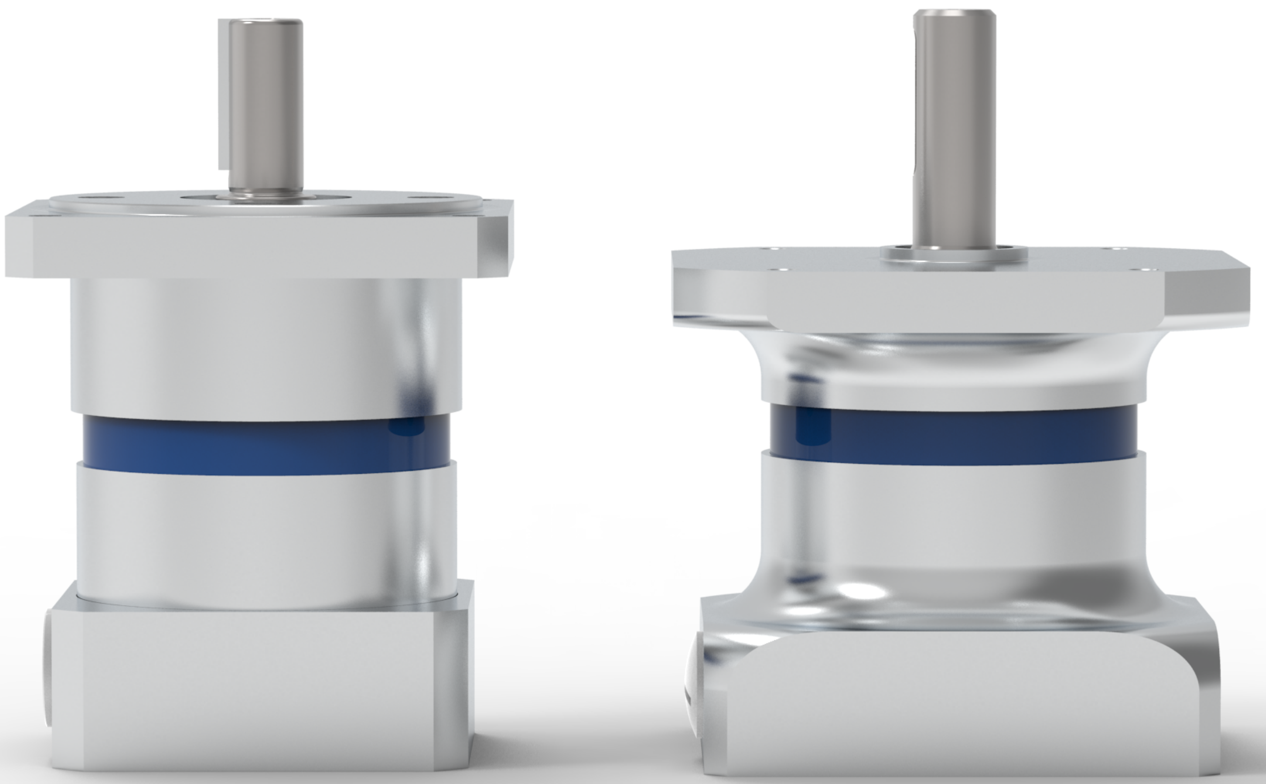
Digital eBook
A Design World Reference

Optimizing the Design of a Precision Mechanical Drive System

SPONSORED BY GAM ENTERPRISES, INC.

GAM



What's Inside:

Design World TechTIPS

Section 1. Beyond Torque: Considerations for Improving Overall System Performance

Mechanical drive trains are at the heart of motion control systems. Whether its robotics and automation or packaging and material handling, many such systems rely on mechanical drive components such as gears and couplings for optimal performance.

When designing a mechanical drive train in a servo motion control system, considerations beyond torque and backlash requirements can improve the overall system, saving cost and improving performance. These considerations can include:

- **Dimensional considerations**
- **Component compatibility**
- **Meeting machine performance specifications**
- **Total cost of ownership**
- **Advantages of single sourcing**

Here we'll take a more in-depth look at each of these considerations, including a few specific application examples.

Dimensional Considerations
When selecting the mechanical drive components for a motion control system, space can be a limitation. The many options for the drive components can also offer opportunities.

Some of the main limitations include:

- Fitting components within the machine frame
  - Can the drive train be shortened? Using a gearbox that can directly connect to the driven component can shorten the overall length, saving space (figure 1).
  - Can you use a right-angle gearbox instead of an inline gearbox – or vice versa? Changing one for the other can make the drive train more compact (figure 2).
  - Is your servo motor direct-driving a system without additional gear reduction? A mounting kit designed for this situation can simplify this direct connection by eliminating

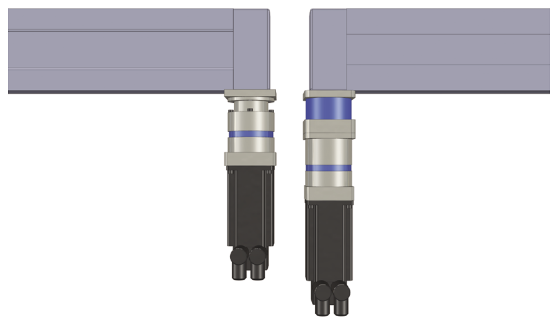


Figure 1: Hollow output inline gearbox (left) has a shorter overall length compared to a gearbox with coupling (right), saving space.

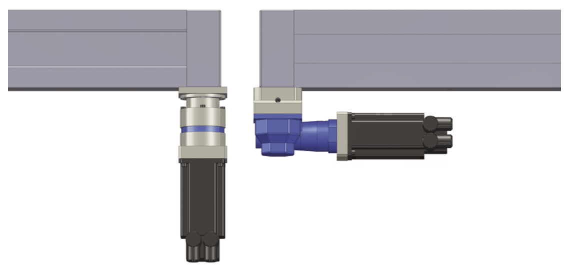


Figure 2: Using an inline gearbox (left) instead of a right angle gearbox (right), or vice versa, can reduce machine footprint.

additional mounting brackets.
    - Where is the drive train? Moving it, say from one side of a linear actuator to the other, can save space.

- Transport
    - Look at the overall weight and envelope of the machine. Can you reduce shipping costs by changing the design to reduce either of these?
    - Can the machine ship in one piece or will it need to be shipped in parts and assembled on-site with a dedicated technician?

- Space at the end user
    - What is the available floor space?
    - What is the ceiling height?

Even given space limitations, there are still opportunities to improve the overall machine within the space limitations. Making small changes and selecting components with dimensional advantages can have big impacts:

- Eliminate components: using a hollow output gearbox eliminates the need for a coupling and increases system stiffness (figure 1).
- Direct mount a motor or gearbox to a driven part such as a linear system, eliminating the coupling and any external brackets.
- Right angle gearboxes can be used to adjust the gear ratio while giving additional flexibility as to how the gearbox assembly protrudes from the actuator
- Wrap around kits offer the ability to 'wrap' the input components alongside the output components, greatly reducing the assembly's overall length.

Application Example

Here's one example of how the preceding considerations were brought to bear on a challenge faced by a specific machine builder. The machine builder's existing design was too long to be shipped in one piece, requiring them to send a service technician to assemble the machine on-site at their customer's location.

As a solution, GAM supplied a custom SPH-W gearbox with a custom input shaft, housing and integrated output adapter, allowing the gearbox to be fully integrated into the drive and eliminating a coupling and coupling housing (see figure 3).

These small changes shortened the overall length of the machine by 3.5 in., allowing the machine to ship completely assembled. This shortened length eliminated the time and cost to disassemble the machine and reassemble it at the customer as well as the expense of sending a technician to the end customer. A small change resulted in a large savings to the builder and their customer.

Component Compatibility

In addition to matching components dimensionally, it's also important to match components on performance compatibility. This can avoid unnecessary costs or sub-optimal performance.

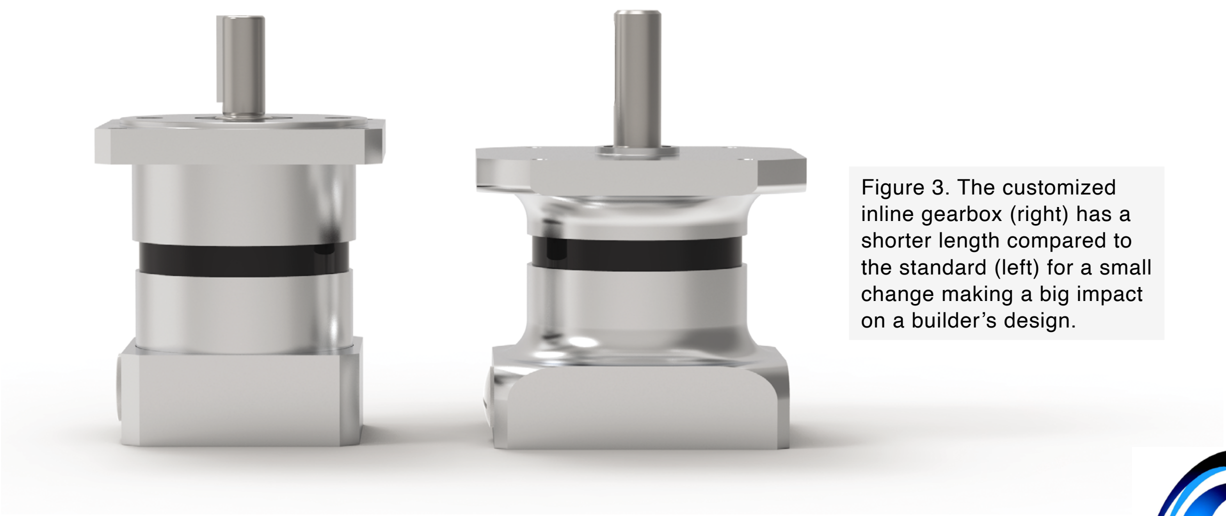


Figure 3. The customized inline gearbox (right) has a shorter length compared to the standard (left) for a small change making a big impact on a builder's design.

For example:

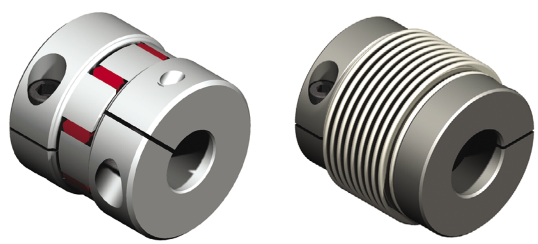
- Using a high precision gearbox with an elastomer coupling at the output. Although the elastomer has zero-backlash, it has lower torsional stiffness, negating the advantages of the high precision gearbox. A bellows coupling would be more appropriate.
- Similarly, using a low precision rack and pinion, connected to a precision gearbox with a set screw, introduces unnecessary backlash. Using a high precision pinion with a keyed or spline connection would maintain the high precision of the whole system.
- Conversely, using high precision components when lower precision is sufficient introduces unnecessary costs into the system.

Meeting Machine Performance Specifications

An application employing a servo motor for motion control will have specific requirements for performance and precision. One of the basic measurements for precision is backlash, but having an understanding of additional measurements can improve overall machine precision. Below are three critical parameters:

- Backlash: Movement in the output shaft position relative to the input shaft when the input is fixed. It is caused by clearance or play in the gears.
- Torsional Stiffness: Twisting angle due to external forces, or "wind up," in the gearbox or coupling. It is a function of the overall rigidity of the gearbox.
- Lost Motion: Combination of backlash and torsional stiffness and is dependent on the applied torque.

In addition, these elements of precision can stack up across components, such as a drive using a gearbox with a coupling connection at the output. The backlash, stiffness, and lost motion of each component add up to the overall precision. Eliminating or improving a component can reduce the stack-up tolerance.



Elastomer Coupling   Bellows Coupling

Figure 4. Servo Couplings

Zero-Backlash Couplings

There are two types of servo couplings; bellows and elastomer (figure 4). Both are zero-backlash but have vastly different torsional stiffness (also referred to as torsional resistance). Additional considerations for a specific application include:

- Will it run continuous or cyclic?
- Is it a high-speed or high torque application?
- Does it require vibration dampening?
- Are there cost considerations?

This is a quick guide for selecting the best type of coupling for an application:

Your application prioritizes...	Use this syle coupling...
Ability to repair	Elastomer
Continuous duty cycle	Elastomer
Cyclic duty cycle	Bellows
Electrical insulation	Elastomer
Extreme temperature range	Bellows
High speed	Bellows
High torque capacity	Bellows
High torosional stiffness	Bellows
Low-cost solution	Elastomer
No maintenance	Bellows
Vibration/resonance dampening	Elastomer

Gearbox Systems

We can also compare mechanical motion control systems by looking at the total lost motion at a specific torque, including:

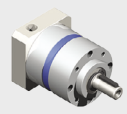
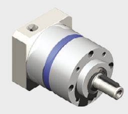
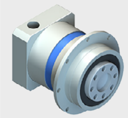
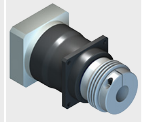
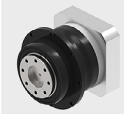
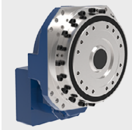
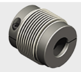
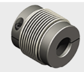
- Lost motion due to backlash (as given)
- Lost motion due to torsional stiffness (applied torque/torsional stiffness)

In this example, we look at the total lost motion in GAM inline gearboxes (refer to Table 1). We use the maximum acceleration torque for each gearbox as the applied torque for a “worst case” scenario. Gearboxes are shown in order of decreasing total lost motion or increasing precision. The servo couplings are all zero backlash.

The total lost motion shows directly connecting a gearbox to the driven mechanism is more precise than using a coupling, and a bellows coupling is more precise than an elastomer coupling. In addition, the helical planetary gearbox outperforms the straight planetary gearbox of similar size, despite the higher applied torque.

Lost motion combines the effect of backlash and torsional stiffness on the precision of a gearbox system. It can be used as a factor in comparing and select the best motion control system for an application when precision is critical.

Table 1: Lost motion at Maximum Acceleration Torque

Gearbox							
		Staight Tooth Planetary			Helical Tooth Planetary		Robotic Planetary
Gearbox Output		Shaft	Shaft	Flange	Coupling	Flange	Flange
Coupling		 Elastomer	 Bellows	None	 Bellows	None	None
Applied Torque	Nm	100	100	100	375	375	625
TOTAL LOST MOTION	arcmin	119.3	32.4	24.1	20.8	5.6	1.6
	degrees	2.0	0.54	0.40	0.35	0.09	0.03

Total Cost of Ownership

One of the goals in machine design is optimizing the total cost for the builder and for their customers. For mechanical motion control, selecting the proper components goes beyond just speed and torque. Over-designing the components can result in unnecessary cost to the builder. On the other hand, under-designing can result in components that do not meet performance requirement or fail prematurely, incurring unnecessary expenses for the end user.

In order to optimize component selection in line with total cost of ownership, keep in mind the following considerations:

- Does the component meet the basic performance requirements of the machine for:
  - Precision level
  - Torque and speed
  - Cost
- Will the components meet the required design life?
  - What is the life rating? The two main components that affect gearbox life are gears and bearings.
  - What is the duty cycle? A continuous running gearbox requires different sizing than the intermittent operation of a servo application.
  - What is the cycle time? More than 1000 cycles/hour may require the application of a service factor
  - Will there be impact loads or e-stops? If not considered, these may decrease the design life.
- Are there opportunities to eliminate components to reduce overall cost and improve system stiffness? For example, use:
  - A hollow output gearbox that mounts directly to a shaft, eliminating the need for a coupling.
  - A linear slide kit to securely connect a servo motor direct driving a linear slide, eliminating the need to mount the motor to a base or bracket.
  - A distance or line shaft coupling to drive multiple components, eliminating the need for external bearings and the brackets or housing to mount them.

- Consider maintenance over the life of the components
  - A component lubricated for life does not require the disruption of shut down to add grease.
  - Some zero-backlash gearboxes require periodic adjustment to maintain backlash. Using a gearbox such as the GAM GPL zero-backlash planetary maintains lifetime zero-backlash.

- Consider the true cost of replacement
  - Machine shut-down time
  - Loss of production

Advantages of Single Sourcing
Minimizing the number of suppliers is always a goal for manufacturers. When designing a motion control system, there are even more advantages to a single source for the mechanical drive components.

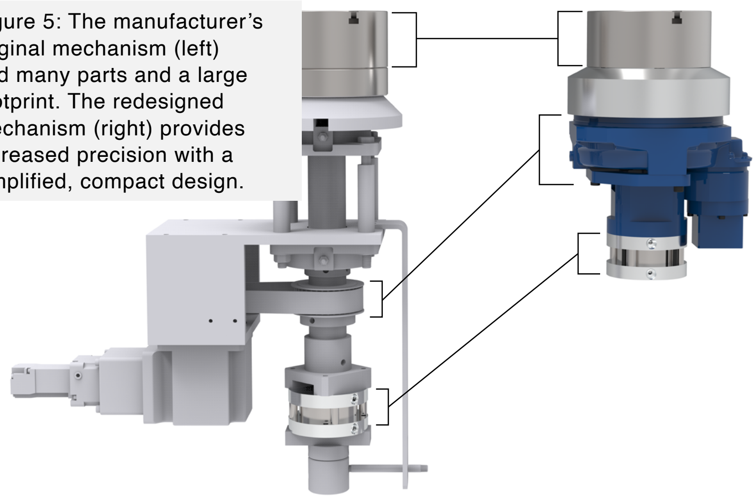
A single supplier takes ownership of the overall design, selecting the best possible components that work together and are optimized for the application. In some cases, the supplier's engineering expertise can improve the overall design. In addition, components can be supplied as subassemblies, saving time in final assembly.

From design through assembly and operation, the single supplier has ownership of the entire design including form, fit and function.

Single sourcing can:

- Reduce the number of purchase orders to track along with decreasing freight costs
- Avoid the situation of different suppliers blaming each other in the case of failure. A single source takes responsibility for the system.
- Reduce the possibility of design errors between mating the components. A single source is familiar with all the parts of the system and can size and select the best components for the application.

Figure 5: The manufacturer's original mechanism (left) had many parts and a large footprint. The redesigned mechanism (right) provides increased precision with a simplified, compact design.



Application Example:
Here is an example of a redesign that eliminated a number of components used in the original design.

A manufacturer came to GAM for a replacement right angle gearbox. The existing design had the gearbox rotating a chuck via a belt and pulley system. A second system was mounted remotely to open and close the jaws of the chuck (figure 5, left).

Before simply replacing the right angle gearbox, GAM engineers reviewed the whole system and proposed a new design. They replaced the drive system with a GAM GPL zero-backlash robotic gearbox (figure 5, right) with a direct connection to the chuck. Taking advantage of the through hole in the GPL, they designed a simple adapter to mount the air cylinder. To further simplify the assembly, the customer's chuck was sent to GAM for mounting to the gearbox.

Conclusion
When specifying the mechanical drive train in a servo motion control system, it's easy to select components based on torque and backlash requirements. However, looking at some additional considerations can improve the overall system, saving cost and optimizing performance.

Section 2. Beyond Backlash: Total Lost Motion in Gearboxes and Couplings

An application employing a servo motor for motion control will have specific requirements for performance and precision. The basic measurement for precision is backlash, but understanding of additional measurements can improve overall machine precision.

- **Backlash**: Movement in the output shaft position relative to the input shaft when the input is fixed. It is caused by clearance or play in the gears.
- **Torsional Stiffness**: Twisting angle due to external forces, "wind up" in the gearbox or coupling. It is a function of the overall rigidity of the gearbox.
- **Lost Motion**: Combination of backlash and torsional stiffness and is dependent on the applied torque.

In addition, these components of precision can stack up across components such as a drive using a gearbox with a coupling connection at the output. The backlash, stiffness, and lost motion of each component add up to the overall precision. Eliminating or improving a component can reduce the stack up of lost motion and improve precision.

We can compare mechanical motion control systems (gearboxes and couplings) by looking at the total lost motion at a specific torque including:

- Lost motion due to backlash
- Lost motion due to torsional stiffness

Next, we can look at several gearbox comparisons.

Total Lost Motion Calculation

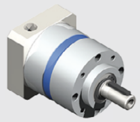
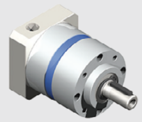
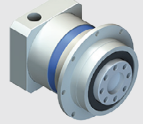
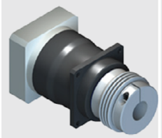
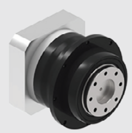
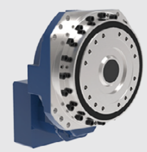
Total Lost Motion is measured as an angle (usually arcminutes) and a combination of backlash and torsional stiffness

$$\text{Total Lost Motion} = \text{Gearbox Backlash} + \frac{\text{Applied Torque}}{\text{Gearbox Torsional Stiffness}} + \text{Coupling Backlash} + \frac{\text{Applied Torque}}{\text{Coupling Torsional Stiffness}}$$

Where

- Backlash (arcmin) and Torsional Stiffness/ Resistance (Nm/arcmin) are provided by the gearbox manufacturer.
- Applied Torque (Nm) is the torque demand of the application.

TABLE 1. LOST MOTION AT MAXIMUM ACCELERATION TORQUE

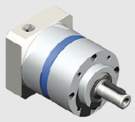
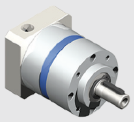
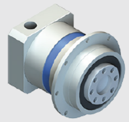
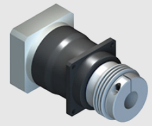
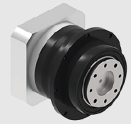
GEARBOX / COUPLING SELECTED							
Gearbox		EPL-W-084 	EPL-W-084 	EPL-F-090 	SPH-C-100 	SPH-F-100 	GPL-F-056 
Coupling at Output		EKM-150 	KLC-125 	Direct Connection	Integral 	Direct Connection	Direct Connection
GEARBOX DATA							
Gearing type		Straight Planetary			Helical Planetary		Robotic Planetary
Ratio		5:1	5:1	5:1	5:1	5:1	50:1
Frame size	mm	84	84	90	100	100	180
Torsional Stiffness	Nm/arcmin	7.1	7.1	7.1	20	82	165
COUPLING DATA							
Coupling Type		Elastomer	Bellows	-	Bellows	-	-
Torsional Resistance	Nm/arcmin	1.05	12	-	*Included with Gearbox*	-	-
APPLICATION DATA							
Applied Torque	Nm	100	100	100	375	375	625
LOST MOTION AT APPLIED TORQUE DUE TO:							
Gearbox backlash	arcmin	10	10	10	2.0	1.0	0.1
Gearbox Torsional Stiffness	arcmin	14.1	14.1	14.1	18.8	4.6	1.5
Coupling Torsional Resistance	arcmin	95.2	8.3	-	-	-	-
TOTAL LOST MOTION	arcmin	**119.3**	**32.4**	**24.1**	**20.8**	**5.6**	**1.6**
	degrees	**2.0**	**0.54**	**0.40**	**0.35**	**0.09**	**0.03**

1. Lost Motion Shows Performance of Different Gearboxes

In Table 1, we look at the total lost motion in GAM inline gearboxes. We use the maximum acceleration torque for each gearbox as the applied torque for a “worst case” scenario. Gearboxes are shown in order of decreasing total lost motion or increasing precision. The servo couplings are all zero backlash.

Looking at the total lost motion for each gearbox or gearbox and coupling, we can see that directly connecting a gearbox to the driven mechanism is more precise than using a coupling, and a bellows coupling is more precise that an elastomer coupling. In addition, the helical planetary gearbox outperforms the straight planetary gearbox of similar size, despite the higher applied torque.

TABLE 2. LOST MOTION AT A SET TORQUE

GEARBOX / COUPLING SELECTED						
Gearbox		EPL-W-084 	EPL-W-084 	EPL-F-090 	SPH-C-100 	SPH-F-100 
Coupling at Output		EKM-150 	KLC-125 	Direct Connection	Integral 	Direct Connection
GEARBOX DATA						
Gearing type		Straight Planetary			Helical Planetary	
Ratio		5:1	5:1	5:1	5:1	5:1
Frame size	mm	84	84	90	100	100
Torsional Stiffness	Nm/arcmin	7.1	7.1	7.1	20	82
COUPLING DATA						
Coupling Used at Output		Elastomer	Bellows	-	Bellows	-
Torsional Resistance	Nm/arcmin	1.05	12	-	*Included with Gearbox*	-
APPLICATION DATA						
Applied Torque	Nm	100	100	100	100	100
LOST MOTION AT APPLIED TORQUE DUE TO:						
Gearbox backlash	arcmin	10	10	10	2.0	1.0
Gearbox Torsional Stiffness	arcmin	14.1	14.1	14.1	5.0	1.2
Coupling Torsional Resistance	arcmin	95.2	8.3	-	-	-
TOTAL LOST MOTION	**arcmin**	**119.3**	**32.4**	**24.1**	**7.5**	**2.2**
	degrees	**2.0**	**0.54**	**0.40**	**0.13**	**0.04**

2. Comparing Gearboxes Using Lost Motion
Next, we compare the inline servo gearboxes at the same torque (100 Nm). In this case, the SPH helical planetary gearbox outperforms an EPL straight gear planetary gearbox of a similar frame size (Table 2)

Inline Gearing Technology

Gearing Type	Gearbox type	Advantages
Straight Planetary	Servo	High precision, best value, many options, easily customized
Helical Planetary	Servo	Highest precision servo gearbox, quiet operation
Robotic Planetary	Robotic	Zero backlash for the life of the gearbox, vibration-free operation
Strain Wave (Harmonic)	Robotic	Zero backlash with high ratios in a small, compact gearbox

Gearing technologies each have their own advantage beyond precision.

3. Looking Beyond Backlash

Looking at gear technologies, zero-backlash robotic gearboxes can seem like the obvious choice for precision motion control. But not all zero-backlash is the same. In Table 3, we compare the SPH helical planetary gearbox with the GSL strain wave (harmonic) gearbox. While strain wave gearing provides zero-backlash, it has lower torsional stiffness and may result in greater lost motion than a helical planetary gearbox.

TABLE 3. USING TOTAL LOST MOTION TO COMPARE GEARING TECHNOLOGIES

GEARBOX DATA					
Gearbox		SPH-F-075 	SPH-F-100 	GSL-HS-A-020 	GSL-HS-A-025 
Gearing type		Helical Planetary		Strain Wave (Harmonic)	
Ratio		50:1	50:1	50:1	50:1
Frame size (dia.)	mm	75	100	90	110
Torsional Stiffness	Nm/arcmin	30	74	4.9	9.2
APPLICATION DATA					
Applied Torque	Nm	35	35	35	35
LOST MOTION AT APPLIED TORQUE DUE TO:					
Backlash	arcmin	2.0	1.0	0.5	0.5
Torsional Stiffness	arcmin	1.2	.5	7.2	3.8
TOTAL LOST MOTION	**arcmin**	**3.2**	**1.5**	**7.7**	**4.3**
	degrees	**0.05**	**0.02**	**0.13**	**0.07**

The lost motion in a strain wave gearbox is not always a factor in an application. These gearboxes have the advantage of providing high ratios in a compact package. When applying strain wave gearboxes, lost motion comes into play during acceleration or with an overhung load.

Conclusion

Lost motion combines the effect of backlash and torsional stiffness on the precision of a gearbox system. It can be used as a factor in comparing and select the best motion control system for an application when precision is critical. ●

Section 3. Accuracy in Gearboxes and Couplings

When looking at gearbox accuracy, there are a number of key parameters to consider. Knowing these parameters and understanding what impact they have on accuracy is critical to designing a system that meets specifications and achieves optimal performance.

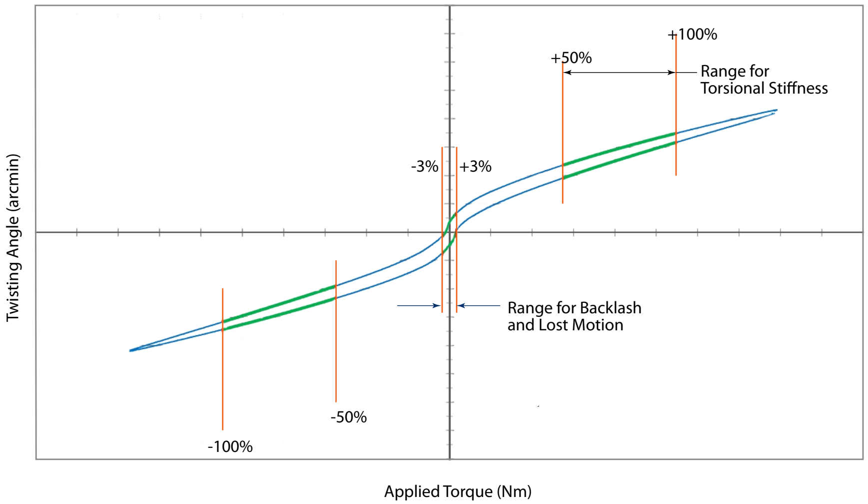
Below is a detailed look at each of these key parameters.

Torsional Stiffness

What is it? The torsional stiffness is defined as the quotient of the externally applied torque and the resulting twisting angle or "wind up" at the output of the gearbox. The value for torsional stiffness is typically given by the manufacturer. It is measured as torque per angle (Nm/arcmin). For couplings, it may be referred to as torsional resistance.

How is it determined? To determine the torsional stiffness, the gearbox is loaded with a continuously increasing torque up to the nominal torque capacity while the input shaft is locked. This is repeated in the opposite direction. The applied torque and angle of deflection at the output flange are measured (see the hysteresis curve, figure 6).

FIGURE 6.
GEARBOX HYSTERESIS CURVE FOR ±100% NOMINAL TORQUE



Torsional stiffness is taken from the slope of the hysteresis curve at 50% to 100% of the nominal torque. Because the curve is relatively flat in this range, the torsional stiffness is close to constant. In addition, many applications have an applied torque that falls in this range.

Similarly, you can look at torsional stiffness in other components. In couplings, it is often referred to as "torsional resistance."

$$\text{Torsional Stiffness} = \frac{\text{Applied Torque}}{\text{Deflection at output at 50\% to 100\% of Nominal Torque}}$$

How can I use it? Torsional stiffness for a system is calculated using the sum of the inverse of torsional stiffness for each component. Total torsional stiffness will be less than any of the individual components.

$$\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_2} + \ldots + \frac{1}{C_n}$$

For example:
EPL-W-064 10:1 Gearbox........ C=1.3 Nm/arcmin
EKM-15 Coupling.................... C=0.24 Nm/arcmin

$$\frac{1}{C_{total}} = \frac{1}{1.3} + \frac{1}{0.24} = 4.94 \longrightarrow C_{total} = 0.20\ Nm/arcmin$$

Backlash

What is it? Torsional backlash is the error of the output shaft position in relation to the input shaft at zero torque. In a gearbox it is primarily clearance between the mating gear teeth.

How is determined? The measurement of backlash is done by rotating the output of a gearbox in both directions with the input shaft locked. The torsional backlash can also be observed in the hysteresis curve at 0 Nm of torque.

Backlash = Maximum deflection - Minimim deflection at 0 Nm of torque

How can I use it? Backlash is used to determine the precision of a gearbox. The lower the backlash, the better the precision. It can be combined with torsional stiffness to determine the total lost motion of an application.

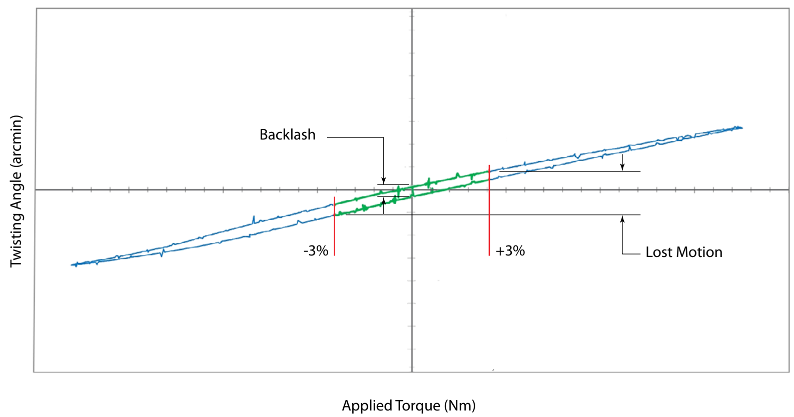
Lost Motion

What is it? Lost Motion, also called positioning error, is the deflection resulting from internal gearbox forces. In a gearbox, it can be caused by settling in the components, such as bearings, and torsional deflection of the components. It is a combination of backlash and torsional stiffness. It is measured as an angle (arcmin).

How is it determined? Similar to torsional stiffness, the gearbox is loaded with a continuously increasing torque up to the nominal torque capacity while the input shaft is locked. This is repeated in the opposite direction. The resulting twisting angle is measured at +/-3% of nominal torque. However, . In most cases it is calculated for a specific torque rather than being a published value.

Lost Motion = Maximum deflection - Minimim deflection at +/-3% of nominal torque

FIGURE 7. GEARBOX HYSTERESIS CURVE (detail of ±3% of Nominal Torque)



How can I use it? Practically, total lost motion can be calculated for an application by summing lost motion due to backlash and lost motion due to torsional stiffness at a specific applied torque.

Total lost motion can be calculated for each component and summed to get the total lost motion for the system.

$$\text{Total Lost Motion at applied torque} = \text{Backlash} + \frac{\text{Applied Torque}}{\text{Torsional Stiffness}}$$

Angular Transmission Accuracy

What is it? The angular transmission accuracy defines the maximum transmission error (maximum amplitude of the variation) of the actual output position relative to the theoretical output position according to the ratio. It is the error during motion (as opposed to the end points) and looks at how close the motion is to the theoretical perfection motion. It is measured as an angle (arcsec).

How is it measured? To measure angular transmission accuracy, the gearbox is rotated without load. The input and output positions are recorded. This is done multiple times in each direction. The range of error over a full revolution of the output is the angular transmission accuracy.

Angular Transmission Accuracy =
Maximum position variation - Minimum position variation

How can I use it? Angular transmission accuracy becomes a factor when an application requires precision during the rotation rather than just end-to-end. For example, a gearbox rotates a part while a robot performs an operation on it. With high angular transmission accuracy, the gearbox can provide continuous coordinated motion with the robot.

Accuracy and Repeatability

Positioning precision is determined by the accuracy and repeatability of the mechanism such as a gearbox.

Positioning Accuracy

The positioning accuracy is determined by the difference between the target position and the actual position. It is influenced by angular transmission accuracy, backlash, and torsional stiffness.

For torque ≤ 3% nominal torque:
Positional Accuracy =
Angular transmission accuracy + Backlash

For torque > 3% nominal torque:
Positional Accuracy =

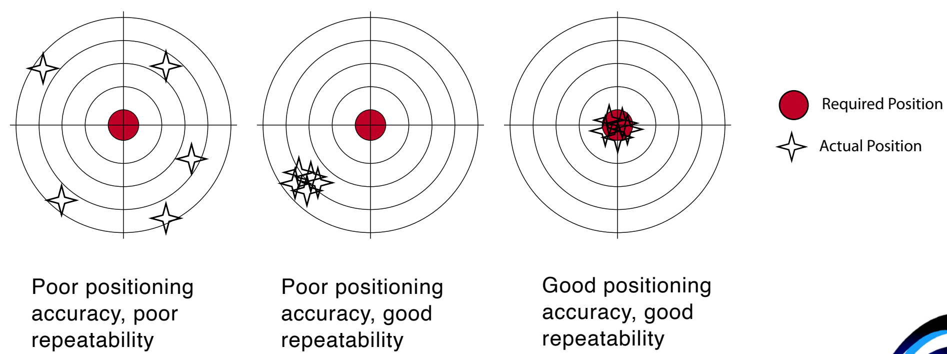
$$\text{Angular Transmission Accuracy} + \frac{\text{Applied Torque}}{\text{Torsional Stiffness}}$$

For torque (T) = 0 Nm, Repeatability = backlash
For torque (T) ≥ 0 Nm, Repeatability ≤ lost motion

Positioning Repeatability

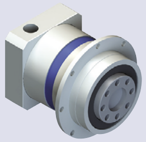
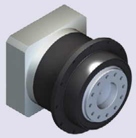
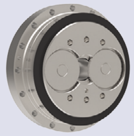
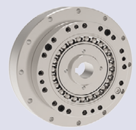
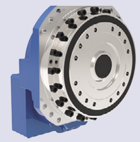
Repeatability refers to the deviation when the gearbox is repeatedly turned to the same position under the same load.

In the repeatability, the errors from the angular transmission accuracy and the torsional stiffness are constant, so that any deviation is solely the result of lost motion.



Section 4. Zero-Backlash & Robotic Flange Selection Guide

INCREASING PRECISION - DECREASING BACKLASH

	Planetary EPL	Helical Planetary SPH	Cycloidal GCL	Strain Wave GSL	Robotic Planetary GPL
Gearbox	 Precision Inline for general servo applications	 High precision inline for demanding servo applications	 Zero-backlash cycloidal Available with integral pre-stage	 Zero-backlash strain wave with high torque density and small, lightweight design for easy integration	 Zero-backlash planetary with the lowest backlash. Vibration-free for high positional accuracy.
Gearbox Type	Servo	Servo	Zero-Backlash Robotic Flange	Zero-Backlash Robotic Flange	Zero-Backlash Robotic Flange
Features	Easily customizeable	Precision Inline	Impact Resistance 5x nominal torque. Precision positioning and point-to-point motion	Small, lightweight design	High precision during motion Unique, revolutionary design maintains lifetime zero-backlash
Advantages	Shaft, hollow or flange output Very high ratio	Quiet operation	Available with integral pre-stage for higher ratios	Quiet operation Easy integration	Very high precision Quiet opration Smooth, vibration-free motion
Applications	Servo	Servo	Zero-Backlash	Zero-Backlash	Zero-Backlash
Backlash	≤ 8-20 arcmin	≤ 1 - 3 arcmin	≤1 arcmin	≤0.5 arcmin (≤30 arcsec)	≤0.1 arcmin (≤6 arcsec)
Ratio:	3:1 - 1000:1	3:1 - 1000:1	57:1 - 258:1 Integral pre-stage option for additional ratio	50:1 - 160:1	50:1 - 200:1 Integral pre-stage option for additional ratio
Service Life	30,000 hours	20,000 hours	6000 hours	7000-15,000 hours	20,000 hours
Torque Range (Nm)	**Model**	**Model**	**Model**	**Model**	**Model**
0 - 50	EPL-F-047 / 064			GSL-CS-014 / 017 GSL-HS-014 to 040	
51 -250	EPL-F-090 / 110	SPH-F-075 / 100	GCL-F-020	GSL-CS-020 to 032	
251 - 1000	EPL-F-140	SPH-F-140	GCL-F-040 / 080		GPL-F-056 / 080
1001 - 2500			GCL-F-110 / 160		GPL-F-112 / 160 / 224
2501 - 5000			GCLC-F-320 / 450		GPL-F-300 / 400

Most gear manufacturers carry a wide assortment of gearing products to accommodate a range of application needs. From robotics and automation to applications in health care and medical devices, gearing components play a key role in attaining accurate, smooth motion.

GAM offers a full range of gearboxes from planetary servo gearboxes through zero-backlash robotic gearboxes for a wide variety of applications. A sampling of those offerings is seen in the selection guide to the left. ●

GAM

GAM, a U.S. company, is your complete source for robotic and servo gear reducers, rack & pinion systems, servo couplings, linear mounting kits, and other precision mechanical drive solutions used in automation technology.

With one of the largest product offerings in the motion control industry as well as the engineering expertise and manufacturing capabilities to develop customized solutions, GAM can help with your application.

U.S. manufacturing, being flexible to meet the needs of customer requests, and great service are what set us apart from the rest.

GAM Can.