ADHESION OF EPOXY PAINT AND POLYURETHANE PAINT BY THE PULL-OFF METHOD

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ABSTRACT

This article presents the results of testing the adhesion between epoxy coatings, with polyurethane coating and steel substrates by the pull-off method. The paint systems tested for adhesion are: Galvanite No.400 primer (white), Univan MIO (brown), Umerguard HS (grey, red brown), Uny marine HS (grey CS-615), Epicon primer HB (brown), Permax No.3000S (grey, red brown). The measurement method used is the pull-off method to evaluate the adhesion between paint coatings. The results showed that the adhesion of epoxy coating system reached the value of 10.48 MPa. With polyurethane paint system, the adhesion reaches 8.60 MPa. These epoxy and polyurethene coatings systems meet the criterion of adhesion, which is an important criterion for the systems to continue to be included in the accelerated test to evaluate the life of epoxy coating and polyurethane coating according to ISO 12944-6:2018(E). Accelerated testing has shown that the criteria for bilstering, rusting, cracking, flaking and chalking have met the requiements according to ISO 12944-9:2018.

ĐỘ BÁM DÍNH CỦA SƠN EPOXY VÀ SƠN POLYURETHANE THEO PHƯƠNG PHÁP KÉO PULL-OFF

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TỪ KHÓA

Sơn hàng hải
Lớp phủ epoxy
Lớp phủ polyurethane
Kiểm tra bám dính
Phương pháp kéo pull-off

TÓM TẮT

Bài báo trình bày kết quả khảo sát độ bám dính của một số hệ sơn epoxy với nhau, với sơn polyurethane và với nền thép bằng phương pháp kéo pull-off. Các hệ sơn được khảo sát độ bền bám dính là: Galvanite No.400 primer (white), Univan MIO (brown), Umerguard HS (grey, red brown), Uny marine HS (grey CS-615), Epicon primer HB (brown), Permax No.3000S (grey, red brown). Phương pháp đo được sử dụng là phương pháp kéo pull-off để đánh giá mức độ bám dính giữa các lớp sơn phủ. Kết quả nghiên cứu cho thấy, độ bám dính của hệ sơn epoxy đạt giá trị 10,48 MPa. Với hệ sơn polyurethane độ bám dính đạt 8,60 MPa. Các hệ sơn epoxy và polyurethane này đáp ứng chỉ tiêu về độ bám dính, đây là tiêu chí quan trọng để tiếp tục được đưa vào thử nghiệm gia tốc đánh giá tuổi thọ của sơn epoxy và sơn polyurethane theo ISO 12944-6:2018(E). Thử nghiệm gia tốc cho thấy, các chỉ tiêu về độ phồng rộp, độ gỉ, độ rạn nứt, độ bong tróc và độ phấn hóa đáp ứng yêu cầu theo ISO 12944-9:2018.

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1. Introduction

Vietnam is located in a humid tropical climate, so protection against metal corrosion is extremely inportant. In the face of complicated developments of global climate change, in addition, structural works operating in the marine environment should prevent corrosion for these materials becoming more and more urgent. Nowadays, coatings to protect against corrosion of metals and alloys against the adverse effects of extreme climatic conditions and corrosive seawater environments are an effective solution [1]. Effective protection, preventing corrosive agents from seawater for each coating is demonstrated through the ability to create a tight coating and ability to adhere to the parts to be protected as well as compatibility, adhesion between coating layers together. The adhesion between the primer and the surface of the part is improved because the surface is cleaned and the choice of a primer system that has good adhesion to these part surfaces, as well as the adhesion of the part top coats with primer. With superior properties of adhesion, durability in seawater, resistance to chemical enviroments, etc., epoxy paint systems are widely and effectively used to cover the structural steel surfaces of marine, island and coastal [1] – [3].

To evaluate the above adhesion ability, pull-off test is the most effective assessment method. The results of the test allow to evaluate the adhesion of the coatings and the usability of the coating under certain conditions [2] – [6]. From the pull-off results and image analysis of area surface after pulling and removing, it is possible to make judgments about the correlation between the adhesion forces between epoxy coatings, between epoxy coatings and the steel substrate surface and between the epoxy coating and the adhesive layer [4]. The surface of the material sample after performing the pull-off is depicted on figure 1a, figure 1b and figure 2.

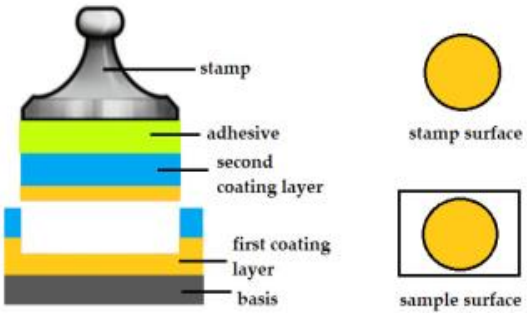


Figure 1a. *The bond is pulled apart at the first coating layer* [4]

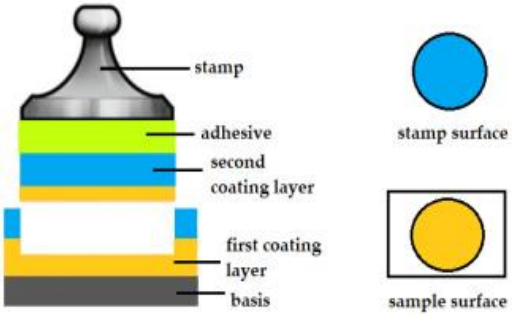


Figure 1b. *The bond is pulled apart at the second coating layer* [4]

If the adhesion between the glue layer and the dolly surface is not good, damage will occur on the surface of the glue layer (figure 2).

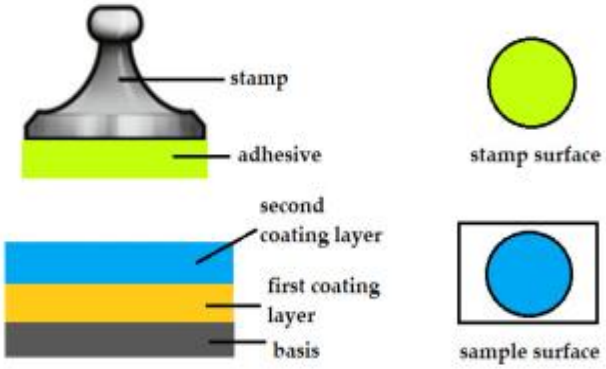


Figure 2. *The surface is destroyed at the glue layer* [4]

This study evaluates the adhesion of epoxy and polyurethane coating systems, and examines the surface morphology of the damaged coating by the pull-off method.

2. Experienctal procedure

2.1. Materials system

Epoxy paints and polyuretane paint (Petro Vietnam paint join stock company - PV paint) [7]: Galvanite No.400 primer (write), Univan MIO (brown), Umerguard HS (grey), Umerguard HS (red brown), Uny marine HS (grey CS-615), Epicon primer HB (brown), Permax No.3000S (grey), Permax No.3000S (red brown). Properties of epoxy paints and polyurethane paint are summarized in table 1; two components special epoxy glue (epoxy glue 611, Vietnam), acetone AR (Xilong, China).

Analytical digital balances AUY220 (Shimadzu, Japan),

Paint gun Lanest (Iwata, Japan),

Steel plate CT3 (150 x 75 x 2 mm),

Glass beaker, glass chopstick (Duran, Germany).

Table 1. *Technical data sheet of epoxy paints and polyurethane paint* [7]

Paint names	Mixing ratio Base:hardener (by volume)	Density, g/mL	Volume solids, %
Galvanite No.400 primer (Two component polyamide cured epoxy)	70 : 30	1.33 ± 0.05	47 ± 2
Univan MIO (Two component polyamide cured MIO (micaceous iron oxide) pigmented epoxy)	75 : 25	1.60 ± 0.05	80 ± 2
Umerguard HS (Mastic epoxy modified)	85 : 15	1.47 ± 0.05	90 ± 2
Uny marine HS (Polyurethane finish paint)	77 : 23	-	57 ± 2
Epicon primer HB (Two component epoxy with zinc phosphate)	73 : 27	1.20 ± 0.05	57 ± 2
Permax No.3000S (Two component epoxy reinforced with glass flake)	80 : 20	1.33 ± 0.05	92 ± 2

2.2. Research method

Preparing samples

Coating layers are sprayed onto the surface of CT3 steel plates in the order of layers and thickness for each layer in table 2.

Table 2. *Dry film thickness of coatings sample*

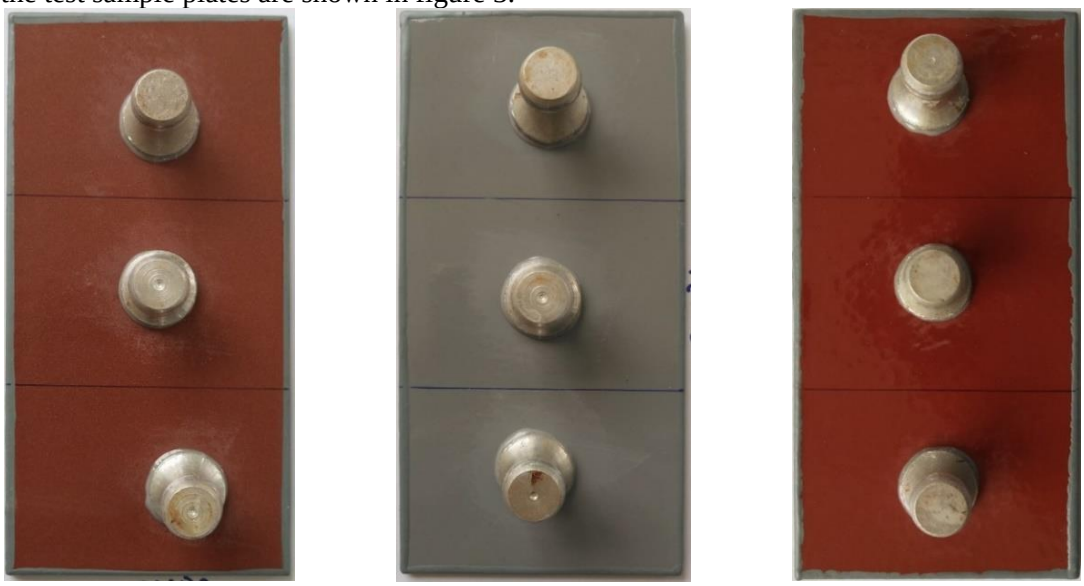
Sign of sample	Paint layer	Thickness, µm
TMP1	Galvanite No.400 primer (write)	50
	Univan MIO (brown)	200
TMP2	Umerguard HS (grey)	150
	Umerguard HS (red brown)	150
	Uny marine HS (grey CS-615)	50
TMP3	Epicon primer HB (brown)	50
	Permax No.3000S (grey)	400
	Permax No.3000S (red brown)	400

Coatings are sprayed at least 24 hours apart. Natural drying time after 7 days, then detemine the adhesion.

The adhesion of coatings is determined according to ISO 16276-1:2007(E) [8].

Preparing test samples

The surface of the coating is lightly abraded to enhance the adhesion of glue layer to the surface, wipe with acetone. Use epoxy glue 611 to link dolly to the sample plate surface. Images of the test sample plates are shown in figure 3.



Sample TMP1 *Sample TMP1* *Sample TMP3*

Figure 3. *Image of the test sample plates*

Test method

The adhesion of coating by the pull-off method was the PosiTest AT-A pull-off device (DeFelsko Corporation, USA). According to ISO 4624:2016 [9], the PosiTest AT-A device evaluates the peel strength of a coating by determining the highest tensile force it can withstand before rupture. A dolly with 20 mm outside diameter was used. The instrument gives a choice of units such as MPa, N, psi or N/mm^2 [10]-[13]. In this assessment and the results of report the unit MPa was chosen. Pulling speed is 1.0 MPa/s. The device and the dolly are illustrated in the figure 4.

The adhesion test is carried out at temperatures in the range of 20 ^{o}C to 25 ^{o}C and humidity from 60 % to 80 %.

(a) *(b)*

Figure 4. *Pull-off device (a) and dolly (b)*

3. Results and discussion

The image of joint destruction after pull-off showed that the bond is separated in the first coating, second coating or glue layer. The results are evaluated by the adhesion force value and by the visual assessment of the surface of the coating being broken and detached.

3.1. Assessment of adhesion

The results of determining the adhesion of the paint film are summarized in table 3.

Table 3. *Adhesion of coatings*

	Paint sample					
	TMP1		**TMP2**		**TMP3**	
Test results, MPa	9.22	9.30	8.66	8.53	10.30	10.65
Average pull value, MPa	-		8.60		10.48	

The results determined in table 3 show that epoxy coatings (sample TMP3, figure 5b) have higher adhesion forces than the adhesion of epoxy coating with polyurethane coating (sample TMP2, figure 5a).

3.2. Evaluation of the surface destruction of coatings

The surface image of the fracture types after tensile dissection is divided into 3 cases as follows:

First case: Destruction of the bond during pull-off occurs on the primer applied directly to the steel plate surface (first layer), which is the case with sample TMP2 (figure 5a).

Second case: Destruction on the topcoat (second or third coating) when pull-off test is due to the adhesion strength of the second or third coating of glue being less than the adhesion strength to the surface of the first coating or with glue layer. This case has happened with sample TMP3.

Figure 5a. *Image of destruction on first coating (sample TMP2)*

Figure 5b. *Image of destruction on second coating (sample TMP3)*

Figure 5c. *Image of destruction on glue layer (sample TMP1)*

Third case: An adhesion error occurred between the dolly and the topcoat (sample TMP1). This error is caused by the adhesion layer having small adhesion strength. In this test, epoxy glue 611 was used. This adhesion error can be overcome by substituting a suitable adhesive with a bond strength greater than that of the test coating. The image of the surface of the sample plate after pulling the pull-off due to adhesion failure is shown in figure 5c.

3.3. Assessment of coating durability by acceleration test

In addition, this work evaluated the coating durability by acceleration test according to ISO 12944-9:2018 after 4200 h exposure testing (25 aging cycles). The evaluation results are shown in table 4.

Table 4. *Assessment after 4200 h exposure testing*

	Sign of sample		
	TMP1	**TMP2**	**TMP3**
Blistering	0 (S0)	0 (S0)	0 (S0)
Rusting	Ri 0	Ri 0	Ri 0
Cracking	0 (S0)	0 (S0)	0 (S0)
Flaking	0 (S0)	0 (S0)	0 (S0)
Chalking	1	1	1

4. Conclusions

The adhesion test of the paint film by pull-off method to evaluate the adhesion strength of coatings to metal surfaces, the method also provides values for peeling stress, and makes it easy to compare the adhesion between coatings through assessment of the specimen surface after failure. However, factors such as the surface of the steel sample plate, the surface of the dolly, the type of glue, etc. affecting the adhesion to be studied. The results of determination of adhesion by pull-off method for epoxy paints and polyurethane which were made by PV paint reached the value for the test according to ISO 12944-6:2018(E).

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