International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-5, June 2013

Analysis of Corrosion Prevention Methods in Railway Coaches and Bogies

K.Velayutham, U.Arumugam, B.Kumaragurubaran, P.Gopal

Abstract**—*****This paper mainly deals with corrosion that occurs in Railway coaches and bogie components, causes of corrosion, steps taken to prevent corrosion, suggestions to minimize this problem. This paper contains new suggestions to minimize the problems: more emphasis has laid on dissimilar welding and special coating which are being done perfunctorily, the various most affected parts near the bottom of lavatory side wall plates are to be identified and replacing by dissimilar material of stainless steel and IRS M – 41.Study of modification in components design and epoxy coating methods are to be applied on the sole bar and destruction tubes. This paper describes the technique and gives details on applications.***

Index Terms—Coating, Corrosion prevention design, Dissimilar welding, Surface treatment,

I. INTRODUCTION

The annual loss for India, on account corrosion is around Rupees 75 crores. Corrosion is destruction of a metal by chemical or electrochemical reaction with its environment.

As Iron exists in nature in its most stable form i.e. Fe2O3, Pure iron available in the steel in unstable condition and always tends to convert back into oxide by corrosion. Under frame and bogie are the main parts in a coach that is subjected to corrosion because of the presence of lavatory. Mechanical strength is reduced and the section ultimately fails if extensive corrosion occurs. Corrosion and its control is an important, but often neglects, element in the practice of engineering. Taking care right from the material selection to successful operation, adhering to the guidelines is the only possible way to minimize losses due to corrosion. Corrosion is a term related to material deterioration mechanism, which may induce flaws affecting the health of components. If these flaws are not detected at the right time, they may lead to the failure if the component resulting in loss productivity and threat to safety. To this effect, Non Destructive Evaluation (NDE) techniques, ultrasonic, radiography acoustic emission, thermograph etc have a significant role to play in the detection and monitoring of corrosion. Water percolation from toilet is one of the main causes for corrosive environment in under frame and bogie components.

Five different main principles can be used to prevent corrosion:

Manuscript published on 30 June 2013.
***** Correspondence Author (s)
K.Velayutham*, BIT Campus, University College of Engineering, Tiruchirappalli,620024, TN India.
U.Arumugham, BIT Campus, University College of Engineering, Tiruchirappalli,620024, TN India.
B.Kumaragurubaran, BIT Campus, University College of Engineering, Tiruchirappalli,620024, TN India.
P.Gopal, BIT Campus, University College of Engineering, Tiruchirappalli,620024, TN India.

- Appropriate materials selection
- Change of environment
- Suitable design
- Electrochemical, i.e. cathodic and anodic protection
- Application of coatings.

The choice between these possibilities is usually based upon economic considerations, but in many cases aspects such as appearance, environment and safety must also be taken care of. Two or more of the five principles are commonly used at the same time

Causes of corrosion in Indian Railway Coaches:

1. Water seepage through the flooring to the top of trough floor.
2. Leakage of water through lavatory flooring.
3. Missing of corrode chute and drainpipe.
4. Defective water pipe fittings.
5. Absence of surface preparation during replacement of commode and drainpipes.
6. Habits of flushing the flooring with the water jet for cleaning.
7. The condensation of the air trapped in between the trough floor and flooring due to climate changes.
8. Striking of flying ballast when the train is running.
9. The design of the window seal leaves the gap between the side panel to allow the rain water flow through the panel and to drain out at the bottom.
10. The blockage of drain water by accumulated dust on the top of the trough floor.

Area subject to high rate of corrosion in coaches

1. Side wall bottom: area below the lavatory and between body side pillars.
2. Head stock: Outer head stock and tubular sections are heavily corroded due to lavatory.
3. Body pillar : bottom portion of pillar near doorways and lavatory area
4. Cross bearer : Joint between sole bar
5. Body side door : Bottom of the door due to water contain luggage
6. Battery box : corrosion due to acid action
7. Roof : rain water
8. Trough floor : adjacent to wash basin and lavatory
9. Floor : Pantry car area
10. Equalizing stay : Tube corrodes due to drain of lavatory water
11. Brake beam: Tube corrodes due to splash of lavatory water.

II. EXISTING SYSTEM

A. Existing system

At present high carbon steels are not widely used for structural work due to its lack of ductility and weld ability.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

Corrosion resistant material should be used for the roof and side panels. For this purpose IRS M-41/97 steels are use which has high ductility, yield strength and weld ability. These steels have good atmospheric corrosion resistance. Tubular structure should be provided under lavatory region.
Turn under with thick section and elongated holes should be provided. Arrangement should be made so that rain water do not seep through the gap between side wall and window sealing. Stainless steel trough floor should be used coaches.

Under frame is the main part prone to corrosion in coaches because of the presence of lavatory. Stainless steel can resist corrosion in coastal environment. Since nickel containing stainless steel does not need painting, the threat of noxious fume is minimized. Cost of using the stainless steel or entire under frame is nearly two times the original cost of the coaches. The complete usage of the stainless steel is restricted due to financial implication.

III. PROPOSED SYSTEM

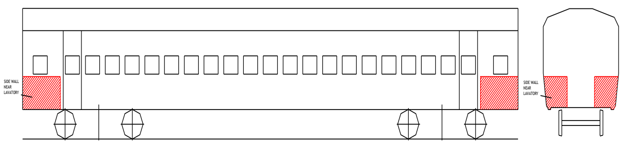
In order to overcome corrosion, the following steps are to be analyzed

a. Use of dissimilar material:
b. Improve surface coating
c. Corrosion prevention design adapted

a. Dissimilar material

By analysis of previous data, collected from various corroded coaches, the most affected areas are to be listed:

- The lavatory area side wall plate up to window and end plate up to side buffers are to be cut by oxy-acetylene cutting and the new material of IRS -41 are to be welded in every POH (Periodic Overhauled) i.e. ones in 12/18 months. The maximum affected area is to be side wall plate. Our suggestion is ***the side wall plates between lavatories bottom to bottom of side wall and side pillar are to be replaced by stainless steel plate in first POH by dissimilar welding***. The shape of the side wall plates are standard one. Hence we can interchangeable the components by stocking the part.



- The sole bar is a fabricated section of IRS –M41.

Our suggestion is the sole bar section under lavatory should be dissimilar weld of stainless steel with IRS -41 steel. The strength of the joints is to be maintained by friction welding and the parts are to be with stand water seepage corrosion from the lavatory and wash basin near the door way. Joining dissimilar metals using EBW has also been a subject of interest in recent years. Due to special features of EBW, e.g., high energy density and accurately controllable beam size and location, in many cases it has proven to be an efficient way of joining dissimilar metals. Numerous successful results have been achieved, and some of them have already been exploited in production. EBW continues to be the subject of investigations and further development, and improvements in the joining of dissimilar metals remain one of the aims. [19]

The dissimilar welding joints of 45, 0Cr18Ni9 and 1Cr9Mo steel using the different welding metal A302 or Inconel182. The thermal stress numerical simulation is carried out to the dissimilar welding joints. The thermal stresses of dissimilar welding joints generated in the heating to 450 °C from the ambient temperature for 45/1Cr9Mo and 45/0Cr18Ni9 and 500 °C for 1Cr9Mo/0Cr18Ni9 are calculated by finite element method. It is shown that large tensile stress is generated in the weld metal, fusion line and heat affected zone (HAZ) when the welding metal is A302, while the compressive or low tensile stress is shown in the HAZ and fusion line of 1Cr9Mo or 45 steel. The stress is decreased when the A302 is changed to Inconel182. It is concluded that the replacement of A302 by Inconel182 can decrease the thermal stress and increase the life of the welding joint [21].

The joint of dissimilar metals between 2205 duplex stainless steel and 16MnR low alloy high strength steel are welded by tungsten inert gas arc welding (GTAW) and shielded metal arc welding (SMAW) respectively. The relationship between mechanical properties, corrosion resistance and microstructure of welded joints is evaluated. There are a decarburized layer and an unmixed zone close to the fusion line. It is also indicated that, austenite and acicular ferrite structures distribute uniformly in the weld metal, which is advantageous for better toughness and ductility of joints. Mechanical properties of joints welded by the two kinds of welding technology are satisfied [22].

Carbon steel SS400 with thickness of 3.0 mm and 1.0 mm thick- austenitic stainless steel SUS304 were lap joined using resistance spot welding. That corrosion fatigue strength of resistance spot welded in sea water is lower than that performed in the air. The endurance limit of fatigue conducted in air is 32.6 MPa whereas corrosion fatigue samples at this stress fail at about 400,000 cycles. It seems that the hydrogen enhanced plasticity mechanism that tends to ease the generation of dislocations is the cause of corrosion fatigue strength weakening. Dissimilar steels commonly used as valve materials for vehicle were friction welded. A small circular defect was precisely worked on weld interface, 0.5 and 1.0 mm distance away from the interface, respectively, to closely analyze the welding zone. Fatigue limits of STR3 and STR35 base metal were 429.0 and 409.4 MPa, respectively. The weld interface notched specimen had much lower fatigue life than the other specimens because of appearance of the interface separation [9]

Dissimilar metal joints between pipes of ferrite and austenitic steels are widely used in steam generators of power plants. The Inconel-82 buttering layer employed in the dissimilar weld joint is useful in reducing the residual stresses in the heat affected zone HAZ of the ferrite steel and thus the buttering will be beneficial to avoid/minimize residual stress related failures of dissimilar weld joints. Metallurgical and mechanical characterization of dissimilar laser spot welds between low carbon and austenitic stainless steel sheets. Microstructural examination, micro hardness test and quasi-static tensile–shear test were performed. Mechanical properties of the welds were described in terms of peak load. The effects of laser mean power on the performance of dissimilar laser spot welds have been studied. It was found that increasing laser mean power leads to the transition of laser welding mode from conduction to keyhole. The low carbon steel sheet is the controlling factors in determination of the mechanical strength of dissimilar austenitic/ferrite laser spot welds.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

The behavior of weldment at elevated temperatures and especially their corrosion behavior has become an object of scientific investigation recently. Investigation has been carried out on friction-welded AISI 4140 and AISI 304 under molten salt of Na2SO4 + V2O5 (60%) environment at 500 and 550 °C under cyclic condition. The influences of welding parameters on the hot corrosion have been discussed. The resulting oxide scales in the weldment have been characterized systematically using surface analytical techniques. Scale thickness on low alloy steel side was found to be more and was prone to spalling. Weld region has been found to be more prone to degradation than base metals due to inter diffusion of element across the interface and the formation of intermetallic compound.[12]

Carbon steel SS400 with thickness of 3.0 mm and 1.0 mm thick- austenitic stainless steel SUS304 were lap joined using resistance spot welding. That corrosion fatigue strength of resistance spot welded in sea water is lower than that performed in the air. The endurance limit of fatigue conducted in air is 32.6 MPa whereas corrosion fatigue samples at this stress fail at about 400,000 cycles. It seems that the hydrogen enhanced plasticity mechanism that tends to ease the generation of dislocations is the cause of corrosion fatigue strength weakening.[13]

The influence of flux cored arc welding (FCAW) process parameters such as welding current, travel speed, voltage and CO2 shielding gas flow rate on bowing distortion of 409M ferritic stainless steel sheets of 2 mm in thickness was discussed. It is revealed that the FCAW process parameters have significant influence on bead profile and the bowing distortion.[20].

Eutectoid rail steels are prone to excessive corrosion in the coastal locations in India. In order to minimize this problem, four new rail steels with micro alloying elements, Cu, Cr, Ni and Si were designed. The corrosion behavior of these four rail steels were compared with the behavior of three rail steels already in commercial application. Quantitative evaluation done by weight loss measurements after simulated wet–dry salt fog exposure test showed similar weight loss values for all rail steels. The FTIR spectra of rust samples revealed the presence of Fe3−xO4 as the major phase in both inner and outer layers of rusts on all the rail steels. Relative amounts of the different rust phases have been compared. SEM micrographs of the rusted samples revealed that the rust on Cr–Cu–Ni and Cr–Cu–Ni–Si rail steel was more compact than other rail steels. Impedance spectroscopy showed that the rust formed on Cr–Cu–Ni and Cr–Cu–Ni–Si rail steels resulted in the higher impedance in the high frequency region, compared to other rail steels.

b. Improve surface coating

Surface coating is the easy and financial possible way to implement in every POH activity. Epoxy-coated reinforcement was developed in the early 1970s.After demonstration projects in the mid 1970s, the market, largely in the transportation sector, expanded rapidly and epoxy-coating became the preferred method of corrosion protection in highway bridges. The effect on the service life of epoxy-coated reinforcement is uncertain because the necessary and sufficient conditions for effective long-term field performance have not been defined.[1]

The epoxy-polyamide mastic/urethane and the solvent-free epoxyamine/urethane had the best corrosion protection barrier properties, with a low water penetration, a limited and constant corrosion rate over time and a low film pore area. The corrosion resistant property of epoxy polyaniline system, coated on mild steel was evaluated by various techniques such as electrochemical impedance spectroscopy, potential time studies, cathodic disbondment test, anodic polarization study, salt spray test and chemical resistance test. it is found that epoxy coating with polyaniline pigment is effective in corrosion protection of steel in concrete environment.[3]

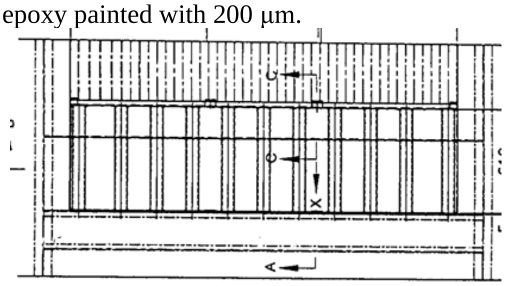
The results of tests on epoxy coated reinforcing steel with comparative data on untreated and galvanized steel. The results show that for a coating thickness of about 200 μm, satisfactory results are obtained regarding bendability of reinforcing steel, structural behavior in reinforced concrete members, and corrosion protection properties. Using specific grade of PANI with low doping, it can be incorporated in epoxy powder coating formulations by twin screw extrusion process. The powder formulations were deposited on steel substrates by electrostatic spray coating at −60 kV and baked at 140 °C for 20 min. The coatings intentionally scratched also exhibited self healing property and there was no rust formation even after prolonged exposure to hot saline conditions.[6]

From the time dependence of pore resistance, coating capacitance and relative permittivity of epoxy coating, diffusion coefficient of water through epoxy coating, D(H2O) and thermal stability, it was shown that Zn–Ni sublayers significantly improve the corrosion stability of the protective system based on epoxy coating. Almost unchanged values of pore resistance were obtained over the long period of investigated time for epoxy coatings on steel modified by Zn–Ni alloys, indicating the great stability of these protective systems, due to the existence of the inner oxide phase layer and the outer layer consisting of basic salts. An amorphous Al-based coating is tuned for corrosion protection by on-demand release of ionic inhibitors to protect defects in the coating, by formation of an optimized barrier to local corrosion in Cl− containing environments, as well as by sacrificial cathodic prevention. In corrosion of metallic materials, dip, spray, chemically or electrodeposited organic-based, metallic, and ceramic coatings are often used to protect a substrate from corrosive damage. In corrosion of metallic materials, dip, spray, chemically or electrodeposited organic-based, metallic, and ceramic coatings are often used to protect a substrate from corrosive damage. Corrosion protection by passive films and coatings Active corrosion inhibition A multifunctional amorphous alloy has been described that possesses three corrosion protection abilities when deployed as a coating over structural alloys. The coating (i) functions as a local corrosion barrier, (ii) serves as a sacrificial anode, and (iii) supplies soluble ions used as corrosion inhibitors by engineering metallurgical and electrochemical properties. Magnesium and magnesium alloys are the lightest structural materials. Due to poor corrosion and wear resistance properties, they need to be coated for usage in service conditions under corrosive and tribological loads. AlSi20 was found to be a suitable coating material to improve the wear and corrosion protection properties of magnesium alloys.

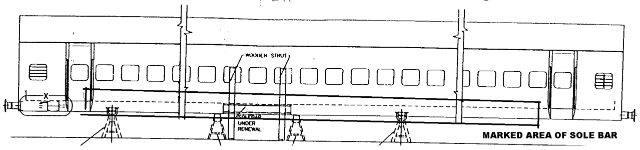
Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

AlSi20 coatings were applied by plasma spraying, laser cladding, and a combination of both processes. First, the coatings are characterized by their microhardness and residual stresses formed within the coating during the different coating processes. The sensitivity to damage of the coatings was characterized and it was found that the pure and double enamel coatings can protect the steel rebar better than the mixed enamel coating due to their denser microstructures with isolated pores. The intact epoxy coating offered better corrosion protection than the enamel coatings. Three types of enamel coatings have different microstructures. All enamel coatings improve corrosion resistance of rebar to various extents. Isolated examples of corrosion of coated reinforcement were reported from about 1990 onwards, though many field investigations reported good performance. Laboratory studies were equally controversial, some predicting good performance, and others only a short extension of service life. Improvements have been made in increasing the adhesion of coatings, and decreasing the number of defects, but the effect on the service life of epoxy-coated reinforcement is uncertain because the necessary and sufficient conditions for effective long-term field performance have not been defined. Epoxy coating on the bogie components of equaling stay its life time can be increased and the renewal of every POH may be avoided.

Our suggestion is, in railway coaches most affected area of destruction tubes, Sole bar sections other than stainless steel are to be epoxy painted with 200 µm.



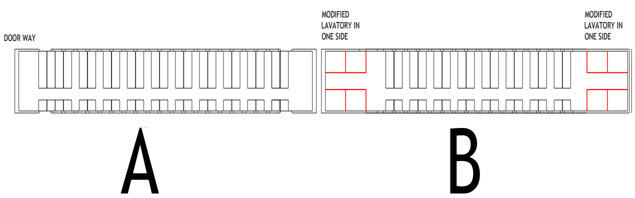
Destruction tube below door way



Sole bar area proposed to epoxy painted

C. Corrosion prevention by design change

Lavatory water leakage is the main cause of maximum corrosion. For avoiding this, Coaches should be classified as A & B. In A coach there should be eight lavatory (two each corner) provided and in B coach there should not be a lavatory. A & B coaches are form together in rack. Hence A coach corrosion is minimized and the B coach is to be made of stainless steel to with stand corrosion.



The above suggestion is a preliminary level design modification. It should require a lot of study with all factors considering and detailed design will be produced later.

IV. CONCLUSION

Corrosion can be minimized by improve surface coating and dissimilar metal welding. Use of complete stainless steel is restricted due to

i) Financial implication
ii) Inadequate availability

Hence our suggestion to improve biomaterial concept and epoxy paint coating the prevention method of corrosion may be achieved. Other method of design changes are to be under study. The complete analysis of elaborate design of the various factors and modifications of components will be under study and will be produced later.

REFERENCES

[1] David G. Manning "Corrosion performance of epoxy-coated reinforcing steel: North American experience" dx.doi.org/10.1016/0950-0618 (95)00028-3
[2] E Potvin "Corrosion protective performances of commercial low – VOC epoxy/urethane coatings on hot-rolled 1010 mild 1010 mild steel". dx.doi.org/10.1016/S0300-9440 (97)00095-7
[3] K.Saravanan "Performance evaluation of polyaniline pigmented epoxy coating for corrosion protection of steel in concrete environment" dx.doi.org/10.1016/j.porgcoat.2007.03.002
[4] B.N. Grgura "Corrosion behavior and thermal stability of electrodeposited PANI/epoxy coating system on mild steel in sodium chloride solution" doi.org/10.1016/j.porgcoat.2006.05.003
[5] K.Kobayashi "Experimental studies on epoxy coated reinforcing steel for corrosion protection" doi.org/10.1016/0262-5075(84)90039-3
[6] R. Radhakrishnan "Epoxy powder coatings containing polyaniline for enhanced corrosion protection" oi.org/10.1016/j.porgcoat.2008.07.024
[7] M.R. Bagherzadeh "Novel water-based nanosiloxane epoxy coating for corrosion protection of carbon steel" dx.doi.org/10.1016/j.surfcoat.2011.05.036
[8] J.B. Bajata "Corrosion stability of epoxy coatings on aluminum pretreated by vinyltriethoxysilane" doi.org/10.1016/j.corsci.2008.04.018
[9] D.G. Leea "Fatigue properties of inertia dissimilar friction-welded stainless steels" doi.org/10.1016/j.jmatprotec.2004.04.400
[10] A. Josepha "Evaluation of residual stresses in dissimilar weld joints" doi.org/10.1016/j.ijpvp.2005.03.006
[11] .M.J. Torkamany "Effect of laser welding mode on the microstructure and mechanical performance of dissimilar laser spot welds between low carbon and austenitic stainless steels" doi.org/10.1016/j.matdes.2011.05.024
[12] N. Arivazhagana "High temperature corrosion studies on friction-welded dissimilar" dx.doi.org/10.1016/j.mseb.2006.02.047
[13] Jamasri "Corrosion Fatigue Behavior of Resistance Spot Welded Dissimilar Metal Welds between Carbon Steel and Austenitic Stainless Steel with Different Thickness" .doi.org/10.1016/j.proeng.2011.04.108
[14] M.V Venkatesana "Influence of FCA Welding Process Parameters on Distortion of 409M Stainless Steel for Rail Coach Building" doi.org/10.1016/S1006-706X(13)60047-3
[15] Bijayani Panda "On the corrosion behaviour of novel high carbon rail steels in simulated cyclic wet–dry salt fog conditions" doi.org/10.1016/j.corsci.2008.02.021
[16] F. Presuel-Morenoa "Corrosion-resistant metallic coatings" dx.doi.org/10.1016/S1369-7021(08)70203-7
[17] Kirsten Bobzin, "Investigation of Wear and Corrosion Protection of AlSi20 Coatings Produced by Plasma Spraying and Laser Cladding on AZ31B" DOI 10.1007/s11666-012-9867-6
[18] Fujian Tanga "Corrosion resistance and mechanism of steel rebar coated with three types of enamel" doi.org/10.1016/j.corsci.2012.02.02
[19] Z. Sun , a "The application of electron beam welding for the joining of dissimilar metals: dx.doi.org/10.1016/0924-0136(95)02150-7
[20] Ion Mitelea "Dissimilar friction welding of induction surface-hardened steels and thermochemically treated steels" dx.doi.org/10.1016/j.jmatprotec.2012.04.01

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

[21] Shu Xu "Thermal Stress Analysis of dissimilar welding joints by Finite Element Method" doi.org/10.1016/j.proeng.2011.08.722
[22] Shaogang Wang "Characterization of microstructure, mechanical properties and corrosion resistance of dissimilar welded joint between 2205 duplex stainless steel and 16MnR dx.doi.org/10.1016/j.matdes.2010.07.012
[23] Jamasri , "Corrosion Fatigue Behavior of Resistance Spot Welded Dissimilar Metal Welds between Carbon Steel and Austenitic Stainless Steel with Different Thickness" doi.org/10.1016/j.proeng.2011.04.108

K.Velayutham ME final year student in Anna University college of Engineering, Tiruchirappalli. He received his diploma in DME in the year 1984 and completed his AMIE (I) in 1992. He is having 22 years' experience in Railway drawing department. Currently he is working as a Senior Section Engineer/Drawing in Railway workshop.

U,Arumugham ME final year student in Anna University college of Engineering , Tiruchirappalli. He received his diploma in DME in the year 1982 and completed his BE in 2009. He completed his PGDOM in 2004 and PGDPM & IR in 2012.He is having 29 years experience in production line, Automotive Manufacturing sector. Currently he is working as Deputuy General Manager in production line.

B.Kumaragurubaran is working as an Asst. Professor in in Anna University College of Engineering, Tiruchirappalli. He received his BE from University Of Madras in the year 2003and did his ME from Annamalai University, Chidambaram2005. He is pursuing Ph.D in engineering material. He is having 7 years of experience in the field of teaching. He has attended 18 conferencesand he has published 7 national and international journals. He is life member in Indian Welding Society from 2004.

P.Gopal, B.E.(Mech), M.E.(Auto) is working as an Asst. Professor in Anna University College of Engineering, Tiruchirappalli. He is having 13 years of experience in the field of teaching. He has attended 24 National and international conferences and he has published 8 national and international journals.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)