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In-situ Damage Assessment on Supporting Structure of Coal Conveyor

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Abstract. The supporting structure of conveyor in a coal power generation plant located in marine environment, was experiencing severe filiform corrosion. The structure has been used since 2009. This supporting structure holds the conveyor for coal transportation from the ship to the turbine. From visual inspection, it was clearly seen that around 80 % of total area of the structure has been corroded, which influenced the strength of the structure. Hence damage evaluation of supporting structure was important to be carried out to determine the level of damage and to give the recommendation for repairment strategies. The damage evaluation method consisted of thickness measuring, chemical composition test, hardness test, microstructure analysis using replica technique and deposit analysis using SEM-EDS. The result showed that the type of material structure was AISI 1020. The highest reduction in measured thickness was 44 %, which occurred dominantly on bottom and top flange of the structure. It was also found that in some joint areas, the material was perforated. The deposit analysis using SEM EDS found that the type of coating used on steel structure was not suitable for the marine environment.

Introduction

Corrosion of metal is a serious problem because it can affect the strength of the metal. Corrosion process is strongly affected by environment. The metal structure located in seaside environment is often attacked by corrosion that can be determined by the brown rust on the surface. One of the types of corrosion is filiform corrosion, which occurs under coating layer. Sharman [1] was the first studied filiform corrosion. Filiform corrosion causes protective film damage and has the form of thread-like filaments. This type of corrosion gives detrimental effect to the appearance of corroded metal. Several factors combination such as a high relative humidity, the presence of coating defects, the presence of oxygen and high salinity promote the increase of filiform corrosion attacks [2,3].

This study reported the damage evaluation of supporting structure that holds the conveyor. The conveyor has a function to carry away the coal with distance around 30 m from the ships to the turbine in a power generation plant. The structure has been used since 2009 and experienced corrosion attacks extremely. The corrosion was initiated by filiform corrosion and continued to attack on the surface. Almost 80 % of total structure has been attacked by corrosion, which may contribute to the decrease of the structural strength. Figure 1 shows the some areas of corroded structure.

Fig.1 Corrosion attacks on top and bottom flange (left) and on web (right).

Fig.2 Corrosion attacks on joint areas.

Figures 1 and 2 show that steel beam structures have been attacked by filiform corrosion in which the corrosion products of a filamentous appearance under coating / paint layer. The corrosion had occurred uniformly on top and bottom flanges and took place around 80 % of total area the flange (see Fig. 1), whereas in other areas (see Fig. 2) the corrosion attacks on joint caused the material was perforated. By considering the function of the structure, it is very important to do the evaluation how severe the damage that had occurred due to corrosion attack. The results of the evaluation will determine the action to be taken for repairment strategies.

Evaluation Methodology

The methodology for damage evaluation consisted of visual inspection, chemical composition test, hardness test, thickness measurement and deposit analysis. Chemical composition and hardness test results were carried out on surfaces that were not corroded and the data were used for material verification. Chemical composition test was measured on six different locations and performed on *Master Pro- Oxford instrument* positive material identification using ASTM E415 – 08. The hardness test used in-situ portable Leeb rebound test in Vickers scale with a 200 grams load. The thickness was measured using Ultrasonic Olympus EPOCH 4. Coating layer analysis was conducted on SEM JEOL 610-LA operated at 20 KV and equipped with EDS. XRD was also used to identify the compound in coating layer and conducted on Shimadzu XD-610 with a copper target. The step size was 0,05 degree/step and the samples were scanned in the range of $2\theta = 5^o – 50^o$.

Results and Discussion

The chemical composition test results shows that the supporting structure material was made of steel with chemical composition can be seen in the Table 1.

Table 1 Chemical composition of supporting structure conveyor (in wt.%).

Location	C	Si	Mn	P	S	Cr	Ni	Cu	V	Fe
1	0.17	0.31	1.3	<0.004	0.02	0.013	0.01	0.03	0.01	balance
2	0.27	0.18	0.41	<0.004	0.02	0.06	0.03	0.01	0.01	balance
3	0.18	0.12	0.38	<0.004	0.02	0.02	0.01	0.01	0.01	balance
4	0.17	0.18	0.45	<0.004	0.03	0.03	0.02	0.01	0.01	balance
5	0.21	0.2	0.51	<0.004	0.02	0.09	0.01	0.02	0.01	balance
6	0.16	0.19	0.37	<0.004	0.02	0.01	0.01	0.01	0.01	balance
Average	0.19	0.19	0.57	< 0.004	0.02	0.04	0.02	0.02	0.01	balance

From the Table 1, it can be seen that the material was made of steel in which its chemical composition was equivalent with AISI 1020. The measured hardness of the steel structure was 113 HV and this data met the hardness of AISI 1020. This type of steel is not resistant to corrosion in marine environment. The thickness reduction was measured from 30 different locations on corroded areas. The result of measured thickness is presented in Table 2.

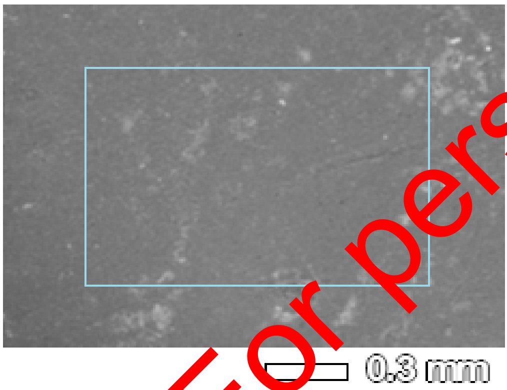
Table 2 The thickness reduction of measured steel structure.

Location	measured thickness (mm)	thickness reduction	Location	measured thickness (mm)	thickness reduction	Location	measured thickness (mm)	thickness reduction
1	7.4	26%	11	5.8	42%	21	6.6	34%
2	8.5	15%	12	6.5	35%	22	6.9	31%
3	6.9	31%	13	7.0	30%	23	7.4	26%
4	9.2	8%	14	6.4	36%	24	7.0	30%
5	7.8	22%	15	7.0	30%	25	7.7	23%
6	7.6	24%	16	6.9	31%	26	5.6	44%
7	7.8	22%	17	6.6	34%	27	5.6	44%
8	9.8	2%	18	6.8	32%	28	6.0	40%
9	5.7	43%	19	7.0	30%	29	6.9	31%
10	7.9	21%	20	5.9	41%	30	7.4	26%

Note: the percentage of thickness reduction was calculated based on the initial thickness of the measured steel was 10 mm.

The data in Table 2 shows that the average measured thickness reduction was 29.5 % and the highest thickness reduction was 44 %. It must be noted that the data in Table 2 was taken from 30 spots areas (approximately 20 % from the total areas) and in some areas (10 %) where the thickness were not measured, the reduction in thickness has already reached 100 % as the material has been perforated. It can be concluded that the thickness reduction had affected the strength of the structure; hence the repair needs immediately to be taken.

SEM EDS was used to determine the elements existed in coating protective layer and X-ray diffraction (XRD) was conducted to identify the type of the compound may exist in coating layer. The results are revealed in Figs. 3 and 4.



Elements	%wt	Elements	%wt
C	41.28	Cl	0.24
O	40.99	K	---
Na	---	Ca	1.81
Mg	0.70	Ti	8.39
Al	1.71	Fe	---
Si	1.92	Cu	0.32
S	---		

Fig.3 SEM-EDS result of coating protective layer.

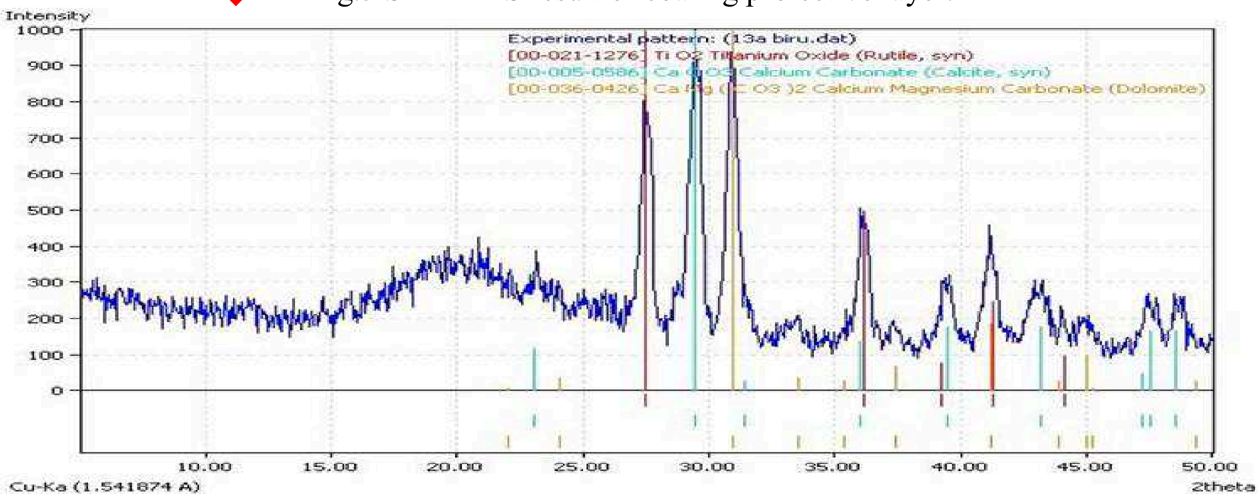


Fig.4 X-ray diffractograms of coating layer.

The SEM-EDS results of coating layer (Fig. 3) shows that the elements detected by SEM-EDS were C, O, Mg, Al, Si, Cl, Ca, Ti and Cu. The presence of Cl was not surprising as the steel structure located in the marine (seaside) environment. Figure 4 shows the XRD results. The peaks were in good a greement with TiO_2 (powder diffraction file: 21-1276), $CaCO_3$ (powder diffraction file: 005-0586), and $CaMg(CO_3)_2$ (powder diffraction file: 036-0426). No indication the presence of Zn either from SEM-EDS or XRD results in which the zinc element or compound should exist as a protective coating layer.

Based on ISO 9223;1992 [4], the environment of the supporting structure was categorized in C5I, e.g.;industrial areas with high humidity and aggressive atmospheres. The corrosion risk of that environment is very high. By considering the steel structure environments was very high corrosion risk, the choice of type of coating became very important. Previous studies [5,6] reported that the application of zinc rich coating metal substrates is a very efficient approach of corrosion resistance protection and has been widely used in many aggressive media such as sea water, marine and industrial environment. According to BS EN ISO 12944: 1998 [7], the coating system for low-alloy carbon steel with environment categories C5-1 must use zinc rich epoxy primer as a primary coat, high build epoxy MIO (micaceous iron oxide) as an intermediate coat and high solid aliphatic polyurethane finish as a top coat. From this point of view, it can be concluded that the pain system used on the steel structure did not meet the coating standard requirement for the category of C5I environment.

Conclusions and Recommendation

From the acquired data, the conclusions that can be drawn are:

a) The supporting structure of coal conveyor was made of AISI 1020.

b) The steel structure needs to be repaired immediately as the corrosion attacks affected the strength of the structure

c) It was found that the application of paint system did not meet the standard requirement.

There are some strategies that can be recommended for the repairment, namely:

a) When corrosion attacks is more than 30 % area either on top or bottom flange and the reduction thickness is more than > 30 %, hence the top or the bottom flange must be replaced by a new one with the same steel. However, if severe corrosion occurs on the web then replacement should be done by replacing the new whole beam of steel.

b) The material joint that has been perforated must be replaced with a new one with the same type of steel

c) The paint system must follow the standard of BS/EN ISO 12944-5 in accordance with the environmental category of C5I.

References

[1] C. Sharman, Filiform under film corrosion of lacquered steel surfaces, Nature 153 (1944), p. 621.

[2] C. Vargel, *Corrosion of Aluminum* (English edition), first ed., Elsevier, Amsterdam, Netherlands, 2004.

[3] A. Bautista, Filiform corrosion in polymer-coated metals, Prog. Org. Coat. 28 (1996), p. 49.

[4] International Organization for Standardization, ISO 9223-1992: Corrosion of Metals and Alloys- Classification of Corrosivity of Atmospheres (1992).

[5] H. Shi, F. Liu, E.H. Han, The corrosion behavior of zinc-rich paints on steel: Influence of simulated salts deposition in an offshore atmosphere at the steel/paint interface, Surf. Coat. Tech. 205 (2011), p. 4532.

[6] A.H. Sofian, K. Noda, in: 224th ECS meeting, The Electrochemical Society, Corrosion resistance and mechanism of zinc rich paint in corrosive media, San Francisco, USA, 2013, p. 29.

[7] International Standardization Organization, BS/EN ISO 12944-5. Paints and varnishes - Corrosion protection of steel structures by protective paint systems (2007).