RESISTING WEAR AND CORROSION

Ryan Evans, The Timken Co., explores how bearing coatings can bring big savings to cement plants.

Introduction

In cement plants, ball and roller bearings are routinely pushed to the limits of reliable performance and many mill operators remain on the lookout for stronger solutions. Sometimes a bigger bearing is the answer, while in certain more demanding applications, a different bearing type may offer distinct advantages. Manufacturers, such as The Timken Co., use special heat-treating processes to produce highly durable bearings, which can withstand the rigors of crushing, rolling, and conveying operations.

Coatings are another way Timken and other leading companies strive to significantly extend the life of bearings in industrial machines. Since the late 1990s, Timken has employed surface engineering technologies on bearing balls and rollers. These technologies provide increased wear resistance and corrosion protection in the harshest environments, where standard bearings struggle to meet customer expectations for long, trouble-free life.

Heavy loads, high temperatures, and the constant threat of dirt, debris, and water ingress are just a few of the threats facing bearings in vertical roller mills, crushers, material handling conveyors, and other critical cement plant equipment. Note that surface engineering technologies were not developed to be temporary fixes. Rather they are designed to address the root causes of the mechanisms responsible for life- limiting bearing wear.

When rolling elements with engineered surfaces are incorporated into a bearing, the assembly is referred to as a 'wear-resistant bearing' by Timken. Decades of intensive R&D by Timken and the bearing industry have resulted in a range of coating options that can greatly expand the performance of bearings well beyond previous limits.

If a plant is experiencing frequent bearing changeouts, or if old bearings are struggling to keep pace with new levels of production, talk to a trusted supplier about coatings that can save considerable time and cost.

Among available surface engineering technologies, these hard coatings typically provide the highest level of wear resistance and friction reduction.

PVD coatings

Physical vapour deposition (PVD) is a vacuum deposition method used to produce thin films.

A spherical roller bearing with a PVD coating for extreme wear resistance.

Electrodeposited coatings can offer tougher protection against water.

A black oxidation surface treatment can promote longer bearing life in heavy-duty applications.

PVD uses physical processes (such as heating or sputtering) to produce a vapour of material, which is then deposited on the object that requires coating. PVD coatings are deposited at temperatures between 150 – 160˚C and are designed to operate at temperatures up to 220˚C.

"Timken became a leader in the application of clean steel technology to bearings long ago," said Ryan Evans, Director of R&D Bearings at Timken. "By using clean steel, we saw a reduction in classical bearing fatigue damage occurrences and an increase in bearing service life. When bearings were removed from the field, we found that damage tended to originate at contact surfaces in the bearing as opposed to in the bulk steel. In response, we developed finishing techniques for creating ultrasmooth contact areas and a tightly controlled lubrication environment inside the bearing, including directly engineering the surfaces of the components themselves to achieve even more with our designs."

This drove the development of Timken Engineered Surface (ES) coatings, which have since been recognised by ASM International with an Engineering Materials Achievement Award. The coatings are commonly used where maximum bearing performance and uptime are critical, making them well suited for severe service in grinding and mixing applications in cement plants.

ES coatings feature a thin film of nanocomposite, metal-carbide matrix design that provides extremely hard and low friction near-surface properties. The ceramic-like properties of the coating inhibits microwelding and adhesive wear at the roller and race interfaces, which greatly minimises metal-to-metal contact to help extend the life of the bearing.

"PVD is a plasma-activated vapour deposition process, which is not a familiar technology to most people," Evans explained. "Imagine you have many bearing rollers inside a box. First you evacuate all the air from the box and inject very low quantities of special process gases around the parts. Then you apply strong electric and magnetic fields inside the box to create a plasma environment around the bearing rollers.

"Essentially this allows us to 'grow' the coating on the roller surfaces, atom by atom. We have precise control of the coating structure down to the nanometer, meaning we can create coatings that are very uniform and possess the exact performance characteristics the application requires. It's a level of accuracy and consistency you simply can't achieve using a traditional bath dip or spray paint process."

Bearings with PVD coatings deliver a wide range of advantages in heavy-duty equipment. These include superior debris resistance, reduced friction and torque, reduced component scuffing and smearing damage, decreased false-brinelling wear, increased life in thin film lubrication conditions, and greater oil-out protection.

Where PVD coatings are used in laboratory studies, Timken has validated bearing life improvements up to six times over standard. Benefits in the field will vary depending on application specifics; Timken can advise customers on their specific situations using application modelling tools and 10+ years of field experience with PVD coatings in a variety of environments. For example, in oil-out conditions, these bearings have been observed to last approximately 10 times longer than those with uncoated rollers. PVD coatings can also help significantly reduce fretting wear damage of raceway surfaces when compared to an uncoated component.

It is important to understand that the PVD coating process is a rigorous one that must be controlled within world-class production facilities, with stringent design and quality specifications. As with any critical bearing purchase, be cautious of misleading claims and rely on a trusted supplier to make the proper recommendations.

Electrodeposited coatings

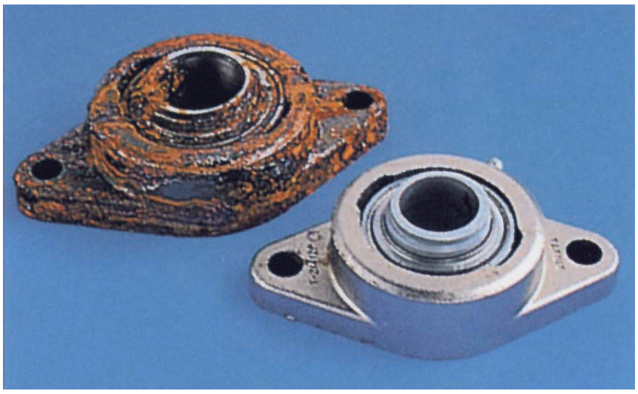
Electrodeposited coatings provide corrosion resistance protection for a wide range of applications. This type of coating is typically applied on bearings experiencing lighter loads and non-acidic solutions. The degree of corrosion protection depends on the type of coating and the application. Some coatings also increase bearing wear life because they harden the contact surfaces.

For example, AquaSpexx® bearings from Timken are specifically designed to combat corrosion damage caused by water. They feature a zinc alloy coating that is applied to inner and outer ring raceways, alongside other functional components, as needed for the application.

Timken first applied the coating to roller bearings for boat trailer wheels with marked success. This lead to the introduction of larger sizes (up to 24.5 in. O.D. for difficult environments, such as steel mills and cement plants, where bearings must battle extremes of heat and intrusions from scale and water). In such cases, custom seals should be added to exclude contaminants.

"Here we are depositing a specially engineered mixture of metals on the component surfaces to resist corrosion," Evans noted. "This is done using electroplating-type operations where you dip a part in a chemical bath and use electric current to drive the plating of the coating onto the bearing surfaces. With this process, you can get good corrosion protection and moderate wear resistance at a reasonable cost."

Thin Dense Chrome (TDC) bearings are another type of roller bearing with an electrodeposited coating. These feature a thin, hard, chrome-based barrier that is designed to protect the bearing from rust and etching corrosion. Commonly applied in wet-end paper mills, food and beverage processing, and maritime applications, these bearings offer strong corrosion protection in cement plants where water poses special concern.



A housed unit with a protective spray coating vs. an uncoated bearing

Particularly in slurry pumps, ball bearings and cylindrical or tapered roller bearings with electrodeposited coatings can resist corrosion better than conventional options.

Surface conversions

Conversion coatings combine wear and corrosion resistance with an ability to withstand false brinelling (fretting wear caused by oscillations or vibrations). While not as strong as PVD coatings, they offer plant operators another way to improve the performance of bearings in critical positions and tend to cost less than premium options.

"With our black oxide coating in particular, we use an alkaline bath to convert the steel bearing surface to an oxide layer that offers some improvement in wear and corrosion resistance," Evans said. "This can help retain lubricant on the bearing surfaces and minimise wear damage in applications where the bearing rollers are prone to slip or skid on the rings, compared to a nontreated bearing. Chemically, black oxide and red rust are similar, but black oxide is more oxygen-lean and has vastly different friction and wear characteristics when deposited properly on bearings."

Spherical and cylindrical roller bearings with black oxide coatings are often specified for vertical rolling mills. This is to reduce the risk of fretting, micropitting and cracking, due to their ability to better withstand impact loads and low-lubrication conditions.

Bearing components are sometimes converted in a phosphate bath that deposits zinc and other compounds on the surface of the steel. These treatments support lubrication during bearing fitting and can provide moderate galling and wear resistance in less demanding applications.

Spray coatings

"There are two types of spray coatings that Timken practices for different purposes. One type is applied to housed bearing units to improve aesthetics and resist environmental corrosion. The other type is a dielectric layer that is used to inhibit electric arcing through the bearing." Dielectric coatings are spray coatings that can be applied to the mounting surfaces of bearing rings to provide electrical insulation if current passage through the bearing is a damage risk. These are typically deposited using carefully engineered plasma thermal spray processes.

"Spray coatings will give you a nice wear-resistant layer and good corrosion protection, but are not intended for functional contact surfaces," said Evans. "You won't see a spray coating on a critical load-bearing contact surface inside the bearing. These are strictly non-contact surface treatments that protect the outside of a bearing housing, for example, in a potentially corrosive environment."

The housed bearing units, commonly found on conveyors and other material handling applications, are good candidates for a spray coating that can deliver excellent corrosion resistance. These units further excel at preventing contaminant and water ingress because of their sealed design.

It is all Greek to me

Tribology is the study of interacting surfaces in relative motion, as it concerns the principles of friction, lubrication, and wear. It takes its name from the Greek word "tribos," meaning "rubbing."

"The term 'tribology' originated with an energy study that was conducted in the UK in the 1960s, where engineers were looking at the cost of friction and wear to the economy," explained Ryan Evans, Director of R&D Bearings at Timken. "Tribos in Ancient Greece described a path or rut that had been worn down by rolling action, like the grooves left behind by chariot wheels."

Understanding friction and wear at the molecular level helps manufacturers like Timken engineer greater efficiency and reliability in a wide range of applications.

"Timken is a tribological products company," he said. "We're a collection of engineering, metallurgy, and manufacturing experts with a constant focus on making bearings that meet customer needs. If a customer is looking for durability to handle more load and speed or evolving lubrication conditions, engineered surfaces and coatings may play a big part in delivering those higher levels of performance."

Comparing coatings

Testing by Timken shows how different coating types compare in relation to corrosion resistance, hardness, and friction. Talk to a supplier about adapting bearings to the specific needs and conditions of an application.

COMPARISON DATA AND TEST RESULTS

Rigorous testing measures how each coating type compares in relation to corrosion resistance, hardness and friction. Each Timken coating is uniquely adapted to the needs and operating conditions of the application.

CORROSION TESTING[1]
Polarization and Tafel curves
Corrosion resistance compared to uncoated baseline product:

Baseline	1
TDC	6/x
AquaSpexx	10x
Zinc Phosphate	6x
ES200	1.4x
ES300	2.3x
ES302	1.9x

[1] Testing performed 3.5% NaCL with Pt (counter electrode, Ag/AgCl, ref electrode, Tafel curve +/- 200 mv). The data is based on Zmod (ohm-cm²).

NANOHARDNESS/ELASTIC MODULUS DATA
A high H/E ratio implies the coating is hard and tough. A low H/E ratio implies the coating is hard and brittle.

H/E Ratio

Baseline	3×10^{-2}
Zinc Phosphate	2×10^{-2}
Black Oxide	4×10^{-4}
AquaSpexx	3×10^{-2}
TDC	4×10^{-2}
ES200	10×10^{-2}
ES300	9×10^{-2}
ES302	9×10^{-2}

FRICTION COEFFICIENT[2]

Baseline	>0.6
ES200	0.28 ± 0.01
ES302	0.29 ± 0.02
Zinc Phosphate	0.17 ± 0.01
Black Oxide	0.51 ± 0.04
TDC	0.49 ± 0.06
AquaSpexx	0.72 ± 0.12

[2] Dry (unlubricated), 200 m distance, 100 mm/s rotation speed, 2N load, 6.35 mm uncoated 52100 ball, 4 mm scar radius.

Good coatings cannot fix bad bearings

Evans stressed that surface engineering technologies cannot usually improve the performance of what is already an inferior product. If a bearing is not properly designed, manufactured and tested, even the best coatings may deliver underwhelming results in difficult applications.

"If you start with a bearing made of substandard steel or having an improperly engineered internal geometry, it is unlikely that a coating or surface conversion is going to do much to improve performance," he said. "A truly effective bearing solution starts with properly designed component geometry and metallurgy for meeting clear application requirements, and it must be manufactured using appropriate methods and quality processes. Only after that will we consider applying advanced finishes and special coatings on functional surfaces to deliver the specific benefits a customer is looking for."

Customers can have many reasons for requesting enhanced bearings, including the need to operate at higher temperatures, speeds, and loads. Occasionally, they want to change from one lubricant to another and discover that they have become susceptible to new surface wear or damage as a result.

"It usually comes down to extending the life of the bearing and having fewer maintenance intervals. Other times, a customer may want to run with a lower-viscosity lubricant to improve the energy efficiency of their equipment, but they don't want to risk damaging the bearing by doing that, so coatings can be a way to get there cost effectively."

If you have become frustrated with frequent bearing repairs and changeouts in a cement plant, an engineered surface solution might be the answer to lower maintenance spending and fewer costly disruptions. Ask a trusted supplier about coating options for bearings in critical positions in the machines that keep operations running smoothly.

About the author

Ryan Evans is the Director of Bearings Research and Development for Timken. For the past 16 years he has focused on tribology, materials and product development in various roles at Timken, and has been granted 13 patents. Evans received his bachelors degree in chemical engineering from The University of Akron and went on to complete his masters and doctoral degrees in chemical engineering from Case Western Reserve University.