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Design Considerations to Enhance Perforation Corrosion and Life Prediction of Automotive Body Panel

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The corrosion forms of automotive body panels are various. One of the representations is a corrosion pitting and its propagation on the lapped portion by galvanic corrosion. But it has been difficult in correlation analysis about the corrosion propagation rate and mechanism of pitting and the actual automotive body in field. This present study interprets experimentally the rust pitting occurrence mechanism on the lapped panels through experimental methods. And field car investigation was executed for correlation analysis with experimental results.

This paper compares corrosion propagation rate by pitting on hot-dip galvannealed steel sheets with corrosion forms in the automotive field condition. The research fundamentals which make it possible to predict the pitting occurrence and propagation on the lapped panels in the actual vehicles are given.

Keywords *: Perforation Corrosion, Automotive Body, Lapped Panel, Rust Pit*

1. Introduction

The corrosion protection of automotive body panels has become major issue since 1980s, in accordance with the development of corrosion-resistance steel sheets. Also the increase of anti corrosion warranty led to increasing in the proportion of zinc-coated steel sheets used in automotive industry. Currently more than 70% of automotive body materials are made of coated steel sheet and for some automotive companies the ratio rise up to 100%. But applying coated steel sheets inevitably results in cost increase, welding problems and poor painting property, etc. Therefore it is more necessary to clarify the exact forms and parts of corrosion occurring in auto -body than to improve the anti-corrosion materials thoughtlessly. And it will help choosing the proper materials for the optimum corrosion protection. In particular, perforation corrosion that occurs in hemming or lapped parts due to moisture or mud has very complicated developing mechanism. Because variables such as auto-body structure, parts and environmental factors apply complicatedly it make difficult to evaluate the perforation corrosion quantitatively.

So far, automotive companies and material suppliers have developed several corrosion evaluation methods such as monitor car test, proving ground test, Volvo test and laboratory cyclic corrosion test. But, though monitor car test is ideal for simulation about real situation with good repeatability, it takes much time with high cost. And proving ground test has drawback for verifying the increasing corrosion lifetime prediction although it is suitable for comprehensive test about auto-body. Laboratory cyclic corrosion test is proper method for studying corrosion mechanism and evaluating pitting corrosion from materials side, but it is difficult to reproduce the real corrosion situation found in field auto-body.

In this paper, we focused on the experimental corrosion characteristics of pitting corrosion in lapped part which is important in auto-body perforation corrosion. The growth rate and characteristics of rust pit of hot-dip galvannealed steel sheet have been studied. And comprehensive analysis about lapped parts of field car used in snow-belt areas of North America is performed for reliability verification about experimental study. Analyzing the growth condition of corrosion pit in various field car, we effort to find correlation between experimental results and actual field corrosion conditions. We analyzed the growth rate of rust pit of lapped part which is grow up locally by cyclic corrosion test simulation. These results were used for the lifetime prediction for auto-body perforation corrosion.

2. Experimental

Two types of corrosion samples are commonly used depend on their shapes; flat panels and lapped panels. The flat panel specimen does only square forms in order to measure the corrosion quantities in bare panel condition, but in order to reproduce of crevice and lapped portion of auto-body, lapped panel must be used. We used lapped panel shown in Fig. 1 to simulate the corrosion behavior of lapped parts of auto-body.

In actual cases, irregular uncoated zone is formed due to panel gap misalignment as well as lack of throwing power during electro-deposit painting. The gap accelerates localized corrosion by accumulation of chloride and oxygen ions on the uncoated zone and subsequently penetrates into deeper parts-crevice corrosion.

We measured both the maximum corrosion depth and the distribution of rust pits to avoid any misleading of real corrosion depth. A simple data of maximum corrosion depth does not represent general corrosion characteristics in real atmosphere. Statistical approach was carried out to analyze corrosion depth and rust pit distribution. The laboratory work that is use before only enables us to evaluate corrosion behaviors of material themselves. It is impossible to predict structural corrosion lifetime which considers environmental factors with this laboratory work. In order to overcome this limit we correlated this data

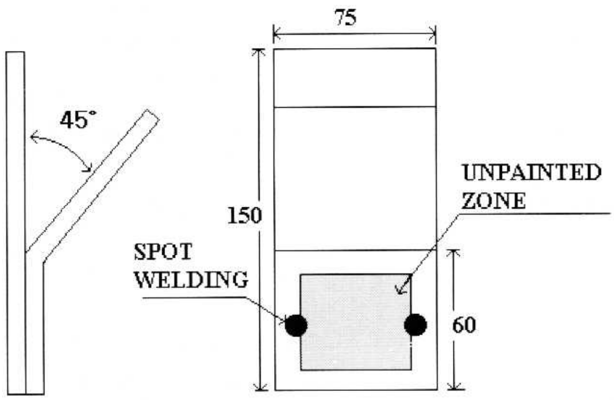


Fig. 1. Lapped Panel Specimen (unit : mm)

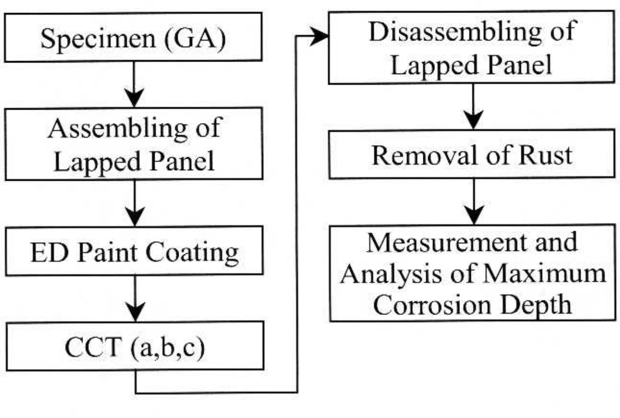


Fig. 2. Experimental Procedure

Table 1. CCT Conditions for lapped panel specimens

CCT (a) : 24h/cycle	CCT (b) : 24h/cycle	CCT (c) : 24h/cycle
SST 8hr (0.5% NaCl, 35°C)	SST 6hr (0.5% NaCl, 35°C)	SST 12hr (0.5% NaCl, 35°C)
DRY 6hr (60°C, 30%RH)	DRY 10hr (60°C, 30%RH)	DRY 3hr (60°C, 30%RH)
WET 8hr (50°C, 95%RH)	WET 6hr (50°C, 95%RH)	WET 6hr (50°C, 95%RH)
Low Temperature 2hr (-20°C)	Low Temperature 2hr (-20°C)	Low Temperature 3hr (-20°C)

to the results of actual auto-parts in field surroundings and tried to predict the corrosion life of auto-body lapped parts. We focused on evaluating hot-dip galvannealed steel sheets (coating spec. 60/60 g/m²) as a major sample material. Table 1. shows test conditions including a detail of different wet ratio in three cases.

3. Results and discussion

The test result of maximum corrosion depth in hemming parts and lapped parts of the vehicles used in North America was show in Fig. 3. The test result included maximum corrosion depth and estimated average corrosion velocity by use of vehicle running years about the parts which uses hot-dip galvannealed steel sheets. Of course, the corrosion pit growth of coated steel sheet in corrosive environmental always does not show linearity in pit growth behavior. In beginning, galvanic protection by paint layer and zinc-coated layer on the steel plate and the protection by corrosion deposit lead to delay in red rust processing and perforation occurrence. Such a retardation time depends upon the kinds of coating method, coated thickness, and the degree of gap in hemming part and lapped part and the treatment of anti-corrosion materials.

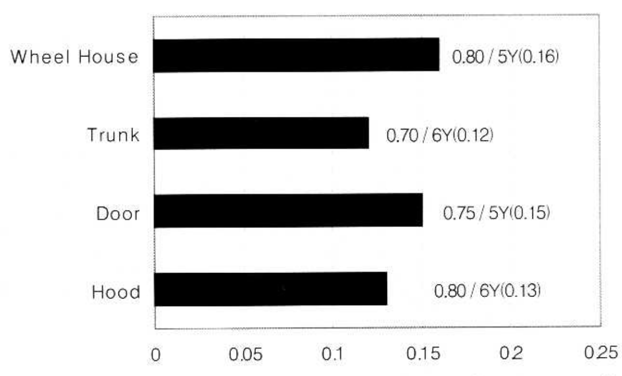
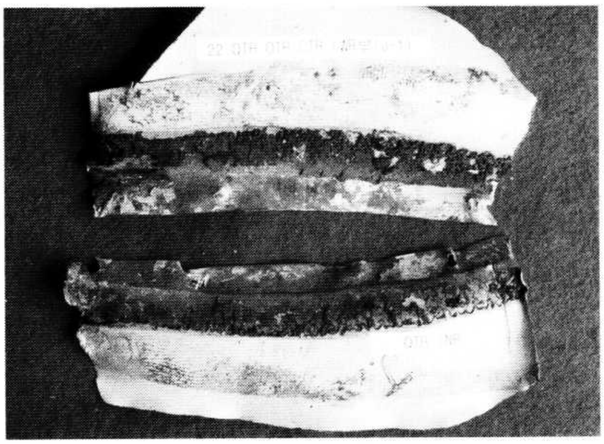


Fig. 3. Analysis results of average corrosion enviroment severity about field car parts (GA 60/60 applied)

(a)



(b)

Fig. 4. Picture of rear wheel house part (5years in North America)

Fig. 4. shows the state of corrosion at wheel house part in the vehicle run for five years in North America. At appearance damage of paint film by stone chipping and severe corrosion at outer gap in wheel house part were observed.(Fig. 4.(a)) But practically, corrosion progress by galvanic corrosion at inner gap was observed with main element.(Fig. 4.(b)) It is confirmed that weldable sealer has the effect of delay in corrosion processing in some part of the component, but does not protect the occurrence of localized corrosion completely.

Fig. 5. shows the appearance of corrosion state of the sample after cyclic corrosion test 70 cycles. By corrosion deposit, at appearance the state of corrosion cannot be confirmed accurately. At every 10 cycles the sample was separated from the test chamber and was measured the maximum corrosion depth with the 5 mm interval grid after completely getting rid of rust film from samples.

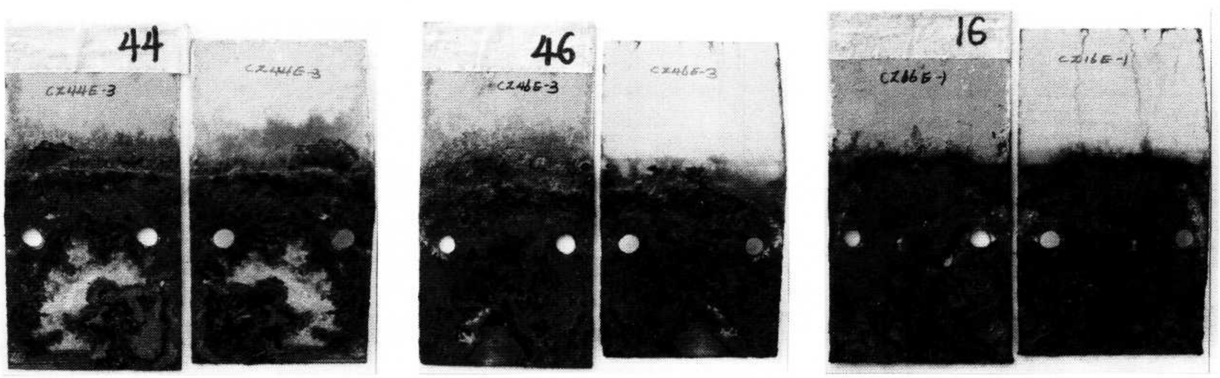
Fig. 6. shows the variation of maximum corrosion depth with running years of vehicles about wheel house part representatively. The regression line formula of exponential type was estimated including the origin (0,0) and the regression line formula of linear type was estimated excluding the origin.

Exponential line formula $Y1 = a*\exp(b*X)$ $Y1,2$ = pitting depth(regression value)
Linear line formula $Y2 = a*X + b$ y = pitting depth(measurement value)
X = running years

Table 2. Regression line formula of wheel house part

	a	b	Σ(lY-yl)
Exponential line formula (Y1)	3.69E-5	1.6986	6.979
Linear line formula (Y2)	0.2535	-0.874	1.803

Table 2 shows the constants for the regression line formula of wheel house part. Also it was calculated the sum of absolute value which is the difference between



CCT (a) CCT (b) CCT (c)

Fig. 5. Appearance after disassembling (CCT 70cycles)

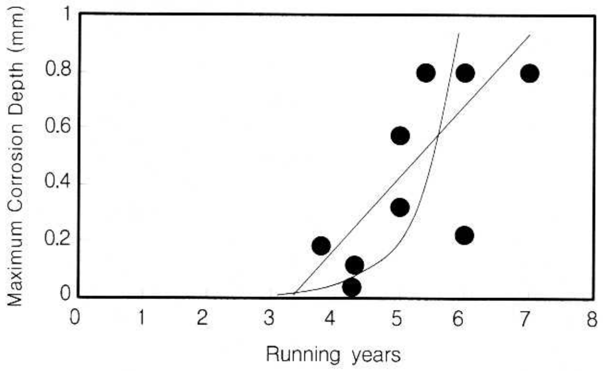


Fig. 6. Corrosion progress aspect about wheel house part

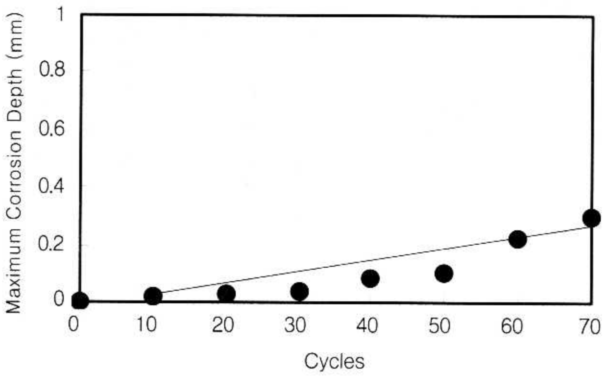


Fig. 7. Corrosion aspect at GA60/60 layer panel.(CCT (a))

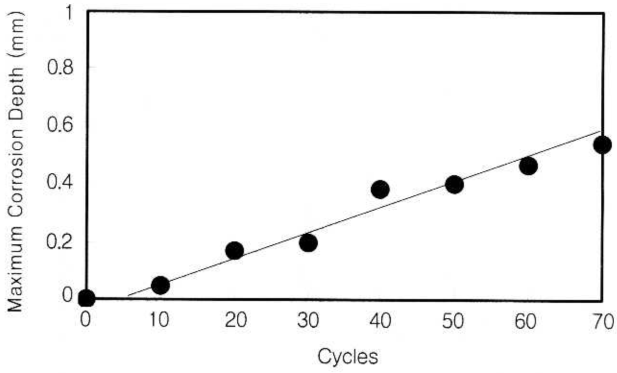


Fig. 8. Corrosion aspect at GA60/60 layer panel.(CCT (b))

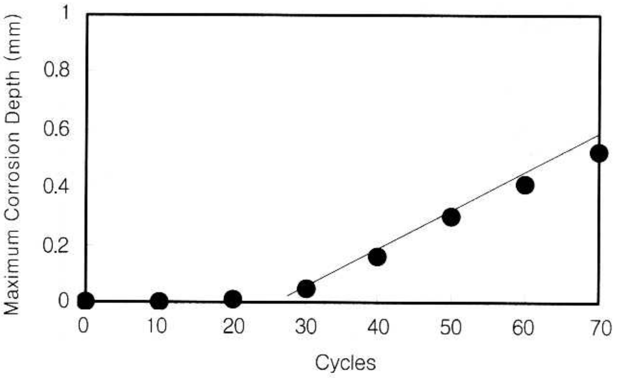


Fig. 9. Corrosion aspect at GA60/60 layer panel.(CCT (c))

regression value and measurement value. Analyzing Fig. 6 and Table 2, the growth rate of rust pit much approximates linear function with some retardation time. According to this linear function, the retardation time is 3.4 year and the pit growth rate is 0.25 mm/year. Of course, the retardation time of corrosion and the growth rate of pit are affected by complicated factor such as body parts, driving environment and the materials. Therefore, further analysis, times and efforts are required for simulating the real situation.

Fig. 7, 8, 9 shows the tendency of maximum corrosion depth at different CCT cycle. CCT (a) and (b) exist retardation time but not significant compared to the total test time. However, CCT (c) clearly reveals the existence of retardation time and it can be assumed that CCT (c) is close to the actual driving condition.

The materials that are used for hemming parts and lapped parts differ from car maker-to-maker, car-to-car and part-to-part. It is used to use different materials in lapped combination and additional protection materials such as wax or sealer can be used for delaying the initiation of corrosion. In such case, CCT (c) is example of proper methods for evaluating the delay of the corrosion initiation. Delaying the corrosion initiation of lapped parts is one of effective ways to improve the corrosion resistance of auto-body. That is, to use of coated steel sheets with good galvanic corrosion resistance or to apply anti-corrosion treatment that delays the beginning time of red rust occurrence. Of course, the structural designs that keep corrosion activators including chloride and oxygen ions from penetrating and accumulating for long time must come beforehand.

4. Conclusions

Following conclusions are achieved from the analyses of many field car used in snow-belt areas of North America and cyclic corrosion tests (CCT) to simulate the corrosion behaviors of lapped parts of auto-body.

1) It is found that the rust pits exhibit a linear growth with time after certain incubation period.

2) We evaluated quantitative data of the corrosion retardation time as well as the growth rate of rust pits of hot-dip galvannealed steel sheets.

3) It is suggested that corrosion resistance can be greatly improved by extending corrosion retardation time with applying sealing on crevice area of lapped parts.

4) We demonstrated a prediction of corrosion life of various coated steel sheets and additional protection by correlating the data of field cars with CCT simulation.

References

1. M. Nakazawa, H. Nomura, and K. Hayashi, "Perforation Corrosion of Automobiles Field Car and Laboratory Investigation". SAE PAPER 932367 (1993).
2. S. Sujita and R. Muko, "Corrosion Behavior of Organic Composite Coated Steel Sheet". SAE PAPER 932362 (1993).
3. M. Uchida and K. Mochizaki, "Corrosion Behavior of Vehicles Placed in Service in North America for 5 Years". Kawasaki Steel Company (2000).
4. B. L. Park and M. S. Choi, "Investigation about Estimation of Automotive Body Perforation Resistance". Hyundai Motor Company (1997).
5. S. G. Fountoulakis, "Perforation Resistance of Precoated of Steels in an Accelerated Automotive Test". SAE PAPER 860270 (1986).