Engineering Materials – Anti-friction Bearings for Agricultural Machines – Specifications and Applications

Foreword

The formulation of this National Standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Enhancing the Implementation of the AFMA Through Improved Agricultural Engineering Standards" which was funded by the Bureau of Agricultural Research (BAR) of the Department of Agriculture (DA).

This standard has been technically prepared in accordance with PNS 01-4:1998 (ISO/IEC Directives Part 3:1997) – Rules for the Structure and Drafting of International Standards. It provides specifications and proper application of anti-friction bearings.

The word "shall" is used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted.

The word "should" is used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that certain course of action is preferred but not necessarily required.

In the preparation of this standard, the following references were considered:

Baumeister, Theodore (ed.) 1997. Mark's handbook for mechanical engineers. 10th Edition. Mc Graw Hill Book Company, USA.

Faires, V. M. 1969. Design of Machine Elements. Macmillan Company, New York USA.

Horton, H. L. (Ed.) 1984. Machinery's handbook. 23rd Edition. Industrial Press Inc, New York.

Richey, C. B. (Ed.) 1961. Agricultural engineer's handbook. Mc Graw Hill Book Company, USA.

SKF General Catalog 1994. Germany

Quayle J. P. (Ed.) 1971. Kempe's engineer's yearbook. Volume 1. Morgan-Grampian Book Publishing Co. Ltd, London.

Engineering Materials – Anti-friction Bearings for Agricultural Machines – Specifications and Applications s

1 Scope

This standard establishes specifications and provides sufficient technical information for the proper application of anti-friction bearings for agricultural machinery.

2 References

The following normative references contain provisions which, through reference in this text, constitute provisions of this standard:

PAES 301:2000, Engineering Materials – V-belts and Pulleys for Agricultural Machines – Specifications and Applications

PAES 305:2000, Engineering Materials – Shafts for Agricultural Machines – Specifications and Applications

3 Application

Anti-friction bearings are designed to support and mount rotating shafts. They transfer loads between rotating and stationary members and permit relatively free rotation with minimum friction. The most significant advantage of anti-friction bearings is that the starting friction is not very much larger than the operating friction.

4 Definitions

4.1
radial load
load or force passing through the axis of rotation

4.2
rated life
L_{10}
the number of revolutions or hours at a given constant speed that 90 percent of an apparently identical group of bearings will complete or exceed before the first evidence of fatigue develops

4.3
basic dynamic load rating
C
the radial load that a ball bearing can withstand for one million revolutions of the inner ring

4.4
equivalent dynamic load
P
constant stationary radial load which, if applied to a bearing with rotating inner ring and stationary outer ring, would give the same life as that which the bearing will attain under the actual conditions of load and rotation

4.5
basic static load rating
C_O
the maximum radial load, which corresponds to a calculated contact stress at the center of the most heavily, loaded rolling element/raceway contact of:

- 4,600 MPa for self-aligning ball; bearings;
- 4,200 MPa for all other ball bearings
- 4,000 MPa for all roller bearings

4.6
equivalent static load
P_O
static radial load, if applied, which produces a maximum contact stress equal in magnitude to the maximum contact stress in the actual condition of loading

5 Nomenclature

Nomenclature of anti-friction bearings is shown in Figure 1.

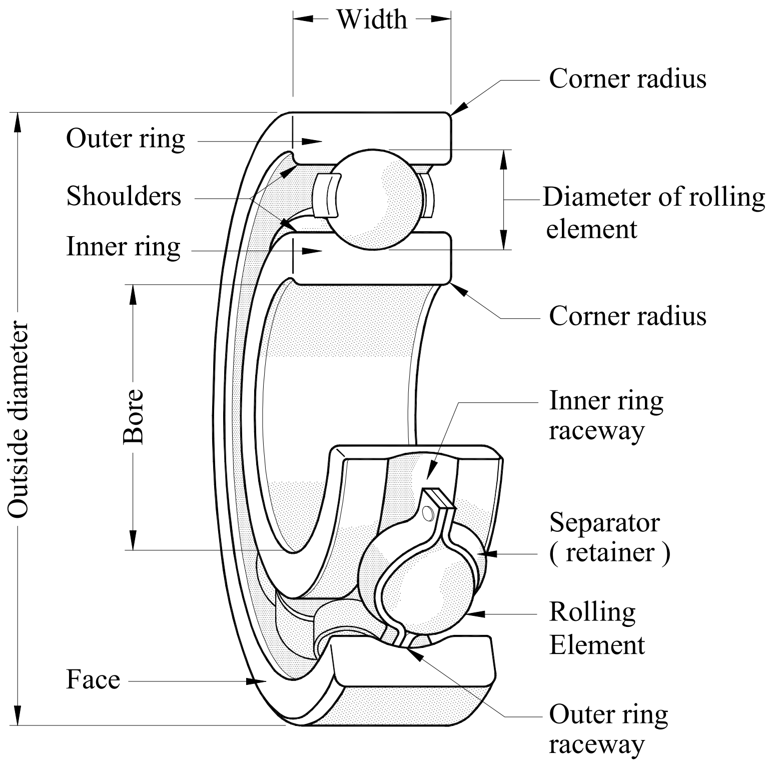

Figure 1 – Nomenclature of anti-friction bearings

6 Types

6.1 Ball Bearings

6.1.1 Single-row Radial
This bearing is often referred to as the deep groove or conrad bearing (Fig. 2). It is available in many variations such as single, double shields, and seals. This type of bearing is normally used for radial; and thrust loads (maximum two-thirds of radial).

Figure 2 - Single-row radial

Figure 3 – Maximum capacity

6.1.2 Maximum capacity

Maximum capacity bearings have a geometry that is similar to that of a deep-groove bearing except for a filling slot (Fig. 3). This slot allows more balls in the complement and thus will carry heavier radial loads. However, because of the filling slot, the thrust capacity in both directions is reduced drastically.

6.1.3 Double-row

This bearing provides for heavy radial and light thrust loads without increasing the outside diameter of the bearing (See Fig. 4). It is about 60 to 80 percent wider than a comparable single-row bearing. Because of the filling slot, thrust loads may be light.

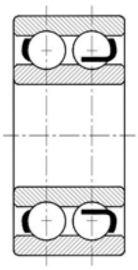

Figure 4 – Double-row

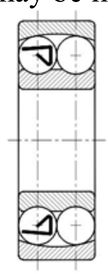

Figure 5 – Internal self-aligning double-row

6.1.4 Internal self-aligning double-row

This bearing may be used for primarily radial loads where self-alignment (±4°) is required. The self-aligning feature (Fig. 5) should not be abused, as excessive misalignment or thrust load (10 percent of radial) causes early failure.

6.1.5 Angular-contact bearings

These bearings are designed to support combined radial and thrust loads or heavy thrust loads depending on the contact-angle magnitude (Fig. 6).

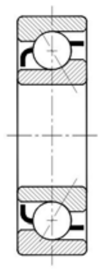

Figure 6 – Angular contact bearings

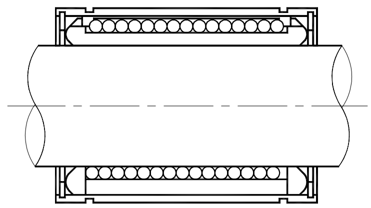

Figure 7 – Ball bushings

6.1.6 Ball bushings

This type of bearing is used for linear motions on hardened shafts (Rockwell C 58 to 64). Some types can be used for linear and rotary motions (Fig. 7).

6.1.7 Split-type ball bearing

This type of ball or roller bearing has split inner, outer ring, and cage, which are assembled by screws (Fig. 8). This feature is expensive but useful where it is difficult to install or remove a solid bearing.

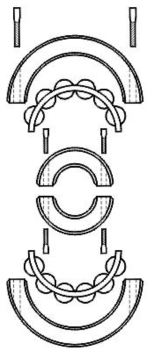

Figure 8 – Split type

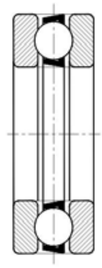

Figure 9 – Ball thrust bearing

6.1.8 Ball thrust bearing

It may be used for low-speed applications where other bearings carry the radial load (Fig. 9). These bearings are made with shields, as well as the open type.

6.2 Roller bearings

6.2.1 Cylindrical roller

These bearings utilize cylinders with approximate length/diameter ratio ranging from 1:1 to 1:3 as rolling elements (Fig. 10). They are normally used for heavy radial loads and especially useful for free axial movement of the shaft. They also have the highest speed limits for roller bearings.

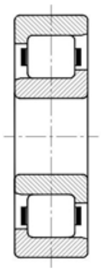

Figure 10 – Cylindrical roller

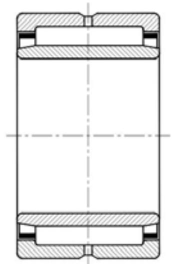

Figure 11 – Needle bearings

6.2.2 Needle bearings

These bearings have rollers whose length is at least 4 times their diameter (Fig. 11). They are the most useful where space is a factor and are available with or without inner race, it must be hardened or ground. Full-complement type is used for high loads, oscillating, or slow speeds. Cage type should be used for rotational motion. They cannot support thrust loads.

6.2.3 Tapered roller

These bearings are used for heavy radial and thrust loads. They are designed so that all elements in the rolling surface and the raceways intersect at a common point on the axis: thus true rolling is obtained (Fig 12). Where maximum system rigidity is required, the bearings can be adjusted for a preload. They are available in double-row.

Figure 12 – Tapered roller

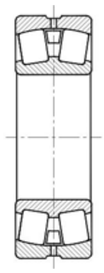

Figure 13 – Spherical roller

6.2.4 Spherical roller

These bearings are excellent for heavy radial loads and moderate thrust (Fig. 13). Their internal self-aligning feature is useful in many applications such as HVAC fans.

6.2.5 Straight-roller thrust bearing

These bearings are made of a series of short rollers to minimize the skidding, which causes twisting of the rollers (Fig. 14). They may be used for moderate speeds and loads.

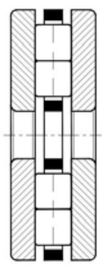

Figure 14 – Straight roller thrust

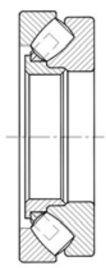

Figure 15 – Tapered roller thrust

6.2.6 Tapered-roller thrust bearing

It eliminates the skidding that takes place with straight rollers but causes a thrust load between the ends of the rollers and the shoulder on the race (Fig. 15). Thus speeds are limited because the roller end and race flange are in sliding contact.

NOTE Types of bearings that were discussed are commonly available /used bearings. Other types of anti-friction bearings are not discussed in this standard.

7 Designation

7.1 Bearings shall be designated by the following:

Prefix – Type code – Width series – Diameter Series – Bore Code – Suffix

EXAMPLE NU 2355

Type:	Roller bearing
Width series:	2
Diameter series:	3
Bore code:	55

NOTE Prefixes and suffixes may also be added to the basic code to indicate special designs.

7.2 The first digit/digits, letters/letters of the bearing code define the bearing type (see Table 1).

Table 1 – Codes for types different types of bearings

Type code	Bearing type	Type code	Bearing type
1	Self aligning ball	22	Spherical roller (Self-aligning)
2	Type 1 but wider	23	Type 22 but wider
3	Double row angular contact	51	Ball thrust bearing
4	Double row ball	M	Radial ball with filling slots
6	Single row ball (Deep groove)	N	Cylindrical roller (Designated as: NU, NC, NF, NH, NJ, NUP depending on the shoulder design, refer to Figure 16)
7	Single row angular contact		
16	Type 6 but narrower	QJ	Single row duplex ball

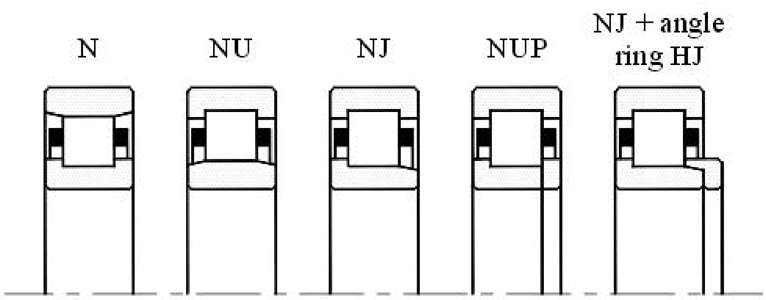

Figure 16 – Classification of roller bearings according to shoulder design

7.3 The second pair of digits defines the dimension series (Refer to Fig. 1 for diameter of rolling element and bearing width). The right hand indicates the diameter series which indicates the size of the radial section. In ascending order of size, the series is: 7, 8, 9, 0, 1, 2, 3, and 4. The left hand digit indicates the width series (8, 0, 1, 2, 3, 4, 5, 6, and 7); 8 being the narrowest bearing and 7 being the widest. The normal range is 0 - 6.

7.4 The last section of the bearing code is a two-digit number that indicates the bore code (Refer to Fig. 1 for bearing bore). For all bearings except double acting thrust bearings, Table 2 shall be applied:

Table 2 – Codes for different bore diameters

Bore diameter (mm)	Bore code
10	00
12	01
15	02
17	03
20	04
Bores from 20-480	Bore diameter divided by 5

8 Materials

8.1 Through-hardened steels

The most common through-hardening steel used for anti-friction bearings is carbon chromium steel containing approximately 1% carbon and 1.5% chromium. For bearing components having large cross-sections, steels alloyed with manganese and molybdenum are used because of their superior through-hardening properties.

8.2 Case-hardening steels

Chromium-nickel and manganese-chromium alloyed steels with a carbon content of approximately 0.15% are those case-hardening steels most commonly used for rolling bearings.

9 Recommended design practices

9.1 Selection of rolling element

9.1.1 Ball bearings function on theoretical point contact. Thus they are suited for higher speeds and lighter loads than roller bearings.

9.1.2 Roller bearings are generally more expensive except in larger sizes. Since they function theoretically on line contact, they will carry heavy loads, including shock, more satisfactorily, but are limited in speed.

9.1.3 Figure 17 serves as a guide for selection of ball or roller bearings. This figure is based on a rated life of 30,000 h.

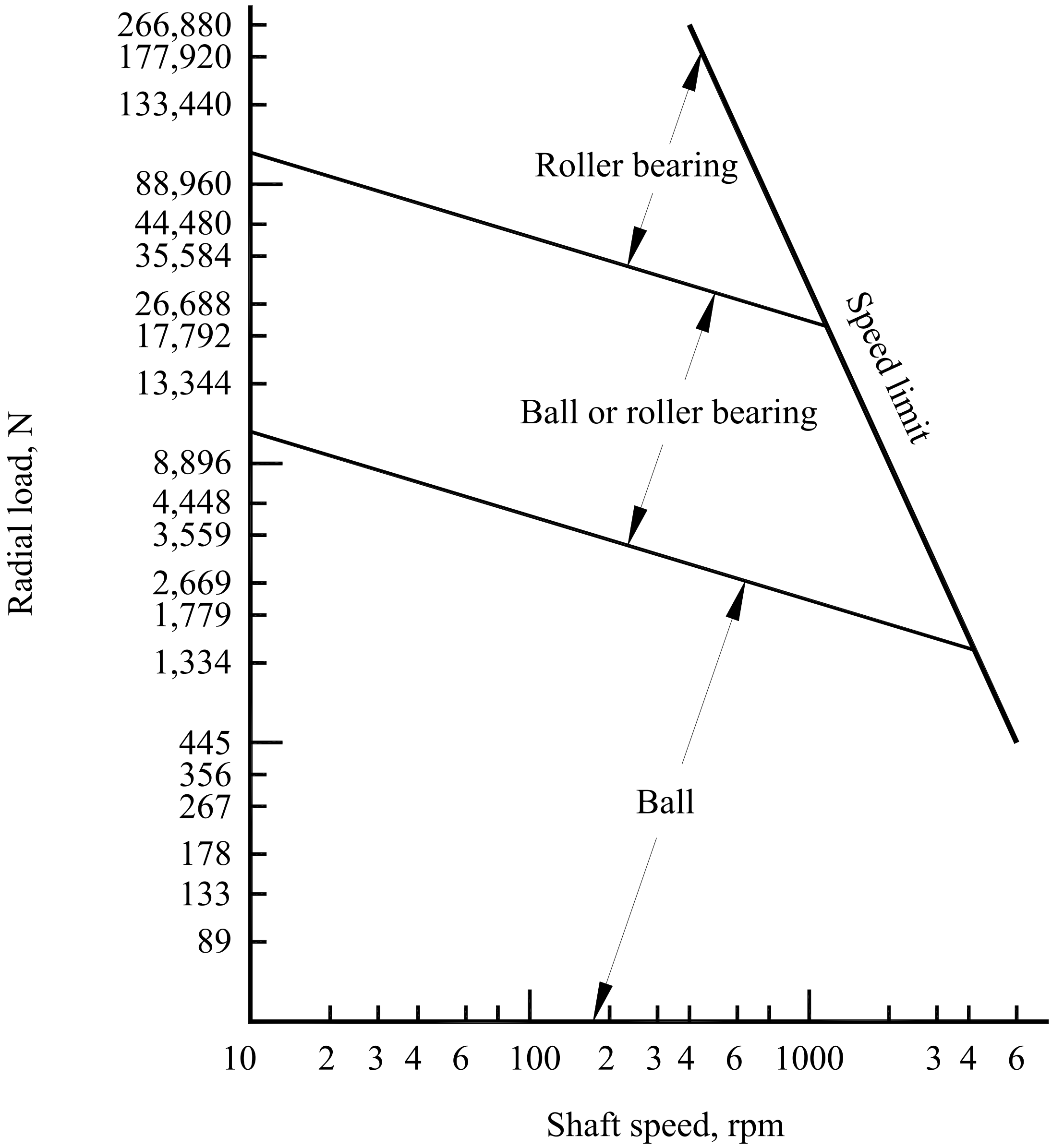

Figure 17 – Guide to selection of roller or ball bearings

9.2 Load rating

9.2.1 Basic dynamic load rating

This rating is always used in determining bearing life for all speeds and load conditions. Basic load ratings for different types and sizes of bearings are shown in Table 3.

9.2.2 Basic static load rating, C_O

This rating is used only as a check to determine if the maximum allowable stress of the rolling elements will be exceeded. It is never used in calculating bearing life. Static load ratings for different types and sizes of bearings are presented in Table 3.

Table 3 – Approximate basic and static load ratings, N

Bearing bore, mm	Ball single-row 2 series		Ball single-row 3 series		Ball double-row 2 series		Roller cylindrical 3 series		Roller spherical 2 series	
	C_O	C	C_O	C	C_O	C	C_O	C	C_O	C
10	2,669	4,626	3,781	6,361	3,558	5,382	4,537	8,718		
12	3,025	5,249	4,626	7,339	5,560	8,095	6,005	11,298		
15	3,469	5,916	5,427	8,763	6,361	9,029	6,761	12,543		
17	4,448	7,384	6,539	10,408	8,184	11,164	9,207	16,458		
20	6,183	9,875	7,828	12,143	11,298	15,479	11,387	19,972		
25	6,939	10,764	10,453	15,790	12,712	16,813	16,547	28,289		
30	10,008	14,945	13,878	20,461	18,281	22,863	22,551	37,630		
35	13,655	19,705	17,881	25,665	24,909	29,802	28,467	46,259		
40	15,657	22,418	22,329	31,403	28,601	34,161	35,273	55,600	52,486	67,610
45	17,792	25,176	27,266	37,497	32,559	38,342	41,411	65,386	56,045	70,723
50	19,794	26,999	35,628	47,816	36,162	41,011	51,597	79,619	60,493	74,726
55	25,042	33,360	41,811	55,200	45,814	50,707	56,045	84,957	73,392	90,294
60	30,914	40,343	48,492	63,068	56,490	61,382	67,610	101,414	92,518	112,090
65	34,072	44,035	55,671	71,395	62,272	66,720	88,515	128,992	113,424	134,330
70	37,408	47,656	63,340	80,197	68,499	72,502	95,187	136,998	122,320	141,891
75	40,877	51,641	71,524	87,181	75,171	76,950	103,194	146,339	129,437	147,229
80	44,524	55,822	80,153	94,431	81,398	84,957	120,096	169,469	142,781	163,686
85	52,264	64,452	89,316	101,770	86,736	87,626	137,443	192,598	169,914	192,154
90	60,626	73,570	98,968	109,332	98,301	100,525	156,570	217,062	197,936	221,510
95	69,611	83,356	109,109	116,982	127,213	127,213	175,696	241,082	217,062	243,306
100	79,174	93,986	130,905	133,173	144,560	142,781	198,826	270,438	247,754	275,331
110	89,405	102,304	142,514	141,446	135,664	136,554	236,634	313,584	320,256	348,723

NOTE Each basic type of bearing is furnished in several standard series. Although the bore is the same, the outside diameter, width and ball size are progressively larger.

9.3 Equivalent load

9.3.1 Equivalent dynamic load

Equivalent radial load for both ball and roller bearings is computed by:

$$P = XR + YT \qquad \text{[Eq. 1]}$$

where:

P = equivalent radial loads, N
R = radial load, N
T = thrust load, N
X = radial load factor for the bearing (see Table 4)
Y = thrust load factor for the bearing (see Table 4)

Table 4 – Radial and thrust factors for computation of equivalent radial load

Bearing type	X_1	Y_1	X_2	Y_2
Single-row ball	1.0	0.0	0.56	1.40
Double-row ball	1.0	0.75	0.63	1.25
Cylindrical roller	1.0	0.0	1.0	0.0
Spherical roller	1.0	2.5	0.67	3.7

NOTE Two values of X and Y are listed. The set X_1Y_1 or X_2Y_2 giving the largest equivalent load should always be used.

9.3.2 Equivalent static load, P_O

The static equivalent load may be compared directly to the static load rating C_O. If P_O is greater than the C_O rating, permanent deformation of the rolling element will occur. Static equivalent load is computed as:

$$P_O = X_O R + Y_O T \quad \text{[Eq. 2]}$$

where:

P_O = static equivalent load, N
X_O = radial load factor (see Table 5)
R = radial load, N
Y_O = thrust load factor
T = thrust load, N

Table 5 – Radial and thrust load factors for computing static equivalent load

Type of bearing	X_O	Y_O
Single-row ball	0.6	0.5
Double-row ball	0.6	0.5
Spherical roller, 22200 series	1.0	2.9
Cylindrical roller	1.0	0.0

9.4 Required capacity

The required capacity is computed as follows:

$$C_r = \frac{P(L_{10}N)^{\frac{1}{k}}}{Z} \quad \text{[Eq. 3]}$$

where:

C_r = required capacity, N
L_{10} = rated life, h (Table 6)
P = equivalent radial load, N
N = rotational speed, rpm
K = constant
  K = 3 for ball bearings
  K = 10/3 for roller bearings
Z = constant
  Z = 25.6 for ball bearings
  Z = 18.5 for roller bearings

Table 6 – Design-life guide

Application	Design life, h, L_{10}	Application	Design life, h, L_{10}
Agricultural equipment	3,000-6,000	Domestic appliances	1,000-2,000
Bus, car	2,000-5,000	Electric motors:	
Trucks	1,500-2,500	Domestic	1,000-2,000
Blowers:	20,000-30,000	Industrial	20,000-30,000
Continuous 8-h service	20,000-40,000	Elevator	8,000-15,000
Continuous 24-h service	40,000-60,000	Gearing units (multipurpose)	8,000-15,000
Continuous 24-h service (extreme reliability)	100,000-200,000	Intermittent service	8,000-15,000
Compressors	40,000-60,000	Paper machines	50,000-60,000
Conveyors	20,000-40,000	Pumps	40,000-60,000

9.5 Speed limits

A convenient check on speed limits can be made from a *dn* value. The *dn* value is a direct function of size and speed and is dependent on the type of lubrication. It is calculated by multiplying the bore in millimeters (mm) by the speed in rpm (Equation 10). A guide for *dn* values is presented in Table 7. When these values are exceeded, bearing life is shortened.

$$dn = bore \times N \quad \text{[Eq. 4]}$$

Table 7 – *dn* values for different bearing types

Bearing type	Series	Maximum *dn* value	
		Grease	Oil
Single-row ball	100, 200, 300, 400, 30, in	200,000	300,000
Double-row ball	200, 300	160,000	220,000
Cylindrical roller	200, 300	150,000	200,000
Spherical roller,	22200	120,000	170,000

10 Markings

10.1 The following information shall be marked on the packaging:

a) Manufacturer's name, trademark and address

b) Bearing designation

10.2 The following information shall be marked on the bearings and/or housing:

a) Manufacturer's name and/or its trademark

b) Bearing designation

11 Safety

11.1 Make drive inspection on a periodic basis. Inspect bearings for wear and tear, for quality and type of lubricant, and for its alignment. Use grease when temperature is below 93°, for temperature above 93°, use oil.

11.2 Tightness of setscrews should also be inspected periodically. Screws used for mounting should also be inspected regularly.

11.3 Use bearings with proper markings.

11.4 Use shafts as specified in PAES 305:2000: Shafts for Agricultural Machines

Annex A
(informative)

Procedure for determining bearing type

A.1 Given parameters

Determine the bearing size and type for a belt drive with a design power of 10,000 W, 180° arc of contact, belt velocity of 5 m/s, and a shaft speed of 1,000 rpm.

A.2 Tension forces

The tension forces for the belt drive are computed as follows:

$$F_1 = \frac{1.25P}{v_m G}$$
$$= \frac{1.25(10,000\,W)}{5\,m/s(1.0)}$$
$$= 2,500\,N$$

$$F_2 = F_1(1-0.8G)$$
$$= 2,500[1-0.8(1.0)]$$
$$= 500\,N$$

where: F_1 = tension at the tight side
F_2 = tension at the slack side
v_m = belt velocity
P = design power
G = arc of contact correction factor (Refer to PAES 301:2000)

A.3 Radial load

Assuming that the shaft is supported by two bearings, the radial load (R) is computed as follows:

$$R = \frac{R_T}{2}$$

Where:

$$R_T = F_1 + F_2$$
$$= 2,500 + 500$$
$$= 3,000\,N$$
$$R = \frac{3,000}{2} = 1,500\,N$$

A.4 Selection of rolling element

Select between ball and roller bearing using Figure 17. Given a radial load of 1,500 N and a shaft speed of 1,000 rpm, opt for a ball bearing for the drive.

A.5 Equivalent radial load

Calculate equivalent load P for various bearing types. Use X and Y values from Table 4 select the value from single-row ball bearing (assume zero thrust load).

$$P = XR + YT$$

$$P = (1.0 \times 1{,}500) + 0 = 1{,}500\ N$$

A.6 Required capacity

A.6.1 Calculate the required capacity, C_r, from Equation 3. Use a rated life value of 3,000 h (Table 6) and a k and Z value of 3 and 25.6, respectively.

$$C_r = \frac{P(L_{10}N)^{\frac{1}{k}}}{Z}$$

$$= \frac{1{,}500(3{,}000 \times 1{,}000)^{\frac{1}{3}}}{25.6}$$

$$= 8{,}451\ N$$

A.6.2 Comparing C_r with capacities (C) presented in Table 3 and selecting the type that has a capacity equal to or greater than C_r. The type that can be used is a single row, 2 series ball bearing with a bore diameter of 20 mm.

A.7 Speed limits

A.7.1 Check bearing speed limit (Eq. 4), the computed dn is:

$$dn = bore \times N$$

$$= 20mm \times 1{,}000rpm$$

$$= 20{,}000$$

A.7.2 Compare computed dn with values presented in Table 7 and check if the computed dn exceeds the value in Table 5. In cases that the computed dn exceeds the dn values in Table 5, make another selection of bearing type.

A.8 Bearing width

Bearings width depends on space limits, availability of bearing, and cost. For this application assume that a 2-width series bearing can be used.

A.9 Bearing specification

For this drive, acquire a single row, deep groove ball bearing; 20 mm bearing bore diameter, 2-diameter series, and 2 width series. The bearing designation for the following specification is 62204.