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*Review Article*

# A REVIEW OF PROPERTIES, APPLICATIONS AND PRESENTLY STUDY DONE ON CERAMIC BEARINGS

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Severe and precise operating conditions have led to the study and invention of antifriction, negligible lubricant and long life bearing materials. Ceramic and Hybrid Ceramics are one of such bearing materials. The low tendency of adhesion between steel and ceramic components and even less between ceramic parts among themselves provides significant advantage in dry run and under lubricated run. The Technology of hybrid ceramics and ceramic bearings along with their applications and wear rate behavior of different ceramics will be discussed in this paper.

***Keywords:*** Ceramic bearing, Hybrid bearing, Friction, Silicon nitride

## INTRODUCTION

Bearing is a machine element used in machines to reduce friction and wear while transmitting motion and power. Bearing supports both linear and rotary motion based on which type of bearing is being employed. Bearings can be classified on basis of

- Type of motion to be allowed, i.e. axial rotation e.g. shaft rotation, linear motion e.g. drawer, spherical rotation e.g. ball and socket joint, hinge motion e.g. door, elbow, knee.
- Type of loading conditions, i.e. axial, radial and radial-thrust bearings.
- Type of lubrication system, i.e. boundary, mixed and hydrodynamic lubrication system.

Factors affecting life of bearing are: loading conditions, lubricant supplied, speed, material to be used.Reducing friction in bearings is often important for efficiency, to reduce wear and to facilitate extended use at high speeds and to avoid overheating and premature failure of the bearing. Essentially, a bearing can reduce friction by:

- By shape, roller, spherical and flexural bearings are mainly preferred.
- By material, exploits the nature of the bearing material used. (An example

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would be using plastics that have low surface friction.)

- By fluid, it avoids surface to surface contact and reduces wear.
- By fields, exploits electromagnetic fields, such as magnetic fields, to keep solid parts from touching.

Combinations of these can even be employed within the same bearing. An example of this is where the cage is made of plastic, and it separates the rollers/balls, which reduce friction by their shape and finish.

The life and effectiveness of bearing extensively depends upon the bearing material. Ceramics, chrome steels, stainless steel and plastics are most common bearing materials being used in industries for making various components of bearings. Every material impart different strength to use of bearing under different operating conditions.

Such as chrome steel - SAE 52100 is used for making components like inner and outer rings, balls and rollers of bearings having (Popp M and Sternagel R, 1999) high strength to resist cracking and a hard surface to resist subsurface rolling contact fatigue.

Stainless steels materials (Popp M and Sternagel R, 1999) 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.

Carbon alloy steel (Popp M and Sternagel R, 1999) materials are used to produce various components of bearings and have two basic types, Medium versus Low Carbon Alloy Steel.

Plastics and non-metallic materials are sometimes used for bearing cages. The most common is molded nylon plastic but molded acetal (POM) is also used.

Bearings made of ceramic materials fall into a profitable segment in the bearing industry. The most common arrangement is a hybrid bearing, usually with stainless steel rings and ceramic balls.

## A NEW DIMENSION IN BEARING TECHNOLOGY

Far more increased wear resistance in dry run have the all ceramic bearings, which are manufactured completely from ceramic. For a long time it was extremely difficult to produce these bearings as the techniques for machining of the ceramics were not available. The high hardness allows only grinding with diamond tools. Initially ceramic bearings were manufactured as ball bearings, angular contact and deep groove type, with balls made from ceramic. The manufacturing process of silicon nitride balls is easier to conduct as that of rollers or rings and thus the hybridbearing was the first step. Additionally, the fact that the ball production is characterized by a mass production technology encouraged the earlier introduction of hybrid bearings. Things became completely different with cylindrical rollers and complete bearing rings, which pose particular requirements:

- Only grinding with diamond tools is applicable for machining of Silicon Nitride ceramic.
- Bearing components have to be manufactured with advanced quality requirements (dimensional andform) as

a consequence to the high Youngs modulus of Silicon Nitride.

- 100% quality assurance from powder to the readymade component because of costly blank material and production process.
- New clamping and grinding tools
- High flexibility of production lines because of small lot sizes.
- High reproducibility because of limited opportunities for dimensional sorting.

Ceramic bearings are mostly made using ceramic silicon nitride ($Si_3N_4$), Alumina Oxide ($Al_2O_3$), Zirconia Oxide ($ZrO_2$), Silicon Carbide (SiC) which are both lighter and harder than traditional steel bearings. (Mazen Al-Hajjar *et al*., 2013).

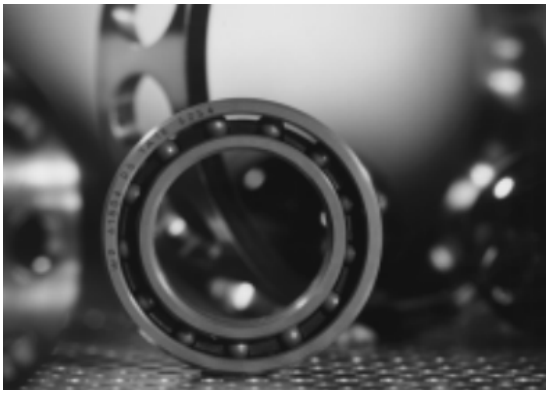
## ADVANTAGES OF CERAMIC BEARINGS OVER STEEL BEARINGS

Ceramic bearings have the normal steel balls replaced by white ceramic balls. The ceramic balls are made of solid silicon nitride. Ceramic silicon nitride balls are called ceramic but have nothing in common with household dish ceramics.

The following is a list of benefits of the ceramic silicon nitride ball bearing:

- **Lighter:** The ceramic ball is lighter than the steel ball. By light in weight it exerts less force on outer ring which results in less friction and less wear.
- **Harder:** The ceramic ball is harder than the steel ball. Which results in appx. 10 times more life than steel balls.
- **Smoother:** The ceramic ball has smoother surface properties than the steel balls. This means less friction between the ball and bearing races giving you a faster spinning bearing.
- **Thermal:** The ceramic ball has better thermal properties than the steel ball. The ceramic ball will not heat up like a steel ball.
- **Lubrication:** The ceramic balls are less reactive and require no lubrication.

**Figure 1: Silicon Nitride Bearing**



## APPLICATIONS OF THE ALL CERAMIC BEARINGS

- Coating facilities for semiconductor industry
- Hot dip galvanizing lines for sheet metal
- In-process measurement in food packing machinery
- Steam fans for pharmaceutical production
- Furnaces for plastic foil treatment
- Motor engines running under-lubricated
- Vacuum pumps and turbo fans running dry

- Compressors running with water injection
- Fans for process gas in Laser plants

## LITERATURE REVIEW

Popp M *et al*. (2010), studied properties of different ceramic materials used for manufacturing of bearings and applications of hybrid ceramic bearings in space usage. CEROBEAR the world largest ceramic ball bearing manufacturers are working on inventing new ceramics having more precise properties. In the past various ceramic materials have been developed that are suitable for rolling bearings. HIPed and gas pressure sintered Silicon Nitride with $Al_2O_3$, $Y_2O_3$ and MgO additions today are standard materials available with high mechanical strength and good corrosion behaviour. With increased understanding of wear and fatigue behaviour of ceramic rolling bearings there is growing demand for improved materials for specific tribological strains.

**Table 1: Material of Bearing Components in Advanced Hybrid Ceramic Bearings are Listed Below**

| Components | Materials |
|---|---|
| Balls/ roller | Silicon Nitride (Si3N4) |
| Rings | X102 CrMo 17, X30 CrMo V 15 2, X40 CrMoVN 16.2, HSS 6-5-2, Alloy 718 |
| Cage | PEEK, PTFE, PI, CrNi Steel, Monel |

Hybrid bearings eliminate almost all limitations (like usage in vacuum conditions, low frictionmomentum, dry run or under lubrications, accuracy, stiffness, variation of load conditions) of conventional bearings being used in space. New ceramic bearings are being invented to further minimize the friction in non-lubricated rolling contacts allowing to improve load capacity and lifetime of the bearings.

Ervin V Zretsky *et al*. (2013), studied about properties of ceramic bearings by conducting endurance test and other experiments. This paper gives an idea about where ceramic bearings are most applicable for gas turbines. In view of experiments conducted, it was concluded that Silicon nitride produces longest life as compared to steel rolling bearings. Ceramic bearing withstands high temperatures of range 644K. They have good fatigue properties.

Mazen Al-Hajjar *et al*. (2013), have studied latest developments in ceramic materials, which have involved mixing alumina and zirconia to produce two new material composites (ATZ and ZTA), have been shown to be more wear resistant under clinically relevant adverse simulator conditions than pure alumina. Finally, the wear performance of alumina-on-alumina, ATZ-on-ATZ and ZTA-on-ZTA bearings have been shown to be superior to other hip replacement bearing materials. And these materials can be effectively used for hip replacement bearings.

## CONCLUSION

From above study done it has been clear that due to low friction and usage in dry run and under lubricated run and comparatively long life ceramic bearings are one of niche factor for bearing industries today. Ceramic bearings overcome certain limitations of conventional steel bearings like corrosion resistance, withstanding high temperatures,

wear resistance, load bearing capabilities, etc. Till now most of the work has been done on rolling ceramic and hybrid bearings but due to its low friction and more surface finish ceramics can be used for manufacturing of sliding contact bearings also.

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