

It is important to know the required specifications, such as operating temperature, load, sliding velocity, PV value, mating material, torque, tolerances, type of motion and expected life, when designing with NTN Bearee.

6-1 Selection of bearing material (PV value)

When selecting the bearing material, examine the operating temperature, mating material, lubrication condition and so forth, along with the allowable pressure and sliding velocity.

PV value, the product of pressure “ P ” and sliding velocity “ V ”, is often used as the criteria to determine if the operating condition is allowable for the sliding material or not.

Each sliding material has its own allowable PV value; however, it also has an independent allowable value for pressure and velocity. Therefore, the allowable range is shown in **Figure 18**.

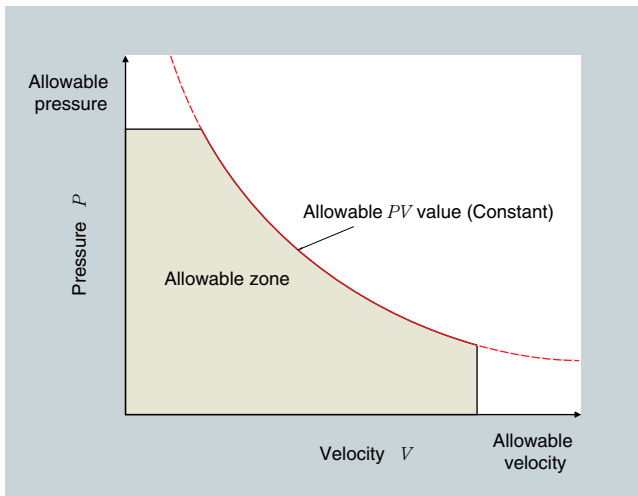


Figure 18 Allowable PV value

$$PV \leq \text{Allowable } PV \text{ value}$$

$$P \leq \text{Allowable } P$$

$$V \leq \text{Allowable } V$$

Pressure “ P ” and sliding velocity “ V ” is given by following formula.

$$P = Fr / d \cdot l$$

$$V = \pi \cdot d \cdot n \times 10^{-3}$$

P : pressure MPa

Fr : Radial load N

d : Shaft diameter mm

l : Length of bearing mm

V : Sliding velocity m / min

n : Shaft rotation rpm

6-2 Estimation of wear

The life of an NTN Engineering Plastics bearing is defined by the wear of sliding surface, as with an ordinary plain bearing.

The amount of wear varies with operating conditions such as sliding velocity, pressure, type of motion, surface roughness of mating material and operating temperature. Generally, the estimation of wear is given by the following formula.

$$R = K \cdot P \cdot V \cdot T$$

where

R : The amount of wear mm

K : Wear factor mm·min / MPa·m·h

P : pressure MPa

V : Sliding velocity m / min

T : Time h

Surface roughness of the mating material influences the wear of the NTN Engineering Plastics bearing; therefore, finish the surface to 0.1 to 0.8a. Moreover, NTN recommends the hardness of shaft to be HRC 22 or higher since it is possible to reduce the wear when the shaft is harder.

<Example>

Determine the amount of wear of R-AR1515 sleeve bearing made of BEAREE FL 3000 for the following operating condition.

<Specification>

Shaft diameter d : 15mm

Bearing load Fr : 300N

Shaft rotation n : 300rpm

Temperature : Room temperature

Service hours : 1000 hours

Lubrication : None

Pressure P (MPa) = $Fr / d \cdot l = 300 / 15 \times 15 \doteq 1.33$ MPa

Sliding velocity V (m/min) = $\pi \cdot d \cdot n = 3.14 \times 15 \times 300 / 1000 \doteq 14.1$ m/min

Wear factor at room temperature is given by page 10

$$K = 1.0 \times 10^{-7} \text{ mm}^3 / \text{N} \cdot \text{m}$$

$$PV = 1.33 \times 14.1 \doteq 18.8 \text{ MPa} \cdot \text{m/min}$$

$$T = 1000\text{h} = 60\,000 \text{ min}$$

Therefore the amount of wear $R = K \cdot P \cdot V \cdot T$ is;

$$R = 1.0 \times 10^{-7} \times 18.8 \times 60\,000 = 0.113$$

The wear after 1000 hours of service is 0.113 mm.

6-3 Fits and clearance

Plain bearings are usually pressed into a housing. The minimum clearance for operation varies by the size of shaft though it can be as small as 0.025mm. When the operating temperature varies widely, the thermal expansion of bearing material should be taken into consideration. Increase the clearance by the amount of thermal expansion, with decreases the operating clearance.

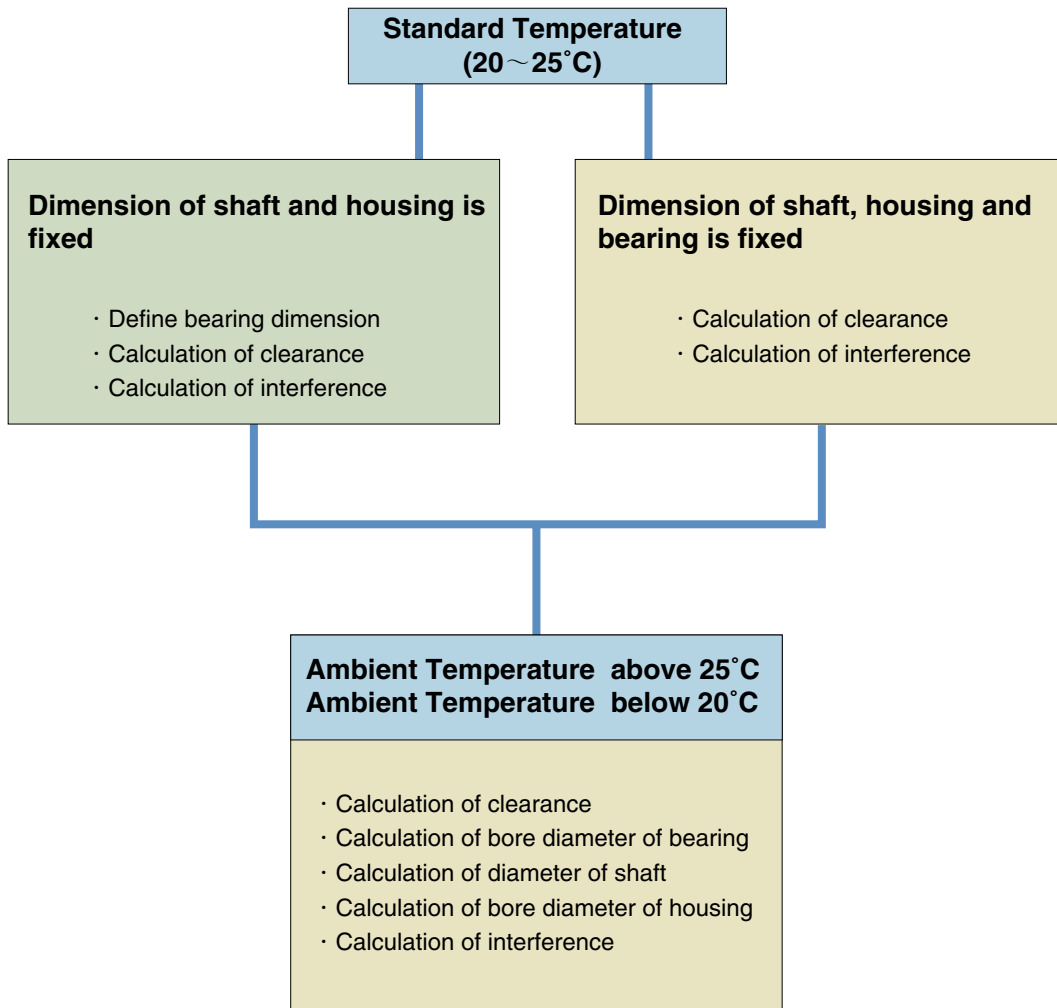
It is also possible to finish the bore of mounted bearing by turning or reaming when accurate operation with small clearance is required. Although recommended shaft and bore diameters and mounted clearance are listed in the tables of standard series of NTN Engineering Plastics

Sliding Bearings, the mounted clearance may increase for soft material housings such as aluminum and plastics, or thin wall housing. Also, it is recommended to fix the bearing with a knock-pin, key, or bonding since the interference fit might be lost when the bearing is used under low temperature.

● **Calculation of bearing clearance (Except M-Liner bearing)**

The calculation step for “Standard temperature” , “Above 25°C” and “Below 20°C” is different. The step chart is shown below.

Calculation Step of Clearance for BEAREE Plain Bearing



Note: Usually, the calculation for standard temperature is applicable to the ambient temperature range of 15 ~ 50°C

1. Calculation of clearance for standard temperature (25°C)

1) Interference

$$\text{Maximum: } F_H = D_H - H_L$$

$$\text{Minimum: } F_L = D_L - H_H$$

2) Reduction of bearing bore dimension due to interference fit

$$\text{Maximum: } E_{\max} = \lambda \cdot F_H \quad (\lambda = 1.0)$$

$$\text{Minimum: } E_{\min} = \lambda \cdot F_L \quad (\lambda = 1.0)$$

3) Bore dimension of bearing at standard temperature when mounted

$$\text{Maximum: } d_{25H} = d_H - E_{\min}$$

$$\text{Minimum: } d_{25L} = d_L - E_{\max}$$

4) Mounted clearance at standard temperature

$$\text{Maximum: } C_{\max} = d_{25H} - S_L$$

$$\text{Minimum: } C_{\min} = d_{25L} - S_H$$

Where

- S_H : Maximum shaft diameter
- S_L : Minimum shaft diameter
- H_H : Maximum housing bore diameter
- H_L : Minimum housing bore diameter
- d_H : Maximum bore diameter of bearing
- d_L : Minimum bore diameter of bearing
- D_H : Maximum outer diameter of bearing
- d_L : Minimum outer diameter of bearing

NOTE

1. The minimum clearance for NTN Engineering Plastic bearing is required 2 ~ 7/1000 of shaft diameter to reduce heat generation when used with no lubrication.
2. Shrink ratio by fit interference usually is set as 100%

<Example>

Calculate the clearance of type AR sleeve bearing R-AR1010 made of BEAREE FL 3000.

Assume shaft and housing bore dimensions follow NTN recommendation.

Shaft : $\phi 10$, h6 ($\begin{smallmatrix} 0 \\ 0.009 \end{smallmatrix}$) therefore $S_H = 10$, $S_L = 9.991$
 Housing : $\phi 14$, M7 ($\begin{smallmatrix} 0 \\ -0.018 \end{smallmatrix}$) therefore $H_H = 14$, $H_L = 13.982$
 Bearing I.D. : $\phi 10$ ($\begin{smallmatrix} +0.24 \\ +0.19 \end{smallmatrix}$) therefore $d_H = 10.24$, $d_L = 10.19$
 Bearing O.D. : $\phi 14$ ($\begin{smallmatrix} +0.10 \\ +0.05 \end{smallmatrix}$) therefore $D_H = 14.10$, $D_L = 14.05$
 Maximum interference : $F_H = D_H - H_L = 14.10 - 13.982 = 0.118$
 Minimum interference : $F_L = D_L - H_H = 14.05 - 14.00 = 0.05$
 Reduction of bearing bore : $E_{\max} = F_H \times \lambda = 0.118 \times 1 = 0.118$
 $E_{\min} = F_L \times \lambda = 0.05 \times 1 = 0.05$

Bearing bore at 25°C when mounted

$$d_{25H} = d_H - E_{\min} = 10.24 - 0.05 = 10.19$$

$$d_{25L} = d_L - E_{\max} = 10.19 - 0.118 = 10.072$$

Mounted clearance at 25°C:

$$C_{\max} = d_{25H} - S_L = 10.19 - 9.991 = 0.199 \div 0.2$$

$$C_{\min} = d_{25L} - S_H = 10.072 - 10 = 0.072 \div 0.07$$

2. Calculation of clearance for high temperature (T_H °C)

1) Housing bore dimension

$$\text{Maximum: } HH_H = H_H \{1 + \alpha_1 (T_H - 25)\}$$

$$\text{Minimum: } HH_L = H_L \{1 + \alpha_1 (T_H - 25)\}$$

2) Shaft diameter

$$\text{Maximum: } SH_H = S_H \{1 + \alpha_2 (T_H - 25)\}$$

$$\text{Minimum: } SH_L = S_L \{1 + \alpha_2 (T_H - 25)\}$$

3) Clearance during operation

Maximum:

$$CH_{\max} = \sqrt{(H_H)^2 \{1 + \alpha_1 (T_H - 25)\}^2 - \{(H_H)^2 - (d_{25H})^2\} \{1 + \alpha_3 (T_H - 25)\}^2} - S_L \{1 + \alpha_2 (T_H - 25)\}$$

Minimum:

$$CH_{\min} = \sqrt{(H_L)^2 \{1 + \alpha_1 (T_H - 25)\}^2 - \{(H_L)^2 - (d_{25L})^2\} \{1 + \alpha_3 (T_H - 25)\}^2} - S_H \{1 + \alpha_2 (T_H - 25)\}$$

Where

- α_1 : Coefficient of linear expansion of housing for T_H °C
- α_2 : Coefficient of linear expansion of shaft for T_H °C
- α_3 : Coefficient of linear expansion of bearing for T_H °C

*Reference Coefficient of linear expansion of various materials ($\times 10^{-5}/^\circ\text{C}$)

Material	α_1, α_2
Mild steel	1.1
Aluminum	2.3
Stainless steel	1.73

3. Calculation of clearance for low temperature (T_L °C)

1) Housing bore dimension

$$\text{Maximum: } HL_H = H_H \{1 + \alpha_{11} (T_L - 25)\}$$

$$\text{Minimum: } HL_L = H_L \{1 + \alpha_{11} (T_L - 25)\}$$

2) Shaft diameter

$$\text{Maximum: } SL_H = S_H \{1 + \alpha_{22} (T_L - 25)\}$$

$$\text{Minimum: } SL_L = S_L \{1 + \alpha_{22} (T_L - 25)\}$$

3) Clearance during operation

Maximum:

$$CL_{\max} = \sqrt{(H_H)^2 \{1 + \alpha_{11} (T_L - 25)\}^2 - \{(H_H)^2 - (d_{25H})^2\} \{1 + \alpha_{33} (T_L - 25)\}^2 - S_L \{1 + \alpha_{22} (T_L - 25)\}^2}$$

Minimum:

$$CL_{\min} = \sqrt{(H_L)^2 \{1 + \alpha_{11} (T_L - 25)\}^2 - \{(H_L)^2 - (d_{25L})^2\} \{1 + \alpha_{33} (T_L - 25)\}^2 - S_H \{1 + \alpha_{22} (T_L - 25)\}^2}$$

Where

α_{11} : Coefficient of linear expansion of housing for T_L °C

α_{22} : Coefficient of linear expansion of shaft for T_L °C

α_{33} : Coefficient of linear expansion of bearing for T_L °C

6-4 Handling

(a) Assembling method

Avoid hammering when pressing the bearing into the housing.

Use press machine with press arbor shown in **Figure 19** after centering bearing; and be sure that the housing chamfer is adequately large.

Use a knock pin or key to prevent rotation of the bearing, or use an adhesive to fasten the bearing for low temperature application, because the fitting might be loosened.

Remarks) Large-sized plastic bearings can be installed easily by cooling the bearing with dry ice.

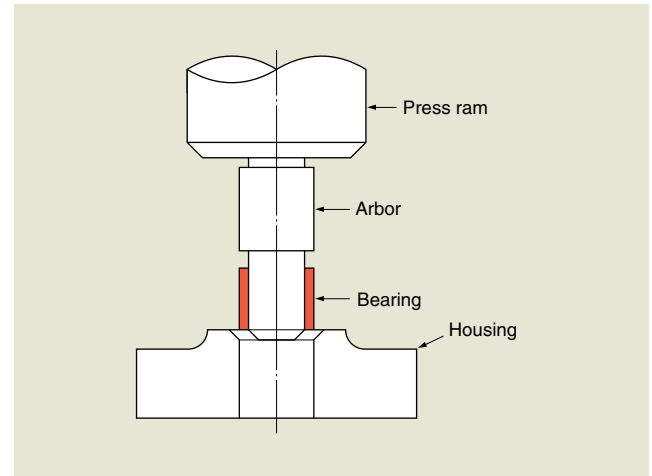


Figure 19 Assembling method

(b) Notice for handling

- (1) BEAREE FL could be deformed or scratched by a shock load, etc. and BEAREE PI could be cracked or chipped.
- (2) The surface roughness of mating material greatly affects bearing life.
NTN recommends surface roughness of 0.1 ~ 0.8a.
- (3) To fasten BEAREE bearing with adhesive, the bearing surface should be treated (etched) to make it bond-able. In that case, please advise us that, "Pre-etched one is required".
- (4) For bonding BEAREE bearing, an epoxy type adhesive is preferred.
- (5) Under some circumstances the operating temperature may loosen the clearance in the shaft and result in overheating, burning and seizing of the mechanism. Completely check the relation ship between fittings and clearances before application.