Notes on Ball Bearings

Bearing Nomenclature

You can learn a lot about a bearing just from its part number.

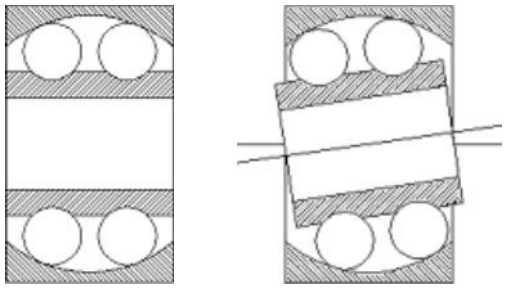
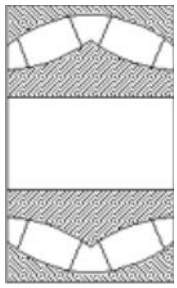
A typical bearing is the 6203ZZ bearing. This part number can be divided into it's components:

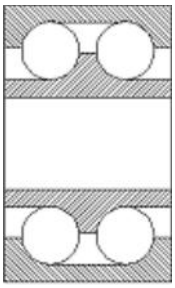
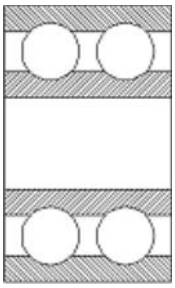
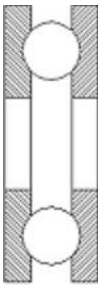
6203ZZ

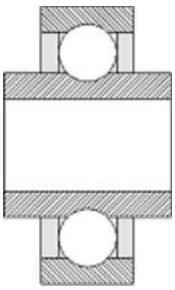
which means:

- Type Code
- Series
- Bore
- Suffix

The type code indicates the type of bearing. While each manufacturer uses their own numbers, there are a few numbers that could be considered standard in the industry.

1	**Self-Aligning Ball Bearing** This kind of ball bearing has a spherical outer race, allowing the axis of the bearing to "wander around". This is important because misalignment is one of the big causes of bearing failure.	
2	**Spherical Roller Bearing**	

3	**Double-Row Angular Contact Ball Bearing** Designed to take axial as well as radial loads.	
4	**Double-Row Ball Bearing** Designed for heavy radial loads.	
5	**Thrust Ball Bearing** Intended for exclusively axial loads.	
6	**Single-Row Deep Groove Ball Bearing** Typical ball bearing. Handles light axial loads as well as radial loads.	
7	**Single-Row Angular Contact Bearing** For axial (one direction only!) as well as radial loads.	

8	**Felt Seal** To assure that the entire inside edge of the seal touches the inner ring, the inner ring is enlarged. If a bearing of more normal proportions is required, the outer ring is also enlarged, and the bearing is referred to as a "wide cup" bearing.	
32	**Tapered Roller Bearing** This is the kind of wheel bearings used in cars. The rollers are not cylindrical, but conical. They handle large raidal and axial loads.	
R	**Inch (Non-Metric) Bearing**	Varies
N	**Cylindrical Roller Bearing** Instead of balls, cylindrical rollers are used. These bearings can handle much more radial load, but can handle much less axial load, than ball bearings.	
NN	**Double-Row Roller Bearing** Handles greater radial loads than standard cylindrical roller bearings.	
NA	**Needle Roller Bearing** Needle bearings are	Varies

	basically roller bearings, but the rollers are much smaller, making the bearing more compact.	

Type 6, "single-row deep groove", is perhaps the most common type of bearing.

If the bearing is an inch bearing (the first digit in the number is an R), then the size is the digit or digits immediately following the R, in 16ths of an inch. An R8-2RS bearing, for example, has an 8/16th or 1/2 inch bore.

If the first digit is a number, however, it is a metric bearing, and the second digit is the *series*, which reflects the robustness of the bearing. The series are, from lightest to heaviest:

8 Extra thin section
9 Very thin section
0 Extra light
1 Extra light thrust
2 Light
3 Medium
4 Heavy

Yes, they go in that order. Gotta keep things simple, you know.

Each of these series also establishes a relationship between the bore size, outer diameter, and thickness of the bearing, in accordance with ISO standards. I have no idea what they are.

The third and fourth digits indicate the *bore size* in millimeters. Except for 0 through 3, the bore size is simply five times the third and fourth digits together. 0 through 3, however, are different:

00 10mm
01 12mm
02 15mm
03 17mm

If there is no fourth digit - for example, a 608 bearing, a common roller skate bearing - then the size is the last digit in millimeters.

The last letters indicate something special about the bearing. For example:

Z	Single shielded
ZZ	Double shielded
RS	Single sealed
2RS	Double sealed
V	Single non-contact seal
VV	Double non-contact seal
DDU	Double contact seals
NR	Snap ring and groove
M	Brass cage

And then there are the completely off-the-wall bearing numbers, like 499502H. I have no idea what that number is supposed to mean, but it applies to what is basically an R10-2RS bearing, only a bit thicker and with a groove and snap ring.

Examples

Common Skate Bearings

Number	Bore (mm)	O.D. (mm)	Width (mm)
608	8	22	7
627	7	22	7
688	8	16	4
698	8	19	6

All these bearing numbers start with 6, which tells us they're *Single-row deep groove ball bearings*. The second digits tell us the robustness of the bearings. The last two, in series 8 and 9, are very thin and lightweight bearings, while the first, in series 0, is an "extra light" bearing without being abnormally thin. The third bearing, in series 2, is the most robust of all, being merely "light".

Light vs Heavy Comparison

Consider the following three bearings:

Number	Bore mm	O.D. mm	Thickness mm
6010-2RS	50	80	16
6210-2RS	50	90	20
6310-2RS	50	110	27

We can see from the part numbers that they're all 50mm single-row deep groove ball bearings. However, we can also see that they're each a different series; specifically, Extra Light, Light, and Medium. Compare the O.D. and thickness of each bearing, and you can see how the Extra Light bearing (series 0) is the smallest, and the Medium Bearing (series 3) is the largest. The larger bearing can take much more load than the smaller bearing, though how much depends on the manufacturer and the RPM the bearing is run at.

Number	Bore mm	O.D. mm	Thickness mm
6904-2RS	20	37	9
6004-2RS	20	42	12
6204-2RS	20	47	14
6304-2RS	20	52	15

These are all 20mm single-row deep groove ball bearings of different series. The first, of series 9, is a "very thin section" bearing, meaning it is much thinner than usual - it is only 25% as thick as its O.D., while the others are approximately 30% as thick as their O.D.

Common Bearing Dimensions

Extra Light Bearings

Number	Bore mm	O.D. mm	Thickness mm
6000-2RS	10	26	8
6001-2RS	12	28	8
6002-2RS	15	32	9
6003-2RS	17	35	10
6004-2RS	20	42	12
6005-2RS	25	47	12
6006-2RS	30	55	13
6007-2RS	35	62	14
6008-2RS	40	68	15
6009-2RS	45	75	16
6010-2RS	50	80	16
6011-2RS	55	90	18
6012-2RS	60	95	18
6013-2RS	65	100	18
6014-2RS	70	110	20
6015-2RS	75	115	20

Light Bearings

Number	Bore mm	O.D. mm	Thickness mm
6200-2RS	10	30	9
6201-2RS	12	32	10
6202-2RS	15	35	11
6203-2RS	17	40	12
6204-2RS	20	47	14
6205-2RS	25	52	15
6206-2RS	30	62	16
6207-2RS	35	72	17
6208-2RS	40	80	18
6209-2RS	45	85	19
6210-2RS	50	90	20
6211-2RS	55	100	21
6212-2RS	60	110	22
6213-2RS	65	120	23
6214-2RS	70	125	24
6215-2RS	75	130	25

6216-2RS	80	140	26

Medium Bearings

Number	Bore mm	O.D. mm	Thickness mm
6301-2RS	12	37	12
6302-2RS	15	42	13
6303-2RS	17	47	14
6304-2RS	20	52	15
6305-2RS	25	62	17
6306-2RS	30	72	19
6307-2RS	35	80	21
6308-2RS	40	90	23
6309-2RS	45	100	25
6310-2RS	50	110	27

Inch Bearings

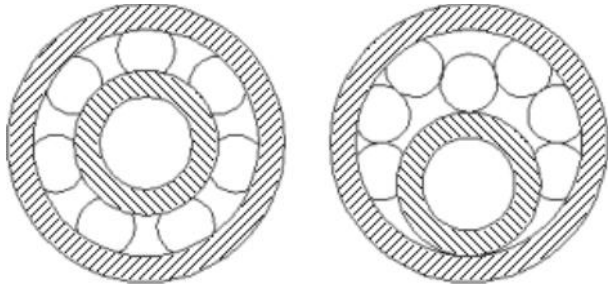
Number	Bore inch	O.D. inch	Thickness inch
SR3-2RS	0.1875	0.5000	0.1960
R4-2RS	0.2500	0.6250	0.1960
R4A-2RS	0.2500	0.7500	0.2813
R6-2RS	0.3750	0.8750	0.2813
R8-2RS	0.5000	1.1250	0.3125
R10-2RS	0.6250	1.3750	0.3438
R12-2RS	0.7500	1.6250	0.4375
R14-2RS	0.8750	1.8750	0.5000
R16-2RS	1.0000	2.0000	0.5000
R20-2RS	1.2500	2.2500	0.5000
1601-2RS	0.1875	0.6875	0.3125
1602-2RS	0.2500	0.6875	0.3125
1605-2RS	0.3125	0.9063	0.3125
1603-2RS	0.3125	0.8750	0.3438
1604-2RS	0.3750	0.8750	0.3438
1614-2RS	0.3750	1.1250	0.3750
1606-2RS	0.3750	0.9063	0.3125
1615-2RS	0.4375	1.1250	0.3750
1607-2RS	0.4375	0.9063	0.3125
1620-2RS	0.4375	1.3750	0.4375
1616-2RS	0.5000	1.1250	0.3750
1621-2RS	0.5000	1.3750	0.4375

1633-2RS	0.6250	1.7500	0.5000
1623-2RS	0.6250	1.3750	0.4375
1638-2RS	0.7500	2.0000	0.5625
1630-2RS	0.7500	1.6250	0.5000
1641-2RS	1.0000	2.0000	0.5625
1652-2RS	1.1250	2.5000	0.6250
1658-2RS	1.3125	2.5625	0.6875

Other Stuff

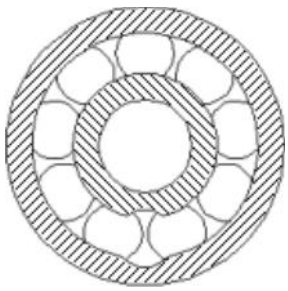
Ever wonder how they assemble ball bearings? There are two ways.

The typical ball bearing, called a Conrad bearing. There is enough space between the balls that if they're all pushed over to one side, the inner ring can be pushed to the opposite side, into the space left by moving the balls. This increases the space on the side where the balls are, letting them be removed. The bearing cage usually keeps the balls evenly spaced so this doesn't happen by accident.



Conrad Type Bearing Assembly

The other kind of ball bearing is called a maximum capacity bearing, and has a special notch cut in the side of the rings, into which the balls are placed during assembly. As a result of this notch, the axial loads this kind of bearing can take are quite small, and must be in combination with a large radial load. However, the increased number of balls that can be fit into the bearing means the maximum capacity type bearing can handle a larger radial load.



Maximum Capacity Bearing

Design Life

The design life of a bearing depends on **rated load** and the **equivalent radial load**.

Deep Groove: $L_{10} = (C/P)^n$

The **rated load, C**, is the load at which 10% of bearings fail after one million revolutions. The manufacturer will provide this number. One million revolutions may sound like a lot, but it's not. A car engine typically has one million revolutions on it after only eight hours.

The **equivalent load, P**, is a combination of axial load and radial load, times some factor to account for shock loading, acceptable noise levels, lubrication quality, cleanliness, speed, temperature, etc. Calculating it can be a pain.

The exponent, **n**, is 3 for radial bearings, and 3.33 for thrust bearings. This large an exponent means that doubling the load on a bearing will decrease its life by a factor of *eight* or *ten*, depending on the type of bearing. Don't overload your bearings!

The formula for calculating equivalent load is

$$\mathbf{P = (XF_r + YF_a) \times s}$$

where F_r is **actual radial load**, F_a is **actual axial load**, X is the **static radial factor**, and Y is the **static axial factor**, and s is the **service factor**, which varies from 1 on up. If F_a is zero (no axial load) you can ignore all this folderol, and $P = F_r$. Likewise, if F_r is zero (no radial load), then $P = F_a$.

Calculating X and Y is so complicated that I avoid it when I can - by using separate thrust and radial bearings, by assuming X is 1 and Y is 3 (values which far exceed anything realistic), or by using software. SKF has an online bearing calculator here.

If you really want to try calculating X and Y, start here.

Sources

These are some places that sell bearings and give satisfactory service for a good price, at least in my experience.

- Skatebearings.com, a Florida company, also sells on eBay under the username http://cgi6.ebay.com/ws/eBayISAPI.dll?ViewSellersOtherItems&userid=skatebearings@aol.com.
- McMaster-Carr, they sell *everything*, so naturally they sell bearings, too.

References

- E-mail me at bill@gizmology.net if you find a mistake!
- Dynaroll Technical Info.
- Basic Bearing Info from Motion Bearings.
- The Bearing Reference Center by Machine Design.
- SKF Online Bearing Calculator
- Formulation of Bearing Numbers from NSK Automotive, Australia.
- Bearing ABC's from NSK Automotive, Australia.

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