

OPTIMIZING OF CORROSION PROTECTION BASED ON A COMBINATION OF CATHODIC PROTECTION (CP) AND COATING.

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ABSTRACT

When cathodically protecting a structure with sacrificial anodes, the required anode weight will decrease if the structure additionally is coated. For a lot of structures, reduction in weight is an important factor. It is important to reduce the lift weight for installation purposes and for design purposes it is important to reduce drag forces.

Coating in combination with cathodic protection doesn't mean that the structure has to be 100% coated. By coating 90% of the surface areas, the anode weight may be reduced dramatically. This means that welding zones and damage to coating systems during fabrication the phase don't need to be repaired as long as this is included as bare area in the CP design.

This paper presents different methods for design of CP with and without coating and comparing the results to show weight savings.

Keywords: cathodic protection, coating, sacrificial anodes, weight savings, uncoated

INTRODUCTION

Coating of offshore structures is mainly used for the splash zone and atmospheric zone where cathodic protection (CP) is not effective. For some platforms it is also chosen to paint also in the submerged zone to reduce the current requirement for the cathodic protection. This paper will present the differences by using coated surface compared with uncoated surface.

If coating is used in combination with CP, the anode weight can be reduced dramatically. Weight will be saved, which will benefit the structure in general (less loads to structural members). Less total weight will also ease the installation of the platform. In addition, the welding will be reduced, since each anode that has to be welded to the structure has a minimum of two (2) attachments. Also purchasing less anode alloy (Al and Zn) will contribute to the cost savings, since less Al or Zn will be required and the anode alloy material is expensive. Additional painting will be required, which will increase the costs.

In the following, the experience from several CP designs performed for both coated and uncoated surfaces are presented to try to find the optimal solution

COATING PROCESS

When a cathodic protection (CP) design is performed, the coating breakdown factor is an important parameter in the current requirement calculations. For instance, the mean current required can be reduced by approximately 80% if a "good" coating is applied, i.e., category IV in accordance with DNV RP B401¹.

To be classified as a "good" coating the following two (2) criteria have to be satisfied:

- Total minimum dry film thickness of 400 μm (16 mils)
- Tested for cathodic disbonding in accordance with ASTM G8² or similar with a maximum acceptance criteria of 10 mm disbonding

Coating Of Framework Structures

When fabricating framework, like jacket structures and compliant towers, legs and bracings are rolled and welded separately before they are assembled to complete a structure. These pipes may be sent through a painting facility before they are assembled. Coating is then applied to the straight pipe, leaving the weld zone at each end uncoated. This uncoated zone is approximately 500 mm (20 inch) at each end. After assembly you will have an intersection of bracings and leg as shown in Figure 1.

Painting of straight pipes before assembly is a simple operation. Painting of welding zones after assembly is more complicated and avoiding this is an advantage. When we know the fabrication method, we also know how many welding zones there will be and the area of these zones can be calculated. In the CP design it is possible to assume some areas coated and other areas uncoated. For this case, the main area will be coated.

Coating Of Floating Structures

Floating structures like tension leg platforms (TLP's) and semi submersibles have different tanks used for ballast or storage of fluids, etc. The internal surface of these tanks consists of a lot of stiffeners, which make these surfaces difficult to paint. Still most of internal tank surfaces are coated to act as corrosion protection alone or to reduce the sacrificial anode weight. External surfaces of floating structures are plain sides without stiffeners, however, with some support or other steel welded on parts of the structure. The external surfaces are therefore easier to paint than the internal surfaces. Still the external surface is often not painted.

The reason why they are not coated is explained by the extra time this will require. If additional painters are used, coating internally and externally can be done in parallel and the extra time is not an issue anymore.

Also for the floating structures, some of the areas may be left uncoated, such as welding zones, etc.

CP DESIGN

CP Design Based On Coated Surface

When painting structural members, some of the coating may be damaged during transportation or assembly. Also, it may be planned to weld supports to the members in the future, and it would be suitable to avoid painting of the lay-down areas (areas where the structure members are supported during coating). All these areas may be estimated and included as uncoated areas in the CP design in addition to the planned welding zones.

When calculating the areas that need cathodic protection the following have to be considered:

- ❑ Calculate the entire surface that needs cathodic protection
- ❑ Calculate the area of all welding zones based on the fabrication method
- ❑ Calculate the area that will be uncoated due to supports etc. will be welded later in the process (after assembly)
- ❑ Calculate areas of components that may be exposed to high wear where coating breakdown factors can be higher than the ones in DNV RP B401¹ (e.g. conductors, underside of pontoons)
- ❑ Estimate how much allowance you need to cover for damages, lay down areas and unforeseen activities that will damage the coating
- ❑ Perform CP design based on a combination of coated and uncoated surface

During project execution the uncoated areas have to be logged, and it has to be controlled that actual uncoated areas don't exceed uncoated areas included in the design. In case of that, additional anodes have to be installed.

Coated Surface vs. Uncoated Surface

CP calculation performed on three (3) different projects will be presented. All three designs were based on DNV RP B401¹. The first two (2) examples are jacket structures with a design life of 30 years installed in the North Sea. The third example is a floating structure installed in the Gulf of Mexico and with a design lifetime of 25 years.

Jacket 1 is an eight (8) legged jacket connected to 40 conductors/wells with an installation weight of approx. 17.000 tons exclusive of piles. Jacket 2 is a four (4) legged jacket connected to eight (8) conductors/wells with an installation weight of approx. 4.000 tons exclusive of piles. Both jackets are installed in the North Sea with a design life of 30 years and with a seawater depth of approx. 100 m. The area calculations were divided into two (2) zones since the current density varies with the depth. A higher coating breakdown factor than the ones specified in DNV RP B401¹ was used for conductors because they could be damaged during installation.

The third example is a semi submersible with four (4) pontoons and four (4) columns with four (4) mooring chains in each corner. The entire structure is above 30 m in depth and the example includes the external structure only. A higher coating breakdown factor than the ones specified in DNV RP B401¹ was used for the underside of the pontoons because the structure was set on a barge during transportation and damage to the coating could occur.

Area calculations, when assuming most of the areas coated, are shown in Table 1. The table summarizes areas for all three (3) examples. Even if you include all assembly zones, spare areas etc. as uncoated, this will only be in the range 3 - 4 % of the total area. The main part of the structure is coated with a "good" coating.

Based on these areas, CP calculations were performed for three (3) alternatives; one assuming all surfaces uncoated; one assuming surfaces mainly coated with a "good" coating; and one assuming surfaces mainly coated with a primer. The results are summarized in Table 2. "Good" coating is defined in Coating Process section.

As seen from the Table 2, 3 to 4 times the anode weight can be saved if the main part of the structural steel is coated with a "good" coating.

A comparison of uncoated surface versus surfaces applied a primer is also performed for all three (3) structures and the results are summarized in Table 2. When assuming the structure primed, the following equation is used when calculating mean coating breakdown, ref. DNV RP B401¹:

$$f_{(mean)} = 1 - \frac{(1 - k_1)^2}{2k_2T}$$

where

k_1 = constant defined in DNV RP B401¹.
 k_2 = constant defined in DNV RP B401¹.
T = design life (years)

Initial and final coating breakdown factors used are 0.1 and 1 respectively. The results show that the anode weight can be reduced by 10 – 30% if the structure is primed. For this alternative assembly zones etc. are included as bare areas in the CP design.

Protection Length

Anodes installed on a structure will throw current further if the structure is coated. This may be important on a floating structure where there may be restrictions to installing anodes on the underside. For an uncoated structure the required protection length may be too long if anodes installed on the sides are expected to protect the entire underside of the pontoon. The same problem may occur on a leg section in a jacket structure where the diameter may be large. It may not be enough with only one

anode on the circumference if the structure is uncoated and anodes have to be installed on the outside of the jacket. It is often not appropriate to have welded items on the outside because it can interfere with other operations.

The protection length can be illustrated by a simplified case, assuming the anodes are installed on a straight pipe. Potential drop calculations can then be performed to investigate the reach of one anode when installed on a coated pipe, versus the reach when the anode is installed on an uncoated pipe. This will be very simplified since a jacket structure is much more complicated, but it will give an indication of the difference between coated and uncoated surface.

By using Ohm's law; $E = I * R$,

the potential drop can be expressed as:

$$\Delta E = 2 * I_c * R_a = 2 * A * i * R_a = 2 * \pi * D * L * i * C_B * R_a$$

where

ΔE = potential drop on both sides of the anode (mV)

$2 * I_c$ = cathodic current necessary to protect a certain length on both sides of the anode

A = area of pipe to be protected (m^2)

i = current density (mA/m^2)

R_a = anode resistance (ohm)

D = pipe diameter (m)

L = protection length on one side of the anode (m)

C_B = coating breakdown factor

Since these are relatively short distances, potential drop in seawater and potential drop internally in the wall thickness are not included.

Table 3 shows the calculated potential drop for both coated and uncoated surface for two (2) diameters. The reach of the anode is decreasing with increasing diameter of the pipe to be protected. As shown, the calculated protection length is 5 times as long when the surface is coated assuming a coating breakdown of 20%.

Anode Distribution

By coating a structure, the reach of each anode would be longer, i.e. distribution of the anodes is not as critical as for an uncoated structure, ref. section above.

Another issue is placement of anodes in narrow spaces. For an uncoated structure the number of anodes required for conductors will be high and the areas available to install anodes is small. Some anodes originally installed to protect conductors have to be installed a certain distance from the conductors. This may lead to anodes being placed in conductor areas are being consumed faster than expected, leading to that at the end of the design life no protection is available.

Conductors, caissons, risers and other appurtenances that are supported by guides will have a narrow space when they pass their guides, which is difficult to protect by CP. The potential drop, caused by this limited space internal to the guide, will be larger for an uncoated structure than a coated structure.

CONCLUSIONS

Coated structures don't necessarily mean that the structure is 100% coated. Jacket structures or similar can save over 3 times the weight of anodes if main parts of the structure are coated. The idea is to coat components that are easy to paint and leave complicated components uncoated. It is also important to include a higher coating breakdown factor in the design, for components that may suffer from coating damage during fabrication/installation, such that repair is not necessary. Repair work is often an expensive process. To save anode weight the following is recommended:

- Paint main components with a "good" coating ("good" is defined in section Coating Process)
- Leave welding zones uncoated and include this area as uncoated in CP design
- Estimate an additional spare area to be included based on the fabrication method
- Include a higher coating breakdown factor on components that have a high risk to be exposed to coating damage during fabrication/installation

A coated structure will have lower cost related to the purchase and welding of anodes. Additional costs will be the purchase and application of paint. These costs can be calculated and compared, and an example for the three (3) structures is shown in Table 4. These prices are based on fabrication and purchase in Europe, and the unit prices used in the calculations are:

Welding of anodes:	714 USD/each
Purchase of anodes:	4 USD/kg
Application of paint:	29 USD/m ²
Purchase of paint:	7 USD/m ²

For both the coated and uncoated alternatives, there are advantages and disadvantages that cannot be priced but have to be evaluated separately. Some of these advantages/disadvantages are listed below:

Advantages:

- Protection length from anodes is expanded
- Easier to distribute anodes
- Better protection in narrow areas
- Weight savings for structural members and installation

Disadvantages

- More difficult to handle components
- May extend project schedule

From a technical point of view, it can be concluded that the best solution is obtained if the structure is coated in combination with CP. It is more complicated to conclude what would be the most economical solution.

Costs related to coated/uncoated surfaces will vary where the structure is fabricated and with what fabrication method is chosen. An individual economic analysis for each project is therefore recommended, before it can be concluded if it is more or less economic to coat the surface.

REFERENCES

- 1 DNV RP B401 Cathodic Protection Design
- 2 ASTM G8 Test Method for Cathodic Disbonding of Pipeline Coatings

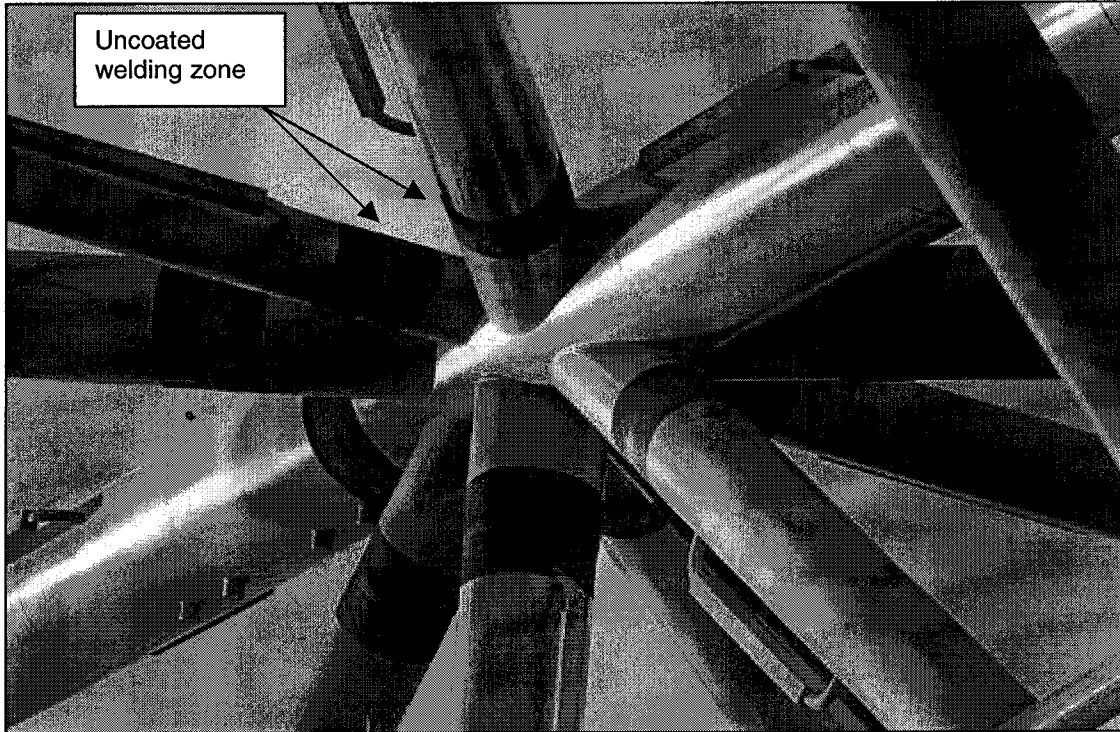


Figure 1 – Intersection between bracings and legs

Table 1
AREA CALCULATIONS

	Area (m ²)		
	0-30 m	30 m and down	Total
<i>Jacket 1</i>			
Structure incl. appurtenances	5000	34500	39500
Conductors	2180	10800	12980
Uncoated piles in mud		7350	7350
Future welding after assembly	100	130	230
Uncoated "spare"	80	220	300
Uncoated welding zones	300	1480	1780
<i>Sum</i>	<i>7660</i>	<i>54480</i>	<i>62140</i>
<i>Jacket 2</i>			
Structure incl. appurtenances	1100	9600	10700
Conductors	490	2165	2655
Uncoated piles in mud		1700	1700
Future welding after assembly	50	50	100
Uncoated "spare"	30	120	150
Uncoated welding zones	70	300	370
<i>Sum</i>	<i>1740</i>	<i>13935</i>	<i>15675</i>
<i>Semi Sub</i>			
Underside pontoons	8170		8170
Structure incl. appurtenances	24730		24730
Uncoated mooring chains	1700		1700
Uncoated welding zones/spare	1000		1000
<i>Sum</i>	<i>35600</i>	<i>0</i>	<i>35600</i>

Table 2
SUMMARY OF CP CALCULATIONS

	"Coated" Alternative ¹⁾			Uncoated Alternative			Ratio Uncoated/ "Coated"	Primed Alternative ^{1,2)}			Ratio Uncoated/ "Primed"
	Net weight anode (kg)	Number of anodes	Total net weight Al (ton)	Net weight anode (kg)	Number of anodes	Total net weight Al (ton)		Net weight anode (kg)	Number of anodes	Total net weight Al (ton)	
Jacket 1	212	889	188690	255	2432	620719	3,3	245	1976	483577	1,3
Jacket 2	212	221	46907	255	616	157222	3,4	245	499	122118	1,3
Semi Sub	260	295	76676	365	832	303497	4,0	354	746	264315	1,1

¹⁾ Not 100% coated (welding zones, piles, mooring chains, spare etc. uncoated)
²⁾ Surface applied approximate 50 microns primer

Table 3
POTENTIAL DROP CALCULATIONS ALONG A PIPE

	Diameter of pipe (m)	Current density (mA/m ²)	Coating breakdown factor	Anode resistance (ohm)	Accepted potential drop (mV)	Protection length - one side (m)	Distance between 2 anodes (m)	Ratio Uncoated/"Coated"
Anode installed on coated pipe	1	80	0,2	0,06	250	41	83	5
Anode installed on uncoated pipe	1	80	1	0,06	250	8	17	
Anode installed on coated pipe	2,5	80	0,2	0,06	250	17	33	5
Anode installed on uncoated pipe	2,5	80	1	0,06	250	3	7	

Table 4
EXAMPLE OF COSTS RELATED TO COATED UNCOATED SURFACE

Project	Description	Number of anodes	Net weight anodes (kg)	Area painted (m ²)	Anodes (USD)	Paint (USD)	Total (USD)	Difference (USD)
Jacket 1	Coated ¹⁾	889	188690	52480	1.389.507,00	1.889.280,00	3.278.787,00	940.538
Jacket 1	Uncoated	2432	620719	0	4.219.325,44	-	4.219.325,44	
Jacket 2	Coated ¹⁾	221	46907	13355	345.423,00	480.780,00	826.203,00	242.508
Jacket 2	Uncoated	616	157222	0	1.068.710,72	-	1.068.710,72	
SemiSub	Coated ¹⁾	295	76676	32900	517.335,60	1.184.400,00	1.701.735,60	106.300
SemiSub	Uncoated	832	303497	0	1.808.035,84	-	1.808.035,84	

¹⁾ Not 100% coated (welding zones, piles, mooring chains, spare etc. uncoated)