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Study on anticorrosion properties of epoxy primers on steel

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Abstract

Epoxy resin DER 671X75 was reinforced by nanoclay cloisite 30B with content of 2% and primer coatings based on epoxy resin DER 671X75 were formed with pigments, fillers. Epoxy coating films were exposed by electrochemical method in NaCl 3.5 % solution in 28 days and salt spray accelerated tester in 330 hrs. The results show that nanoclay cloisite 30B are improved anticorrosion properties of primer coatings based on epoxy resin DER671X75.

Keywords. Epoxy primer coating, nanoclay cloisite 30B, epoxy resin DER 671X75, electrochemical, anticorrosion properties steel.

1. INTRODUCTION

Corrosion of steel structure caused calamitous consequences to the economy. To protect steel from corrosion, coating systems based on epoxy, polyurethane and polyurea binders have been used. Polyurea resins possess excellent properties such as mechanical durability, anticorrosion and weather resistances [1-3]. Recently, special additives as nanosilica and nanoclay were studied to improve physical and mechanical properties of composites and coating [4-7].

Studies on primer coating based on epoxy resin DER 671X75 with pigment/fillers and nanoclay cloisite 30B have not seen on publication.

This paper has shown the effects of nanoclay cloisite 30B to mechanical properties and anticorrosion properties of primer coatings based on epoxy resin DER 671X75.

2. EXPERIMENTAL

2.1. Materials

Epoxy resin DER 671X75 (Dow Chemicals): epoxy equivalent weight (EEW) 430-480 g/eq, content of epoxy group 9-10 wt %, viscosity at 25 ^{o}C 7500-11500 mPa.s, non-volatile content: 74-76 %.

Hardener polyamide Epicure 3125 (Hexion): amine number 330-360 mgKOH/g, amine hydro equivalent weight (AHEW) 127 g/eq, viscosity at 40 ^{o}C 8000-12000 cP.

Nanoclay 30B (Cloisite 30B-Southern Clay Products), d_{001} = 18.5 Å.

Xylene, toluene, acetone (China).

Pigment oxide iron (China), zinc phosphate (France), talc filler (Taiwan), zinc cromate (China).

Additives: disperser Crayvallac super (France), plastilizer dioctylphtalate DOP (China), Troysperse CD1(Thailand).

NaCl (China). Distillation water.

2.2. Preparation of samples

2.2.1. Dispersing method for nanoclay cloisite 30B in epoxy resin DER 671X75

Nanoclay cloisite 30B was dispersed in epoxy resin DER 671X75 according to work [9]: mechanical stirring at speed 2000 rpm for 35 hrs or mechanical stirring at speed 1000 rpm for 15 mins followed by ultrasonic vibration for 40 mins.

2.2.2. Preparation of epoxy coating primer samples

Firstly, epoxy resin DER 671X75 is reinforced with 2 wt % nanoclay cloisite 30B according to 2.2.1.

The method of ball grinding was used for 8 hrs to disperse components in coatings.

Components of primer coatings based on epoxy resin DER 671X75 and pigment/filler are shown in table 1.

Pigment/filler: iron oxide (O)/zinc cromate (C)/talc (T) (sign:OCT) and iron oxide (O)/zinc phosphate (P)/talc (T) (sign: OPT) with O/C/T = 50/40/10 (wt/wt/wt) and O/P/T = 50/40/10 (wt/wt/wt).

Table 1: Components of epoxy primer coating

Sample	Component	Note
P1	Epoxy resin DER 671X75, OCT, Crayvallac super, DOP, Troysperse CD1, toluene, xylene, acetone	DER 671/OCT =40/70 (wt/wt)
P2	Epoxy resin DER 671X75, OPT, Crayvallac super, DOP, Troysperse CD1, toluene, xylene, acetone	DER 671/OPT =40/60 (wt/wt)
P3	Epoxy resin DER 671X75, nanoclay cloisite 30B, OCT, Crayvallac super, DOP, Troysperse CD1, toluene, xylene, acetone, nanoclay cloisite 30B (2%)	DER 671/OCT =40/70 (wt/wt)
P4	Epoxy resin DER 671X75, nanoclay cloisite 30B, OPT, Crayvallac super, DOP, Troysperse CD1, toluene, xylene, acetone, nanoclay cloisite 30B (2%)	DER 671/OPT = 40/60 (wt/wt)

2.2.3. Preparation of epoxy primer coating samples to determine mechanical properties

Carbon steel samples were cut and prepared according to standard, treated surface by mechanical method, wiped out by acetone and dried. Epoxy resin DER 671X75 was cured by hardener Epicure 3125 with weight ratio: Epoxy resin DER 671X75/epicure 3125 = 100/35 [8]. Preparation of coatings is carried out by rolling method and dry film thickness is 50-60 µm.

2.3. Standards for determination of mechanical properties of coating films

Flexibility of coating films ISO 1519:2002 (TCVN 2099:2007), Erichsen, model 266.

Impact of coating films ISO 6272:2002 (TCVN 2100-1:2007), Erichsen, model 304.

Abrasion of coating films ASTM 7027, method Clement, Erichsen, model 239/II.

Adhesive of coating films ASTM D3359-93, Erichsen, model 295 (TCVN 2097:1993).

Pencil hardness of coating films JIS K5400-90.

Dry film thickness ASTM D1005 (TCVN 9406:2012), Erichsen, model 296.

2.4. Electrochemical method

Electrochemical method was used to evaluate corrosion process of steel according to standard ASTM G5-94, G102-189 and G106-89 on Biologic Equipment Model VMP3B-5. Results were processed by EC-lab software.

2.5. Method of salt spray accelarated test

The coated steel samples were exposed by salt spray accelerated test in salt spray box Corrosionbox (Model CRBX-1000E-H) under standard ASTM B-117 in 330 hrs and were evaluated results according to standard ASTM D 1654-61.

Test conditions:

Temperature in salt spray box: 35 ^{o}C

Humidity: 98-99 %

Content of NaCl solution (wt %): 5±1 %

pH of NaCl solution (35 ^{o}C): 6.5-7.2

Air spray pressure: 0.9-1.0 bar.

3. RESULTS AND DISCUSSION

3.1. Mechanical properties of epoxy coating films

Mechanical properties of epoxy coating films are shown in table 2.

Results from table 2 show that mechanical properties of coating samples respond to requirements of standard TCVN 8789-2011. However, impact strength of epoxy coating films P3 and P4 that were reinforced by 2 wt% nanoclay cloisite 30B are lower than impact strength of epoxy coating films P1 and P2 with the same weight ratio between resin and pigment, filler. These results prove role of nanoclay is a filler to increase hardness of coating films and decrease impact strength.

Table 2: Mechanical properties of epoxy coating films

Sample	Impact strength (kg.cm)	Flexibility (mm)	Pencil hardness	Abrasion (N)	Adhesive
P1	72.5	2	3H	2	5B
P2	50	2	3H	2	5B
P3	50	2	3H	2	5B
P4	45	2	3H	2	5B

3.2. Evaluation of corrosion processing by electrochemical method

3.2.1. Method of measuring open circuit potential (OCP)

Coated steel panels with epoxy coating films P1, P2, P3, P4 were tested corrosion in NaCl 3,5wt% solution in 28 days. Results of measuring open circuit potential (OCP) of coated epoxy steel panels by Tafel extrapolate method are shown in figure 1.

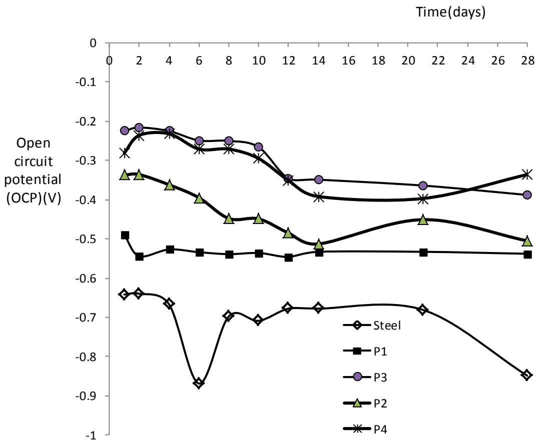

Figure 1: Open circuit potential (OCP) of coated epoxy steel panels

Results in figure 1 realize that open circuit potential (OCP) of coated epoxy coating steel P3 and P4 are bigger than OCP of P1 and P2. So, epoxy coatings P3 and P4 are reinforced 2 wt% nanoclay cloisite 30B which inhibited corrosion process and improved ability of protection steel. Open circuit potential (OCP) is arranged according to descending order: coated epoxy coating steel panel P3, P4, P2, P1, steel. Ability of protection anticorrosion steel are also arranged according to descending order: coated epoxy steel panel P3, P4, P2, P1, steel

3.2.2. Method of measuring resistance polarization

Density of corroded current (i-corrosion (mA/cm^2)) of coated epoxy steel panels P1, P2, P3, P4 were measured by measuring resistance polarization in 28 days, results are shown in figure 2.

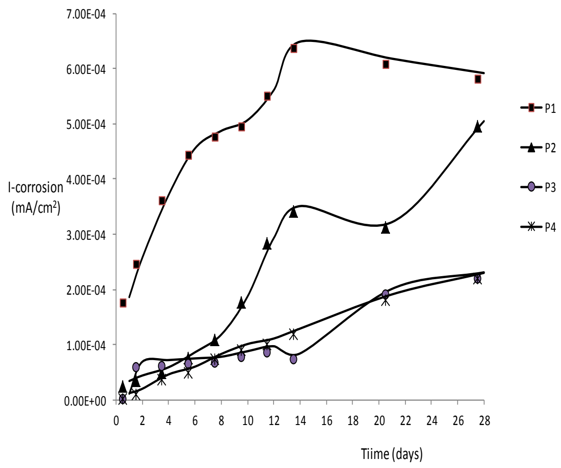

Figure 2: Density of corroded current (i-corrosion) of coated epoxy steel panels

From figure 2, realizing that density of corroded current (i-corrosion(mA/cm^2)) of coated epoxy coating steel in NaCl 3,5 wt% are arranged according to descending order: coated epoxy coating steel panel P1, P2, P4, P3. Those results are suitable with method of measuring open circuit potential.

3.2.3. Method of measuring electrochemical impedance spectroscopy (EIS)

Electrochemical impedance of coating films was measured by method electrochemical impedance spectroscopy (EIS). Results are shown in figures 3 and 4.

From figure 3, realizing that impedance of coating films P2 are descending and bigger than impedance of coating film P1. Those results demonstrates that ability for protection anticorrosion steel of pigment/filler OPT (epoxy P2) are better than pigment/filler OCT (epoxy P1).

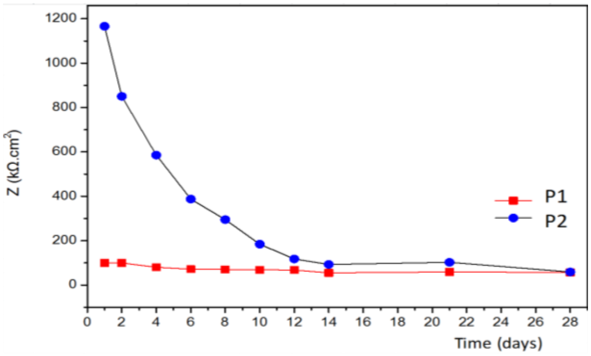

Figure 3: Impedance of epoxy coating films P1 and P2

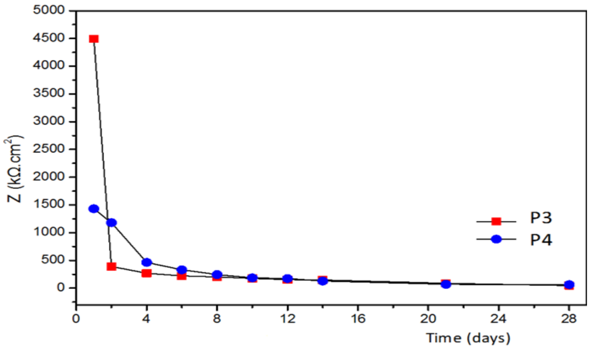

Figure 4: Impedance of epoxy coating films P3 and P4

From figure 4, showing that impedance of epoxy coating films P3 and P4 are descended according to time test. Because of flaws inside coatings films, NaCl solution diffuses into films, causes corrosion steel. Impedance of epoxy coating films P3 and P4 are not remarkable difference.

3.3. Salt spray accelerated test of coatings films

Results of salt spray accelerated test of epoxy coating films in 330 hrs were shown in table 3 and figure 5.

Table 3: Results of salt spray accelerated test of epoxy coating films

Sample	Score			
	0	100 hrs	200 hrs	330 hrs
P1	5	5	3	2
P2	5	5	4	3
P3	5	5	4	3
P4	5	5	4	3

(a) epoxy primer P1

(b) epoxy primer P2

(c) epoxy primer P3

(d) epoxy primer P4

Figure 5: Pictures of salt spray accelerated test of epoxy primers in 330 hrs

Results from table 3 realize that, after 100 hr test of salt spray accelerated, epoxy coating films do not appear signal corroded at slitting position and score at 5. At slitting position begin to appear rust after 200 hrs test of salt spray accelerated, score of coating epoxy film P1 descending to 3 while coating film P2, P3, P1 goal at 4. After 330hr test, coating films appear bigger rust, more blister at cutting place and score at 2, while coating films P2, P3 and P4 have smaller rust, less blister score at 3. Those results prove that nanoclay cloisite 30B with 2wt% has improved ability of protecting anticorrosion steel of epoxy coating films DER 671X75.

4. CONCLUSIONS

Anticorrosion properties of epoxy coatings based on epoxy resin DER 671X75 with pigment/filler OPT (P2 sample) were better than pigment/filler OCT (P1 sample).

Anticorrosion properties of coating films epoxy DER 671X75 with pigment/filler OCT, OPT were reinforced by 2 wt% nanoclay cloisite 30B were better than coating films epoxy DER 671X75 with pigment/filler OCT, OPT without nanoclay closite 30B.

Anticorrosion properties to protect steel were not remarkable difference between epoxy primers DER 671X75/OCT/2% nanoclay cloisite 30B and epoxy DER 671X75/OPT/2% nanoclay cloisite 30B.

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