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Utilization of Polyurethane with Bentonitee-Chitosan Filler As an Anti-Corrosion Paint

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ABSTRACT

In this study, the manufacture of polyurethane uses bentonitee-chitosan filler materials to improve the ability of heat resistance. The characteristics carried out were assessed in terms of functional group analysis, heat resistance analysis, morphological structure analysis, corrosion test and paint thickness test. The coating process has the advantage of being able to protect the iron surface from environmental influences that result in corrosion of the metal. This study aims to see the effect of mixing polyurethane with Bentonitee-Chitosan filler. The sample formulation used was polyurethane with variations of bentonitee and chitosan of 2%, 4%, 6%, 8%. The results of the Fourier Transform Infra Red (FT-IR) test showed that there were functional groups N-H, C-H, C=O. Based on the results of the Thermogravimetry Analysis (TGA) test, the Polyurethane sample with 8% bentonitee modification : chitosan 8% b/b had the best thermal stability among other samples where the sample began to degrade (on set) at a temperature of 307.04 (ºC) and stopped degrading (end set) at a temperature of 399.50 (ºC). In the Polyurethane sample with 2% bentonitee modification/8% chitosan b/b had lower thermal stability where the sample began to degrade (onset) 293.09(ºC) and stopped degrading (end set) at 348.32(ºC). The results of the morphological test using SEM tools showed that the chitosan chain was well dispersed into the bentonitee interlayer. The corrosion test showed that the addition of bentonitee and chitosan affected the corrosion rate, the greater the composition of bentonitee and chitosan, which could reduce the corrosion rate. The best sample with a ratio of Polyurethane/Bentonitee/Chitosan 8:8 % b/b experienced the smallest corrosion rate of 5.79 mpy and mass loss of 0.10 grams.

Keywords : *Biodegradable, Corrosion, Polyurethane, Bentonitee, Chitosan*

INTRODUCTION

Corrosion is a problem that often occurs in the industrial world. Metal corrosion is a serious problem and causes huge economic losses every year in the world (Wang et al., 2021). Corrosion can cause severe damage to metal facilities, which can lead to great economic losses as well as can threaten personal safety. There are many approaches used to prevent corrosion, organic coatings attract a lot of attention from materials scientists where organic coatings are usually developed in the form of coating paints. Paint is a general term used to protect and color objects. Meanwhile, coating is the process of deposition of coating particles on metal surfaces both by electrolysis and non-electrolysis (Arifullah & Widyastuti, 2015). Organic coatings are widely used as a physical barrier to inhibit metal corrosion. The coating process has the advantage of being able to protect the metal surface from environmental influences that result in corrosion of the metal.

Traditional solvent-based coatings that can produce volatile organic compounds (VOCs) that are damaging to human health and the environment are gradually being replaced by environmentally friendly materials (Chang et al., 2021). Among them are vegetable oil-based polyurethane, vegetable oil-based polyurethane coatings have proven their ability by displaying superior properties such as excellent toughness, abrasion resistance, corrosion and chemical resistance (Paraskar et al., 2021).

In this decade, polyurethane (PU) became one of the most popular materials in the world (Teuku Rihayat et al., 2016). Polyurethane is an important division of synthetic polymers that are widely used in biomedical applications and various industries, especially the motor vehicle industry. Products that contain 2 polyurethanes include synthetic resins, furniture coatings, construction materials, paints, elastomers, synthetic leather materials and paints as mentioned polyurethane is one of the polymers that is used as a raw material for making coating paints. However, polyurethane has a stability coating system and low thermal barrier properties (Chang et al., 2021). To improve the physical properties of polyurethane (thermal and stracth resistance), modifications are made with the addition of fillers including Bentonitee and Chitosan (Teuku Rihayat et al., 2021). Polyurethane in general is a polymer compound whose main chain constituent is a urethane group (-NHCOO-) (Agusnar et al., 2014). The urethane group -NH-COO- is an ester of carbaic acid, i.e. a hypothetical acid that is unstable (and impossible to obtain under normal conditions) (R-NHCOOH). To synthesize urethane groups can be done by various methods, but the most appropriate is the reaction between isocyanate and alcohol. Polyurethanes can be crystalline solids, segmented solids, amorphous glass, orviscoelastic solids. The properties of linear polyurethane are also highly dependent on temperature and humidity.

Bentonitee is a term in the trading world for clays containing monmorillonite. The use of clay itself is widely used in the polymer industry. Based on previous research in the field of polyurethane nanocomposites, it was found that to increase the heat resistance of polyurethane materials, Bentonitee was added to the polyurethane coating (Teuku Rihayat., 2016). The addition of Bentonitee nanocomposite filler shows an increase in the mechanical and temperature properties of Polyurethane. The use of clay itself is widely used in the polymer industry. Clay-coated silicates can play an important role when it comes to providing a barrier and heat-resistant properties for the coating system. The main content of Bentonitee is the mineral monmorillonite (80%) with the chemical formula ($Al_2O_3.4SiO_2.X\ H_2O$). It has a variety of colors ranging from white to yellow, to olive green, stored in a variety of freshwater and marine basins, characterized by the sedimentation energy that is by the environment and temperate climatic conditions.

With the addition of Chitosan which is a guide in modifying polyurethane, it can be an anti-bacterial property in polyurethane. According to the results of the study, chitosan interkalation through the cation exchange process can increase the antimicrobial activity power. Chitosan is a chemical compound derived from the biological material chitin. Chitin is generally obtained from invertebrate animal skeletons from the Arthopoda sp, Molusca sp, Annelida sp, Nematoda sp, and some from the fungal group. Chitosan is a fiber-form multifunctional chemical and is a thin, yellow-colored, odorless sheet-shaped copolymer. Chitosan is a poly – (2-amino-2-deoxy-β-(1-4)-D-glukopiranosa) with a molecular formula ($C_6H_{11}NO_4$) that can be obtained from complete or partial deacetylation of chitin.

Some of the studies that have been conducted before are: (Agusnar et al., 2014) making polyurethane films is carried out by modifying the manufacture of palm oil-based polyurethane mixed with arganoclay at room temperature for 10 minutes, then adding diphenylmethane diisocyanate (MDI) isocyanate and stirring for 5 minutes to obtain a homogeneous mixture. Based on the test results, it was obtained that the oil palm polyurethane coating with additional montmorillonite insulation (MMT) experienced an increase in heat compared to polyurethane without the addition of montmorillonite. The addition of montmorillonite (MMT) can improve adhesion to polyurethane paint coating applications and also increase the gloss index of the paint coating surface. (Teuku Rihayat et al., 2016) carried out polyurethane synthesis with the addition of Bentonitee filler, chitosan as a heat resistance property in the coating material obtained a temperature of 500°C while the addition of B:K 2.5:2.5% b/b was obtained at a temperature of 580°C.

In this study, polyurethane will be made using oleic acid based on palm oil with the addition of Bentonitee-chitosan filler in order to improve the ability of heat resistance and anti-bacterial properties. Oleic acid in palm oil will be used as a source of polyol production to produce polyurethane. The characteristics carried out were assessed in terms of functional cluster analysis, bacterial activity analysis, and heat resistance analysis.

RESEARCH METHOD

Material and Equipment

The tools used in this study are a set of polyurethane synthesis tools, magnetic stirrers, baths, glass beakers, measuring flasks, spatula, desicator, volume pipettes, centrifuges, petri dishes, filter paper, and analytical scales. The materials used are polyol based on palm oil, glacial acetic acid, aquadest, bentonitee from North Aceh, distillate water, AgNO3, commercial chitosan, toluene diisocyanate (TDI), Cetyl Trimethyl Ammonium Bromide (CTAB), H_2O_2 30%, concentrated H_2SO_4, methanol, and steel plate.

Trial and Testing Procedures

The outline of the stages of this research includes: preparation of bentonitee into montmorillonite then into organoclay and its characterization, preparation of chitosan and its characterization, making polyurethane paint through polymerization of polyol with toulene diisocyanate / bentonitee / chitosan and its characterization.

Bentonitee Processing

A total of 18.2 grams of cetyl trimethyl ammonium bromide (CTAB) was dissolved in 250 mL of aquades in a 500 mL beaker glass, then this solution was heated at 80ºC for 1 hour. Separately, 20 grams of bentonitee were dissolved with 250 mL of aquades in a 1000 mL beaker glass. The dispersion of the bentonitee solution is then incorporated into the CTAB solution and stirred for 1 hour. After that, bentonitee is filtered and washed with aquades several times until there is no more bromide. Filtrate is tested by dripping $AgNO_3$ 1 M until a white precipitate is formed. The bentonitee that has gone through the process is put into an oven at a temperature of 60ºC and then filtered using a sieve tray with a size of 100 μm.

The filtered bentonitee is then put in an oven at 60°C to dry it. After that, bentonitee is filtered back using a sieve tray with a hole size of 100 μm, resulting in a final product that is ready to use. This process aims to clean and modify bentonitee with CTAB so that it can be used in specific applications.

Chitosan Preparation

A total of 4.25 grams of chitosan were dissolved in a 100 mL solution of 2% glacial acetic acid while stirring at 500 rpm for 2 hours with a pH of 4.0, until a chitosan suspension was formed. Next, 50 mL of NaOH 0.1 N is slowly added to the chitosan suspension. Then, the chitosan suspension is cleaned using 150 mL of aquatics or until it reaches a neutral pH, and dried in an oven at 60°C. Next, chitosan is analyzed.

Manufacturing of Polyurethane / Bentonitee / Chitosan Coating Paint

Polyols, TDI, bentonitee and chitosan, are mixed in *beaker glass* using a *200 rpm magnetic stirrer* for 1 hour. In this procedure, a number of bentonitee and chitosan are used as much as 2,4,6,8, and 10 percent by weight (wt%), respectively. The resulting polyurethane is then cooled at room temperature. Furthermore, the chemical structure of polyurethane, chitosan, and bentonitee paints was analyzed using FTIR. The heat resistance analysis of the paint coating was analyzed using TGA and the surface shape analysis using SEM.

Testing

Analisis *Fourier Transform Infra Red* (Shimadzu FTIR Prestige-21)

FT-IR is used to analyze the characteristics of polymer materials and analyze functional groups. The synthetic polyurethane samples were milled using mortar equipment. Samples were mixed with KBr. Infrared spectroscopy of composites obtained with KBr pellets using a Shimadzu FTIR spectrophotometer. The spectra is obtained in the mid-infrared region (4000 – 400 cm^{-1}) at room temperature.

***Thermogravimetric analysis* (TGA)**

In principle, this method measures the reduction of material mass when heated from a high-temperature room temperature of about 900ºC with a heating rate of 20ºC/minute. The TGA (*Thermogravimetric Analysis*) tool is equipped with a microscale in it so that the weight of the sample at any time can be automatically recorded and presented in a graphical display.

The material in the form of powder is simply put into a small cup of Platinum, or alumina or Teflon after the sample is inserted, then we can program the heating sequence. The heater can be deprogrammed according to the needs, for example, we can set the heating of the sample. All specimens are tested under a stream of nitrogen gas.

Analisa *Morfologi Surface Scanning Electron Mikroskopi* (SEM)

An instrument that forms a microscopic shadow of the specimen surface. Electron beams with a diameter of 5-10 nm are directed at the specimen. The SEM technique is basically an examination and analysis of the surface of the specimen, the data or display obtained is data from the surface or layer that has a thickness of about 20 μm from the surface. The surface image obtained is a photography of all protrusions, indentations and holes on the surface.

Corrosion Test

It was carried out to determine the effect of the addition of anti-corrosion coating paint on steel plates. Steel plates that are not coated by coating paint and steel plates coated with coating paint will be soaked with seawater containing Ions for ±1 month. 48 Iron Samples were observed in the 3rd week to find out the changes that occurred in the steel plates.

Paint Layer Thickness Test

To determine the thickness of the paint layer in painting, a coating thickness test equipment is needed. Because this coating thickness test tool functions to determine the thickness of the paint layer at each point of the material according to the standards applied, it is indispensable for industrial companies or other companies.

RESULT AND DISCUSSION

Research on the use of polyurethane with bentonitee-chitosan filler as anti-corrosion paint has been carried out at PT. Fugha Pratama Mandiri and chemical properties analysis was carried out using Fourier Transform Infrared (FT-IR) to determine the functional groups formed from polyurethane paint, Thermal Gravimetry Analysis (TGA) to determine thermal stability, then surface shape analysis was carried out using Scanning Electron Microscopy (SEM), the resulting polyurethane coating material was analyzed using fourier transform infrared spectra to see the clusters in polyurethane, Scanning Electron Microscopy to see the surface of the resulting material and Thermogravimetric testing to see the thermal resistance of the resulting coating material.

Table 1 Fourier Transform Infrared *(FT-IR)* Test Observation Data

Sample	Number of Waves	Gugus Fungsi
Polyurethane	3631,96	N-H
	2935,66	C-H
	1716,65	C=O
Polyurethane/Bentonitee /Chitosan8:8% b/b	3614,60	N-H
	2937,59	C-H
	1714,72	C=O

Polyurethane/Bentonitee /Chitosan2:8% b/b	3631,96	N-H
	2935,66	C-H
	1716,65	C=O

Table 2 Thermal Resistance Test Data with *Thermogravimetry Analyzer* (TGA)

No	8:8 Temp °C	Tga mg	6:8 Temp °C	Tga mg	4:8 Temp °C	Tga Mg	2:8 Temp °C	Tga mg
1	26.67	-0.01	29.71	0.07	28.42	-0.51	27.89	-0.50
2	71.02	-0.01	70.55	0.07	70.40	-0.55	71.13	-0.57
3	140.73	-0.03	140.44	0.05	140.54	-0.62	140.65	-0.64
4	190.47	-0.05	190.89	0.04	190.45	-0.65	190.81	-0.72
5	250.68	-0.21	250.56	-0.07	250.14	-0.76	250.77	-0.92
6	299.34	-1.22	299.42	-0.64	299.39	-1.28	299.53	-1.82
7	355.78	-6.20	355.66	-2.48	355.42	-3.30	355.88	-4.18
8	391.99	-7.85	391.42	-3.59	391.44	-4.93	392.01	-4.39
9	430.31	-8.04	430.78	-3.88	430.42	-5.65	430.81	-4.49
10	525.92	-8.19	525.39	-4.10	525.44	-8.17	525.57	-4.69
11	587.36	-8.28	587.72	-4.29	587.52	-8.24	587.48	-4.81
12	600.53	-8.29	600.82	-4.33	600.46	-8.26	600.47	-4.83
Onset	307,04°C		303,29°C		293,85°C		293,09°C	

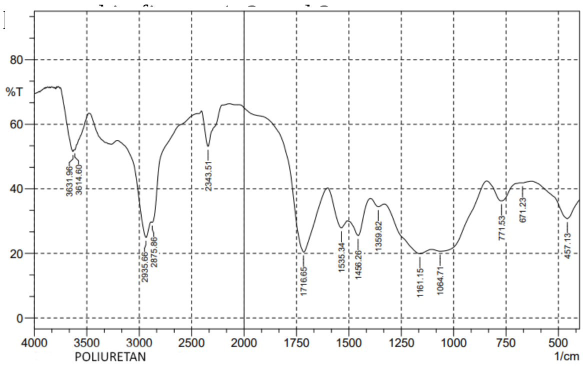
Table 3. Corrosion Test Data and Paint Thickness

Bentonitee Weight (%)	Heavy Chitosan (%b/b)	Mass Beginning (gr)	Mass End (gr)	Mass Loss (gr)	Corrosion (mpy)	Thickness Cat (µm)
0	0	18.32	17.87	0.45	26.08041	80
2	2	18.81	18.52	0.29	16.80737	81
		18.69	18.42	0.27	15.64825	85
		18.48	18.22	0.26	15.06868	83
	4	18.5	18.26	0.24	13.90955	88
		18.58	18.37	0.21	12.17086	90
		18.39	18.15	0.24	13.90955	93
	6	18.74	18.53	0.21	12.17086	90
		18.39	18.16	0.23	13.32999	93
		18.74	18.53	0.21	12.17086	95
	8	17.82	17.65	0.17	9.852599	95
		18.22	17.98	0.24	13.90955	97
		18.03	17.89	0.14	8.113905	95
4	2	18.39	18.14	0.25	14.48912	96
		18.45	18.16	0.29	16.80737	98
		18.93	18.7	0.23	13.32999	97
	4	18.45	18.22	0.23	13.32999	95
		18.73	18.52	0.21	12.17086	97
		18.27	18.06	0.21	12.17086	96
	6	17.73	17.56	0.17	9.852599	97
		18.24	18.01	0.23	13.32999	95
		18.29	18.08	0.21	12.17086	98
	8	17.98	17.79	0.19	11.01173	99
		17.78	17.54	0.24	13.90955	96
		17.83	17.73	0.1	5.795647	98
6	2	18.58	18.36	0.22	12.75042	97
		18.06	17.83	0.23	13.32999	94
		18.21	17.98	0.23	13.32999	97
	4	18.55	18.34	0.21	12.17086	96
		17.63	17.41	0.22	12.75042	98
		18.07	17.91	0.16	9.273034	97
	6	18.11	17.87	0.24	13.90955	94
		18.22	18.09	0.13	7.53434	97
		18.09	17.9	0.19	11.01173	98
	8	18.27	18.12	0.15	8.69347	93
		17.76	17.69	0.07	4.056953	95
		18.37	18.19	0.18	10.43216	90
8	2	18.31	18.09	0.22	12.75042	96
		17.67	17.4	0.27	15.64825	98
		18.55	18.43	0.12	6.954776	99
	4	18.14	17.97	0.17	9.852599	101
		18.3	18.2	0.1	5.795647	99
		18.23	18.01	0.22	12.75042	93
	6	18.1	17.98	0.12	6.954776	95
		18.19	18.05	0.14	8.113905	103
		18.47	18.27	0.2	11.59129	96
	8	18.11	18.01	0.1	5.795647	98
		18.75	18.64	0.11	6.375211	105
		18.25	18.14	0.11	6.375211	109

Discussion

Fourier Characterization of Infra Red Transformm (FT-IR)

Fourier Transform Infra Red (FT-IR) was used to determine the functional group bonds found in polyurethane paints that had been modified with the addition of chitosan bentonitee filler. The purpose of FT-IR analysis on polyurethane paint samples is to determine the wavelength and peak characteristics of the sample. Each functional cluster has a specific peak of characteristics. The FTIR spectrum is



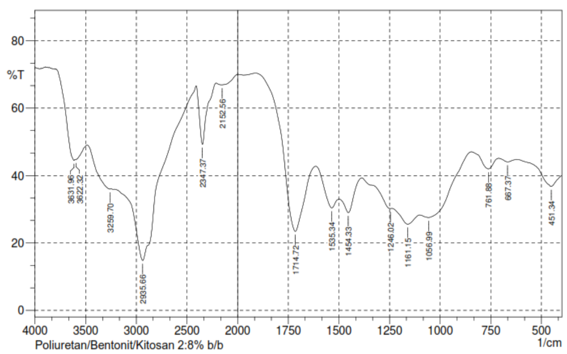


Figure 2. Spektrum FT-IR Polyurethane/Bentonite/Chitosan 8:8% b/b

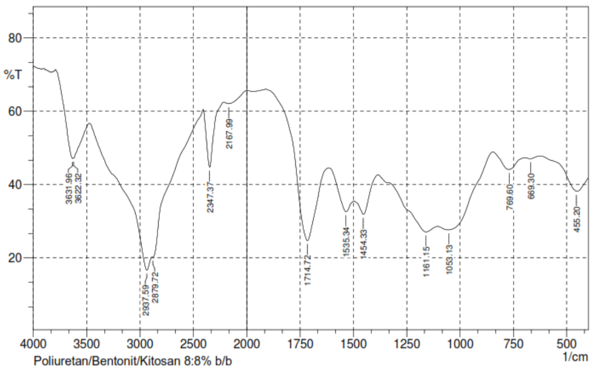


Figure 3. Spektrum FT-IR Polyurethane/Bentonite/Chitosan 2:8% b/b

The results of FT-IR analysis showed that the formation of N-H urethane groups in polyurethane compounds was indicated by the absorption of the N-H wave number which widened at 3631.96 cm^{-1}. Wave absorption of 2935.66 cm^{-1}, 1716.65 cm^{-1} shows C-H and C=O groups. In polyurethane that has been modified with the addition of bentonitee of 8% and chitosan of 8% and the results of FT-IR analysis show the formation of N-H urethane groups at the absorption of wave number of 3614.60 cm^{-1}. C-H wave absorption at 2937.59 cm^{-1} and 1714.72 $^{cm-1}$ shows C=O wave absorption. In Figure 4.3 with a modified polyurethane comparison sample with the addition of bentonitee of 2% and chitosan of 8%, it shows the characteristics of the wave number area of 3631.96 cm^{-1}, 2935.66 cm^{-1} and 1716.65 cm^{-1} showing the N-H, C-H and C=O groups.

Based on the results of the analysis, it can be seen that the functional group of polyurethane and polyurethane that has been modified with the addition of bentonitee-chitosan does not change the functional group. The mixing of polyurethane with bentonitee and chitosan does not alter or affect the wavelength absorption of the functional group of polyurethane. This is because the mixing process that takes place does not change the chemical bonds, what occurs is only a change in the physical bonds.

Analisa *Thermo Gravimetric Analysis* (TGA)

Thermal stability studies using thermogravimetric analysis (TGA) were conducted to understand the degradation characteristics of specimens. The thermal stability of fiber is a key parameter in the processing and utilization process of materials. Composite manufacturing involves mixing fillers and matrices at high temperatures, so that the degradation effect on the properties of the filler-containing materials can be estimated. The results of the TGA analysis in this study can be seen in Figure 4 below.

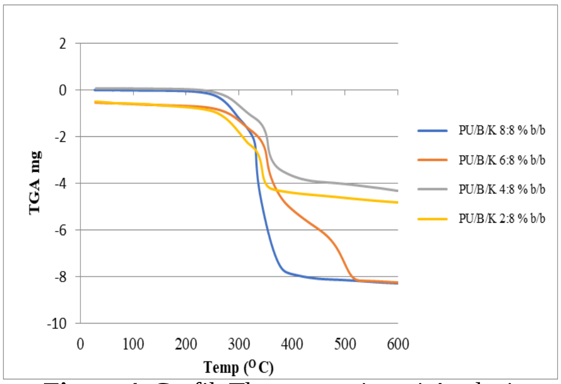


Figure 4. Grafik Thermogravimetri Analysis Polyurethane/Bentonite/Chitosan

Figure 4 can be seen that the more the concentration of chitosan bentonitee added, the higher the thermal produced by the polyurethane itself, In previous studies, thermal analysis of polyurethane has also been carried out by several researchers, such as polyurethane/clay (Rihayat et al., 2006, 2015; Zaimahwati et al., 2015). The graph shows that all Polyurethane/Bentonitee/Chitosan samples underwent single decomposition due to onset and endsets occurring only once. Onset is the temperature at which the sample begins to degrade thermally and the endpoint is the temperature at which the sample retains its mass from the combustion reaction. The degradation temperature of Polyurethane/Bentonitee/Chitosan in this study ranged from 250° C – 400°C. Based on graph.4, Pure Polyurethane begins to experience a mass decrease at a temperature of 75-135°C (Legiviani, 2018). Polyurethane with the addition of Bentonitee and Chitosan in the ratio of 8:8, 6:8, 4:8, and 2:8 began to degrade at a temperature of 307.04oC respectively; 303.29°C; 293.85°C and 293.09°C. The results show that the addition of Bentonitee and Chitosan in Polyurethane has succeeded in improving thermal stability compared to pure Polyurethane without mixing. Based on the principle of Thermogravimetric Analysis (TGA), the samples with the highest degradation (onset) and degraded (endset) temperatures are the samples with the best thermal stability (Yusuf et al., 2023). In this study, Polyurethane/Bentonitee 9%/Chitosan 9% is the sample that has the best thermal stability because it has the highest degradation temperature (onset) and degradation temperature (endset).

Morphological Structure Test with *Electron Microscopi* (SEM) Scanning Tool

SEM testing aims to support the best sample results which aims to support the best sample results taken from TGA test testing. The tested samples are the best samples with a Bentonitee variation of 8% :

8% chitosan and a sample with a Bentonitee variety of 2% : 8% Chitosan.

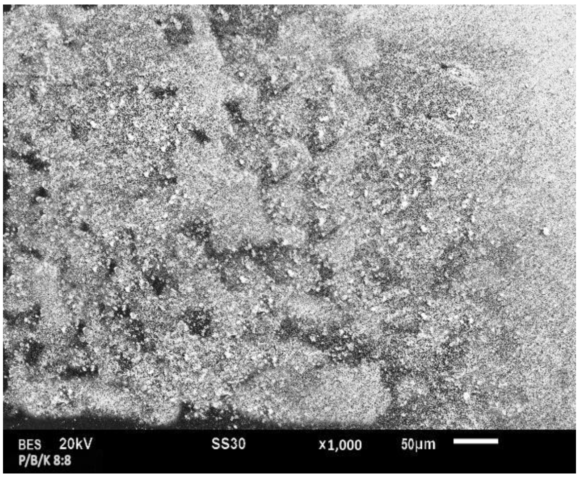


Figure 5. Results SEM Poliurhane/Bentonitee/Chitosan8:8% b/b

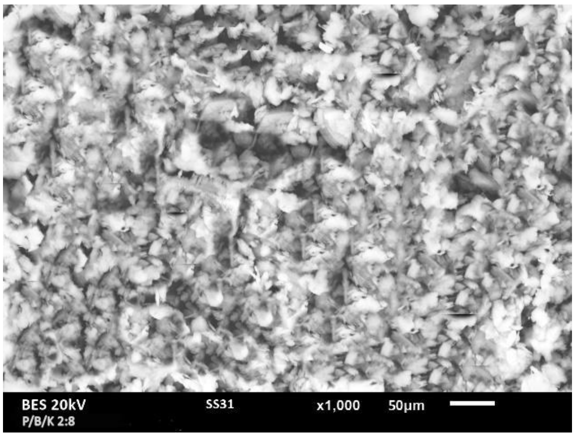


Figure 6. Results SEM Poliurhane/Bentonitee/Chitosan2:8% b/b

Testing using SEM tools showed that the chitosan chain was well dispersed into the bentonitee interlayer. The formation of composite flocculation can be attributed to the hydroxylation edge interaction of the silicate layer between the silicate hydroxylized edge group and the chitosan chain (Rihayat et al., 2019). Figure 5 shows the surface structure of the sample where chitosan contains a mixture of bentonitee and chitosan. The darker surface is an iron plate that has been applied with polyurethane with the addition of bentonitee-chitosan filler. Figure 6 shows that the sample is homogeneous and does not agglomerate. In the sample with a ratio of Polyurethane/Bentonitee/Chitosan 2:8 % b/b, it shows that the surface of the sample is not homogeneous where the sample shows several forms of aggregates that are clumped and have large pores, agglomeration occurs so that the surface of the sample appears uneven and rough.

Corrosion Test Result Data

Corrosion is the main thing that we want to review in this study. Corrosion tests were carried out to determine whether the variation in the amount of bentonitee and chitosan was able to minimize the occurrence of corrosion. Corrosion testing in this study uses the mass loss method to calculate the amount of mass reduced due to corrosion. In this study, the tested sample was directly contacted with the medium that caused corrosion, namely seawater, the sample to be tested was soaked in seawater for 21 days. The goal was to see if the steel plate that had been coated with the addition of variations in the amount of bentonitee-chitosan affected the rate of corrosion. The following is a graph of the effect of the comparison of the variation in the number of bentonitee-chitosan on the corrosion rate.

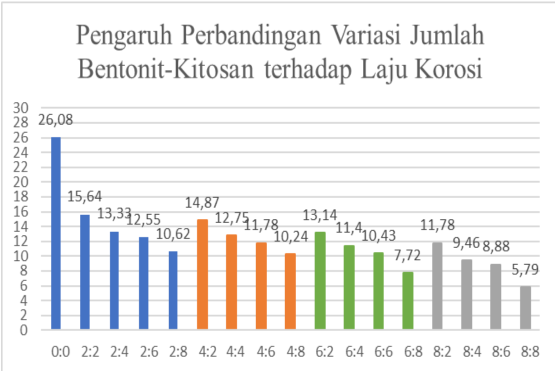


Figure 7. Comparison Chart of Variation in Bentonitee-Chitosan Amount to Corrosion Rate

From the graph above, it can be concluded that the amount of bentonitee-chitosan contained in polyurethane paint affects the rate of corrosion. The higher the amount of bentonitee-chitosan, the smaller the rate of corrosion. In this study, the largest mass loss was in the ratio of 2% Bentonitee : Chitosan 2% grams, which was 0.27 grams with a corrosion rate of 15.64 mpy. In the sample with a ratio of 8% Bentonitee : 8% Chitosan experienced a mass loss of at least 0.10 with a corrosion rate of 5.79 mpy. This shows that the increasing amount of bentonitee and chitosan contained in polyurethane is able to suppress the rate of corrosion on steel plates. Based on the corrosion resistance level table, all tested samples have a good level of corrosion resistance, where the corrosion rate in each sample is 5-50 mpy.

When compared to the corrosion rate of the specimen tested in the pure seawater medium of 26.08 mpy, the corrosion rate value is greater than that of 8% Polyurethane Bentonitee : Chitosan 8% with a corrosion rate of 5.79 mpy. From the results of the test, it can be concluded that the ChitosanBentonitee Polyurethane coating is able to reduce the corrosion rate when compared to Pure Polyurethane Coating. The use of Chitosan Bentonitee Polyurethane coating is able to prevent corrosion that occurs on the material. This will certainly affect the age of the material.

Paint Thickness Test Result Data

After going through the *sandblasting* process, the next process of painting the surface of the material is carried out using Chitosan Bentonitee Polyurethane paint. After painting, the Dry *Film Thickness* (DFT) measurement process is carried out, which is the thickness of the paint layer after drying that has been applied to the material. To analyze the measurement of the thickness of this paint, it was carried out using the *Coating Thickness tool*, and the following results were obtained.

Table 4. Dry Film Thickness *Measurement Results*

Bentonitee Weight (%)	Chitosan Weight (%)	Paint Thickness (µm)
0	0	80
2	2	83
	4	90.3
	6	92.7
	8	95.7
4	2	97
	4	96
	6	96.7
	8	97.7
6	2	96
	4	97
	6	96.3
	8	94
8	2	97.7
	4	97.7
	6	98
	8	104

In Table 4, the results of the Dry *Film Thickness* (DFT) measurement using *the Coating Thickness Tool* can be seen that the highest paint thickness value is found in 8% Bentonitee Polyurethane: Chitosan 8% with a value of 104 µm while the lowest thickness value is found in Pure Polyurethane with a value of 80 µm. This is because the surface that is formed is getting rougher so that it causes its thickness to increase, where in the painting process the thick and thin paint layer produced in the painting process depends on the surface roughness of the object. This occurs because it is influenced by the increase in the depth of the roughness of an iron as a result of the *sandblasting* process so that in deep roughness iron requires a lot of paint to close/flatten the pores of the surface.

The thickness of the paint layer affects the rate of corrosion, where the smaller the value, the better the protection (Kurniawan et al., 2015)(Iman et al., 2019). The test results show that the thicker the paint layer, the better the role of the paint as a barrier between the substrate and the environment (Das et al., 2017). However, keep in mind that too much paint thickness can also lead to problems such as greater corrosion rates, blistering, and wrinkling (Afandi, 2015). To find the optimal thickness of the paint layer to ensure good corrosion protection.

CONCLUSIONS

1. The best results were obtained from the composition of Polyurethane/Bentonitee/Chitosan 8:8 % b/b. This shows that the increasing amount of bentonitee and chitosan can improve *the reinforcement*, thermal stability and mechanical properties of *the coating* material. The FT-IR test shows the presence of N-H, C-H, C=O groups representing the functional groups of polyurethane (NHCOO-). In the *Thermogravimetric Analysis* (TGA) test, the sample experienced *single decomposition* and showed the best results in the Polyurethane/Bentonitee/Chitosan 8:8 % b/b sample where the sample began to degrade at a temperature of 307.04% (OC). SEM tests show that the chitosan chain is well dispersed into the bentonitee interlayer.
2. The corrosion test showed that the addition of bentonitee and chitosan affected the corrosion rate, the greater the composition of bentonitee and chitosan, which could reduce the corrosion rate. The sample with a Polyurethane/Bentonitee/Chitosan composition of 8:8 % b/b is the best sample where the sample experiences the smallest corrosion rate of 5.79 mpy and mass loss of 0.10 grams.
3. In the paint layer thickness test after the painting process of Polyurethane Bentonitee Chitosan showed variations between samples, with the highest thickness in Polyurethane Bentonitee 8%:Chitosan 8% (104 µm) and the lowest in Pure Polyurethane (80 µm). The roughness of the surface after sandblasting affects the required paint thickness. The thickness of the paint layer has a significant impact on corrosion protection, but keep in mind that excessive thickness can cause problems such as high corrosion rates, blistering, and wrinkling.

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