

Couplings come into focus

Learning the ins and outs of coupling choices and what each type has to offer will help when you face your next machine vision or optical inspection system design.

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It's not easy specifying and setting up a machine vision or optical inspection system. These highly technical, multi-purpose systems requiring high precision components are used for a number of tasks where they essentially replace the human eye with a camera. While no application setups are exactly alike, two common traits are shared between all machine vision systems — the need for motion and a demand for precision.

Sizing up system choices

System designers must choose components that meet the most stringent demands of their applications. In motor-driven ap-

plications where precision rules, one of the most important considerations is picking the right zero backlash coupling; and there are more than a few from which to choose. When selecting a coupling, there is a degree of give and take as each type has its strengths and weaknesses. It's best to start thinking about the coupling choice early in the design process.

Automated machine vision systems are one example of a motion system where couplings play an essential role. Usually, automated vision systems operate in one of two general modes.

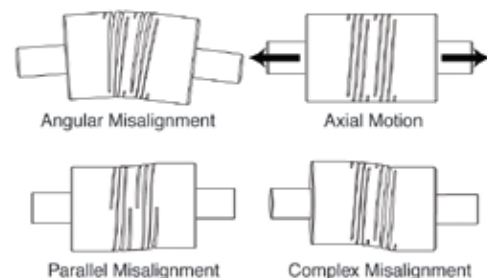
One type is stop-and-go, where a camera moves quickly to one spot, snaps a picture, and then moves to the next location where it captures another image. The energy built up and released by the rapid starts and stops can excite resonance frequencies, causing vibration. Couplings that dampen vibration are quite helpful here because they reduce settling time and increase throughput.

A second type of automated vision system operates in constant scanning mode. Unlike stop-and-go systems that require accuracy only upon stopping, scanning systems require accuracy throughout their entire motion profile. This calls for the

use of a coupling with high torsional rigidity, and vibration is less of an issue here.

In addition to vibration damping and torsional rigidity, important coupling selection criteria for machine vision systems include misalignment, inertia, speed, and torque capabilities. Speed and torque are fairly straightforward concepts, but misalignment and inertia are more complex.

Inertia is the coupling's tendency to stay at constant speed unless acted upon by a force. In other words, inertia is the amount of force required to start the coupling from a rest or stop



Three types of misalignment must be considered — parallel, angular, and axial motion — and often more than one type exists in an application. A coupling that cannot accommodate the type and amount of misalignment present in a system will likely fail. Depending on the coupling used, misalignment can also result in high bearing loads that can lead to premature bearing failure.



Beam couplings

- Max speed: 6,000 rpm
- Excellent misalignment capabilities
- Low to moderate torsional rigidity and torque capacity
- Vibration damping
- Low inertia for aluminum couplings



it during rotation. In even simpler terms, inertia refers to the coupling's mass. In the case of a stop-and-go system, it's best to use a coupling that has low inertia, to conserve the system's energy and place less wear on its components. Inertia is less of an issue for systems that operate in constant motion.

Let's now take a look at common coupling styles and their strengths and weaknesses with regard to machine vision. Every coupling style we will consider is free of backlash, which is essential to the accuracy of vision and inspection systems. Zero backlash ensures that there is no play between coupling components; if one shaft turns 90°, a zero backlash coupling guarantees that the mating shaft turns the same 90°.

Beam couplings

Beam couplings use continuous cuts in the body to transmit torque and accommodate misalignment. They're a good fit for machine vision systems that operate at moderate speeds (up to 6,000 rpm), have significant misalignment, and do not require torsional rigidity for scanning applications.

Two common variations of the beam coupling are single beam types with one long continuous cut, and multiple beam

types that have one or two sets of shorter, overlapping cuts. Generally, couplings with fewer and longer continuous cuts offer more flexibility than those with a larger number of shorter cuts. Increased flexibility means lower bearing loads under angular and axial motion. On the other hand, if multiple beams are used, the coupling can better accommodate parallel offset.

Beam couplings undergo a certain amount of windup when under torque, so they are less torsionally rigid than some of the other coupling choices. This property may be desirable, however, for stop-and-go applications requiring damping and decreased settling time. Higher torsional rigidity in a beam coupling is possible with a multiple beam type or one made of stainless steel instead of aluminum. However, with stainless steel, the heavy material offsets aluminum's low-inertia advantage and it's also more expensive. Usually, it's advisable to look elsewhere if torsional stiffness is a concern.

Rigid couplings

Rigid couplings are exactly like they sound — rigid. They can be manufactured from several materials and are available in a number of styles. Clamp style couplings, as opposed to set-

Rigid couplings

- Max speed: 4,000 rpm
- No misalignment capabilities
- High torsional rigidity and torque capacity
- No vibration damping
- Low inertia in aluminum body



screw style couplings, are probably more applicable to machine vision systems. They provide better holding power by exerting clamping force onto the shaft, while setscrew style couplings only rely on the screws themselves. Clamp style rigid couplings require no maintenance, provide better holding power, and do not damage shafts.

Rigid couplings have the highest rated torsional rigidity, making them ideal for scanning applications as they can withstand relatively high rpm and aluminum versions have

low inertia. However, there is no misalignment capability in a rigid coupling and they don't reduce vibration, which means they could be problematic in stop-and-go systems. A note of caution: Bearing loads for this type are the highest of all couplings, so make sure all shafts are perfectly aligned. Thermal expansion under extremely high speeds is also something to monitor; rigid couplings have no means to accommodate stresses caused by thermal expansion and the subsequent (negative) impact on bearings.

Zero backlash jaw couplings

The zero-backlash curved-jaw coupling is a variation on the straight-jaw coupling, which has inherent backlash and is not suitable for machine vision systems. Composed of three parts — two aluminum hubs

Jaw couplings

- Max. speed: 8,000 rpm
- Small misalignment capabilities
- Low to moderate torsional rigidity
- High torque capacity
- Good vibration damping
- Moderate inertia, but negated by vibration damping characteristics

Further, the spider is available in several levels of hardness: The stiffer the spider, the more torsionally stiff the coupling will be, though at an expense of some damping capability.

Jaw couplings are typically not torsionally rigid enough to be placed on a scanning style system, even with the hardest elastic spider. They also don't handle misalignment well, causing high bearing loads and accelerated wear. On the other hand, jaw couplings are failsafe, meaning the jaws of the hubs will lock together and continue to transmit torque even if the spider fails. However, this may or may not be desirable, depending on the system.

Besides superior damping, another advantage of the jaw coupling is the ability to mix and



and an elastic insert referred to as the "spider" — the curved-jaw coupling press fits together for zero backlash operation. The design of the hubs' jaws helps reduce deformations that the spider may undergo during normal operation.

While curved-jaw couplings can operate at high rpm, their real strength lies in their spiders. The elastic material absorbs vibration, making it the best choice for stop-and-go systems that require a damping compo-

match spiders and hubs. The inertia of the jaw coupling is relatively high compared to other motion control couplings (on par with aluminum rigid couplings), but this issue is negated by the spider's damping characteristics. The coupling's balanced design enables it to run at high rpm without causing vibrations. However, if a high amount of misalignment exists and rigidity during motion is important, it may be wise to choose a different coupling type.

Oldham couplings

- Max speed: 4,500 rpm
- Good misalignment capabilities; excellent parallel misalignment
- Good torsional rigidity with acetal center disc
- Little vibration dampening
- Low to moderate inertia



Oldham couplings

Similar to jaw couplings, oldham couplings also consist of three components — two aluminum hubs and an insert, which press fit together.

The oldham coupling has a few clear advantages. First is the ability to accommodate a high level of parallel misalignment, since the center disc is made to slide over the tenons of the hubs. This lack of resistance (other couplings have a spring-like resistance to misalignment) results in low and stable bearing loads.

The second advantage is the ability to interchange the center disc. Generally, two types of material are used, acetal to provide torsional stiffness and nylon to provide damping, much like the jaw coupling. What's more, the oldham coupling has the unique ability to act as a mechanical fuse: The tenons of the hubs will not interlock if the center disc fails and torque will cease to be transmitted. The oldham coupling's aluminum hubs help keep

inertia low.

Although oldham couplings work well for parallel misalignment, they can only handle small amounts of angular misalignment and axial motion. Too much angular misalignment will cause the coupling to lose its constant velocity characteristic; and they can literally fall apart with too much axial movement.

The ability to choose the center disc's material for either torsional rigidity or damping makes the oldham coupling a versatile option for machine vision systems. Because the "settling time versus torsional rigidity" conflict is quelled by this option, the remaining factors are speed and misalignment. For applications running less than 4,500 rpm, with high parallel misalignment and little angular and axial motion requirements, the oldham may be suitable for either stop-and-go systems or scanning operations requiring torsional stiffness.

Disc couplings

Disc couplings are either composed of two hubs joined by a flexible metallic center disc, or two hubs and a center piece joined by two metal discs. Double disc couplings can accommodate parallel and angular misalignment because the two discs are able to bend in different directions; single disc couplings

Bellows couplings

- Max speed: 10,000 rpm
- Good misalignment capabilities
- Excellent torsional rigidity and torque capacity
- No vibration damping
- Very low inertia



accommodate only angular misalignment.

Both variations of the disc coupling are torsionally rigid. The discs are flexible and allow for an ample amount of misalignment, especially in the double disc design. Bearing loads and inertia are low as well. Furthermore, the disc coupling can handle upwards of 10,000 rpm, with low inertia due to the light materials used.

Because of its torsional rigidity, the disc coupling is best suited for applications where accuracy and strength are emphasized; however, it's not a useful choice when damping is needed. Disc couplings are thus more suitable for scanning as opposed to stop-and-go vision systems.

While the best coupling for accuracy and torsional rigidity is the rigid coupling, disc couplings allow misalignment in the shafts while retaining high torque capabilities. The one drawback to using disc couplings is that they

are delicate and can damage easily if installed incorrectly. If applied correctly, however, the disc coupling has outstanding qualities for torsionally rigid applications with misalignment.

Bellows couplings

Bellows couplings are constructed of two aluminum hubs connected either by welding or an adhesive to a metallic bellows. The two most common materials for the bellows are nickel and stainless steel. They normally have a thin wall, which adds to responsiveness and accuracy. The bellows coupling's flexibility accommodates all misalignment types, and bearing loads are low and constant throughout all points of rotation. With aluminum hubs, this coupling has very low inertia ratings, which saves the system from unnecessary force and provides even greater response.

All of these strengths do not compromise the coupling's torsional rigidity, which is even greater than that of the disc coupling. Running speed capability is on par with disc couplings at about 10,000 rpm. The bellows coupling is an excellent option for machine vision systems requiring accuracy, though vibration damping is nonexistent. They can operate at high speed and have excellent torsional rigidity while still retaining moderate misalignment capabilities.

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Disc couplings

- Max speed: 10,000 rpm
- Good misalignment in double disc style
- Excellent torsional rigidity and torque capacity
- No vibration damping
- Low inertia

