

Load Capacities

Static Thrust Loads

1. ALLOWABLE THRUST LOADS - RINGS (P_r or P'_r)

Maximum allowable static thrust capacities for rings normally used with grooves are listed in the data charts for each ring type. The load limits are given for rings (P_r or P'_r) and grooves (P_g).

The values for P_r or P'_r are applicable only when the ring is installed in a housing or on a shaft made of hardened steel where the thrust load capacity of the groove is equal to or greater than that of the ring. When the ring is seated in a groove cut in softer material, and P_g is less than P_r or P'_r , P_g becomes the limiting factor in the assembly.

For maximum thrust capacity in both static and dynamic loading, the abutting face of the retained part should have a square corner. Fit of the retained part in the housing or on a shaft should allow reasonably concentric uniform loading against the ring.

Table 1: Shear Strength of Ring Material

Material	Ring Series	Ring Thickness (in.)	Shear Strength (psi)
Carbon Spring Steel (SAE 1060-1090)	HO	Up to and including .035	120,000
	SH		
	BHO		
	BSH	.042 and over	150,000
	VHO		
	VSH		
	HOI		
	SHI		
	C	.035 and over	150,000
	SHR		
	SHM		
		.020 and .025	120,000
		.035 and over	150,000
Beryllium Copper (Alloy #25 UNS C17200)	LC	All available	150,000
	RE		
	PO/POL		
	BE	.010 and .015	100,000
	E	.025	120,000
		.035 and over	150,000
	EL	All available	130,000
Beryllium Copper (Alloy #25 UNS C17200)	SH	.010 and .015 (Sizes -12 thru -23)	110,000
	BSH	.015 (Sizes -18 thru -23)	110,000
	E	.010 (Size -4 only)	95,000

When there is radial play between the retained part and the shaft or housing, such play must be treated as though the retained part had a chamfered corner. The magnitude of the chamfer should be considered equal to the play. Loading data for rings abutted by chamfered parts (P'_r) as shown in the specific ring data charts must be considered. (See CORNER RADII & CHAMFERS, page 6, right column.)

Allowable load capacities for rings (P_r) apply only to standard thickness rings made of standard materials using the shear strength values listed in Table 1, below, left.

When the following special materials are used, multiply the allowable thrust load of the ring by the conversion factor shown below.

Ring Material	Type	Rotor Clip Code	Conversion Factor All Sizes
Stainless Steel	PH 15-7Mo or equivalent AISI 632-AMS 5520	SS	1.0
Beryllium Copper*	Alloy = 25, UNS C17200	BC	0.75

* Except those noted in Table 1.

2. ALLOWABLE THRUST LOADS — GROOVES (P_g)

The allowable thrust loads listed in column P_g of the data charts for rings used in grooves are based upon a housing or shaft material of cold rolled steel with a tensile yield strength of 45,000 psi. In the case of Series VHO and VSH beveled rings, the values given are for minimum contact between ring and groove—i.e., engagement of the beveled edge of the ring with the beveled groove wall at a length equal to half of the groove depth ($d/2$).

When the following materials are used, multiply the allowable thrust load of the groove by the conversion factor shown below.

Groove Material	Tensile Yield Strength Type	Conversion Factor
Hardened Steel (RC-40)	150,000 psi	3.3
Hardened Steel (RC-50)	200,000 psi	4.45
Aluminum (2024-T4)	40,000 psi	0.89
Brass (Naval)	30,000 psi	0.66
Other	x psi	x psi/45,000

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3. CALCULATING EDGE MARGIN

The distance from the groove to the end of the shaft or housing is known as edge margin. Edge margin is a calculated distance based on the relationship between the edge margin (y) and the groove depth (d). When $y/d \geq 3$, the groove will withstand the maximum thrust load as indicated in the Rotor Clip catalog specification page for that particular size and type of retaining ring.

Example: SH-50 external retaining ring installed on a cold-rolled steel shaft. The catalog specifications for this ring call for a minimum edge margin of 0.048" and a groove depth of 0.016." Our formula is as follows:

$$y/d \geq 3 \frac{0.048''}{0.016''} = 3$$

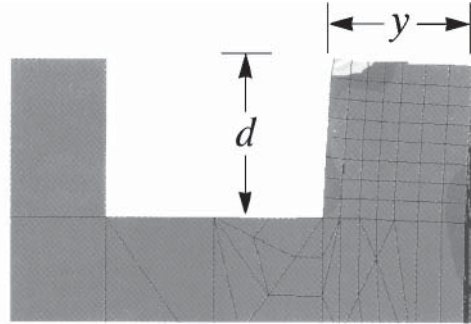
There is sufficient edge margin for the groove to withstand the maximum thrust load of 550lbs. listed in the catalog specifications. If an application requires an edge margin less than the recommended specifications, it is necessary to calculate the thrust load (P_g)-capacity of the groove, to determine if the reduced margin is capable of handling the anticipated thrust load. The following formula applies (Note: see Correction Factors table for G_f value; Yield Strength of Groove Material for σ_y value; Edge Margin Graph for K_1 value; Nomenclature Table for remaining catalog specifications):

$$P_g = \frac{G_f D_s d \pi \sigma_y}{K_1 F_s}$$

For this example, assume that the edge margin will only be half the listed catalog value or, $y/d = 1.5$. The above equation is as follows:

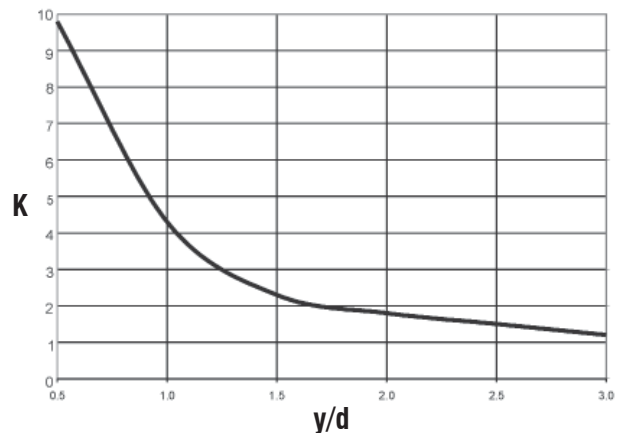
$$\begin{aligned} P_g &= \frac{(1) .5 \times .016 \times 3.14 \times 45,000}{2.20 (2)} \\ &= \frac{1130.4}{4.40} \\ &= 256.9 \text{ lbs.} \end{aligned}$$

Maximum thrust load for reduced edge margin



Finite Element Analysis shows stress gradients for a retaining rings in an application with insufficient edge margin. When loaded, the high stress region extends over the entire groove wall to the end of the shaft (or housing) and the groove wall actually distorts. Under these conditions, the ring would buckle, possibly leading to catastrophic failure.

EDGE MARGIN



Yield Strength of Groove Material	
Groove Material	Yield Strength (psi)
Cold-drawn steel (SAE 1010)	45,000
Steel (SAE 1045, Rc 42)	185,000
Steel (SAE 1045, Rc 48)	220,000
Aluminum (2042-T4, Rb 75)	48,000
Naval Brass (Rb 82)	53,000

Correction Factors	
Ring Series	Correction Factor, G_f
HO, MHO	1.20
SHI, HOI	0.50
SH, MSH	1.00
C, MC	0.50
E, ME	0.33
RE, MRE	0.25
SHR, MSR	2.00
PO	0.50
SHM	1.00

Nomenclature Table	
d = Groove depth, in.	
D_s = Shaft or housing diameter, in.	
F_s = Safety Factor	
G_f = Correction Factor	
K_1 = Edge Margin	
P_g = Thrust Load on Groove, lb.	
σ_y = Tensile Yield Strength of groove material, psi	

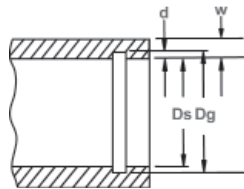
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4. THICKNESS OF HOUSINGS AND HOLLOW SHAFTS

The allowable load of a part in which a retaining ring groove is cut depends upon the ultimate tensile strength and tensile yield strength of the material used, and on the bearing area of the ring against the groove wall. For internal rings used in bores and housings — and external rings assembled on hollow shafts — wall thickness dimension w , illustrated below, can be calculated from the formulas:

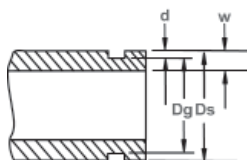
For internal rings:

$$w = \sqrt{\frac{3G_f D_s d \sigma_y}{\sigma_u} + \frac{D_g^2}{4}} - \left[\frac{D_s}{2} \right]$$



For external rings:

$$w = \frac{D_s}{2} - \sqrt{\frac{D_g^2}{4} - \frac{3G_f D_s d \sigma_y}{\sigma_u}}$$



where:

D_s = Shaft or housing dia. (in.)

D_g = Groove dia. (in.)

G_f = Correction Factor [See Table 2, Page 4]

d = Groove depth (in.)

σ_y = Tensile yield strength of groove material (psi)
[See Table 3, Page 7]

σ_u = Ultimate tensile strength of groove material (psi)

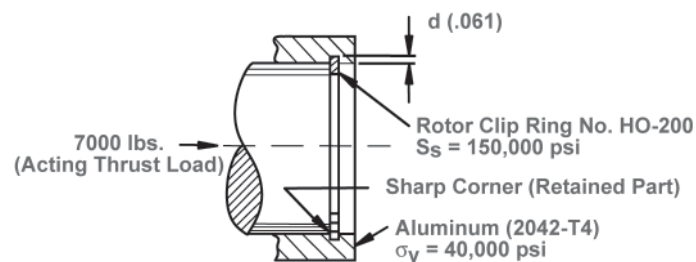
These formulas provide for a wall thickness that is safe for allowable groove thrust loads (P_g) calculated with the formula at the right. If substantially lighter loads will be encountered and a thinner wall is desired, actual tests are recommended.

5. LOAD LIMIT FORMULAS

Formulas for determining ring and groove load limits — with sample calculations for Series HO internal rings and Series SH external rings — are given below. The loads are calculated for retained parts having sharp corners. Correction factors (G_f) for calculating P_r and P_g are given in Table 2 on right. The correction factors are based upon the load characteristics of the rings.

In these examples assume $y \geq 3d$. Therefore, $K = 1$ (see previous page) and is not shown in formulas for P_g .

Internal Ring (Example: Series HO-200)



ALLOWABLE THRUST LOAD — RING (P_r in lbs.)

$$P_r = \frac{G_f D_h T \pi S_s}{F_s}$$

where:

G_f = Conversion Factor [See Table 2, Page 4]

D_h = Housing dia. (in.)

T = Ring thickness (in.)

S_s = Shear Strength of ring material (psi)
[See Table 1, Page 1]

F_s = Safety factor

$$P_r = \frac{(1.2) 2.000 (.062) \pi 150,000}{4}$$

$$= 17,500 \text{ lbs.} > 7000 \text{ lbs.}$$

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ALLOWABLE THRUST LOAD — GROOVE (P_g in lbs.)

$$P_g = \frac{G_f D_H d \pi \sigma_y}{F_S}$$

where:

- G_f = Correction Factor [See Table 2, right]
- D_H = Housing dia. (in.)
- d = Groove depth (in.)
- σ_y = Tensile yield strength of groove material (psi)
[See Table 3, Page 7]
- F_S = Safety factor

$$P_g = \frac{(1.2) 2.000 (.061) \pi 40,000}{2} = 9200 \text{ lbs.} > 7000 \text{ lbs.}$$

ALLOWABLE THRUST LOAD — GROOVE (P_g in lbs.)

$$P_g = \frac{G_f D_S d \pi \sigma_y}{F_S}$$

where:

- G_f = Conversion Factor [See Table 2, below]
- D_S = Shaft dia. (in.)
- d = Groove depth (in.)
- σ_y = Tensile yield strength of groove material (psi)
[See Table 3, Page 7]
- F_S = Safety factor

Note: For series RE only: Substitute value of groove diameter (D_g) for shaft diameter (D_S)

$$P_g = \frac{(1) 1.000 (.030) \pi 45,000}{2} = 2100 \text{ lbs.} > 2000 \text{ lbs}$$

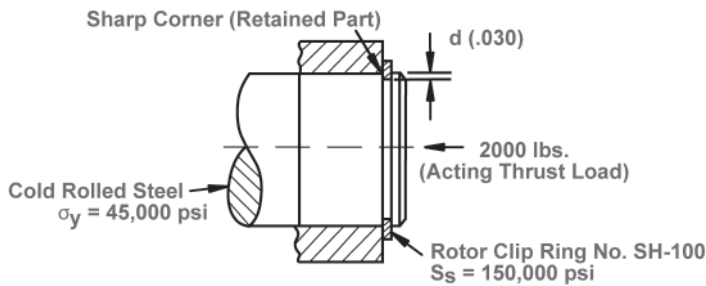


Table 2: Correction Factors (G_f) for Calculating P_r and P_g

Ring Series	Correction Factor G_f	
	Ring: P_r	Groove: P_g
HO, BHO, MHO	1.2	1.2
VHO	1.2	1.2 (Use $d/2$ instead of d)
HOI, SHI	2/3	1/2
SH, BSH, MSH	1	1
VSH	1	1 (Use $d/2$ instead of d)
C, MC	1/2	1/2
LC	3/4	3/4
BE, E, ME	1/3	1/3
RE, MRE	1/4	1/4
EL	Use listed data chart values	1/2
SHR, MSR	1.3	2
PO	1/2	1/2
SHM	Inquire	1

External Ring (Example: Series SH-100)

ALLOWABLE THRUST LOAD — RING (P_r in lbs.)

$$P_r = \frac{G_f D_S T \pi S_S}{F_S}$$

where:

- G_f = Conversion Factor [See Table 2, right]
- D_S = Shaft dia. (in.)
- T = Ring thickness (in.)
- S_S = Shear Strength of ring material (psi)
[See Table 1, Page 1]
- F_S = Safety factor

$$P_r = \frac{(1) 1.000 (.042) \pi 150,000}{4} = 4950 \text{ lbs.} > 2000 \text{ lbs}$$

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Dynamic Thrust Loads

Dynamic conditions most often encountered in retaining ring assemblies include sudden loading, impact, vibration, and relative rotation. Very often the loading pattern is cyclical in nature and may induce fatigue in the assembly. Where dynamic loads are likely to exist, it is necessary that actual tests of such applications be made by the ring user to insure proper functioning of the assembly. The following formulas are given for calculating the ring and or groove thrust load capacity for various conditions.

1. SUDDEN LOADING

This can occur when a surge in thrust load is transmitted to a ring installed in a tight assembly, without play between the retained part and the ring. Sudden loads of this nature should not exceed, at their maximum, 50% of the allowable static thrust load (P_r or P_g , whichever is lower).

2. IMPACT LOADING

To calculate the safe impact load capacity of the ring (I_r), the following formula should be used:

$$I_r = \frac{P_r t}{2}$$

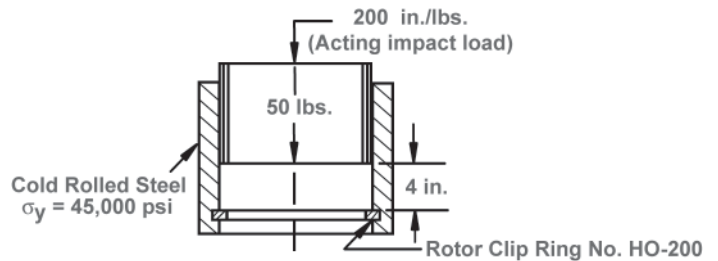
where: I_r = Allowable impact load (in. lbs.)
 P_r = Allowable thrust load of ring (lbs.)
 t = Ring thickness (in.)

The formula for calculating the safe impact load capacity of the groove (I_g) is:

$$I_g = \frac{P_g d}{2}$$

where: I_g = Allowable impact load (in. lbs.)
 P_g = Allowable thrust load of groove (lbs.)
 d = Nominal groove depth (in.)

• External Ring (Example: Series SH-200)



FOR THE RING:

$$I_r = \frac{P_r t}{2} = \frac{17,500 (.062)}{2}$$

$$= 540 \text{ in. lbs.} > 200 \text{ in. lbs.}$$

FOR THE GROOVE:

$$I_g = \frac{P_g d}{2} = \frac{10,400 (.061)}{2}$$

$$= 320 \text{ in. lbs.} > 200 \text{ in. lbs.}$$

3. VIBRATION LOADING

It is possible to calculate the approximate vibration load capacity of a ring and groove if there is a tight fit between the ring and the abutting retained part. (If there is space between the ring and the part, the load capacity must be calculated as impact.)

The formula for calculating the vibration load capacity of the ring is: $wa \leq 540 P_r$

where: w = Weight of retained parts (lbs.)
 a = Acceleration of parts (in./sec.²)
 P_r = Allowable thrust load of ring (lbs.)

To calculate the vibration load capacity of the groove, the formula is: $wa \leq 400 P_g$

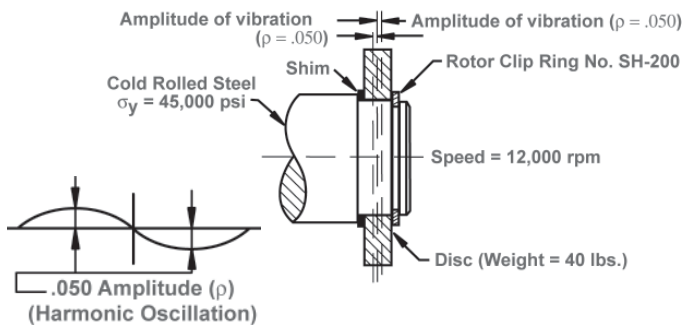
where: w = Weight of retained parts (lbs.)
 a = Acceleration of parts (in. sec.²)
 P_g = Allowable thrust load of groove (lbs.)

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Harmonic oscillation for both ring and groove may be calculated with the following formula: $a \cong 40 pf^2$

where: a = Acceleration of parts (in./sec.²)
 p = Amplitude (in.)
 f = Frequency (cycles/sec.)

• Sample Calculation (Example: Series SH-200)



FOR THE RING: $wa \leq 540 P_r$

For harmonic oscillation:

$$a \cong 40 pf^2$$

$$f = \frac{12,000}{60} = 200 \text{ cycles/sec.}$$

$$a \cong 40 (.050) 200^2 = 80,000 \text{ in./sec.}^2$$

$$wa = (40) (80,000) = 3.2 \times 10^6$$

$$540 P_r = (540) (14,600) = 7.9 \times 10^6$$

$$\therefore wa < 540 P_r \text{ and ring is safe}$$

FOR THE GROOVE:

$$wa \leq 400 P_g$$

$$wa = 3.2 \times 10^6$$

$$400 P_g = (400) (8050) = 3.22 \times 10^6$$

$$\therefore wa < 400 P_g \text{ and groove strength is adequate.}$$

Corner Radii and Chamfers - R_{max} and Ch_{max}

All of the formulas above and the values for P_r given in the data charts for each ring type are calculated for assemblies in which the retained parts have square corners. If the abutting face of the retained part has a corner radius or chamfer, the assembly's thrust load capacity will be lower. A Series HO-100 ring which abuts a square-cornered part, for example, has a static thrust capacity of 5,950 lbs. The same ring, seated next to a part having the maximum allowable corner radius or chamfer, has an allowable load of 1,650 lbs.

Maximum allowable corner radii and chamfers for each ring size are listed in the charts with corresponding static thrust capacities. If these thrust capacities are not sufficient for the assembly, a rigid square-cornered flat washer should be inserted between the part and the ring. The thrust capacity of the assembly will then be approximately the same as if a square-cornered retained part had been used.

When the actual corner radius or chamfer is less than the listed maximum, the allowable thrust load of the assembly increases proportionately in accordance with the following formulas:

$$P''_r = P'_r \frac{R_{max.}}{R} \quad (\text{for radius})$$

$$P''_r = P'_r \frac{Ch_{max.}}{Ch} \quad (\text{for chamfer})$$

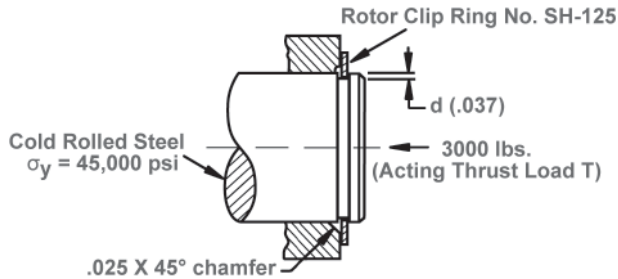
where: P''_r = Allowable assembly load when corner radius or chamfer is less than listed maximum
 P'_r = Listed allowable assembly load with maximum corner radius or chamfer
 $R_{max.}$ = Listed maximum allowable corner radius
 R = Actual corner radius
 $Ch_{max.}$ = Listed maximum allowable chamfer
 Ch = Actual chamfer

(Continued on next page...)

Load Capacities

Corner Radii and Chamfers - R_{max} and Ch_{max} Continued...

- Sample Calculation (Example: Series SH-125)



ALLOWABLE THRUST LOAD — RING (P''_r in lbs.)

$$P''_r = P'_r \frac{Ch_{max.}}{Ch} = \frac{(1950) (.041)}{.025}$$

$$P''_r = 3200 \text{ lbs.} > 3000 \text{ lbs.}$$

ALLOWABLE THRUST LOAD — GROOVE (P_g in lbs.)

$$P_g = \frac{G_f D_s d \pi \sigma_y}{F_s} \quad (\text{See formula derivation page 2})$$

$$P_g = \frac{(1) 1.250 (.037) \pi (45,000)}{2}$$

$$P_g = 3270 \text{ lbs.} > 3000 \text{ lbs.}$$

NOTE: If the allowable thrust load capacity of the ring (P_r) or the groove (P_g) is less than P''_r , P_r or P_g — whichever is lower — becomes the limiting factor in the assembly.

ELASTIC DEFORMATION WITH CORNER RADII OR CHAMFERS

Elastic deformation of an assembly (retained part, retaining ring and groove wall) where the retained part has a corner radius or chamfer can be calculated with the following formulas:

$$\delta = \frac{T (.01) D_s (R + t/4)}{(P''_r) t} \quad (\text{for radius})$$

$$\delta = \frac{T (.01) D_s (Ch + t/4)}{(P''_r) t} \quad (\text{for chamfer})$$

where: δ = Deflection (in.)

T = Acting thrust load (lbs.)

D_s = Shaft or housing dia. (in.)

R = Actual radius (in.)

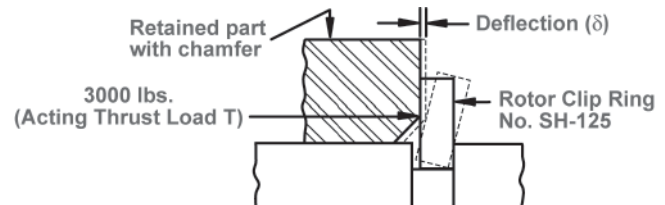
Ch = Actual chamfer (in.)

t = Ring thickness (in.)

P''_r = Allowable thrust load of ring when actual corner radius or chamfer is less than listed maximum (lbs.)

NOTE: R and Ch cannot exceed the values for R_{max} and Ch_{max} listed in the data charts for the individual ring types.

- Sample Calculation (Example: Series SH-125)



$$\delta = \frac{T (.01) D_s (Ch + t/4)}{(P''_r) t}$$

$$\delta = \frac{(3000) (.01) (1.250) (.025 + .0125)}{(3200) (.050)} \cong .0087 \text{ in.}$$

Table 3: Tensile Yield Strength of Groove Material

Groove Material	Tensile Yield Strength (psi)
Cold-drawn steel (SAE 1010)	45,000
Hardened steel (RC-40)	150,000
Hardened steel (RC-50)	200,000
Steel (SAE 1045, Rc 42)	185,000
Steel (SAE 1045, Rc 48)	220,000
Aluminum (2024-T4)	40,000
Aluminum (2042-T4, Rb 75)	48,000
Naval Brass	30,000
Naval Brass (Rb 82)	53,000

Table 4: Maximum Working Stress of Ring During Expansion or Contraction

Ring Material	Rotor Clip Code	Maximum Allowable Working Stress (psi)
Carbon Spring Steel (SAE 1075)	ST	250,000
Stainless Steel (PH 15-7 Mo)	SS	250,000
Beryllium Copper (Alloy #25)	BC	200,000

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Relative Rotation

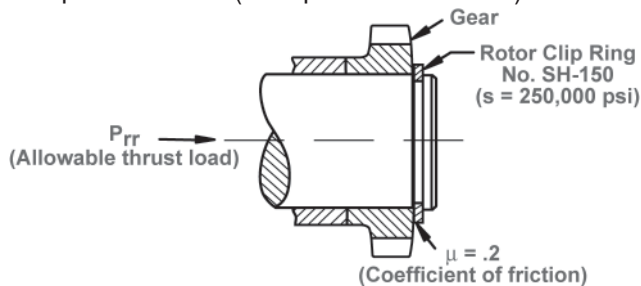
When a retained part rotates relative to and exerts thrust on the ring, frictional forces act on the ring body. Relative rotation can reduce substantially the thrust capacity of the assembly. The use of a keyed washer or other non-rotating device between ring and retained part to eliminate relative rotation should be considered.

To prevent the rings from being “walked out” or otherwise unseated from the groove, maximum allowable rotating thrust loads may be calculated from the following formula:

$$P_{rr} \leq \frac{s t E^2}{\mu 18 D_s}$$

where: P_{rr} = Allowable thrust load exerted by adjacent part (lbs.)
 s = Maximum working stress of ring during expansion or contraction [See Table 4, left]
 t = Ring thickness (in.)
 E = Largest section of ring (in.)
 μ = Coefficient of friction between ring and retained part or groove whichever is higher (consult appropriate references)
 D_s = Shaft or housing dia. (in.)

- Sample Calculation (Example: Series SH-150)



$$P_{rr} \leq \frac{s t E^2}{\mu 18 D_s}$$

$$P_{rr} \leq \frac{250,000 (.050) (.168)^2}{.2 (18) (1.500)} = 65 \text{ lbs. max.}$$

NOTE: Relative rotation applies to the following rings made of standard materials when used in grooves: Series HO, BHO, VHO, HOI, SH, BSH, VSH, C,SHI, BE, E, RE, SHR, PO, SHF and SHM. Series LC and EL are not affected.

Deflection

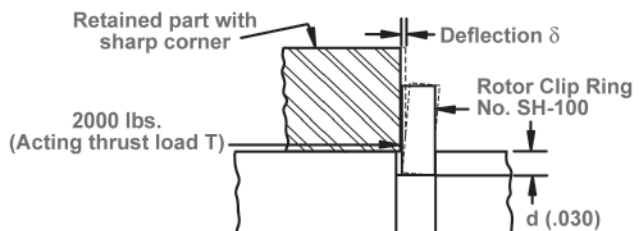
Permanent deflection of ring assemblies (retained part, retaining ring and groove wall), permitting movement of the retained parts, is negligible when loads do not exceed the governing allowable thrust load (static, impact, vibration, etc. — whichever is present).

Elastic deformation, which is a temporary displacement of the retained part under load, can be calculated by the following formula:

$$\delta = \frac{T}{E d}$$

where: δ = Deflection (in.)
 T = Acting load (lbs.)
 E = Modulus of elasticity of groove material
 d = Groove depth (in.)

- Sample Calculation (Example: Series SH-100)



$$\delta = \frac{T}{E d} = \frac{2000}{3 \times 10^7 (.030)} = .0022''$$