



江苏帝达贝轴承有限公司

地址：江苏省无锡锡山经济开发区蓉洋一路8号

邮政编码：214192

电话：86-510-8562 0688

销售直线：86-510-8562 5303 8562 6501

传真：86-510-8562 6208 8562 6308 8562 9206

网址：www.TWB.com.cn

Jiangsu TWB Bearings Co., Ltd

Address: No. 8 Rongyang Yi Road, Xishan Economic

Development Zone, Wuxi, Jiangsu

Post Code: 214192

Telephone: 86-510-8562 0688

Sales Tel: 86-510-8562 7206 8562 6109

Fax: 86-510-8562 6208 8562 6308 8562 9206

Website: www.TWB.com.cn

轴承游隙选用指南

AN INSTRUCTION TO DETERMINE CLEARANCE OF BEARINGS



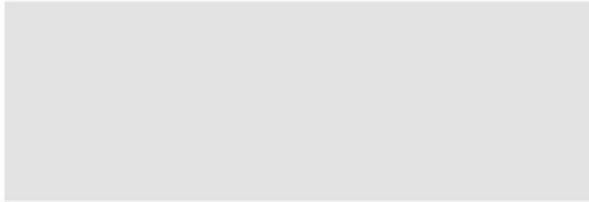
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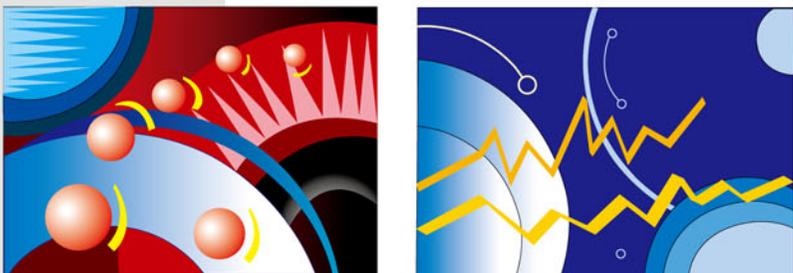
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正确选择游隙的重要性

轴承的径向(轴向)游隙是当轴承无外负荷作用时,一套圈相对另一套圈,从一个径向(轴向)极限位置移向相反极限位置的径向(轴向)距离。在现实中由于套圈的形状误差和滚动体的一致性,它应采用在套圈的不同方向以及套圈和滚动体不同相对位置状态下的径向(轴向)位移的平均值。

游隙是轴承的一个重要技术参数,它直接影响到轴承的载荷分布、振动、噪音、摩擦、温升、使用寿命和机械的运转精度等技术性能。游隙过大,会引起轴承内部承载区域减小,接触面应力增大,从而使用寿命缩短。过大的游隙还会使轴承运动精度下降,振动和噪音增大。游隙过小,可能会在实际运行中出现负游隙(过盈),引起摩擦发热增大,温升提高,进而使有效游隙更小或过盈更大,如此恶性循环导致轴承抱死。

The importance of right clearance

The radial (lateral) internal clearance of a bearing is a radial (lateral) movement of a ring relative to another ring from a radial (lateral) limited position to the opposite limited position. In practice because of the roundness error of rings and the nonidentity of rollers, an average movement should be taken in various directions of a ring and at various relative positions between rings and rollers.

Clearance is an important parameter of a bearing that directly effects the load distribution in a bearing as well as its performances such as vibration, noise, friction resistance, temperature raise, service life, rotation accuracy, etc. Excessive clearance could decrease the loading area in a bearing, increase the stress of contacting surfaces and therefore shorten its life. In addition excessive clearance could also cause worse motion accuracy and increasing vibration and noise. Insufficient clearance may become negative clearance (i.e. Interference) in running time, consequently more heat is generated, the temperature is raised, and the effective clearance become further negative, like as in a vicious circle, finally the bearing lead to unable to rotate.

不同状态下的游隙和相互关系

初始游隙 Δ_0 : 轴承在未安装状态下不承受载荷时的游隙，即供货游隙。

残留游隙 Δ_r : 轴承安装后的游隙。轴承在安装后由于配合作用一般内圈胀大，外圈缩小，因此

$$\Delta_r = \Delta_0 - \delta_{fo} - \delta_{fi} \quad (1)$$

式中， δ_{fo} 为外圈和轴壳配合引起的游隙减少量； δ_{fi} 为内圈和轴配合引起的游隙减少量。

有效游隙 Δ_e : 轴承在实际运行时的游隙。由于轴承在实际工作时受温升和散热条件的影 响一般是内圈温度高于外圈温度，导致游隙减少，因此

$$\Delta_e = \Delta_r - \delta_t \quad (2)$$

式中， δ_t 为轴承内外圈温差导致的游隙减少量。由(1)、(2)可得到

$$\Delta_e = \Delta_0 - \delta_{fo} - \delta_{fi} - \delta_t \quad (3)$$



The relations of clearances under various states

Initial clearance Δ_0 : The clearance of a bearing before its installation, or in delivery state.

Remaining clearance Δ_r : The clearance of a bearing after its installation Because of the effect of the fits after installation the inner ring is usually expanded and the outer ring is constricted, so that

$$\Delta_r = \Delta_0 - \delta_{fo} - \delta_{fi} \quad (1)$$

Here δ_{fo} is the decrease of clearance due to the fits of the outer ring to the housing, δ_{fi} is the decrease of clearance due to the fits of the inner ring to the shaft.

Effective clearance Δ_e : The clearance of a bearing in running time Because of the effect of the temperature rise and the heat radiation in practical working time the temperature of inner ring is usually higher than of outer ring, so the clearance is decreased as

$$\Delta_e = \Delta_r - \delta_t \quad (2)$$

Here δ_t is the decrease of clearance due to the temperature difference between inner ring and outer ring.

From (1) and (2), following relation can be obtained:

$$\Delta_e = \Delta_0 - \delta_{fo} - \delta_{fi} - \delta_t \quad (3)$$



有效游隙的计算

只要计算出上述几个影响游隙的因素，轴承的有效游隙即可按照(3)式计算出来。

3.1 装配影响

$$\delta_{fi} = \Delta_d \frac{d}{d_i} \frac{1 - \left(\frac{d_o}{d}\right)^2}{1 - \left(\frac{d_o}{d_i}\right)^2} \quad (\text{mm})$$

$$\delta_{fo} = \Delta_D \frac{D_e}{D} \frac{1 - \left(\frac{D}{D_h}\right)^2}{1 - \left(\frac{D_e}{D_h}\right)^2} \quad (\text{mm})$$

式中，

Δ_d - 内径和轴配合的过盈量(mm)；

Δ_D - 外径和轴壳配合的过盈量(mm)；

d - 轴承内径(mm)；

D - 轴承外径(mm)；

D_e - 轴承外圈平均内径(mm)；

D_e 如无确切数据，可按下式估计：

$$D_e = (7D + 3d) / 10$$

d_i - 轴承内圈平均外径(mm)；

d_i 如无确切数据，可按下式估计：

$$d_i = (3D + 7d) / 10$$

d_o - 空心轴的内径(mm)，如实心轴

$d_o = 0$ ；

D_h - 轴承座外径(mm)，如刚体轴承座，

$D_h = \infty$ 。

Calculation of effective clearance

According to (3) the effective clearance can be obtained provide

the factors that effect clearance have been calculated out.

3.1 The effect of installation

$$\delta_{fi} = \Delta_d \frac{d}{d_i} \frac{1 - \left(\frac{d_o}{d}\right)^2}{1 - \left(\frac{d_o}{d_i}\right)^2} \quad (\text{mm})$$

$$\delta_{fo} = \Delta_D \frac{D_e}{D} \frac{1 - \left(\frac{D}{D_h}\right)^2}{1 - \left(\frac{D_e}{D_h}\right)^2} \quad (\text{mm})$$

here

Δ_d - the interference between bore and shaft (mm)；

Δ_D - the interference between OD and housing(mm)；

d - Bore of bearing(mm)；

D - OD of bearing(mm)；

D_e - Mean bore of outer ring(mm)；

If no definite D_e , estimate it as $D_e = (7D + 3d) / 10$

d_i - Mean OD of inner ring(mm)；

If no definite d_i estimate it as $d_i = (3D + 7d) / 10$

d_o - Bore diameter of hollow shaft (mm). $d_o = 0$ if solid shaft；

D_h - OD of housing(mm). $D_h = \infty$ if rigid housing.



3.2 温差影响

$$\delta_t = \alpha \Delta t D_o \quad (\text{mm})$$

式中, α - 轴承钢的膨胀系数

$$1.12 \times 10^{-5} \text{ (1/}^\circ\text{C)};$$

Δt - 内外套圈的温度差($^\circ\text{C}$),

$$\Delta t = T_{内} - T_{外}$$

D_o - 外圈滚道直径(mm)。

D_o 如无确切数据, 可按以下方法估计:

对球轴承、调心滚子轴承:

$$D_o = (4D+d)/5$$

对圆柱滚子轴承: $D_o = (3D+d)/4$

例: 轴承23132 CA配合主轴(实心)公差为p6($^{+0.068}_{+0.043}$), 配合的轴壳(外径330)公差为K7($^{+0.012}_{-0.028}$), 轴承正常工作时内圈温度高于外圈约10 $^\circ\text{C}$ 。试作有效游隙验算。

23132 CA数据: 外径D=270mm($^{+0}_{-0.035}$)mm, 内径d=160mm($^{+0}_{-0.025}$)mm, 接触角 $\alpha=11^\circ 45'$, 外圈内径De=248mm, 内圈外径di=190mm, 外圈滚道直径Do=248mm, 基本组游隙: 最大0.17, 最小0.11

$$\delta_{fi} = \Delta d \frac{d}{d_i} \frac{1 - \left(\frac{d_o}{d}\right)^2}{1 - \left(\frac{d_o}{d_i}\right)^2} = (0.068 + 0.025) \times 160 / 190 = 0.078$$

$$\delta_{fo} = \Delta D \frac{D_e}{D} \frac{1 - \left(\frac{D}{D_h}\right)^2}{1 - \left(\frac{D_e}{D_h}\right)^2} = 0.028 \times \frac{248}{270} \frac{1 - \left(\frac{270}{330}\right)^2}{1 - \left(\frac{248}{330}\right)^2} = 0.019$$

$$\delta_t = \alpha \Delta t D_o = 1.12 \times 10^{-5} \times 10 \times 248 = 0.028$$

$$\Delta e_{\min} = \Delta o - \delta_{fo} - \delta_{fi} - \delta_t = 0.11 - 0.078 - 0.019 - 0.028 = -0.015 \text{mm}$$

3.2 The effect of temperature

$$\delta t = \alpha \Delta t D_o \quad (\text{mm})$$

Here α - Thermal expansile factor $1.12 \times 10^{-5} \text{ (1/}^\circ\text{C)}$;

Δt - The temperature difference between inner and outer($^\circ\text{C}$).

$$\Delta t = T_i - T_o$$

D_o - Race diameter of outer ring (mm).

If no definite D_o , estimate it as

$D_o = (4D+d)/5$ for ball bearing or spherical roller bearing,

$D_o = (3D+d)/4$ for cylindrical roller bearing.

Example: A bearing of 23132 CA fitted a solid Shaft with a tolerance of p6 ($^{+0.068}_{+0.043}$) and a housing (330 OD) with a tolerance of K7 ($^{+0.012}_{-0.028}$) works under normal condition when the temperature of the inner is about 10 $^\circ\text{C}$ higher than the temperature of the outer Please to calculate the effective clearance and give your comment or advice.

The data of 23132 CA: The outer diameter D=270 ($^{+0}_{-0.035}$)mm, the bore diameter d=160 ($^{+0}_{-0.025}$) mm, the internal diameter De=248mm, the OD of inner ring di=190mm, The race diameter of outer ring Do=248mm. the clearance of C0 is 0.17 maximum to 0.11 minimum.

$$\delta_{fi} = \Delta d \frac{d}{d_i} \frac{1 - \left(\frac{d_o}{d}\right)^2}{1 - \left(\frac{d_o}{d_i}\right)^2} = (0.068 + 0.025) \times 160 / 190 = 0.078$$

$$\delta_{fo} = \Delta D \frac{D_e}{D} \frac{1 - \left(\frac{D}{D_h}\right)^2}{1 - \left(\frac{D_e}{D_h}\right)^2} = 0.028 \times \frac{248}{270} \frac{1 - \left(\frac{270}{330}\right)^2}{1 - \left(\frac{248}{330}\right)^2} = 0.019$$

$$\delta_t = \alpha \Delta t D_o = 1.12 \times 10^{-5} \times 10 \times 248 = 0.028$$

$$\Delta e_{\min} = \Delta o - \delta_{fo} - \delta_{fi} - \delta_t = 0.11 - 0.078 - 0.019 - 0.028 = -0.015 \text{mm}$$

经验算，轴承的有效游隙小于0，表明实际上有可能在过盈状态下运行。如果改变选用C3组游隙(最大0.22，最小0.17)，则最小有效游隙

$$\begin{aligned} \Delta_{e \min} &= \Delta_0 - \delta_b - \delta_{fi} - \delta_t = 0.17 - 0.078 - 0.019 - 0.028 \\ &= 0.045\text{mm} \end{aligned}$$

游隙的选择

TWB 可向用户提供 C2, C0, C3, C4, C5 标准游隙轴承。它与国内和国际主要轴承制造厂商的游隙标准是一致的。具体的游隙值(初始游隙)可在轴承样本等资料上查得。用户在订货时应将游隙代号加在轴承代号后面，基本组游隙 C0 可以省略。例如：C3 组标准游隙 23132 CA 轴承，应写为 23132 CA/C3。

用户在选择游隙时，有条件情况下应该按照公式(3)做有效游隙验算。理想的有效游隙应当是零游隙，因为能得到最佳的载荷分配和最长的使用寿命。为了获得较大的刚性和较高旋转精度，可以让轴承在适当的负游隙状态下工作。但是当工作条件变化较大，安装配合控制得不严，内圈散热条件差，从安全性考虑，则应保留一定的有效游隙，或以最坏情况来验算有效游隙。如用户没有条件做有效游隙验算时，可以参照下表选择游隙。



As the result, the effective clearance is less than 0. that indicate the bearing is probable in interference condition. It is suggested to change C0 to C3, which maximum clearance is 0.22 and minimum clearance is 0.17, then the possible minimum clearance will be

$$\begin{aligned} \Delta_{e \min} &= \Delta_0 - \delta_b - \delta_{fi} - \delta_t = 0.17 - 0.078 - 0.019 - 0.028 \\ &= 0.045\text{mm} \end{aligned}$$

Determine clearance of Bearings

TWB can provide bearings with standard clearance of C2, C0, C3, C4 and C5, which clearance are conformity with the major domestic and overseas manufacturers All clearance data are available from the catalogues Customer should add the clearance code after the bearing number when he orders bearings except C0 that could be omitted For example, a 23132 CA bearing with C3 clearance should be designated as 23132 CA/C3.

To determinate clearance of a bearing, the effective clearance should be checked if possible. An ideal effective clearance is zero clearance, because it can obtain optimum load distribution and longest serve life In order to achieve more rigid and more accuracy rotation, a bearing may be allowed to work under a certain negative clearance. However, in case that the working condition is variable, or the fits of installation is not controlled strictly, or the inner ring is not easy to radiate its heat, a certain effective clearance should remain when it is checked upon the worst condition. If customers are impossible to check the effective clearance, following table can be referred to when determine clearance of the bearings.



使用条件	应用举例	选用游隙
<ul style="list-style-type: none"> • 安装配合精密或非过盈配合 • 要求严格控制振动噪音 • 要求精确的径向或轴向定位 	测试设备, 仪器 低噪音、小型电机 精密轧机	C2
<ul style="list-style-type: none"> • 一般的安装配合条件 (由样本推荐) • 一般载荷和转速, 工作温升不大 	通用机械 减速机, 传动机构	C0
<ul style="list-style-type: none"> • 内圈和外圈过盈配合, 或其中某一件过盈量大 • 内圈不容易散热 • 调心滚子轴承以承载为主要目的, 工作条件变化大时 	铁路车辆 造纸干燥机 矿山机械	C3
<ul style="list-style-type: none"> • 内圈和外圈过盈配合, 且过盈量较大; • 工作温升高, 且内圈不容易散热 • 角接触使用的球轴承: 球轴承内外圈轴线有倾斜时 	振动筛 烘干机 汽车后轮	C4
<ul style="list-style-type: none"> • 内圈和外圈过盈配合, 且过盈量很大, 并且工作温升高, 内圈不容易散热; 	振动式压路机	C5

如果轴承的工作条件非常特殊, 上述5种标准游隙都不能满足其要求, 则可以选择非标准游隙C9, 用户在订货时应注明具体的初始游隙值。用户还可以根据以往的使用情况和发现的问题改变选择游隙, 例如, 若出现严重发热或抱死情况, 则应改变选择较大的游隙。

Working Condition	Application Examples	clearance
<ul style="list-style-type: none"> • Precise fits of installation or non-interference fits • Vibration or noise are required to control strictly • Radial or lateral position are to accurately locate 	Metrological instruments and devices Low noise motor, mall motor Precise steel mill	C2
<ul style="list-style-type: none"> • Common fits of installation (suggested by catalogue) • Normal load and speed, not high temperature rise 	General machinery Reducer, transmission	C0
<ul style="list-style-type: none"> • Interference fits on inner and outer or one of them is more interference fits • Inner is difficult to radiate heat • Spherical roller bearing for being loaded mainly works under variable condition 	Railway vehicles Paper dryer Mining machinery	C3
<ul style="list-style-type: none"> • Extra interference fits on inner and outer • Inner is difficult to radiate heat while working at high temperature rise • Ball bearing working at angular contact state, or at a slight tilt between inner and outer 	Shock screen Dryer Rear wheel of auto	C4
<ul style="list-style-type: none"> • Extra interference fits on inner and outer while inner is high temperature and difficult to radiate its heat 	Vibratory road roller	C5

If a bearing worked under so particular condition that above 5 standard clearances can not meet the requirement, a non-standard clearance C9 should be adopted and its initial clearance limits should be stated when order. The customers can also determine the clearance based on their experience, successful or failure, in application of the bearing. For example, if a serious heated or clipped bearing was presented, a increased clearance should be adopted.