Metal surface
mo
Offprint
Plastic and metal coating
3/2006
March 2006
Volume 60
www.metalloberflaeche.de

Coatings suitable for coping with extreme exposure

Dr. Uwe Hasselmann, Hans-Werner Herr

Bolted connections used in wind energy plants are subject to complex stresses and hence need to be constructed to withstand these by correspondingly adapting the design of the individual components and by using specialist coating processes. This, in turn, can only be achieved through close collaboration between bolt and coating manufacturers.

When building and setting up wind energy plants, all individual turbine components are connected to one another using fasteners. The dimensions of the load-bearing fasteners for the latest types of wind turbine often range from between M30 to M64. Secondary bolted connections are often smaller. However, to give an impression of the quantity of fasteners of that size used in the wind energy plant sector, we are taking a conventional, 2-megawatt wind turbine to perform a simple calculation: Weighing a total of 400 tons - that's including the tower - a staggering 3,730 kilograms of fasteners are used in the wind turbine's tower alone; an additional 1,780 kilograms in the power house and 600 kilograms just for mounting the rotor blades. Not counting any of the smaller bolts and fasteners that are used in components such as the gearbox and generator, this means that the fasteners used in this type of turbine make up 1.5 percent of its total weight.

High static and dynamic loads

The types of bolting used in wind turbines include the kind used for pedestal bearings in the area of the shaft bearing - as shown in figure 1 - flange connections for joining tower segments, coupling flanges and the rotating assemblies of large-diameter anti-friction bearings (figure 2). These types of connections in wind turbines are subject to complex stresses, which include high static loads created through the pre-tensioning of the bolts and the great weight of the connected elements, added to which are high dynamic loads with stochastic amplitude- and frequency distributions created by the wind forces and the varying operating states of the plant.

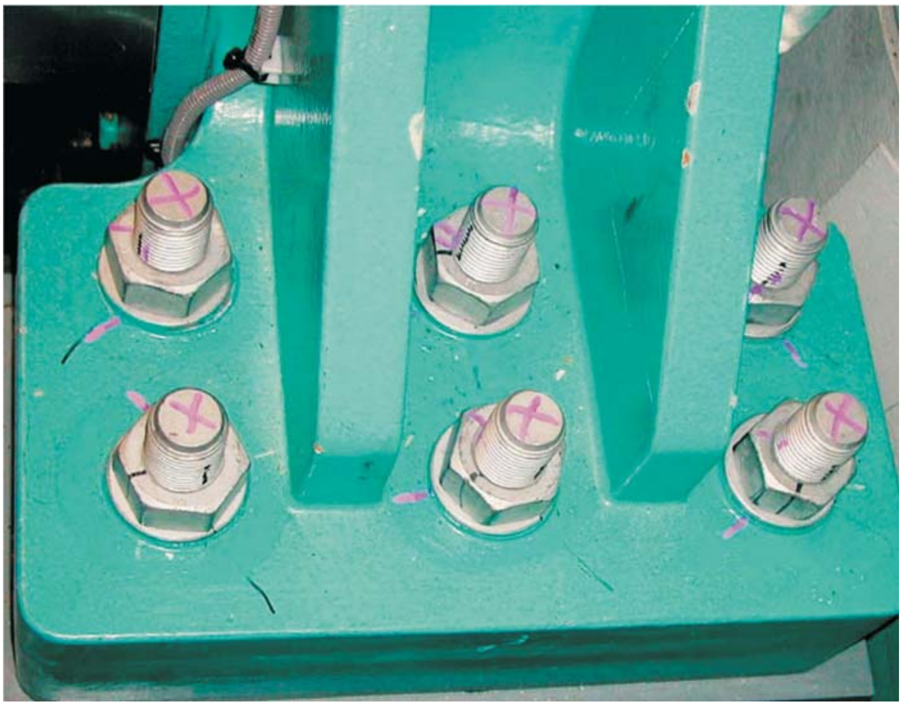


Figure 1. Pedestal bearing bolt connection in the drive train. Picture: August Friedberg GmbH

The wind turbines - and consequently so are the bolted connections - are furthermore subject to significant temperature fluctuations and significant corrosion, which applies in particular to offshore wind turbines. This is also why the fasteners used in wind turbines are made of high-strength-materials; the bolts used generally have a tensile strength of 10.9 in accordance with ISO 898-1 and the nuts generally have a tensile strength of 10, in accordance with ISO 898-2. Special measures taken with regard to material durability for bolts employed at low temperatures include the specification of special material properties. A whole set of additional restrictions, well in excess of the requirements of ISO 898-1, must furthermore be taken into account to prevent the occurrence of brittle fractures as a result of hydrogen inclusion during surface treatment. Further measures taken include those that ensure that the fatigue strength of the bolts is sufficient and to ensure and free assembly. The last step required in the production of high-performance fasteners is to provide them with effective corrosion protection by using corresponding coating systems.

The end of chromium (VI) -use

Traditionally, the fastener technology used in wind turbines has always been based on comparable technologies used in civil engineering, which often uses hot dip galvanising to protect fasteners against corrosion. However, there a many cases where it is not possible to use hot dip galvanising for corrosion protection. This is because allowances regarding the load capability of the fasteners must be made in accordance with the calculation methods for fatigue parameters used for wind turbine connections exposed to collective loads.In such cases, inorganic zinc lamella coatings in accordance with ISO 10683 are used. As of 1st July 2007, the use of any carcinogenic, hexavalent chromium in corrosion protection systems for fasteners installed in new vehicles will be prohibited by the EC End-of-life vehicles directive 200/53/EC. Although the wind energy plant sector is not directly affected by this EC directive, the concept of applying a potentially harmful corrosion protection system to fasteners used on environ-mentally friendly technologies will most probably not be tolerated for long, not least because of any potentially resultant image distortions and because there are viable alter-natives that do not contain any hexa-valent chromium. It is furthermore to be expected that the above directive will lead to changesin the conditions of the market for surface treatments, slowly but surely making systems that contain chromium (VI) a thing of the past. This is one of the reasons why - at least for new wind turbines - the continued use of chromium (VI) systems is out of the question. The Delta-MKS Corrosion Protection Systems manufactured by Dörken MKS-Systeme GmbH & Co. KG, Herdecke, have always been free from hexavalent chromium as a matter of principle and have long become established as the most effective corrosion protection system used in the wind energy plant industry. The Delta-Tone/Delta-Seal GZ system, for example, is available in silver and black - as shown in figure 3 on a conventional stud bolt for use on drive trains - and is widely used across the industry.

Figure 2. The bolting on a rotor blade bearing of a modern wind turbine Picture: August Friedberg GmbH

Close collaboration

There are a number of aspects that need to be taken into account when coating large, high-strength fasteners for use in wind turbines that require close collaboration between fastener manufacturers and job coaters. High-strength fasteners with tensile strengths of more than 1,000 MPa, for example, have an intrinsic susceptibility to brittle fractures. Brittle fractures are triggered in particular by atomic hydrogen that is absorbed during pre-treatment before the fastener is coated. Absorption of hydrogen can, however, also occur as a result of corrosion processes affecting the component at its place of installation, which is a factor that cannot be remedied through manufacturing procedures. It is therefore of particular importance to limit the susceptibility of a particular material to hydrogen embrittlement fractures as much as possible.

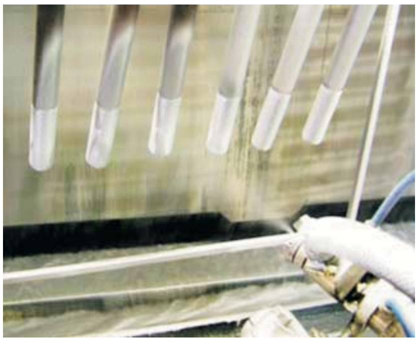
Figure 3. Size of a M36 stud bolt with black Delta-Tone/Delta-Seal GZ coating for the drive train of a wind turbine in comparison with M 12 hexagon bolts and micro-bolts for plastics applications

This can be achieved by ensuring the appropriate manufacture of the fasteners; starting with the selection of suitable materials up to ensuring proper heat treatment and the performance of corresponding inspections during production. The absorption of hydrogen can be categorically excluded if the employment of acid cleaning when preparing the bolts for coating is prohibited and one of a range of other innovative cleaning methods is used instead. Bolted connections are usually preloaded using the torque method, although more progressive inelastic methods are also starting to be used. When using torque-controlled assembly, the friction between the threads and the contact areas of the fastener head or nut is highly significant for the upper limit and uniformity of the pretension that can be achieved using a pre-determined tightening torque. These friction processes are described by the friction coefficients specified by ISO 16047. By using the top Delta-Seal GZ coat, it is possible to achieve a uniform friction coefficient in correspondence with the VDA test sheet 235-104 specifications for the automotive industry. This friction coefficient is verified through torque-tension tests on equipment specifically adapted to the dimensions of the fasteners. August Friedberg GmbH, for example, is equipped with test equipment with a maximum tightening torque of 15,000 Nm and a preload measuring range of up to 2,500 kN, manufactured by Schatz AG.

Deadline pressure and difficult conditions

Wind turbines are generally assembled and set up subject to tight deadlines and under difficult conditions on the construction site. Additional complications and loss of time caused by stiff threads and connections are therefore something that cannot be tolerated. This is why the regulations of ISO 6157-1 and ISO 10683 have been significantly tightened and all connections are now generally expected to be able

Figure 4. Delta-MKS rack coating of stud bolts for wind energy plants Picture: EOT



Picture 6. Delta-MKS rack coating of hexagon bolts for wind energy plants Picture: EOT

to be assembled manually. A special package of measures is currently being devised in close collaboration with fastener manufacturers and fastener coating companies to address these issues. These measures primarily involve the specification of potential thread tolerance restrictions and careful treatment of the fasteners by minimizing drop heights throughout the entire production process.

This is closely followed in importance by heat-sealing specifications and specifications relating to the actual coating process performed using racks (figure 4). In some cases, such as in parts with internal threads, the use of racks for coating has actually become a requirement since, as in the case of the nuts shown in figure 5, the weight of the nuts or parts is such that it can cause significant damage if used with other types of equipment such as drums. In order to ensure that all parts of the components are sufficiently protected against corrosion when using racks for coating, special measures and the application of multiple coats is often required (figure 6). In the case of high-strength and bolted connections subject to high dynamic loads used in wind turbines, high specification application characteristics have been achieved by adapting the design of the fasteners and by using well-coordinated coating processes that ultimately increase the safety of the connection. This is a feat that can only be achieved if competent fastener manufacturers and specialist coating manufacturers enter into close collaboration with one another as early as the development phase.

Authors:

Dr. Uwe Hasselmann, Head of Quality Management, Research and Development and Logistics at August Friedberg GmbH in Gelsenkirchen, 0209/9132-207, www.august-friedberg.de

Hans-Werner, Director of Technology at EOT Eibach Oberflächentechnik GmbH in Lüdenscheid, 02351/9546-0, www.eot-gmbh.de

Figure 5. Delta-MKS rack coating of nuts for wind energy plants, picture: EOT