Bearing Materials

The bearing industry uses different materials for the production of the various bearing components. The materials are processed to achieve desirable properties to maximize bearing performance and life. The materials described here are the most commonly used. Additional information can be found in the Technical Information Sheets for Balls, Closures, and Retainers.

Chrome Steel – SAE 52100

The most common material used to produce the load carrying components in precision ball bearings, roller bearings, and tapered roller bearings is 52100 chrome steel. These components are the inner and outer rings, balls and rollers. The chemical composition of this steel has high carbon and about 1.5% chromium content. Using controlled processing and heat-treating methods the finished bearing components have high strength to resist cracking and a hard surface to resist subsurface rolling contact fatigue. The typical surface hardness for bearing components made from this material ranges from 60-64 on the Rockwell hardness C scale (Rc).

Extra clean 52100 chrome steel

The raw steel used to produce high precision miniature bearings is processed with additional melting steps. The result is a type of steel with very uniform fine grain material structure, the bearing contact surfaces can be super finished very smooth so the bearing is very quiet.

The most common heat treating method for chrome steel is to thru harden the steel in a controlled atmosphere furnace. Bearings manufactured from chrome steel can operate at continuous temperatures up to 120°C.

Where higher temperatures are encountered, it is possible to Heat Stabilize the bearing components. By varying the heat treating process, bearings can be produced so they are capable of operating at temperatures of 220°C, and higher. For these applications, the components must be subjected to a tempering treatment at a higher temperature corresponding to the service temperature. This elevated tempering treatment has a detrimental effect on the hardness of the material and the load carrying capacity of the bearing is reduced.

SAE 52100 is an excellent general purpose bearing steel. Due to its excellent hardness and wear resistance, it exhibits good fatigue life in rolling element bearings. However, the corrosion resistance of chrome steel is poor because of the low chromium content. The surfaces of the bearings must be protected with a coating of rust inhibitor or oil to stop oxidation.

As can be seen in the following table, the standard chemical composition of chromium steel will vary depending on the country where it is produced.

Designation Country	C% Carbon	Si% Silicon	Mn% Manganese	P% Phosphorous	Cr% Chromium	Mo% Molybdenum	Ni% Nickel	S% Sulfur
AISI 52100 USA	.95-1.1	.15-.35	.5 max	.012 max	1.3-1.6	.08 max	.25 max	.025 max
100CR6 Germany	.95-1.1	.15-.35	.25-.45	.03 max	1.35-1.65	.1 max	-	.02 max
SUJ2 Japan	.95-1.1	.15-.35	.5 max	.025 max	1.3-1.6	.08 max	.25 max	.025 max
GCR15 China	.95-1.05	.15-.35	.25-.45	.027 max	1.4-1.65	.1 max	.23 max	.02 max

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Stainless Steels

Stainless steel materials are used to make bearing components because it is more resistant to surface corrosion due to the higher content of chromium (~18%) with the addition of nickel. The chromium reacts with oxygen to form a layer of chromium oxide on the surface, creating a passive film.

Martensitic Stainless Steel- AISI 440C

The carbon content in 400 series stainless steels is high enough so it can be hardened using standard heat-treating methods up to Rc58. Due to the lower hardness, the load carrying capacity is 20% lower in bearings made from this material, than they are with 52100 chrome steel bearings. The level of carbon content means the components are magnetic. The corrosion resistance is “good”, when 440C material is exposed to fresh water and mild chemicals. This material is primarily used by US bearing manufacturers.

Miniature bearings made from conventional 440C stainless steel will be slightly noisy because the large carbides that normally concentrate at the grain boundaries are exposed in the raceway finishing process. Larger bore bearings are not as affected by this condition. Bearings made from 400 series stainless steel can operate at higher temperatures than chrome steel, up to 250°C continuous. Bearings made from this material are generally more expensive than chrome steel bearings.

Martensitic Stainless Steel – ACD34

Many miniature bearing manufacturers make their rings and balls with a stainless steel material with slightly lower carbon and chromium content than AISI 440C – ACD34. After heat treatment, this material has smaller carbides so the bearing will have superior low noise characteristics while offering the same corrosion resistance as 440C. For bearings produced from this material, some manufacturers will publish the same load ratings as those for chrome steel. This is due to the use of tightly controlled heat treating methods that result in hardness up to Rc 60. Although this is one of the most widely used stainless steels for ball bearings, there is no AISI designation for this material.

Martensitic Stainless Steel – SV30

Martensitic stainless steel can be modified during the processing of the raw steel by lowering the carbon content and introducing nitrogen as an alloying element. The nitrogen increases the saturation of the chromium which transforms into chromium nitrides, instead of chromium carbides. The result is a high strength, high hardness steel with a superior microstructure that extends fatigue life by as much 100% (double) in certain applications. This material also offers better corrosion resistance than 440C and ACD34, up to 5 times. Bearings manufactured from this material can carry a price premium of 20-40%. More information is available in the SV30 Technical Information Sheet.

Heat Treatment of Bearing Steels

When bearing steels are in their soft (unhardened) state, metallurgists refer to their structure as being in the pearlite state. In order to harden the steel it must be heated to a very high temperature and then cooled very rapidly. When heated in the heat treat furnace to 1,750˚F, the structure transforms from pearlite to what is known as austenite. After quenching (very rapid cooling), the structure then transforms from austenite to martensite. Once transformed to martensite, the steel becomes very hard. However, at this point it is not considered "thermally stabilized". This is because not all of the austenite transforms into martensite during the quenching process. This phenomenon is called "retained "austenite".

If the steel is not thermally stabilized, the retained austenite will over an extended period of time (possibly years) transform into martensite. This transformation is accompanied by an increase in volume that is called metallurgical growth (not to be confused with thermal growth). Metallurgical Growth will cause a change in dimension and form of any steel parts such as bearings' even at room temperature.

While not a problem with low precision commodity type bearings, in high precision (ABEC 5P, 7P, 9P) miniature bearings this lack of dimensional stability can cause problems. In order to eliminate this unwanted metallurgical growth, the steel must be subjected to thermal stabilization. This is accomplished by repeated cycles of chilling at -120˚F and tempering to transform a large percentage of the retained austenite to martensite.

The tables below show the chemical composition of the stainless steel alloys discussed above.

Designation Country	C% Carbon	Si% Silicon	Mn% Manganese	P% Phosphorous	Cr% Chromium	Mo% Molybdenum	Ni% Nickel	S% Sulfur
AISI 440C USA	.95-1.2	1.0 max	1.0 max	.04 max	16-18	.75 max	.25 max	.03 max
SUS440C JAPAN	.95-1.2	1.0 max	1.0 max	.04 max	16-18	.75 max	.25 max	.03 max
9Cr18 CHINA	.90-1.05	.75 max	.75 max	.035 max	16-19	.75 max	.23 max	.03 max

Enhanced 440 Stainless Steel- ACD34

Designation Country	C% Carbon	Si% Silicon	Mn% Manganese	P% Phosphorous	Cr% Chromium	Mo% Molybdenum	Ni% Nickel	S% Sulfur
KS440 JAPAN	.6-.7	1.0 max	1.0 max	.03 max	12-13.5	.25 max	-	.01 max
X65Cr13 GERMANY	.6-.7	1.0 max	1.0 max	.04 max	12-14	.75 max	-	.03 max

AISI316 Austenitic Stainless Steel

Bearing components made from 300 series stainless steel materials have greater corrosion resistance and are non-magnetic because of the low carbon content. However, the tradeoff is that this material cannot be hardened so the bearings can only operate under low loads and speeds. The surfaces of the bearing undergo a chemical reaction with the oxygen called a passivation process; the passive film developed on the surface protects the bearing from corrosion. The corrosion resistance is best when the bearing is not completely submerged in liquid (such as underwater applications). Bearings made from this material are usually special order items requiring minimum quantities; in addition they are more expensive.

Other 300 Series Stainless Steel

The bearing shields, seal washers and ball retainers are sometimes made from AISI303 or AISI304 stainless steel because they have moderate corrosion resistance and are better for forming into the various shapes.

Carbon Alloy Steel

Carbon steel materials are used to produce various components of bearings and have two basic types, Medium versus Low Carbon Alloy Steel.

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Medium Carbon Alloy Steel

Bearings made from medium or low carbon alloy steel material are typically called “semi-precision” or “commercial grade” bearings. The typical materials are AISI8620 or AISI4320. The inner and outer rings are surface hardened in a heat-treating process call case hardening or carburizing. Bearings made from these materials cannot carry high loads or operate at high speeds and they do not have corrosion resistance. The bearings made from these materials are usually low cost.

Low Carbon Alloy Steel

Low carbon steel is used in the production of bearing cages, metal shields and metal washers around which rubber is molded for seals. Common materials are AISI C1008 and C1010. The material needs to be protected from corrosion with a coating of oil/grease (cages) or by plating (shields). Additional information on Retainers and Closures can be found in the respective technical bulletins.

Plastics and Non-Metallic Materials

Cages

Plastic materials are sometimes used for bearing cages. The most common is molded nylon plastic but molded acetal (POM) is also used. Other polymers are used in special bearing designs where specific performance requirements such as high speed, or low torque or low noise are identified.

Cages made from phenolic (phenol-formaldehyde) materials are most common in high speed ball bearings used in machine tool equipment spindles. The phenolic cages are lightweight and have high strength. The cost of processing this material has led to an increase use of plastics in its place. Additional information is contained in the Cages technical bulletin.

Seals

The most common seal material is nitrile rubber or Buna rubber. It has good mechanical properties, can be used across a wide temperature range, is resistant to many chemicals and is low in cost. Materials such as Viton and Silicone are expensive elastomers and they’re usually used when an application requires their unique properties.

Ceramic Materials

Bearings made with ceramic materials fall into a specialty niche in the bearing industry. The most common arrangement is a hybrid bearing, usually with stainless steel rings and ceramic balls. The most common ceramic material used is silicon nitride. Balls made from this material are hard, up to Rc78, and have a very smooth surface. Hybrid bearings are more expensive than all stainless steel bearings.

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