International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

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The effect of SiO_2 nanoparticles in polyurethane paint formulation on metal surfaces

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International Journal of Science and Research Archive, 2021, 03(01), 031–036

Publication history: Received on 11 June 2021; revised on 13 July 2021; accepted on 15 July 2021

Article DOI: https://doi.org/10.30574/ijsra.2021.3.1.0101

Abstract

Polyurethane (PU) paint is being widely used in industry and life. Currently, nanotechnology can create a variety of materials as small as nanometers with many applications, it has brought many outstanding properties to PU paint. The aim of this study is to investigate the effect of SiO_2 nanoparticles in PU paint formulation on metal surfaces. We created a sample of two-component PU paint, part A is Desmophen A-160, Bentone 34, BYK 066, Disper 710S, Foamex N, Airex 900, TiO_2, SiO_2 nanoparticles, $BaSO_4$, Cloparafin, Xylen, Thinner 132, Desmodur N75, and part B is a curing agent Desmodur N75. Methods of analyzing the properties of the PU paint film are based on Vietnam standards. The study results showed that SiO_2 nanoparticles have increased the properties of the PU paint film, improving the Impact and Glossy of the PU paint film. SiO_2 nanoparticles increase from 1% to 6% by weight, the Impact increased by about 21.62% (74 to 90 kg.cm), Glossy 60^0 increased by about 13.75% (80 to 91). SiO_2 nanoparticles are a good coating substance in PU paint, it improves the properties of the paint film, it increases the Impact and Glossy for the paint film. The higher the rate of SiO_2 nanoparticles, the better the properties of the PU paint film. Because the cost of nanomaterials is higher than that of normal coating materials, the nanomaterial should only be added with a ratio of about 2-4% by weight.

Keywords: Coating powder; Metal surface; Nanotechnology; Polyurethane paint; SiO_2 nanoparticles

1. Introduction

Polymers have become indispensable materials in recent years in the age of technology and science, it has a very important place in our daily lives. Polyurethanes (PU) are among the most useful polymers and are widely used both in industry and in consumer products [1, 2, 3]. Because of their special chemical structure, these materials have different properties such as varied hardness, excellent wear resistance, and good resistance to solvents, flexibility, and high strength. High compressive and tensile strength. Currently, PU has a very special position in the field of coatings [4, 5, 6].

PU paint is a 2 component paint, part A is a mixture of polyurethane resin, additives and solvents; part B is a curing agent. Today, before the strong development of nanotechnology, the coating field has made great progress. Nanotechnology is considered as one of the keys to open the technology of the future. Nanomaterials have been widely used to improve the properties of PU due to their small size. Nanotechnology has researched and applied particles smaller than 100 nanometers (nm) in at least one dimension, artificially produced nano-sized particles with new properties that are important for development of products in the field of coatings [7, 8, 9].

Currently, the coating industry is developing very strongly in both quantity and type of paint used in industry, aviation, ships and life. Nanomaterials are increasingly widely applied in the field of coatings such as epoxy paint, alkyd paint, acrylic paint, PU paint, it has made the paint film more durable to the impact of the environment, better than paint without nanomaterials [10, 11, 12]. There have been many research works on nanoparticle addition in PU coating, the

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incorporation of metal oxide nanoparticles such as nanoalumina, nanosilica, nano zinc oxide, nano titanium dioxide, clay, cellulose nanocrystals, etc. coatings to improve the properties of PU coating films [13, 14, 15, 16].

In a study by Yern Chee Ching and Nurehan Syamimie investigated PU coatings with nano-SiO_2 of about 16 nm in diameter. Friction and abrasion test is carried out using a piston wear tester, the wear surface of the coating film after the test is examined by optical microscope. The PU/nanosilica composite coating containing 3% by weight of nano-SiO_2 content provides the lowest coefficient of friction and wear rate to the substrate [17].

Our research group continues to investigate the addition of SiO_2 nanoparticles in PU paint to metal surfaces. The purpose of the study is to investigate the Impact and Glossy of nano SiO_2 on metal surfaces.

2. Material and methods

2.1. Materials

- **Desmophen A 160**

Desmophen A 160 is a polyacrylate resin bearing a hydroxyl group. It is used as a co-reactant in the formulation of two-component polyurethane coatings, Desmophen A 160 is also used in anti-corrosion coatings and coatings for steel.

- **Bentone 34**

Bentone 34 is a special clay mineral, it is a sodium-aluminum hydrosilicate. Bentone 34 is used to refer to natural stone, it is a very fine particle material that mainly consists of clay minerals.

- **BYK 066**

BYK 066 is defoamer for coatings, and ambient curing resin systems on the basis of PU resin.

- **Disper 710S**

Disper is an effective dispersant that disperses organic and inorganic additives in the paint to create a Gloss for paint film.

- **Foamex N**

Foamex N is effective against micro-foam in the stirring process.

- **Airex 900**

Airex 900 is a foam breaking agent, it breaks down bubbles formed in the process of grinding, mixing, to make the paint film glossy and smooth.

- **TiO_2**

TiO_2 is a compound with a high melting point (heat resistance), little chemical effect, abrasion resistance, large hardness but still remains stable, good plasticity, less cracking, TiO_2 has a high coverage, fine particles, good oil permeability and very durable under the effect of moist air, seawater. TiO_2 is not denatured over time, it is widely used in the paint industry.

- **SiO_2 nanoparticles**

The silica nanopowder has an average particle size of 20-60 nm. SiO_2 nanoparticles have small size, uniform distribution, high porosity, large specific surface area. It is used in paint production, which can greatly improve the toughness, wear resistance and aging resistance properties of the paint film.

- **$BaSO_4$**

Barium sulfate is an inorganic compound with the chemical formula $BaSO_4$, Density: 4.49 g/cm3. It is an odorless white crystalline substance and is insoluble in water. Barium sulfate is used as a pigment as a coloring additive for the paint industry, which can increase adhesion, keep the color bright, and not fade.

- **Cloparaffin**

Chlorinated Paraffin Oil is a clear or pale yellow liquid. Chlorine content: 51.7, Density (g/ml) at 25oC:1.26.

- **Xylene**

Xylene is a clear colorless liquid with a pleasant aroma. Auto-ignition temperature 500^{o}C. Density at 20^{o}C is 0.865-0.875 kg/l. This mixture is liquid, colorless.

- **Thinner 132**

Thinner 132 is a specialized mixed solvent product for dilution of two-component paints. It is combined from solvents with high solubility, medium volatility, it helps to add other outstanding properties such as waterproofing, anti-adhesion, anti-moss. It is a clear liquid, with a slight pungent odor of solvent, density 0.86 g/ml

- **Desmodur N75**

Desmodur N75 is soluble in esters, ketones and aromatic hydrocarbons such as ethyl acetate, butyl acetate, cyclohexanone, toluene, xylene. It is well compatible with the aforementioned solvents. Desmodur N75 is Desmophen A 160 resin curing agent.

2.2. Method of Blending PU Paint Samples

Table 1 Composition of PU paint formulations

No	Component	Raw materials	Uses	C 1 Wt. %	C 2 Wt. %	C 3 Wt. %	C 4 Wt. %	C 5 Wt. %	C 6 Wt. %	C 7 Wt. %
1	Component A	Desmophen A-160	Resin adhesion for paint	50	50	50	50	50	50	50
2		Bentone 34	Anti-sedimentation	0.3	0.3	0.3	0.3	0.3	0.3	0.3
3		BYK 066	Defoaming Additives	0.3	0.3	0.3	0.3	0.3	0.3	0.3
4		Disper 710S	Dispersant substance	0.4	0.4	0.4	0.4	0.4	0.4	0.4
5		Foamex N	Anti-foam	0.2	0.2	0.2	0.2	0.2	0.2	0.2
6		Airex 900	Foam breaking agent	0.3	0.3	0.3	0.3	0.3	0.3	0.3
7		TiO_2	Cover substance	18	17	16	15	14	13	12
8		SiO_2 nanoparticles	Cover substance	0	1	2	3	4	5	6
9		$BaSO_4$	Cover substance	2.5	2.5	2.5	2.5	2.5	2.5	2.5
10		Cloparafin	Plasticizer Additives, Chemical resistance	2	2	2	2	2	2	2
11		Xylen	Solvent	11	11	11	11	11	11	11
12		Thinner 132	Solvent	15	15	15	15	15	15	15

13	Component B	Desmodur N75	Solidifying agent	18	18	18	18	18	18	18
		Total		100	100	100	100	100	100	100

We have blended PU coating formulations C1, C2, C3, C4, C5, C6, C7 with the same composition and different on TiO_2 and SiO_2 nano coating materials. The composition of SiO_2 nanoparticles in the above formulas increased from 1-6% by weight (Table 1).

2.3. Method of Creating PU Paint Film

To evaluate the effect of SiO_2 nanoparticles in PU paint formulation on metal surfaces we applied paint samples to metal surfaces. Each sample PU paint formulation was painted on 12 metal sheets measuring 70x150 mm and 0.5 mm thick with the same film thickness. We created a variety of patterns to then choose from. The paint film is created based on the Doctor Blade technique. A common tool for creating coatings in the lab is the manual film forming machine. We used manual scissors model BGD 201/5 with size 100 µm from manufacturer Biuged. It is made of stainless steel with 2% accuracy, easy to use, produces a relatively uniform paint film.

2.4. Methods of Analysis

The drying time of the paint film is determined according to Vietnam Standard TCVN [22]. The coverage of dry paint film is determined according to Vietnam Standard TCVN [23]. The Gloss 60^0 is determined according to Vietnam Standard TCVN [24]. The Impact is determined according to Vietnam Standard TCVN [25].

3. Results and discussion

Table 2 Properties of PU paint

No	Properties	Unit	C 1	C 2	C 3	C 4	C 5	C6	C 7
1	Face dry time	minutes	40	40	40	40	40	40	40
2	Natural drying time	hours	12	12	12	12	12	12	12
3	Density 30^0C		1.19	1.19	1.19	1.19	1.19	1.19	1.19
4	Smoothly	µm	25	25	25	25	25	25	25
5	Impact level	kg.cm	74	76	80	84	87	89	90
6	Coverage of dry paint film	g / m^2	111	111	111	111	111	111	111
7	Glossy 60^0		80	81	84	87	89	90	91

The data in Table 2 show that with increasing concentration of SiO_2 nanoparticles, the degree of Impact also increases. Impact of PU paint formulations 1 to 7 rapidly increased from 74 - 90 kg. cm when increasing the proportion of SiO_2 nanoparticles from 1 to 6% by weight. Without adding SiO_2 nanoparticles, Impact of C1 was 74 kg.cm, adding 1% of SiO_2 nanoparticles, Impact of C2 increased by 2.70%, adding 2% of SiO_2 nanoparticles, Impact of C3 increased by 8.11%, adding 3% of SiO_2 nanoparticles, Impact of C4 increased by 13.51%, adding 4% of SiO_2 nanoparticles, Impact of C5 increased by 17.56%, adding 5% of SiO_2 nanoparticles. Impact of C6 increased by 20.27%, adding 6% of SiO_2 nanoparticles, Impact of SiO_2 nanoparticles C7 increased by 21.62%. Thus, the Impact index increased rapidly when SiO_2 nanoparticles were added from 2 to 4% by weight.

The data in Table 2 show that as the concentration of SiO_2 nanoparticles increases, Glossy also increases. Glossy 60^0 of PU paint formulations 1 to formula 7 increased from 80 to 91. Without adding SiO_2 nanoparticles, Glossy 60^0 of C1 was 80, adding 1% of SiO_2 nanoparticles, Glossy 60^0 of C2 increased by 1.25%, adding 2% of SiO_2 nanoparticles, Glossy 60^0 of C3 increased by 5.00%, adding 3% of SiO_2 nanoparticles, Glossy 60^0 of C4 increased by 8.75%, adding 4% of TiO_2 nanoparticles, Glossy 60^0 of C5 increased by 11.25%, adding 5% of SiO_2 nanoparticles, Glossy 60^0 of C6 increased by 12.50%, adding 6% of SiO_2 nanoparticles, Glossy 60^0 of C7 increased by 13.75%. Thus, the Glossy 60^0 index increased rapidly when SiO_2 nanoparticles were added from 2 to 4% by weight.

The data in Table 2 show that when increasing the concentration of SiO_2 nanoparticles, the Impact level and Glossy 60^0 of the PU coating film also increase. This can explain that SiO_2 nanoparticles are very small and fine, so they create Glossy on the metal surface. This issue has also been raised in some previous studies on nano coatings in paints. SiO_2 nanoparticles are oxide nanostructured particles with spherical or multifaceted high surface areas. SiO_2 nanoparticles are SiO_2 particles with a molecular size smaller than 100 nm. SiO_2 nanoparticles have the advantages of low density, thermal stability, mechanical stability, and inertness. Particle size plays a very important role in the application of silica nanomaterials to PU coatings. SiO_2 nanoparticles have porosity so the surface area is large, so SiO_2 nanoparticles are easy to adsorb. SiO_2 nanoparticles are insoluble in water and any solvents, non-toxic, odorless. SiO_2 nanoparticles are very chemically inert, it does not react with Oxygen, Chlorine, Bromine, and acids even when heated.

Incorporation of nanoparticles into PU paint is a solution to enhance coating durability as fine particles dispersed in the coating can fill the voids, reducing the porosity of the paint film. Nanoparticles can also prevent PU separation during curing, making the coating more uniform. Nanoparticles tend to reduce pore defects as a result of local shrinkage during PU curing. In addition, PU coatings containing nanoparticles will protect against corrosion and reduce the tendency of the coating to blister or delamination

4. Conclusion

SiO_2 nanoparticles are a good coating substance in PU paint, it improves the properties of the paint film, and it increases the Impact and Glossy for the paint film. We found that only 2-4% by weight of SiO_2 nanoparticles should be added to PU paint because the cost of SiO_2 nanoparticles is higher than that of conventional coating materials.

Compliance with ethical standards

Acknowledgments

The authors would like to thank Mr. Nguyen Huy Tong, former President of Vietnam Paint and Ink Association.

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