UDC 62-233.2

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PECULIARITIES OF ASSIGNMENT OF ROLLING BEARING MOUNTING AND PARAMETERS OF GEOMETRIC ACCURACY OF MOUNTING SURFACES OF SHAFTS AND FRAMES

The standards and methods concerning assignment of rolling bearing fit with shafts and frames via example of bearing 6-208 are analyzed. We set certain differences of recommendations according to GOST 3325-85, "Rolling bearings. Tolerance zones and technical requirements to mounting surfaces of shafts and frames. Attachment" and by reference of rolling bearing manufacturers. The following factors should be taken into consideration when assigning the mounting with the tension the internal ring of the bearing with shaft and mounting with a gap in the outer ring with a housing bore. The methods of achieving accuracy of mounting surfaces of shafts and frames via form tolerance assignment: roundness tolerance, profile of longitudinal cut, cross section, cylindricity and others. It is possible to limit the bearing rings in different ways, for example appointing the cylindrical mounting surfaces and bead end surfaces the appropriate tolerances, namely: coaxiality tolerance or full radial beat of mounting surfaces, and also perpendicularity tolerance, butt beats and full butt beats of mounting end surfaces. We suggest to expand methods of achieving the accuracy of shafts and frames depending on seriation of production and production operations metrology support.

Keywords: *tolerance; rolling bearing; the mounting of the bearing; form tolerance of the shaft; form tolerance of the bore, the roughness of the mounting surface.*

Introduction. Statement of the problem. Rolling bearings are widely used in all fields of modern mechanical engineering. Durability, low noise, reliability of bearing assemblies are largely determined by the precision of the bearing, correct choice of mounting of the bearing with the shaft and frame, as well as geometric precision of mounting surfaces. The accuracy of manufacturing of bearings is regulated by DSTU GOST 520:2014 "Rolling bearings. General technical requirements". The specified standard meets the international standards ISO 492:2002 and ISO 199:2005. When designing the bearing assemblies for installation of mounting and geometrical precision of parts designers use GOST 3325-85 «Rolling bearing. Tolerance zones and technical requirements to mounting surfaces of shafts and frames. Tolerances". Now, with the development of international cooperation during the manufacture and maintenance of products they widely use bearings not only of domestic production, but also of leading companies in Europe, the United States, Japan, South Korea, etc. Foreign manufacturers of bearings provide their recommendations for the appointment of mounting and the accuracy of the details that differ from those recommended by GOST 3325-85. In some cases there is a conflict, namely, what document should be given priority to during the appointment of tolerances and mountings. To make reasonable decisions it is necessary to find out the differences in the recommendations for the design of bearing assemblies and set the list of factors that affect the choice of tolerances and mountings of geometrical precision of shafts and frames.

Analysis of recent research and publications. Rolling bearings are bearing elements of machines that largely determine the whole of their technical and economic characteristics, such as reliability, durability, accuracy, maintainability, etc. Therefore the works are constantly performing on improving part bearing assemblies with regard to the impact of working conditions, technology, manufacturing, operation and maintenance.

Recommendations for the calculation and selection of bearing mountings, as well as the parameters of the accuracy of the surfaces that are connected with rings of bearings are given in [4, 5, 9].

The work [6] states that as a result of unnecessary regulation accuracy (mountings) of surfaces coupled with rolling bearings, the durability of the bearing reduces, ring turning around the mounting surface takes place, resulting in increased clearances and accelerates the process of wear.During the current and general maintenance of agricultural machinery up to 80 % of the bearings and 30-70% of mounting surfaces connected with the bearings are sorted out. Analysis of working conditions of bearings showed that bearing failure most often occurs as a result of the runout of the bearing rings (50 %), the destruction of the separators (20 %), the runout of mounting surfaces (15 %) and destruction through material fatigue (10 %).

The authors developed the methodology for the calculation and selection of mountings of rolling conical straight-line bearing, which takes into account: the possibility of reducing the lowest radial clearance in the bearing to zero; decrease the tension resulting from the flanks of roughness surface during insert; thermal deformation of mounting of internal and external rings; elastic deformation of bodies and tracks of rolling; the possibility of bearing assembly folding [6].

When choosing bearing mountings the factors that lead to their wear should be taken into account. The main causes of wear of bearing assembly are ring rotation and fretting corrosion on the contact surfaces. Fretting corrosion in friction connections occurs both in moving mountings (the outer ring of the bearing-frame) and fixed mounting (internal ring of the bearing-shaft). The reason of the wear is a micro motions, the source of which is not only a working machine, but even its transportation [7].

The work [8] investigates the factors that influence the target bearing mountings with detachable frames. It is established that the diameters of the holes of detachable frames under the outer rings with a local load, it is advisable to assign the field tolerances *H6*, *H7*, *G6*, *G7*, and in large units -field tolerances *G6*, *G7*, it allows to create a gap in the junction and, therefore, makes it possible the periodic turning of the latter in the process of exploitation.

It is important to note that the recommendations of the authors on the use of rolling bearing mountings and coupled details with them differ from standard and require a separate analysis.

The purpose of the article is to establish the possibilities of expanding recommendations for appointment of rolling bearing mountings and geometrical precision of mounting surfaces, shafts and frames.

The main part. The mountings of the bearings depend on their accuracy class, type of load of the rings of the bearing, magnitude and dynamics of current loads, the speed of rotation. When choosing mountings it is necessary to take into account the difference of temperatures between the shaft and the frame, mounting and contact deformation of rings that affect the operating clearance in the bearing, material and condition of mounting surfaces of the shaft and frame, conditions of installation.

The mounting of a bearing ring that rotates relative to the load, is performed with guaranteed tautness, in order to exclude its turning relatively to the surface of the shaft or frame in the process of work under load. The mounting of motionless ring is performed with guaranteed gap to ensure the adjustment of axial tension or the bearing gap, as well as to compensate for temperature extension shafts or frames [1].

There are local, circulation and resonant kind of load. In practice, there are other possible different versions of load bearing rings. Outer ring in the bearing may be fixed (fig. 1, d) or with (fig. 1 b); internal ring can with (fig. 1, d) or real (fig. 1 b); radial force can be fixed (fig. 1 a, b) or with together with the outer ring (fig. 1B) or internal (fig. 1, d).

According to the data of SNR firm, France [10] the scheme is often met in practice (fig. 1, a) – approximately 95 % when the outer ring of the bearing is installed in the frame and it is motionless, and internal ring rotates with the shaft, radial constant magnitude and direction of the force F acts on the bearing .While the outer ring has a local load, and internal one - circulating.

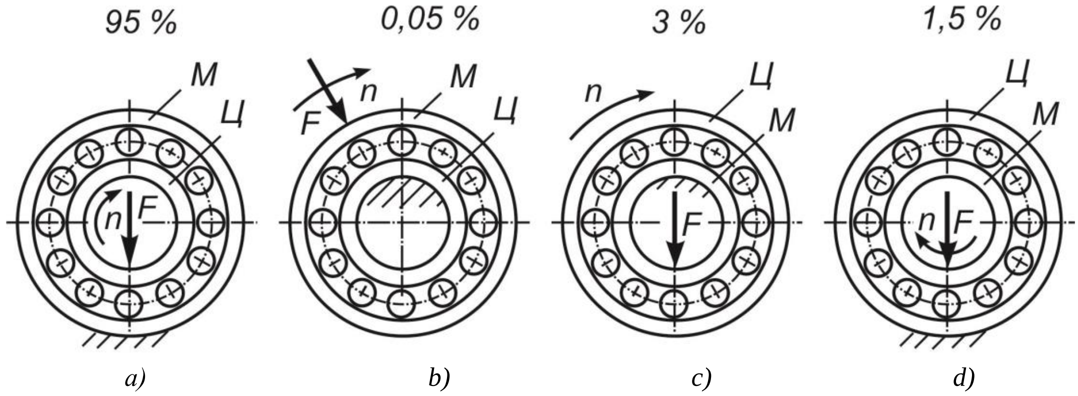


Fig. 1. Types of mountings of rolling bearing rings: L – local; C – circulating; F – radial force; n – direction of ring rotation

Since the bearing load diagram (Fig. 1, a) is the most common, the comparative analysis of assignment of mountings and parameters of precision of mounting surfaces of shafts and frames is made for this diagram using different methods and recommendations for various conditions.

Output data for selecting bearing mountings have chosen as following: single-row radial ball bearing 6-208 [3]; nominal diameter of the internal ring d = 40 mm; nominal diameter of the outer ring D = 80 mm; nominal width of ring B = 18 mm; nominal coordinate mounting chamfer r = 2 mm; dynamic load capacity C = 32000 N; static load capacity C0 = 17800 N; class precision bearing – 6; deviation of the mean diameter of the hole in the internal ring plane unit Δdmp – top: 0 mm, bottom: -10 m [2]; deviation of single width of internal ring ΔBs – top: 0 mm, bottom: -120 microns; deviation of the mean outside diameter in a plane unit ΔDmp – top: 0 mm, bottom: -11 m; deviation of single width of internal ring ΔSs – top: 0 mm, bottom: -120 microns. Conditions: radial force value F – 2; 4; 12; 18 kN; overload of 300 %. Design features: shaft – solid material – steel; frame – thick-walled material – iron.

Selection of mountings according to GOST 3325-85. Appointment of mounting of rolling bearing is tabulated by the recommendations made by GOST 3325-85. Depending on the ratio of the radial load F and C-duty radial dynamic bearing modes are divided into light (F / P ≤ 0,07), normal (0,07 <F / C ≤ 0,15) and heavy (F / C> 0 15).

To force F = 2 kN: F / C = 0,063 light mode;

to the force F = 4 kN: F / C = 0.125 normal mode;

to the force F = 12 kN: F / C = 0.375 heavy mode;

to the force F = 18 kN: F / C = 0.523 heavy mode.

Internal circulating loaded radial ball of bearing ring diameter d = 40 mm for all modes (easy, normal and heavy) mounting *L6 / js6* and *L6 / k6* are recommended.

For the outer ring of the bearing (*D* = 80 mm), which takes local type load following landing in frame: for easy and normal mode - *H7 / l6, J7 / l6, JS7 / l6*; and for normal and heavy mode - *JS7 / l6 and K7 / l6* are recommended.

Selection of mountings according the intensity of radial load. The selection of mounting of circulating loaded bearing ring is performed with the calculation method for intensity of radial load mounting surface PR [9]:

$$P_R = \frac{F}{b} k_1 \cdot k_2 \cdot k_3 , \quad (1)$$

where F – radial frame reaction on the bearing, kN;

b – working width bearing ring, m ($b = B - 2r$, where *B* – bearing width; *r* – radius of curvature or width of the bearing ring chamfer);

k_1 – coefficient of dynamic mounting, depending on the nature of loads (overload to 150 %, moderate shocks and vibrations k1 = 1, 300 % overload, bumps and vibration k_1 = 1,8);

k_2 – coefficient taking into account the degree of easing tension of mounting for thin-walled hollow shaft or frame. For continuous shaft k_2 = 1;

k_3 – coefficient of uneven distribution of radial load between the rows of rollers in biserial tapered rolling bearings or dual ball bearings between the presence of axial load *Fa* on frame. For radial and angular contact bearings with an external or internal ring k_3 = 1.

So for internal recirculation loaded ring

$b = B - 2r$ = 0,018-2·2 = 0,014 м; k_1 =1,8; k_2 =1; k_3 =1:

- to the force *F* = 2 kN P_R = 257 kN / m; recommended mounting *L6 / js6*;
- to the force *F* = 4 kN P_R = 514 kN / m; recommended mounting *L6 / k6*;
- to the force *F* = 12 kN P_R = 1542 kN / m; recommended mounting *L6 / m6*;
- to the force *F* = 18 kN P_R = 2313 kN / m; recommended mounting *L6 / n6*.

For external locally loaded ring mounting *H7 / l6* and *JS7 / l6* is recommended.

Selection of the minimum mounting tension. For circulating loaded internal ring mounting, the minimum tension can be assigned [9]. The formula is obtained by V.N. Treier based on equality of normal stresses of mounting tension and stress from the largest radial load:

$$N_{\min} = \frac{13 F \cdot k}{b \cdot 10^6} , \quad (2)$$

where $N_{\min}$ – the lowest calculated tension that provides the necessary strength mounting ring on the shaft, mm; *F* – radial force acting on the bearing, *kN*; *k* – factor depending on bearing series, light series for $k \approx 2{,}8$; medium series $k \approx 2{,}3$; heavy $k \approx 2$; b – working width of the ring bearing, m.

So for the internal ring (k = 2,8; b = 0,014 m):

- to the force F = 2 kN $N_{\min}$ = 0.0052 m = 5.2 m; nearest mounting *L6/k6;*
- to the force F = 4 kN $N_{\min}$ = 0,001 m = 10 microns; nearest mounting *L6/m6*;
- to the force F = 12 kN N_{min} = 0.0312 m = 31.2 m; nearest mounting *L6/r6*;
- to the force F = 18 kN N_{min} = 0.0468 m = 46.8 m; nearest mounting *L6/s6*.

Selection of mounting according to SNR catalogue, France. To distinguish normal load bearing (*P <C / 5*) and high (*P> C / 5*) [10].

To force *F* = 2 кN та *F* =4 кN load is normal (P <6.4 kN) for mountings for the internal ring *L6 / j6* and *L6 / k6*, and for external *H7 / l6* and *J7 / l6* are recommended.

To force *F* = 12 кN та *F*=18 кN load is high and for mountings for the internal ring *L6 / m6* and *L6 / p6*, and for external *G7 / l6* and *H7 / l6* are recommended.

Selection of mounting according to NTN catalogue, Japan. To distinguish light load bearing (P ≤ 0,06 • C), normal (0.06 C • <P ≤ 0,12 • C) and heavy mode (P> 0,12 • C) [11]. For 6208 the company bearing NTN: C = 29.1 kN.

To force kN F = 2 and F = 4 kN load is normal (1.746 <P ≤ 3,49), mountings for the internal ring L6 / k5, L6 / k6, L6 / m6 and external H7 / l6 and G7 / l6 are recommended.

To force F = 12 kN and 18 kN F = load is heavy and it is recommended to fit the internal ring L6 / k5, and for external G7 / l6 and H7 / l6.

Selection of mounting according to SKF catalogue, Sweden. If P ≤ 0,05 • C, it is considered an easy mode, and if P ≥ 0,05 • C, it is normal and heavy. For 6208 bearing company SKF: C = 32.5 kN [12]. So, for the full range of variation of F, mode can be considered normal. In this case, mountings for the internal ring *L6 / k5*, and for external – *H7 / l6* are recommended.

Recommended fields bearing tolerances and landings are given in Table. 1 and 2, and field tolerance scheme – Fig. 2.

As seen from the table. 1 and 2 for bearing accuracy class 6 quality of shafts prescribed *IT6* or *IT5* or [11], and for holes in the frame – *IT7*.

If the radial force *F = 2 kN* and *F = 4 kN*, for mounting surfaces shafts prescribed tolerance field *js6, j6, k5, k6, m6*. Obviously, these field tolerances can be considered close, as they almost overlap.

Table 1

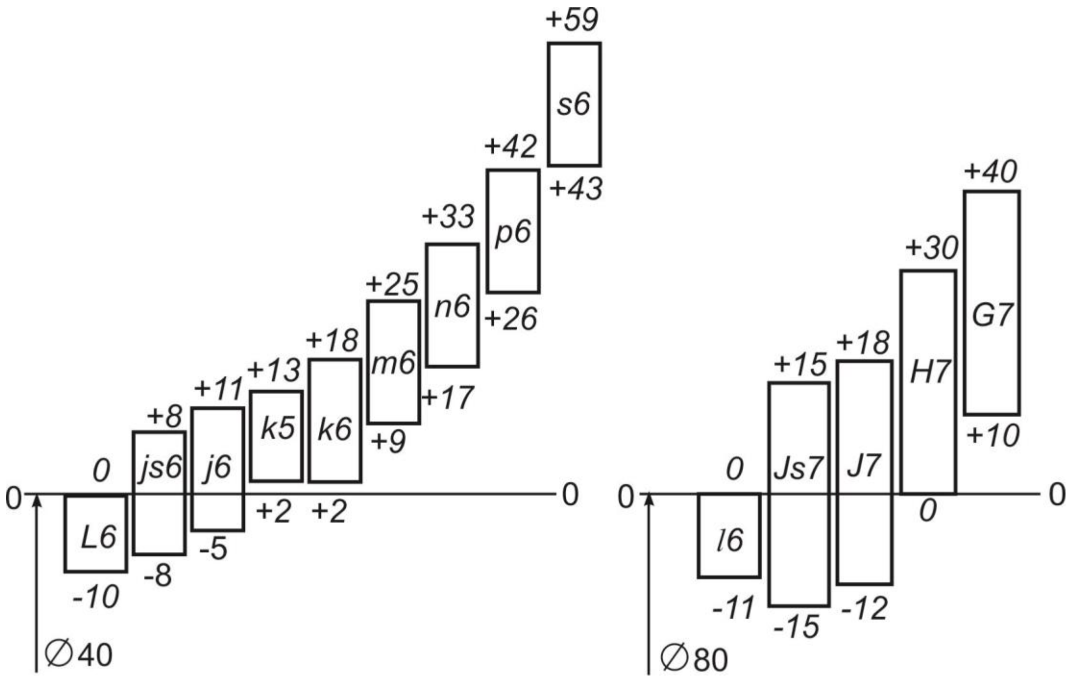
Field tolerances of a bearing for connection with an internal ring of a bearing L6

Force *F*, кН	GOST 3325-85	P_R	N_{min}	SNR, France	NTN, Japan	SKF, Sweden
2	*js6, k6*	*js6*	*k6*	*j6, k6*	*k5, k6, m6*	*k5, k6*
4		*k6*	*m6*			
12		*m6*	*p6*	*m6, p6*	*k5*	
18		*n6*	*s6*			

Table 2

Field tolerances of a bearing for connection with an external ring of a bearing l6

Force *F*, кН	GoOST 3325-85	P_R	SNR, France	NTN, Japan	SKF, Sweden
2	*H7, J7, JS7*	*H7*	*H7, J7*	*H7, G7*	*H7*
4	*H7, J7, JS7, K7*	*JS7*			
12	*JS7, K7*		*H7, G7*		
18					



а) *б)*

Fig. 2. Bearing field tolerances: a) connection of internal ring and a shaft; b) connection of external ring and a frame

The average value of shaft deflection in the mentioned field tolerance range is +8.5 microns. The average value in mounting tension ranges from Nc = 5 microns in mounting ∅40*L6*/*js6* to N_c = 22 microns in mounting ∅40*L6*/*m6*.

To force F = 12 кN and F = 18 кN the following bearing field tolerances are recommended: *js6, k5, k6, m6, n6, p6, s6*. The average value of tension for a number of mountings ranges from N_c = 5 microns in mounting ∅40*L6*/*js6* to Nc = 56 microns in mounting ∅40*L6*/*s6*. These differences in the average tension value for the same working conditions of a bearing are apparently essential. Mounting *L6*/*s6* is obtained by calculations of minimal tension. This mounting is not found among the recommended GOST 3325-85 or in catalogues of manufacturers of rolling bearings. Obviously, the available method of calculation gives inflated values of tension in the range of high load bearing and it should not be used.

When choosing mounting with tension circulating loaded internal ring to the shaft a number of circumstances should be taken into account. In particular, the tension must be sufficient to ensure the accuracy and stability of the rotation position relative to the frame moving parts as bearings are the frame assembly and largely determine the accuracy and life time of the entire machine as a whole. [5] The tension on the contact surfaces has to eliminate the possibility of cranking the bearing under load mounting on the surface of the shaft. Rotation of the bearing rings reduces the precision rotation and unbalance moving system. There is intense mounting wear and assembly failure mechanism.

With value and dynamics increasing of operating loads and heating unit is necessary to increase the tension, as the increased rotational speed causes an increase in resistance to rotation bearing points, increased vibration that can release the mounting and cause rotation of the rings relatively to mountings. In the bearing rings rotational cranking of mechanical friction prevents axial load of the bearing [5]. Mounting with a greater average tension should be used for hollow shafts for compensation of radial deformation.

On the other hand the tension should not be too intense. Increased tension of mounting on the shaft can cause a significant decrease in radial bearing clearance, which causes an increase in friction, reduced reliability and durability. It is also important to ensure ease of installation and dismantling. The tension should not cause significant deformation of parts. Significant tensions and efforts of pressing out or rings may cause damage to the mounting surfaces and working surfaces of bearings [1].

In connections of loaded external bearing ring with a frame hole, gaps are formed. In mounting ∅80*JS7*/*l6* S_{min} = 5,5 microns and in the mountings ∅80*G7*/*l6* S_{min} = 20,5 microns. Openings with deviations in the range of 10 ... 15 mm enter all fields of recommended tolerances.

Ensurence of the bearing and the frame composition can be only provided by mounting clearance or transition with a small percentage of tension, as provided for one-piece frames. If the frame is sectionalized, the most loaded bearing assembly unit can be installed with the tension, if the bearing is not «floating» [6].

The gap is preferably selected so that on the one hand to eliminate the possibility of cranking the ring, but be able to regulate the axial tension or the bearing clearance, and temperature compensation to assembly extension detail. But ther is a point of view that at low speeds irregular cranking a shaft fixed ring is sometimes even useful, because this changes the position of the load external ring. It improves the durability of the bearing, but such angular displacement may allow only radial bearings [5].

Excessive increase in the gap between the bearing ring and the frame impairs distribution of the load on the bearing rolling elements, which reduces its life. It is necessary to note that the value gap remains constant throughout the life of the assembly, and gradually increased - first by reducing the surface roughness and grinding in, and then by wear often resulting from fretting corrosion. Increasing the gap can lead to the ring bearing rotation, and subsequent failure of the bearing surface and the frame mounting.

The choice of tolerance form and location of the mounting surfaces. Rolling bearings rings are thin-walled parts and after installation they usually take the form of mounting surface. Shape inaccuracies of shaft can be transmitted to the rolling surface and cause vibration and wear. [5] Therefore, to limit the deviation forms of the tracks of rolling bearing rings, suitable tolerances of mounting surfaces of cylindrical shaft and frames are set. Deviations of forms can have an impact not only on the geometry of the bearing surfaces, but also to create additional local mounting tensions and affect the accuracy of the position of the rings, as mountings are essential. It is also important that mutual fitting of surfaces are equal, for better load distribution and heat dissipation during operation of the machine.

For normal operation of the bearing it is important to minimize skew error of bearing rings. Mutual skewing of internal and external bearing rings is one of the primary causes of damage to the bearings and concentration contact stresses and triggers additional resistance to rotation of the shaft. The greater the imbalance, the greater the energy loss and lower bearing service life [4]. Skewing of bearing rings causes axis whipping, the concentration of stress on the contact surfaces, as well as increased noise and vibrations, whose intensity is proportional to the square of the rotation frequency [5].

To reduce skew error of bearing rings and the violation of its geometric form of rolling paths it is necessary to ensure alignment axes of rotation of the bearing rings and the supporting ends perpendicular relative to the common axis. This task can be performed in different ways by setting the appropriate tolerances of form and location of the landing surface details.

According to GOST 3325-85 tolerances of mountings of shafts and frame holes can be defined in terms of radial (roundness tolerance, profile tolerance of longitudinal section) or diametric dimension (diameter tolerance of volatility in cross and longitudinal section).

Variability in diameter of cross and longitudinal section of the mounting surface is the difference of largest and smallest single diameters measured in the same cross or longitudinal section. Diameter volatility tolerance determines the largest allowable value of diameter volatility in the cross or longitudinal section.

Selection of control parameters of form deviation in a radial or diametric dimension is provided by a product manufacturer. It should be noted that the profile tolerance of longitudinal section is provided in the current GOST 2498-94 "Basic norms of interchangeability. Tolerances of form and position of surfaces. Terms and definitions", but it is absent in a new standard of ISO 1101: 2009 "Specification of product geometry (GPS). Geometric tolerances. Tolerances of form, orientation, location and runout". Instead the deviation profile tolerance of longitudinal section, parallelism tolerance of cylindrical surface is often used.

For shaft ∅40*k6* [1]: roundness tolerance is 4 microns; admission profile of longitudinal section is 4 microns; volatility tolerance of diameter in cross and longitudinal section is 8 mm (Fig. 3, a).

For hole ∅80*H7*: roundness tolerance is 7.5 microns; profile tolerance of longitudinal section is 7.5 microns; volatility tolerance of diameter in cross and longitudinal section is 15 microns.

Coaxility tolerance of frame mounting surfaces are appointed depending on the allowable skew angle of bearing rings Θ_{max} between the axes of the internal and external rings of rolling bearings, mounted in a bearing assembly. For single-row radial ball bearings with normal radial clearance $\Theta_{max} = 8'$.

Alignment tolerances in diametrical expression relatively to common axis of mounting surface are determined by the formulas: for the shaft; for frame $T_в = B \cdot tg\theta_в$, where B – the width of the ring bearing. Alignment tolerance given in the standard is fair to ring width = 10 mm. If the width of the ring is different then table values should be multiplied by the value $B/10$.

So for a given shaft alignment tolerance in diametrical expression is:

$T_в = B \cdot tg\theta_в = 18/10 \cdot 4 = 7{,}2$ microns; accepted 0,007 mm.

For frame: $T_к = B \cdot tg\theta_к = 18/10 \cdot 8 = 14{,}4$ microns, accepted 0,014 mm.

The drawings of the shaft and frame it is permitted to determine radial runout tolerance instead of alignment tolerance relatively to common axis of mounting surfaces.

Shoulder face is optional clamping base, which tightly pressed against ring bearings for increasing the rigidity of bearings. At the basic end surface of the shoulder shafts and frames mechanical beating tolerance is set, for shaft ∅40 and bearing of accuracy class 6 - 16 microns; for frame - 30 microns.

According to the SNR catalogue, France for shaft ∅40*k6* and bearing of accuracy class 6 a tolerance of set cylindricity of mounting surfaces is 4 mm [10].

Alignment tolerance is determined by a formula $T = 1{,}5 \cdot L$, where L is a distance in axial direction between the midpoints of support surfaces for rolling bearings. For L = 180 mm alignment tolerance T = 270 microns (0.25 mm accepted). Radial runout tolerance of bearing surfaces of the shoulder faces is 16 microns (Fig. 3, b).

For a frame hole ∅80*H7* tolerance of cylindricity of mounting surface is 8 microns; radial runout tolerance of shoulder faces is 30 microns; alignment tolerance is determined by the relationship: $T = 2 \cdot L$, where L is a distance of axial direction between the midpoints of support surfaces of rolling bearings. Assuming that L = 180 mm, the alignment tolerance is T = 360 microns.

Manufacturer of bearings SKF firm, Sweden offers two ways to designate tolerances of form and location of the mounting surfaces. In the first method appointed tolerances of cylindricity of mounting cylindrical surfaces and tolerances of perpendicular end bearing surfaces. In the second method the same surface tolerances are assigned full and complete mechanical radial runout (Fig. 3, c).

So according to the first method of shaft cylindricity tolerances must be one or two quality classes above the size tolerance. For example, if the mounting on the shaft tolerance *k6* is performed, then the form tolerances must correspond to quality class Kvalitet *IT5* or *IT4*. For shaft ∅40*k6* and bearing of accuracy class 6 it is recommended to assign cylindricity tolerance $T_1 = IT4/2 = 7/2 = 3{,}5$ microns. For the mounting surface of frame hole ∅80*H7*: $T_1 = IT4/2 = 8/2 = 4$ microns.

The perpendicular tolerances of the supporting end surfaces are defined relatively to a common axis of the mounting surface and should be at least one quality class higher compared with tolerances conjugate diameter cylindrical seat. According to the shaft: $T_2 = IT4 = 7$ microns, and for hole $T_2 = IT4 = 8$ microns.

According to the second method to ∅40*k6* shaft and bearing of accuracy class 6 prescribed tolerance of full radial runout $T_1 = IT4/2 = 7/2 = 3{,}5$ microns. For the mounting surface casing hole ∅80*H7* $T_1 = IT4/2 = 8/2 = 4$ microns.

To end bearing surfaces of the shaft tolerance $T_2 = IT4 = 7$ micron is prescribed, and for a hole $T_2 = IT4 =$ microns.

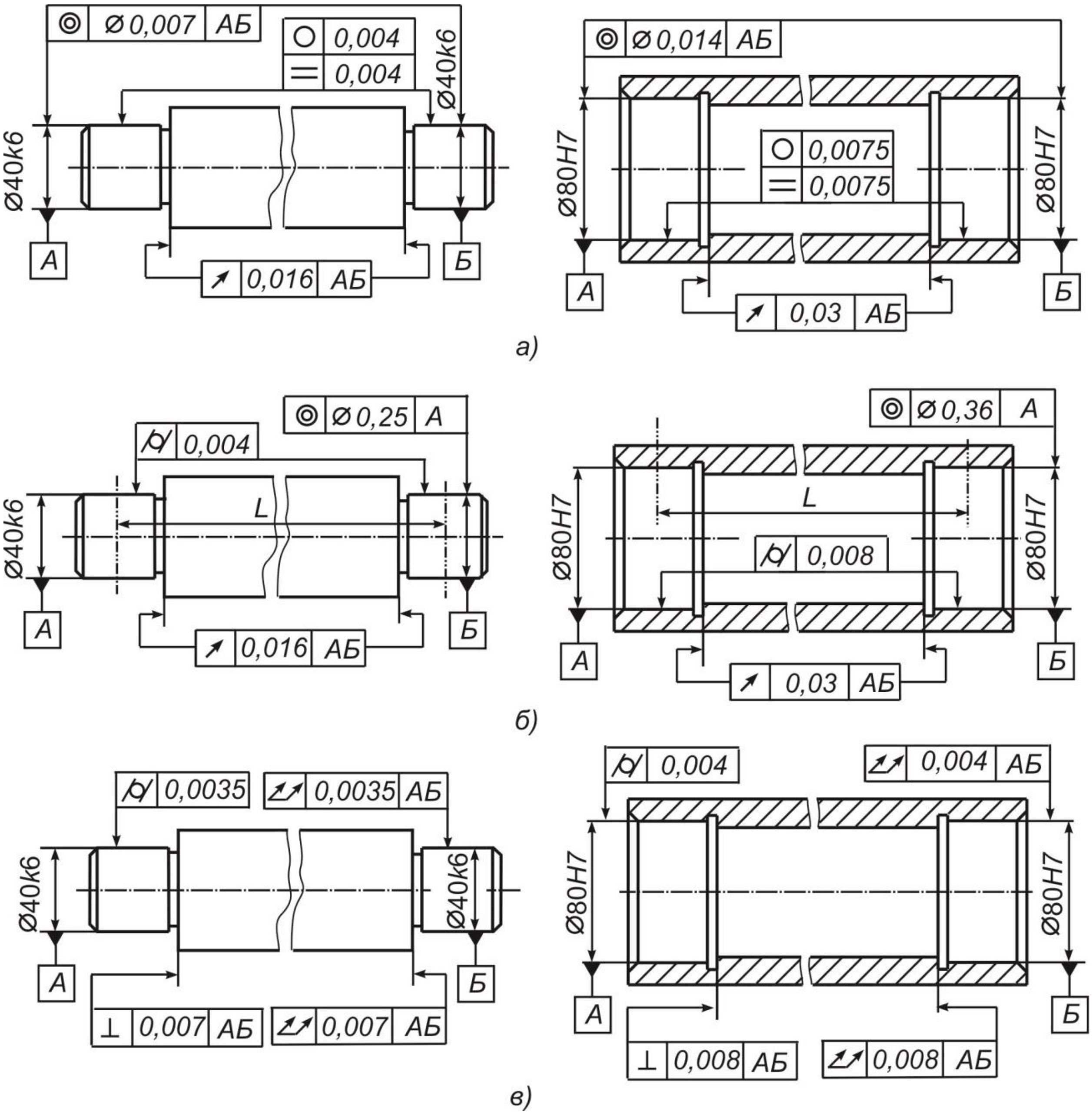


Fig. 3 Form tolerances and alignment of mounting surfaces of shafts and frames:
a) according to GOST 3325-85; b) according to SNR catalogue, France;
c) according to SKF catalogue, Sweden

As shown in Fig. 3, numerical values of form tolerances (cylindricity or roundness and profile of the longitudinal section) is virtually identical to the shaft and are 3.5–4.0 mm and for hole – 4.8 mm. Selection of parameters that must be controlled depending on batch production and features metrology of a company provision.

GOST 3325-85 and manufacturers of rolling bearings in different ways face the challenge of providing alignment of mounting surfaces. GOST 3325-85 for example recommends alignment tolerance of axes mounting surfaces relatively to common axis in diametrical terms: for shaft – 7 mm and for hole – 14 microns.

The SKF firm, Sweden recommended to appoint tolerances of a full radial runout of mounting surfaces. To shaft the access is 3.5 mm and for hole - 4 mm, that tolerance is approximately two to three times more accurate than the recommended standard. In addition, tolerance is complete radial runout of total tolerance of form and position, which includes cylindricity tolerances and alignment.

The SNR firm, France and as GOST 3325-85 recommends installing alignment tolerance, but there are some differences. In particular, the tolerance of axis alignment is set to a mounting surface, while the other axis of the mounting surface is taken as the base (in the standard the tolerance is assigned relatively to common axis of both surfaces). In addition, the tolerance is wider (2–3 times greater than GOST 3325-85) for the shaft is 25 microns and for hole is 36 microns. The choice of numerical tolerance depends on the distance L between the midpoints of landing surfaces for bearings.

At the end bearing surface of the shoulder face GOST 3325-85 and SNR firm, France recommend to assign the tolerance of radial runout, which includes deviations from flatness and deviation from the perpendicular end relatively to common axis. Recommended tolerance is 16 microns. The SNR firm sets the perpendicular tolerance or access of the full radial runout to the end of the surface. This numerical value of both tolerances for the shaft 7 microns and for frame hole is 8 microns and it is two to three times more accurate than the tolerances GOST 3325-85.

The roughness of the mounting and end surfaces. Mounting surfaces must be well machined to prevent cutting and crushing of microscopic bearings during installation. Surface roughness characterizes the state of the bearing surface and affects the real area of actual contact. Friction and wear of parts during operation depend on microscopic size and shape of contact surfaces significantly.

Small roughness values make it possible to increase the accuracy of measuring diameters of devices of the contact point. To limit the roughness of mounting and support surfaces for bearings up to 500 mm parameter *Ra* is set, and for larger diameters - parameter *Rz*. Recommendations for the purpose of mounting surface roughness parameters and standard catalogues of manufacturers of rolling bearings are shown in Table. 3.

Some manufacturers of bearings [10, 12] believe that the mounting surface roughness of bearing has such a significant impact on working bearing characteristics as compliance with tolerances of specified size, shape and relative position. However, the given tension value is as more accurate, as smaller the roughness of conjugated surfaces is.

Table 3

Roughness of shaft and frame mounting surfaces Ra, micron

Source of information	Shaft		Frame	
	cylindrical surface	end surface	cylindrical surface	end surface
GOST 3325-85	0,63	1,25	0,63	1,25
NTN, Japan	0,8-1,6		1,6-3,2	
SNR, France	1,0	2,0	2,0	4,0
SKF, Sweden	0,4-2,0			

Conclusions. Comparative analysis of the most common recommendations [4, 9] GOST 3325-85 and manufacturers of rolling bearings on the selection of parameters of bearing mounting and precision shafts and frames to accept the conditions revealed:

1. GOST 3325-85 recommends connecting with bearings of accuracy class 6 to use *IT6* quality class shafts and holes *IT7*. Several bearing manufacturers, including company NTN (Japan), SKF (Sweden), and others to improve the accuracy of assemblies recommend to assign for shafts not only *IT6*, but also more accurate *IT5* quality class.

2. During assigning the rolling bearing mounting the list of mountings can be extended compared to GOST 3325-85 guidelines, it is proved by long practice of global manufacturers of rolling bearings.

3. By the method of calculating the minimum mounting tension we obtained *L6 / s6*, which is not found among the recommended GOST 3325-85 or in catalogues of manufacturers of rolling bearings. Obviously, the available method of calculation gives inflated values of tension in the range of high load bearing and its use is not necessary.

4. It is possible to provide the necessary accuracy of mounting surfaces of shaft and frames by assigning different tolerances, roundness tolerance and tolerance profile longitudinal section (GOST 3325-85); cylindricity tolerance (SNR, France, SKF, Sweden and others.) access to the full radial runout is relatively to common axis (SKF, Sweden) and others.

5. The tolerance of profile longitudinal section (recommended GOST 3325-85) is provided in the current GOST 2498-94 "Basic norms of interchangeability. Tolerances of form and position of surfaces. Terms and definitions ", but it is not in a new standard of ISO 1101: 2009 "Specification of geometrical product (GPS). Geometric tolerances. Tolerances of form, orientation, location and runout". Instead of deviation tolerance profile of longitudinal section parallelism tolerance of generators of the cylindrical surface can be used.

6. To limit the distortion of the bearing rings can be assigned to different tolerances, alignment tolerance mounting surfaces and radial runout tolerance of shoulder face [1, 10]; admission of perpendicular supporting end tolerances or complete radial runout tolerance of mounting surfaces and complete mechanical beating the shoulder face [12] and others. Choosing the type of tolerance depends on the batch production and features metrology of company provision.

7. Roughness of mounting bearing surfaces has such an important influence on bearing performance as compliance with tolerances specified size, shape and relative position, and can vary widely: for mounting surfaces of shafts *Ra* 0,4 microns to *Ra* 1,6 microns; for mechanical shaft surfaces from *Ra* 0,4 microns to *Ra* 2

microns; mounting surfaces for holes - from *Ra* 0,4 micron to *Ra* 3,2 microns; for mechanical surface holes - from *Ra* 0,4 micron to *Ra* 4 microns.

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The article was sent to the publishing department on 13.03.2017.