

# Construction, Working and Installation of Keyless Shaft Locking Devices

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The information contained in this article represents a significant collection of technical information about construction, working and installation of keyless shaft locking devices. This information will help to achieve increased reliability at a decreased cost. Assemblage of this information will provide a single point of reference that might otherwise be time consuming to obtain. Most of information given in this article is mainly derived from literature on the subject from sources as per the references given at the end of this article. For more information, please refer them. All information contained in this article has been assembled with great care. However, the information is given for guidance purposes only. The ultimate responsibility for its use and any subsequent liability rests with the end user. Please view the disclaimer uploaded on <http://www.practicalmaintenance.net>.

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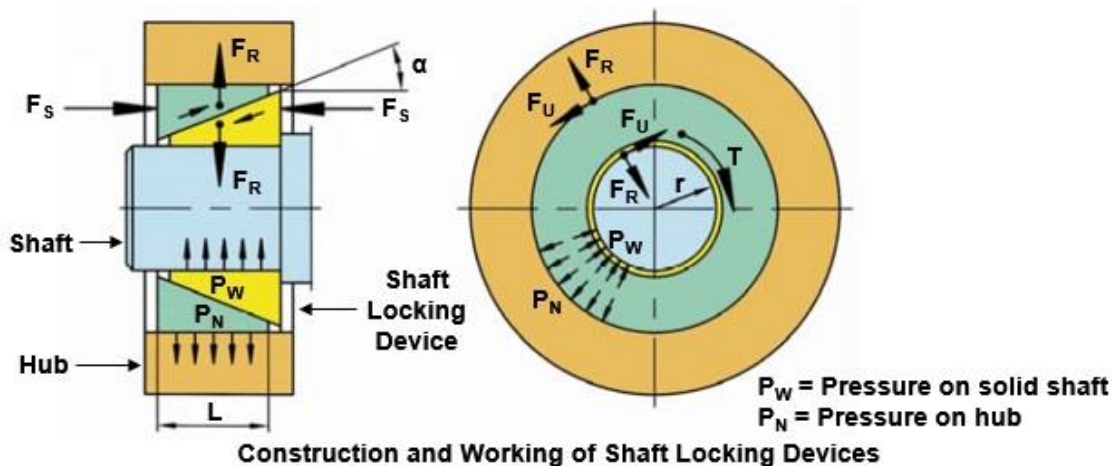
# Keyless Shaft Locking Devices

Traditional shaft connection methods include keyways, keyways with interference fit (also called press fit and shrink fit), Taper Lock® Bushing and “Quick Detachable”, QD® bushings.

Keyless shaft locking devices/assemblies/elements/bushings (also called shaft locking devices as called in this article or friction locks or shaft to hub connections) are standard machine elements used to connect shafts and hubs. They are capable of transmitting torque, radial forces, axial forces and bending moments. They also have many advantages over traditional methods. In view of this, information on them is given in this article.

## Construction and Working

Shaft locking devices connect hubs solidly to shafts, using a keyless mechanical interference fit, to transmit torque or to withstand axial thrust. This mechanical interference fit utilizes screw tension in the shaft locking device, converted into radial pressure  $P$  (see the following figure) via inclined planes (cones). This pressure expands the shaft locking device to eliminate the gap between the hub and the shaft. The shaft locking device uses the friction bond between the shaft locking device and the shaft/hub to create a zero backlash connection. This connection is easily releasable to remove the mechanical interference fit.



As shown in above schematic figure, when screws of the shaft locking device are tightened, the forces applied to the screw,  $F_s$ , are transformed into radial forces,  $F_R$ , via the setting angle,  $\alpha$ , of the inclined planes, with consideration of the sliding friction. The radial force,  $F_R$  and the coefficient of friction,  $\mu$ , yield a friction force,  $F_U$  (circumferential force). The friction force,  $F_U$  with the shaft radius,  $r$ , results in the transmissible torque,  $T$  (the main load).

Shaft locking device are primarily used for joining components on smooth, groove-less shafts. However, they can be used on shafts with keyways. The function of the locking device is not getting affected due to keyways on a shaft. But, the edges of the keyways should be blunted and free from burrs. However, it may be noted that keyways in the hub are not allowed!

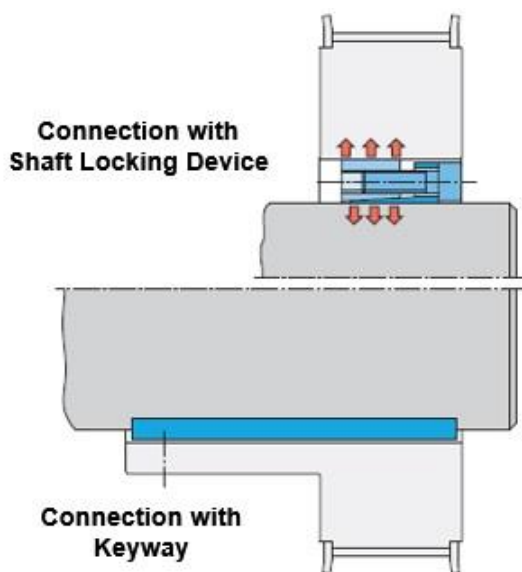
A distinguishing feature of shaft locking devices is the integrated screws for their installation and removal without destruction/damage.

Shaft locking devices are suitable for use on conveyor pulleys, gear wheels, chain sprockets, flywheels, cams, pulleys, couplings (flexible types and rigid types), clutches, impellers, fans and numerous other applications.

## Limitations of Traditional Shaft Connections

Keys and keyways are relatively easy to prepare, quick to install and provide a low cost solution. Although they are commonly used, they are not effective because keys and keyways require a clearance fit on several planes. The combined effect of these clearances is backlash, which in some cases can enlarge the keyways, while promoting fatigue failures and fretting corrosion.

When keyways are cut into components and shafts, they reduce the cross section and, consequently, the strength of the machined parts. As a result, any shaft, coupling or pulley containing a keyway must be oversized to compensate for the reduced cross section.



**Comparison between Shaft Locking Device and Keyway**

Above figure shows the relationships between shaft diameter and shaft length for connection with a keyway (lower half of the figure) and connection with a shaft locking device (upper half of the figure) for transmitting the same torque. It can be seen that the shaft diameter is smaller and shaft length is shorter for the connection with a shaft locking device. Thus connection with a shaft locking device offers a compact and cost effective solution.

Compared to keyways with a clearance fit, interference fits offer some advantages, like zero backlash and uniform contact pressures. However, interference fits need extremely close machining tolerances of the shaft and component bore. Also, depending on the size of the shaft, the use of a press or heat source might be necessary. In addition, maintenance is often difficult and components can seldom be reused.

## Advantages of Shaft Locking Devices

Shaft locking devices expand to fill the gap between the shaft and hub, allowing for easy installation and removal, saving time over traditional interference fit techniques. The contact pressures created using a shaft locking device can be greater than traditional interference fit pressures, allowing for more torque to be transmitted. The easy installation also allows the hub to be positioned more accurately on the shaft, and can facilitate angular timing of the hub. Shaft locking devices will slip when the rated torque values are exceeded. In this regard they can provide overload protection but should not be used primarily for this purpose. The advantages of shaft locking devices can be summarized as under.

## Advantages Versus Traditional Keyed Connections

- No Backlash
- No impact effect from reversing loads
- Ability to adjust axial position and angular timing
- No fretting corrosion due to movement at the fit interface

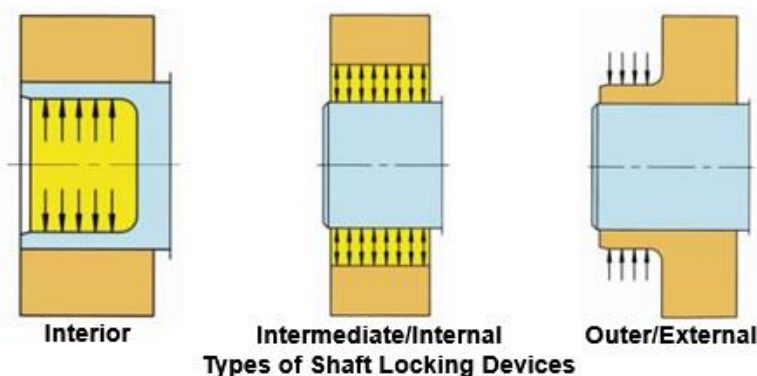
## Advantages Versus Traditional Interference Fits

- Easier and quicker to install
- Higher contact pressures can transmit greater torques
- Easy and quick to remove without damaging the shaft or hub - even after years of service

## Design Benefits

- Eliminate cost of machining keyways and close machining tolerances
- Reduce the shaft stress by removing keyways (No notch effect)
- Eliminating keyways often allows the use of a smaller diameter shaft
- Can be placed anywhere on shaft, and allows for easy angular timing
- Easy removal without damaging the shaft or hub means easier maintenance

## Types of Shaft Locking Devices



As shown in above figure, shaft locking devices can be divided in three different types.

Interior locking type shaft locking devices (called locking bolts) widen the hollow shaft from inside to the hub. The forces are transmitted directly between shaft and hub.

Intermediate/Internal shaft locking devices (called cone clamping elements or locking assemblies) are fixed between shaft and hub. The forces are transmitted through the locking assemblies.

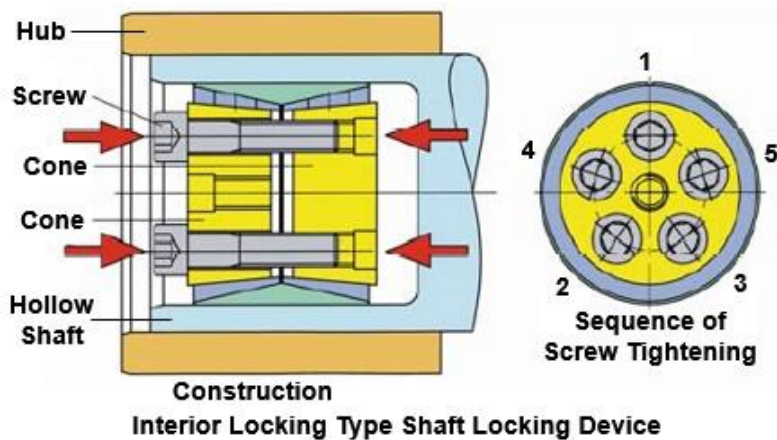
Outer/External shaft locking devices (called shrink disks) compress the hub onto the shaft. The forces are transmitted directly between shaft and hub.

### Note:

As interior locking type devices are used rarely, many manufacturers make/supply only intermediate locking type and outer locking type devices only. They also refer intermediate locking type devices as **internal shaft locking devices** or cone clamping elements and outer locking type devices as **external shaft locking devices** or shrink discs. Thus at the broadest level, keyless shaft locking devices may be split into two types/categories: internal shaft locking devices and external shaft locking devices.

Though manufacturers offer several constructions/designs in each type, information on most popular constructions of each type of shaft locking devices is given in the following sections.

### Interior Locking Type Shaft Locking Devices



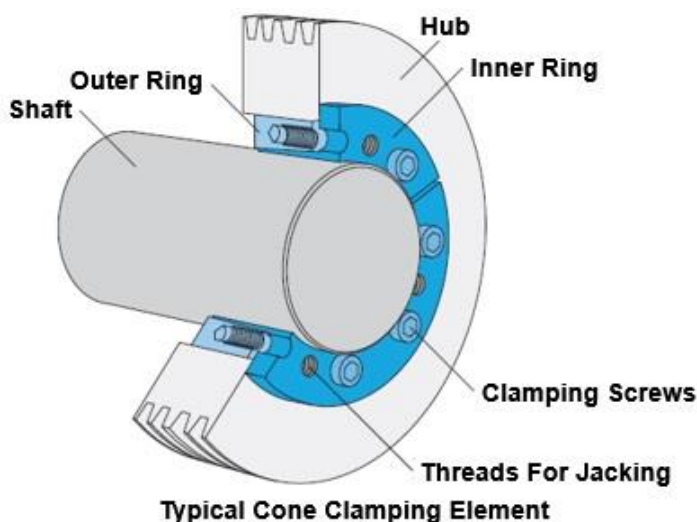
Above figure shows construction of a typical interior locking type shaft locking device. The figure shows construction of DOBIKON 2000 (Standard) manufactured by Bikon®. On tightening the screws, the cones are pulled together generating radial force over the hollow shaft. This force presses the hollow shaft onto the hub.

#### Installation Steps

- Clean the hollow shaft and the hub thoroughly to remove all dirt.
- Slide the hub on the hollow shaft.
- Release all screws a few turns to keep the rings spaced during insertion of the assembly.
- Lubricate locking assembly with oil (Do not use molybdenum-disulfide, MoS<sub>2</sub> or grease).
- Tighten screws evenly, alternating diagonally/crosswise (star pattern) and in progressive rounds of tightening with a torque wrench to the specified value (starting from hand tight).
- Verify the tightening torque on all screws in circumferential succession (circular pattern). Installation gets completed when none of the screws yields any further.

For disassembly, release all screws a few turns.

### Internal Shaft Locking Devices (Cone Clamping Elements)

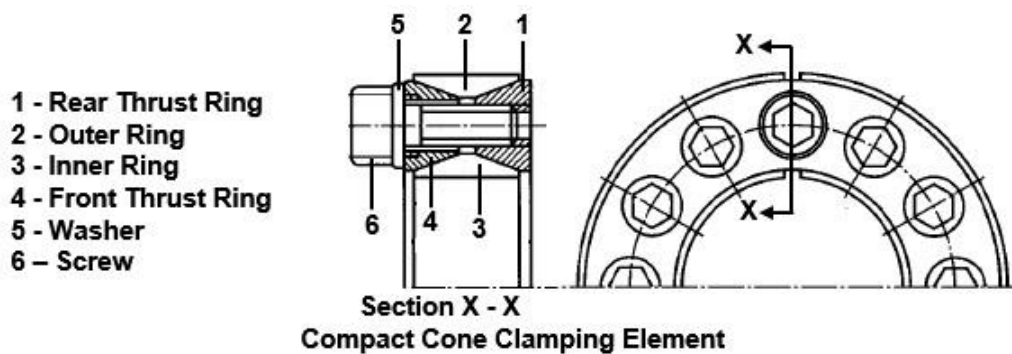


Internal shaft locking devices are available in many designs/constructions to suit different applications. As these devices use cones for clamping, they are commonly called **cone clamping elements**. As shown in above figure, a typical cone clamping element consist of an outer ring with inside cone and an inner ring with outside cone as well as number of clamping screws.

When the outer ring is pulled onto the inner ring by tightening the clamping screws, radial clamping forces are generated by the conical surfaces which are dependent on the torques of the clamping screws, the cone angle and the friction coefficients at the screws (at the threads and under the head of the screws) and conical surfaces.

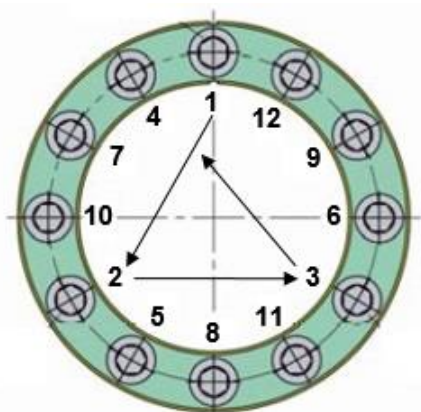
The radial clamping forces press the outer ring into the hub bore and the inner ring onto the shaft and create a frictional connection at the respective contact surfaces. In this way, torque and/or axial force can be transmitted between the shaft and the hub.

For dismantling, the clamping screws should be released and turning some of the clamping screws into the threaded bores for the jacking screws. This presses off the outer ring.



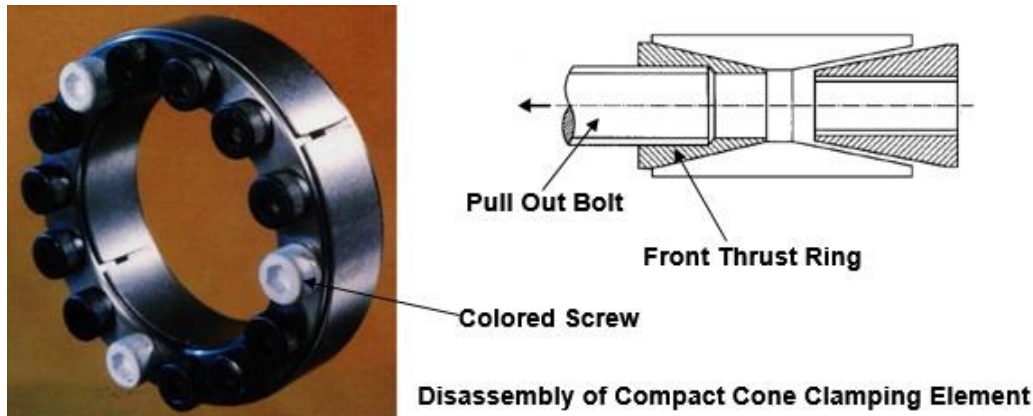
Above figure shows construction of a widely used and popularly called compact (designed) cone clamping element. Tightening screws of the compact cone clamping element causes increase in its outer radius and decrease in inner radius (by pushing the outer and inner rings apart). Thus, it creates strong friction grip on shaft and hub to transmit force. It may be noted that for transmission of high torques and axial loads, several compact cone clamping elements can be used in series in an assembly. In such case, transmissible torques and axial loads are added but addition is reduced based on number of elements (example: for two elements, transmissible torque is approximately 1.8 times that of a single element).

### Installation and Disassembly of Internal Shaft Locking Devices

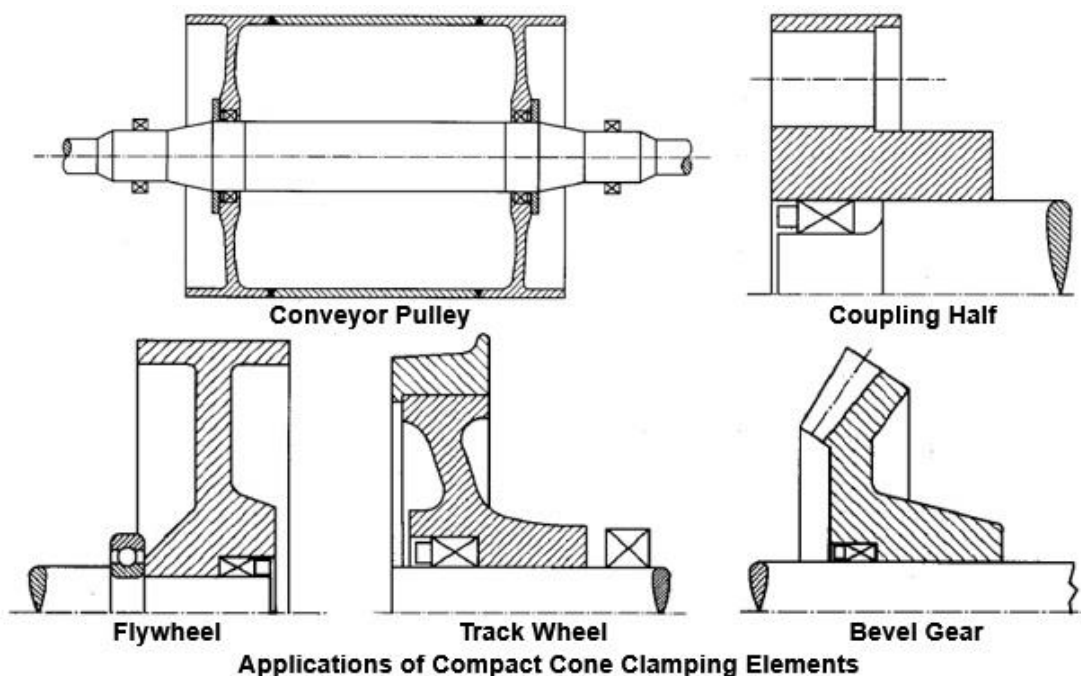


**Tightening of Screws in Diagonal/Star Pattern**

- Clean the shaft and the hub thoroughly to remove all dirt and lightly oil the contact surfaces.
- Lubricate locking devices with oil (Do not use molybdenum-disulfide, MoS<sub>2</sub> or grease).
- Hand tighten the screws until the surfaces are in contact.
- Tighten screws evenly, alternating diagonally/crosswise (star pattern) and in progressive rounds of tightening with a torque wrench to the specified value.
- Verify the tightening torque on all screws in circumferential/circular succession. Installation gets completed when none of the screws yields any further.



For easy of disassembly, removal threads are provided in the front thrust ring. The removal threads have only 3 to 5 threads and are not suitable for high pulling forces. They are to be used only for removal of the thrust ring by means of pull out bolts (bolts having larger diameter than screws). As shown in above figure, for easy of identification, the locations with removal threads are fitted with different colored (zinc plated) screws with washers.

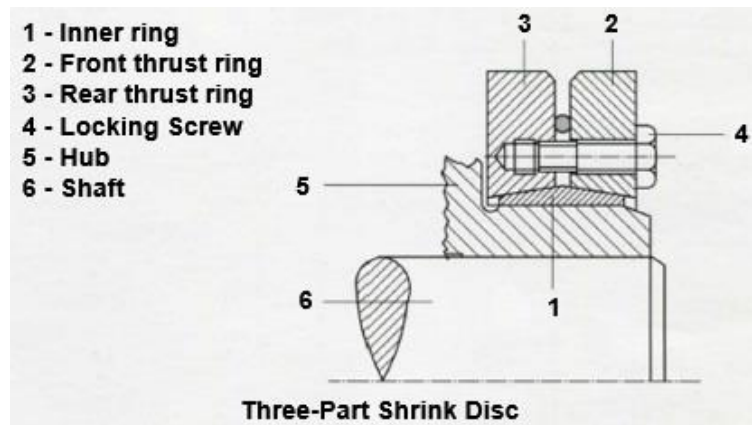


Above figure shows some applications of compact cone clamping elements.

Mounting bearings with keyless shaft locking devices is not recommended because the expansion forces generated will distort the bearing's inner race, causing premature failure.

## External Shaft Locking Devices (Shrink Discs)

**Shrink Discs** are external clamping connections for the backlash free fastening of hubs (or hollow shafts) to shafts. By providing number of locking screws in the connection with lubricants containing MoS<sub>2</sub> on the cones, remarkable torque/force can be transmitted by them. They are made in two design, three-part shrink discs and two-part shrink discs.



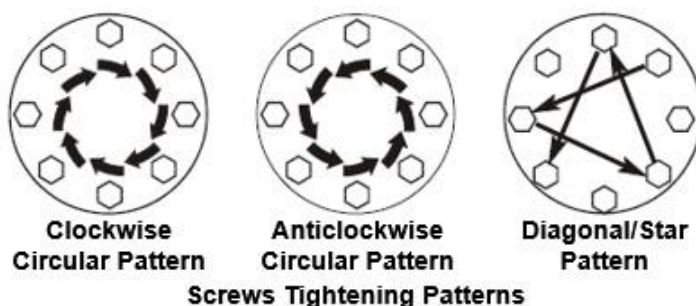
Above figure shows components of a three-part shrink disc (also called double taper shrink disc). It shows connection of a hub with a shaft.

By tightening locking/clamping screws conical surfaces (front thrust ring and rear thrust ring) are pulled together generating radial force over the inner ring. This force presses the hub onto the shaft.

### Installation and Dismantling of Three-Part Shrink Discs

Clean the shaft and the hub bore thoroughly to remove all dirt. Apply a light coat of oil to the hub at the point at which the shrink disc is to be positioned. However, MoS<sub>2</sub> should not be used on this surface. For easy positioning, the surface area between the hub and the solid shaft may be oiled but must be free of lubricant (MoS<sub>2</sub>) or the connection may slip in service.

**Note:** As per some manufacturers, surfaces between the hub and the solid shaft should be solvent cleaned and dry (coefficient of friction,  $\mu = 0.15$ ). Follow manufacturer's recommendation.



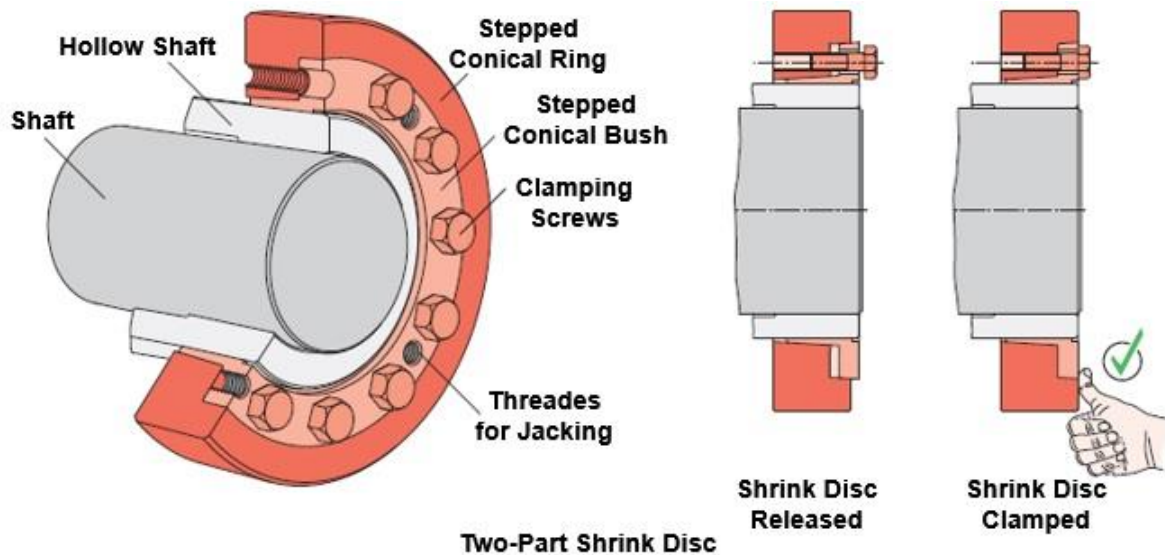
Now install the shrink disc on the hub and tighten locking screws in a diagonal/star pattern by hand (finger tight) whilst aligning the thrust rings to lie parallel to each other.

Next, locking screws should be tightened using a torque wrench in a sequence called circular pattern, that is, in clockwise or anticlockwise direction (NOT in a diametrically opposite sequence, called diagonal/cross/star pattern). The locking screws have to be



tightened in two, three or more stages up to the specified tightening torque. Never tighten locking screws in a diagonal/star pattern or the connection may slip in service.

For dismantling, the locking screws should be released in clockwise or anticlockwise direction in several stages to avoid tilting of the thrust rings. Under no circumstances the locking screws should be taken out of the threads because due to pretensioning, the shrink disc could jump apart.



Two types of two-part shrink discs (also called single taper shrink discs) manufactured are: distance-controlled shrink discs and torque-controlled shrink discs.

Above figure shows a two-part distance-controlled shrink disc assembly. It consists of an outer stepped conical ring, an inner stepped conical bush and number of clamping/locking screws. A radial clamping force is generated by the conical surfaces which is independent of the friction coefficients at the screws and conical surfaces when the clamping screws are tightened without a torque wrench till assembly state is reached. Ringspann GmbH (Shrink Discs RLK 606 and Shrink Discs RLK 608) and Fenner Drives (Shrink Discs SD40) manufactures two-part distance-controlled shrink discs.

For installation of a distance-controlled shrink disc, the clamping screws are tightened uniformly in a circular pattern, that is, in clockwise or anticlockwise direction until the front face of the stepped conical ring is flush with the front face of the stepped conical bush. The clamping screws should be tightened in number of stages. Once this assembly state is reached, the rated torque or axial force values can be reliably transmitted between the hollow shaft (hub) and the shaft.

The connection is released by tightening clamping screws in the threaded bores for the jacking screws.

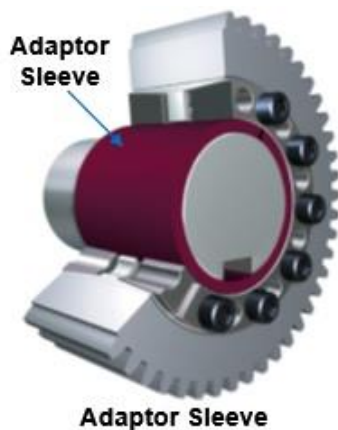
Many suppliers (e.g. Ringfeder Power Transmission, GmbH) are manufacturing two-part torque-controlled shrink discs. Their construction and working is similar to the two-part distance-controlled shrink disc shown above. However, for their installation, the clamping screws are tightened to the specified torque. For their installation, follow the installation instructions given for the three-part shrink discs. For dismantling, the clamping screws should be released in clockwise or anticlockwise direction in several stages to avoid tilting of the thrust rings.

## Attention

Never tighten shrink disk before the shaft is mounted, as otherwise a plastic deformation of the hub (hollow shaft) could result.

Shrink discs (three-part type as well as two-part type) are delivered with MoS<sub>2</sub> grease/paste, resulting in coefficient of friction,  $\mu \approx 0.05$  (e.g. Molykote G Rapid by Dow Corning, Gleitmo 100 by Fuchs Lubritech GmbH, etc) between the tapered surfaces of the inner segment and outer segment. While MoS<sub>2</sub> grease/paste is also applied on the threads and under the head of the screws by some manufacturers, some are applying commercially available bolt lubricants (multipurpose grease) resulting in coefficient of friction,  $\mu = 0.1$ . MoS<sub>2</sub> grease/paste must not be removed. Proper installation is not possible without this MoS<sub>2</sub> grease/paste. It may be noted that insufficient or missing lubrication between the conical surfaces as might happen during maintenance/servicing will make the two-part distance-controlled shrink disc assembly procedure impossible to complete whereas two-part type or three-part type torque-controlled shrink disc assemblies may fail to transmit the rated torque.

## Adaptor Sleeves



When an existing shaft diameter does not fit the bore of a standard shaft locking device, it is recommended to use an adapter sleeve that can be sized to allow for the use of a standard shaft locking device and the existing shaft. The maximum wall thickness of the adapter sleeve should be approximately 10% of the existing shaft diameter.

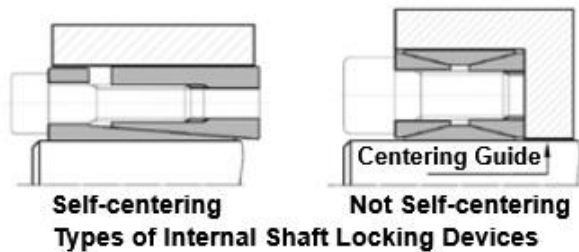
In order to maximize the torque capacity of a sleeved keyless connection, the shaft/sleeve bore interface must be free of any lubricant. This makes the sleeve outside diameter/keyless locking device bore the point of lowest torque capacity and allows for full use of the larger keyless locking device's higher torque capacity.

### Notes:

- Tolerance on Sleeve OD = Sleeve Diameter + 0" / - 0.002"
- Sleeve ID = Shaft Diameter - 0 / +0.001" (0.025mm)
- Sleeve to be manufactured with one lengthwise slit (after machining) and from material equal to or better than shaft material.
- Install dry (cleaned with non-petroleum-based solvent) at shaft/sleeve bore interface for coefficient of friction  $\mu = 0.15$ .
- Sleeve can be installed over existing keyway; position slit approximately opposite to the keyway.

## Design Considerations (Technical Requirements)

Internal shaft locking devices (cone clamping elements) are placed between shaft and hub and result in a friction-locked connection between locking device and shaft and between locking device and hub.



As shown in above figure, there are two types of internal shaft locking devices: self-centering and not self-centering. In case of self-centering type devices, shaft and hub are getting centered in relation to each other by means of the locking device itself and additional centering of the hub is not necessary. However, in case of not self-centering type, for accurate centering, centering guide/hub between shaft and hub is necessary.

When internal shaft locking devices are mounted, a friction-locked connection is established by means of surface pressure. As a rule, the surface pressure on a solid shaft ( $P_w$ ) is non-critical as it acts on the shaft. However, as the surface pressure is exerted against the hub ( $P_N$ ), the hub must be checked to make sure that it has a minimum diameter. The minimum hub diameter basically depends on length of the hub, hub construction (with or without centering guide) and the hub material. For calculation of the minimum hub diameter, the same formula is used as for a thick hollow cylinder.

External shaft locking devices (shrink discs) are placed on hub/hollow shaft and friction locking takes place between shaft and hub/hollow shaft. Since external shaft locking devices (shrink discs) are placed on hub/hollow shaft, surface pressure is not critical because it acts on the shaft and hub/hollow shaft. As specifications limit the size of the shaft diameter recommended for use with each shrink disc, the hub wall thickness for shrink disc applications is nominally the difference between the shrink disc inside diameter and the shaft diameter.

For more information on selection of a keyless shaft locking devices and design detail, please refer manufacturer's literature (references given at end of this article).

Locking devices can be installed over existing empty keyways. However, it is recommended that the locking devices should be rotated to position the inner ring radial slits approximately opposite the keyway and a locking screw directly over the keyway.

### Lubricity and Surface Finish

Locking devices carry rated capacities that rely upon both lubricity and surface finish. Follow manufacturer's recommendation. In case information is not available, following may be used.

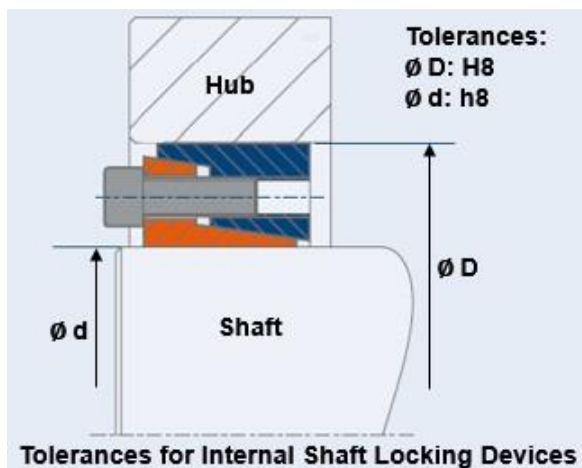
Generally, it is recommended that surface finish for shafts and hub bores should be between 64 and 125 micro-inch (1.6 and 3.2 micro-meter) RMS. Usually a machine (lathe) turned finish ( $R_a = 3 \mu\text{m}$  /  $R_z = 13 \mu\text{m}$ ) is sufficient. A smoother finish, such as that found on components supplied TG&P (turned, ground and polished) is NOT recommended and can result in a failure of the connection.

As delivered, locking devices are supplied with lubricant, ready for installation. Generally internal shaft locking devices (cone clamping elements) are supplied with light oil (ordinary machine oil / mineral oil) to provide the necessary coefficient of friction ( $\mu = 0.12$ ) to the sliding surfaces and on all locking screws. External shaft locking devices (shrink discs) are supplied with Molybdenum Disulphide based lubricant ( $\text{MoS}_2$  grease/paste) applied to the tapers and to the locking screw threads and head contact areas.

## Machining Tolerances

Ensure that the shaft and the housing bore sizes are within the catalogue specified tolerances because the transmissible torques listed in the catalogue are subject to the specified tolerances. If the actual fit between shaft and hub is tighter, then the transmissible torque consequently increases. On the other hand, the transmissible torque decreases if the actual fit is looser than that given in the catalogue. Mating shaft tolerances are normally tighter (h6 / g6) for shrink discs due to the gripping forces needed. In case tolerances are not available, following values for the maximum permissible tolerances may be used.

### Internal Shaft Locking Devices (Cone Clamping Elements):

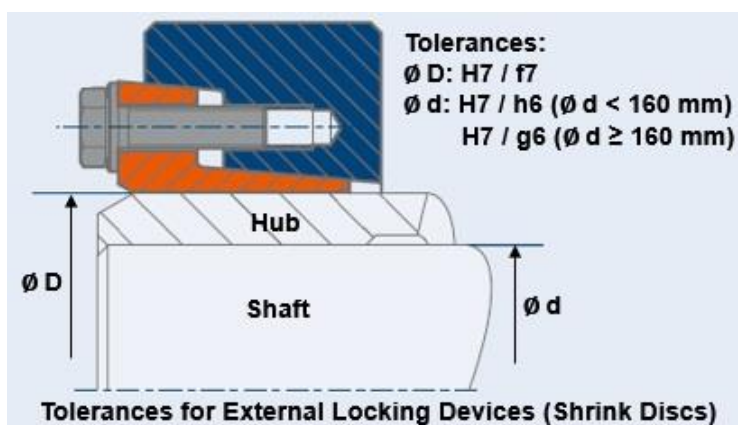


Tolerances:

Cone Clamping Elements - H8 for the hub and h8 for the shaft

Compact Cone Clamping Elements - Preferred H8 / h8 (Maximum up to H11 / h11)

### External Shaft Locking Devices (Shrink Discs):



Tolerances:

At  $\varnothing D$  (hub and shrink disc interface): H7 / f7 (f7 for hub outside diameter)

At  $\varnothing d$  (shaft and hub interface): H7 / h6 (for  $\varnothing d < 160$  mm) and H7 / g6 (for  $\varnothing d \geq 160$  mm)

Some manufacturers also recommend the following tolerances.

At  $\varnothing D$  (hub and shrink disc interface): h8 for hub outside diameter

At  $\varnothing d$  (shaft and hub interface): H6/j6 (for  $\varnothing d$ , 10 to 30 mm), H6/h6 (for  $\varnothing d$ , 30 to 50 mm), H6/g6 (for  $\varnothing d$ , 50 to 80 mm), and H7/g6 (for  $\varnothing d$ , 80 to 500 mm).

## **Servicing/Maintenance**

Internal as well as external shaft locking devices are maintenance-free. However, signs of settling may appear in connections during operation. It is therefore recommended to check the tightness of the clamping screws each time maintenance is performed on the machine.

Undamaged locking assemblies can be reused. Inspect locking screws. Replace missing or damaged locking screws with screw of quality grade (e.g. 12.9, 10.9) as per drawing/catalogue only. One of the leading manufacturer of locking devices recommends that the screws must be changed after each use!

Insufficient or missing lubrication of the conical surfaces as might happen during servicing, results in a reduction of the radial clamping force. Due to this, the torques or axial forces listed in the catalogue can no longer be transmitted reliably. This often goes unnoticed as the specified tightening torque was achieved during assembly and the assembly procedure is considered completed. In view of this, ensure that the conical surfaces of the locking devices and locking/clamping screws are lubricated as per manufacturers recommendations.

For tightening of clamping/locking screws, use calibrated torque wrench only because a faulty torque wrench may result in under/over tightening.

## **References**

Shaft-Hub-Connections by Ringspann GmbH ([www.ringspann.com](http://www.ringspann.com)).

RINGFEDER® Locking Assemblies by Ringfeder Power Transmission ([www.ringfeder.com](http://www.ringfeder.com)).

Shaft-to-Hub-Connection by BIKON-Technik GmbH ([www.bikon.com](http://www.bikon.com)).

Product Catalog by Fenner Drives ([www.fennerdrives.com](http://www.fennerdrives.com)).

Shaft Locking Devices by Lovejoy Coupling Solutions ([www.lovejoy-inc.com](http://www.lovejoy-inc.com)).

SKF FX Keyless Bushings (PUB PT/P1 10114 EN • May 2010) by SKF ([www.skf.com](http://www.skf.com)).

Frictional Connections Catalogue by STÜWE® GmbH & Co. KG ([www.stuewe.de](http://www.stuewe.de)).

Locking Assemblies  Shrink Discs  Keyless Rigid Couplings by Climax Metal Products Company ([www.climaxmetal.com](http://www.climaxmetal.com)).

Mechanical clamping elements by Lenze Selection ([www.lenze-selection.com](http://www.lenze-selection.com)).

Power-Lock® by Tsubaki ([www.ustsubaki.com](http://www.ustsubaki.com)).