Asian Journal of Chemistry Vol. 19, No. 2 (2007), 1170-1176

Studies in Protective Coatings of Metals with Special Reference to Organic Inhibitors Mixed with Polyurethane

REETA M. AGRAWAL*, VIJAY R. CHOUREY and S.L. GARG†
Department of Chemistry, Government Model Autonomous Holkar Science College Indore-452 017, India

The inhibition of corrosion of steel strips and aluminium strips in different chemical medium and atmosphere have been studied by immersion method. In this investigation, resorcinol and furfural have been tested as corrosiion inhibitors for aluminium and steel strips. These organic compounds have been used by mixing with protective coating material like polyurethane. The study shows that these compounds act as a good corrosion inhibitors with an efficiency which reaches from 40 to 90 % in different environment. The inhibition action of these compounds seems to be due to their adsorption on the metal surface, hence blocking the available area for corrosion.

Key Words: Protective coatings, Polyurethane, Furfural, Resorcinol.

INTRODUCTION

In spite of the large number of material which have been reported as inhibitors for corrosion for steel and aluminium[1-4], yet researchers are directed for highly efficient inhibitors to be used for specific applications[5-8]. For this purpose, resorcinol and furfural have been tested in the present work.

Corrosion inhibitors are the substance which when added to a particular environment decreases the rate of attack of that environment on material. They are generally mixed with the protective coating materials.

There are numerous protective coating material available in the market *e.g.* epoxy, polyurethane, *etc*. For resistance to corrosion control over metal by various chemicals, the coating must be completely inert to prevent permeation of the chemical and moisture. Polymeric organic coating of polyurethane combined with organic inhibitors serve this purpose well because their film properties are superior and chemical resistance is excellent with high degree of impermeability. This coating have a wide scope in prevention of corrosion for a period of 9 to 40 years.

†Department of Chemistry, Principal Government College, Depalpur, India.

The present study, therefore, deals with the protection of steel and aluminium by applying protective coating of polyurethane (A+B) mixed with organic inhibitors like resorcinol and furfural.

It has been observed that it is better to apply a good primer like redoxide, as a first layer followed by minimum two coats of polyurethane (A+B) *i.e.* double coating mixed with organic inhibitors.

EXPERIMENTAL

All the chemical used were of AR grade and their solutions were prepared in double distilled water. Two types of metal strips mild steel and aluminium were tested for chemical resistance. The composition of mild steel was 0.15 to 0.3 % C, 0.3 %, S, 1.0 % Mn, 0.5 % P, 0.03 % Si and the remaining is iron. The composition of aluminium strip was 0.130 % Si, 0.520 % Fe, 0.068 % Mn, 0.021 % Mg, 0.010 % Cu and 99.25 % Al.

The strips of steel and aluminium were cut into the size of 10 × 2.5 cm. They were first washed with soap water, cleaned by brushing and rubbing by sand paper and finally washed with water. These strips were dried in oven at 100ºC for 24 h.

Initially both types of strips were uniformly coated with redoxide primer and dried. Now these strips were uniformly coated with two packs polyurethane mixed with different organic inhibitors either resorcinol or furfural. In both the cases the thickness of coating was taken as 100 microns which is found to be ideal.

Immersion test: Each type of dried strips was taken for immersion test. strips suspended by a glass hook, were immersed in 150 mL of tested solution at 303 ± 1ºC in 250 mL capacity corning glass beakers for a period of 24 h. After the exposure period the test specimens were restudied.

Each type of dried strips was taken for immersion test in: (1) dilute acid, (2) different concentrations of HCl, (3) different concentrations of HNO_3, (4) different concentration of H_2SO_4, (5) different concentration of alkali solutions, (6) different concentrations of salt solutions, (7) diffrent organic solvents, (8) different commercial detergents and (9) strips were also tested in the atmosphere of different gases for one month.

RESULTS AND DISCUSSION

The results of immersion test are given in the Tables 1-15.

Durability test over steel and aluminium coated with: (1) primer (redoxide), resorcinol (organic inhibitor) and polyurethane (A+B) coating (2) primer (redoxide), furfural, (organic inhibitor) and polyurethane (A+B) coating.

Resorcinol as a inhibitor

The primer coated strips were coated with two pack polyurethane system mixed with rersorcinol. Above coating offered complete resistance to dilute acids in both the cases (Table-1).

TABLE-1
IMMERSION IN DILUTE ACIDS

Inhibitor	Metal	Dil. HCl	Dil. HNO_3	Dil. H_2SO_4
Resorcinol	Steel	NC	NC	NC
	Aluminium	NC	NC	NC

NC = Not corroded.

While the strips were dipped in different concentration of concentrated HCl strips corroded in 80 % and above as shown in Table-2.

TABLE-2
IMMERSION IN DIFFERENT CONCENTRATION OF HCl

Inhibitor	Metal	1.2 N HCl	2.4 N HCl	3.6 N HCl	4.8 N HCl	7.2 N HCl	9.6 N HCl	12 N HCl
Resorcinol	Steel	NC	NC	NC	NC	NC	F	F
	Aluminium	NC	NC	NC	NC	NC	F	F

NC = Not corroded; F = Failed.

When polyurethane coated strips were dipped in concentrated nitric acid, 60 % and above concentrations of nitric acid have corrosive effect in both the case (Table-3).

TABLE-3
IMMERSION IN DIFFERENT CONCENTRATION OF HNO_3

Inhibitor	Metal	1.6 N HNO_3	3.2 N HNO_3	4.8 N HNO_3	6.4 N HNO_3	9.6 N HNO_3	12.8 N HNO_3	16 N HNO_3
Resorcinol	Steel	NC	NC	NC	NC	F	F	F
	Aluminium	NC	NC	NC	NC	F	F	F

NC = Not corroded; F = Failed.

When steel and aluminium strips were dipped in different concentrations of concentrated H_2SO_4 then the strips coatings offered resistance upto 40% in both the cases (Table-4).

TABLE-4
IMMERSION IN DIFFERENT CONCENTRATION OF H_2SO_4

Inhibitor	Metal	3.6 N H_2SO_4	7.2 N H_2SO_4	10.8 N H_2SO_4	14.4 N H_2SO_4	21.6 N H_2SO_4	28.8 N H_2SO_4	36 N H_2SO_4
Resorcinol	Steel	NC	NC	NC	NC	F	F	F
	Aluminium	NC	NC	NC	NC	F	F	F

NC = Not corroded; F = Failed.

Both the strips offred resistance in all the concentrations and saturated solution of alkalies and salt solution (Tables 5 and 6).

TABLE-5
IMMERSION IN ALKALIS

Inhibitor	Metal	NaOH (%)						KOH (%)					
		10	20	30	40	50	Sat	10	20	30	40	50	Sat.
Resorcinol	Steel	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Al	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

TABLE-6
IMMERSION IN SALT SOLUTION

Inhibitor	Metal	NaCl (%)						KCl (%)					
		10	20	30	40	50	Sat	10	20	30	40	50	Sat.
Resorcinol	Steel	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Al	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

NC = Not corroded.

On immersion in different organic solvents acetone, chloroform, carbon tetra chloride and toluene have corrosive effect on strips in both the cases (Table-7).

TABLE-7
IMMERSION IN ORGANIC SOLVENTS

Organic solvent	Inhibitor resorcinol		Inhibitor furfural	
	Steel	Aluminium	Steel	Aluminium
Acetone	F	F	F	F
Aniline	NC	NC	NC	NC
Chloroform	F	F	NC	NC
Benzene	NC	NC	NC	NC
Carbon tetra chloride	F	F	NC	NC
Ether	NC	NC	NC	NC
Toluene	F	F	F	F

NC = Not corroded; F = Failed.

Strips kept in commercial detergents they did not have any corrosive effect on coating as shown in Table-8.

TABLE-8
IMMERSION IN DIFFERENT DETERGENTS

Detergents (Brands)	Inhibitor Resorcinol		Inhibitor Furfural	
	Steel	Aluminium	Steel	Aluminium
Surf	NC	NC	NC	NC
Nirma	NC	NC	NC	NC
Rin	NC	NC	NC	NC
Ariel	NC	NC	NC	NC
Wheel	NC	NC	NC	NC

NC = Not corroded.

When the strips were kept in gases only sulphur dioxide had the corrosive effect in both the cases (Table-9).

TABLE-9
IMMERSION IN GASES

Gases	Inhibitor Resorcinol		Inhibitor Furfural	
	Steel	Aluminium	Steel	Aluminium
Chlorine	NC	NC	NC	NC
Hydrogen chloride	NC	NC	NC	NC
Ammonia	NC	NC	NC	NC
Hydrogen sulphide	NC	NC	NC	NC
Nitrogen dioxide	NC	NC	NC	NC
Sulphur dioxide	F	F	NC	NC

NC = Not corroded; F = Failed.

Furfural as a inhibitor

The primer-coated strips were coated with two pack polyurethane system mixed with furfural. Above coating offered complete resistance to dilute acids in both the cases (Table-10).

TABLE-10
IMMERSION IN DILUTE ACIDS

Inhibitor	Metal	Dil. HCl	Dil. HNO_3	Dil. H_2SO_4
Furfural	Steel	NC	NC	NC
	Aluminium	NC	NC	NC

NC = Not corroded.

While the strips were dipped in different concentration of concentrated HCl strips corroded in 80 % and above as shown in Table-11.

TABLE-11
IMMERSION IN DIFFERENT CONCENTRATION OF HCl

Inhibitor	Metal	1.2 N HCl	2.4 N HCl	3.6 N HCl	4.8 N HCl	7.2 N HCl	9.6 N HCl	12 N HCl
Furfural	Steel	NC	NC	NC	NC	NC	F	F
	Aluminium	NC	NC	NC	NC	NC	F	F

NC = Not corroded; F = Failed.

When PU coated strips were dipped in concentrated nitric acid, 60 % and above concentrations of nitric acid have corrosive effect in both the case (Table-12).

TABLE-12
IMMERSION IN DIFFERENT CONCENTRATION OF HNO_3

Inhibitor	Metal	1.6 N HNO_3	3.2 N HNO_3	4.8 N HNO_3	6.4 N HNO_3	9.6 N HNO_3	12.8 N HNO_3	16 N HNO_3
Furfural	Steel	NC	NC	NC	NC	F	F	F
	Aluminium	NC	NC	NC	NC	F	F	F

NC = Not corroded; F = Failed.

When steel and aluminium strips were dipped in different concentrations of concentrated H_2SO_4 then the strips coating failed at 80 % and above in both the cases (Table-13).

TABLE-13
IMMERSION IN DIFFERENT CONCENTRATION OF H_2SO_4

Inhibitor	Metal	3.6 N H_2SO_4	7.2 N H_2SO_4	10.8 N H_2SO_4	14.4 N H_2SO_4	21.6 N H_2SO_4	28.8 N H_2SO_4	36 N H_2SO_4
Furfural	Steel	NC	NC	NC	NC	NC	F	F
	Aluminium	NC	NC	NC	NC	NC	F	F

NC = Not corroded; F = Failed.

Both the strips offred resistance in all the concentrations of alakalies and salt solution (Tables 14 and 15).

TABLE-14
IMMERSION IN AKLALIS

Inhibitor	Metal	NaOH (%)						KOH (%)					
		10	20	30	40	50	Sat.	10	20	30	40	50	Sat.
Furfural	Steel	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Al	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

NC = Not corroded.

TABLE-15
IMMERSION IN SALT SOLUTION

Inhibitor	Metal	NaCl (%)						KCl (%)					
		10	20	30	40	50	Sat.	10	20	30	40	50	Sat.
Furfural	Steel	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Al	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

NC = Not corroded.

It is concluded that for steel and aluminium organic inhibitors like resorcinol and furfural act as a good organic inhibitor. It is also seen that it is better to apply a good primer like red oxide and then to apply minimum two coats of polyurethane$_{(A+B)}$. A film thickness of 100 microns was found to be an ideal.

In general, the strips offered excellent resistance with furfural inhibitor on comparison with resorcinol inhibitor when mixed with polyurethane$_{(A+B)}$ against water, dilute acids, alkalies, salt solutions, gases, *etc.* The scratch hardness, flexibility and drying time were more or less same for all the strips. The inhibition action of these compounds seems to be due to their adsorption on the metal surface, hence blocking the available area for corrossion[9-11].

On comparison with different coating, we find that polyurethane coating are highly suitable as maintenance coatings. Their film properties are superior and chemical resistance is excellent. Polyurethane coating are not only resistant towards chemical corrosion but they also provide a barrier which prevent or control the corrosion reaction through the film. Polyurethane coatings are non-conductor of electricity experimentally as well as theoretically. Another requirement is that the coating should be impermeable to air, moisture, water, vapour, *etc.* Polyurethane coating serve this

purpose well. Polyurethane coating have all the characteristics for an effective coating and therefore, the future of polyurethane coating is very bright. Polyurethane coating are designed for tough exposures and they prevent corrosion and act as water proofing. They resists chemicals looking to corrosion resistance offered for a longer period of time. Polyurethane coating are more economical justifying their price and application and their efficiency increases on mixing with inhibitors.

ACKNOWLEDGEMENTS

The authors are thankful to the institutions CAT Indore, RRL Bhopal, MAPCOST Bhopal, MS University, Baroda and INSDOC, New Delhi for providing reference materials.

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(*Received*: 2 December 2005; *Accepted*: 1 September 2006) AJC-5071