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A REVIEW ON SELECTION OF MATERIALS USED FOR BALL BEARING

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ABSTRACT
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. This paper highlights the various materials used for ball bearing. Temperature rise is the limiting factor to increase rotating speed. Ball bearings with ceramic balls have been gradually used on many high speed rotating systems due to low material density, low thermal expansion, high young's modulus and hardness. A review on polymer materials is done which are widely used for cryogenics. Suitable composite materials like silicon nitride and Aluminum oxide are suggested for carrying out the research work.

KEYWORDS:Ball Bearing, Composite Material, Ceramic Material, Silicon Nitride

INTRODUCTION
In today's scenario, maintenance of any machinery is very important in view of downtime of machinery. The bearing sector is one of the examples without which any single rotating machinery work. Products of bearing sector are of high value which leads to the aspects of bearing life & application in more demanding situations.

The rangeofmaterialsusedinbearingsincludesmetals, polymers, ceramics,and composites. The material most commonly used for the production of balls in ball bearing is chrome steelwhich is 52100 chrome alloy steel. This is a relatively inexpensive material. Type 1018 soft mild steel has very low carbon content. This steel isnot hard. It can be machined, drilled and tapped. Thismaterial is highly magnetic. It will be strongly attracted by a magnet. This is one of the mostweldable steel alloys. Hardness is rated at 28 HRC. Now a day, there is a requirement of bearing which will be operated at elevated temperature. Composite ball bearing is the best solution for these kinds of cases. It can be manufactured by using the Al_2O_3 and Si_3N_4.

LITERATURE REVIEW
Osman Asi, 2009 have Analyzed strength behavior of pinned jointsof glass fiber reinforced composite filled with different proportions of Al_2O_3 particles, as a function of fillerloading and joint geometry. The increase of the Al_2O_3 particle loading in the matrix improved thebearing strength of the composites.

Qi-hua Wang et.al, 2009 have focused on the factors forimproving the friction and wear behavior of basalt fabric reinforced phenolic composites, single graphiteor nano-SiO_2 and both of them were incorporated. The tribological properties of the resulting compositesunder different sliding conditions were investigated systematically on a model ring-on-block test rig. Thefriction and wear mechanisms of the composites were studied through analyzing the worn surfaces andtransfer films by a scanning electron microscopy (SEM). Experimental results showed that graphite (Gr)was more beneficial than nano-SiO2 in improving the tribological properties of basalt fabric composites(BFC) when they were singly incorporated. It is well worth noting that the friction and wear behavior ofthe filled composites was improved further when nano-SiO2 and graphite were added together, indicatingthat there was a synergistic effect between them

Benjamin P. Boesl et.al, 2011 have worked on metal oxide nanoparticle reinforced epoxy systems by using multi scale approach Samples on varying scales were fabricated using a shear mixing deviceand the dispersion of the particles was characterized. On the macro-scalefour-point bend testingshowed a maximum of an 80% increase in fracture toughness over neat resin samples for composites withlow filler volume percent. Novel testing completed within the chamber of a focused ion beam providedinsight into the mechanisms of fracture on the micro scale, providing validation of the existence of micro crackingand crack pinning in the material.

Nishant Jonathan et.al, 2013 have focused on metallic, polymeric and ceramic materials used to manufacture the bearings,the kind of failures experienced with those materials and their causes. He has also discussed properties, composition of the materials used for bearing

suggested to carry out the research work in improving the wear resistance and fracture toughness of the bearing material. This is because the material removal in the surface (inner race) of the bearingduring the service and subsequent crack initiation and propagation are mainly identified as the failuremechanism. It is also proposed to analyze the adaptability of property enhancement of the bearingmaterials at lower temperatures (Cryogenic temperatures). It is identified that the presence of Ni, Cr, andW and Silicon nitride has improved the wear resistance; Ni, silicon nitride also improved the fracturetoughness because of their presence. Any of these elements and compound (silicon nitride) can be takento the Nano scale and can be used as reinforcement to form a composite material to improve the wearresistance and the fracture toughness.

Ranjith-Kumar Sreenilayam-Raveendran et.al, 2013 have presented comparative evaluation of metal and polymer ball bearings. In their paper they highlight use of polymer bearings in corrosive and lubricant-free work environments as well as applications in which weight reduction is desirable.

BALL BEARING

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearingraces. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls.

Ball bearings are comprised of four major parts: a large ring (outer ring), a small ring (inner ring), balls between the rings (steel balls), and a cage to prevent the balls from hitting each other. The modern structure dates back to around 1500, when Leonardo da Vinci invented ball bearings to reduce friction against the axles of horse drawn carts. For more than 500 years, the ball bearing has been defined by this simple structure.

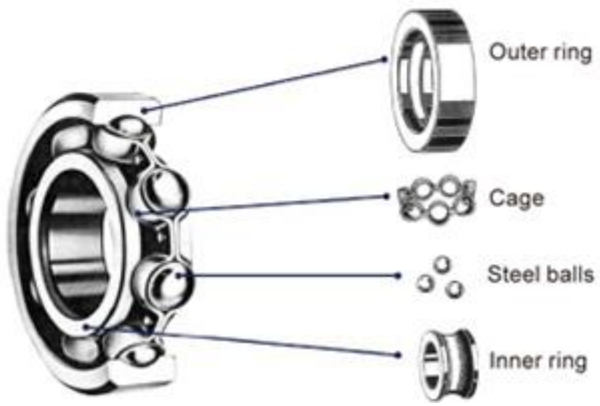

Figure 1Components of ball bearing

The performance of ball bearing is depends on working environments, loading conditions, types of loads and bearing materials, hence it is very important to select proper 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.

BEARING MATERIAL

Various materials used for bearing along with their composition are discussed in this session. The materials reviewed are steels, composites and polymers.

Steels

Steels are alloys of iron and other elements, primarily carbon, widely used in manufacturing of various components because of their high tensile strengths and low costs.

Chrome steel

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 (1%) 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

Table1 Composition of Chrome Steel

Designation	C%	Si%	Mn%	P%	Cr%	Mo%	Ni%	S%
AISI52100	0.95-1.1	0.15-0.35	0.5	0.12	1.3-1.6	0.08	0.25	0.25
100CR6	0.95-1.1	0.15-0.35	0.25-0.45	0.03	1.35-1.65	0.1	-	0.02
SUJ2	0.95-1.1	0.15-0.35	0.5	0.025	1.3-1.6	0.08	0.25	0.025
GCR15	0.95-1.05	0.15-0.35	0.25-0.45	0.027	1.4-1.65	0.1	0.23	0.02

Rockwell hardness C scale (Rc). The material composition of chrome steel is shown in table1.

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 acontrolled 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.

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 steelmaterial with slightlylower carbon and chromium content than AISI440C – 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%.

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.

Hard Carbon Steel

For the most part, these less expensive balls are used incheap bearings for casters, conveyors, bicycles and toys.This material is highly magnetic. It has a thin carbon rich layer, cooked into the surface, that is thenhardened to the equivalent of 60 HRC.

This material is extremely rust prone. These balls aremanufacturedfrom low carbon steel wire, i.e. type 1018 steel. The ball blanks are coldheaded, flashed and ground. They are then heated to 1700 °F in a verycarbon-rich, gaseous environment to develop a high carbon case or shell in arotary hearth furnace--carbon is literally cooked into the outer surface of thesteel balls. After cooling, they are re-heated and oil or water quenched,depending on size. Next, they are tempered at 325 °F to relieve the stressesand to reduce the hardness slightly so they won't be brittle. After carbonizing,

this material may be heat treated to the equivalent of 60 HRC. Because of thethin hardened layer, a special micro hardness test must be used to evaluatethe hardness. It should be remembered that the hard outer surface is only athin case or shell. Finally, these balls are ground and polished.

High Speed Steel Balls

The last common bearing material is high-speed extremely hightemperature alloy steel. This is only found in hot bearing applications. Highspeed steel balls are usually produced from type M50 or M10 steel. Many ofthe "T" type high speed steels are almost impossible to purchase today,High speed steel's main property is its very high temperature resistance. Highspeed steel will remain hard even at red temperatures. High speed steels aregenerally harder than the standard chrome steel. It is typically 65 HRC. Thismaterial is highly magnetic. We can usually grind this material with expensivecubic boron nitride abrasive.

Composite Materials

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The composite materials may be lighter, stronger and durable compared to traditional materials. Silicon Nitride, Aluminum Oxide is the best composite material for ball bearing.

Silicon nitride is a chemical compound of the elements silicon and nitrogen, with the formula Si3N4. The material is prepared by heating powdered silicon between 1300 °C and 1400 °C in an atmosphere of nitrogen:

$$3Si + 2N_2 \rightarrow Si_3N_4$$

The silicon sample weight increases progressively due to the chemical combination of silicon and nitrogen. Without an iron catalyst, the reaction is complete after several hours (~7),It is a white, high-melting-point solid. Silicon nitride has high strength over a wide temperature range, high fracture strength and hardness.

Another composite material used for ball bearing is aluminum oxide. Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formulaAl_2O_3. It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium (III) oxide. It is commonly called alumina.Al_2O_3 is an electrical insulator but has a relatively high thermal conductivity for a ceramic material. Aluminium oxide is insoluble in water. In its most commonly occurring crystalline form, called corundum or α-aluminium oxide, its hardness makes it suitable for use as an abrasive and as a component in cutting tools and bearing balls.

CONCLUSION

Chrome steel material is widely used in ball bearing as it is having good mechanical properties and comparatively low cost. At elevated temperature hardness of the chrome steel material gets reduce hence the load carrying capacity of the bearing is reduced. Composite materials are alternative materials as it can be operated at elevated temperature. Silicon Nitride balls are preferred for hybrid bearing operating at elevated range of temperature. There is future scope to work on aluminium oxide material which can be used for balls material in ball bearing.

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