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Process of Making VCI Paper Using Vappro MBL 2200-Amino Carboxylate Corrosion Inhibitor (ACCI)

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Abstract

The main purpose of this technical paper is to develop a process that can produce Vapour Corrosion Inhibitor (VCI) paper that delays and prevents corrosion of ferrous metals to a certain extent. The VCI paper is manufactured by adding MBL 2200, a Magna International Private Limited product that contains 20% amino-carboxylate corrosion inhibitor (ACCI), to Kraft paper. An experiment was carried out to access the effectiveness of the Kraft paper by doing a humidity test on polished steel plates wrapped with the Kraft paper. The results of the experiment were observed over a period of 5 days. From the observations, we concluded that 5% of amino-carboxylate corrosion inhibitor in the Kraft paper will have the best effect on corrosion protection compare to papers without any corrosion inhibitor.

Introduction

Corrosion has been an anathema for various industries that rely heavily on metals. Storage and shipping after production are the main culprits that give rise to problems that stem from corrosion. Corrosion occurs on pure metal surfaces and alters the physical and chemical properties of the area it affected, rendering it useless.

Corrosion inhibitors are introduced to address this problem; by applying them to the metal's surface, the corrosion rate can be significantly reduced or even prevented. However, the effectiveness of corrosion inhibitors lies in the fact that there are no actual mediums to contain them. The corrosion inhibitor that was directly applied to the metals can escape to the surroundings easily, either due to the volatile characteristic like amines or accidentally scratched off while moving it.

Moreover, while shipping metals, the corrosion inhibitor may be accidentally scratched off. Thus the VCI plastic film is invented. By impregnating VCI into plastic films, the VCI cannot escape easily. The plastic film isolates the metal from corrosive agents. The use of plastic, however, is not environmentally friendly. Although plastic can be recycled, not all of them go through recycling process. A portion of the plastic will be disposed due to the accident and immoral act of people which in the end they wound up in the ground like the normal waste.

During their decomposition, they will release toxic and harmful substances to the soil thus polluting the environment. Hence, this report postulates the replacement of plastic with paper and by extension, aims to expound on a process of manufacturing VCI Kraft paper.

Kraft Paper

Kraft Paper is made up of chemical pulp that was produced from Kraft process [1], a sulfate process that converts wood into pulp. The process differs from normal paper production, for the solution that uses to convert wood into wood pulp consists of water, sodium hydroxide, and sodium sulfide. This chemical liquid mixture helps to break down the bonds between lignin, hemicellulose, and cellulose. As such, the amount of lignin present in the wood pulp is significantly reduced. As lignin weakens the formation of hydrogen bonds between the cellulose in the fibres when the paper is forming, the lower amount of lignin strengthens and increases the paper's resistance to wear and tear due to the successful formation of hydrogen bonds. However, due to the sulfate process, Kraft paper contains some sulphur in it as residue [2]. The sulphur will react with moisture in the air and form hydrogen sulfide which gives off a foul smell.

Corrosion caused by moisture

This corrosion is very common to take place if metals are exposed to environment without any protection. In this case, iron (Fe) will be taken as example due to its high usage in the industry. When iron is exposed to environment, it comes in contact with water moisture (H_2O) and oxygen. It then undergoes a redox reaction (rusting) [3]. The rusting process first begins with the electrochemical process of iron donating ions to oxygen by reducing itself. The reactions are shown below:

$$\mathbf{Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-}$$

$$\mathbf{O_{2\,(g)} + 4e^- + 2H_2O_{(aq)} \rightarrow 4OH^-_{(aq)}}$$

Iron ions (Fe^{2+}) then react with hydroxide ion (OH^-) to form iron (II) hydroxide ($Fe(OH)_2$):

$$\mathbf{Fe^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Fe(OH)_{2(s)}}$$

Lastly, rust ($2Fe_2O_3 \bullet H_2O$) is then quickly formed by the oxidation of iron (II) hydroxide:

$$\mathbf{4Fe(OH)_{2(s)} + O_{2(g)} \rightarrow 2Fe_2O_3 \bullet H_2O_{(s)} + 2H_2O_{(l)}}$$

Corrosion caused by sulphur

Kraft paper contains sulphur after its production process. The sulphur in the Kraft paper will cause the rusting when it is converted to hydrogen sulfide upon contact with water moisture in the air [4] [5]. The products of the reaction will be hydrogen sulfide (H_2S) and sulphuric acid (H_2SO_4), which is shown below:

$$\mathbf{S_{8\,(s)} + 8H_2O_{(aq)} \rightarrow 6H_2S_{(g)} + 2H_2SO_{4\,(aq)}} \text{ [5]}$$

Both of the products later on will react with metals and form rust. For the hydrogen sulfide (H_2S), it will adsorb onto iron and undergo certain reactions. The reactions are shown below:

$$\mathbf{Fe_{(s)} + H_2S_{(g)} \rightarrow Fe_{(s)} + HS^-_{(aq)} + H^+_{(aq)}} \text{ [6]}$$

There are 2 paths for this reaction according to Taylor's pairing [6]:

Path 1

$$Fe_{(s)} + HS^{-}_{(aq)} + H^{+}_{(aq)} \rightarrow FeHS^{-}_{(aq)} + H^{+}_{(aq)}$$

$$FeHS^{-}_{(aq)} + H^{+}_{(aq)} \rightarrow FeHS^{+}_{(aq)} + H_{(g)} + e^{-}$$

$$FeHS^{+}_{(aq)} + H_{(g)} + e^{-} \rightarrow FeS_{(s)} + 2H_{(g)}$$

Path 2

$$Fe_{(s)} + HS^{-}_{(aq)} + H^{+}_{(aq)} \rightarrow Fe_{(s)} + S^{-}_{(aq)} + 2H^{+}_{(aq)}$$

$$Fe_{(s)} + S^{-}_{(aq)} + 2H^{+}_{(aq)} \rightarrow FeS_{(s)} + 2H_{(g)}$$

The final product of FeS(s) is the rusting product.

As for the sulphuric acid, it will react with metal and form iron sulfate ($FeSO_4$), which is another rust product [7]:

$$Fe_{(s)} + H_2SO_{4(aq)} \rightarrow FeSO_{4(s)} + H_{2(aq)}$$

Vapour Corrosion Inhibitor

Corrosion inhibitor is a term introduced to the chemical substances that can delay or prevent corrosion of ferrous and non-ferrous metals. The corrosion inhibitors function to neutralize the corrosive agents or form a passivation layer on the surface of metals that prevent corrosive agents from reaching the metals [8]. A vapour corrosion inhibitor leans toward the later. When it is put near or comes in contact with metals, it will react with the moisture of the surroundings and deposit a passivation layer on the metals that will prevent them from reacting with the corrosive agents.

Amino-Carboxylate Corrosion Inhibitor was chosen because it is less toxic compared to the commonly used corrosion inhibitors. It is also available in liquid form and is easier to apply compared to other corrosion inhibitors that are mostly in powder form. The Amino-Carboxylate is also colourless in liquid form. Hence, it will not alter the appearance of paper or hinder the vision when viewing if it is put into transparent medium. Also, it does not taint the metals when it forms a protective layer on the surfaces which will expedite routine inspection processes [9].

Applying method

There are several tests that are feasible to apply vapour corrosion inhibitor to the Kraft paper. The processes are lithography [10] and impregnation.

Lithography

Lithography is printing process where the paper is saturated with vapor corrosion inhibitor. This process requires a precise value that the paper can absorb which ensures allocative efficiency in the usage of materials.

Impregnation

There are 2 types: roller impregnation and spraying impregnation. Roller impregnation is the process of pulling papers through a pool of liquid vapour corrosion inhibitor before drying them off. Spraying impregnation involves pulling papers through a chamber where vapour corrosion inhibitor is constantly sprayed onto the papers. The papers are then allowed to dry off. Both impregnation processes do not require precise amounts of liquid to be measured. However, impregnation process will have more wastage than lithography process, resulting in higher costs. In this experiment, the roller impregnation method is adopted to impregnate Kraft paper with the respective percentages of Amino-Carboxylate.

Determining the effectiveness of MBL 2200

This experiment is to determine the effectiveness of MBL 2200 on ferrous steel when applied onto Kraft paper. The experiment is carried out to determine the minimum amount of Amino-Carboxylate needed to have good protection on metals.

Experiment

Before carrying out the experiment to determine how many percent of amino-carboxylate is needed to prevent corrosion, the amount of mixture between water and MBL 2200 is required.

Determine the amount of mixture

In this experiment, an A4-sized (210mm x 297mm) of MG Interleaving 57 gsm Kraft paper was chosen to be the specimen. Due to lack of data on how much does a Kraft paper absorb, 6g of MBL 2200 mixture was decided to be put onto the Kraft paper as a first attempt to find out if it is enough to cover the paper. The mixture was slowly put onto the surface by using a brush. After the first attempt, the area coverage by 6g of mixture is only 65%. Hence, by adding up to 100% and considering wastage during brushing, 11g of mixture is decided as the second attempt. After the second attempt, the 11g mixture had completely covered the whole area of a new Kraft paper.

Grams used for brushing (g)	Percentage coverage (%)
6	65
11	100

By using 11g of the mixture,

$$\frac{\text{Grams needed for } 1\text{m}^2}{11\text{g}} = \frac{1000 \text{ x } 1000}{210 \text{ x } 297}$$

$$\text{Grams needed for } 1\text{m}^2 = 176 \text{ grams}$$

$$= 0.176 \text{ kg}$$

Converting to grams per ft^2,

1 ft^2 = 0.0929 m^2

Grams needed for 1 ft^2 = 0.0929 x 0.176

= 0.0163 kg

Materials and apparatus used

- 8 Pieces of steel pieces with the dimension of 7.5 cm X 2 cm
- Normal paper with the size of 12cm x 10 cm
- 7 pieces of 12 cm x 10 cm Interleaving Kraft paper with 57 gsm
- MBL 2200 which is 20% of Amino-Carboxylate Corrosion Inhibitor
- Humidity Chamber

Procedures

1. 8 steel pieces were polished with new No. 220 abrasive paper to remove all the grit and rust. Next, the metal pieces were polished with new No.120 abrasive paper to leave a smooth surface. After that, the metal pieces

were rinsed in the Ethanol to remove any organic stains (oil & grease) on the metal pieces. Then the metal pieces were dried.

2. Photos of steel pieces were taken.
3. 6 pieces of each 12 cm x 10 cm Kraft paper were impregnated with 2.1 grams of Amino-Carboxylate Corrosion Inhibitor with different percentage by roller impregnation method. For this testing, we used 1%, 2%, 3%, 4%,5% and 20% Amino-Carboxylate Corrosion Inhibitor of MBL 2200.
4. The steel pieces are wrapped individually, each with a different type of paper:
   - Normal paper
   - Kraft paper without Amino-Carboxylate Corrosion inhibitor
   - Kraft paper with 1 % Amino-Carboxylate Corrosion Inhibitor
   - Kraft paper with 2 % Amino-Carboxylate Corrosion Inhibitor
   - Kraft paper with 3 % Amino-Carboxylate Corrosion Inhibitor
   - Kraft paper with 4 % Amino-Carboxylate Corrosion Inhibitor
   - Kraft paper with 5 % Amino-Carboxylate Corrosion Inhibitor
   - Kraft paper with 20% Amino Carboxylate Corrosion Inhibitor which is 100% MBL 2200
5. Two steel pieces wrapped with normal paper and Kraft paper without Amino-Carboxylate Corrosion Inhibitor are used as blank samples (control items). They have no Amino-Carboxylate Corrosion Inhibitor in them and they are only used as a control/ yardstick for the experiment.
6. The humidity chamber was turned on and the temperature is set to 35^{o}C.
7. When the temperature inside the chamber reached 35^{o}C and humidity level reached 100%, the specimens were placed in it.
8. The specimens were then taken out after 1 day and the paper was carefully opened.
9. Any changes on the metals and papers were observed. Images were taken as a record.
10. The specimens were then wrapped again with the same paper and put back into the chamber.
11. Steps 8 and 10 were repeated for 5 days.

Observations

Type of paper used	Day 1 (Before putting into humidity chamber)	Day 3	Day 5
Normal Paper			
Kraft paper without Amino-Carboxylate Corrosion Inhibitor			

Kraft paper with 1% Amino-Carboxylate Corrosion Inhibitor			
Kraft paper with 2% Amino-Carboxylate Corrosion Inhibitor			

Kraft paper with 3% Amino-Carboxylate Corrosion Inhibitor			
Kraft paper with 4% Amino-Carboxylate Corrosion Inhibitor			

Kraft paper with 5% Amino-Carboxylate Corrosion Inhibitor			
Kraft paper with 20% Amino-Carboxylate Corrosion Inhibitor			

Type of paper used	% of corrosion on surface at Day 3	% of corrosion on surface at Day 5
Normal Paper	15	50
Kraft paper without Amino-Carboxylate Corrosion Inhibitor	40	60
Kraft paper with 1% Amino-Carboxylate Corrosion Inhibitor	1	1
Kraft paper with 2% Amino-Carboxylate Corrosion Inhibitor	1	1
Kraft paper with 3% Amino-Carboxylate Corrosion Inhibitor	1	2
Kraft paper with 4% Amino-Carboxylate Corrosion Inhibitor	0.5	1
Kraft paper with 5% Amino-Carboxylate Corrosion Inhibitor	0.2	0.5
Kraft paper with 20% Amino-Carboxylate Corrosion Inhibitor	1	1

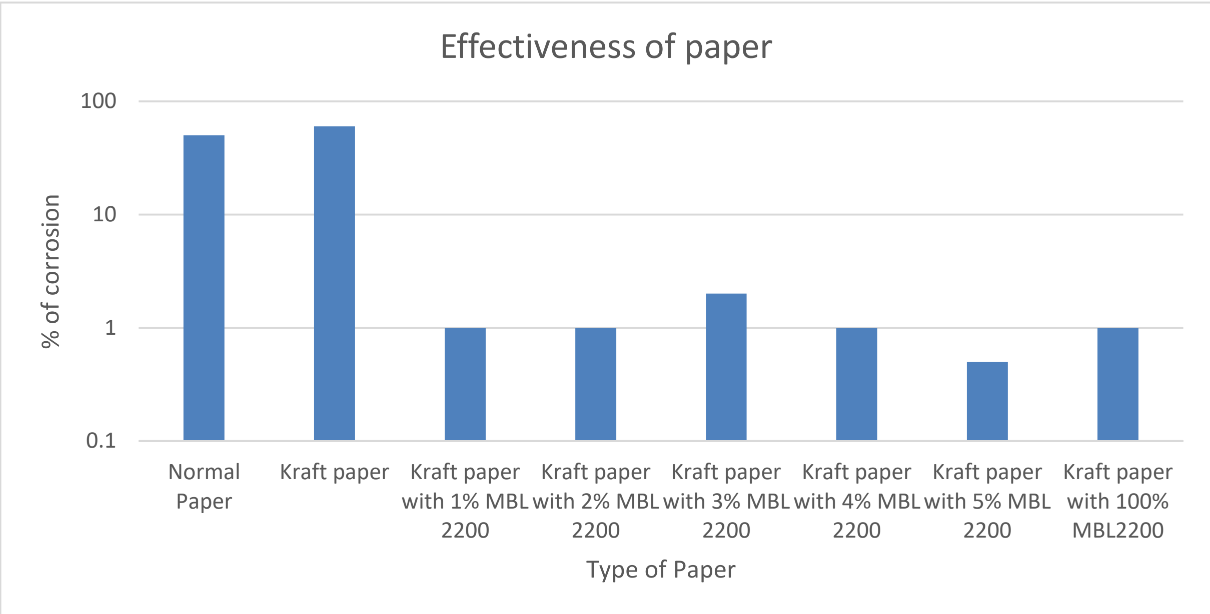

Figure 1. Log graph depicting effectiveness of the types of paper

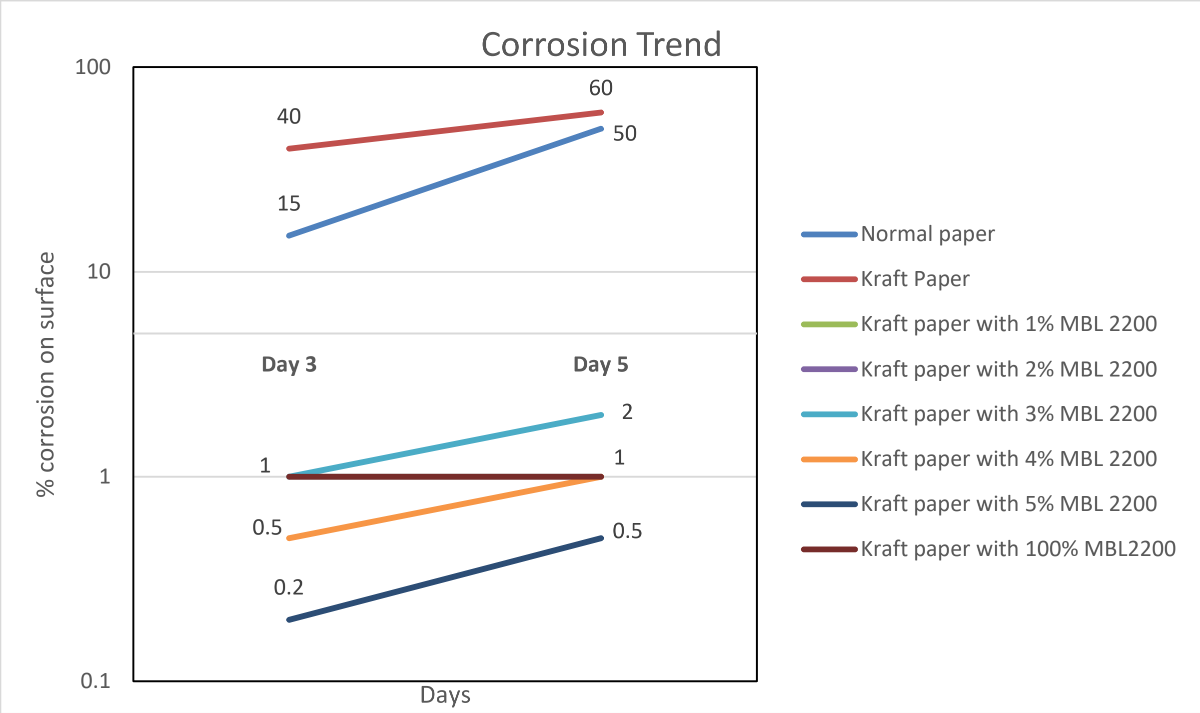

Figure 2. Log graph depicting corrosion trend and percentage comparison

Conclusion

From the experimental results, we observed that 5% Amino-Carboxylate has the better effect than 20% Amino-Carboxylate. Hence, we concluded that Kraft paper with 5% Amino-Carboxylate has an excellent effect in protecting metals from corrosion observed after 5 days in extreme humid condition. Hence, the process of producing VCI paper in this laboratory can be justified as success.

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