Studies on corrosion resistant properties of sacrificial primed IPN coating systems in comparison with epoxy–PU systems

SM. Krishnan

Central Electrochemical Research Institute, Karaikudi 630 006, India

Abstract

The continuous development in the field of protective coatings and the search for newer materials with improved properties have led to the emergence of interpenetrating polymer networks (IPNs) as binders for high performance organic coatings for corrosion protection. In this study, one such ambient curing IPN polymer alloy poly(epoxy–urethane–acrylate) developed specially for use in protective coatings has been studied. Undercoat and a topcoat based on the alloy have been formulated and coated over zinc ethyl silicate primed steel surfaces. Similar formulations based on an epoxy polyamide undercoat and a PU topcoat has been formulated and coated over zinc ethyl silicate primed steel surfaces. Both the systems were evaluated for their physical and corrosion resistant properties by subjecting them to accelerated laboratory tests and field test at a corrosive location. The results are reported and conclusions drawn in this paper.
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1. Introduction

Among the various methods used for surface modifications of metals, the use of organic coatings takes the privilege of covering around 85% of the metallic surfaces in the world either for corrosion protection or for decoration or both [1,2]. As the performance of any organic coating should invariably rely upon the type and nature of the film-forming polymer, the search for still better performing polymers is always there. Blending of polymers has been in practice in the industry for a very long time and the type of blending of polymers after the polymerization of the constituent polymers resulted only in marginal improvement of the properties of the blend. But the recent development in the field is the emergence of a new kind of polymer class known as interpenetrating polymer networks (IPN), which is a novel type of polymer alloy, in which two or more incompatible polymers are alloyed or made compatible by a special kind of synthetic procedure. These IPNs exhibit synergistic properties of the constituent polymers from which they are made. The maneuverability of the IPNs allow the formulator to manipulate the composition and other factors of the constituent polymers to arrive at tailor made products to suit a specific requirement,

which can be considered as a major advantage in the field of polymer development. IPNs are the resultant products of an attempt of compatibilization of two or more immiscible polymers to achieve a compatibilized polymer alloy [3–13].

The main advantages of these IPNs are that they are relatively not easily affected by external stresses (which happen to polymer blends where the component polymers are not compatibilized due to simple physical mixing). The IPNs also possess improved properties than two chemically dissimilar homo/neat polymers. The end properties of the IPNs can be tailor made to suit any anticipated conditions [10–13].

The present study, examines the feasibility of using ambient curing IPNs synthesized out of the existing polymer components to develop paints for providing better corrosion resistance, chemical resistance and improved mechanical properties.

In this study, formulations were developed based on one full IPN of poly(epoxy–urethane–acrylate) alloy which was already developed by the author and his co-workers as an ambient curing binder material for protective coatings. In order to establish its suitability as a binder, paints were made and studies were conducted on their physical properties as per standard procedures and the properties were optimized and reported.

The corrosion resistant properties of the coatings were studied by subjecting the coated panels to accelerated laboratory tests and also to field exposure tests in a severely corrosive location.

E-mail address: fiftysmk@yahoo.com.

Performance of this system was compared with similarly formulated conventional epoxy and polyurethane systems and results are reported and discussed.

2. Experimental

In today's protective coating scenario, a coating system consisting of a sacrificial zinc ethyl silicate primer with an epoxy-MIO undercoat and an aliphatic polyurethane topcoat is supposed to be one of the best performing systems for atmospheric corrosion service. It was intended to design a coating system similar to this based on IPN polymer alloy as the binder in order to compare the performance of both the systems. So the following multi-coat systems were designed and codified as shown in Table 1. The table clearly shows each system of paint with the corresponding individual component paints constituting the paint system.

In the nomenclature, the first letter refers to the type of binder used, such as A for polymer alloy and E for epoxy based system. The second letter, digit, refers to the number of coats and S indicates silicate primer. Here, E3S is the conventional system used and A3S is a similar 3-coat system with an MIO undercoat whereas A2S is a 2-coat system without an undercoat. This is done to ascertain the level of performance of the system without an undercoat. In case A2S and E3S give equal performance the former will be a cheaper and economic alternative to the later E3S system which is one of the widely used expensive systems today. This is the logic behind choosing the systems for comparison.

The three types of polymeric binder systems used in the study are described below.

2.1. IPN polymer alloy (synthesised)

The IPN polymer alloy used in this study is a poly-(epoxy–urethane–acrylate) alloy, which is an alloy of epoxy and acrylic polyurethane systems. The synthesis of the alloy consisted of two steps viz. synthesis of epoxy–acrylate precursor (EAP) and urethane prepolymer (UPP) and then mixing them for forming the IPN alloy. In the epoxy–acrylate precursor, the ratio of epoxy to acrylate optimized by earlier studies was 50:50 [14]. The EAP was synthesised using sequential polymerization technique. Likewise, the cross-linker UPP was also synthesised in the laboratory using conventional methods with hexamethylene diisocyanate and trimethylol propane as the monomers. The complete synthetic procedures and techniques followed in the preparation of IPNs have been covered by two Indian patents

[15,16]. This IPN alloy was used in preparing the IPN-MIO and IPN-TiO$_2$ topcoat (CP2 and CP4).

2.2. Epoxy polyamide system

For the epoxy polyamide system, commercial epoxy resin Araldite 6071 was used. It is a diglycidyl ether of bisphenol A with an epoxide equivalent of 450–465. It was cured with a polyamide curing agent Synpol 125, which is a polyamide adduct dimerised tung oil based cross linker with an amine value of 280–320 mg KOH. This resin combination was used in preparing the epoxy-MIO undercoat (CP3).

2.3. Acrylic polyol based aliphatic PU system

To prepare the aliphatic polyurethane system, a commercial product acrylic polyol Kondicryl SV 0L7 of 63% (w/w) solid content and a hydroxyl value of 63–75 was used with a commercial urethane cross linker Tolonate HDB 75, an aliphatic polyisocyanate of 75% (w/w) solids and an NCO content of 13.5–14%. They were used in the paint formulation PU-TiO$_2$ topcoat (CP5).

2.4. Formulation of component paints

The systems require the following individual component paints:

(1) Zinc ethyl silicate primer (CP1);
(2) IPN-MIO undercoat (CP2);
(3) Epoxy-MIO undercoat (CP3);
(4) IPN-TiO$_2$ topcoat (CP4);
(5) PU-TiO$_2$ topcoat (CP5).

Though paints CP3 and CP5 systems are available in the market, since the performances of different systems have to be compared, it was decided to formulate and prepare the paints in the laboratory itself so that the formulation and film parameters for IPN based coatings and their counterparts are kept identical. However, the zinc ethyl silicate primer (CP1), which was not based on IPN, was procured from commercial vendors. The formulations of paints nos. 2–5 were worked out. In the worked out formulations of CP2 to CP5, in the IPN-MIO (CP2) and epoxy-MIO (CP3) undercoat formulations, the pigment volume concentration (PVC) was 31% out of which the MIO content was 55% (w/w) and the other contents of mica, talc, silica and china clay being 19, 8, 11 and 7%. In the case of IPN topcoat

Table 1
Nomenclature of paint systems

Nomenclature of the paint systems	Component paints		
	Primer	Undercoat	Finish coat
A2S	Zinc ethyl silicate (CP1)	–	IPN topcoat (CP4)
A3S	Zinc ethyl silicate (CP1)	IPN-MIO (CP2)	IPN topcoat (CP4)
E3S	Zinc ethyl silicate (CP1)	Epoxy-MIO (CP3)	PU topcoat (CP5)

Table 2
Surface preparation and application of paints

Coating system	Surface preparation	Method of application		
		Primer	Undercoat	Finish coat
A2S	Sand blasting	Air spray	–	Air spray
A3S	Sand blasting	Air spray	Brush	Air spray
E3S	Sand blasting	Air spray	Brush	Air spray

Table 4
Dry film thickness of coating systems

Coating system	Dry film thickness in microns			
	Primer	Undercoat	Finish coat	Total dry film thickness
A2S	55	–	55	110
A3S	50	105	55	210
E3S	50	105	55	210

(CP4) and PU topcoat (CP5), the PVC was 13.5% out of which the TiO_2 content was 57% (w/w) and the other contents of talc and barites constituting 23 and 20%. All the above four component paints were prepared as per the worked out formulations in a laboratory model attritor. The formulations also included commercial additives in appropriate percentages.

2.5. Preparation of panels

For preparing the painted panels, mild steel specimens of sizes 15 cm × 10 cm, 7.5 cm × 5 cm and 10 cm × 10 cm with 1–2 mm thickness were cut to size from cold rolled/cold annealed mild steel sheets. The panels were then surface cleaned by sand blasting to Swedish Standard SA 2 1/2. The zinc ethyl silicate primer was applied over blasted specimens by air spray and allowed to cure for 24 h. Followed by it, undercoat and top-coats were applied as described in Table 2.

The time interval between subsequent coats was maintained at 24 h in order to get a sound inter-coat adhesion between coats. After application of final coat, the system was left at ambient conditions for another 7 days to get completely cured. Before subjecting them to various tests, the panels were edge-sealed to an extent of 5–8 mm from the edges using an epoxy type adhesive (supplied by Hindustan Ciba-Geigy Ltd., India).

Coated panels were used in triplicate for exposure in all the accelerated tests, out of which two were scribed diagonally, so that the cut penetrated the entire thickness of the coating and reached the substrate. This was done only on one side of the panel in order to allow the corrosion process to take place, which will enable assessing the blister resistance of the coated film and its ability to adhere to the substrate under aggressive conditions.

2.6. Measurement of physical properties of liquid paint

Though the protective property of a coating is of prime interest here, the physical properties of the coating like hardness, flexibility, adhesion, resistance to impact and abrasion are important and they are to be optimum to ensure its existence under

different conditions during its service. The physical properties of the liquid paints and the cured dry films were determined. These properties were already optimized during the formulation stage itself. The values of specific gravity, volume solids, viscosity, spreading rate and drying time were determined for the component paints. A single coat of component paints CP2 to CP5 was applied individually over pickled MS panels and allowed to cure. The physical properties like dry film thickness (DFT), hardness, flexibility, impact resistance and abrasion resistance were determined for component paints and the values are reported in Table 3. The DFT values of all the coating schemes are described in Table 4.

2.7. Evaluation and comparison of corrosion resistant properties of the coatings

For evaluating and comparing the corrosion resistant properties of the coatings, the coated panels were exposed in triplicate as described earlier to the following accelerated laboratory tests:

- Salt spray test (ASTM-B-117).
- Cyclic temperature humidity chamber test.
- QUV Weatherometer test.
- Immersion tests in the following:
  (i) distilled water (free from ions);
  (ii) sodium chloride, 5% (w/v) aq. solution;
  (iii) sodium hydroxide, 2% (w/v) aq. solution;
  (iv) saturated urea solution.

The panels were also subjected to field exposure test at Mandapam Camp, South India. In all the performance evaluation tests in the laboratory and in the field conducted in this study, the observations of the exposed specimens were done periodically but while presenting the results of such exposures, only the final cumulative result is presented taking into consideration all aspects of failures.

Table 3
Physical properties of the dry films of individual component paints

Component paint	Scratch hardness (1 kg load)	Pencil hardness	Flexibility (3 mm mandrel)	Impact resistance (kg cm)		Adhesion cross-hatch test	Abrasion resistance (wt. loss mg/kg 1000 rev.)
				Direct	Indirect		
CP2	Passes	5H	Passes	48.4	25.3	Passes	136
CP3	Passes	5H	Passes	47.2	23.0	Passes	140
CP4	Passes	6H	Passes	54.0	32.2	Passes	98
CP5	Passes	6H	Passes	51.8	31.0	Passes	100

Table 5
Results of salt spray (fog) test

| Coating system	Observations after 500 h	Observations after 1000 h
A2S	White rust along the scribes, no other change	White rust along the scribes, no other changes
A3S	White rust along the scribes, no other changes	White rust along the scribes, no other changes
E3S	White rust along the scribes, no other changes	White rust along the scribes, rust creep 2 mm along scribes
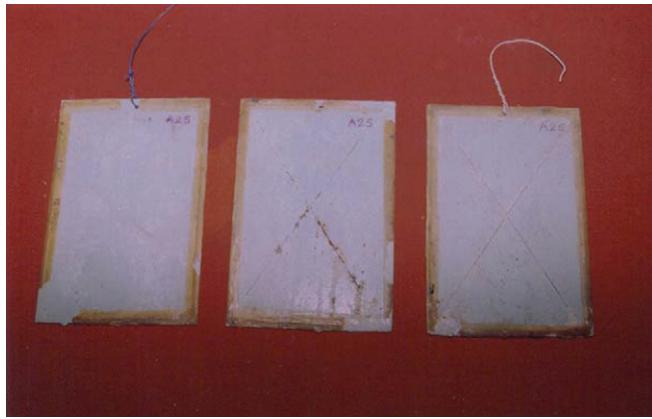
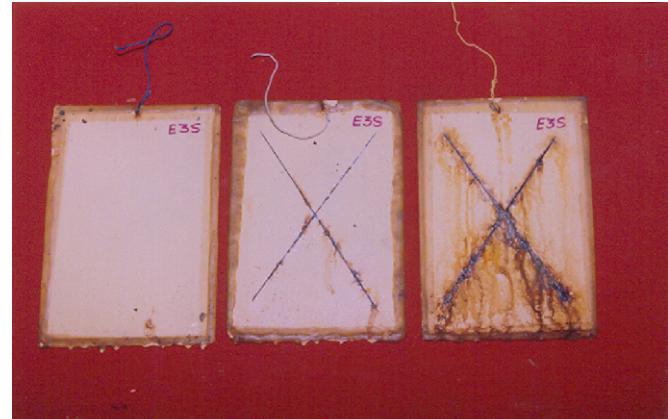Fig. 1. Panels exposed to salt spray (A2S).

Fig. 3. Panels exposed to salt spray (E3S).

2.8. Salt spray test

Salt spray test is the most popular laboratory accelerated test that has been used and accepted by many to compare the corrosion resistance of coatings. The test can also compare the resistance of the film to transfer of sodium and chloride ions through it. In addition, when the panel is scribed, it tells about the resistance of the coating to corrosion and undercutting. According to Munger, a coating which withstands salt spray test for 1000 h without the coating getting damaged or the metal getting corroded, should possess good resistance to moist air conditions in the field [19].

The results of the test conducted for a period of 1000 h is presented in Table 5, and the photographs of the tested panels at the end of 1000 h exposure are shown in Figs. 1–3. The table shows the results of the observations made at 500 and 1000 h.

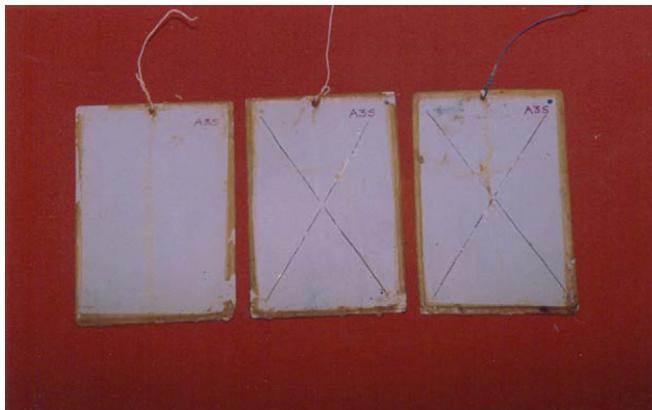## 2.9. Cyclic temperature humidity chamber test

As cyclic humidity test is a more severe test compared to ordinary humidity exposure, this test was done in this study as per the standard BS3900 part 2. The temperature was made to cycle between 42 and 48 °C in 1 h. Air circulation was maintained inside the chamber using a fan. Coated panels were exposed inside the chamber and examined visually every 24 h. The test was carried out for a duration of 1000 h. At the end of the test, the panels were taken out and kept for 24 h before testing for loss of adhesion or other evaluations. The results are reported in Table 6.

2.10. Weather resistance test

One of the reasons for failure of organic coatings is due to the effects of UV radiation. Actual weathering process of exterior exposure under UV radiation is simulated in this testing.

In this study, a QUV weatherometer supplied by QUV Panel Co., USA was used. According to C.G. Munger, the three tests of salt spray, humidity and weatherometer provide a good combination of screening tests for evaluating a coating scheme to withstand atmospheric exposure—rural, mild, industrial or

Fig. 2. Panels exposed to salt spray (A3S).

Table 6
Results of cyclic temperature humidity chamber test

Coating system	Observation made after 1000 h
A2S	White rust along scribes, no other defects
A3S	White rust along scribes, no other defects
E3S	White rust along scribes, no other defects

Table 7
Results of QUV weatherometer test

Coating system	Percentage of gloss retention [60°] (h)			Other observations
	After 400	After 800	After 1200	
A2S	85	80	70	No chalking, slight color fading
A3S	85	75	70	No chalking, slight color fading
E3S	80	70	60	Chalking after 1000 h, slight color fading

marine. A coating resistant to these above three tests would also perform well in actual exposure [19].

The test was conducted as per ASTM-B-53-77 standard. In this study, the painted panels were subjected to a set of eight intense B-40 UV lamps leading to photo degradation of the polymer. The operating cycle was 4 h UV radiation followed by 4 h condensation. The coating was tested for resistance to flaking, loss of gloss and degree of yellowing and chalking. The results of the QUV Cabinet test are presented in Table 7.

2.11. Immersion tests

In order to evaluate the chemical resistance of the coating to such exposures, all the coating systems under study were immersed in selected chemical solutions at ambient aerated conditions. In this study, the prepared specimens were immersed in the following aqueous solutions for evaluation:

  (i) distilled water (free from ions);
 (ii) sodium chloride, 5% (w/v) aq. solution;
(iii) sodium hydroxide, 2% (w/v) aq. solution;
(iv) saturated urea solution.

PVC tanks with compartments were used for the purpose. Each compartment was filled with different solutions and the panels were immersed.

2.12. Immersion in water

Immersion in distilled water provides direct results on the resistance to water under immersed conditions. In this test, water used was free from corrosive ions. The results of the test are given in Table 8, and the photographs of the tested panels are shown in Fig. 4.
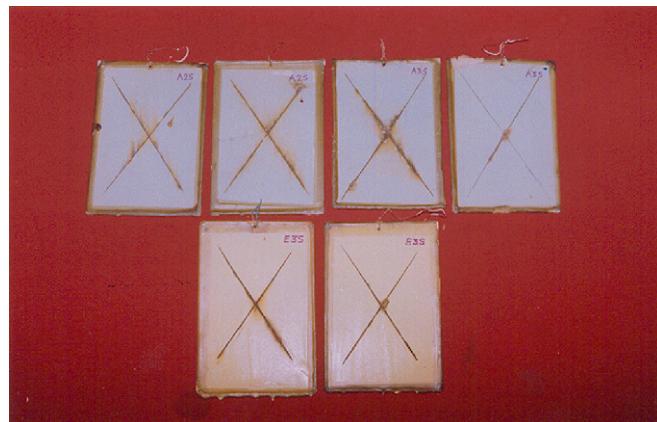

Fig. 4. Panels after water immersion (A2S, A3S and E3S).

2.13. Immersion in aqueous sodium chloride solution

Sodium chloride is one of the most detrimental materials, which initiates and continues the process of corrosion in coated panels. The results of the immersion test in the 5% (w/v) aqueous sodium chloride solution is given in Table 9, and the photographs of the immersed panels are shown in Fig. 5.

2.14. Immersion in aqueous sodium hydroxide solution

In general alkaline medium bestows passivity on mild steel above a pH value of 10. The test of alkali resistance is to ascertain the coatings' ability to withstand the alkaline condition, which is a pre-condition for the coating to be considered for being used with cathodic protection. In such medium, the performance of coatings is mainly dependent on the type of binder, which should be non-saponifiable to withstand such a condition. Hence, this test was proposed and carried out. The results of the test are presented in Table 10.

Table 8
Results of immersion test in distilled water

Coating system	Observations made after 12 months of immersion
A2S	Rust along the scribes, white rust spots appeared, no blistering
A3S	Rust along the scribes, rust creep to 2 mm in one panel, no blistering
E3S	Rust along the scribes, rust creep to 1 mm in one panel, no blistering, de-lamination at the centre in one of the panels

Table 9
Results of immersion test in 5% aq. NaCl solution

Coating system	Observations made after 12 months of immersion
A2S	Rust along the scribes, blistering 1 mm, 30% area, white rust under the blisters, no film de-lamination
A3S	Rust along the scribes, no rust creep, blistering only along the scribes
E3S	Rust along the scribes, no rust creep, blistering only along the scribes

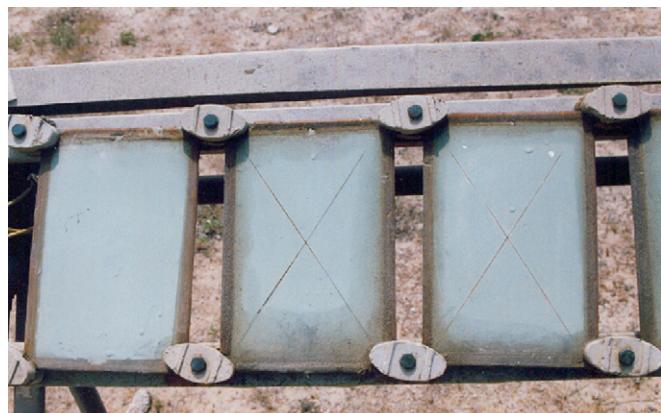Fig. 5. Panels after immersion in NaCl solution (A2S, A3S and E3S).

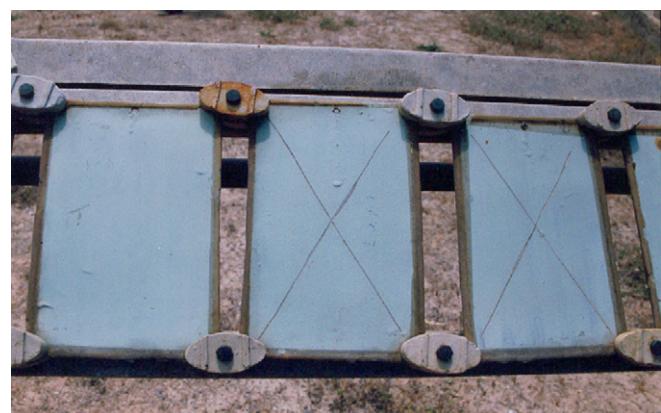Fig. 6. Panels at the end of 24 months (A2S).

Table 10
Results of immersion test in aq. NaOH solution

Coating system	Observations made after 12 months of immersion
A2S	White rust along the scribes, no blistering, no film de-lamination
A3S	White rust along the scribes, no blistering, no film de-lamination
E3S	White rust along the scribes, no blistering, no film de-lamination

2.15. Immersion in saturated urea solution

Testing of all coatings under saturated urea solution receives significance as this test assesses the suitability of the coatings to the fertilizer industry, which in India require large quantum of anti-corrosive coatings. Hence, this testing was proposed and carried out. The results of immersion testing in saturated urea solution for a period of 1 year on all coating systems are presented in Table 11.

2.16. Field exposure test at Mandapam Camp, India

To evaluate the paint schemes, field exposure was done at Mandapam Camp, South India, which is located in the coast of Gulf of Mannar in the Bay of Bengal near Rameswaram. This location is severely corrosive and was earlier judged to be the second in the world for severity of corrosion along the coast.
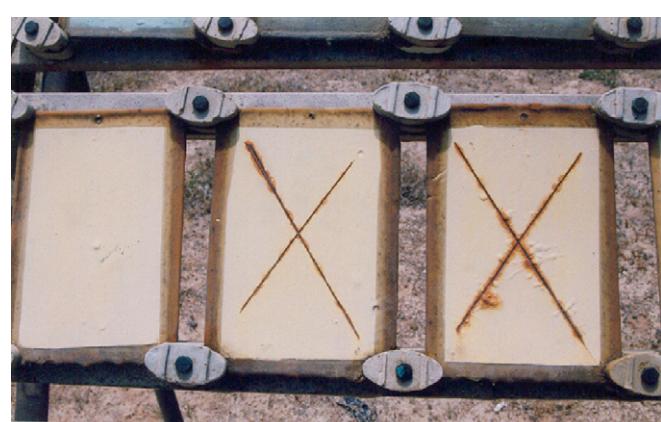

Fig. 7. Panels at the end of 24 months (A3S).

Central Electrochemical Research Institute of Karaikudi, India has a corrosion testing station at this location.

The overall corrosion rate for typical mild steel in this region under atmospheric conditions is around 83.8 μpy (microns per year) for a period from January to December with highest corrosion rate being 192.7 μpy during April–June, 159.9 μpy during July–September; lower 42.3 μpy during October–December and 34.5 μpy during January–March.

Table 11
Results of immersion test in saturated urea solution

Coating system	Observations made after 12 months of immersion
A2S	White rust along the scribes, no blistering, no film de-lamination
A3S	White rust along the scribes, no blistering, no film de-lamination
E3S	White rust along the scribes, no blistering, no film de-lamination

Fig. 8. Panels at the end 24 months (E3S).

Table 12
Results of field test at Mandapam Camp, India

Coating system	Observations made after 24 months of exposure
A2S	White rust along the scribes, no blistering, no chalking
A3S	White rust along the scribes, no blistering, no chalking
E3S	Brown rusting along the scribes, rust creep 2 mm along the scribes

At the marine exposure facility along the coast, the coated specimens were fixed in an exposure stand that was inclined at 45° facing the south. The panels were observed periodically for a period of 24 months in this severe marine atmosphere. The photographs of the panels were taken after 6 months, 12 months and finally after 24 months of exposure. The last photographs are only shown here in Figs. 6–8, because they only contain some information on the performance of the systems. The results observed are presented in Table 12. The observation includes formation of rust along the scribes, rust creep in mm, blister, and film de-lamination. The results indicated here was the sum of the observations made from triplicate panels of each system.

3. Results and discussion

3.1. Physical properties

The paints prepared with IPN polymer alloy as the binder and the other counterpart paints prepared for the study possessed good leveling and flow properties under ambient conditions. Regarding drying times, they exhibited a touch dry time of 30 min and a hard dry time of 8 h matching the requirements of any cross linked two pack coating system [17]. All the paints showed complete coverage over mild steel panels with good hiding property. All the other physical properties of the liquid paints and dry films as reported in Tables 3 and 4 are quite reasonable resembling values that a protective coating should possess [18]. As already reported, during formulation stage itself these properties were optimized.

3.2. Salt spray test

From the results, it can be seen that the systems A2S, A3S and E3S (Figs. 1–3) have shown only white rust, i.e. oxide of zinc, which is the corrosion product of zinc in the primer coating, indicating the active sacrificial type of protection provided by zinc to the steel. From the photographs (Fig. 3), it can be seen that only in E3S, the conventional epoxy based system, brown rusting has appeared along the scribes. This indicates that A2S and A3S have outperformed the E3S system thus establishing the superiority of the alloy system. From the fact that no blistering and other defects are noticed with A2S and A3S, even after the 1000-h testing, it can be said that for a severe marine environment, A2S and A3S can serve still better than the conventional system for a longer period. The important finding here

is that a 2-coat alloy system A2S is an economic and cheaper alternative to the conventional 3-coat E3S system.

3.3. Cyclic temperature humidity test

From the results of the cyclic humidity chamber test, it can be seen that the systems A2S, A3S and E3S have not been affected by the 1000-h testing. Only white rust is observed along the scribes in the scribed panels indicating that all the systems have shown sufficient water resistance coupled with temperature deviations. The presence of white rust confirms the active sacrificial type of protection offered by zinc ethyl silicate primer. As no film de-lamination and blistering is observed, it can be said that all the coatings have adhered with the substrate very well. Here also, A2S has proved to be an economic and cheaper alternative to E3S by giving equal performance.

3.4. Weather resistance test

From the table, it can be seen that all the systems in general have shown good weather resistance. The systems, A2S, A3S and E3S have only shown nearly 70% of gloss retention after 1200 h, of which the UV light hours account to 400 h. When compared, A2S and A3S have shown marked difference over E3S. Epoxy based coating systems have shown high loss of gloss than the IPN type polymer alloy systems. This clearly indicates the superior UV resistance of IPN type polymer alloys over that of polyurethane. This property is due to the high interpenetration and high cross-link density that resist the UV radiation. The loss of gloss upto 30% in the IPN series may be due to the formation of free radicals formed by the unzipping process of acrylic polymer component in the polymer alloy, upon UV exposure.

The excellent UV stability exhibited by the IPN alloy obviates the need for an expensive UV resistant topcoat as done in the conventional protective coating systems based on epoxies, which is a real breakthrough in the coating technology field.

3.5. Immersion in water

From the table and also from Fig. 4, it can be seen that the systems A2S, A3S and E3S have shown white rust followed by brown rusting after 12 months of exposure. The rust creep extended upto 1–2 mm only with absence of blisters. That too the creep is present only in one of the panels in the case of A3S and E3S, whereas in the other panel there is no creep. But there is de-lamination in the case of one of the panels of E3S at the centre. The general performance of all the three systems seems to be good but the alloy systems show a slight edge over that of epoxy, because of the de-lamination in one of the epoxy coated panels. However, the low DFT type 2-coat system A2S has equally performed well to the three coat systems. This shows the excellent performance of IPN type polymer alloy systems. This can be attributed to the interpenetration effect present in these polymer alloys and the higher content of epoxy–urethane elastomeric parts in the alloy, which is known, for their water resistance. Here again, the 2-coat alloy system A2S has proved

to be an economic alternative to the 3-coat E3S system, by giving equal performance.

3.6. Immersion in aqueous sodium chloride solution

In the systems A2S, A3S and E3S (Fig. 5), they have performed equally but a little film de-lamination is observed in the system E3S. The rust creep along the scribes has not extended and brown rusting alone appears. Though this kind of excellent performance is aided by the zinc ethyl silicate primer, the film de-lamination over zinc coatings was observed in the case of E3S. This behaviour is due to poorer film adhesion of epoxy system when compared to that of the alloy system. This also leads to the comparatively poor performance of the epoxy system to that of the alloy system in corrosion resistance and spread of corrosion, as observed in this test and also in water immersion test.

3.7. Immersion in aqueous sodium hydroxide solution

From the results, it is seen that the zinc ethyl silicate primer based systems A2S, A3S and E3S have not shown any type of defects until the end of the 12 months test. This is due to the strong alkaline resistance property of the systems and the passivity developed at the pH. Only white rust is seen in all the scribed panels, which is due to the reaction of exposed zinc, which is amphoteric in nature to the alkali to form zincates.

3.8. Immersion in saturated urea solution

In the systems A2S, A3S and E3S, the formation of white rust is seen along the scribes. The rust creep has not extended in all the systems indicating that the environment is not so aggressive and a higher duration study is required to assess the performance of the coatings.

3.9. Field exposure test at Mandapam Camp, India

From the results presented in Table 12, and also as seen from photographs of the three systems, the alloy systems A2S and A3S have shown only white rust, i.e. oxide of zinc which is the corrosion product of zinc even at the end of 24 months as seen in Figs. 6–8, whereas in the epoxy based system E3S, brown rust was observed at the end of 12 months itself near the scribe and it has grown more at the end of 24 months period also a few blisters are seen along the scribe. No other defect, such as blistering (except a few in one E3S panel), corrosion spots and film de-lamination are observed in all the coatings. When comparing the performance of both 2-coat type A2S and conventional epoxy based 3-coat system, while A2S has not shown brown rusting and other defects, epoxy system has shown brown rusting with no other defects. This clearly shows that efficiency and the performance of the 2-coat alloy system is on par with the 3-coat epoxy system. From the results, it is clear that the IPN type polymer alloy systems perform better than the epoxy-based system due to their high cross link density with permanent physical entanglements where through passage of corrosive ions is prohibited. This confirms the superiority of the IPN type polymer alloys over that of the presently used epoxy systems thus reinforcing the earlier finding in other tests.

4. Conclusions

The newly synthesised ambient curing poly(epoxy–urethane–acrylate) IPN polymer alloy binder, synthesised from epoxy, acrylic and urethane polymers is a suitable candidate for formulation of all types of protective coating-primers, undercoats and topcoats. It can be used as a two-pack system for corrosion protection in aggressive environments similar to presently used epoxy polyamide and polyurethane systems. The alloy has exhibited excellent UV resistance than even the aliphatic polyurethane system. This behaviour in spite of a considerable content of epoxy in the back-bone is justified by the fact that more energy is required to overcome the permanent physical entanglements in networks than to break the covalent bonds. It is hereby established that unlike epoxies, this IPN alloy can be used as a topcoat. This achievement is a real breakthrough in coating technology and good news for the coating industry, which is trying to develop weather-resistant epoxies through many other techniques.

This study establishes that in the case of zinc ethyl silicate primed coating system; this alloy has out performed the epoxy–polyurethane system. Even a 2-coat system of the alloy without an MIO undercoat is providing equal performance to the 3-coat epoxy–polyurethane system with an undercoat, making the 2-coat IPN system a cheaper alternative to the epoxy–polyurethane system. The developed alloy is a potential future candidate for protective coating binders.

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