Analysis and Prevention of Rust Issue in Automobile Industry

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***Abstract*—Automobile vehicle bodies are prone to rust on exposure to long & short duration at normal atmospheric conditions due to design, material, and/or process related issues. In addition, sometime improper handling is also noted to be a factor resulting in major rusting on automobile body. In this study, two case studies were performed on car bodies that experienced severe corrosion during service. The first case study was performed on rusting at fire wall area and the second one on inner hood. The root cause analysis was performed with the help of fishbone diagram. Two major causes were identified as the potential source causing rusting of car body. These are: 1) Rusting resulting from stagnant liquid owing to the absence of drain hole (i.e. Design related issue) and 2) Process related issue caused by over coating thickness, Improper Backing of ED & low DFT of paint. Containment action & Permanent actions were taken to mitigate the rusting problem on car body by drilling drain holes at appropriate location to prevent liquid from stagnating at corroded area and properly maintaining GPL of Zn in ED bath, increasing painting thickness at inner hood area and increasing backing time. Containment & Permanent actions are validated at laboratory scale.**

Keywords—Corrosion; Automotive Industries; Primer and paint; Salt spray test

I. INTRODUCTION

Automobile car body is made from various grades of low alloy and low carbon steels that are prone to corrosion in the absence of proper surface protection [1,2]. Therefore, car body is traditionally coated with primer, followed by paint for better corrosion resistance. However, due to process complication, design intricacy and other issues, it is often observed that despite of applying several layers of primer and paint on the car body, it suffers from General, Pitting, and Crevice corrosion. When such corrosion occurs within the warranty period, it usually costs the car manufacturer significantly and more importantly, it results in bad customer experience. The success of automobile industries depends on keeping the customer satisfied with quality of product and services. Therefore, it is highly imperative that such problems are identified at an early stage and find effective solutions to mitigate them efficiently.

Cold rolled steel sheets remained the most widely used car body material. However, to meet the future energy efficiency requirement of automobiles, automobile industries will have to look for optimum way in designing and usage of steel sheets. The standard TS-4011 summarizes the additional requirement for cold rolled sheets for critical auto body components and outer panels. In general, steel alloy must have high formability and high strength. In addition, car body material must have good joining characteristics. It is a common observation that areas around the vicinity of welded section are more prone to severe corrosion. This is because of the microstructural effect at the heat affect zone (HAZ) around the welded area. This is verified during microstructure examination of corroded samples after the corrosion test. General idea is to observe the damage in microstructure and determine the type of the corrosion. The microstructural examination at corroded site showed that the corrosion damage is concentrated around the welding line. General damage is observed due to the pitting corrosion. Here, the HAZ and Weld bead have undergone heavily damage after exposing the corrosion [4].

The other grades of steel showed similar damage due to severe corrosion at heat affected zone. In addition, crack initiation site and propagation at the pitting sites is observed in the specimen kept under the stress during the corrosion test. In some specimens, it is noted that porosity in the corroded sample played a major role in accelerating the crack initiating and propagation rate. However, observations carried out on the vast corroded samples have shown that the pitting damage and crack initiation sites were located in the HAZ. Microstructurally, the HAZ zone of these grades of steel used for making car body exhibits metallurgical problem like excessive grain growth.

To solve the corrosion problem on car body, several factors are considered to determine the root cause of the problem and effective solutions are implemented to resolve the problem. In this investigation, Fishbone diagram was constructed to brainstorm various potential sources resulting in corrosion of car body. Special attention was paid on design and process changes required to prevent corrosion on car body. In addition, Pre-cut off

& Post- cut off samples were examined and their corrosion resistance were evaluated by Salt Spray Test & in-house developed special purpose test as discussed below.

II. EXPERIMENTAL PROCEDURE

In passenger vehicle different types of rust are produced at various locations due to the combination of following factors: i) environmental conditions, ii) paint peel off from the component, iii) design and iv) process related deficiencies. In this investigation, several cars were being audited to document various locations at which corrosion was commonly observed. During the audit, it was noted that the area near to the fire wall and at inner side of the hood are most vulnerable to corrosion. Some basic metallurgical analyses were performed to determine the type of corrosion. Subsequently, various processes were audited and reviewed to determine the potential source of corrosion on car body. Accelerated corrosion cycle test of entire car body was performed to evaluate its corrosion resistance. This test helped in identifying the source of corrosion and subsequently corrective actions were taken to resolve the problem of severe rusting of car body at various locations. Validation tests were performed at laboratory scale on corrective actions.

A. *Salt Spray Test*

Salt spray test was performed as per ASTM B117 [5] standard specification for 120 hours using 5% NaCl solution at room temperature. Subsequent to the test, samples were visually examined.

B. *In House Developed Corrosion Test*

(1) **Accelerated shower testing**: In the accelerated shower testing, car body was kept under high pressure normal water jet for 100 hours as per IS 11865:2006 and visual observation is made after the completion of test.

(2) **3-Year aging test:** Parts are aged for three years and after long duration test, the corrosion mechanism was determined.

III. RESULTS AND DISCUSSION

In this study, two major cases were identified and studied. These are: (a) Case of non-uniform corrosion on fire wall area (See Fig. 1(A)) and (b) uniform corrosion on inner section of the hood (See Fig. 1(B)).

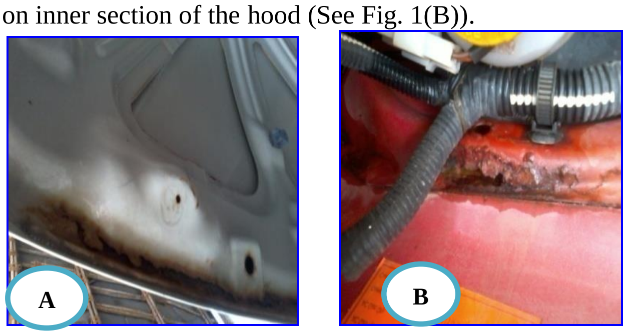

Fig. 1: a) Non-uniform rust on fire wall, and b) Uniform rust on inner side of the Hood.

Case A - Analysis of fire wall area

To determine the root cause of corrosion on fire wall, a fishbone diagram was constructed. Several potential factors were considered to determine to root cause of rusting on fire wall area. These factors are: i) Contributions for human factors like unskilled operator performed painting, change of manpower during the process etc., ii) Machine related factors, such as use of wrong machine, use of wrong spraying gun, wrong program, improper current applied, iii) Methods such as pH and concentration of ED bath not maintained to desired value, use of improper mixture of thinner and paint, poor baking, overheating and current not maintained properly in the ED bath, and iv) Design related factors resulting in water stagnation, sharp edges with insufficient paint, exposed to high temperature or area more prone to physical damage etc. After considering all these factors, it is observed that the fire wall area is prone to rust due to direct contact of water over an extended period of time. This occurred because of the uneven shape around the wall area resulting in water being remaining stagnant for long duration. In addition, wiper water which uses NaOH (part of Soap solution) with higher pH up to 9~10 is also considered a contributing factor to increase the corrosion rate of fire wall area. Therefore, the solution of this problem was resolved by drilling drain hole at appropriate locations to allow the water and soap solution to flow without remaining stagnant for long duration. In addition, non-conductive Mastic sealant was applied on the fire wall area before painting to prevent corrosion of steel body. After the application of sealant, salt spray test and acceleration tests were performed. No evidence of rust was observed after the completion these test (Fig. 3a). The corrective action is implemented in service and the rusting issue on the fire wall area is resolved.

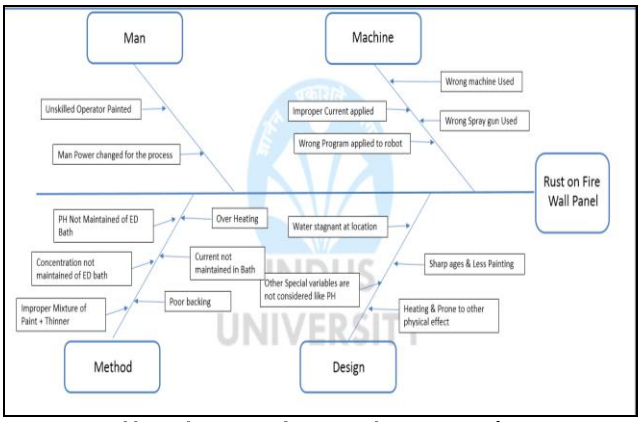

Fig. 2: Fishbone diagram to determine the root cause for corrosion.

Case B - Analysis of Hood area

In the case B, uniform rusting occurred on hood inner panel. To determine the role of several potential factors, a fishbone diagram was considered. In the fishbone following factors are considered:

(a) Human factors such: (i) High gap between two sheets, (ii) Over loading on sheet while crimping, (iii) Excess crimping, and (iv) Improper painting and coating.

(b) Machine factors such as: (i) Wear of fixture, (ii) Dimensional distortion of die & punch, (iii) Over pressure by hydraulic crimping machine, and (iv) Variation in painting coating thickness.

(c) Processing factors such as: (i) Improper machine used, (ii) improper tool used, (iii) Improper painting process applied, and (iv) Over loading or excess plastic deformation

(d) Design factors such as: (i) Creates local galvanic couple between two sheet metal panels, (ii) No drain hole to exit water and soap solution, (iii) Ineffective drain hole, and (iv) Areas not accessible to apply coating.

In this case, multiple causes played role in formation of rust. These are: huge contact area, less effectiveness of grain hole, and improper design resulting in inadequate painting & coating inside the area.

Therefore, as a counter measure, white mastic sealant was applied between panel skin and reinforcement panel. In addition, the drain hole location was changed to eliminate the occurrence of stagnant water and soap solution in the area. Subsequently, salt spray and accelerated tests were performed on the hood assembly. Both of these tests showed no evidence of rust in inner hood area (Fig. 3b).

IV. CONCLUSIONS

In Case A, the root cause of corrosion is primarily attributed to design factors that resulted in stagnant water at the fire wall area. To avoid the corrosion and to reduce the corrosion rate, nonconductive material (Mastic Sealant) was applied on fire wall area before painting. The Mastic sealant reduced direct contact of OH^- and H^+ ion with the steel body and thus helped in reducing the rate of corrosion. After the application of sealant, vehicle was tested at accelerated corrosion test and salt spray test. Both tests showed no evidence of white or red rust at the fire wall area (Shown in the Fig. 3).

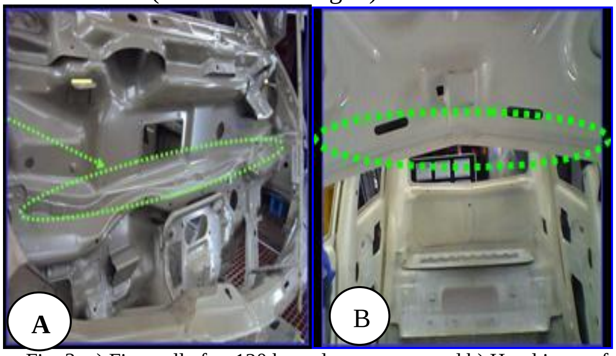

Fig. 3: a) Fire wall after 120 hrs salt spray test, and b) Hood inner after 120 hrs salt spray test. No rust observed.

In Case B, to avoid corrosion between reinforcement and the hood skin panel, a hole was drilled to drain the excess amount of ED and water that remained stagnant in that area. So during heating (Backing) ED, the part was dried properly and subsequently produced corrosion resistance film. To provide additional corrosion resistance, a part of the hood skin was covered with Mastic sealer to prevent erosion of paint. Salt spray and accelerated corrosion tests showed no evidence of rust on inner hood area after applying sealant to it.

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