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Corrosion Under Insulation (CUI): The Absorption Characteristics of Rockwool

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Abstract: Corrosion under insulation (CUI) is a degradation of metal which has occurrence under the part of the equipment which is insulated. Corrosion under insulation is a major issue that many industries face on a daily basis. In the project, the absorption characteristics of the rockwool sample is studied. For moisture absorption, the sample weight is measured after every 90 drops of water. For drying, five samples were put in a closed beaker, non-closed beaker, heated hotplate at 70 ℃ ,soaked in tap water and soaked in tap water and water bath at room temperature. The closed and non-closed beaker samples is monitored every two days whereas every two hours for the heated hotplate sample. The samples are observed under the Scanning Electron Microscope(SEM). For moisture absorption, there is saturation at 990 drops of water. For drying, the rockwool sample in the non-closed beaker returned to the initial weight faster and the heated rockwool sample took twelve hours to return to the initial weight. Based on SEM analysis, the surface of the samples showed almost similar morphology. There are some suggestions for future work such as using different insulation materials and the use of constant temperature.

Keywords: Corrosion Under Insulation, Characteristics, Rockwool

1. Introduction

The title of the project is about CUI and the absorption characteristics of rockwool. In the project, the objectives are to measure the moisture absorption of rockwool, measure the drying rate of rockwool under different temperature and environment and to obtain the surface morphology of rockwool samples. This research is done because because corrosion is a natural process and most insulators are not able to prevent CUI from occurring. Corrosion has long been a major issue in the engineering world and it is a natural process that slowly degrades metals into oxides and other compounds by reacting chemically or electrochemically with its surroundings[1]. The occurrence of corrosion under insulation is caused by the presence of oxygen and water on the surface of the steel. The rate of corrosion is determined by the temperature, availability of oxygen , insulation type and the chemical composition of water[2]. Corrosion under insulation (CUI) usually occurs as a result of water ingress into the insulation material and moisture build up outside the insulated metallic equipment or piping[3]. Water collects in the annulus space between the insulation and the metal surface, causing corrosion to occur.

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[3]. Conservation of energy, fireproofing, staff safety, thermal tracking, winterization, acoustic deadening, and any mixture of these are common reasons for using insulation on industrial equipment[4].

Corrosion under insulation (CUI) is described as the electrochemical breakdown of an alloy or metal under the insulation[5]. Water from the environment has an inclination for penetrating the insulation and corroding the underlying steel surfaces and similarly, humid air can penetrate through insulation defects and condense on steel surfaces, causing corrosion[6]. The pipeline damage for oil and gas transmission caused by corrosion could result in a gas waste, leading to a huge amount of money related loss[7]. Rockwool, foam glass, and calcium silicate are the most used insulation materials and all of these materials absorb water to varying degrees, needing stainless steel cladding or specific tape binding to keep them in place, protect the insulation material from weathering, and prevent water penetration through cracks and gaps [8].

In the petrochemical industry, mineral wool is one of the most widely used insulation materials and the mineral wool is made by the melting of the volcanic rock. [9] The melted volcanic rock is then spun into fibers which is then processed by using binding and curing techniques[9]. The mineral wool is usually utilized in thermal insulation[10]. It is used as a protection for the equipment against the risk of fire[10]. In any issue of corrosion under insulation (CUI), there are five factors involved that are important in corrosion under insulation[11]. The five factors are insulation material, coating material, substrate metallic material of the equipment, atmosphere and the design[11]. The objectives of this project are to measure the moisture absorption of rockwool. Besides that, the drying rate of rockwool under different temperature and environment will also be measured. The surface morphology of rockwool samples will also be obtained.

2. Materials and Methods

This part describes the steps that are taken in this project to identify the absorption characteristic of the rockwool insulation material in terms of its water absorption properties. The steps in the project are done to ensure that the objectives are achieved.

2.1 Materials

Six beakers from the range of 250ml to 1000ml and a thermometer are used in the experiment to measure any temperature changes and ensure the temperature needed for the experiment is maintained. A weighing machine is used to measure the initial weight of the rockwool samples and measure any changes in the weight of the rockwool samples. Tap water is used in the experiment. A hotplate is used for providing heat during the heated hotplate experiment and a water dropper is also used in the moisture absorption experiment. The insulation material will be rockwool. The thickness of the insulation materials used will be 30mm respectively.

2.2 Methods

The experimental work will be done using the ASTM G189-07 test standard. The ASTM G189-07 test standard is the standard guide for laboratory simulation of corrosion under insulation. The first part of the experimental work is the preliminary experiment preparation of the rockwool insulation material according to the required measurements. Precaution should be taken such as using gloves when handling rockwool sample because it might cause skin or eye irritation due to its makeup. The second part of the experimental work is the preparation of the rockwool samples for analysis of surface morphology under Scanning Electron Microscopy to reveal the fine microstructure in the rockwool samples.

For moisture absorption of rockwool insulation, the insulation material is cut to a length of 2.5 inches and the initial weight of the insulation material is measured and recorded. Tap water is used in the experiment. After that, the insulation material is put in a beaker and 90 drops of water at a time is added to each insulation material. The number of drops needed to soak the insulation material is recorded. A weighing machine is used to measure the weight of the rockwool sample after every 90 drops of water is added to the rockwool sample. The results are obtained and recorded and the graph is plotted.

For drying, the rockwool insulation material is cut into three separate insulation samples which is 2.5 inches in length. The initial weight of the rockwool insulation materials is measured and recorded. The rockwool insulations are then soaked in water for 10 minutes and the weight is recorded. Two of the insulation samples are run under normal temperature where one beaker is left open while the other beaker is closed with aluminium foil but has two small holes in the aluminium foil to simulate the situation when there is a hole in the covering of the insulation material at a power plant. The weight loss is measured every two days until the samples return to their initial weight and the data is recorded. The third rockwool sample is put into a beaker. The beaker is then put into a water bath. The waterbath is heated to 70 ℃ using a hotplate. The water bath is used to distribute the heat equally during the experiment. A thermometer is used to monitor the temperature readings. The weight loss of the rockwool is measured every two hours until the sample has returned to its initial weight and the data is recorded. There were another two rockwool samples. One rockwool sample was soaked in a beaker with tap water. The other rockwool sample was soaked in a beaker with tap water and put in a water bath. This was done to see the surface morphology of the rockwool insulation after soaking in water without removal for 24 days.

For phase and characterisation analysis, the morphology of the rockwool sample is evaluated by the Scanning Electron Microscopy (SEM). This is to differentiate between and observe the microstructure of the rockwool sample. The SEM is chosen because it can help to reveal the fine microstructure of the rockwool samples. First, a small sample of rockwool is taken from the six rockwool samples respectively and is placed stuck on six carbon samples. After that, the four rockwool samples were spun in a FISON SEM coating system to put a coating on the sample. This is to make sure the sample image will be improved and also to make sure that no thermal damage occurred. After that, the samples were put one by one in the SEM to observe the microstructure of the rockwool samples and the material present in the arrangement of rockwool samples.

3. Results and Discussion

The results that have been achieved from the moisture absorption, drying rate and also surface morphology has been discussed. The results of the experiment consist of moisture absorption of sample and rate of drying of insulation sample. The microstructures of the rockwool samples are discussed.

3.1 Results

For the moisture absorption of rockwool, when there are no drops of water added to the insulation, the initial weight of the rockwool insulation material is 10.188g. Then, after every 90 drops of water, as the weight started to increase, the rockwool sample has a little bit of water come out at 360 drops of water. Then at 720 drops of water, the water will start to drip. At 990 drops of water, the rockwool sample will become saturated. At 1170 drops of water, the insulation is fully saturated with water.

For drying, the rockwool sample in the non-closed beaker returns to its initial weight at a faster pace compared to the rockwool sample in the closed beaker. The rockwool sample was placed in a room temperature environment to ensure the temperature conditions were the same. After 24 days where the weight is measured every two days, the rockwool sample in the non-closed beaker returned to its almost initial weight which is 11.184 grams but the rockwool sample in the closed beaker dried slower which resulted in a slower weight loss and a weight of 103.724 grams compared to the rockwool in the non-closed beaker sample. The percentage of drying rate of closed rockwool sample is 16.79% whereas for non-closed rockwool sample, the percentage is 91.03%. For the heated hotplate rockwool sample, the rockwool sample which was heated at a temperature of 70 ℃ returned to its initial weight of 11.183 grams after 12 hours of heating where the weight of the sample is measured every 2 hours.

3.2 Discussions

For drying, the rockwool sample in the non-closed beaker dried faster because the rockwool had more exposure rate to the environmental conditions compared to the rockwool in the closed beaker which was closed and had two small holes in the closed area. This is because for the sample in the non-closed beaker, the surrounding air is dry which can allow the rockwool sample to dry faster compared to the sample in the closed beaker where the surrounding air is moist due to the covering. Therefore, this will cause the rockwool sample to dry slower. For the heated hotplate rockwool sample, the reason the sample dried quickly is due to the presence of heat which allows the water moisture in the rockwool sample to evaporate at a very fast pace. The temperature was also kept at 70 ℃ to simulate the hot temperatures at the power plant. For morphological observations of rockwool samples, from the SEM images, it can be seen that there is not much change in the morphology of the samples.

Table 1: Weight reading of moisture absorption

Drops of water	Weight	Unit or Dimension
0	10.188(initial weight)	Grams (g)
90	14.526	Grams (g)
180	19.078	Grams (g)
270	23.363	Grams (g)
360	28.265	Grams(g)
450	32.622	Grams(g)
540	37.310	Grams(g)
630	41.336	Grams(g)
720	44.913	Grams(g)
810	48.355	Grams(g)
900	52.539	Grams(g)
990	57.078	Grams(g)
1080	60.397	Grams(g)
1170	65.349	Grams(g)

Table 2: Weight reading of closed and non-closed rockwool sample

Day	Weight of rockwool in closed	Weight of rockwool in non-closed	Unit or Dimension
0	11.183(initial weight)	11.183(initial weight)	Grams(g)
0	124.659	124.659	Grams(g)
2	118.773	108.20	Grams(g)
4	117.234	97.69	Grams(g)
6	115.883	87.198	Grams(g)
8	114.532	76.706	Grams(g)
10	113.181	66.214	Grams(g)
12	111.830	55.722	Grams(g)
14	110.479	45.23	Grams(g)
16	109.128	34.738	Grams(g)
18	107.777	24.246	Grams(g)
20	106.426	13.754	Grams(g)

22	105.075	11.911	Grams(g)
24	103.724	11.184	Grams(g)

Table 3: Weight reading of heated hotplate rockwool sample

Hours	Weight of heated hotplate rockwool	Unit or Dimension
0	124.659	Grams(g)
2	86.406	Grams(g)
4	65.35	Grams(g)
6	45.641	Grams(g)
8	23.098	Grams(g)
10	13.726	Grams(g)
12	11.183	Grams(g)

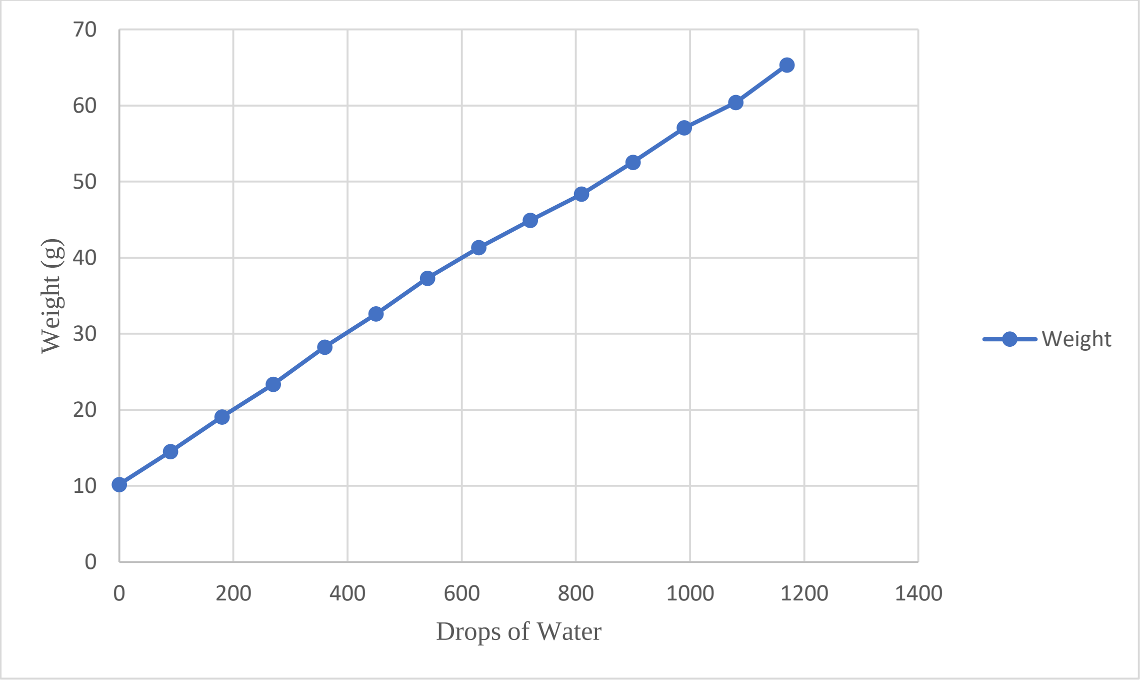


Figure 1: Graph for moisture absorption of rockwool sample

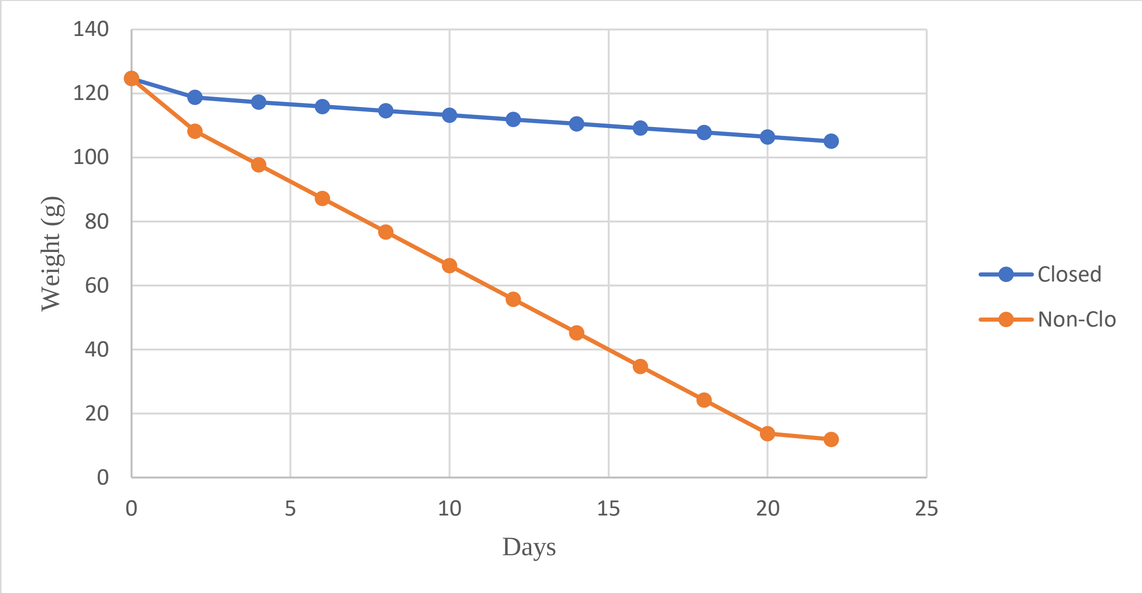


Figure 2: Graph for rockwool sample in closed and non-closed beaker

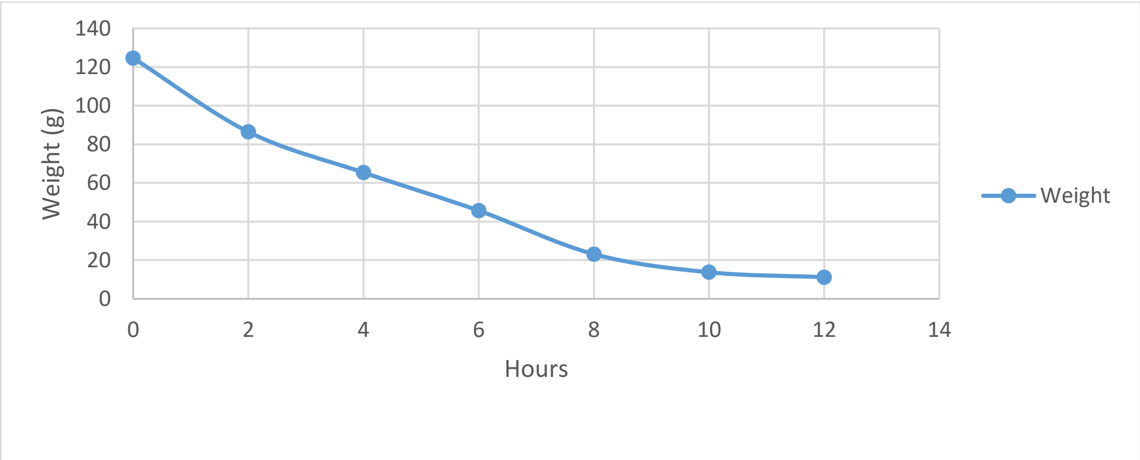
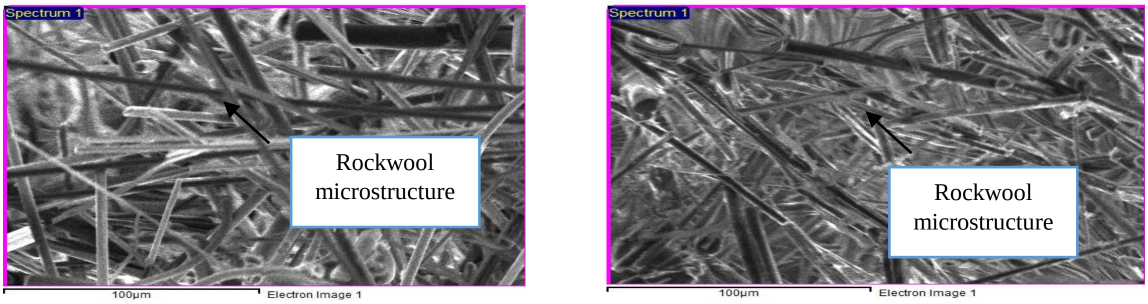


Figure 3: Graph for heated hotplate rockwool sample

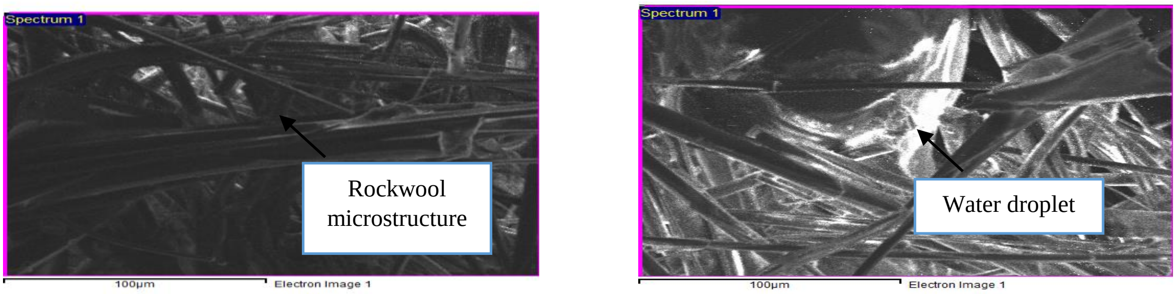
3.5 Observation of microstructure of rockwool samples

The SEM images below show the point spectrum that have been analyzed to show the morphology of surface and the elements present.



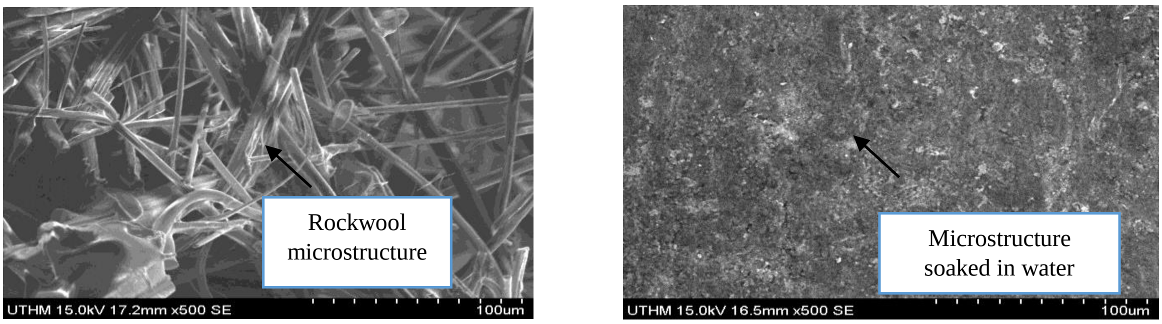
(a) (b)

Figure 4: Point Spectrum Selection for (a)heated hotplate rockwool sample and (b)moisture absorption rockwool sample



(a) (b)

Figure 5: Point Spectrum Selection for (a)closed rockwool sample and (b)non-closed rockwool sample



(a) (b)

Figure 6: Point Spectrum Selection for (a)rockwool sample soaked in tap water at room temperature and (b)rockwool sample soaked in tap water and waterbath at room temperature

4. Conclusion

From the results that have been obtained from the experiment, there are some conclusions that can be derived. The objective of the project to measure the moisture absorption of rockwool, measure the drying rate of rockwool under different conditions and obtain the surface morphology of rockwool samples. For the moisture absorption, from the initial weight of 10.188 grams and after every 90 drops of water, at 990 drops of water, the rockwool sample has reached saturation. For the drying rate of closed and non-closed beaker sample, rockwool sample in the non-closed beaker has a higher drying rate compared to the rockwool sample in the closed beaker as it returned to its almost initial weight of

11.184 grams within 24 days of drying. The percentage of drying rate of closed rockwool sample is 16.79% whereas for non-closed rockwool sample, the percentage is 91.03%. For the heated hotplate rockwool sample, the rockwool sample in the heated hotplate returned to its initial weight of 11.183 grams within 12 hours of heated drying. Based on the SEM analysis, the surface of the samples show almost similar morphology.

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