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Performance analysis of thermal arc spray aluminium coating as a sacrificial anode and mechanical properties in artificial seawater

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ABSTRACT – Aluminium coating with 99.5% purity and different coating thickness (200 µm – 700 µm) were applied on 15 mild steel plates by using thermal arc spray method and immersed in artificial seawater within 12 months. The variation in microstructural characteristics and properties of coating was investigated. Surface microstructures were viewed and analyzed using scanning electron microscope and energy dispersive x-ray analysis. The hardness was inspected using Vickers Hardness testing. Corrosion rate was measured using thickness reduction method and surface quality (surface pores and holes) were estimated using image analyzer. Surface roughness was viewed using Infinitefocus G4 machine. Experimental results were found that no direct correlation between surface roughness and coating thickness. However the coating thickness directly impacts the coating surface quality and reduces the coating hardness. It also found that sacrificial action works well in coating form for all coating thickness and recorded potential difference range from -0.79 V until -0.886 V. From the analyses, the thickness of coating at 500 µm-600 µm provides better coating performance in terms of optimum potential difference and least corrosion rate. However the 200-300 µm coating thickness produced the best surface quality and the highest surface hardness.

1. INTRODUCTION

Corrosion is one of the critical problems exist in most of working industry and many of them have struggle to overcome the problem. From the moment a part of metal is manufactured, it must be protected from its environment to avoid or minimize corrosion rate. Corrosion can be considered as a hazard since it will cause fatal accident and expensive damage. Due to this reason, corrosion especially in the oil and gas industry has been viewed and given high impact on capital and operational expenditures (CAPEX and OPEX,U.S corrosion study, 1991- 2001), direct corrosion cost was $276 billion per annum **.**

Thermal arc spray coating is a protective coating which useful to protect steel surface from environment especially in marine condition. Thermal arc spray coating offers better protection due to its capability to withstand high temperature, better corrosion control and at low operation cost. Currently thermal arc spray aluminium coating usage is applied widely in atmospheric condition to reduce corrosion rate but very rare to see its application in seawater for corrosion control. This research will discuss effectiveness of thermal arc spray aluminium coating as a sacrificial anode for subsea structures protection and the impact on its mechanical properties of the coating.

2. RESULTS AND DISCUSSION

After immersed in artificial seawater, all samples were cleaned and tested for its performance and mechanical properties (surface hardness and roughness, and estimation of surface voids and pores). It can be observed that no distinct surface profile when compared to different coating thickness as shown in Figure 1. However, the estimated surface voids and pores of 99.5% arc spray aluminium coating were ranged from 12.14% to 20.64% and presented a rising pattern with increase in coating thickness. The increasing of coating thickness also causes in the reduction of coating hardness. Hardness and surface pores level of 200 µm - 300 µm thickness coating are 51.2 HV and 12.14% respectively. While for the coating thickness at 600 µm - 700 µm ranges, the hardness was reduced at 10% level, and surface pores were increased at 65%**.** As a result, the lowest pores level and highest hardness of thermal arc spray aluminium 99.5% can be found from the thinnest sample (200-300 microns) under seawater condition.

From Figure 2, closed image was captured at coating thickness range (500-600 microns). Two different areas were spotted and an analysis was carried using EDX.

At spectrum 21 area, aluminium content just represented 1.55% out of total weight and considered very low element in this area. The oxygen content is a major element exists around 64% from total weight and calcium element having almost 14%. Since carbon element exists in this analysis (5.4%), main possibility of the white area in Figure 2 is calcium carbonate ($CaCO_3$); all elements of calcium carbonate exist such as carbon, calcium and oxygen. Calcium carbonate precipitation on coating is very important discovery because it is a proof that sacrificial action occurred between coating and mild steel plate as shown in Equation (1).

$$CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3(s) \quad (1)$$

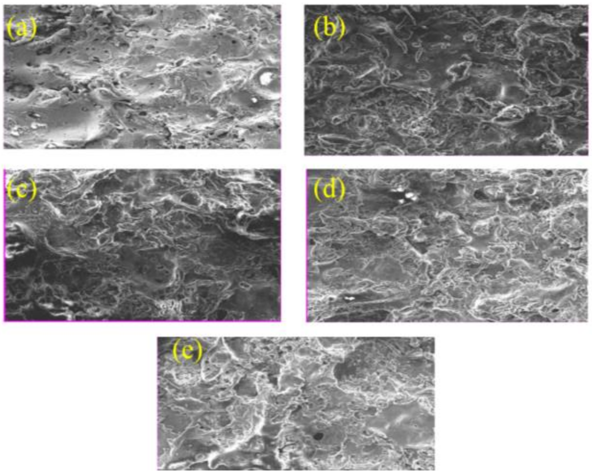

Figure 1 Surface morphology have been viewed on all samples (after immersed in artificial sea water): (a) 200µm-300 µm (b) 300 µm -400 µm (c) 400 µm -500 µm (d) 500 µm -600 µm (e) 600 µm -700 µm.

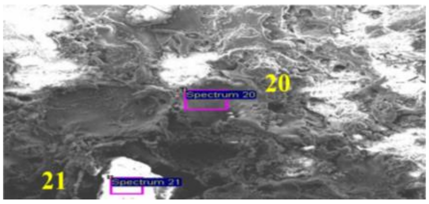

Figure 2 Two different areas are checked at coating thickness range of 500 µm – 600 µm.

At spectrum 20, major element represented in this area is aluminium and recorded weight percentage is 77% from total weight. It also consists of 12% Carbon element and followed by 8% oxygen. It clearly showed that the dark area is an aluminum base reacted with oxygen element and formed an oxide layer. The layer protects underlying aluminium from outside sources to prevent it from corrosion progression**.**

This discovery also is supported by measuring potential difference exists between coating and mild steel plate as shown in Table 1.

Table1: Results of potential difference.

Coating Thickness , µm before immersed	**Coating Thickness , µm after immersed**	**Coating Thickness Reduction , mm in a year**	**Average Potential Difference (-V)**
270	245	0.025	0.791
329	307	0.022	0.836
477	458	0.019	0.852
560	552	0.008	0.886
658	645	0.013	0.871

The critical coating thickness as a function of the potential difference was applied to evaluate sacrificial action between 99.5% aluminium coatings with mild steel plate. The results were revealed in Table 1. As an example, it was given that at coating thickness of 200 µm-300 µm, 300 µm – 400 µm, 400 µm -500 µm, 500 µm -600 µm and 600 µm – 700 µm, the potential difference recorded were -0.79 V, -0.83V, -0.85V, -0.89 V, and -0.87 V, respectively. The potential differences indicate that sacrificial action was occurred to protect mild steel from corrosion and the aluminium coating part will corrode itself. The theory also supported by coating thickness reduction (because of corrosion) and were recorded at 0.025 mm, 0.022 mm, 0.019 mm, 0.008 mm, and 0.013 mm for different ranges of coating thickness. The initial sample of 500-600 microns recorded the highest potential difference and the least thickness coating reduction.

3. CONCLUSIONS

a) Surface pores of thermal arc spray 99.5% aluminium coating was expanded with increasing in coating thickness, which thus lessening the coating hardness.

b) The increase in thickness ranges from 200 µm to 600 µm has increased potential difference and lowered the corrosion rate. Enhancing further coating thickness (more than 600 µm) has decreased the potential difference and increased back the corrosion rate. Low value of corrosion rate because of the sacrificial action works well (consumption rate is directly proportional to corrosion rate).

4. REFERENCES

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