MAINTENANCE

Operations • Service & Repair • Inspection • Safety • Equipment • Condition Monitoring • Lubrication

COMPOSITE ELECTROLESS NICKEL COATINGS FOR THE WIND ENERGY INDUSTRY VARIETIES AND PERFORMANCE ADVANTAGES

This paper presents information on composite electroless nickel (CEN) coatings — a class of coatings with a wide variety of performance and economic advantages to the diverse and demanding components used in the wind energy industry.

By Michael Feldstein

Coatings can be advantageous, and, in many applications, they are essential for proper performance, protection, lifetime, and many other factors. Therefore, selecting the proper coating for each application is vital. But choosing the right coating for components used in the wind energy industry is especially challenging because parts used in the wind industry come in a tremendous array of shapes, sizes, and base metals and are utilized in an equally exceptional range of climates, requirements, and usage conditions.

One category of coatings that can enhance many applications in the wind industry is composite electroless nickel plating. Electroless nickel (EN) is a sophisticated and reliable chemical process with many inherent features well-suited to applications in the wind industry including hardness, corrosion resistance, and perfect conformity to even the most complex geometries. Composites are formed with the addition of super fine particles into the EN. These particles can provide hardness, wear resistance, low friction, release, heat transfer, high friction, and/or even identification and authentication properties.

This paper discusses all varieties of composite EN (CEN) that take advantage of the synergies between EN and particles to dramatically enhance existing characteristics and even add entirely new properties. This makes CEN coatings especially advantageous for applications in the wind industry to:

1. Meet ever more demanding usage conditions requiring less wear, lower friction, and heat transfer.
2. Facilitate the use of new substrate materials such as titanium, aluminum, lower cost steel alloys, ceramics, and plastics.
3. Allow higher productivity of equipment with greater speeds, less wear, and less maintenance efforts and downtime.
4. Replace environmentally problematic coatings such as electroplated chromium.

As shown in Image 1, CEN coatings will naturally maintain their properties and performance even as some portions of the coating may be worn or removed during use. This feature results from the uniform manner with which the particles are dispersed throughout the entire plated layer. Particles from a few nanometers up to about 50 microns in size can be incorporated into coatings from a few microns up to many mils (0.001 inch) in thickness. The particles can comprise approximately 10 to over 40 percent by volume of the coating depending on the particle size and application.

WEAR RESISTANCE

Coatings designed for increased wear resistance have proven to be the most widely utilized CEN coatings in the wind industry to date. Particles of many hard materials such as diamond, silicon carbide, aluminum oxide, tungsten carbide, and boron carbide can be used. But the unsurpassed hardness of diamond has made this material the most common composite. Despite the expensive-sounding name, CEN with diamond is actually comparable to the cost of similar coatings, yet the performance advantages are far greater. These coatings are also inherently beneficial to the environment as they make parts last longer, reducing scrap, and often save energy.

The Taber Wear Test is the most common test method employed to evaluate wear resistance of different materials and coatings. It evaluates the resistance of surfaces to abrasive rubbing produced by the sliding rotation of two unlubricated, abrading wheels against a rotating sample. This test measures the worn weight or volume. The Taber results in Table 1 demonstrate the highly superior wear resistance of a composite diamond-EN coating versus other surface treatments and a hardened tool steel.

More practical and relevant than standardized test results are, of course, actual performance benefits experienced in real-life wind industry applications. In that regard, CEN coatings have the ability to make high-wear components last significantly longer and thereby reduce the need or frequency for maintenance or replacement. For a bearing, rotor, gear, housing, and many other wind system components installed in very inconvenient locations in all sorts of environments on- and offshore, the ability to extend their life is of exemplary value.

Coating or Base Material	Taber Wear Index per 1,000 cycles (10^4 mils^3) [a]	Wear Rate versus Composite Diamond Coating®
Composite Diamond Coating® [b]	1.159	1.00
Cemented tungsten carbide [c]	2.746	2.37
Electroplated hard chromium	4.699	4.05
Tool steel, hardened Rc 62	12.815	13.25

Table 1: Taber Wear Test Results of Various Materials

[a] Weight loss in mg/1,000 cycles (average of 5,000 cycles with CS 100 wheels and 1,000g load.
[b] Composite Diamond Coating® is a registered trademark of Surface Technology, Inc., Trenton, NJ, USA
[c] Grace C-9 (88WC, 12 Co)

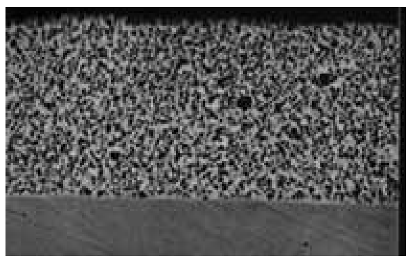

Image 1: Example of a CEN coating that is a cross sectional photomicrograph at 1,000x showing a uniform dispersion of fine diamond within EN

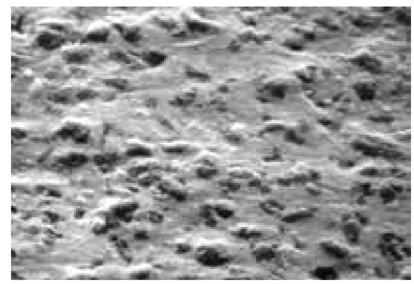

Image 2: The surface of a composite electroless nickel coating at 3,000x magnification

HEAT TRANSFER

Diamond is not only the hardest material known, it is also the best conductor of heat. Fortunately for wind energy components where it is advantageous to draw heat away from the component, the incorporation of diamond in a CEN coating can provide this benefit as well. Prime examples are electrical components, heat sinks, and any component operating in thinner atmospheres where heat transfer is compromised. In testing comparing aluminum to EN and CEN with diamond and CEN with carbide particles, the CEN with diamond yielded a 20-percent heat transfer increase over aluminum.

LOW FRICTION

Certain particles can be incorporated into EN to produce a coating with all the properties of EN as well as a low coefficient of friction. Although these composite coatings also provide wear resistance benefits, they are considered in a separate category based on the unique characteristics they embody — dry lubrication, improved release properties, and repellency of contaminants such as water and oil.

Composite coatings with lubricating particles are generally in thicknesses of 6-25 microns (0.00025" to 0.001"), which is thinner than coatings typically designed for wear resistance. Most commercial interest in composite lubricating coatings has focused on the incorporation of sub-micron Teflon® (PTFE) particles into EN deposits. The properties of PTFE are widely recognized from industrial applications to frying pans.

But, as with wear-resistant particles, there are a variety of low-friction particles that produce self-lubricating properties when co-deposited into EN. Materials other than PTFE have become increasingly popular in the plating field, especially certain specialty ceramics. PTFE is organic and decomposes at temperatures above 250°C. By contrast, many ceramic lubricating materials are harder and withstand higher temperatures than PTFE. As PTFE is a very soft material, its inclusion in EN makes the composite coating comparatively softer, especially as the percentage of PTFE increases. Higher temperature resistance permits higher post-plating heat treatment temperatures yielding greater hardness of the EN matrix. These factors make the composite ceramic lubricant coatings harder and more wear resistant than PTFE-EN in many conditions.

Table 2 shows the coefficients of friction for a variety of coatings under different load conditions. Boron nitride (BN) is one such inorganic material with lubricating properties. It has the ability to withstand temperatures up to 3,000°C depending on the atmosphere; and, as demonstrated in Table 2, composite EN with boron nitride has a lower coefficient of friction than composite EN-PTFE under higher load conditions. For the highly demanding components in the wind industry, the ability to apply thicker and harder CEN's with materials like BN are highly advantageous for both performance and service reliability.

HIGH FRICTION

While many moving components in wind energy equipment require low

[1] Teflon® is a registered trademark of E. I. du Pont de Nemours and Company or its affiliates.

Coating	Load kg/cm²	Friction Coefficient
EN-PTFE	0.1	0.12
EN-BN	0.1	0.13
EN (No particles)	0.1	0.18
Chrome	0.1	0.25
EN-BN	0.3	0.09
EN-PTFE	0.3	0.13
EN (No particles)	0.3	0.16
Chrome	0.3	0.40
EN-BN	0.5	0.08
EN-PTFE	0.5	0.13
EN (No particles)	0.5	0.15
Chrome	0.5	150.00

Table 2: Coefficients of Friction for Various Coatings

friction, others benefit from deliberately textured surfaces to allow friction or grip between mating surfaces. One example is assemblies with adjacent components where one engages with the other and transfers motion or breaking to the other. In such applications, a lightly textured surface can enhance this engagement. CEN coatings with a variety of carbides, oxides, diamond, and other particles can provide this textured surface, as shown in Image 2 where such particles can be seen protruding from the surface of the CEN coating. For such applications, the particles are sized from 10 to about 75 microns, which is significantly larger than the smooth coatings used primarily for wear resistance that employ particles less than 10 microns in size.

INDICATION

The following four sections show a variety of synergistic coatings with valuable identification and authentication properties for unique benefits for wind industry applications.

Phosphorescence

One method to create coatings for authentication is to incorporate particles with light-emitting properties into EN coatings. These novel coatings appear like normal EN under traditional lighting (sun, incandescent, fluorescent, etc.), but under an ultraviolet (UV) light, these coatings emit a distinct brightly colored glow. A person simply needs to shine a hand-held, battery-operated UV light on parts to display the light emission of a composite EN coating and thereby confirm the authenticity of the parts. As there are a number of materials that fluoresce under UV light, it is possible to produce a variety of EN coatings that each give off a different color glow when a UV light source is shined on the coating.

This coating variety can also be used under a functional coating such as CEN to demonstrate wear to avoid damage to the part itself. With a thin layer of a light-emitting coating between the substrate and the functional coating, an operator may then inspect the part periodically with a portable UV light, often while the part is still in use. Once colored light is observed, it is known that the functional coating has worn away. The part can then be recoated and reused before substrate damage to the part itself occurs and before inferior product is produced. In the wind energy industry, such a feature can be of tremendous value to allow inspection of a component without the cost of part removal and downtime.

Forensic Markers

While the composite phosphorescent-EN coatings are a useful technology for many applications, other applications

Images 3 and 4: A bolt coated with the Illumi-Layer™ CEN coating containing light-emitting particles and photographed under normal light (left) and ultraviolet light (right) to illuminate for authentication and indication

require an even greater need for covert authentication. This can be accomplished by the use of certain forensic markers, which are a family of materials that have been developed using unique substances and can be detected by an electronic meter. The test is non-invasive, instantaneous, and infinitely repeatable. These materials are chemically inert, safe, and strong enough to persist in almost any conditions including an EN plating bath and heat treatment. Only small amounts of the ceramic-based materials need to be co-deposited into the EN coating to make their properties evident to the electronic meter. Therefore, the slight presence of the material in the coating is not readily visible and essentially does not affect the performance of the coating in other regards such as wear resistance, corrosion resistance, and friction.

There are dozens of such materials that can be used alone or in combination to create a unique marking or tracking system that can be embedded in almost any material or coating from paints and powder coating to CEN. This creates many new opportunities for product management, manufacturing process and logistics control, inventory management, quality assurance, and pollution control and authentication — all necessities in the global wind systems market.

Sound Activating

A further variety of authentication coating technology has been developed that actually allows the coating to activate a small detector to produce an audible report. This innovative technology is similar to that by using forensic markers since only a small quantity of specialized materials need to be incorporated into the coating to trigger the response of the detector. The test is instantaneous and generates a clear pass or fail indication. The detector is small and battery-operated for economy and convenience, which can be essential to the maintenance technicians and others in the wind energy industry.

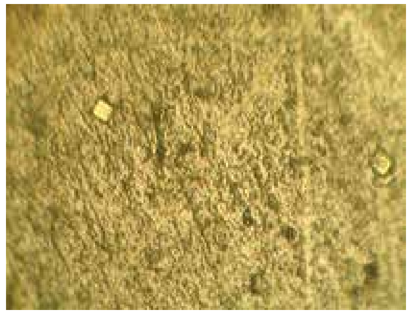

Image 5: A 400x view of the surface of a coating incorporating structured micro taggants to permit authentication of a product simply by microscopic examination

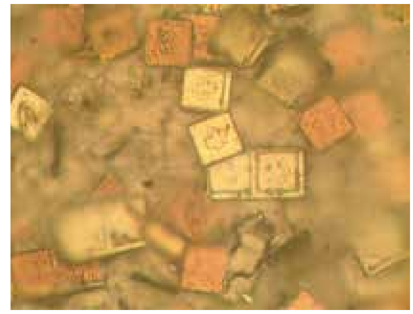

Image 6: A 1,000x view of one example of structured micro taggants showing an intricate design able to be imparted into the taggant

Micro Taggants

This variety of coating technology provides a fourth means of authentication of a product simply by inspection of the surface under magnification. A key to making this type of coating useful in authentication and product protection is that the micro taggants are manufactured by a complex and proprietary process.

The ability to customize the taggants in these ways means that their design can be modified on a continual basis to thwart counterfeiters or incorporate product identification and tracking information right on the surface of the product within a hard and durable coating.

MULTI-LAYER COMPOSITE EN SOLUTIONS

Underlayers

When a degree of corrosion resistance is needed above the level already provided by a CEN coating, as is often the case in wind energy equipment, it is routine to apply an underlayer to a part before it is coated with a CEN. This underlayer is most often a high phosphorous alloy of EN. This provides a barrier layer for corrosion, and the outward functional layer will still be the CEN for part performance.

Overcoating

Overcoating is a procedure often utilized for composite wear-resistant coatings. Composites containing particles (as discussed earlier) are smooth to the touch and sufficient for most applications. When the coating is intended to contact certain delicate materials, these protruding particles may be deleterious or require a break-in period of use to smooth the surface. A break-in period is a luxury that most applications in wind energy equipment cannot afford. So, instead of employing mechanical means to smooth the surface, and instead of operating a coated part for a less productive break-in period, an overcoat can be applied. For a CEN coating, an overcoat layer of only about 5 microns of conventional EN is sufficient to cover the composite surface and provide a new, smoother surface.

CONCLUSION

The performance requirements of components used in the wind energy industry are exceptionally diverse. They range from wear resistance, low friction, high friction, heat transfer, and authentication to identification. For this reason, the ability to tailor CEN coatings with an array of synergistic particles makes these coatings uniquely beneficial for applications in the wind energy industry.

CONDITION MONITORING DOES NOT NEED TO BE OVERWHELMING

Condition monitoring is a useful practice for wind farm owners and operators to better manage maintenance workflow and data collection while increasing turbine reliability and reducing overall downtime.

By Jeff Walkup

While condition monitoring has a rather simple definition, it is only when we are caught up in "analysis paralysis" syndrome that our minds get in the way and a common sense Czar is required with regards to our thinking. Performance, operations, and engineering managers are overwhelmed with information when what they need is insight and to be told what is required and when.

Condition monitoring can be defined as the process of systematic data collection and evaluation to identify changes in performance or condition of a system or its components, such that remedial action may be planned in a cost-effective manner to maintain operational reliability, productivity, and profitability.

In the wind energy industry, thousands, if not millions, of data points are collected every second through methods such as real-time sensors installed to monitor conditions including temperature, lubricant conditions, drive train vibrations, turbine production, generator output, and weather conditions. This information is typically fed into an online recording system and analyzed through sophisticated algorithms to determine if the data point is within acceptable limits. When an alert level is reached, most systems will flag it according to criticality and issue a predetermined maintenance decision that includes some type of corrective action.

Unfortunately, this is where most of these sophisticated systems stop and the completion of the ensuing maintenance work is turned over to a computerized maintenance management system (CMMS) or an enterprise resource planning (ERP) system. ERP is a business-management software (typically a suite of integrated applications) that an organization can use to collect, store, manage, and interpret data from many business activities including product planning and cost; manufacturing or service delivery; marketing and sales; inventory management; and shipping and payment.

While these systems by design are excellent at managing tasks (work orders) and parts (inventory and procurement), they often lack the necessary depth or detail to facilitate the full maintenance workflow of inspection, troubleshooting, repair, and documentation of the defect. This is typically left in the hands of the technician with little more than a one-line task description (i.e., perform borescope on gearbox, inspect bearings for flaking, change oil and filters, etc.).

While most experienced technicians are capable of performing the maintenance workflow and restoring the turbine to a normal state, they often require access to additional resources in order to complete the work, such as equipment history, specific defect troubleshooting, and repair procedures created from previous similar defects, as well as OEM or engineering technical advice. This is often difficult to obtain while up-tower performing the work. This can be quite overwhelming for a less-experienced technician and lead to significant downtime in order to address anything but the simplest defect.

When the work is finally completed, any documentation that is recorded is typically paper-based and minimally detailed. A CMMS or ERP system usually only requires minimum feedback from the work performed, such as an update of the task status to be completed or closed, indicating that the work was indeed performed. It is only through the initiative of dedicated technicians or maintenance clerks that additional detailed information, such as inspection findings, performed work activities, and any identified additional work requirements, make it into these available systems due to the limited tools available or the complexity of entering such information. The limitations of this process usually only surface at the next maintenance service when a different technician attempts to perform work on the same turbine and discovers the limited or nonexistent historical information to reference.

In an environment of rapid growth, employee turnover, and cost pressures, the challenge for wind farm owners and operators is to better manage this maintenance workflow and data collection/feedback loop. Some of the financial and performance benefits of improving this process include increased turbine reliability and availability, a reduction in overall downtime (particularly mean time to repair) leading to a reduction in overall maintenance costs, and improved employee output and knowledge.

Based on experience and collaboration with experts from other global industries over the past 20 years, I have identified some key gaps. I would like to highlight just a few characteristics of an effective maintenance workflow and feedback process that, when combined with a well-organized condition monitoring program, can leverage vibration and oil analysis, allowing for better, more informed decisions.

Condition monitoring in a 360-degree holistic approach provides the potential tools and abilities to make your operations better in the following ways:

- The ability and process to capture and leverage the experience and knowledge of the entire workforce through a knowledge management system that is readily accessible when performing maintenance activities.
- Tools that allow expert collaboration over defect resolution while the technician is performing the maintenance work, either through live access to experts or technical information.
- Tools that simplify field inspection and data capture, including photos, notes, and quantitative measurements, eliminating the need for paper-based recording, the additional time needed to do so, and error-prone inefficiency when simple things have to be hand-written.
- Historical data presentation so previous maintenance work is available for reference. (The old saying that what gets measured gets done, is true.)
- Ability to determine the effectiveness of maintenance work and not just the completion of the task, such as was the defect removed, as well as KPI metrics to measure.
- Historically used oil and grease analysis compared bulk lubricants within service lubricants; typically, oil sampling that is taken and sent to a testing lab takes place approximately every six months. Test results from oil compare the condition of the lubricant in service as well as the wear anomalies that may be taking place. These are identified within the lubricant and filters as applicable. The development of Best Practices and Consistency is vital and can go a long way on lubricant change on condition.
- Regarding condition monitoring, ensuring proper sensor sensitivity ranges as well as installation locations and knowing your drive train configurations and kinematic details is extremely important.
- Setting alert levels, alarms, and recommended actions that are achievable use the power of fleet benchmarking.
- Know your assets and ensure your work force is properly trained to do their jobs, since often we see that the only training they may have received was from a previous employer.
- Finally, take charge by using all data and information available and do not rely on just one particular technology; instead, use all that is at your disposal since each will have inherent strengths versus another.

In conclusion, with condition monitoring, a world of information is at your disposal. What's most important is what you choose to do with it. Will you be an early adopter creating opportunities for yourself and your organization, or will you chase after opportunities while the world around you passes you by?

SCHNEIDER ELECTRIC OFFERS MOST COMPREHENSIVE SUPPORT PACKAGE IN THE WIND MARKET


iStock

It's no secret that wind farm operators, like all renewable energy generators, struggle with maximizing power generation. In addition to performing maintenance at optimal times, wind farm operators have the added challenge of needing to know when the wind speeds they rely on to generate power might actually damage operating turbines.

To overcome these challenges, Schneider Electric is releasing two new solutions that will help the wind power industry maximize generation, efficiency, and crew safety.

First, turbine blade inspection reports to help wind farm operators efficiently respond to lightning strikes, a leading cause of blade damage and unplanned outages. Using Schneider Electric's lightning tracking technology, this solution offers operators a daily data report that lists all lightning activity in the past 24 hours, including the likelihood that turbines within a given area were struck. The solution benefits users by:

- Allowing a more efficient inspection and repair process, as crews know which turbines may need attention and can prioritize their inspection and maintenance schedules
- Improving lightning damage detection that allows blades to be repaired before damage progresses, reducing overall blade repair costs and turbine downtime
- Providing useful information such as the affected turbine's name/ID, lightning strike date and time, and the exact location and intensity of the strike
- Offering a customizable strike confidence level, which allows customers to tailor their report by choosing the degree of confidence that a strike occurred within a certain number of meters
- Sharing the most updated forecast information with operators through Weather Sentry Online or a mobile application, ensuring better safety in the field

These reports can ultimately save wind farm operators thousands of dollars in blade repair and replacement costs. Lightning damage is not always easily visible, but it can lead to larger issues if undetected — a very real possibility in a wind farm that is operating dozens, if not hundreds, of turbines. By detecting strike damage early, operators save money and significant time as they no longer have to visually determine whether any strikes came close to the turbines.

In addition to lightning, wind-related intelligence is also important when enhancing efficiency and crew safety. Schneider Electric's hub height wind forecasts solution provides hourly wind speed and direction forecasts at typical turbine heights as opposed to the ground speed forecasts normally available. With this technology, wind farm operators can make better informed operation and maintenance scheduling decisions to maximize generation, benefiting from the following:

- Highly accurate hourly forecasts at the three most popular turbine hub heights — 80, 100, and 120 meters — which are more useful than standard forecasts at 10 meters
- Operators can confidently schedule maintenance not only when it is safe for crews but also during periods of lowest generation capacity
- Minimizing generation loss from turbines damaged when operating in excessive wind conditions
- Improved generation capacity forecasting with more accurate and timely forecast information

These new solutions enhance Schneider Electric's support package for the wind market that already includes highly accurate wind power forecasts and a complete lightning safety solution. Together, these offerings represent the most comprehensive wind power support solution available on the market.

For more information, go to www.schneider-electric.com.

— Source: Schneider Electric

CENTRICA ENERGY BENEFITS FROM ROMAX INSIGHT'S WIND FARM SOLUTION SERVICES

A multi-national integrated energy business and parent company of British Gas, Centrica Energy has 27.9 million customer accounts and a total operating profit of £1.7 bn. Romax InSight wind energy services support the company's Lincs, Lynn and Inner Dowsing (LID) wind farms with an all-in-one fleet monitoring solution including monitoring, inspecting, giving advice, and performing grease flushing and root cause analysis.

Romax has supported Centrica Energy's co-owned LID wind farms for almost three years by analyzing data, providing monthly performance and condition reports, and advising on lead times to major component failure.

In one particular investigation, vibration increases prompted main bearing inspections to confirm micropitting damage and metallic debris in the grease. This was closely monitored by Romax over the winter months to ensure the damage did not reach a critical level when turbine access is limited. When the weather improved, Romax deployed its patented flushing process to remove the contaminated grease and allow a complete inspection of the downwind main bearing on both sides. After repacking with fresh grease, to improve the operating conditions of the rolling elements, post-flush condition monitoring of both the vibration and SCADA data was performed. The results showed a plateau in the vibration levels in the bearing and a reduction in operating temperature of between 5°C and 10°C, meaning the life of the component was extended and it could be removed from service at the same time as other remedial works.

"Romax provides technical insights to guide our investigations, to ensure turbines operate more reliably, and to have an extended lifespan, which allows us to better protect and leverage our investments," said Tom Kent, senior wind turbine engineer at Centrica Energy. "Romax helps us to understand and control rising O&M costs. We have the peace of mind that we are highly unlikely to experience a serial drivetrain issue any time soon, and we have an opportunity to optimize the smooth running of our operations and energy production as well as to reduce the overall cost of energy."

To find out more about the benefits that Centrica Energy found through Romax' InSight offerings, go to www.romaxtech.com, click on the Customers tab, and then select Case Studies.

For more information, go to www.romaxtech.com.

— Source: Romax Technology