RULAND

Carefully Made Shaft Collars and Couplings

Getting a Hold on Shaft Collars

Choosing the Right Shaft Collar for the Job

Shaft Collars are one of the simplest components in power transmission and are the most indispensable. They can be found in virtually any type of machinery, and are frequently accessories to other components. Among their many roles, shaft collars hold bearings and sprockets on shafts, situate components in motor and gearbox assemblies, and serve as mechanical stops.

Sets Screw Shaft Collar

The first mass produced shaft collars were solid ring collars which utilized square headed set screws which protruded from the collar. These early collars were considered dangerous because of the workers risk of catching their clothing on the protruding screw head. Set screw collars have come a long way since those early days and are now manufactured with a recessed set screw.

Set screw collars derive all of their holding power from the screw as it is tightened onto the shaft. The amount of holding power depends greatly on the material of the shaft on which the collar is installed. In order for a set screw collar to obtain maximum holding power, the shaft must be of softer material than that of the set screw. This allows impingement of the screw point into the shaft keeping the screw and collar in its installed position under torque and axial loads, instead of sliding along the shaft.

The very nature of the set screw collar is its greatest fault. The tightening of the set screw causes marring on the shaft which is undesirable for functional as well as cosmetic reasons. The impingement of the screw causes an eruption of material around the point resulting in a raised burr on the surface of the shaft. The marring of the shaft makes it difficult to remove the collar or fine-tune its position. Small angular or lateral adjustments are almost impossible to make, since the screw point will be drawn back to its original location.

Clamp Style Shaft Collars

An improvement from the set screw collar, the clamp style shaft collar does not mar the shaft. While it is not known with certainty who invented the clamp style collar, Ruland Manufacturing was developing them for bomb sights and guidance instruments during World War II. These seemingly basic mechanical instruments were considered very high tech (and top secret) at the time and were the forerunner of the analog computer industry. While they are taken for granted today; at the time, clamp style collars were the cutting edge precision components required for such advanced equipment.

Clamp style collars solve many of the problems that exist with the set screw collar and are available in one and two-piece designs. Instead of marring the shaft with a set screw, clamp style collars utilize compressive forces to lock the collar onto the shaft. For this reason, clamp style collars are easily

removed, indefinitely adjustable, and work well on virtually any shaft. Tightening a few clamp screws closes the collar onto the shaft for a nearly uniform distribution of forces around the shaft's circumference. The uniform clamping is mechanically more secure than point contact, as much as doubling holding power, depending on shaft size and condition.

Although clamp type collars work very well under relatively constant loads, shock loads can cause the collar to shift its position on the shaft. This is due to the very high forces that can be created by a relatively small mass during impact, compared to a statically or gradually applied load. As an option for applications with this type of loading, an undercut can be made on the shaft and a two-piece clamp collar used to create a positive stop that is more resistant to shock loads.

This approach demonstrates the benefits of the two-piece design. It has more holding power than a one-piece design because it uses its full seating torque to apply clamping forces to the shaft. One-piece collars sacrifice some of their clamping ability because the screw must use a portion of its seating torque to bend the collar around the shaft.

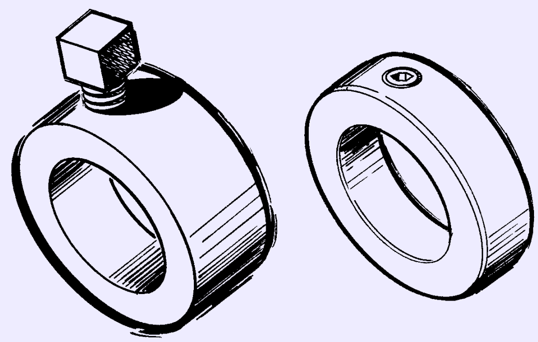
Two-piece collars also boast advantages in installation and assembly. While set-screw collars and one-piece clamp collars must slide over the end of a shaft, two-piece collars can be disassembled and installed in position without having to remove other components from the shaft. In the case of an undercut shaft, a one piece collar has to be pried open to accommodate the shaft's diameter while a set-screw collar cannot be installed properly in any case.

Another approach to increase secure positioning under shock loads is to stack several collars, or to add pads or bumpers. Multiple collars increase load capability due to the additional clamping force provided by multiple screws and the frictional benefits of increased shaft contact. Double or other extra-wide clamping collars with multiple screws have the same advantages as a stack of collars. Bumpers or pads absorb some of the shock load and can also reduce some of the noise caused by impact.

Collar Evolution

The first mass-produced collars were used primarily on line shafting in early manufacturing mills. These early shaft collars were solid ring types, employing square-head set screws that protruded from the collar. Protruding screws proved to be a problem because they could catch on a workmen's clothing while rotating on a shaft, and pull them into the machinery.

Shaft collars saw few improvements until the early 1900's when Howard T. Hallowell created the first recessed head socket set screw shaft collar. Hallowell received a patent on his safety set collar, which was soon copied by others and became an industry standard. The invention of the safety set collar was the beginning of the recessed-socket screw industry.



Set screw collars derive all their holding power from the screw as it is tightened onto the shaft. Holding power depends greatly on the shaft material and condition. For a set screw shaft collar to achieve maximum grip, the shaft must be of softer material than that of the set screw. This allows for impingement of the screw point into the shaft, which keeps the collar in its installed position under torque and axial loads, and prevents it from sliding along the shaft.

Set screws tend to damage shafts which is undesirable for functional and cosmetic reasons. Screw impingement causes an eruption of material around the screw resulting in a raised burr on the shaft surface. This raised material makes it difficult to remove or reposition the collar. The invention of the clamp style shaft collar solved the destructive issues associated with the set screw. Clamp collars utilize compressive forces to lock onto the shaft without any damage.

Nobody is certain who first invented the clamp style shaft collar, but they have been around since WWII when they were used in bombsights and guiding systems. These mechanical instruments consisted of precision gearing, differentials, couplings, and collars in combination with electrical selsyn motors, resolvers, precision potentiometers, and a variety of electronics. At the time, they were considered high tech, top secret, and were cutting edge precision components.

Holding Power

Clamp style shaft collars perform critical duties. Choosing the best shaft collar is a matter of matching one or more performance factors with specific application requirements. In many applications, the collars holding power is paramount. Other important factors include its ability to weld, inertia, conductivity, corrosion resistance, and collar-face precision as it relates to the bore.

Holding power is the most important feature when the collars are used on split hubs or as mechanical stops. (Split hubs are interfaces for connecting components such as gearboxes, sprockets, encoders, and couplings to shafts.) Collars are effective split-hub clamps, but the application is particularly demanding since a portion of the clamping force is expended closing the hub, which reduces the forces applied to the shaft. Maintaining close tolerances between the shaft, hub, and collar (and keeping hub thickness as small as possible helps minimize the amount of force lost on the hub itself.

Several design and manufacturing features such as bore size and concentricity, influence the holding power of clamp style shaft collars. However, many of the most important factors are related to the fundamental mechanics; a function of the amount of screw torque *indirectly* transmitted to the shaft by frictional forces between the shaft and bore.

Screw size and quality also factor into holding power. Some of the many attributes of superior screws are thread quality, tensile strength of material, and closely held geometry and size tolerances, which eliminates frictional drag on the collar socket. In general, forged screws are superior to those that are broached. But with so many attributes to consider, comparisons are best made empirically.

Material strength and collar design are factors affecting the translation of screw torque in to shaft collar holding power. The material needs to be strong enough to withstand the recommended screw torque. Low-grade materials could crack or deform under torque, reducing holding power and possibly result in catastrophic failure. The threads, the bottom of the counter-bore, or the sides of the counter-bore, can all deform, resulting in reduced collar performance.

Misconception

It is a common misconception that a larger outer diameter makes a collar stronger. A larger outer diameter has the advantage of being able to hide the clamp screws within the shaft collar, rather than be left protruding. But unless width is also increased allowing for a larger screw (which would be protruding) to be used, increasing shaft collar outer diameter relative to the bore size has no performance benefit and can reduce holding power. Holding power can be reduced for the reason that some of the screw torque must be expended to bend the collar around the shaft before the remaining forces are applied to the shaft.

To create extra clamping force, a larger screw must be used or the screw location must be moved away from the center line of the shaft to create greater mechanical advantage, resulting in increased holding power. Increasing the outer-diameter of the collar without changing the screw size or location only creates a condition where excess material must be deformed elastically before any forces are applied to the shaft. Some forces will be expended this way regardless but these can be reduced and holding power increased by having the collar OD no larger than necessary.

Holding power can be increased further by having a back-cut opposite the clamp-cut in the bore of a one-piece clamp collar, thus reducing the material at the collar's hinge point. Using a two-piece collar further reduces the amount of material to bend and has the added advantage of a second screw to transmit torque but the result is only an approximately 2% increase in holding power over a properly designed one-piece clamp collar. This small increase may not be worth the added cost of the two-piece design, especially if it adds complication in design and installation such as the need access to both screws when the collar is in an enclosure.

Although the holding power gains may not be significant and the one-piece design is often more convenient, two-piece collars have the advantage of easy disassembly and removal from the shaft without needing to remove other components. Two-piece collars can also be balanced more easily (by opposing the screws) than one-piece collars. Balancing is sometimes necessary where the collar rotates at high RPM, as may be the case with split-hub applications.

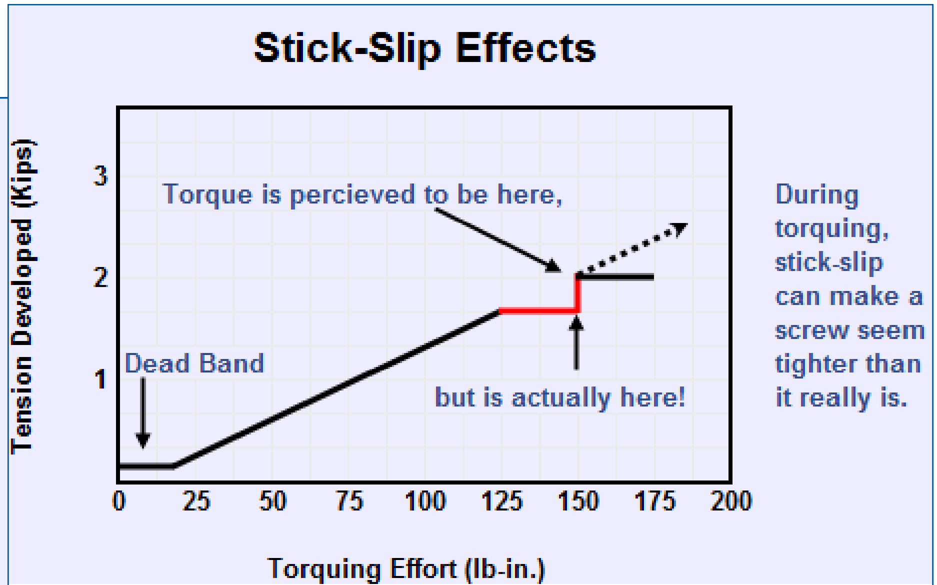
Stick Slip

Another important contributor to shaft collar holding power is the surface treatment of the collar and

Tightening a screw is a deceptively simple task. When it's done to attach collars to shafts, any number of difficulties can arise. One common problem is stick slip. Stick-slip can create a false impression that a screw has been tightened to its appropriate stress level.

During tightening, a screw rotates uniformly as it's torqued down, then it reaches a point where its rotation gets sticky. The screw begins to turn in a choppy manner, stopping and starting even though tightening torque is constantly applied. The lost torsioning effort during stick-slip is typically absorbed as excess friction between the threads or underside of the head and the mating parts of the clamp body, instead of contributing to the stress in the joint elements. If these stresses in the joint are too low, the collar will not hold well.

The best way to avoid the effects of stick-slip is by using specially coated elements. For example, black oxide helps to smooth the torqueing of screws without diminishing the frictional characteristics and holding power of the bore. Clamping screws that operate smoothly during torquing are the best assurance that stick slip is not present.



screws. The most common shaft collars are steel with black oxide finish, which enhances the torque of the screws yet does not significantly diminish the frictional characteristics of the bore with a net increase in holding power.

This increase can be optimized through combination of the black oxide formulation and a well chosen light oil treatment on the screw. Alternative surface treatments such as zinc have better corrosion resistance than black oxide but tend to significantly reduce holding power significantly.

Black oxide is effective partly because it is an anti stick slip compound. Stick-slip is the false impression that a screw has been tightened to the appropriate stress level. Instead of the screw rotating uniformly as the torquing continues, there is a point at which the uniform rotation converts to a stop and start pattern. The tensioning effort on the screw is being absorbed as excess friction between the threads or the underside of the head and the mating parts of the clamp body, instead of contributing to the stress in the joint elements. If the stresses are low, the collar will not hold well.

The stick-slip condition can be elusive. A silky smooth operation of the clamping screw during torquing is the best assurance that stick slip is not present. Properly formulated black oxide helps to create this condition.

Stick-slip compounds and other surface treatments on the screw threads such as zinc, molybdenum, or nylon alter the tightening characteristics of the screw. If the normal torque is applied to the screw the most likely result would be an over-torquing of the system with the risk that the screw or the collar could be damaged and subject to sudden failure. Furthermore, the unevenness in application of some screw thread surface treatments may make the torque inconsistent and lead its holding power to be unpredictable.

Precision Facing

As well as their holding power, a primary performance characteristic of shaft collars is their ability to locate and align other shaft components with a precisely machined bearing face. In order to assure this level of precision, high performance shaft collars are single point faced at the same time that the bore is finished. This results in very low run-out when the collar is mounted on the shaft, which is extremely important when interfacing with other precision components.

Clamp style shaft collars in both one- and two-piece styles allow for easy installation and adjustment and are used commonly to locate components on a shaft, such as sprockets, gears, pulleys, and ball bearing units. In these cases the ability to retain axial loads is important, but the perpendicularity of the collar face to the shaft is critical.

A precise face-to-bore relationship ensures squareness of the component to the shaft with no shifting or tilting relative to the shaft axis. Such displacements can cause premature wear and possibly affect the performance of the assembly. In cases where sprockets or pulleys are used with chain or belts, the alignment of the component is critical to proper operation. Failure to maintain alignment can result in unacceptable performance, including excessive noise, slippage, whipping, rapid wear or total failure, depending on the application.

A perpendicular face also ensures even pressures at the interface with the mounted component, eliminating spot loading which can shorten life of the components. In applications where collars are used against bearings, this is an extremely important characteristic since uneven loading of bearings is detrimental to long life and high performance.

This is also beneficial in applications that see moderate axial shock loading such as linear actuators. In applications such as these, where the collar is used as a mechanical stop, face squareness is important to assure even force distribution across the face of the collar to minimize the impact pressure and ensure that the collar does not shift position on the shaft.

Threaded Collars & Bearing Locknuts

A popular shaft collar variation is the threaded bore collar. Typically, threaded collars are available in the same styles as smooth bore collars, but are most popular in the one and two piece clamp styles. This is because set screw styles would do large and permanent damage to the threaded shaft the collar is installed on, by impinging the screw into the threads. Clamp-Style threaded collars open possibilities for many applications using threaded shafts, but stand out particularly in two areas; application with high axial loads, and applications requiring fine location or preload adjustments.

For high axial-load applications threaded collars have a distinct advantage over smooth-bore collars which rely on friction for resistance to axial loads, making them susceptible to movement when shocked. Threaded collars have a positive mechanical stop created by the interface of the threads on the collar

and the shaft, making the collar almost impossible to move axially without breaking the shaft itself.

Clamp style threaded collars also make it easier to perform fine adjustments and / or preloading of components such as bearings. This is preformed by simply threading the collar into location and locking it in place by tightening the screw to proper torque levels.

Bearing locknuts are a special designed threaded collar intended solely to mate up with bearings. They have a more precise control tolerance for face run-out to the threads to ensure even pressure on the entire bearing face and precise control of preload. Typically, spanner wrench slots are machined into the outer diameter of the collar to allow for easy access and precise adjustment of this preload. As with other threaded collars, once the preload is established, the locknut can be secured by tightening its screw.

Quick-Clamping Collars

Quick-clamping shaft collars are relatively new to the shaft collar market. Much like the clamping type collars, they do not mar the shaft. The greatest advantage of the quick-clamping shaft collars is they do not require tools to install or remove them, and are especially designed for quick adjustments. They also work well with light duty split hub components such as gears and sprockets and they can be machined to facilitate mounting of other components.

Quick-clamping shaft collars are ideal for light duty applications with frequent setup changes or adjustments. The quick clamping collars are designed with a low profile clamping lever which makes them suitable for rotating and stationary applications. Industries such as printing and packaging, as well as others, can benefit from the use of quick clamping collars to retain frequently changed items, such as rolls of media, or for rapid and precise adjustment. of guide rails or other setup alterations.

Conclusion

Shaft collars are versatile components that have evolved from the basic set-screw design to high performing versatile clamp styles. Shaft collars are produced in a variety of materials and in a wide range of sizes, making them convenient solutions to a variety of engineering problems. Many shaft collar applications are demanding, so selecting shaft collars with the correct features required for top performance is vital to equipment functionality.