8 Materials of bearings

8.1 Materials of rings and rolling elements

During working, the rings and rolling elements of bearings carry complex stress, including stretch, compression, shearing, bending, reversal and friction etc. Furthermore along with the technologic development of bearing, some bearings for special purpose trend to high speed, high load etc. This make the partial contact stress as high as 4000 MPa and require the ring and rolling element material have the following performance after strengthening treatment:

- ◆High hardness
- ◆High abrasion resistance
- ◆High contact fatigue strength
- ◆High limit of flexibility
- ◆Certain impact and fracture toughness
- ◆Satisfactory dimension stability

To achieve the above requirements, the materials are required to have high metallurgic quality:

- ◆ Strict chemical composition
- ◆ Very strict degree of purity
- ◆ Strict macrostructure and microstructure
- ◆ Specially strict surface quality

See Table 8.1 for the main physical properties of bearing steel. See Table 8.2 for the comparison of the bearing steel brands from different countries.

Table 8.1 Main physical parameters and mechanical properties of Gcr15

Physical parameter (measured in annealling state	Melting point(℃)	T_c=1395～1403	Density (g/cm³)	ρ=7.81
	Critical point(℃)	A_{c1}≈760	Linear expansion coefficient (1/K)	α=13.3×10⁻⁶
		A_{cm}≈900	Thermometric conductivity [W/(m·K)]	λ=40.11
		A_{c3}≈707	Poisson ratio(28～125℃)	μ=0.29
		A_{r1}≈695	Elasticity modulus (Gpa)	E=207
Mechanical property		780℃ Annealling	900℃ Annealling	840℃ Oil quenching 150℃ Tempering
	Tensile strength δ_b(Mpa)	588 ～ 715	1186 ～ 1260	2157～2550
	Yield point σ_s(Mpa)	353 ～ 412	–	1667～1814
	Extensibility δ(%)	15～25	–	–
	Contractility ψ(%)	25～59	–	–
	Impact toughness α_k(J/cm²)	48～88	–	5.4～8.4
	Hardness (HRC)	179～207HBS	–	61～65 HRC

Table 8.2 Steel grades of different kinds of high-carbon chrome bearing steel

China	U.S.A.		Japan	Germany		SKF	International standard
GB/YB	SAE	AISI	JIS	DIN	Material type		ISO
GCr15	52100	E52100	SUJ2	100Cr6	1.3505	SKF3	1
GCr15SiMn	—	—	SUJ5	100CrMo6	1.3520	SKF832	3
GCr18Mo	—	—	SUJ4	—	—	SKF24	—

8.1.1 High-carbon chrome bearing steel

High-carbon chrome bearing steel are mostly used to harden chrome bearing part by quenching, After quenching and tempering, the hardness of high-carbon chrome bearing steel is generally In HRC 58~HRC 65.these steel is good usability and good machining property, and is the most common steel for bearing rings and rolling elements manufacturing. High-carbon chrome bearing steel is applied under a working temperature below 200° C .this steel series usually include:

GCr4、GCr15、GCr15SiMn、GCr15SiMo、GCr18Mo .

Table 8.3 Chemical composition of high-carbon chrome bearing steel （GB /T18254-2002）

Brand	C	Si	Mn	Cr	Mo	P	S	Ni	Cu	Ni+Cu
GCr4	0.95～1.05	0.15～0.30	0.15～0.30	0.35～0.50	≤0.08	≤0.025	≤0.02	≤0.25	≤0.20	
GCr15	0.95～1.05	0.15～0.35	0.25～0.45	1.40～1.65	≤0.10	≤0.025	≤0.025	≤0.30	≤0.25	0.50
GCr15 SiMn	0.95～1.05	0.45～0.75	0.95～1.25	1.40～1.66	≤0.10	≤0.025	≤0.025	≤0.30	≤0.25	0.50
GCr15 SiMo	0.95～1.05	0.65～0.85	0.20～0.40	1.40～1.70	0.30～0.40	≤0.027	≤0.02	≤0.30	≤0.25	
GCr18 Mo	0.95～1.05	0.20～0.40	0.25～0.40	1.65～1.95	0.15～0.25	≤0.025	≤0.02	≤0.25	≤0.25	

8.1.2 Carburizing bearing steel

This kind of steel contains lower carbon and alloy elements. after strengthening of carburizing or carbonitriding, it can take greater impact load and fracture toughness property, and also, it will have relatively stronger abrasion resistance and contact fatigue strength ,.this steel bearing is applied under working temperature below 150℃.

Usually includes:

G20Cr、G20CrMo、G20CrNiMo、20CrNi2Mo etc.

Table 8.4 Chemical composition of carburizing steel

Brand	Chemical composition								
	C	Si	Mn	Cr	Ni	Mo	Cu	P	S
G20CrMo	0.17 ~0.23	0.20 ~0.35	0.65 ~0.95	0.35 ~0.65		0.08 ~0.15	≤0.25	≤0.030	≤0.030
G20CrNiMo	0.17 ~0.23	0.15 ~0.40	0.60 ~0.90	0.35 ~0.65	0.40 ~0.70	0.15 ~0.30	≤0.25	≤0.030	≤0.030
G20CrNi2Mo	0.17 ~0.23	0.15 ~0.40	0.40 ~0.70	0.35 ~0.65	1.60 ~2.00	0.20 ~0.30	≤0.25	≤0.030	≤0.030
G20Cr2Ni4	0.17 ~0.23	0.15 ~0.40	0.30 ~0.60	1.25 ~1.75	3.25 ~3.75		≤0.25	≤0.030	≤0.030
G10CrNi3Mo	0.08 ~0.13	0.15 ~0.40	0.40 ~0.70	1.00 ~1.40	3.00 ~3.50	0.08 ~0.15	≤0.25	≤0.030	≤0.030
G20Cr2Mn2Mo	0.17 ~0.23	0.15 ~0.40	1.30 ~1.60	1.70 ~2.00	≤0.30	0.20 ~0.30	≤0.25	≤0.030	≤0.030

8.1.3 High-temperature bearing steel

This type of steel, which possesses general quality of bearing steel with specified high temperature hardness , high temperature abrasion resistance, is designed to manufacture bearing parts used in 150° It usually contains: Cr4Mo4V highest application temperature 315 ℃; Cr4Mo4V highest application temperature 425 ℃; W6Mo5Cr4V2 highest application temperature 425 ℃.

Table 8.5 chemical composition of high temperature bearing steel

Standard	Brand	Chemical composition									
		C	Si	Mn	Cr	Ni	Mo	V	Cu	P	S
YB/T688	Gr4Mo4V	0.10 ~0.75	≤0.35	≤0.35	3.75 ~4.25	≤0.20	4.00 ~4.50	0.90 ~1.10	≤0.20	≤0.020	≤0.027
YB/T1205	Gr14Mo4V	0.95 ~1.10	0.95 ~1.10	0.95 ~1.10	0.95 ~1.10	0.95 ~1.10	0.95 ~1.10	0.95 ~1.10	≤0.25	≤0.020	≤0.025

8.1.4 Stainless bearing steel

This type of steel is classified to high-alloy steel, therefore, it is of quite high harden ability .Outstanding mechanical property and corrosion resistance .It usually includes:
9Cr18、9Cr18Mo、1Cr13、2Cr13 etc

Table 8.6 Chemical composition of stainless bearing steel.

Standard	Brand	Chemical composition						
		C	Si	Mn	Cr	S	P	Mo
GB/T3086	9Cr18	0.90~1.00	≤0.80	≤0.80	17.0~19.0	≤0.030	≤0.035	—
	9CrMo	0.95~1.10	≤0.80	≤0.80	16.0~18.0	≤0.030	≤0.035	0.40~0.70

8.2 Material for the cage

Cages keep the rolling elements arranged equidistantly, guide or drive rolling elements to rotate. It also helps to prevent rolling elements from dropping when bearing is rotating, cages mostly take friction and stretch, as well as some impact load . Therefore, material for the cages is required to be of these characteristics:

- ◆ Proper obdurability
- ◆ Nice rigidity and flexibility
- ◆ Minor friction coefficient and nice abrasion resistance
- ◆ Good conductivity coefficient
- ◆ Thermal expansivity closed to that of rolling elements
- ◆ Good machining property

8.2.1 Carbon structure steel

This steel can be used to make pressed cages wave shape, case shape, chrysanthemum shape etc. It can also be applied to manufacture shields, shield ring, and seals frame. The temperature scope of this steel applied is quite wide and its chemical oil resistance is very good. Mainly contain: 08,10,08F,10F, or SPCC of JIS standard, and ST 12, ST 14 of DIN standard etc.

8.2.2 Copper and copper alloy

Copper and copper alloy are used to make high-strength large size, cages and machined spacers, they usually contain:H62、H69、HPb59-1、H96 etc.

8.2.3 Non-metallic material

This type of material is light, easy to form and have characteristic of shake and noise reduction. Phenolic rubberized fabric is of very high mechanical property. Axial direction compression resistance strength ＞ 180 Mpa ,Radial tensile strength ＞ 70 Mpa , axial tensile strength ＞ 100 Mpa . Toughening nylon 66 (PA 66-GF 25) is designed for bearing cage under temperature below 120° C, it is a kind of engineering plastics used to produce bearing cages because of its high strength.

Table 8.7 Chemical composition of metallic material of normal cages.

Brand	Chemical composition				
	C	Si	Mn	P	S
08(GB)	0.15~0.12	0.17~0.37	0.35~0.65	≤0.035	≤0.035
10(GB)	0.07~0.14	0.17~0.37	0.35~0.65	≤0.035	≤0.035
ST12(DIN)	≤0.10	≤0.04	≤0.50	≤0.035	≤0.035
ST14(DIN)	≤0.08	≤0.03	≤0.40	≤0.025	≤0.020
SPCC(JIS)	≤0.12	≤0.04	≤0.50	≤0.04	≤0.045