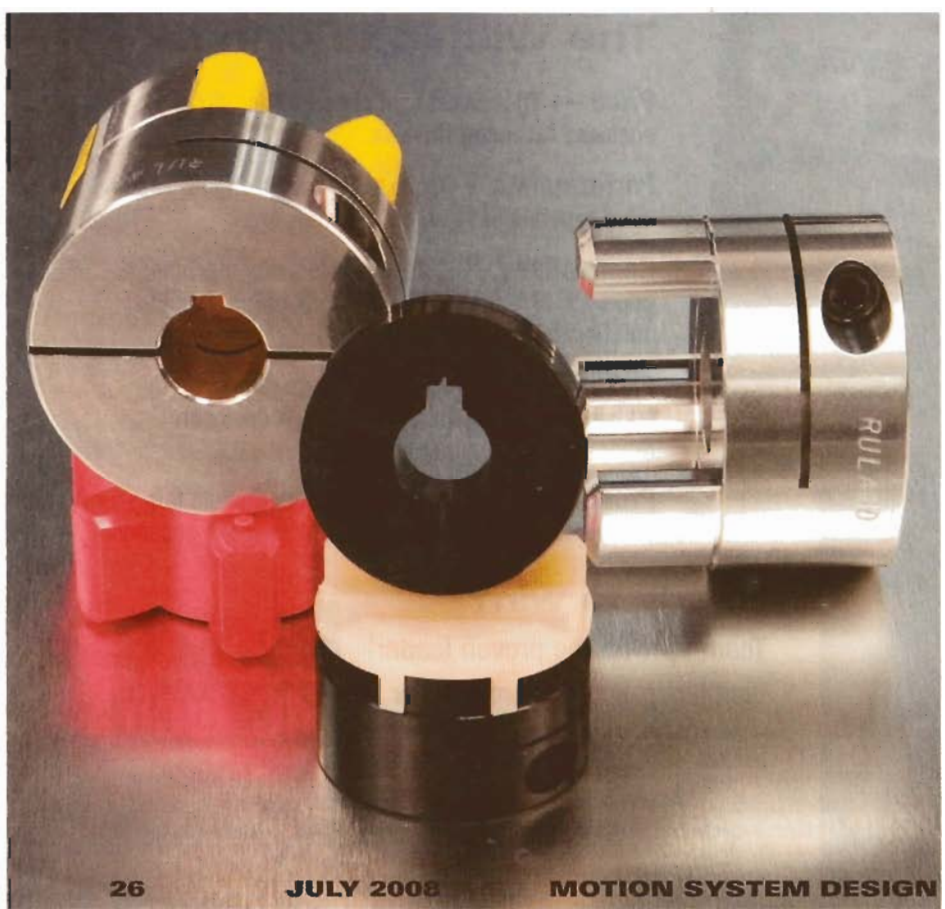
Servo coupling savvy

Choosing the right coupling is no small feat. Backlash, misalignment, torsional stiffness, and the variety of coupling types to choose from all enter into the selection equation. See what the experts have to say about servo coupling technology in this forum on maximizing productivity.



Making sense of servo couplings

How does coupling selection affect productivity in today's automation environment?

Bill • Rexnord: Selecting couplings for servo systems can be a daunting task. Some systems can detect errors as small as 1 to 2 arc-minutes. Projected over the length of a football field, 1 minute of arc amounts to roughly 1.06 in. of positioning error. Servo systems continually correct for positioning errors through the drive, which is connected by the coupling. Coupling errors take a heavy toll, making the system work overtime.

A coupling for servo duty should have no backlash, high torsional stiffness, low inertia, and the ability to connect misaligned rotating shafts while maintaining constant velocity. Shaft-to-shaft misalignment should be minimized because it influences positioning errors in many coupling styles. The torsionally soft properties inherent in a non-compliant coupling often initiate significant errors. The system must continually make corrections for position when, in fact, the errors are being introduced solely by the coupling. Only a change to a fully compliant coupling will bring the overworked system under control.

Andrew • R+W: Proper servo coupling selection is critical to system stability and accuracy. Most important to the efficiency of a mechatronic system, with respect to the coupling, are stiffness and inertia. The goal in most mechatronic systems is to be able to control the force, velocity, or position of the load as efficiently as possible within given performance parameters. When couplings exhibit backlash or

torsional deflection (wind-up), more energy is required to overcome the load inertia within a given time frame. The degree to which this is a concern varies depending on the application. The more aggressive a motion profile is, the more critical the moment of inertia of all components becomes. Especially in cases where a highly torsionally rigid coupling is desired, designers should be sure that the coupling does not inadvertantly become a flywheel.

Kevin • Zero-Max: Coupling selection influences the performance of any servo-controlled application, so it's important to select a coupling with the desired operating characteristics for your application. A common use for a servo coupling is between a servomotor and a ball screw. This application requires a zero backlash, torsionally stiff coupling for accurate and precise positioning. Selecting a coupling with low inertia allows users to have higher acceleration/deceleration rates while consuming less of the system's energy.

Robert • Ruland: Matching the coupling to application requirements ensures maximum machine productivity. Use a curved jaw coupling, for example, to help dampen the shock of acceleration changes on an axis or stage; a bellows or disc type coupling, on the other hand, can be used to accommodate a higher speed motor. Curved jaw couplings are also a good choice to reduce the settling time on optical stages.

Sarah • Ringfeder: Many times a coupling is the last thing considered in the system design, almost an afterthought. The irony is that if the correct coupling is not selected, the machine may never work properly. The first thing to consider is coupling type. Every coupling has its place. On the market today are rubber jaw type, bellows couplings, disc couplings, and more. All of these are torsionally rigid to varying degrees.

Once coupling type has been selected, the next step is to select a size that will work in the application. Often, coupling size is determined by the application's torque requirement with the appropriate service factor added. For smooth applications, drive torque can be used directly. For applications with quick direction reversals, torque developed by the system inertia starting and stopping must also be considered. Many manufacturers provide a service factor guide in their coupling catalogs to help designers apply the correct factor.

Size and apply servo couplings wisely

Any advice on specifying, sizing, and applying couplings where the main goal is productivity?

Bill • Rexnord: Where coupling selection falls into a system critical application, it's highly suggested that users contact potential suppliers with their operating and full dimensional-envelope requirements. Users should be sure to disclose all operating conditions, including items such as start-up torque, oscillating torque loads, over-speed conditions, high system inertia load, unusual stoppage or braking conditions, and low or high operating temperatures. Connections to interface shafting should not be overlooked either. All of these factors can lead to downtime and loss of productivity if they exist and weren't considered in the coupling selection process.

Andrew • R+W: Sometimes the old fashioned way is best. Contacting application engineers at your preferred servo coupling manufacturer is often the quickest and most effective way to select the right coupling.

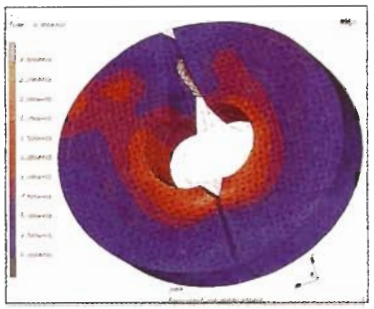


Image courtesy of R+W

Note the more even distribution of stress around the shaft circumference.

Image courtesy of R+W

When using a coupling to adapt mismatched shaft diameters between a driving element and a hollow bore — say, when mounting a servomotor to a belt driven actuator — expanding shaft servo couplings save space and components by eliminating the need for a stub shaft.

Designers can avoid oversizing couplings by looking at the actual requirements of the application rather than simply matching the peak acceleration torque ratings of the gearbox. Servo coupling manufacturers that offer more advanced sizing formulas, accounting for duty cycle, load inertia, positional accuracy, and mechanical frequency, give designers the best chance of making the most suitable selection.

On another note, servo couplings are normally designed to hold the load without keyways. It can be tempting to view the keyway as

cheap insurance against shaft slippage, and servo coupling manufacturers do offer to include them (and on rare occasions do still recommend them). However, in many cases keyways add unnecessary cost, imbalance, and stress concentration that decades of coupling design have worked to overcome.

Kevin • Zero-Max: • Select your coupling based on application requirements

• Consider peak torque as well as normal operating torque for the application

• Determine maximum rpm

Image courtesy of Rexnord

This high speed coupling (several thousand rpm) exceeded its design speed by a substantial amount and burst apart, but was properly captured inside a concrete bunker.

• Check shaft stress to determine proper shaft diameter

• Use a coupling with a clamp-style shaft connection; a keyed connection can weaken the shaft

• Check torsional stiffness requirements; ultra high torsional stiffness could lead to premature failure

Robert • Ruland: Here are several tips:

• Dampening type couplings allow for higher acceleration/deceleration rates. Example: Curved jaw type

• Easy repair-or-replace coupling designs can reduce system downtime. Example: Oldham type - replaceable disc

• Dampening type designs can reduce settling time on machine vision systems and optics. Example: Curved jaw

• High speed couplings allow for higher system speeds. Example: Bellows and disc types

• It's a good idea to protect the motor, gearbox, or actuator in your system by making the coupling the weak or breaking point. Keep a spare coupling or two on hand to avoid being down for hours, or days, waiting for a new motor or actuator.

Sarah • Ringfeder: **Torque** — It's important to quickly identify the source for the highest system torques. Is it from the drive or from

the driven inertia? Inertial torque is often ignored in the design phase on applications with torque reversals. This will cause the coupling to be sized too small and cause unnecessary down time.

Fatigue — In reversing applications, it's important to select a coupling that will not fatigue easily. Certain designs that are fine in smooth applications don't last long in reversing applications.

Torsional rigidity — If it's important to hold the torsional timing from one side of the coupling to the other, choose the coupling with the highest torsional stiffness. It may cost a bit more, but this will ensure the percentage of good parts manufactured is much higher.

Backlash — In motion-centric machines, backlash causes timing problems and eventual failures due to the hammering effect that occurs in reversing applications. Choose couplings without any backlash in the coupling or the connection between the shaft and hub.

Misalignment — The designer needs to be realistic about what misalignment can be maintained between the shafts for the life of the machine. If a coupling without sufficient misalignment capability is chosen, it can cause failures at the coupling or even the more expensive parts adjacent to the coupling.

The human factor — Get to know your end user or factory personnel. Which type of coupling do they prefer or have the most experience using? As long as the coupling is appropriate for the application, downtime will be significantly reduced by listening to those who have to use or maintain these couplings.

Coupling catastrophes

What's the worst that can happen if a coupling is not specified or installed correctly?

Bill • Rexnord: When couplings are not properly specified or applied, the consequences can be catastrophic. Parts and pieces may become projectiles, creating an unsafe condition for personnel and equipment. High speed coupling operation demands that enclosures be properly designed to contain all components and that the coupling design also contain the spacer section in the event of flexing element failure. Using flex element fasteners as the sole method of spacer retention is considered unacceptable.

Andrew • R+W: Limiting current to the drive isn't always enough to prevent damage in the event of a machine crash. It's important to re-

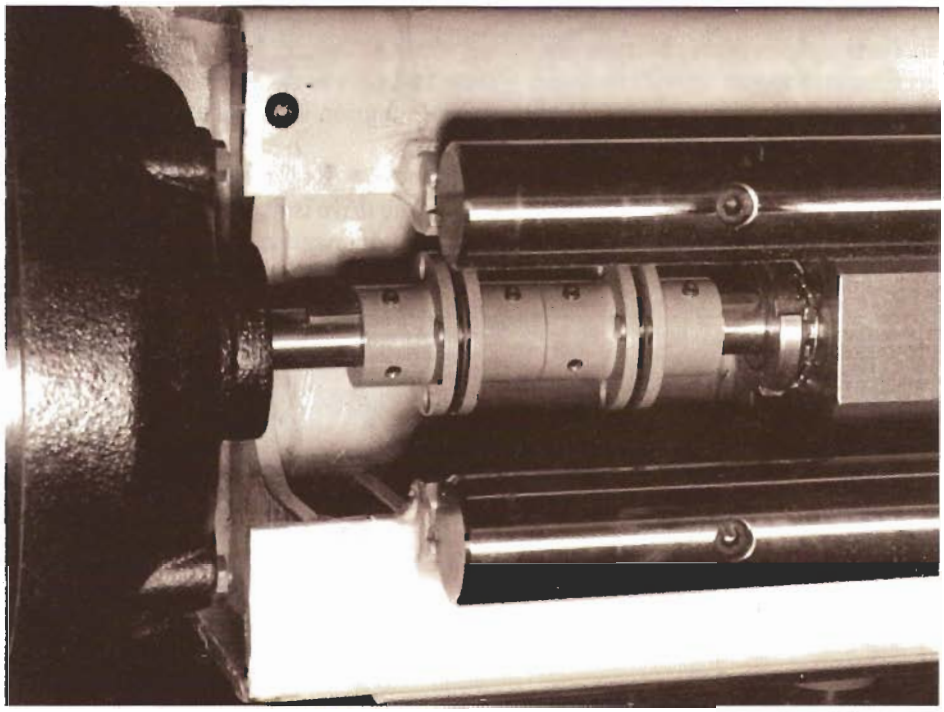


Image courtesy of Rexnord

Electro servomotors are connected to gearboxes by miniature couplings on the press tables of these tape-controlled turret punch presses.

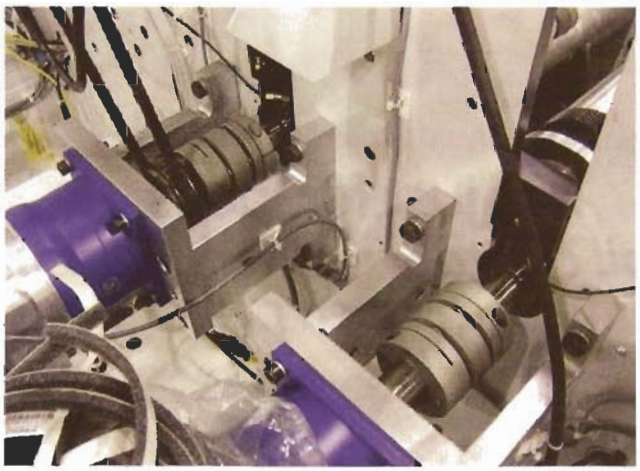


Image courtesy of Zero-Max

In this printing application, a zero backlash, torsionally stiff coupling is required to maintain print registration and roll speed. Here, the coupling connects a servomotor to printing rolls.

member that in high speed applications with high acceleration rates, a substantial amount of kinetic energy may already exist within the load and mechanical components at the time of impact. This is why servo-rated torque limiting couplings exist.

If, over time, bearings begin to wear and machinery no longer runs as smoothly as it once did, it's possible that torque limiters will begin to disengage due to the higher level of torque required to accelerate the load. This can frustrate production efforts, and occasionally technicians have been known to weld torque limiters together so that they never disengage. Stand back next time someone accidentally hits a hard stop.

Kevin • Zero-Max: If a coupling is misapplied, performance and life are dramatically affected. For example, when coupling torsional stiffness is too low, something in the system must be adjusted in order to accommodate the lower stiffness. Typically the servo gain is reduced, resulting in a slower system response. This will reduce the performance and productivity of a servo system. An often overlooked concept is the relationship between ultra high torsional stiffness and the ability to withstand high speed reversing loads. If a coupling has ultra high torsional stiffness, the coupling is often brittle. A balanced approach is needed in high performance systems.

If a coupling is not properly selected or installed correctly, a catastrophic coupling failure may occur. An improperly aligned coupling can increase reaction load on the connected shafting, which can cause premature bearing, shaft, and/or coupling failure. Due to the high peak torque and smaller shaft diameters of today's servo systems, the shaft connection is increasingly important. To avoid slippage, an adequate shaft connection must be selected. Failure to review the shaft connection can result in coupling slippage on a keyless shaft, which may result in loss of machine timing and galling of the shaft and/or coupling hub.

Robert • Ruland: Here's a bad idea — using a rigid coupling to replace a flexible servo coupling when misalignment is the underlying problem. We receive many inquiries for rigid couplings, with customers telling us they keep breaking flexible types. They believe that by going to the very strong rigid type it will solve their problem. Rigid couplings can only be used when the shafts are in perfect alignment. If a rigid coupling is installed in an application where misalignment is present, the forces applied by the rigid coupling to the surrounding components can be extreme.

It would not be unusual for a rigid coupling mounted between a misaligned servomotor and a linear actuator to destroy both expensive components. We once heard about a $4,000 precision gearbox and $2,000 servomotor both destroyed by using a rigid coupling to connect them without perfect align-

ment. If frequent coupling failure is a problem, do the following: Check the alignment of the shafts to be sure it is within the limits of the coupling being used, and check the speed, torque, and misalignment of the system to be sure that the proper coupling type and size are being used.

Sarah • Ringfeder: The worst-case scenario is when the machine does not work properly and many months or even years go by fighting with it, because the right coupling was never used. One experience we had involved a coupling on a machine that flipped pick-up tailgates from one conveyor to another. The company that designed the machine based the coupling size on the torque from the motor and gearbox. In actuality, the highest torque occurred when the drive tried to lift the inertia of the tailgate. This value was much higher and the coupling bolts basically ripped through the center spacer sleeve. In order to keep running, the customer brazed the spacer back together. In the end, they needed a coupling at least two sizes larger.

The perfect coupling

If you could create the ideal coupling, what would it look like? What would it do?

Bill • Rexnord: The ideal coupling would have no wearing parts, would not require lubrication, would be easily assembled, have an infinite operating life, have no fasteners, and be low cost. Maybe it will drive the perpetual motion machine some day.

Andrew • R+W: The ideal servo coupling would be weightless, corrosion proof, and present zero resistance to any misalignment. It would limit torque to an ideal value, tell you what that value is, and adjust itself automatically. It would have the ability to damp vibration but also be infinitely torsionally rigid, and not make any noise. While we're at it, how about free of cost?

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Kevin • Zero-Max: A future servo coupling must have the following traits: Durable and reliable design; zero backlash; high torsional stiffness without being brittle; low inertia; high misalignment capacity (angular, parallel, and axial); large bore capacity; compact design to fit in a variety of installations; and a choice of shaft mounting configurations.

Robert • Ruland: The perfect coupling would feature zero wind-up, zero reactionary forces, zero inertia, an adjustable length, torsional stiffness, dampening/shock absorbing and electrically isolating qualities, and would offer tool-free installation.

Sarah • Ringfeder: The perfect coupling for motion-centric machines would be torsionally rigid to 109 lb-in./rad, allow 0 to 0.25 in. of parallel misalignment without any problems, always be in stock, and cost nothing. For simplicity, I picture a flexible tube that can be expanded around each shaft, is stiff in torsion, flexible in bending, and durable against fatigue. **MSD**