig. 5). To keep the deflection and the load as low as possible, the flexible shaft should be operated at the highest possible speed

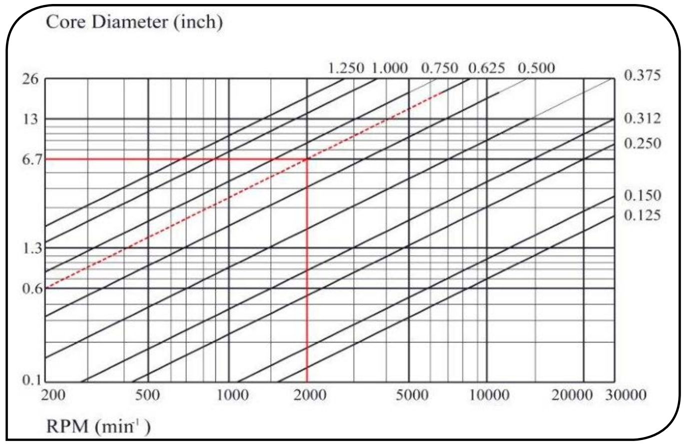

Figure 3 Power and speed depend on the flexible shaft's diameter.

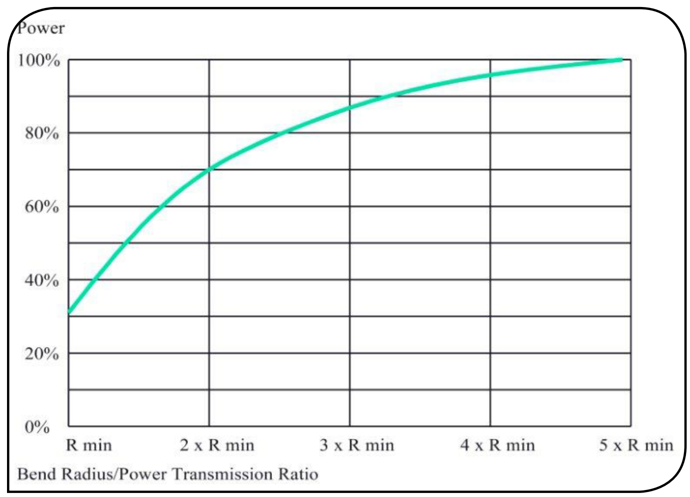

Figure 4 The amount of transmittable power depends on the bend radius.

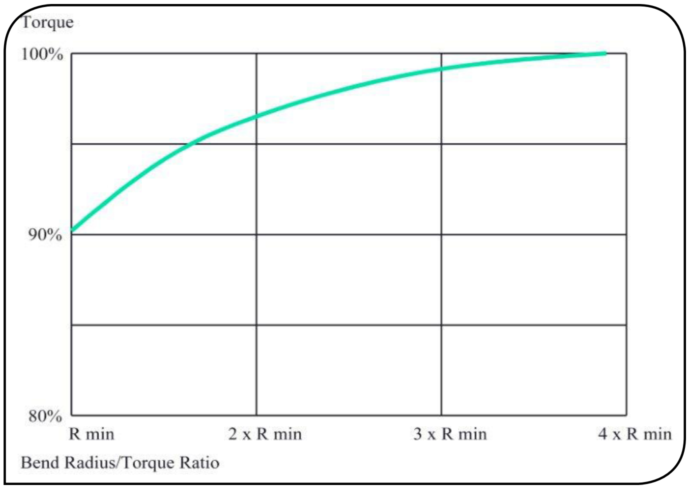

Figure 5 The degree of torsional deflection varies proportionally with the torque.

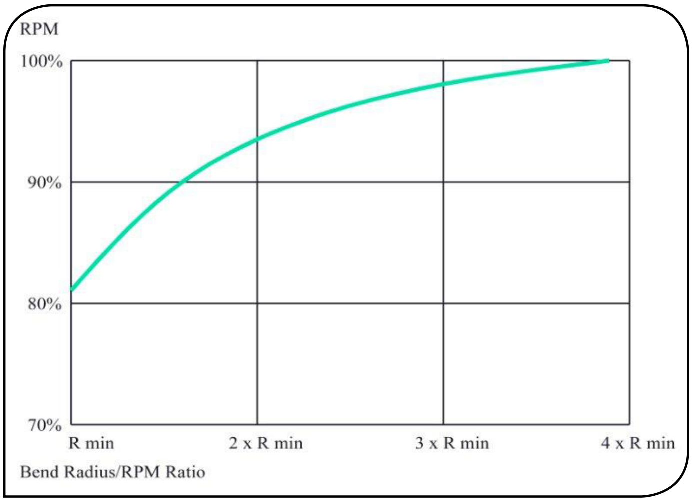

Figure 6 Higher speeds result in lower deflection and lower loads.

(Fig. 6). If needed, gear systems can also be added. Attention must also be paid to the environment in which the flexible shaft will be used. Examples include extremely high or low temperatures, moisture, corrosive influences, dust, magnetic fields, vibrations, etc. Environmental factors influence the choice of the material for the core and casing and their fabrication. The usage of brass-coated wires allows a nearly corrosion-free flexible shaft. Other effective materials are stainless steel or plastic-covered shafts (for convertible car top folding or head lamp mechanisms on some modern cars).

By knowing torque and RPM requirements and minimum bending radius, you can roughly check if a flexible shaft will suit your needs. As previously noted, there are many other parameters in flexible shaft design and manufacturing that influence the specification and performance of the shaft. It is possible to have a 3.2 mm speedometer shaft designed in two different ways to achieve double flexibility and therefore a smoother running shaft. This can reduce the diameter, and with that the material consumption and weight. An experienced design and manufacturing partner can help you optimize flexible shafts for price, performance, weight and other criteria.

Examples: Automotive

Flexible shafts have a growing and compelling future in the automotive industry. Ongoing competitive challenges push suppliers to develop innovative and ever-more functional and efficient solutions.

As important as changes in physical performance and outer design and style, automobiles also need equal or better interior improvements in function and comfort. Seat adjustments and other features controlled from the dashboard have made big contributions to the feel-good factor for new car owners. Flexible shafts are small, durable and extremely effective at transmitting rotary power from a small motor (where it needs to be) to where the motion is needed.

Reliable and inexpensive flexible shafts avoid complicated (high-cost) gears, high tolerance alignments and can make difficult design situations possible. Flexible shafts, long known as speedometer cables, are not just doing the job in seat adjustments; today they are the solution in demanding head, ventilation, lighting adjustments, sun roofs or locking systems.

In power seats, each movement requires a small electric motor. These motors, sometimes 8-per-seat, can't always be placed exactly where needed. Using flexible shaft technology, motors are placed in the most practical place for the designer and transparent to passengers. Consider also door locking systems where car designs no longer permit solid shaft connection between the keyhole and the lock. A flexible shaft has given designers more freedom to create attractive designs for new models.

Experience and the right machinery, processes and knowledge assure you the best flexible shaft solution for the next innovation in cars. Self-opening doors, gliding doors, new convertible concepts, foot pedal adjustments and moveable back-up cameras are all projects in the pipeline for flexible shafts. **PTE**

For more information:

Suhner Manufacturing Inc.
P.O. Box 1234
Rome, GA 30162-1234
Phone: (706) 235-8046
michael.boehm@suhner.com

Guido Broder is VP and general manager of Suhner Manufacturing Inc.

Michael Boehm is director of marketing & sales, and global marketing coordinator for flexible shafts at Suhner Manufacturing Inc.