"Keyed Versus Keyless Connection"

by Scott Moulis

Utilizing a key and keyway to fix rotating shafts to power transmission components, such as gears, sprockets, and lever arms is a traditional connection method. Sometimes, a setscrew is used to prevent axial movement during operation. This connection, while relatively simple and reliable when transmitting smooth, consistent power, proves to be inadequate when vibratory, shock, or reversing loads are present. The setscrews used to lock the shaft in a bore can damage the shaft.

Many engineers have turned to keyless connections to handle applications with inconsistent power. Keyless locking devices are the preferred choice in Europe. Keyless connections rely on a clamping force to hold a shaft in a bore. With the advances in motion control, higher levels of precision and compactness, reduced backlash, smaller shafts and more secure connections have become critical. This paper will compare and contrast keyless and keyed connections.

Advantages of Keyed Connections:

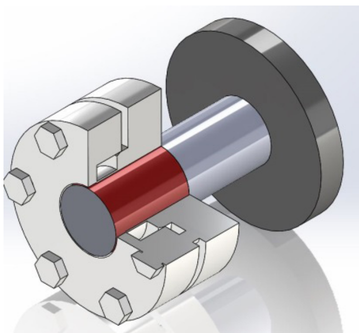
Some of the advantages for utilizing a keyed connection include:

1) A keyed connection will provide a positive stop until failure, whereas a keyless connection could allow slippage between the two mating parts if it is not assembled correctly or the design torque is exceeded.
2) A keyed connection provides a visual that the mating parts are locked in place. A keyless connection could only do so if the two mating parts were inscribed with a timing mark.
3) A keyed connection will allow for more tolerance between the two mating parts. The mating parts for keyless connections must be cleaned and machined to precise tolerances.

Torque Transmission

A keyless connection can transmit more torque than a keyed shaft due to more shaft surface contact. Figures 1 and 2 compare the contact area of a shrink fit connection to a keyed connection.

Figure 1
Keyless



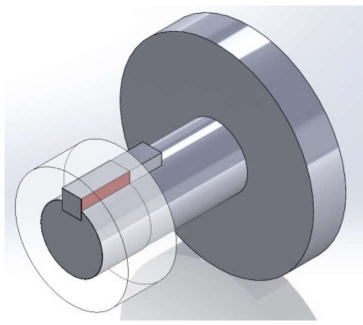


Figure 2
Keyed

The following calculations determine the maximum torque that can be transmitted through both keyed and keyless shafts, as well as the maximum transmissible torque. A 19-mm shaft was used. Assume the shaft and key are made of 1045 steel. The key and keyway dimensions were sized according to DIN Standard 6885.

Keyless Shaft

The torque transmitted through a keyless coupling without slipping or damage is:

$T = \pi J/r$.

The polar moment of inertia is: $J = \pi r^4/2$

Pi (π) = 3.14159

r (Shaft radius) = 9.5mm

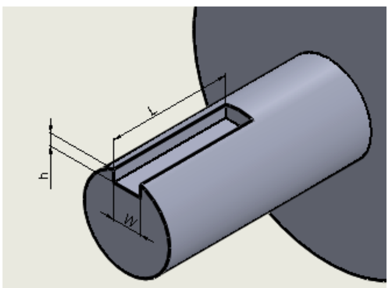
The yield stress for 1045 steel is $380 \times 10^6 N/m^2$

$J = 8.1\ 10^{-9}\ m^4$

$T = (380 \times 10^6)(8.1 \times 10^{-9})/(0.0085) = 362$ Nm

Keyed Shaft

The limiting pressure point of a keyed shaft is the keyway side of the male shaft, provided the proper key material is selected.



The maximum allowable torque a keyed shaft can transmit is:

$T = \pi dLh/2$

L, the effective length of the keyway = 25 mm

d, the shaft diameter = 19 mm for the keyed shaft

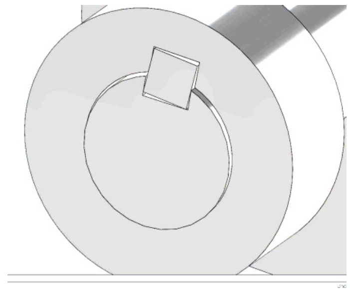
h, the keyway depth = 3 mm

$T = (380 \times 10^6)\ (0.019)\ (0.025)\ (0.003)/2 = 270$ Nm

Thus, 270 Nm is the maximum torque that can be transmitted before the 19 mm diameter keyed shaft plastically deforms.

Backlash

Keyed connections subjected to extreme operating environments will deform over time. The deformation occurs with reversing loads or cyclic loads as the drive element rotates the shaft through the clearance between key and keyway and stops abruptly upon contacting the key.



The illustration above shows how the key reacts in the keyway when torque is applied. This is referred to as “backlash.” Backlash is unacceptable in applications where indexing and positioning accuracy is critical.

The following example shows the amount of backlash expected for a 19 mm diameter shaft.

A 19 mm diameter shaft has a standard key of 6 mm. According to ISO JS9 for a parallel key with normal fit, the tolerance for a 6-mm-wide keyway is ±0.015 mm. Key tolerance per DIN 6885 is +0.05/-0.00. Thus, clearance between the shaft keyway, key and coupling bore is up to 0.03 mm.

$$\text{Backlash} = \frac{(Mc)\times(360°)\times(60\ \text{arcmins/degree})}{(Sd)\pi}\ \text{arcmins}$$

Where: Mc = Max accumulated clearance in mm
Sd = Shaft diameter in mm

Backlash = $0.03 \times 360 \times 60/19\pi$ = 10.9 acrmin

In many cases, this backlash would exceed the backlash of the reducer and more than double the backlash of the system.

Keyed – 10.9 arcmin backlash
Keyless – 0 backlash

Timing

On occasion, two drives must be timed to each other. When using a keyed input, the timing is only adjustable to one revolution of the input divided by the ratio. If a drive reduction is 50:1, an adjustment of 360/50° or 7.2° is the smallest increment allowed. With a keyless connection the adjustment is infinite.

Beware of Fretting Corrosion

The rubbing between shaft and component bore surfaces during slippage leads to fretting corrosion. This is caused by backlash, which over time can cause cold welding of components that ultimately lead to weakened shafts and/or shaft failures. The picture above shows an example of severe fretting and extreme failure.

Ease of Installation

When a motor is mounted to a reducer or a reducer is mounted to a keyed drive shaft, the rotational position must be exact and key must be held in place. In many cases, it is difficult to see the keyway position and hold the position while installing the reducer. A captured key can help with holding the key in place, but the keyways must still be aligned to install the reducer onto the shaft.

When a motor is mounted to a reducer or a reducer mounted to keyless drive shaft, the shaft position is not a concern and the motor or reducer shaft can slide on in any position. Installation becomes much simpler with a keyless drive shaft.

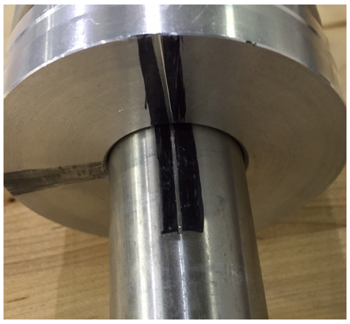
Ease of Removal

With a keyed connection, the looseness between the key and shafts allows for movement. This movement causes friction that can cause fretting corrosion. In extreme cases the fretting will permanently weld the coupling and shaft together, making it impossible to separate the two pieces.

With keyless connections, fretting corrosion is very unlikely to occur. Removal of the gearbox from the motor will be relatively easy.

Conclusion

Both keyed and keyless connections offer advantages when applied in certain applications. Keyed connections provide a visual to verify that slippage does not occur. Inscribing keyless shafts and couplings with a timing mark, as shown below, will show if slippage has occurred and provide a benchmark for future inspections.



Keyless connections are ideal for avoiding fretting corrosion and allow easy installation and removal between a reducer and motor. Keyless connections also provide a zero backlash connection that can transmit more torque than a keyed connection.

Scott Moulis
STOBER Drives, Inc. • Maysville, KY
us.stober.com • 800-711-3588

STÖBER