Alternatives to Keyways in Motion Systems

The age-old tradition of using shaft keys in mechanical drives has served the power transmission industry well for many years. When appropriately sized, it guarantees that virtually no relative motion can take place between a shaft and its respective shaft hub in a unidirectional continuous motion application. Today's increasing demands for speed, precision, and small size have changed the standard for shaft locking devices, and challenged motion components manufacturers to develop new methods of keyless shaft locking for dynamic loading. As motors and drives become increasingly capable of rapid acceleration and rotary positioning accuracy in smaller and smaller packages, backlash, stress distribution, and balance have all needed to be addressed in shaft locking devices, in many cases rendering the shaft key obsolete.



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Backlash

Keyway backlash is the area of primary concern when addressing such performance issues. Precise fitting and complicated machining can serve to reduce the clearance between the key and the shaft or hub keyway, though the backlash can rarely be fully eliminated. As an increasing number of frequent machine starts, stops, and load reversals — all at increasing acceleration and deceleration rates — emerge, keyway wear is increased in terms of both the frequency and force of the impact between the key and keyway. Backlash will also tend to increase at an accelerated pace over time. As material is compressed and removed from the keyway as the result of the impact, the keyway widens, and the velocity at which the key impacts the keyway will be higher at each load change. Under highly dynamic loading or heavy shock and vibration, keyways can wear to the point of problematic backlash or even failure in a very short time. In cases where rotary positioning accuracy is critical, the problems associated with backlash are clear. A delay in angular transmission causes lost motion, which in turn leads to an inaccurately positioned part of the machine. Small amounts of backlash, even when not detrimental to the operation, can still contribute to vibration, chatter, and fatigue in many drive lines.

Torque vs. Shaft

A further disadvantage to shaft keys in a world of increasingly compact motion components is the reduction in the torque density of the shaft and its respective locking element. The introduction of a DIN or ANSI standard keyway into a shaft normally reduces the shaft radius by 20 to 25%, and often as much as 50%. Larger shaft diameters must be selected in order to ensure that the shaft will be able to withstand the full torque of the application. In shaft hubs, the keyway poses a similar torque density-related problem. In many cases, bearings, shaft couplings, sprockets, gears, etc. that would otherwise be capable of transmitting all of the mechanical power required of them, must be selected in larger sizes in order to accommodate the increased size of the keyed shaft. This can significantly increase not only the outside diameter, but also the cost, mass, and moment of inertia of the driven element.

Balancing Act

Yet another concern associated with shaft keys, though not quite as widely applicable, relates to balance. In high speed systems, balance and the smoothness of rotation become increasingly important. A growing number of shaft hubs are manufactured from high-strength aluminum rather than steel, as this helps to reduce inertia. The use of a steel key adds a natural imbalance to the system, which in many cases must be compensated for. The concentricity and natural balance of most keyless locking devices eliminates the need for complicated, multi-component balancing procedures.

Clamping Solutions

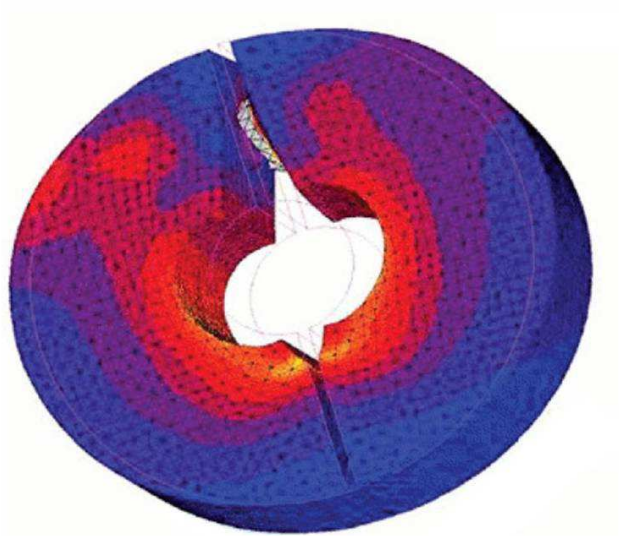


Figure 1. Keyless clamping hubs evenly distribute clamping and torsional stress around the entire inner circumference of the collar, allowing for better holding torque and reducing stress concentration.

A variety of different keyless shaft locking devices have been developed over the years in order to address the backlash, density, and balance problems associated with dynamic loading of keys while ensuring adequate holding torque around the shaft. Up to a certain size clamping hubs with a single tangential screw are the most common because of their simplicity, low cost, and relative ease of assembly. When properly manufactured, a total shaft-hub clearance between 0.0004 and 0.002" is adequate to ensure that the clamping screw will generate a high-force frictional clamp connection. Industry standards for precision motion components ensure that almost any motor or gearbox will present a properly toleranced shaft for keyless locking devices. The diameter of the shafting in nearly all cases allows for much more surface area contact to exist between the shaft and hub than the power requirements would dictate. Tangential clamping collars more evenly distribute the stress associated with shaft locking and torque transmission. As demonstrated in Figure 1, the entire surface area in contact between the shaft and hub is utilized, as compared to the single

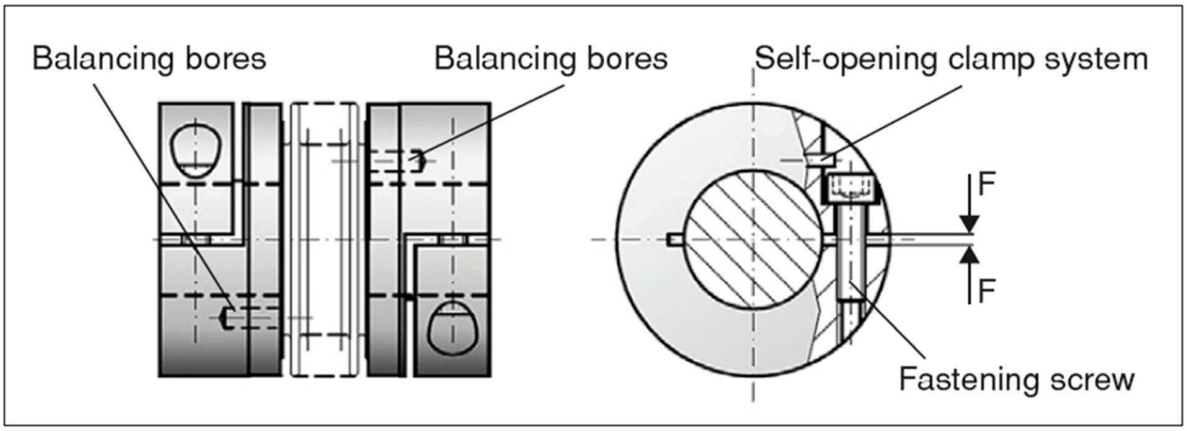


Figure 2. Hubs with single tangential fastening screws are most common for shafts less than 50mm in diameter. They are easy to manufacture and run smoothly with the help of balancing holes to offset the features of the screw itself.

face of a shaft key. This represents approximately a tenfold increase in torque-related shaft-hub engagement when the surface area of one side of a standard square key is compared to its respective shaft circumference across the same hub fit length. Conical clamping type hubs provide further protection from torque overload and potential shaft slipping in high torque applications where a hard stop or aggressive load reversal takes place. Conical clamping hubs typically are manufactured from steel and tend to generate extremely high clamping pressure relative to normal application requirements. Other keyless clamping devices include expansion shafts, fully split clamping hubs, as well as some others, each with their own unique purposes.

The Future

As the field of precision motion control continues to develop faster, smaller, and more accurate systems, mechanical products are required to evolve in order to keep up with demands for acceleration and control that were not possible 50 years ago. Performance issues related to backlash, size, inertia, and balance have all lead mechanical component

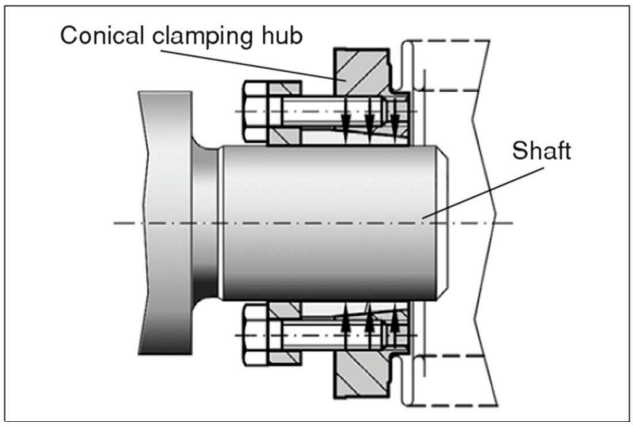


Figure 3. When tapered frictional connections are used, very high clamping pressure results. Shown here is a conical clamping bushing. This system can be reversed to drive a ring with a tapered inside over a corresponding taper in the hub, offering self centering features well suited to higher speed applications.

suppliers to adapt to new standards and practices in order to eliminate shaft keys. While most keyless hub designs have existed for quite some time, their use in power transmission and motion control has increased widely over the past few years.

More Information

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