CORROSION

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Class 1

Contents

Introduction

Sites, ideal to wind turbines, are exposed to very harsh weather conditions. Strong winds, humidity and salt are often normal conditions – especially in connection with wind turbines sited offshore. But contrary to popular belief, corrosion is not a major problem – even offshore – if metal parts are adequately protected.

This document presents the nature of corrosion and describes what Vestas does to avoid corrosion.

Purpose

Based on the assumption that proper maintenance is carried out, Vestas' aim is to ensure a trouble-free operation during the design lifetime of 20 years. The Vestas anticorrosion treatments are chosen to meet this objective.

Advantage

- The corrosion protection ensures that the design lifetime is reached, and it is futher more likely to prolong the lifetime.
- A proper corrosion protection reduces the probability of emergency repairs – a large advantage especially for wind turbines sited in remote locations.
- Corrosion protection provides good visible appearance.

Theory of corrosion

Most metals are found in nature in the form of various chemical compounds, called ores. In the refining process, energy is added to the ore to produce metal.

Corrosion is a natural process and is a result of the inherent tendency of metals to revert to their more stable compounds.

There are several kinds of corrosion. Atmospheric corrosion is the most interesting in connections with wind turbines.

Humidity increases atmospheric corrosion. Also the corrosion severity is increased when salt, sulphur compounds and other atmospheric contaminants are present. On the opposite, low relative humidity combined with ventilation will decrease the process.

History

When Vestas decided to take corrosion protection to a higher level, investigations were made on Vestas turbines located on the coast of Western Jutland, Denmark, close to the North Sea. This site was chosen because of its similarity with a given offshore position exposing the turbines to extreme conditions.

The Force Institute[1], which performed main parts of the investigation, concluded that only minor improvements were needed, and made a proposal for the future surface protection.

Vestas Corrosion Protection

All Vestas Wind Turbines are partly manufactured out of metal. The most visible part is the tower, but also the nacelle and even the rotor blades consist of various metal parts, all of which is exposed to corrosion. The degree of exposion depends on the type of metal, the environment and the countermeasures taken.

Today all Vestas Wind Turbines are protected against corrosion according to the classification specified in ISO 12944-2:1998 “Classification of environments”. This standard divides the environment into 6 classes as follows.

Typical environments in temperate climates		
Corrosion class / exposure	**Outdoor**	**Indoor**
C1 Very low		Heated building with clean atmosphere, e.g. hotels, offices and schools.
C2 Low	Atmosphere with low pollution and dry climate	Non heated buildings with risk of condensation, e.g. storage buildings and gyms.
C3 Average	City and industrial atmosphere with moderate influence from sulphur dioxide. Coastal areas with low salinity.	Production facilities with high humidity and some pollution, e.g. food processing plants, laundries, breweries, dairies
C4 High	Industrial areas. Coastal areas with moderate salinity.	Chemical plants, shipyards
C5-I (Industrial) Very high	Industrial areas with high humidity and aggressive atmosphere.	
C5-M (Maritime) Very high	Coastal and offshore areas with high salinity.	

All Vestas turbines are manufactured and protected according to these corrosion classes.

Outside fittings and sensors are protected against corrosion according to class **C5-M**.

Inside surfaces, directly exposed to outside air, e.g. inside nose cone and transformer housing are protected against corrosion according to class **C4**.

Inside surfaces, not directly exposed to outside air, e.g. components inside the nacelle, are protected against corrosion according to class **C3**.

Towers are delivered in various protection classes. Standard towers are protected according to class **C4** on outside surfaces and **C3** inside. For offshore use, the outside is protected according to class **C5-M** and the inside according to **C4**.

Foundation sections also are classified according to ISO 12944-2, but in another corrosion class called **IM3** as standard and **IM2** for offshore use.

The technology

Various metal parts of the Vestas Wind Turbines are treated to resist corrosion in different ways. The type of protection is taken in consideration during the design phase.

If the appearance is of no importance **hot dip galvanising** is often used according to DS/ISO 1459 and 1461.

Metallization is used where metal parts are too large (2,5m x 12m), or where hot dip galvanising is not used for other reasons. The **metallization** is a spray treatment according to ISO 2063, and it often substitutes the primer before spray painting.

If metal parts are only **painted**, the painting is carried out according to the above-mentioned corrosion classes and ISO 12944-5 or another system proven to fulfil requirements. In case of demands to colour stability and high gloss, or in case of ultraviolet exposure, the painting is completed with an aliphatic polyurethane coating.

Interior components in aluminium and aluzinc plates are protected according to DS/EN 10215. Protection-caps etc. are normally **zinc-electroplated** and **yellow-chromated** according to ISO 2081 and ISO 4520.

Screws, bolts, washers and rivets etc. are protected in different ways depending on their function and the requirements. Among others, **Stainless steel** is used in the best quality A4/AISI 316. Screws, bolts, washers and rivets etc. may be exposed to corrosion, but their durability is always more than sufficient.

Heating and ventilation

The outer environment of wind turbines is easily categorised. But uncertainty is related to the environment inside tower and nacelle, where ventilation, heating supply and entry of water influence the corrosion aggressiveness.

The glass fibre reinforced nacelle-cover protects the components in the nacelle against direct contact with the outside environment, which together with an adequate surface protection provides a good resistance to corrosion. But it is also essential to observe the temperature. By keeping the nacelle temperature higher than the outside temperature it is possible to lower the relative humidity of the air. Condensing will thus not occur, and the risk of corrosion is minimised.

Wind turbines in operation automatically produce sufficient heat to ensure a low corrosion rate. That is also why it was only necessary for the Force Institute to propose minor improvements when some of the first Vestas turbines were examined in respect of corrosion.

The most recent Vestas turbines control the inside climate by means of heaters, fans and on some types: flap-valves/registers to the outside. The inside temperature in most situations is kept 5 - 10° C higher than outside. An exeption may occure in given periods with no or low wind and temperature above 0° C.

In most occasions a 5° C raised temperature will lower the relative humidity to below 70%, (figure 1), i.e. a low corrosion rate (fig. 2).

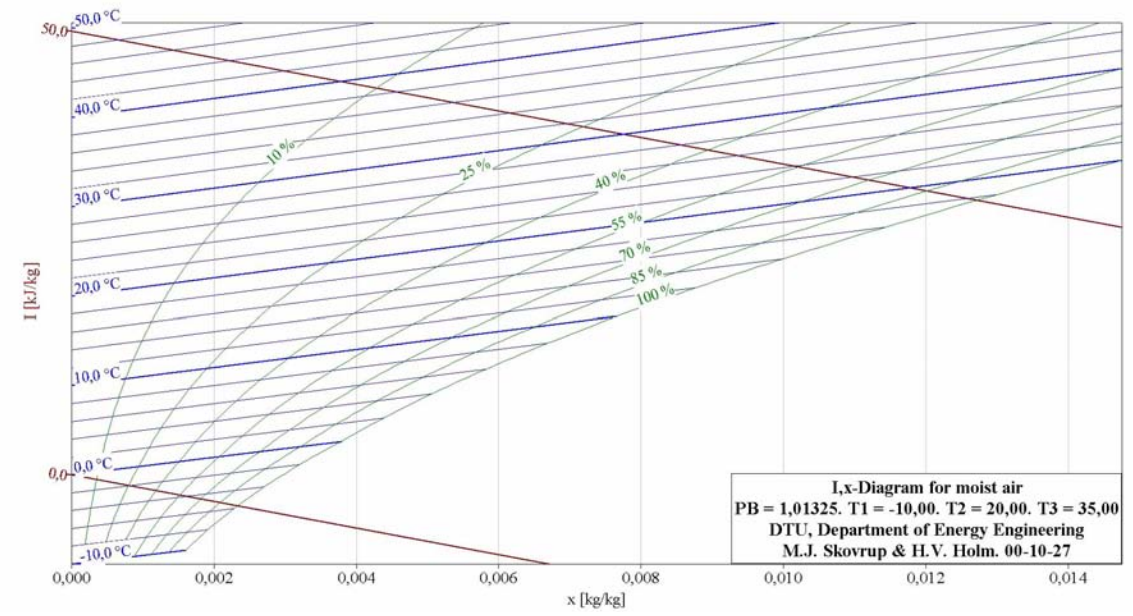

Figure 1. Relative humidity in relation to temperature

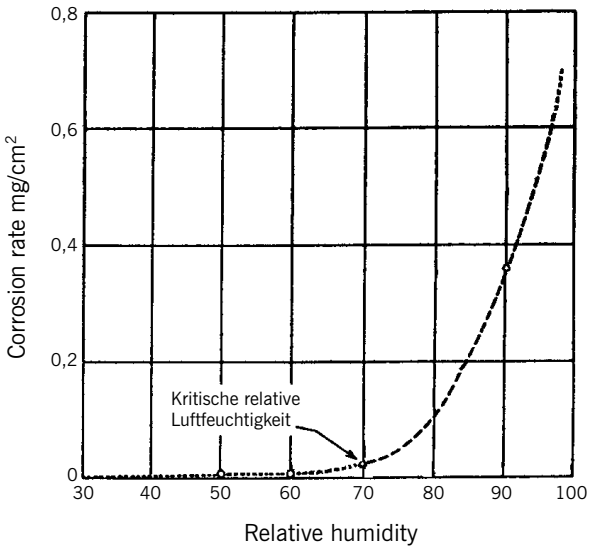

Figure 2. Atmospheric corrosion in relation to relative humidity. Simplified curve. (Rosten von Stahl durch Natureinflüsse, Hans Eggers, Verlag Stahleisen 1975, figure: Eisens, W.H.J. Vernon)

The above figures show that by raising the temperature, the relative humidity is lowered (fig. 1), which, according to (fig. 2) means a low rate of corrosion.

Lifetime- and cost optimisation

By taking countermeasures against corrosion it is possible to prevent or at least postpone the corrosion process. The possible countermeasures are numerous. It is possible to prevent corrosion totally, but it is very expensive. Which countermeasures to choose must therefor be seen in the ligth of the design lifetime.

Vestas selects anticorrosion treatments based on a comparison of costs of alternative materials. But the final choice is never based solely on the price. Important considerations such as ease of repair, costs associated with scheduled and unscheduled maintenance and the effect of component failure on overall turbine operations are also included in the considerations.

Factors that Vestas consider before the type of anti-corrosion is chosen:

- Initial cost
- best estimate of expected lifetime
- atmosphere of exposure
- length of emergency repair (the time value)
- cost of planned maintenance, and
- effect of failure on total turbine operation.

Summary

All Vestas wind turbines are protected against corrosion according to international standards. The concrete anticorrosion treatments are chosen on the basis of more than 20 years of experience with turbines sited in different climates and on serious lifetime- and cost considerations.

Sources

www.corrosionsource.com

Literature

ISO 12944 ”Corrosion protection of steel structures by protective painting systems”

1) The FORCE Institute is an independent non-profit institution approved by the Danish Ministry of Trade and Industry as a technological service institute and affiliated with the Danish Academy of Technical Sciences.

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