

Clamping Systems for Torque Motors

Connecting torque motors with cylindrical or hollow shafts

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Summary

Torque motors are rotation angle controlled, permanent magnet excited synchronous servomotors with large numbers of magnetic pole pairs which produce correspondingly high torques in the lower rpm range (0 – approx. 250 rpm, depending on the number of pole pairs). Thanks to modern high performance electronics, torque motors, as direct drive motors, are capable of meeting such system requirements as high repetition and control accuracy, low energy consumption, low noise levels, high dynamics, ease of maintenance and reduced space requirements. Users can benefit from all of the advantages of torque motors only if the connection between the torque motor and the machine shaft is properly effected. Friction shaft hub couplings play a significant role in this context. In close cooperation with SIEMENS, RINGSPANN has developed clamping systems that meet both the special requirement of torque motors and those of machine shafts, which are often designed as hollow shafts. Alternative solutions for friction connections between torque motors and machine shafts are discussed in this paper, important aspects of relevance to the selection of such clamping systems for special applications will also be addressed.

1. Introduction

Modern drive technology benefits significantly from the possibilities offered by high performance electronics for guidance and control of electric drive systems. All of the advantages gained by the user, such as the use of high dynamic direct drives (with low mass inertia) also pose new requirements for shaft hub connections. In addition to reliable, play-free torque transmission, it is also important to ensure that sufficient consideration is given to stress factors to which motor components and machine shafts are exposed. Depending upon the specific application, a number of different engineering solutions are possible. The purpose of this paper is to illustrate the various possibilities available for achieving friction connections between torque motors and cylindrical shafts.

2. Torque motors

With the aid of modern high performance electronics, the long familiar concept of permanent magnet excited synchronous electric motors with large magnetic pole pair numbers has been augmented by incorporating characteristics that make it possible to use torque motors in applications that depend upon high rigidity, avoidance of torsional play, a minimum of mechanical components and a short, compact form.

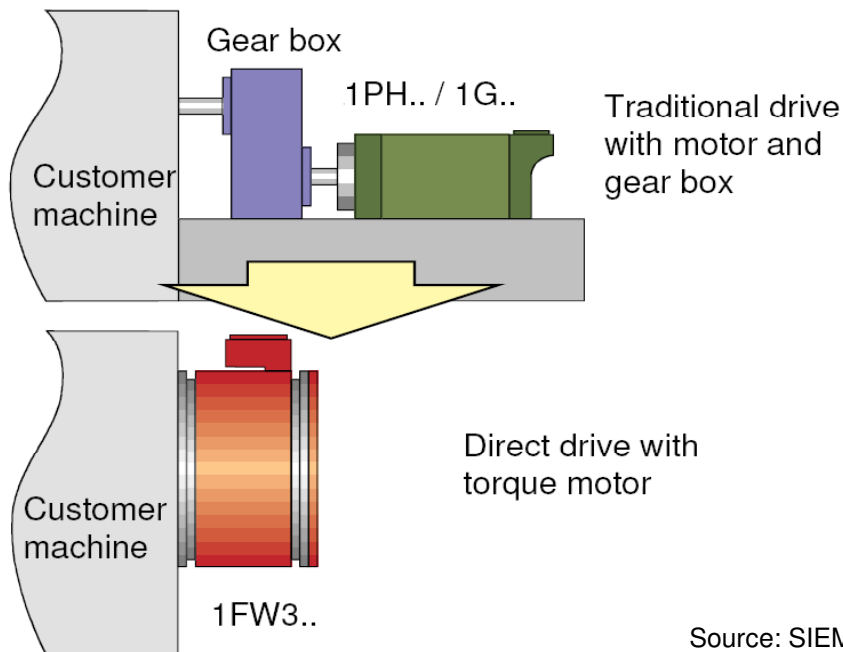


Fig 1: The development of direct drive technology

The benefits to users of direct drive technology with torque motors include the simple integration of the drive into the machine, ease of maintenance, good overall efficiency, very good repetition accuracy and controllability, high dynamics and, last but not least, low noise emissions.

There are two basic types of torque motors, known as “complete torque motors” and “built-in torque motors”.

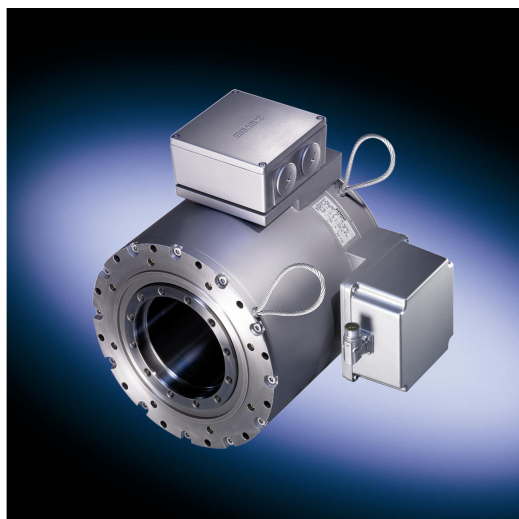


Fig. 2: Complete torque motor

Sources:
SIEMENS AG

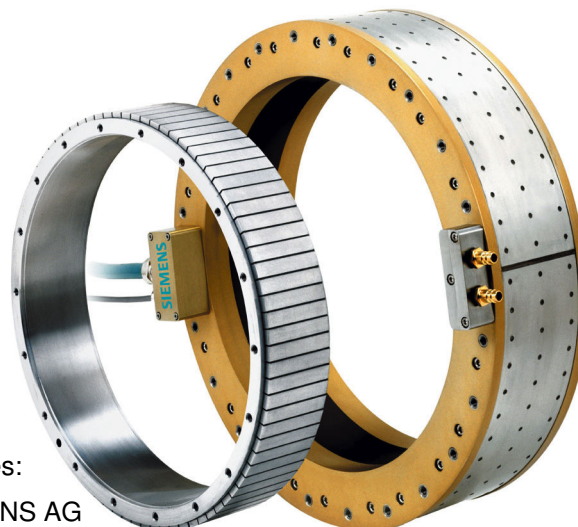


Fig. 3: Built-in torque motor

Complete torque motors manufactured by SIEMENS have hollow bored rotors which are fully bearing mounted and sealed and thus optimized for use in production machines. These motors are available with a range of different shaft highth. Motor sizes within each shaft highth group differ with respect to motor length.

Built-in torque motors consist of a stator and a rotor. Bearings and seals are part of the machine in which the stator and rotor are integrated. Internal torque motors are optimized for use in machine tools but are also found in production machines.

Among other applications, torque motors are used in multiple drive systems when it is important to ensure a high degree of synchronization between the individual drives. This was once possible only with the aid of complex mechanical solutions. Today, each driven shaft is attached to a torque motor. With the aid of high performance electronics, all drives can be perfectly synchronized or deliberately set to run asynchronously without difficulty. Torque motors are also used in applications in which individual drives require highly dynamic control and play free operation.

Other applications include those in which low noise emissions (sound pressure level <70dBA) and high overall efficiency are required.

Frequently encountered applications include foil drawing machines, wire drawing machines, paper machines, plastic injection moulding machines, extruders, etc.

3. Possible approaches to the installation of complete torque motors

Complete torque motors can be connected to a machine via the stator housing. In this case, the rotor shaft must be connected to the machine shaft by a self-aligning coupling.

Alternatively, it is also possible to connect the rotor shaft rigidly to the motor shaft. In this case, a torque arm prevents the torque motor housing from rotating with the shafts.

This type of connection is used whenever a very rigid connection between the rotor and the machine shaft is needed or when the machine shaft passes through the hollow bore rotor shaft and the torque motor “sits on the shaft”. This mounting solution is particularly appropriate whenever media is to be conveyed through a hollow-bored machine shaft. One example of this type of application is a system in which rollers in a foil production machine must be heated. In these foil drawing machines, several rollers arranged in sequence are heated by a medium and driven synchronously with the aid of torque motors. The hollow bore rotor shaft is connected by friction to the hollow bore machine shaft with the aid of a RINSPANN clamping systems.



Fig. 4: RINGSPANN clamping system RTM607

Another type of rigid connection involves the design of the machine shaft as a flange shaft, i.e. a shaft with a flange forged to one end which matches the connection pattern of the face of the rotor of the torque motor. Like the mounting option with the clamping system, this solution offers the advantage of a rigid connection, but also has certain disadvantages, such as very high shaft manufacturing costs and problems with service when machine bearings or seals require replacement. Replacement of these parts in systems with flange shafts ordinarily require time consuming disassembly and reassembly of the machine. Service

personnel can ordinarily replace bearings and seals much easier in systems with cylindrical shafts and releasable connections to the torque motor.

4. Possible approaches to the installation of Built-in torque motors

Built-in torque motors were originally conceived for use in machine tools, in which the stator and rotor are fully integrated into the machine system.

Today, however, internal torque motors are also used in production machines, most notably in cases in which high torques and the control characteristics of torque motors are required but minimum axial space is available. Because internal torque motors are not equipped with bearings, the clamping system must ensure both torque transmission and precise centering of the rotor, since bearing support for the rotor must be provided by the machine.

Internal torque motor control requires identification of each rotor position. As a rule, this is accomplished with the aid of a transducer ring and a sensor. The transducer ring can be affixed to the clamping system. The clamping system for built-in torque motors must ensure very precise concentricity between the machine shaft supported by the machine bearings and the centering devices for both the rotor and the transducer ring.

5. RINGSPANN clamping systems for torque motors

RINGSPANN GmbH is a prominent supplier of shaft hub connections with a high level of consulting expertise. Standard clamping elements are not suitable for applications in which complete torque motors are used in combination with thin walled hollow bored machine shafts, due to the maximum surface pressure limits on the hollow bore machine shaft and the load capacity limits of the hollow bored rotor shaft. It is also essential to ensure that, in addition to torque transmission, the shaft hub connection also ensures wobble free operation of the torque motor. In close cooperation with SIEMENS and other users of torque motors, RINGSPANN has developed a number of different types of clamping systems for torque motors, which are described in the following sections.

5.1. Clamping system for complete torque motors on hollow bore machine shafts

RINGSPANN presented the RTM 607 clamping system at the Hanover Trade Fair in 2005 (see Figs. 4 and 5).

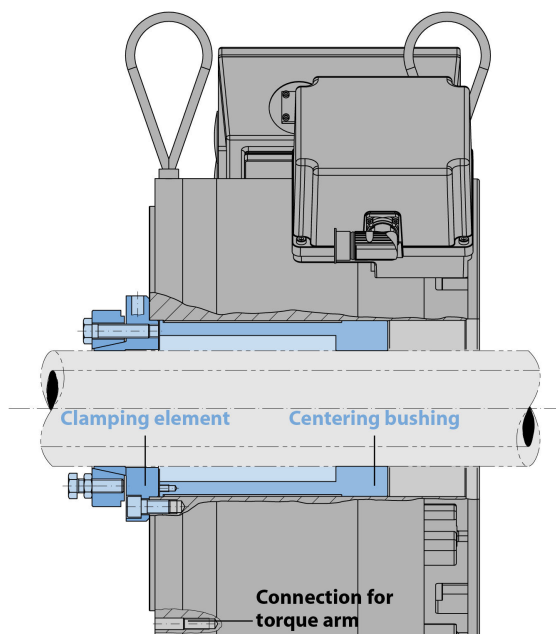


Fig. 5: RINGSPANN RTM 607 clamping system with SIEMENS torque motor

This clamping system consists of a clamping element, which performs the two functions of torque transmission and centering, combined with a centering bushing which supports the centering function.

5.1.1 Clamping element

The clamping element is designed in such a way that the friction connection to the hollow bore machine shaft generates pressures which are high enough to transmit the required torque reliably but not too high for the thin walled hollow shafts. An especially important factor when using such a device is the tangential tension on the inside circumference of the hollow machine shaft.

The inner tapered ring of the clamping element has multiple slots. These slots help to bridge the fitting play between shaft and clamping element and to follow the radial deformation of the hollow machine shaft. Without the slots there would be a risk that an excessively large portion of the radial force generated with the aid of the clamping screws via the taper angle is consumed in order to deform the inner tapered ring of the clamping element.

The part of the clamping element that is in contact with the hollow machine shaft and the torque motor has a nickel plated surface. This reduces the risk of corrosion and “freezing” of the clamping element in moist environments.

In order to ensure minimum possible drive length, it is important to install the torque motors as close as possible to the machine bearing plate. This means that the space between the clamping element and the bearing plate may be too small to allow for mounting of the press off screws in the pressure ring of the clamping element. For this reason, the press off screws are already in place, secured with nuts.

5.1.2 Centering bushing

The centering bushing is a one part unit but consists of two “functional segments”, the actual “centering ring” between the hollow machine shaft and the rotor of the torque motor and the “spacer bushing with collar”. The “centering ring” supports the torque motor on the shaft; the “spacer ring with collar” ensures axial fixing. The collar is fixed in place between the hollow rotor shaft and the clamping element.

The centering bushing is made of aluminium, which rules out the possibility of fretting corrosion. The differing degrees of heat expansion in the hollow machine shaft and the hollow rotor shaft of the torque motor cause axial slippage which can lead to fretting corrosion wherever steel is in contact with steel.

The length of the centering bushing depends on the length of the torque motor. The “centering ring” should always be positioned on the far side of the center of gravity of the torque motor (viewed from the clamping element). However, centering bushings of the same length can be used for 2 or 3 motors of a given series.

Torque motors may overheat in applications in which media with very high temperatures (e.g. 160°C) are conveyed through the hollow machine shaft. RINGSPANN has developed the RTM clamping system with thermal insulation for use in such cases (Fig. 6).

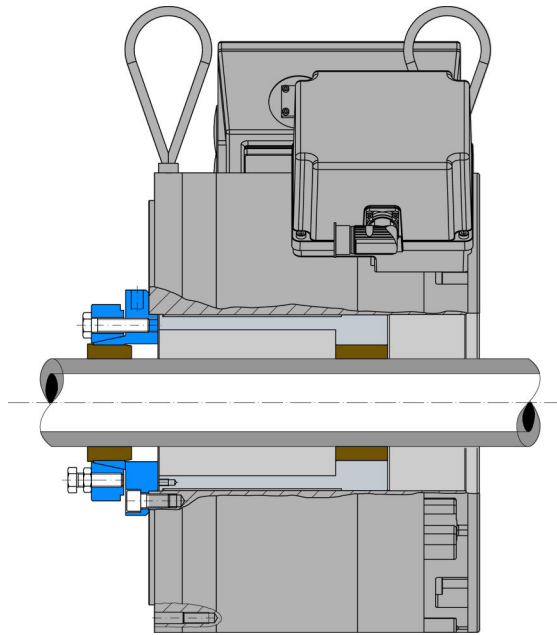


Fig. 6: RTM 607 clamping system with thermal insulation

The idea of the configuration shown in Fig. 6 is that thermal insulation is placed between the “hot hollow shaft” and the clamping system in order to prevent the transmission of heat to the torque motor. The system uses slotted insulation sleeves made of fibreglass reinforced epoxy resin. This material has a heat conduction rating of $0.25 \text{ W}/(\text{mK})$ as compared to $50 \text{ W}/(\text{mK})$ in non-alloyed steel.

When designing this special clamping system it is important to know that the insulating sleeves have a relatively low E-modulus ($24,000 \text{ N}/\text{mm}^2$), which means that the clamping element must be capable of covering a relatively large radial clamping distance. It is also to take into account the fact that hollow shafts heated to 160°C will increase in diameter from installation condition at 20°C . This expansion is hindered by the clamping element, however, which in turn leads to an increase in component tension. It is important to ensure in this connection, that no excessive plastic deformation occurs. Plastic deformation may reduce joint pressure following cooling of the hollow shaft to the point that is no longer sufficient to transmit torque.

The material used for the insulating sleeves can also be used for electrical insulation. The insulation resistance rating (after being in contact with water) is $10^{12} \Omega$.

5.1.3 Further development of the centering bushing

The version of the centering bushing described in Section 5.1.2 has proven itself in many different applications. It has also become evident, however, that installation of the long centering bushing, especially in systems with very long torque motors, is not always easy to perform, as the centering bushings must be pushed through the entire length of the bore of the hollow rotor shaft. In some cases, installation was possible only when additional force was applied, which posed the risk of damage to the relatively soft aluminium surface. Users also expressed the need for further minimization of non drive end radial runout, especially in systems with very long torque motors.

The modified form of the centering bushing is illustrated in Fig. 7.

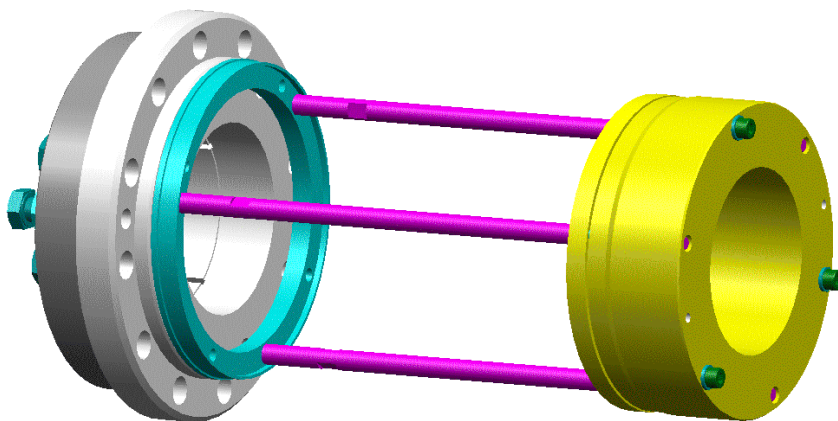


Fig. 7: RTM 607 clamping system with modified centering bushing

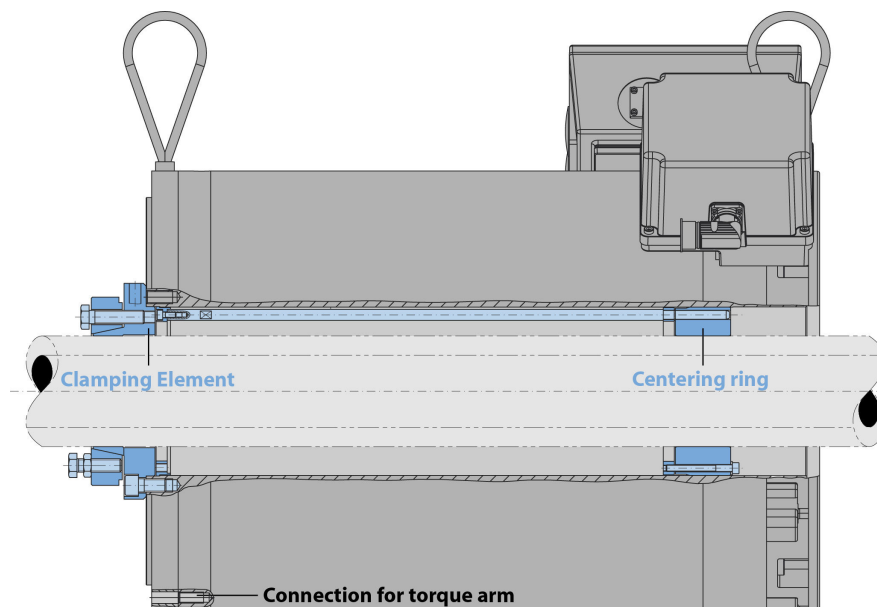


Fig. 8: Modified RTM 607 clamping system installed in a long torque motor

The basic function did not change. Modifications affected only installation and the installation position of the centering ring.

Two options are now available for installation. Either the entire unit is installed in the torque motor as before or the unit is initially installed in the torque motor without the “centering ring”: The three spacer rods on the one side are centered through the “ring with collar” and on the other through a “pre-centering ring”. The centering ring can then be inserted into the bore of the rotor from the non drive end of the torque motor at the pointed ends of the spacer rods. The “centering ring” is then fixed in place with three screws.

With respect to the installation position of the centering ring, the optimum position of the second support point for every torque motor in immediate proximity to the non drive end torque motor bearing is achieved with the aid of spacer rods of different lengths without significant added cost. This method makes it possible to minimize possible slant in the position of the torque motor relative to the shaft, which also results in the desired minimization of non drive end radial runout.

The “centering ring” is made of aluminium; due to strength and cost considerations, the other components are made of steel.

5.2. Clamping system for complete torque motors on machine shaft ends

In applications in which there is no need to run the machine shaft through the entire torque motor, the shaft end is designed as a solid shaft and should be as short as possible (to reduce costs).

RINGSPANN has developed the RTM 608 clamping system for these applications.

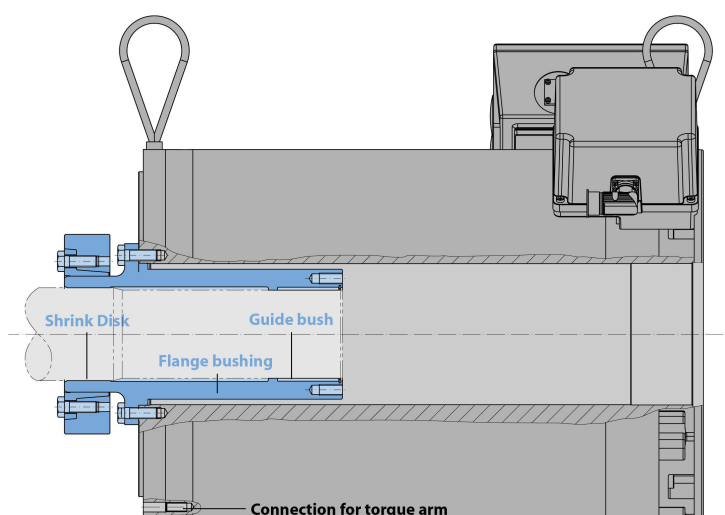


Fig. 9: RTM 608 clamping system with slide bushing

In contrast to the RTM 607 clamping system, the torque motor is centered “flying” on the clamping system (without centering ring). The RTM 608 clamping system creates an installation configuration for the torque motor similar to installation on a flange shaft. The advantage as compared to the flange shaft is that the shaft end exposed after removal of the RTM 608 clamping system is cylindrical, meaning that machine seals and bearings can be replaced without difficulty.

The RTM 608 clamping system has two functional segments in the area of contact with the machine shaft.

Torque transmission is effected with the aid of a two part RLK 608 shrink disc. The two parts of the RLK 608 shrink disc are attached flush without a torque wrench during installation. This offers several advantages, one of which is a high degree of concentricity between the machine shaft and the rotor of the torque motor.

The second support point is designed with a slide bushing (see Fig. 9), which prevents fretting corrosion formation resulting from micro-slippage.

As a rule, the RTM 608 clamping system offers a high level of reliability with respect to transmissible torque relative to the maximum drive torque of torque motors and thus can be used even in very rough applications with high dynamic load factors.

In systems with very short shaft ends with relatively small diameters, the second support point can be designed with a cone clamping element (see Fig. 10).

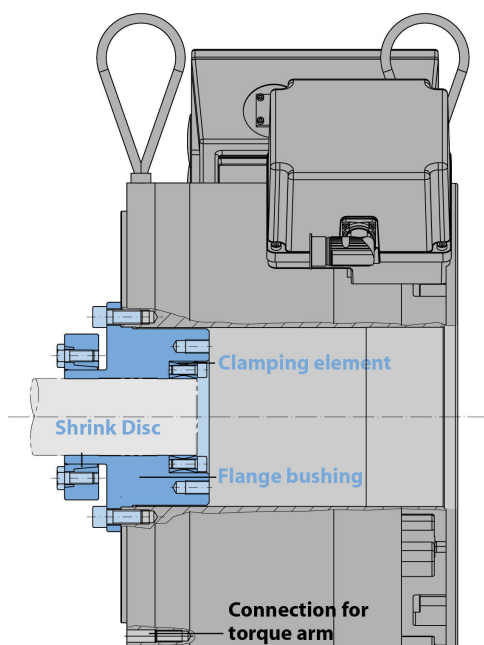


Fig. 10: RTM 608 with cone clamping element

In this case, however, it is important to ensure that excessive heat is not generated in the application.

This solution is used effectively in applications in which existing systems are retro fitted with torque motors, for example. Keyway grooves in existing shaft ends should be filled with a “filler element”.

5.3. Internal clamping systems for complete torque motors

The RTM 607 and RTM 608 clamping systems are technically preferable clamping systems for friction connections of torque motors in machines. However, these solutions cannot be realized in some applications due to constructive restrictions. RINGSPANN has developed the RTM 134 clamping system for such cases (see Fig. 11).

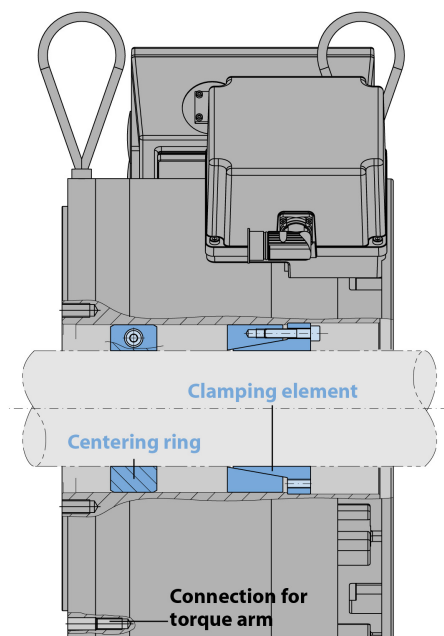


Fig. 11: RTM 134 internal clamping system for low and moderate torques

In this application, torque transmission is effected via clamping elements developed specifically to meet the requirements of torque motors. The thin walled hollow rotor shaft of the torque motor permits only minimal contact pressure, which means that standard clamping elements cannot be used, as an excessive deformation of the hollow rotor shaft is virtually unavoidable. Ordinarily, a flat taper angle is used for internal clamping elements with a conical segment in order to transform the screw forces into high radial forces. Flat taper angles (e.g. 4°) exhibit a “self locking” tendency and thus must often be released with the aid of press off screws for removal. Variations in friction coefficients in cone joints with flat taper

angles also exert a stronger influence on the tolerance of the generated radial forces than those with steeper taper angles.

The additional influence of friction coefficient variations on screw forces in the contact area of the clamping screws when clamping screws are tightened with a torque wrench are discussed in [1].

Thus in the selection the clamping element for the RTM 134 internal clamping system, a relatively steep taper angle was chosen in order to keep the influence of the entire range of friction coefficient variations to a minimum and ensure easy release during disassembly. The supposed disadvantage of a lower translation ratio is actually an advantage in this application, as restriction to low contact pressures makes it unnecessary to rely on excessively small screws. Small screw sizes pose the risk of screw breakage during installation.

The bore of the hollow torque motor shaft is designed with a recess, the axial contact creates a form fitting connection between the flange on the inner ring of the clamping element and the hollow shaft of the torque motor. Consequently, axial movement of the torque motor relative to the machine shaft during the process of tightening the clamping screws is avoided. The additional friction loss between the outer tapered ring and the hollow shaft must be taken into account in calculating contact pressure and transmissible torque.

The pitch circle of the screws and the maximum permissible machine shaft diameter were selected so as to ensure that the screws can be tightened with standard tools.

A slotted centering ring made of aluminium is clamped to the shaft with a clamping screw as a second bearing point.

Fig. 12 shows the version equipped with a second clamping element for long torque motors with correspondingly high torques.

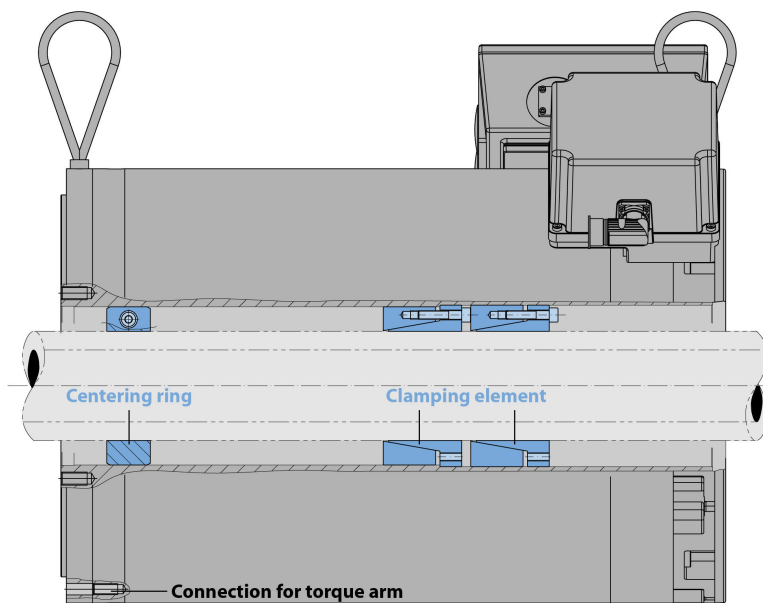


Fig. 12: RTM 134 internal clamping system for high torques

The second clamping element differs from the first in that the outside diameter of the outer clamping ring is larger in order to fit the larger bore diameter on the far side of the recess in the bore of the hollow rotor shaft.

5.4. Clamping system for Built-in torque motors

Fig. 13 shows a clamping system for an internal torque motor.

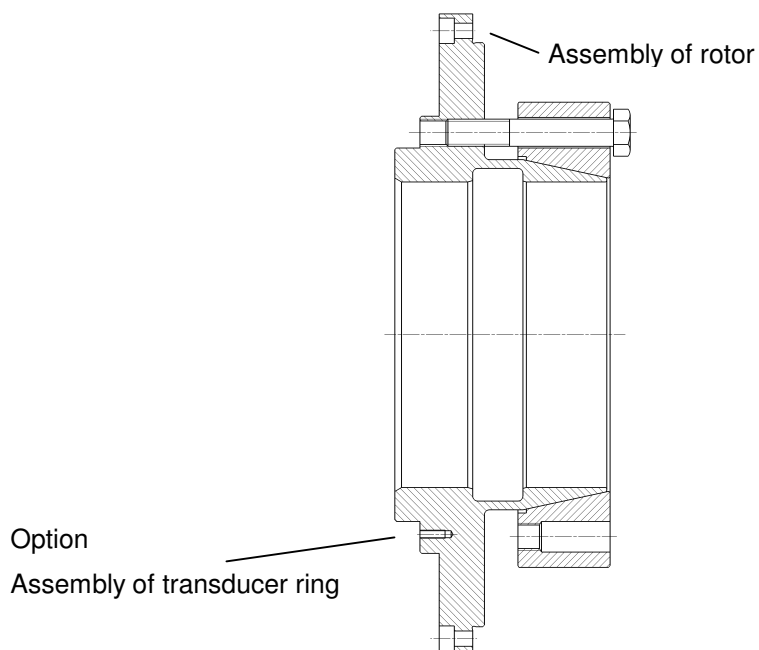


Fig. 13: RLK 607 clamping element for built-in torque motors

This RLK 607 clamping system transmits the torque generated in the gap between the stator and the rotor to the machine shaft with dependability. The length of the cylindrical bore of the tapered bushing ensures that pressure between the clamping system and the machine shaft is not too high, thereby avoiding excessive deformation of the hollow machine shaft. The total length of the clamping system and the permissible component deviations in the clamping system are designed in such a way that the required concentricity between the rotor and the stator of the internal torque motor is ensured.

A second option provides for the possibility of integrating a transducer ring for torque and rotor position monitoring as an add-on component to the clamping system. However, this option should be chosen only when it is possible to ensure that the sensor (which must be mounted in a stationary position) and the transducer ring are held in the same axial position relative to each other. This may be difficult to ensure in situations in which the shaft expands significantly under the influence of heat. In this case, it is important to determine how far the clamping system with the transducer ring can actually move away from the sensor when the shaft is heated.

In order to minimize the risk of corrosion, the surfaces of the clamping system in contact with the rotor and the shaft are nickel plated.

6. Summary and outlook

RINGSPANN offers users of torque motors a solution for the friction connection of torque motors to machine shafts for all conceivable applications. RINGSPANN has the knowhow required to develop new, customized solutions for even the most challenging applications, thanks to over 60 years of experience in the field of clamping technology.

As in other areas of mechanical and systems engineering, releasable friction tight shaft hub connections will play an increasingly more important role in applications with torque motors due to the advantages they offer, which include play free operation and easy releasability.

7. Literature

[1] MOKA, TH., MAURER, R., "Beitrag zur Berechnung von Welle-Nabe-Verbindungen mit Konus-Spannelementen", *VDI Bericht* 1384, 1998, p. 313.