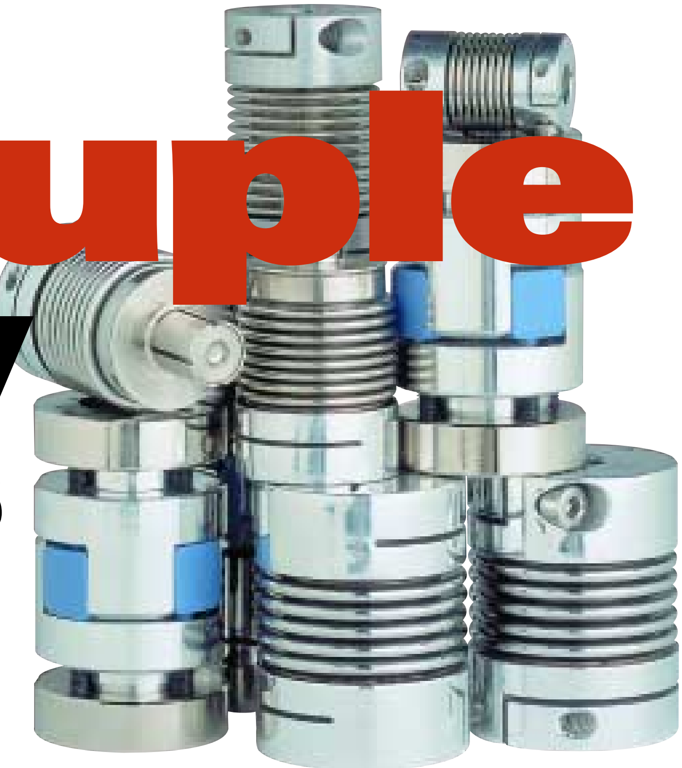
A Couple of New Ideas



1 Lightweight, miniature metal bellows couplings pack high capability into a small package and are ideal for use in limited space.

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The revolution toward using highly dynamic digital drives with high-speed, accurate AC servo and induction motors has dramatically changed machine design and coupling performance.

Currently, machines are made to be smaller, smoother, and faster. In addition, smaller motors, with or without planetary gearboxes, let them achieve the speed, torque, and precision previously accomplished using larger, full-speed (2,000–3,000 rpm), analog AC servomotors.

Various new coupling designs provide advanced, servo-quality machine and drive protection for every type of industrial machine.

Conventional coupling design is incompatible with the performance levels of today's machines. Gear-type couplings exhibit backlash and, with repeated positioning in both directions, have high wear and replacement rates. Jaw-type couplings are suitable for pumps and hydraulic drives, but are too soft for highly dynamic drives.

The disc type, with low inertia and high stiffness, is preferred over the jaw and gear types for servo-controlled machines. However, its use is limited to machines with small coupling requirements. On larger applications with frequent reversing, the screw connecting the disc to the clamps will experience backlash and eventual wear.

Small step motors or encoders make cost-effective use of aluminum, helical split-beam couplings. However, this coupling type isn't torsionally stiff enough to handle applications requiring load reverses. A stainless-steel version improves stiffness, but its high inertia uses up most of the torque on small motors, leaving little to move the load.

A wide range of new coupling designs allows every type of industrial machine to experience advanced, servo-quality machine and drive protection. New capabilities include the following:

- Zero backlash
- Low inertia
- High torsional stiffness
- Long life with no wearing parts
- Compensation for axial, radial, and angular misalignment

Metal Bellows Couplings

The stainless-steel bellows coupling, as shown in Figure 1, is ideal for achieving zero backlash and high torsional stiffness, as it was specifically designed to meet the demands of high-end servo systems. The low-inertia bellows achieve fast response time without backlash, while compensating for axial (0.5 mm or 0.020 in), radial

(0.2 mm or 0.008 in), and angular (1.5°) misalignment. The bellows coupling also compensates for thermal changes in shafts when AC servomotors run at high speeds (up to 3,000 rpm).

This coupling design's only challenge is meeting its tight alignment-specification requirement. Since this can't be accomplished visually, machine manufacturers typically use either a laser system or a precision gauge to set the alignment. If the specification isn't met, speed, radial loads, and other factors will eventually fatigue and ultimately break the bellows. However, if properly aligned, the bellows lasts forever, with absolutely no wear and no spare parts required.

A more advanced bellows coupling design incorporates a unique outside-taper lock that avoids misalignment problems altogether. When assembled, the coupling automatically self-centers the motor shaft, then self-loosens for easy release when disassembled. This clamping style is particularly cost effective, as it achieves highly accurate manufacturing tolerances and reduces bearing wear, machine downtime, and the need to inventory replacement drives.

Resonance is another challenge with high-end servo-positioning systems. The bellows coupling is torsionally stiff, as per the following equation:

$$F_{res} = \frac{1}{2\pi}\sqrt{G_{dyn} \times \frac{J_{motor} + J_{machine}}{J_{motor} \times J_{machine}}}$$

Where:

- F_{res} = frequency at which the bellow coupling will have resonance for the motor-machine coupled
- G_{dyn} = torsional stiffness of coupling (N·m/rad)
- $J_{machine}$ = reflected machine or load inertia (kg·m^2)
- J_{motor} = motor inertia (kg·m^2)

A typical machine's natural frequency (300–400 MHz) is usually lower than the bellows coupling's, so no resonance occurs. However, even with a calculation that anticipates no resonance, coupling experts sometimes know that the combined load/motor inertia will nevertheless unite with slide friction to create resonance. The load inertia should be 30–50% less than that of the motor for highly dynamic positioning systems. Consequently, if it's sometimes difficult to make the exact calculation, control engineers often look for some dampening in the system.

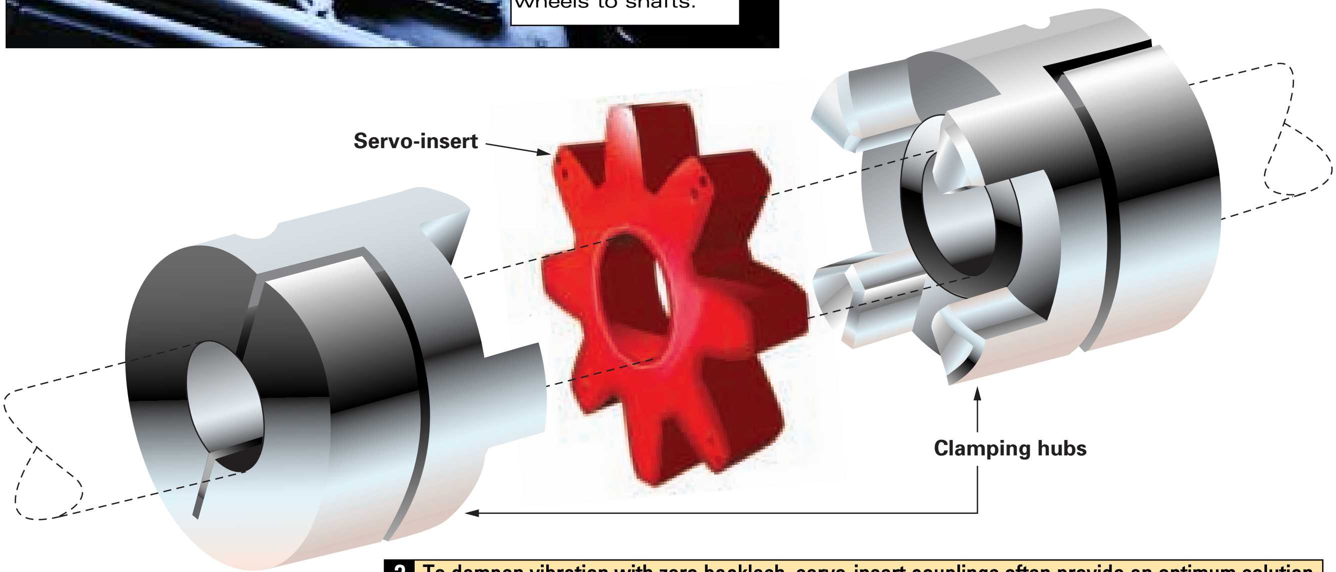
This torque-limiting safety coupling accommodates indirect drives mounted with a belt drive. The integral bearing and clamp make it easy to assemble gear wheels to shafts.

Servo-Insert Couplings

The best methods for achieving this additional dampening are to use either a bellows coupling manufactured with a special polyurethane material injected between the bellows, or servo-insert couplings with the correct dampening and stiffness specifications to meet the particular resonance problem.

For example, a machine slide with linear bearings cannot accelerate at the speed available from today's high-end drives (from zero to 2,000 rpm in 10–15 seconds), and thus sometimes experiences a very high resonance of 800 Hz or more. Sometimes a control manufacturer can optimize the closed-loop circuit with special filters, then play with the gains to achieve a solution. However, this problem is very difficult to solve mechanically.

It's easier to achieve the optimum solution by using a servo-insert coupling with special polyurethane inserts. This type has a limited radial-misalignment value (0.1 mm or 0.004 in), but it provides higher dampening with zero backlash, as shown in Figure 2. Better servo-insert designs have an interior ring that prevents splashing; some have a lateral stub to insulate against transmitting electrical frequency through the coupling.



2 To dampen vibration with zero backlash, servo-insert couplings often provide an optimum solution.

Servo-insert couplings are also highly advantageous in tight assembly situations where preassembly of the two clamping halves on the shafts is possible. This type can also be used, along with metal bellows couplings, to dampen vibration on machines with extreme space limitations and to obtain higher torsional stiffness (hybrid type).

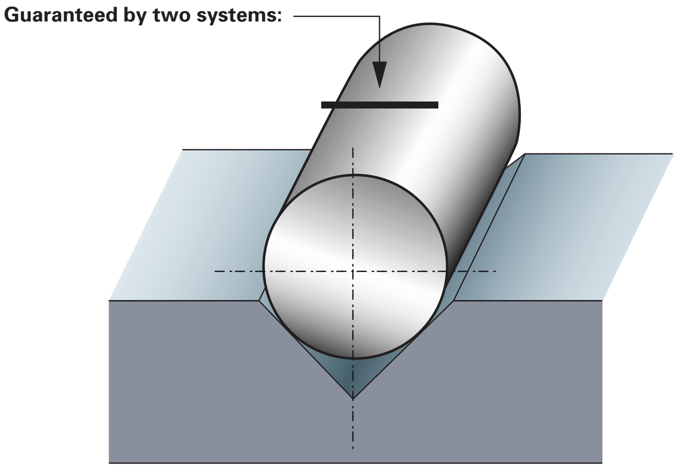
Torque-Limiting Safety Couplings

While bellows couplings usually can take 2.5 times their rated torque in a crash or runaway situation, the application might be better served with the speed of torque-limiting safety couplings.

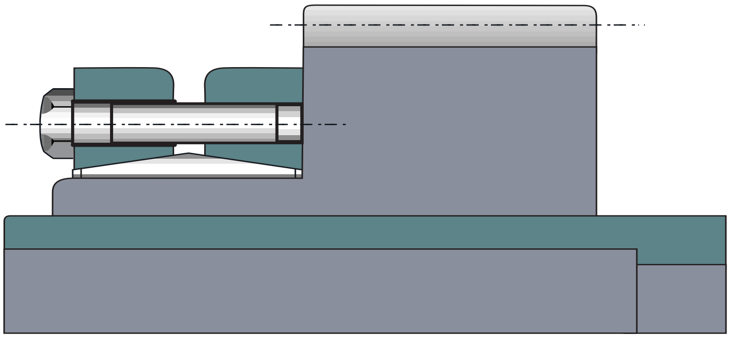
Conventional spring-loaded torque limiters typically take a full second or longer to disengage. The springs have long switching times and expend too much energy to disengage. More recent direct-drive and indirect, torque-limiting safety couplings bypass these problems to disengage today's highly dynamic drives with zero backlash.

The industry's fastest-response safety coupling design can disengage within 2–4 milliseconds of an overload signal, and doesn't need elaborate monitoring systems. This is accomplished with an integral Bellville spring with prestressed, high-precision roll or ball guides placed unevenly (to get one position, as in Figure 3). The design requires little energy to disengage, resulting in its unusually fast response, and even protects equipment from ultrashort surges in speed. Then the coupling re-engages at the precise angular position within one revolution.

To prevent the coupling from constantly engaging and disengaging, a proximity switch or sensor is used to detect the movement of the coupling's outer ring and provide an electrical signal telling the control to shut down the machine.



3 A cylinder roller locking element is recommended for safety couplings used in transmitting power for highly dynamic loads.



4 A shrink disc "squeezes" shafts together, establishing the positive friction that permits power transmission.

Magnetic Safety Couplings

Mechanical torque limiters can easily wear down on machines that frequently jam. The magnetic coupling has been developed for applications that disengage frequently.

Magnetic couplings are designed as two parts that nestle together without physical contact. A magnetic field is produced across the air gap between the two sections of the coupling, offering extremely smooth, constant torque. They are also capable of safely transmitting torque through a wall, as is sometimes required in the food industry.

Following an overload, long-life magnetic couplings safely disengage without the abrasions and jerks that limit the wear life of conventional mechanical-type couplings.

Typical Applications

Metal Bellows Couplings

- High-production transfer lines
- Robots' ball screw slides and gearboxes
- Computer numerical control (CNC) machine tools
- Packaging machines
- Textile machines
- Printing presses
- Any other manufacturing with high rotational speeds and high torque

Servo-Insert Couplings

- Machines with higher load inertias, such as cutting knives
- Machines with tight space requirements

Safety Couplings

- High-production transfer lines
- Stand-alone CNC milling, turning, and boring
- Plastic-injection molding machines
- Materials handling
- Robots

Magnetic Safety Couplings

- Tension control
- Bottle-filling and cap-tightening packaging machines
- Packaging
- Converting
- Food industry

This safety coupling's exceptionally fast disengage of 2–4 ms saves damage and downtime.

For machines with very frequent engagement and disengagement, but less requirement for positioning accuracy, a synchronous magnetic coupling with zero maintenance requirements is most practical. Following an overload, the coupling disengages without transmitting any torque.

Hysteresis magnetic couplings are a good fit for applications with constant slipping and some torque, such as bottlecap tightening or tension control on packaging machines. Following an overload, the torque transmitted remains at the set torque level, which holds the tension. Today, hysteresis-type friction clutches are also used to avoid the frequent wearing that's typical on capping machines.

Keyless Clamping and Locking

Of course, all these different couplings need some type of clamp to attach them to the shafts. Conventional keyed shafts, sometimes joined with setscrews, have lost ground to the many advantages of keyless clamps, which combine greater machine uptime with less repair and maintenance costs.

Keyless clamping offers easy shaft/hub assembly and removal without having to machine keyways. Typically, for the clamping hubs or taper shaft, the maximum clearance shouldn't exceed 0.03 mm (0.001 in), with a surface finish of an R_t value less than 16 microns. Recommended shaft/hub tolerances are h7/g6.

The most advanced keyless clamp design is a *shrink disc*, which locks via radial clamping pressure, squeezing the hollow shaft to the solid shafts (Figure 4).

The resulting positive friction permits power transmission. Shrink discs maintain locking pressure indefinitely, allowing for slippage if the preset torque is exceeded. This eliminates the need for expensive, close-tolerance fits; milling work; and multiple splining.

Keyless locking assemblies are also available to connect gears/sprockets to shafts. For the outside of gearboxes with a hollow shaft, a shrink disc provides an ideal connection to the motor shaft.

Digital control and drive technology is now widely accepted and used. Thus, it's important that engineers take advantage of the comparable advances in coupling and clamp designs to productively match new performance capabilities right down to the shaft.

Zero backlash and zero maintenance are critical for producing straight shafts on today's highly dynamic machines. The coupling technology is available and well proven in industry experience. MC

Make Contact!

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