1.7 Backlash

Summary of the backlash is **"play"** or **"clearance"** between one pair of gear.

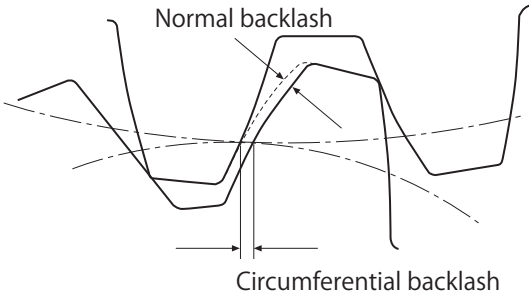

Fig. 17 Backlash

Great care is taken to produce the gear with zero deviation. However we are unable to completely eliminate deviation from manufacturing and surface heat treatment. A gear always has innate deviations of Tooth profile, Pitch, Runout, Tooth thickness and Helix by manufacturing process.
The Gearbox has innate deviation from manufacturing process. For example, shorter Centre distance compared with designed dimension, insufficient parallelism of axis or inaccurate right angle.
When starts the operation for gearbox, generation of heat from the load causes the gearbox to deform. Continuous operation increases the temperature of gearbox and thermal expansion of each part. As a result, swelling of the teeth causes oscillation, noise, sand burning and damages the tooth or bearing.

Proper backlash from the **"Play in the gears"** are necessary to absorb the deviations of noise and oscillation in order to have smooth rotation.
When assembling the gears, please provide the proper backlash between flanks.
Methods that provide the proper backlash to the gears are as follows;

1) Method to shift centre distance away. (Locating distance for Bevel gear)
This method does not provide the modification to the Tooth thickness, as it does not decrease Tooth thickness. This method simply shifts Centre distance away to obtain proper backlash to flanks.

2) Method of deeper cut during gear cutting process.
This method provides a deeper cut to reduce Tooth thickness when manufacturing the gear. Proper backlash is obtained if the gears are assembled with designated Centre distance.

Backlash for KG-STOCK GEARS

KG STOCK GEARS has been using method 2) from previous page. This method gives a proper backlash when assembled with designated centre distance of gearbox without adjustments.
Refer to the below references 11 to 13 for amount of backlash when assembling a pair of KG STOCK GEARS with designated centre distance.

Table 11. Amount of backlash for KG Spur gear (engagement of one pair with same material)

Module (m)	Materials	Amount of backlash (mm)
Range below m=0.9 is 0.02 - 0.06		
Range from m=0.9 to m=3.0	D, SU, BS	$0.06 \times m - 0.12 \times m$
	S	$0.04 \times m - 0.10 \times m$
	SC*M*	$0.04 \times m - 0.08 \times m$
Range from m=3 to m=5	S	$0.06 \times m - 0.12 \times m$

D: Polyacetal, SU: Stainless steel, S: Carbon steel, BS: Brass
SCM: Chromium molybdenum steel (Ground spur gear)

Table 12. Amount of backlash of Worm gear pair range from m 1.0 and above (one pair of engagement)

Centre distance	Amount of backlash (mm)
Range below m=0.8 is 0.06 - 0.15	
Below 50	0.08 – 0.20
Range from 50 to 150	0.15 – 0.30
Range from 150 to 300	0.30 – 0.50

Range below m=0.8, is 0.06 - 0.15(mm)

Table 13. Backlash of Bevel gear (one pair of gear engagement)

Module (m)	Backlash (mm)	
	SCM, S, SU, BS	D
Range below m=0.9	0.02-0.08	0.03-0.10
Range from m=0.9 to m=2.0	0.05-0.12	0.05-0.16
Range from m=2 to m=4	0.06-0.15	-
Range from m=4 to m=6	0.08-0.20	-
Range from m=6 to m=7	0.10-0.22	-

SU: Stainless steel, S: Carbon steel, SCM: Chromium molybdenum steel, D: Polyacetal

Measurement of the backlash

(1) Spur and Helical gears

There are a number of methods to measure the backlash for Spur and Helical gears.
Introduced are two (2) methods of measurement as follows;

a) Circumferential backlash j_t

Assemble one pair of gear with designated centre distance, fix one side of gear, put an indicator (Dial gauge) to Pitch circle of Mating gear and turn gear to the left and right to measure the amount of backlash. For Helical gear, measure backlash on the Pitch circumference at right angle section to axis.
In JIS, this is called the Circumferential backlash. Circumferential backlash for **Spur and Helical gears is stipulated in JIS B 1703.**

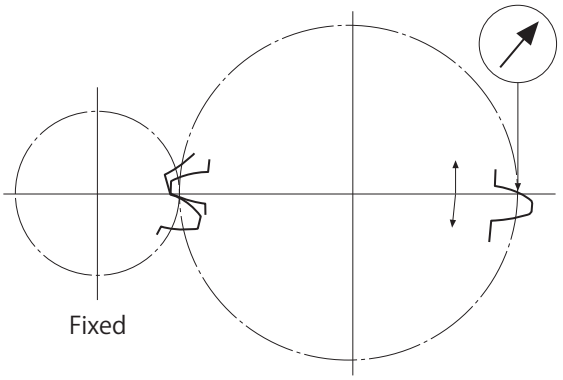

Fig. 18 Measurement of Circumferential backlash

b) Backlash j_n in perpendicular direction to flank.

Method of placinging indicatior perpendicularly to flank then follow same procedure in a).
In addition, another method is by putting a soft metal, eg. lead, between Flanks to measure the flattened metal thickness by a micrometer. This method of measurement may show different results compared with the method of simply using indicator to Flank because it is under the influence of play from bearing or other part's tolerance deviation. This method is called Normal backlash in JIS.

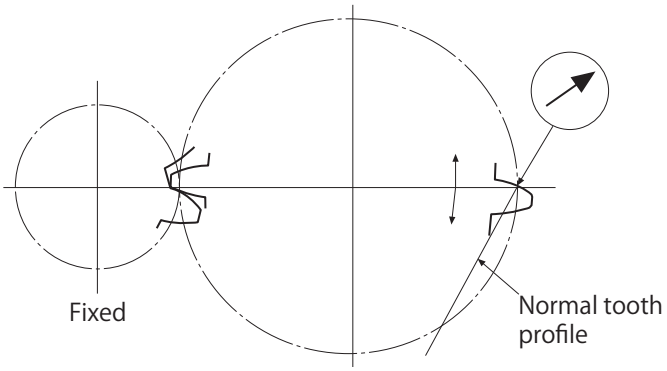

Fig. 19 Measurement of Normal backlash

For Spur gear with Pressure angle α, it has the following relationship between j_t and j_n .

$$j_n = j_t \cos\alpha \qquad j_t = j_n / \cos\alpha$$

When α is 20°, cosine 20° = 0.93969, j_t and j_n have similar value.

For Helical gear, an indicator is placed perpendicularly to the helixes of tooth for measurement. When Normal pressure angle is α_n and a helix angle is β,the relationship between j_t and j_n are as follows.

$$j_n = j_t \cos\alpha_n \cos\beta \qquad j_t = j_n / \cos\alpha_n \cos\beta$$

To measure backlash for Crossed helical gear pair (Screw gear) with indicator, fix either Pinion or Gear. When using either Pinion or Gear with Non-parallel and Non-intersecting axis, the reading on the indicator depends on which is chosen to be fixed. Usually Pinion is fixed and indicator is placed to flank of gear.

(2) Bevel gear

To Measure the backlash for Bevel gear pair, there are two (2) types of measurements. Circumferential backlash j_t and normal backlash j_n, which is the same for Spur and Helical gears.

Fix the pinion and put an indicator to outer gear to measure.

Normal pressure angle α_n and centre (mean) gear tooth of helix angle β_m of Spiral bevel gear have the following relationship between j_t and j_n.

$$j_n = j_t \cos\alpha_n \cos\beta_m \qquad j_t = j_n / \cos\alpha_n \cos\beta_m$$

(The above calculation formula is for Spiral bevel gear. For Straight bevel gear, it is $\text{cosine}\,\beta_m = 1$)

Circumferential backlash for **Bevel gear pair is stipulated in JIS B 1705.**

In addition to this, there is another method to assemble the Bevel gear with a designated Locating distance. Fix a gear and move the Pinion in axis direction. Measure the amount of movement with an indicator.

Bevel gear has the following relationship between Circumferential backlash j_t and Locating direction j_x.

$j_x = j_t / 2 \tan\alpha_n \sin\delta_1$ Straight bevel gear

$j_x = j_{tt} / 2 \tan d_t \sin\delta_1$ Spiral bevel gear

Hereby

j_{tt}: Circumferential backlash at Transverse plane

$j_{tt} = j_t / \text{cosine}\,\alpha_t$

α_t: Transverse pressure angle $\alpha_t = \tan^{-1}(\tan\alpha_n / \cos\beta)$

For example, Straight bevel gear with Pressure angle 20° and gear ratio 1:1. Assuming that Circumferential backlash j_t is 1.0mm therefore backlash of Locating direction is 1.94mm. Which means it can measure minute backlash to about twice the accuracy.

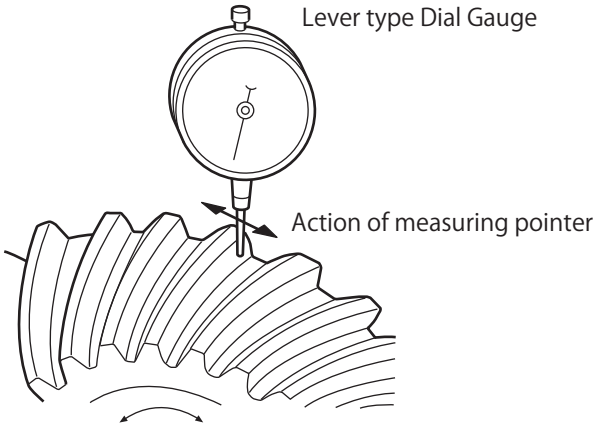

Fig. 20 Measurement method of backlash for the Bevel gear (Circumference direction)

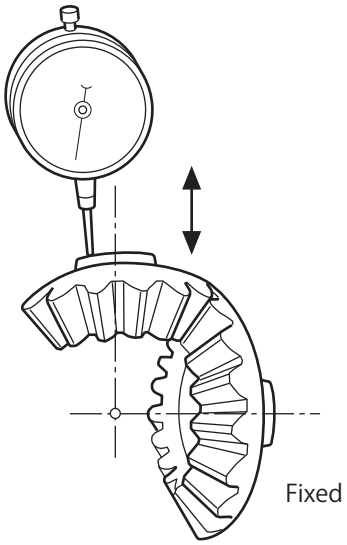

Fig. 21 Move the pinion in axis direction to measure the backlash.

(3) Backlash of Worm gear pair

Generally the Worm gear is fixed and indicator is placed to flank of Worm wheel for backlash measurement. This is the same method for both Spur and Helical gears pair.

Shown in Table 22, value for KG-Worm gear pair with assembled designated centre distance. Due to undefined backlash for Worm gear in JIS currently.

When using worm gear pair for accurate locating and positioning, it is necessary to keep backlash to a minimum. Providing large backlash for power transmission is recommend due to expansion caused by generation of heat. Even though the backlash may be larger, performance of worm gear pair will almost be the same.

Racing angle of Worm gear caused by backlash become a crucial problem occasionally.

Below is the explanation of the calculation formula for racing angle of Worm gear instead of backlash of Worm wheel.

Place an indicator to flank of Worm Wheel as show in Fig. 22 to measure circumferential backlash.

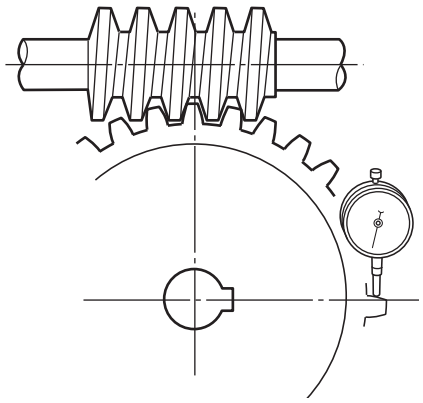

Fig. 22 Method of measurement for Worm gear pair (Circumference direction)

For example,
Module is 2.0,
Gear ratio 1：30,
Reference diameter of Worm gear is 31.0 mm,
Lead angle of Worm gear is 3°42′′ ,
Lead of Worm gear is 6.2963,
Measurement amount of Circumferential backlash is 0.2 mm.
Calculation formula is as follows.

(Lead) : (360°) = (Measured circumferential backlash) : (Racing angle of Worm gear) therefore,

$$\text{Racing angle of Worm gear} = \frac{360° \times \text{Circumferential backlash}}{\text{Lead}} = 360° \times 0.2 / 6.2963$$

$$= 11°27'$$

Worm gear provides the racing of 11°27′ .

(Lead of Worm gear : It is the distance of a point on the flank as it moves forward in axis direction when the Worm gear turns one revolution.)