Technical Article

Extending the life of precision components in demanding applications

by Oerlikon Balzers

Specialised PVD coatings increase surface hardness and durability of precision components such as bearings, gears and rollers to significantly increase lifespan under high load conditions.

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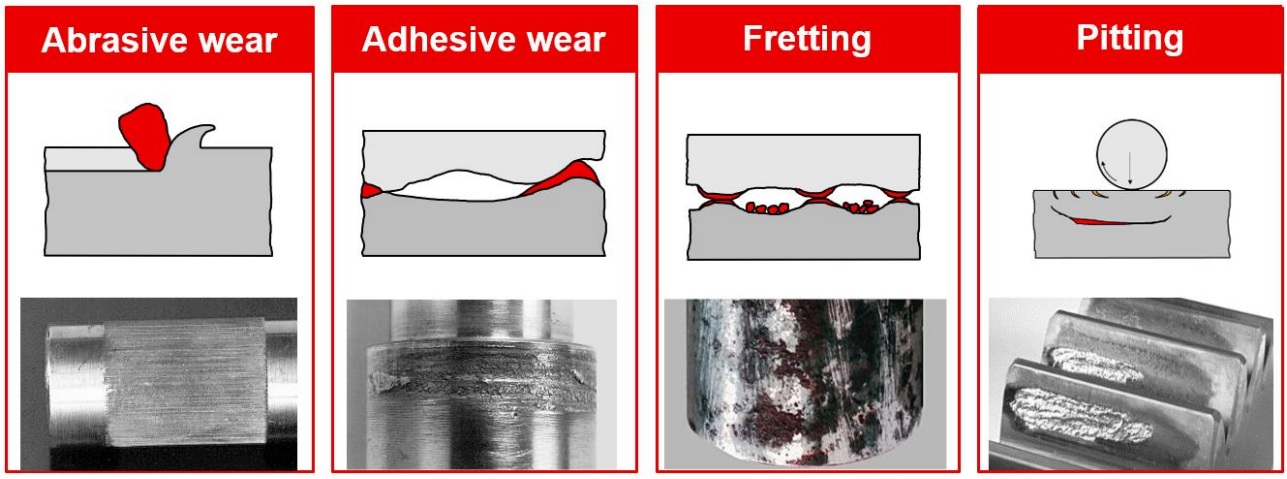
Although bearings, gears, rollers and other precision components are generally made of hardened steel or metal alloys, those utilised in high load applications still can fail due to excessive wear, surface fatigue, pitting, galling and corrosion.



(Image: Oerlikon Balzers)

This is exacerbated in applications with metal-to-metal interaction, repetitive friction at high speeds or where little to no lubrication is present. Other factors include the presence of contaminants, the prevailing service temperatures, the loads applied, and loading modes such as sliding, rolling, oscillating and pulsating.

To address this problem, product engineers and component manufacturers often turn to specialised PVD (Physical Vapour Deposition) coatings that can be applied in thicknesses of 0.5 to 5 micrometres (µm) to further harden the surface of these parts.

By applying coatings optimised for these types of punishing environments, components benefit from increased surface hardness and a much lower coefficient of friction (COF). As a result, these critical parts do not have to be replaced as frequently, if at all, reducing maintenance and unplanned downtime while improving machinery performance.

Today, these coated components are utilised for a variety of applications from performance automotive and racing to wind turbine shaft bearings and planetary gears; stainless steel cutting blades and piston pumps for food processing; and sliding components in filling and bottling operations. The coatings are also a proven technique for upgrading critical rotating parts in hydraulic drives, pumps and valves.

Hardened components and alternative coating techniques

Many components are not coated at all. Instead, these parts are often made of heat-treated, nitrided or case-hardened steels, along with durable high performance materials such as titanium or nickel based alloys. Even those used in high load, high wear applications are subject to wear and premature failure under poor lubrication. Some industries allow no lubrication at all, such as cryogenic and vacuum systems, clean rooms, food and pharmaceutical equipment.

When this is the case, engineers often turn to a variety of coating, plating or nitriding options to modify the surface to improve wear and corrosion resistance. Examples include coating the parts with black oxide. Black oxide is a coating produced by a chemical reaction between the iron on the surface of a ferrous metal and oxidising salts. After a post-treatment with oil, the surface provides protection against corrosion, improved lubricity and prevents galling during metal-to-metal interactions.

However, black oxide is not very durable and can be worn away quickly in repetitive, high load applications.

PTFE (polytetrafluorethylene), another popular coating alternative, is known for its low coefficient of friction but is not recommended for high load applications where it, too, can wear away.

Hard chrome and chemical nickel plating are often specified, as well, to provide protection against wear and corrosion. Although hard chrome is suitable for components that experience abrasive wear, microcracking inherent to the process limits its use against corrosion. Although this can be addressed with thin coatings that increase surface hardness, these solutions only offer limited wear resistance.

Chemical nickel can be applied over a range of hardnesses. However, the maximum is only 600 HV (Vickers Pyramid Number). Concerns over polluting compounds, emissions or residues are also associated with these plating techniques.

Specialised PVD coatings

Physical vapour deposition (PVD) describes a variety of vacuum deposition methods that can be used to produce thin coatings. PVD is typically used to coat components at relatively low coating temperatures of 200-500 °C. These temperatures are ideal because they are below the tempering temperature of steels so as to avoid altering the fundamental material properties.

Fortunately, there are several carbon-based coatings available that provide a unique combination of extreme surface hardness, low friction coefficient and anti-corrosion properties like those provided by global coating provider Oerlikon Balzers.

According to Dr Florian Rovere, Market Segment Manager General Engineering Components for Oerlikon Balzers, the company's BALINIT® C coating is a WC/C ductile carbide carbon coating that is highly resistant to adhesive wear (scuffing) in particular. It has a high load-bearing capacity even under conditions of deficient lubrication or dry contact. Due to its low friction coefficient, it acts to reduce pitting and fretting corrosion

Another example is the BALINIT® DLC coating, a metal-free, carbon based coating that is even more durable. Applied through Plasma-Assisted Chemical Vapor Deposition (PACVD), this coating is designed for more severe wear conditions and high relative sliding speeds to protect against abrasion, scuffing and cold welding.

These and other coatings within the BALINIT® family that are tailored to specific requirements can be applied to a variety of case-hardened or tempered steels, austenitic stainless steel as well as nickel, titanium, copper, magnesium and aluminium alloys.

"These materials provide an excellent combination of low coefficient of friction like PTFE, but with the hardness of a ceramic," explains Rovere.

The coatings also have the advantage of being thin, typically 0.5-5 µm. This feature, in conjunction with close tolerancing, means that the component retains its form, fit and dimensions after coating without the need for re-machining.

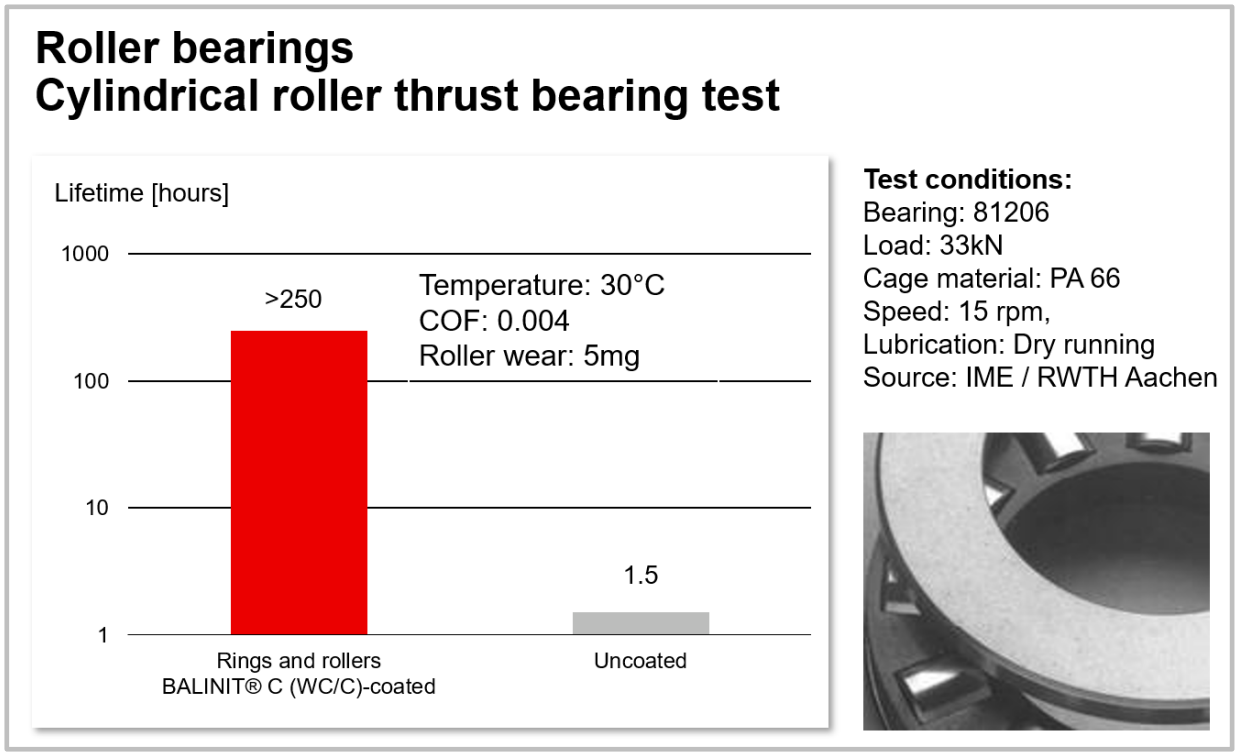
Potential applications

Bearings

Bearings often suffer from severe and disproportionately distributed abrasive wear. A coating such as BALINIT C is particularly suitable for case-hardening as well as ball- and roller-bearing steels because it can be applied at temperatures under 200 °C.

The PVD coating can be applied not only to inner and outer races and cylinders but also to the balls in ball bearings in a highly uniform coating thickness of 0.5-1 µm. The slight increase in roughness is offset by the

good burnishing qualities of the coating, which smoothes the raceway of the inner and outer rings, providing additional protection against scuffing and pitting.



The BALINIT® C (WC/C) coating of rings and rollers result in significantly increased lifetime, low friction and nearly no wear at this dry running bearing test. (Graph: Oerlikon Balzers)

Bearings in the soft calendar rolls of paper machines frequently experience smearing. Not only does PVD coating reduce the possibility of smearing, but by making the bearings harder with coating, it has been shown that the life of these parts can be increased by a factor of three or four. As a result, paper mills are able to hold off on bearing replacement until the calendar roll needs regrinding, significantly reducing costly production downtime.

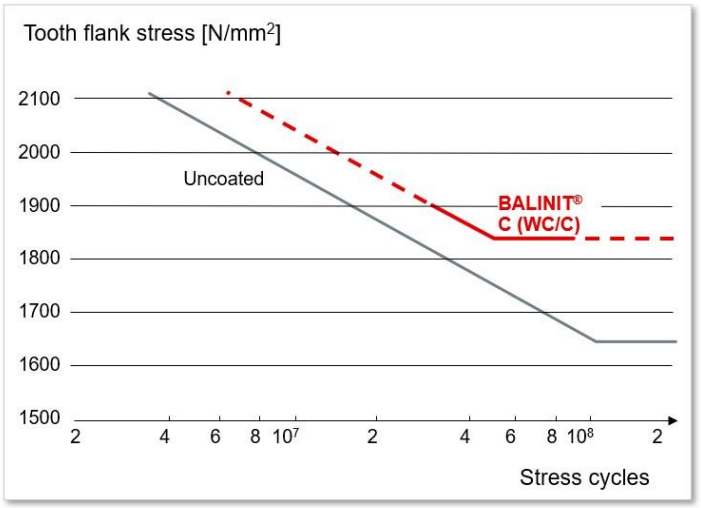
Similarly, cylindrical roller bearings in compressors are often exposed to low loads and vibrations, causing potential smearing. Applying PVD coating to the bearings removes any such possibility.

Gears

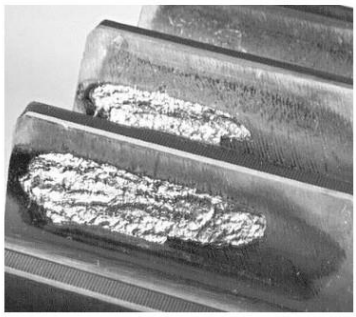
Gears experience similar wear conditions. The PVD coating significantly reduces scuffing and pitting in gear as well. In fact, BALINIT C has been shown to quadruple the service life of high-speed gears.

The standard FZG C test shows that the fatigue strength is increased by 10-15% over case-hardened but uncoated gears. In the test, the failure criterion for gear service life was defined as single-tooth wear of 4% due to pitting.

Highly loaded, fast-running gear



Test method: FZG-C-test
Material: Case hardened steel
Hardness: 62 HRC
Roughness: R_Z = 3 µm
End of test after 4% material wear per tooth (weight-based)



BALINIT® C (WC/C) increases load carrying capacity (fatigue endurance limit) of case hardened gears by 10-15%. The reason is the reduced hertzian stress due to lowering of the friction and running-in of the coating. (Graph: Oerlikon Balzers)

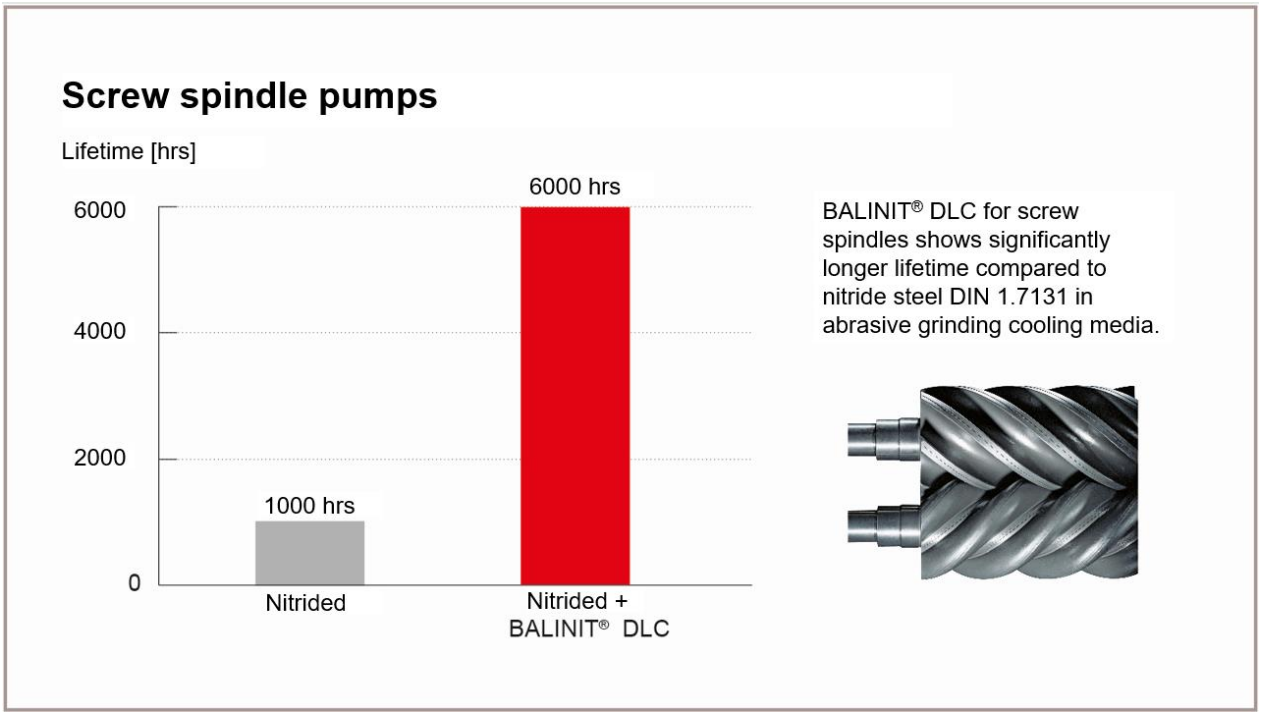
The main factors in these improved figures were the lower local surface pressure (Hertzian pressure), which resulted from reduced friction in the rolling contact, and the superior running-in behaviour of BALINIT C.

Coatings can also benefit worm gears, where lubrication is not always enough to protect helical-gear transmissions against friction and wear. The sliding motion and the force between the worm and gear faces make it difficult for a lubricant film to form. For this reason, the gear is most often made of bronze in order to avoid scuffing.

In service, however, the teeth of the bronze gear wear away quickly and the gear must be realigned or replaced. Coating the steel worm with a carbon-based coating can improve reliability and performance by reducing wear on both the worm and the bronze gear.

Pumps, compressors

Screw spindle-, vane-, gear-, lobe- and centrifugal pumps often function in abrasive and poorly lubricating media. This may be cooling media in grinding machines such as screw pumps and internal gear pumps. BALINIT coated screws provide the ideal combination of hardness and low friction for preventing wear in such poorly lubricated conditions.



BALINIT® DLC for screw spindles shows significantly longer lifetime compared to nitride steel DIN 1.7131 in abrasive grinding cooling media. (Graph: Oerlikon Balzers)

Similarly, industrial compressor components, such as reciprocating pistons, screws or valve plates can undergo extensive wear when oil-free operation, dry gases, refrigerants, high or low temperature limit the use of lubricants.

Customised solutions

In addition to designing and manufacturing PVD coating equipment, Oerlikon Balzers offers coating services at more than 110 coating centres worldwide.

According to Florian Rovere, Oerlikon Balzers have the R&D capabilities to tailor coating solutions to meet unique requirements. In addition to coating thickness and hardness, properties such as structure, chemical and temperature resistance, and adhesion can be precisely controlled.

In most cases, no alteration of the formula for the coatings is required, as it is already optimised for high load, high friction environments.

“I find engineers are most surprised about two factors when learning about these specialised PVD coatings,” says Rovere. First, that the coating can be applied in a thickness as low as 0.5 or 1 micrometres. The other is that these coatings can last the lifetime of the machine or systems it is in, despite the difficult operating conditions.”

For more information about coating solutions for components with Oerlikon Balzers, e-mail: balzers.components@oerlikon.com; or visit www.oerlikon.com/balzers

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About Oerlikon Balzers

Oerlikon Balzers is one of the world's leading suppliers of surface technologies that significantly improve the performance and durability of precision components as well as tools for the metal and plastics processing industries. Extremely thin and exceptionally hard coatings, marketed under the BALINIT and BALIQ brand names, reduce friction and wear. The BALITHERM brand opens up a broad range of heat treatment services, whereas BALTONE comprises coatings that are available in a full range of elegant colours, perfectly suited for decorative applications. BALIMED ThinFilm coatings, with wear-resistant, biocompatible, antimicrobial and chemically inert properties, have been developed especially for medical applications. Under the BALIFOR technology brand the company has introduced technologies which provide tailor-made solutions for the automotive market, while ePD allows the metallisation of plastic parts with a chrome look.

Worldwide, more than 1'300 coating systems are in operation at Oerlikon Balzers facilities and its customers. Equipment engineering and assembly of Balzers' systems are processed in Liechtenstein, in Langenthal (Switzerland) and in Bergisch Gladbach (Germany). Oerlikon Balzers operates a dynamically growing network of more than 110 coating centres in 36 countries in Europe, the Americas and Asia. Oerlikon Balzers is – together with Oerlikon Metco and Oerlikon AM – part of the Surface Solutions Division of the Switzerland-based Oerlikon Group (SIX: OERL).

About Oerlikon

Oerlikon (SIX: OERL) is a global innovation powerhouse for surface engineering, polymer processing and additive manufacturing. The Group's solutions and comprehensive services, together with its advanced materials, improve and maximise the performance, functionality, design and sustainability of its customers' products and manufacturing processes in key industries. Having developed pioneering technology for decades, everything Oerlikon does is guided by its passion to help its customers achieve their goals and to foster a sustainable world. The Group is headquartered in Pfäffikon, Switzerland, and operates its business in two divisions: Surface Solutions and Polymer Processing Solutions. It has a global footprint of more than 10,600 employees at 179 locations in 37 countries and generated sales of CHF 2.3 billion in 2020.