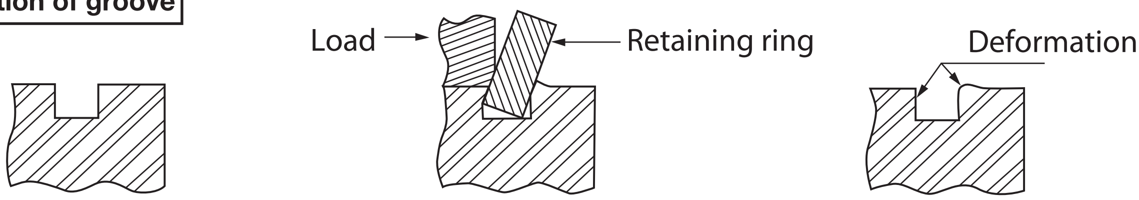
2) Calculations for Retaining Rings (Reference)

(1) Allowable Thrust Load

The allowable thrust load is a load specified when the groove is not deformed and the retaining ring is not sheared.

Deformation of groove



① Allowable Thrust Load of Retaining Ring

The allowable thrust load where static load is applied to a retaining ring can be calculated according to the following formula:

$$R_S = \frac{ADTS_S\pi}{S}$$

RS : Allowable thrust load of ring (N)
A : Shape factors of retaining rings (See Table 1)
D : Shaft diameter or housing diameter (mm)
T : Plate thickness of ring (mm)
The Beveled Rings need to allow for the plate thickness when fit since they may be fit at half of the groove depth in relation to the retained work.
π : Circumference ratio
SS : Strength in shear of ring (N/mm^2)
Basic External Ring (Carbon steel) : Approx. 980N/mm^2 as a guideline. (According to the JIS B 2804)
S : Safety factor
: General safe factors are listed in a table. (See Table 2)

Table 1

Shape factors of retaining rings (Table)

Shape of ring	A (Ring)	B (Groove)
Basic External Ring	1.0	1.0
Beveled External Ring	1.0	1.0
Basic Internal Ring	1.0	1.0
Beveled Internal Ring	1.0	1.0
Inverted Internal Ring	0.7	0.5
Inverted External Ring	0.7	0.5
E Ring	0.3	0.3
C Ring	0.5	0.5
U King	0.5	0.5
K Ring	0.5	0.5

Table 2

Guideline on safe factors (S)

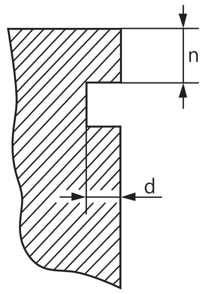
Type of load	safety factors
Static load	3 or 4
Cyclic load	5
Alternate load	8
Shock load	12

② Thrust Load of Groove

It is necessary to design the groove to obtain a sufficient thrust load of retaining ring.
It is important to set the edge margin in this design.
We recommend that the margin be set as given below to increase the through load of groove.

$$n/d \geqq 3$$

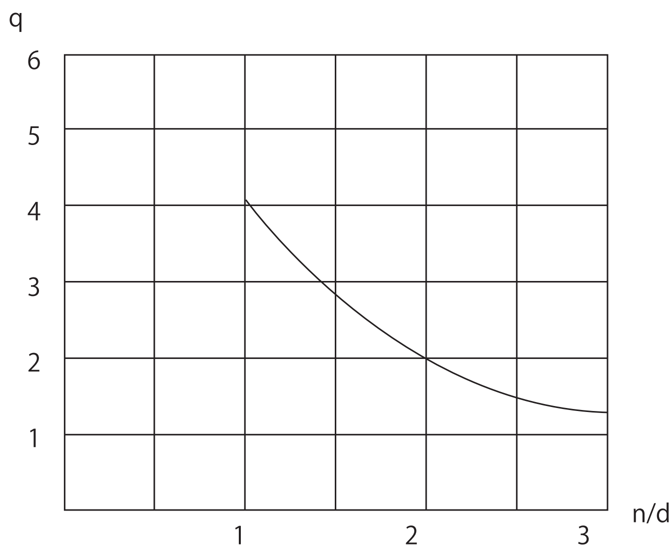
n: Edge margin (mm)
d: Depth of groove (mm)



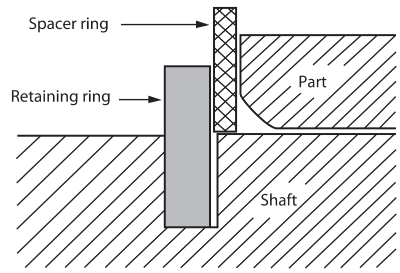
Note: If the value n/ d is less than 3, care must be taken since the thrust load in the groove is reduced.
Note: For small-sized retaining rings, the value n/d must take a value more than 3.
(Refer to for the table of ring dimension for the recommended dimension.)
If n/ d is equal or more than 3, the allowable thrust load can be calculated according to the following formula:

$$G_1 = \frac{BDdG_y\pi}{Sq}$$

G_1 : Static thrust load in groove (N)
B : Shape factor of ring (See Table 1)
D : Shaft diameter or housing diameter (mm)
d : Depth of groove (mm)
G_y : Yield strength of groove (N/mm^2)
π : Circumference ratio
S : Safety factor (See table 2)
q : Decreasing factor, a value obtained from the value n/d using the graph. However, if the value n/d is 3 or more, the value q is 1.



The above formula assumes that retained parts have sharp corners.
For retained parts having corner radii, care must be taken as the thrust load is reduced.
If the thrust load does not satisfy the requirement because of retained parts having corner radii or chamfers, the thrust load can be improved by inserting a spacer ring like a rigid flat washer in the groove.



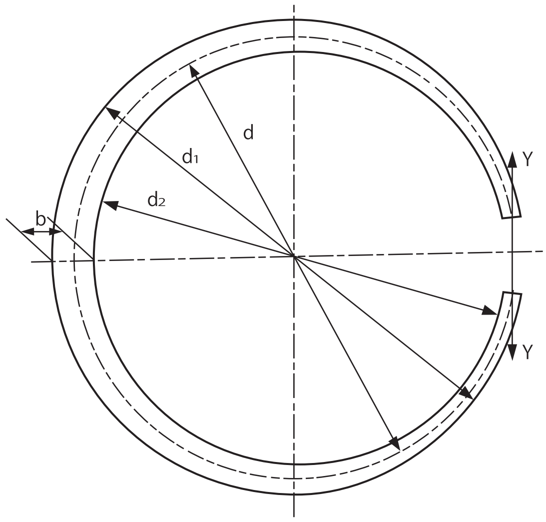
(2) Calculation of Stress

This section calculates the maximum stress where a retaining ring is fit.

Basic Ring

When the retaining ring (Basic External Ring) that is circumscribed by two eccentric circles is to be spread in the Y directions as shown in the figure:

- M : Bending moment
- E : Longitudinal elastic modulus (206000N/ mm^2)
- I : Second moment of area
- r : Average curvature radius (mm)
- ρ : Average curvature radius after change (mm)
- ξ : Rate of change
- d : Average diameter (mm)
- d_1 : Diameter of outer periphery (mm)
- d_2 : Diameter of inner periphery (mm)
- Z : Section modulus
- t : Plate thickness (mm)
- b : Maximum rim width (mm)



If the average curvature radius in the free condition is changed to ρ by spreading the ring in the Y directions as shown in the figure, this relationship is given by the following equation.

$$\frac{1}{r} - \frac{1}{\rho} = \frac{M}{EI}$$

Here, if I is the maximum second moment of area in the section having the maximum width and t is the plate thickness, the value I can be expressed as tb3/12.
In the above equation, assume that $\rho = r(1+\xi)$ (ξ : Rate of change from r to ρ).
From the equation of the maximum stress, $\sigma max = M/Z$, M is given to be $\sigma maxZ$.

From the equation of the section modulus, Z=tb2/6, substituting these relations into the above equation yields:

$$\sigma_{max} = \frac{\xi}{1+\xi} \cdot \frac{Eb}{d}$$

For the Internal Ring, assume that $\frac{1}{\rho} - \frac{1}{r} = \frac{M}{EI}$ and $\rho = r(1-\xi)$. Substituting these relations in the same manner indicates the maximum stress by following formula:

$$\sigma_{max} = \frac{\xi}{1-\xi} \cdot \frac{Eb}{d}$$

(3) Beveled Rings

① Purpose of Use

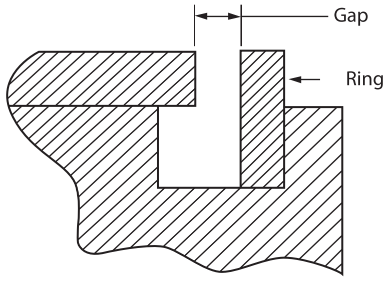


Fig. 1

When using the Basic Rings, the accuracy of machining in the groove position and variation of retained parts may cause a gap between the ring and the part to be retained resulting in looseness and unsteadiness (Fig. 1). This gap will cause abnormal sound and damage to the ring.

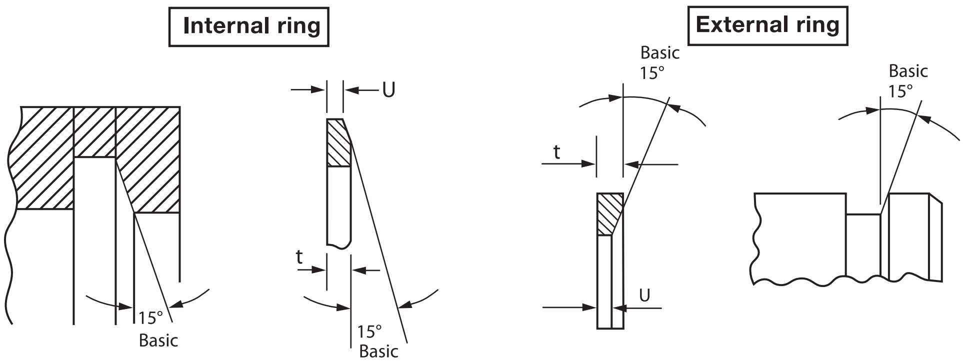
The conventional measures of eliminating looseness are as follows:

- By using the Ring with the gap adjusted by shims having a different thickness
- By using the Wave Washer or other pressurized spring
- By using the Ring that has a different plate thickness.
- By using the Bowed Ring and the like in which the ring is worked on an arched line.

However, there are limitations of a more quantity of parts, the need of a wide variety of rings and weak spring force.
Thus the Beveled Ring products are developed.

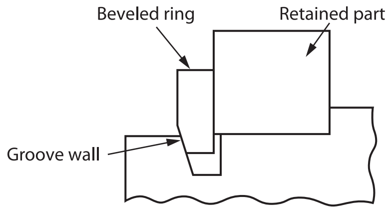
② Characteristics of the Rings

The Beveled Rings basically have the same structure with the Basic Rings. However, their ring segments to be fit in the groove have a bevel of 15 degrees differently from the basic ones.
This bevel is provided on the outer periphery for internal ring and on the inner periphery for external ring.
These rings are designed to be set in the groove that basically has a slant of 15 degrees of the groove wall supporting the load (Fig. 2).



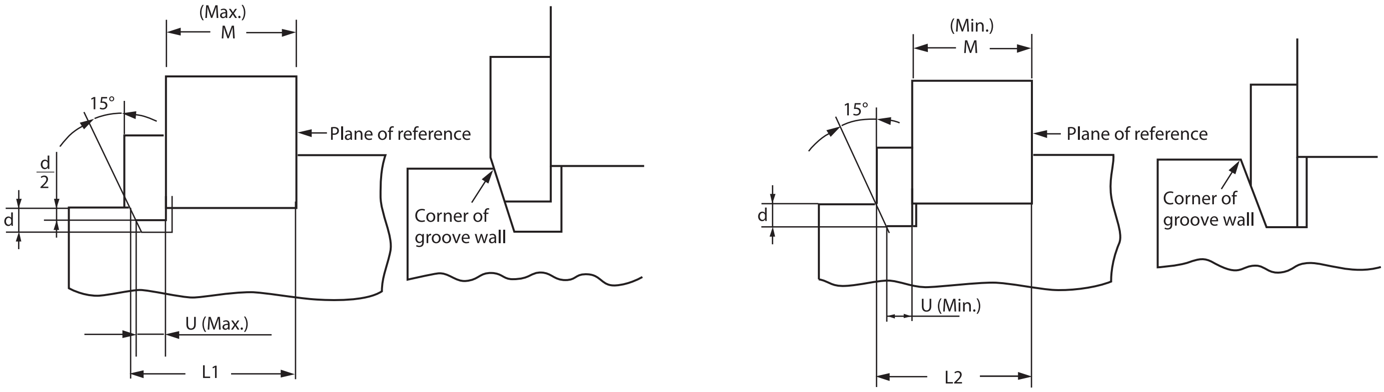
(Fig. 2)

It is necessary to keep such an area that is sufficiently in contact with the groove wall.
The Ring needs to be inserted at least half the groove width.
When the Beveled Ring is inserted in the groove, it acts as a wedge between the outer groove wall and the retained part. When there is a gap between the Ring and the adjacent face of the retained part, the spring action of the ring will correct the gap and slide it deeply into the groove (Fig. 3).



(Fig. 3)

③ Positioning of the Ring in the Groove



1) If the distance from the corner of the outer groove wall to the plane of reference is at minimum with M (Max.) and U (Max.), the ring should engage at least half the depth of the groove

$$L1 \geqq M(Max.) + U(Max.) + \frac{d}{2}\tan 15°$$

2) IIf the distance from the corner of the outer groove wall to the plane of reference is at maximum with M (Min.) and U (Min.), the ring should engage the full depth of the groove

$$L2 \leqq M(Min.) + U(Min.) + d \tan 15°$$

④ Take-up (End-play Take-up)

To allow the Ring to function properly, the ring take-up must be equal to or exceed the sum total of the tolerances.

$$\text{Take-up} = \frac{d}{2}\tan 15° \geqq \triangle L + \triangle M + \triangle U$$

$$\triangle L = L(Max.) - L(Min.)$$

$$\triangle M = M(Max.) - M(Min.)$$

$$\triangle U = U(Max.) - U(Min.)$$