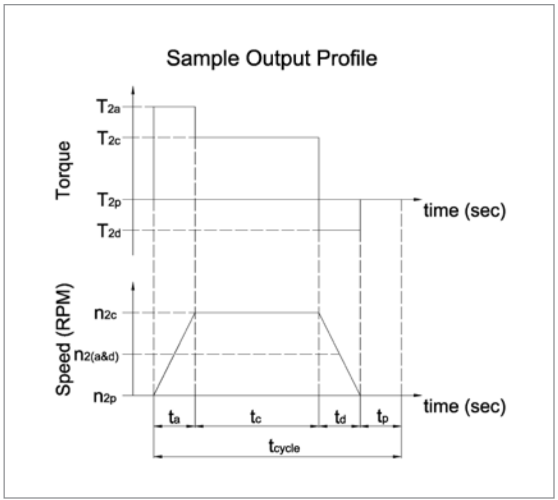
Determination of the Duty Cycle (ED)



$$ED = \frac{t_a + t_c + t_d}{t_{cycle}}$$

If ED < 60% and $(t_a + t_c + t_d) < 20$ minutes, perform a cycle operation selection (S5)

If ED > 60% or $(t_a + t_c + t_d) > 20$ minutes, perform a continuous operation selection (S1)

Index	
1	Input
2	Output
a	Acceleration
B	Maximum Acceleration
c	Constant
d	Deceleration
m	Mean
max	Maximum
n	Nominal
p	Pause

Symbol	Unit	Description
ED	%	Duty Cycle
fs	-	Shock Factor
i	-	Ratio
J	kg-cm2	Moment of Inertia
n	RPM	Speed
t	s	Time
T	Nm	Torque
Zh	-	Number of Cycles
η	%	Efficiency

Selection of Optimum Gearbox for a Continuous Operation (S1)

Data needed before selection can be performed:

1. Output profile
2. Desired ratio (i)

Calculations to be performed:

1. Mean Output Speed

$$n_{2m} = \frac{n_{2a}t_a + n_{2c}t_c + n_{2d}t_d}{t_a + t_c + t_d} = \_\_\_\_\_\_$$

2. Root – Mean Output Torque

$$T_{2m} = \sqrt[3]{\frac{n_{2a}t_aT_{2a}^3 + n_{2c}t_cT_{2c}^3 + n_{2d}t_dT_{2d}^3}{n_{2a}t_a + n_{2c}t_c + n_{2d}t_d}} = \_\_\_\_\_\_$$

Selection Criteria for Gearbox:

1. Mean Output Speed must not exceed the nominal speed rating of the gearbox.

   $n_{2m}\, i \leq n_{1n}$

2. Mean Output Torque must not exceed the nominal torque rating of the gearbox.

   $T_{2m} \leq T_{2n}$

See technical data tables for values of n_{1n} and T_{2n}

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Selection of Optimum Gearbox for a Cycle Operation (S5)

Data needed before selection can be performed:

1. Maximum Torque of the motor (T_{1B})
2. Output profile
3. Desired ratio (i)
4. Inertia of the load (J_L)*
5. Inertia of the motor (J_{motor})*

*optional

Calculation to be performed:

1. Shock Factor (fs)

$$Zh = \frac{3600}{t_{cycle}}$$

		Zh	<	1000	=>	fs = 1.0
1000	<	Zh	<	1500	=>	fs = 1.1
1500	<	Zh	<	2000	=>	fs = 1.3
2000	<	Zh	<	3000	=>	fs = 1.6
3000	<	Zh	<		=>	fs = 2.0

2. Maximum Output Torque

$T_{2max} = T_{1B}\ i\ fs\ \eta =$ ____________________

Selection Criteria for Gearbox:

1. Maximum Output Speed must not exceed the maximum speed rating of the gearbox. $n_{2c}\ i \leq n_{1max}$
2. Maximum Output Torque must not exceed the maximum torque rating of the gearbox. $T_{2max} \leq T_{2B}$
3. (optional) Match inertia of the motor to the inertia of the load. $J_{motor} \approx J_1 + \frac{J_L}{i^2}$

See technical data tables for values of η, n_{1max}, T_{2B}, and J_1

Sizing and Selecting for Couplings and Safety Couplings

Sizing

1. Determine torque (M_N)

$$M_N = M_a \frac{J_{load}}{J_{load} + J_{drive}} 2.5$$

M_N	Nominal Torque of Coupling
M_a	Acceleration Torque of Motor
C	
f	Resonant frequency [Hz]
J_{mot}	Motor inertia + 1/2 coupling inertia [kgm²]
J_{moch}	Load inertia + 1/2 coupling inertia [kgm²]

In general $f_{coupling} \geq 2\ f_{drive}$

2. Verify resonant frequency

$$f_{coupling} = \sqrt{C_{coupling}}$$

$$f_{drive} = \frac{1}{2\pi} \sqrt{C_{drive} \cdot \frac{(J_{drive} + J_{load})}{(J_{load}\ J_{load})}}$$

3. Apply operating temperature safety factor only for elastomer couplings

Operating Temperature	< 50°C	50°C - 70°C	70°C - 90°C	90°C - 110°C	> 110°C
Multiply M_N by	1	1.3	1.6	1.8	2

Selecting:

1. Determine series of coupling
2. Determine size of coupling based on MN
3. Verify shaft diameters are within range

Ordering Examples:

(When ordering, please include shaft sizes and tolerances)

Standard Coupling KM-20

D1 = 14 mm k6

D2 = 1.00″ +0/-.0005″, x 1/8″ keyway

Safety Coupling SKB-30

D1 = 19 mm k6

TA (disengagement torque) = 25 Nm

Drive Shaft Coupling WDS-100

D1 = .500″ +/- .0005″

D2 = 32 mm k6

Distance Between Shafts = 915 mm

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Accuracy in Gearboxes and Couplings: Definitions

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.

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.

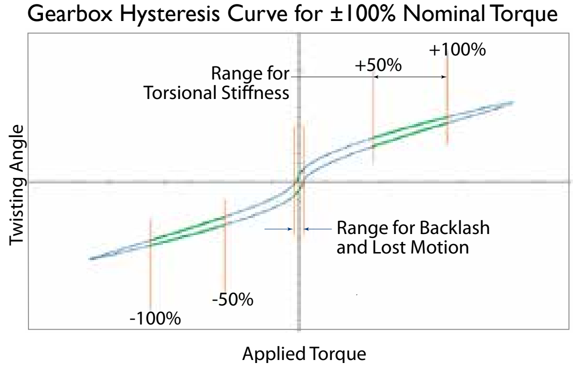
How is it determined?

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).

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."

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

Gearbox Hysteresis Curve for ±100% 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.

$$\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}$$

For example:

EPL-W-064 10:1 Gearbox .... C = 1.3 Nm/arcmin

EKM-15 Coupling .... C = 0.24 Nm/arcmin

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

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 – Minimum 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?

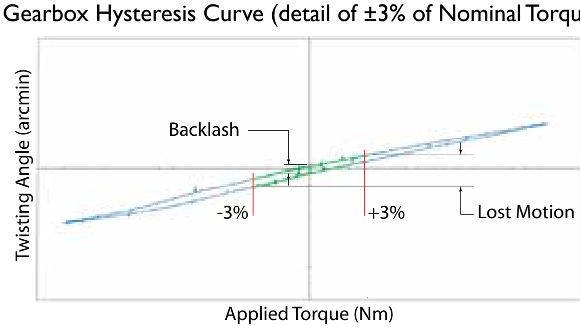
Lost Motion, also called positioning error, is the deflection resulting from internal gearbox forces. In a gearbox, it can be caused by settling in the components, such as bearings, and torsional deflection of the components. It is a combination of backlash and torsional stiffness. It is measured as 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 – Minimum deflection at +/- 3% of $T_{nominal}$

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.

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

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

Angular Transmission Accuracy

What is it?

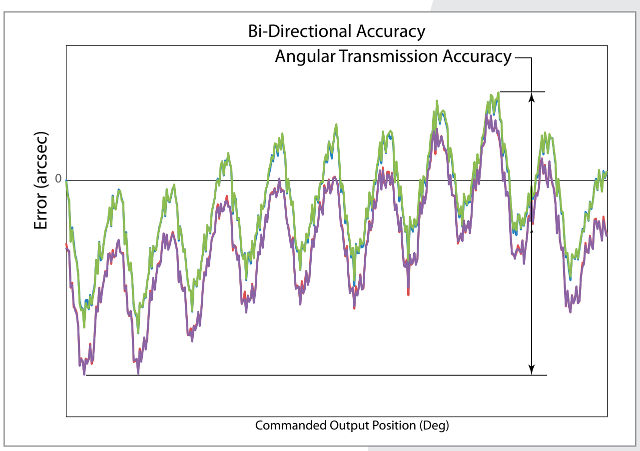
The angular transmission accuracy defines the maximum transmission error (maximum amplitude of the variation) of the actual output position relative to the theoretical output position according to the ratio. It is the error during motion (as opposed to the end points) and looks at how close the motion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

$$\text{Angular Transmission Accuracy} = \text{Maximum Position Variation} - \text{Minimum Position Variation}$$

Measurement of angular transmission accuracy



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 $\leq 3\%$ nominal torque:

$$\text{Positional Accuracy} = \text{Angular transmission accuracy} + \text{Backlash}$$

For torque $> 3\%$ nominal torque:

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

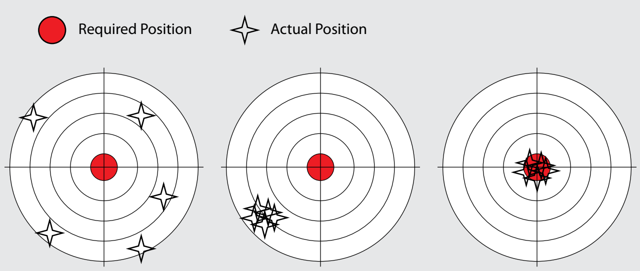
Positioning Repeatability

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.

For torque $(T) = 0$ Nm, Repeatability $=$ backlash

For torque $(T) \geq 0$ Nm, Repeatability $\leq$ lost motion



Poor positioning accuracy, poor repeatability — Poor positioning accuracy, good repeatability — Good positioning accuracy, good repeatability