

13. Bearing Materials

13.1 Raceway and rolling element materials

While the contact surfaces of a bearing's raceways and rolling elements are subjected to repeated heavy stress, they still must maintain high precision and rotational accuracy. To accomplish this, the raceways and rolling elements must be made of a material that has high hardness, is resistant to rolling fatigue, is wear resistant, and has good dimensional stability. The most common cause of fatigue in bearings is the inclusion of non-metallic impurities in the steel. Non-metallic inclusion includes hard oxides that can cause fatigue crack. Clean steel with minimal non-metallic inclusion must therefore be used.

For all NTN bearings, steel low in oxygen content and non-metallic impurities, then refined by a vacuum degassing process as well as outside hearth smelting, is used. For bearings requiring especially high reliability and long life, steels of even higher in purity, such as vacuum melted steel (VIM, VAR) and electro-slag melted steel (ESR), are used.

1) High/mid carbon alloy steel

In general, steel varieties which can be hardened not just on the surface but also deep hardened by the so-called "through hardening method" are used for the raceways and rolling elements of bearings. Foremost among these is high carbon chromium bearing steel, which is widely used. For large type bearings and bearings with large cross sectional dimensions, induction hardened bearing steel incorporating manganese or molybdenum is used. Also in use is mid-carbon chromium steel incorporating silicone and manganese, which gives it hardening properties comparable to high carbon chromium steel.

Table 13.1 gives chemical composition of representative high carbon chrome bearing steel that meets JIS standards. SUJ2 is frequently used. SUJ3 with enhanced hardening characteristics containing a large quantity of Mn is used for large bearings. SUJ5 is SUJ3 to which Mo has been added to further enhance hardening characteristics, and is used for oversized bearings or bearings with thick walls.

The chemical composition of SUJ2 is equivalent to AISI 52100 (US) and DIN 100Cr6 (Germany).

2) Case hardened (carburizing) steel

Carburizing hardens the steel from the surface to the proper depth, forming a relatively soft core. This provides hardness and toughness, making the material suitable for impact loads. NTN uses case hardened steel for almost all of its tapered roller bearings. In terms of case hardened steel for NTN's other bearings, chromium steel and chrome molybdenum steel are used for small to medium sized bearings, and nickel chrome molybdenum steel is used for large sized bearings.

Table 13.2 gives the chemical composition of representative JIS case hardened steel.

3) Heat resistant bearing steel

When bearings made of ordinary high carbon chromium

steel which have undergone standard heat treatment are used at temperatures above 120°C for long durations, unacceptably large dimensional changes can occur. For this reason, a dimension stabilizing treatment (TS treatment) has been devised for very high temperature applications. This treatment however reduces hardness of the material, thereby reducing rolling fatigue life. (See item 3.3.2 on page A-18.)

For standard high temperature bearings used at temperatures from 150°C – 200°C, the addition of silicone to the steel improves heat resistance and results in a bearing with excellent rolling fatigue life with minimal dimensional change or softening at high temperatures.

A variety of heat resistant steels are also incorporated in bearings to minimize softening and dimensional changes when used at high temperatures. Two of these are high speed molybdenum steel and high speed tungsten steel. For bearings requiring heat resistance in high speed applications, there is also heat resistant case hardening molybdenum steel. (refer to **Table 13.3**)

4) Corrosion resistant bearing steel

For applications requiring high corrosion resistance, stainless steel is used. To achieve this corrosion resistance a large proportion of the alloying element chrome is added to martensite stainless steel. (**Table 13.4**)

5) Induction hardened steel

Besides the use of surface hardening steel, induction hardening is also utilized for bearing raceway surfaces, and for this purpose mid-carbon steel is used for its lower carbon content instead of through hardened steel. For induction hardening of the deep layers required for larger bearings and bearings with large surface dimensions, mid-carbon steel is fortified with chrome and molybdenum.

6) Other bearing materials

For ultra high speed applications and applications requiring very high level corrosion resistance, ceramic bearing materials such as Si₃N₄ are also available.

13.2 Cage materials

Bearing cage materials must have the strength to withstand rotational vibrations and shock loads. These materials must also have a low friction coefficient, be light weight, and be able to withstand bearing operation temperatures.

For small and medium sized bearings, pressed cages of cold or hot rolled steel with a low carbon content of approx. 0.1% are used. However, depending on the application, austenitic stainless steel is also used.

Machined cages are generally used for large bearings. Carbon steel for machine structures or high-strength cast brass is frequently used for the cages, but other materials such as aluminum alloy are also used.

Tables 13.5 and 13.6 give the chemical composition for these representative cage materials.

Besides high-strength brass, medium carbon nickel, chrome and molybdenum that has been hardened and tempered at high temperatures are also used for bearings used in aircraft. The materials are often plated with silver to enhance lubrication characteristics.

High polymer materials that can be injection molded are

also widely used for cages. Polyamide resin reinforced with glass fibers is generally used. Cages made of high-polymer materials are lightweight and corrosion resistant. They also have superior damping and characteristics and lubrication performance. **Heat resistant polyimide resins now enable the production of cages that perform well in applications ranging between -40°C – 120°C.** However, they are not recommended for use at temperatures exceeding 120°C.

Table 13.1 Chemical composition of representative high carbon chrome bearing steels

Standard	Symbol	Chemical composition (%)							Remarks
		C	Si	Mn	P	S	Cr	Mo	
JIS G 4805	SUJ2	0.95~1.10	0.15~0.35	Max. 0.50	Max. 0.025	Max. 0.025	1.30~1.60	Max. 0.08	
	SUJ3	0.95~1.10	0.40~0.70	0.90~1.15	Max. 0.025	Max. 0.025	0.90~1.20	Max. 0.08	
	SUJ5	0.95~1.10	0.40~0.70	0.90~1.15	Max. 0.025	Max. 0.025	0.90~1.20	0.10~0.25	
ASTM A295	52100	0.98~1.10	0.15~0.35	0.25~0.45	Max. 0.025	Max. 0.025	1.30~1.60	Max. 0.10	SUJ2 equivalent
ASTM A485	Grade 1	0.90~1.05	0.45~0.75	0.95~1.25	Max. 0.025	Max. 0.025	0.90~1.20	Max. 0.10	SUJ3 equivalent
	Grade 3	0.95~1.10	0.15~0.35	0.65~0.90	Max. 0.025	Max. 0.025	1.10~1.50	0.20~0.30	SUJ5 equivalent

Table 13.2 Chemical composition of representative case hardened steel (carburizing steel)

Standard	Symbol	Chemical composition (%)							
		C	Si	Mn	P	S	Ni	Cr	Mo
JIS G 4104	SCr420	0.18~0.23	0.15~0.35	0.60~0.85	Max. 0.030	Max. 0.030	—	0.90~1.20	—
JIS G 4105	SCM420	0.18~0.23	0.15~0.35	0.60~0.85	Max. 0.030	Max. 0.030	—	0.90~1.20	0.15~0.30
JIS G 4103	SNCM220	0.17~0.23	0.15~0.35	0.60~0.90	Max. 0.030	Max. 0.030	0.40~0.70	0.40~0.65	0.15~0.30
	SNCM420	0.17~0.23	0.15~0.35	0.40~0.70	Max. 0.030	Max. 0.030	1.60~2.00	0.40~0.65	0.15~0.30
	SNCM815	0.12~0.18	0.15~0.35	0.30~0.60	Max. 0.030	Max. 0.030	4.00~4.50	0.70~1.00	0.15~0.30
ASTM A534	5120	0.17~0.22	0.15~0.35	0.70~0.90	Max. 0.030	Max. 0.040	—	0.70~0.90	—
	4118	0.18~0.23	0.15~0.35	0.70~0.90	Max. 0.030	Max. 0.040	—	0.40~0.60	0.08~0.15
	8620	0.18~0.23	0.15~0.35	0.70~0.90	Max. 0.030	Max. 0.040	0.40~0.70	0.40~0.60	0.15~0.25
	4320	0.17~0.22	0.15~0.35	0.45~0.65	Max. 0.030	Max. 0.040	1.65~2.00	0.40~0.60	0.20~0.30
	9310	0.08~0.13	0.15~0.35	0.45~0.65	Max. 0.025	Max. 0.025	3.00~3.50	1.00~1.40	0.08~0.15

Table 13.3 Chemical composition of high-speed steel

Standard	Symbol	Chemical composition (%)											
		C	Si	Mn	P	S	Cr	Mo	V	Ni	Cu	Co	W
AMS	6491 (M50)	0.77~0.85	Max. 0.25	Max. 0.35	Max. 0.015	Max. 0.015	3.75~4.25	4.00~4.50	0.90~1.10	Max. 0.15	Max. 0.10	Max. 0.25	Max. 0.25
	5626	0.65~0.80	0.20~0.40	0.20~0.40	Max. 0.030	Max. 0.030	3.75~4.50	Max. 1.00	0.90~1.30	—	—	—	17.25~18.25
	2315 (M50NiL)	0.11~0.15	0.10~0.25	0.15~0.35	Max. 0.015	Max. 0.010	4.00~4.25	4.00~4.50	1.13~1.33	3.20~3.60	Max. 0.10	Max. 0.25	Max. 0.25

Table 13.4 Chemical composition of stainless steel

Standard	Symbol	Chemical composition (%)						
		C	Si	Mn	P	S	Cr	Mo
JIS G 4303	SUS440C	0.95~1.20	Max. 1.00	Max. 1.00	Max. 0.040	Max. 0.030	16.00~18.00	Max. 0.75
AISI	440C	0.95~1.20	Max. 1.00	Max. 1.00	Max. 0.040	Max. 0.030	16.00~18.00	Max. 0.75

Table 13.5 Chemical composition of steel plate for pressed cages and carbon steel for machined cages

	Standard	Symbol	Chemical composition (%)						
			C	Si	Mn	P	S	Ni	Cr
Pressed retainer	JIS G 3141	SPCC	—	—	—	—	—	—	—
	JIS G 3131	SPHC	—	—	—	Max. 0.050	Max. 0.050	—	—
	BAS 361	SPB2	0.13~0.20	Max. 0.04	0.25~0.60	Max. 0.030	Max. 0.030	—	—
	JIS G 4305	SUS304	Max. 0.08	Max. 1.00	Max. 2.00	Max. 0.045	Max. 0.030	8.00~10.50	18.00~20.00
Machined retainer	JIS G 4051	S25C	0.22~0.28	0.15~0.35	0.30~0.60	Max. 0.030	Max. 0.035	—	—

Table 13.6 Chemical composition of high-strength cast brass for machined cages

Standard	Symbol	Chemical composition (%)							Impurities	
		Cu	Zn	Mn	Fe	Al	Sn	Ni	Pb	Si
JIS H 5120	CAC301	55.0~60.0	33.0~42.0	0.1~1.5	0.5~1.5	0.5~1.5	Max. 1.0	Max. 1.0	Max. 0.4	Max. 0.1