

The shaft coupling is one of the mechanical elements that make up a servo-mechanism. The coupling must transmit rotation exactly from the drive shaft to the driven shaft without backlash. Also, high torsional stiffness is a fundamentally important quality, so that the displacement due to rotational torque is sufficiently small and the natural frequency is sufficiently high.

Additionally, couplings must have the qualities necessary to the design of the servo-mechanism (i.e. allow parallel and angular misalignment, have identical clockwise and counter-clockwise rotational characteristics, a low moment of inertia, constant rotational velocity, durability in the work environment, etc.). In choosing couplings, designers should refer to the manufacturer's catalog and

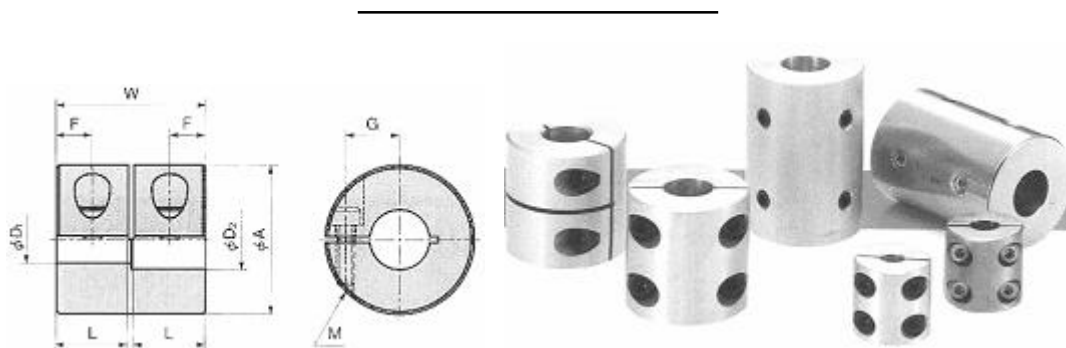
review these characteristics.

In actuality, there is a variety of couplings used in the servo-mechanism, such as the flexible couplings with metallic springs (e.g. leaf springs and bellows), the correcting couplings, and the rigid couplings. No coupling, however, meets all specifications; there are both advantages and disadvantages.

Therefore, the following outlines the characteristics of various couplings (using NBK's products as examples), as well as points to pay attention to in their use in servo-mechanisms.

### **The rigid coupling**

One of NBK's rigid couplings (the MRG) is shown as an example in **Figure 1** and **Photo 1**. We are standardizing the shaft into three types, according to the



**Diagram and Photo 1:** Rigid coupling (MRG)

attachment method. They are the

setscrew, clamping, and split types. Also,

we use aluminum alloy and stainless steel these couplings.

In the rigid couplings, the two shafts are aligned straight, allowing a constant rotational velocity with zero backlash, and high torsional stiffness and torque transmission. Also, they are generally simple in structure; with their small size, their moment of inertia and price are low.

This is one of the couplings suitable for high precision servo-mechanisms. However, in the event of rotational vibration or assembly-induced misalignment, forcefully aligning the two shafts into a straight line produces a large reaction force adversely affects not only the coupling, but also the shaft, bearings, and other surrounding machine parts.

Therefore, the shafts must be sufficiently aligned during assembly. Also, one should consider rotational vibration and measurement variations due to temperature and time changes, increase the stiffness of the surrounding elements, and, even if a degree of reaction force does occur, be careful to not let its influence become a problem.

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### **The flexible coupling**

When the reaction force from rotational vibration and misalignment is great, and when you can anticipate breakdown and shortened life, the flexible coupling must be used to meet the occurring reaction force. Generally speaking, flexible and correcting couplings must be used, according to the allowable radial load for motors and encoders. The flexible coupling metallic springs is often the flexible coupling used in servo-mechanisms. The following is an explanation of the leaf spring and bellows type couplings.

#### Leaf spring type coupling

NBK's MHS and MST are shown in Figures 2 and 3, and in Photos 2 and 3, respectively.

These leaf spring type couplings have no backlash, identical clockwise and counter-clockwise rotational characteristics, and high torsional stiffness. The MHS in Figure 2 has a structure that allows for angular



**Figure and Photo 2:** Leaf spring type coupling (MHS)

misalignment utilizing the elasticity of the stainless steel leaf springs. High

torsional stiffness is realized by doubling the leaf spring at a diameter greater than the applicable shaft. This structure increases the outer diameter, and by layering the leaf spring, it's possible to make torsional stiffness equality to that of

the shaft. However, one should be aware of that on the flip side, flexibility is lost and the allowable misalignment decreases.

The MST in Figure 3 is a coupling that forms a leaf spring with eight slits in



**Figure and Photo 3:** Leaf spring type coupling (MST)

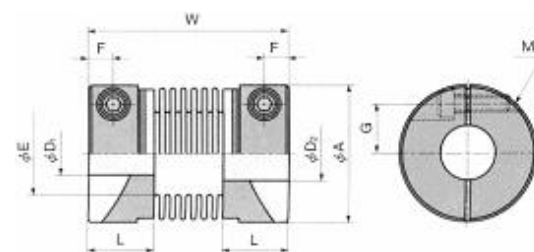
the cylinder and preserves flexibility. Its make-up is simple, and it is comparatively easy to respond to specific characteristic specifications (e.g. material, measurements, torsional stiffness, etc.) because the spacing and depth of the slits can be easily changed.

The disadvantage of these leaf spring couplings is the loss constant velocity in the event of angular misalignment. Because the velocity change in the driven shaft influences the accuracy of the positioning and also becomes the source of vibration and noise trouble, sufficient alignment adjustment is required.

Also, one should be aware that, due to misalignment, the torque direction becomes out of parallel with leaf spring and the torsional stiffness decreases.

#### Bellows type coupling

NBK's MFB is shown in Figure 4 and Picture 4 as an example of a bellows



**Figure and Photo 4:** Bellows type coupling (MFB)



type coupling.

This coupling can rotate at a uniform velocity without backlash and has high torsional stiffness and a low moment of inertia. Because the bellows section is thin, the misalignment-induced reaction force is comparatively small.

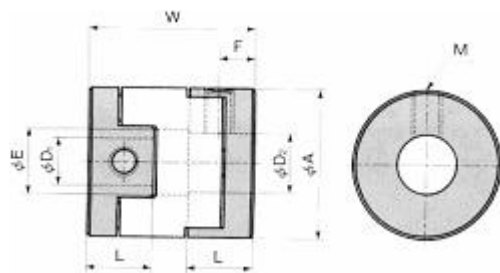
These are used a lot in the measuring instruments of encoders. However, because it is weaker in the direction of the bend, inattentive handling could deform the bellows section. Also, sufficient alignment adjustment is necessary, because it breaks down easily through repeated bending if the

misalignment exceeds the allowable value.

### Correcting type coupling

While flexible couplings use of the elasticity of the metal springs to allow misalignment, correcting couplings do this through the relative movement of its parts, thus making the reaction force small. Also, because of its structural inelasticity, the torsional stiffness and torque transmission is high. NBK's MOL and MCT are in Figures 5 and 6 and in Pictures 5 and 6, respectively.

The MOL in Figure 5 is the Oldham

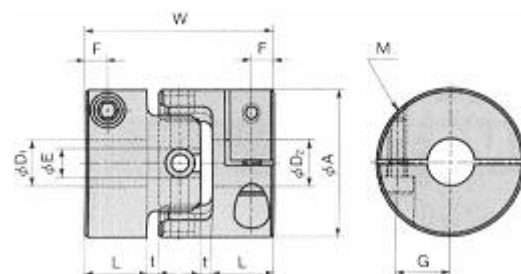


**Figure and Photo 5:** Oldham type coupling (MOL)

type coupling. This coupling is made up of two hubs (aluminum alloy) and a spacer (special polyacetal), and the hubs fit into the perpendicular flutes cut on both sides. In the event of parallel misalignment, the hubs and spacer slide in the flutes while remaining fit together. Also, protrusions are provided on the end face, enabling movement centered on the protrusions to correct of angular misalignment.

The structure of the MCT in Figure

6 is a compound of the Oldham type mentioned above and the adjustable joint.



**Figure 6:** Correcting coupling (MCT)



**Photo 6:** Correcting coupling (MCT)

The cross-shaped spacer with its four cylindrical pins mediates the dry bearing bush and is connected to the two hubs. In the event of parallel misalignment, the spacer moves with respect to the hubs; in the case of angular misalignment, the pins rotate with respect to the bush. This movement is smooth and the misalignment-induced reaction force is very small compared to flexible couplings.

The disadvantage of these correcting couplings is the gaps resulting from structural movement. Initially, there is little backlash from the gaps, and they can be controlled. However, wear and backlash is unavoidable in the long

run so long as there is relative motion due to misalignment. Also, as in the leaf spring type coupling, one should watch for velocity changes in the event of angular misalignment.

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For full-closed controlled servo-mechanisms, the issues mentioned with the couplings above will probably not become such a problem. However, many servo-mechanism systems are semi-closed controlled, and often the general accuracy of the servo-mechanism the mechanism including the coupling. In this article, I have outlined the characteristics of the shaft couplings that influence the accuracy of these servo-mechanisms, but the most practical measures are those that decrease parallel and angular misalignments as much as possible. I hope that it can be a useful reference to designers.

**Table:** Comparison of specifications of 32mm dia. couplings

Part Number	A	L	W	Max. Bore	Rated Torque	Moment of Inertia	Static Tors. Stiffness	Misalignment		End-play
								Pararel	Angular	
	(mm)				(N.m)	(kg.m <sup>2</sup> )	(N.m/rad)	(mm)	(deg)	(mm)
MRC-32C	32	15.5	32	14	2	$7,1 \times 10^{-6}$	---	---	---	---
MHS-32C	32	13.7	32	10	2	$4,5 \times 10^{-6}$	1300	---	1	$\pm 0,2$
MST-32C	32	12.0	41	14	2	$9,7 \times 10^{-6}$	280	0.15	2	$\pm 0,5$
MFB-32C	32	13.5	42	14	2	$9,6 \times 10^{-6}$	330	0.2	2	+0.8/-2.5
MOL-32	32	13.0	33	14	4.5	$9,5 \times 10^{-6}$	280	2.5	3	---
MCT-32C	32	13.5	40	14	2	$1,0 \times 10^{-5}$	820	0.5	3	---