



17/02/2022  
Rev.1  
Test Report

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## Cyclical ageing test of HDG 120 $\mu\text{m}$ + ZINGA 150 $\mu\text{m}$

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# 1. Introduction

Vestas Wind Systems A/S is looking for a system to protect steel against corrosion in a CX environment for a durability of more than 30 years. ISO 12944-9 describes a test regime for a durability of 15-25 years. There are no other test regimes that stand for a longer durability. ISO 12944-9 CX includes 4200 hours of cyclical ageing (ISO 12944-9 Annex B). For this test, we are prolonging the cyclical test to the point where the test panels show severe corrosion. By prolonging the cycles, we intend to prolong the expected durability.

## 2. Coating properties

Zinga	
Density (g/cm <sup>3</sup> )	2.67
Solid by volume (%)	58%
Solid by weight (%)	80
VOC (g/l)	474
Gloss	Matt
Colour	Grey

## 3. System

Surface preparation of steel panels: Blasting to Sa 3 with medium G roughness profile.

Surface preparation of steel panels coated with HDG: sweep blast to an angular roughness profile with Rz value between 30-70 µm

Table 1. System 2 properties (application date: 30/3/2021)

Product	Application Type	Required DFT (µm)	Application Method	Dilution	Solvent	Overcoat time (20°C)
HDG	NA	120-150	Hot-dip galvanizing	NA	NA	NA
ZINGA	Full coat	150	Conventional spray	15 m%	Zingasolv	NA

## 4. Test methods

Table 2. Test methods

Test Method	Standard
Cyclical ageing	ISO 12944-9
DFT measurement*	ISO 19840

\*As stated in ISO 19840, the DFT of a coating is the thickness remaining over the peaks of a rough surface when the coating has hardened. The correction value of 25 µm is applied (Table 2 ISO 19840, medium surface profile).

## 5. Requirements – Assessment after Cyclic Ageing Test

According to ISO 12944-9 CX, 4200 hours of cyclical ageing is requested. After the ageing, the panels are rated towards blistering, rusting, cracking, flaking and corrosion from scribe. The requirements are shown in Table 3.

For this test we will prolong the 4200 hours of cyclical testing and take notes at the time one of the phenomena describes in Table 3 is observed.

Table 3. Assessment after cyclic ageing test

Method		Requirements
ISO 2409 Cross Cut	Individual values	Class 0 - 2
ISO 4624 method B Pull Off (MPa)		$\geq 2,5$ MPa
ISO 4628-2 Blistering		0 (S0)
ISO 4628-3 Rusting		Ri 0
ISO 4628-4 Cracking		0 (S0)
ISO 4628-5 Flaking		0 (S0)
Corrosion from scribe (mm)		$\leq 3,0$ mm

The area subjected to assessment, as per ISO-12944, is 1 cm from the border. In the UV chamber the panels are placed into holders, which cover a part of the panels. The covered surface area is also not of interest. The red rectangle in Figure 1. is indicating the area of interest.

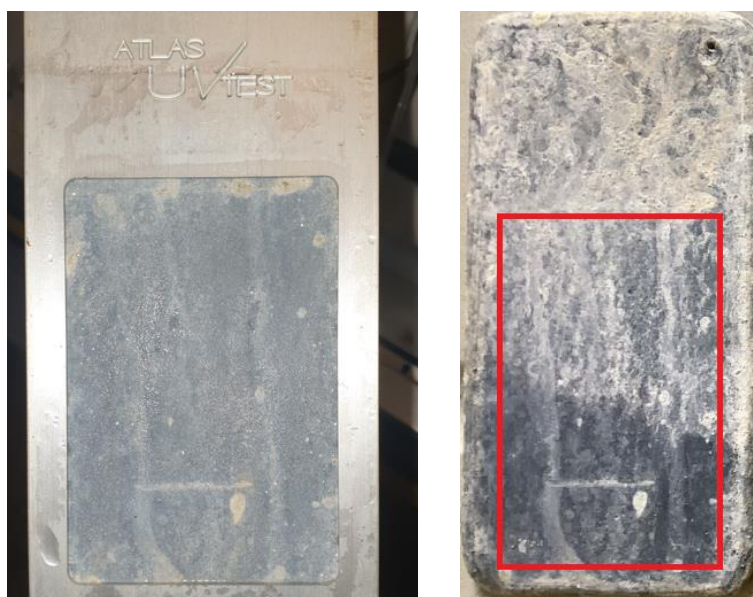
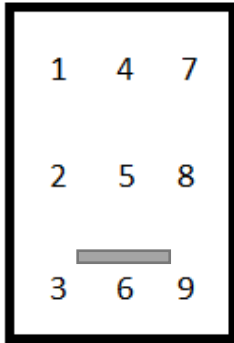


Figure 1. Panel in holder of UV chamber (left) and area subjected to assessment (right)

## 6. Test Results

### 6.1. DFT measurements



The total DFT is measured on 9 spots (correction for roughness is applied).

Test panel 11 :			
Average DFT HDG ( $\mu\text{m}$ )	<b>147</b>		
Average DFT ZINGA ( $\mu\text{m}$ )	<b>113</b>		
Total DFT ( $\mu\text{m}$ )	255	258	272
	240	265	274
	248	271	258
Total Average ( $\mu\text{m}$ )	<b>260</b>		

Test panel 12 :			
Average DFT HDG ( $\mu\text{m}$ )	<b>131</b>		
Average DFT ZINGA ( $\mu\text{m}$ )	<b>146</b>		
Total DFT ( $\mu\text{m}$ )	261	297	287
	283	298	279
	277	270	240
Total Average ( $\mu\text{m}$ )	<b>277</b>		

Test panel 14 :			
Average DFT HDG ( $\mu\text{m}$ )	<b>121</b>		
Average DFT ZINGA ( $\mu\text{m}$ )	<b>154</b>		
Total DFT ( $\mu\text{m}$ )	250	294	272
	275	288	288
	259	266	280
Total Average ( $\mu\text{m}$ )	<b>275</b>		

Test panel 15 :			
Average DFT HDG ( $\mu\text{m}$ )	<b>132</b>		
Average DFT ZINGA ( $\mu\text{m}$ )	<b>143</b>		
Total DFT ( $\mu\text{m}$ )	234	275	287
	283	279	294
	264	285	278
Total Average ( $\mu\text{m}$ )	<b>275</b>		

## 6.2. Cyclical ageing

Start date: 19/04/2021

End date: pending

0 hours			
	System	Total DFT (µm)	Observations
Test panel 11	HDG + ZINGA	260	2 mm scribe was applied
Test panel 12	HDG + ZINGA	277	2 mm scribe was applied
Test panel 14	HDG + ZINGA	275	2 mm scribe was applied
Test panel 15	HDG + ZINGA	275	No scribe is applied



Figure 2. From left to right, Panel 11, 12, 14 and 15 before cyclical assessment

2688 hours			
	System	Total DFT (µm)	Observations
Test panel 11	HDG + ZINGA	260	No observations
Test panel 12	HDG + ZINGA	277	No observations
Test panel 14	HDG + ZINGA	275	No observations
Test panel 15	HDG + ZINGA	275	No observations



Figure 3. From left to right, Panel 11, 12, 14 and 15 at 2688 hours of cyclical testing (Requirement for C5 Very High)

**4200 hours**

	<b>System</b>	<b>Total DFT (µm)</b>	<b>Observations</b>
<b>Test panel 11</b>	HDG + ZINGA	260	No observations
<b>Test panel 12</b>	HDG + ZINGA	277	No observations
<b>Test panel 14</b>	HDG + ZINGA	275	No observations
<b>Test panel 15</b>	HDG + ZINGA	275	No observations



Figure 4. From left to right, Panel 11, 12, 14 and 15 at 4200 hours of cyclical testing (Requirement for CX)

**7200 hours**

	<b>System</b>	<b>Total DFT (µm)</b>	<b>Observations</b>
<b>Test panel 11</b>	HDG + ZINGA	260	No observations
<b>Test panel 12</b>	HDG + ZINGA	277	No observations
<b>Test panel 14</b>	HDG + ZINGA	275	No observations
<b>Test panel 15</b>	HDG + ZINGA	275	No observations





Figure 5. From left to right, Panel 11, 12, 14 and 15 at 7200 hours of cyclical testing

## 7. Conclusions

The system protects the steel from corroding up to 7200 hours of cyclical testing and the test is still pending. Moreover, there is no sign of any defect after 7200 hours. Even in the scribe that has been made, no corrosion occurs. Due to the electronegativity of HDG and ZINGA, the steel in the scribe is protected. It seems HDG and ZINGA have a very good compatibility. Let's see if we reach 8400 hours (double the requirement of CX with life expectancy 15-25 years) without corrosion.