CORROSION SCIENCE AND TECHNOLOGY, Vol.4, No.4(2005), pp.155~163

Development of Durable Reliability Assessment Methods for Heavy Duty Coatings

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Heavy duty coating are required to have minimum durable period of 15 years under average usage environment because these paints are coated with purpose of anti-corrosion, antifouling, plastering etc. Onto steel structures constructed upon land and sea and other ferrous structures of electric power generation plants, electricity transmission towers, large structures of various plants, etc. Therefore we tried to estimate heavy duty coating longevity through reliability evaluation method and used combined cyclic anti-conrrosion test method composed of drying, moisturizing and salt spray as for accelerated life test to estimate longevity. Accelerated life test hours to heavy duty coating of first grade (with longevity not less than 15 years) specification may be obtained from troubleless test hours $t_n = \frac{B_p}{n^{1/\beta}}\left[\frac{\ln(1-CL)}{\ln(1-p)}\right]^{1/\beta} = 19.671$ (yr) where shape parameter β = 1.1, confidence level CL = 80 %, warranty life B_{10} = 15 yr and sampling size n = 10 (2 sets). Because acceleration factor {AF} found by accelerated test is 41.7, accelerated life test hours required may be represented about 4,132 hr so that if this amount of hours is converted to number of cycles(6 hr/cycle) of complex cycle corrosion resistance test then the amount is tantamount about 690 cycles. That means if there does not occur trouble failure (with defect factor sum not more than 20) during when there is performed 690 cycles of combined cyclic anti-corrosion test to heavy duty coating specimen then it signifies that there can be warranted longevity B_{10} of 15 yr under condition of confidence level CL = 80 %.

Keywords *: heavy duty coatings, degradation, reliability assessment, durability, acceleration factor*

1. Introduction

As the social overhead capital (SOC) built in the wake of explosive economic development in 1970s to 80s got worn out over time, more than 50% of the SOC investment is expected to be spent on maintenance or repair of such assets in the 21st century. For that reason, life cycle cost of architectural structures is becoming increasingly important. Life cycle cost reflects interest cost and escalation on costs associated with planning, design, construction, operation and disposal of structures, doing justice not only to construction of structures but also to their maintenance and repair.[1),2)] Notably, Korea is a peninsular whose three sides are surrounded by sea and there are many SOC structures near coastline, therefore, exposed to corrosion by seawater. Moreover, explosive industrial development is polluting the air of Korea increasingly. Therefore, many of the SOC structures of Korea are built of metals and concretes coated with surface protecting anti-weather.[3),8)] However, as environmental conditions are getting progressively deteriorating, taking a greater toll as aggravated by increasing maritime environment or acid rain, it is essential that durability and reliability of heavy duty coating materials protecting structures from corrosion be improved.[4),5)] To that end, deterioration state of surface coating should be checked at a pre-defined interval and identified correctly. In principle, deterioration model of anti-corrosion coating may be expressed by years elapsed on axis X and state of coating on axis Y as suggested in Fig. 1 (Deterioration Model of Anti-Corrosion Coating).[6)]

(1) Defective construction leads to deterioration of coating (Graph: O→A).
(2) Deterioration of coating stays for the time being (Graph: A→B).
(3) Deterioration can be detected with naked eyes (Graph: B→C, deterioration progresses slowly).
(4) Deterioration accelerates over time (Graph: C→D).

It seems economically sensible that recoating be applied

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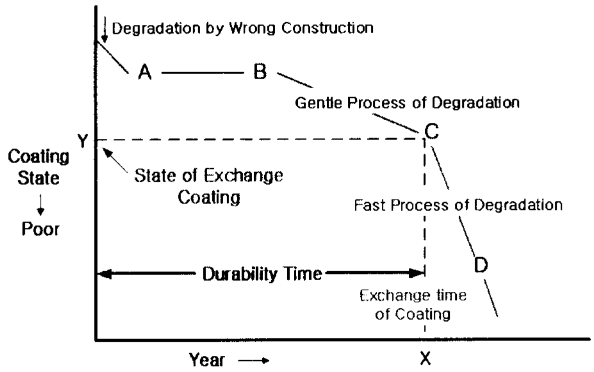


Fig. 1. Degradation models of havy duty coatings.

when initial coating has deteriorated to point C, in other words, coating deterioration has not become serious. In addition, time taken to reach point C, or until pace of deterioration accelerates can be regarded as the effective service life of coating. However, as surface of structure gets eroded under coating for some time before coating deterioration becomes noted, it is highly difficult to identify point C, namely, to determine whether coating will deteriorate abruptly soon or is still capable of preventing corrosion.

Heavy duty coating is applied to the surface of steel structures built on land or at sea or power transmission towers, large structures in manufacturing plants or generation stations to keep off corrosion and filth or for aesthetic look and service life of minimum 5 years is required under average conditions of use.[7] This study is to develop an approach to assessment of quality of heavy duty coating materials and reliability of their service lives to identify causes of their defects and service life test methodology.

2. Experimental and investigation

As heavy duty coating is exposed to a variety of environmental conditions including ultraviolet ray, pollutants or acid rain over time, cohesion between different coating layers and their resistance against alkali or shock get weakened and coating blisters up, whitens, breaks up or get rusted. Therefore, an approach to assessment of durability and reliability of heavy duty coating has been developed in three steps. Firstly, changes in the local environmental conditions were examined to identify factors leading to deterioration in nature and deterioration mode. Then, heavy duty-coated structures were examined on site to further investigate and analyze deterioration mode of heavy duty coating. Weathering-resistance test was conducted, using sun-shine weather meter to assess environmental impacts on deterioration of coating and cycle conditions and test approach was applied to the weather-resistance test to identify acceleration factor applicable to heavy duty coating. Results of outdoor exposure test conducted in Japan were used to identify correlation coefficient between accelerated service life test and outdoor exposure test and such results were reviewed in reference to comparable test data to determine acceleration factor. To assess durability and reliability of coating, salt spray tests based on various spraying patterns were conducted to analyze the findings of the outdoor exposure test and the acceleration test and to calculate acceleration factor with a test method of highest correlation coefficient. Based on the data, service life of heavy duty coating materials in each grade was assessed. Also, to identify fault occurrence timing in weather-resistance test and accelerated service life test, quantitative assessment approach applicable to blistering, whitening, breakage or rust was proposed.

3. Results and discussion

3.1 Analysis of deterioration mode of heavy duty coating

To test corrosion (corrosion-resistance) of metals or metal covering, salt spray test was developed by Dr. Capp in 1914 and adopted by ASTM standard 10 years after and widely used for many other standards.[2),3),8)] However, the purpose of the salt spray test was initially limited to quality control and its relevance to coating deterioration in outdoor conditions was nearly negligible. In 1970, it was questioned if it was adequate not to consider relevance of outdoor exposure conditions to coating deterioration and as it became known that salt spray test alone could not solve the issue, life cycle test method incorporating various conditions in a cyclic pattern was proposed to reproduce effective corrosion conditions.[9),10)] In addition, corrosion induced by acid rain became an issue in the U.S.A. following Europe in 1970s and ASTM has been still trying to resolve the issue since 1980s. Against that background, study on acid rain test was initiated based on the cycle test and acid rain cycle test to reproduce outdoor conditions was developed. The acid rain cycle test is already turning out to be effective and a discussion regarding standardization of the test is now underway at ISO. Local data on impact of acid rain on heavy duty coating is not available at the moment, but, data on corrosion induced by acid rain in Japan as presented in Table 1 shows that list of influential causes of coating deterioration has changed greatly in 10 years and acid rain is ranked on the top from the previous 9th in the list.[9)]

Table 1. Change of degradation defects for coating film (Okinawa, Southern KyuShu)

Investigated in 1980			Investigated in 1989		
Rank		Percent	Rank		Percent
1	Crack	24%	1	Acid rain	40%
2	Chalking	20%	2	Scratch	19%
3	Blistering	9%	3	Rust	19%
4	Peeling	6%	4	Discoloration	15%
5	Discoloration	4%	5	Chalking (Repair)	6%
6	Mildew	4%	6	Crack(Repair)	4%
7	Scratch	2%	7	Chalking	2%
8	Rust	1%			
9	Acid rain	1%			

First of all, acceleration test must model real outdoor conditions as closely as possible, which needs to be evidenced by sequence of corrosion in test matching that of real life environment and reproducibility of test results. In the U.S.A. deterioration by acid rain containing high-polymer substances became an issue already and it was reported that deterioration of nylon got aggravated when SO_2 and high humidity were added to light. Causes of corrosion and blistering of heavy duty coating are illustrated in Fig. 2.[2),11),12),13)]

Coating deteriorates for a mixture of various causes. Deterioration of coating is also triggered by chemical or physical changes to components of coating including resin, pigment or other additives attributable to various causes. To identify abrupt timing of coating deterioration, it is necessary to understand durability of heavy duty coating. Data on causes of deterioration in various local structures after 10 years from construction is shown in Table 2 and the table indicates that intensity of deterioration in splash zone is way higher in submerged area and progress of deterioration is related to thickness of coating.[4),14),15)]

As heavy duty coating is exposed to a variety of environmental conditions including ultraviolet ray, pollutants or acid rain over time, cohesion between different coating layers and their resistance against alkali or shock get weakened and coating blisters up, whitens, breaks up or get rusted.

Critical causes and their correlations to deterioration mode of heavy duty coating are described in Table 3 and Fig. 3. Also, as discoloring and loss of gloss occurs, which is an aesthetical issue, when deterioration performance (weather, corrosion and shock-resistance) is not maintained at a level required in reliability and quality certifi-

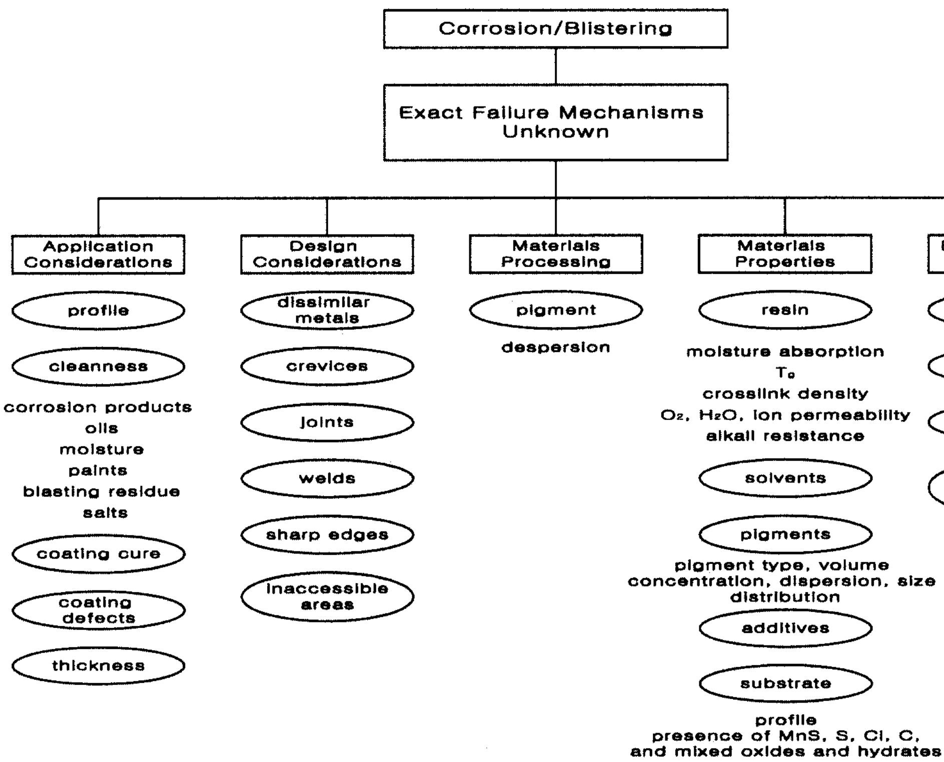


Fig. 2. A phenomenon of degradation defect for coating film

Table 2. Research on the actual condition of degradation factor for domestic heavy duty coating film (KICM)

Corrosion environment (seaside)	Degradation state	Degraded Coating system
Atmospheric	Rusting of scratch and edge part Rusting of scratch part Crack of film surface	Tar epoxy resin paints Epoxy resin paints Hot melts hydrocarbon resin paints
Splashzone	Rusting of scratch part Crack of film surface Film abrasion of edge part Partial pitting Partial rust of general part	Epoxy resin paints Hot melts hydrocarbon resin paints inorganic zincrich paints Zinc thermal spray Tar urethane resin paints
Under the sea	Blistering of scratch part Partial Blistering of general part Rust caused in blistering Deterioration fo adhesion Peeling of scratch Partial pitting	Tar epoxy resin paints Epoxy resin paints Tar urethane resin paints inorganic zincrich paints Zinc thermal spray

Table 3. Relationship of Requirements(Stresses and Performance) and Failure Modes

Failure Modes/ Mechanisms Requirements (Stresses & Performance)	Corrosion	Physical property	Crack	Peeling	Blistering	Illuminance	Discoloration	Chalking
Outdoor exposure		◎	◎			◇	○	○
Temperature		○	○			◇	◇	◇
Humidity	◎	○		◎	○	○	◇	
Environmental pollution	○	○	○			○	○	
Salty particle	◎	◎		◎	○	○	○	

* Important level: ◎ Very important ○ important ◇ normal
* Failure Modes and Mechanisms are properties of items and materials

cation test of heavy duty coating material, it is regarded as the final fault of heavy duty coating.[9,16,17] Therefore, the reliability assessment standard proposed in this study referred to blistering, discoloring, glossiness and breakage to determine fault timing and regarded points assigned to measurement of each assessment item and multiplied by influence vector as fault element factor to assess fault timing of heavy duty coating.

3.2 Development of weather-resistance test approach

The simple question of how many hours of accelerated weathering test are equal to how many years of real outdoor conditions is the longest enduring question that has yet to be answered in the study of weather resistance. Validity of the question itself may be debatable, but, from heavy duty coating material user's perspective, answer to the question may be information that is wanted most regarding weather-resistance of the coating materials. Outdoor exposure test takes a long time to produce outcomes, but, the test is the most fundamental test of all light exposure tests conducted by laboratories. Also, data on detailed analysis of correlations to meteorological factors is hard to find. Detail records annual changes ultraviolet spectrum distribution, temperature, alternation of wetness and dryness, impacts of pollutant at a single day resolution is also non-existent.[11,13]

Also, if weathering is accelerated, correlation of test to real outdoor conditions is lowered while correlation of test conditions is improved at the cost of test acceleration. It is no exaggeration that there is no test method that can satisfy both requirements. As a means of accelerating weathering, strengthening light intensity, raising temperature or shedding short wavelength light can be named, but, ISO tends not to endorse tests that include lights that do not exist in real outdoor conditions. Given the past experiences, any of the current laboratory light exposure tests do not ensure equivalence of several dozens of laboratory test hours to a year in real outdoor conditions. Many of the tests require 700~800 hours at least. Some even say that the current test methods cannot catch up with the weather resistance of the heavy duty coating products whose performance keeps upgrading and service life extended and some industry stakeholders may be satisfied with acceleration-specific test methods. What is the second most important then is the selection of light source. As source of light in laboratory weather-resistance test, Xenon lamp, ultraviolet light, sun-shine carbon (hereinafter called Sun-shine), metal halide lamp can be named.[2),8)]

Weather resistance test conducted as a part of reliability certification test of heavy duty coating products is supposed to use Sun-shine carbon arc to reproduce deterioration of coating in real life conditions. Sun-shine weather meter is similar to real Sun-shine, has ample energy in ultraviolet spectrum and provides high reproducibility and acceleration. JIS, ISO and ASTM specifies 3 types of filters to model correlation to outdoor conditions, and indoor materials (ex. indoor finish materials of automobiles) are supposed to be tested with filter C and outdoor materials are to be tested with filter A or B. In general, filter A accelerates weathering more than filter B.[2),9),11)]

Coating deterioration phenomena were classified by significance to determine influence vector and rating schedule to grade level of coating deterioration were developed to quantify coating deterioration. Lastly, weather-resistance of coating was assessed in reference to fault element factor calculated by multiplying influence vector and fault rating. Influence vector applied to assessment items of heavy duty coating was determined in reference to quality standard on heavy duty coating material enforced by Institute of international container lessors. Table 5 shows influence vectors mapped to deterioration phenomena observed in weather resistance test.

Accelerated weathering test of heavy duty coating was conducted in accordance with KS R 4069 and JIS K 5400 and the conditions are illustrated in Table 6. Accelerated weathering test duration was determined in reference to results of outdoor exposure test conducted in various regions of Japan for 20 years by Suga Weathering Technology Foundation of Japan. 250 hours of test were assumed to be equal to 1 year of real outdoor exposure

Table 5. Effect ratio of durability test for environment

Classification		Effect ratio(%)	Vector
Accelerated weathering test (Sun-shine carbon arc type)	Blistering	40	4
	Color difference	7	0.7
	Maintenance rate of illuminance	10	1
	Chalking	10	1
	Crack	33	3.3
Total		100	-

Table 6. Test conditions of Accelerated weathering test for sun-shine carbon arc weather meter

Classification		Condition
Voltage	Range	48~52V
	Average	50V(±2%)
Amphere	Range	58~62A
	Average	60A(±2%)
Application time of Glass filter		2,000h
BPT		63±3℃
Spray condition of water	Pressure	0.08~0.13MPa ({0.8~1.3}){kg/cm^2})
	Water quantity	2,100±100 ml/min
	Spray time	18min(in 120 min)
	Water quality	pH 6.0~8.0, Conductivity 100μS/cm and less
	Temp. of water	16±5℃

Table 4. A Filter for sun-shine weather meter used for test of polymer materials

Classification	A	B	C
Geometry · size	Panel type, length 302.5±2.0nm, width 164±1.5nm, thickness 2.4±0.2nm		
Spectrum transmittance before the use (Room temperature)	255nm: 1% and less 302nm: 71~86% more than 360nm: 91% and upward	275nm: 2% and less 320nm: 65~80% 400~700nm: 90% and upward	295nm: 1% and less 320nm: 40% and upward 400~700nm: 90% and upward
Rate of expansion	about $5\times10^{-6}K^{-1}$	about $3\times10^{-6}K^{-1}$	about $10\times10^{-6}K^{-1}$
Total application time	2000h		

Table 7. Relationship of outdoor exposure test and accelerated weathering test

Classification	Test time on equal to outdoor exposure(Hour)			
Sample / Place	Melamine alkid	Acryl	Epoxy	Polyurethane
Yocaichi	410	460	430	370
Tsu	530	470	610	690
Ise	490	250	540	360
Kadoma	270	400	520	460

and Grade 3 material(service life of 5 years guaranteed) were tested for 1,250 hours, Grade 2 products (service life of 10 years guaranteed) were tested for 2,500 hours and Grade 1 materials (service life of 15 years guaranteed) were tested for 3,750 hours in the accelerated weathering test program. Table 7 shows correlations between real outdoor exposure test conducted by Suga Weathering Technology Foundation of Japan and this accelerated weathering test.

Level of deterioration following weathering-resistance test was assessed in reference to glossiness, blistering and breakage. As for blistering and breakage, image analysis method that would ensure more quantitative results than the rating number approach which is generally used. Measured outcomes were then multiplied by influence vector to determine fault element factor and weather-resistance of heavy duty coating was assessed based on the fault element factor.

3.3 Accelerated service life test results

As corrosion cycle acceleration test for heavy duty coating is not available, JH Test Laboratory compared and reviewed existing cycle test conditions to develop a corrosion cycle acceleration test method that has a close correlation to outdoor exposure test results. 6 different types of cycle test conditions and existing salt spray test conditions cross-reviewed are presented in Table 8.

As indicated in Table 9, it was found that Seawater NS was highly correlated to Hokuriku, Okinawa Coast and Hujisawa while S-6 was the closest to Tokyo and ASTM to the inland of Okinawa. In terms of average of each region, Seawater NS had the highest correlation and S-6

Table 8. Accelerated corrosion conditions compared to decision upon relationship of outdoor exposure test and accelerated weathering test

No.	Classification	Test condition(SST · Dry Cycle condition)			
①	Slat spray ※(S.S)	S.S. 5%, NaCl 35℃ continue			
②	SPIA Cycle(S-6)	S.S. → 5%, NaCl 30℃ 0.5h	Wet → 95%, R.H 30℃ 1.5h	Dry → 20%, R.H 50℃ 2h	Dry → 20%, R.H 50℃ 2h
③	DS Cycle	S.S. → 5%, NaCl 30℃ 0.5h	Dry → 50%, R.H 50℃ 2h	Wet → 90%, R.H 50℃ 15h	Dry → 50%, R.H 50℃ 5h
④	NS Cycle	S.S. → 5%, NaCl 35℃ 4h	Dry → 50%, R.H 60℃ 2h	Wet → 95%, R.H 50℃ 2h	
⑤	JASO	S.S. → 5%, NaCl 35℃ 2h	Dry → 50%, R.H 70℃ 4h	Wet → 95%, R.H 50℃ 2h	
⑥	NS Cycle (Sea water)	Use artificial sea water instead of 5% Nacl solution and do salt spray test in cycle of No ④			
⑦	ASTM	S.S → 5%, NaCl 35℃ 4h	Wet → 100%, R.H 100℃ F(37.8℃) 18h	Freeze → 10±3F (-23.3±2℃) 2h	

Table 9. Relationship of outdoor exposure test and accelerated weathering test

Condition		Tokyo	Hokuriku	Okinawa (inland)	Okinawa (seaside)	Hujisawa	Average
①	SS	0.120	0.275	0.576	0.505	0.444	0.384
②	S-6	0.690	0.825	0.718	0.786	0.853	0.774
③	DS	0.523	0.754	0.491	0.669	0.845	0.656
④	NS	0.609	0.793	0.675	0.672	0.832	0.716
⑤	JASO	0.512	0.774	0.777	0.734	0.853	0.730
⑥	SW-NS	0.665	0.841	0.745	0.907	0.859	0.803
⑦	ASTM	0.561	0.766	0.900	0.813	0.805	0.769
Average		0.526	0.718	0.697	0.727	0.784	0.690

and ASTM followed. In the comparison of each cycle condition, no issue was observed in single coating layer, but, in multiple coating layers, it is probable that remainder of solvent under coating may affect blistering during high temperature cycling. Given the conclusions of the comparative review, S-6 that is highly correlated to various outdoor exposure test sites such as North Land, Tokyo, DengTaek, capable of assessing multiple coating layers and economically efficient are used for seashore and ordinary environment test and ASTM is used to test special environmental conditions such as observed in Okinawa.

Combined cyclic anti-corrosion test composed of salt water spraying, hot wind drying, moisturizing and warm wind drying to reproduce outdoor corrosion pattern as closely as possible was conducted in accordance with provisions ISO 11997-1 and ISO 11997-2 on specimen that passed basic performance test and weather-resistance test.[18] Prior to the test, to prevent unwanted influence on the corrosion of the specimens, about 5 mm from the end of specimen and its other side were masked and X-shape groove was made on 10 out of 20 specimens. Grade 3 paint went through 230 cycles, Grade 2 460 cycles and Grade 1 690 cycles to assess their characteristics. Deterioration characteristics developed after combined cyclic anti-corrosion test were assessed by computer image analysis system rather than by naked eyes observation to ensure a more objective analysis.

Table 10. Analysis of effect ratio for accelerated service life test

Classification			Effect ratio(%)	Vector
Combined cyclic anti-corrosion test	Rust	Scribed	45	4.5
		Unscribed	35	3.5
	Blistering		20	2
Total			100	-

3.4 Determination of accelerated service life test coefficient

To determine accelerated service life test coefficient of heavy duty coating, Weibull distribution-based MTTF (mean time to failure) test criteria that is most widely used to assess reliability and capable of estimating deterioration of high polymer substances were applied. Table 11 shows acceleration factor of combined cyclic anti-corrosion tests conducted on heavy duty coating by Suga Weathering Technology Foundation in various regions of Japan. To determine acceleration factor between deterioration characteristics observed in real life conditions and in combined cyclic anti-corrosion test, it is essential that heavy duty paint be applied to steel bridges or structures and outdoor exposure test be conducted for an extended period of time to measure coating deterioration characteristics attributable to various deterioration factors.[7),8)] However, as local data from outdoor exposure tests of heavy duty coating is not available, acceleration factor

Table 11. Acceleration Factor of Combined cyclic anti-corrosion test

Exposure place and conditions	Outdoor exposure place				
	Tokyo	Hokuriku	Okinawa (inland)	Okinawa (seaside)	Hujisawa
Tokyo	1.00	0.52	1.24	0.60	0.39
Hokuriku	1.93	1.00	2.41	1.16	0.75
Okinawa (inland)	0.80	0.42	1.00	0.48	0.31
Okinawa (seaside)	1.67	0.87	2.08	1.00	0.65
Hujisawa	2.59	1.34	8.22	1.55	1.00
SST	29.58	15.29	36.78	14.78	11.4
CCT	34.49	17.33	41.70	16.70	12.96

calculated in reference to comparison between outdoor exposure tests and combined cyclic anti-corrosion tests conducted on heavy duty coating by Suga Weathering Technology Foundation in various regions of Japan. Specifically, acceleration factor of 41.7 applicable to the inland of Okinawa which is the standard outdoor exposure test site of Japan was selected. The acceleration factor will be supplemented as local data on outdoor exposure test of heavy duty coating become available.

If all the specimens of each paint showed no fault for MTTF which was t_n, such a paint was regarded as passing the test and if any of the specimens showed a fault by t_n, the paint was regarded as failing the reliability test. If when test is conducted on samples of n number and unreliability is $F(t_n)$ and reliability is $R(t_n)$, number of faults until t_n follows a binomial distribution where parameter is n and unreliability is $F(t_n)$. In other words, t_n satisfying confidence level CL (consumer risk β =1-CL) can be calculated from the following equation.[2),15)]

$$1-CL=\sum_{x=0}^{0}\binom{n}{x}F(t_n)^x R(t_n)^{n-x}=R(t_n)^n$$ from

$$R(t_n)=(1-CL)^{\frac{1}{n}}$$

Regarding design of reliability certification test, where average service life is $MTTF_q$ and guaranteed service life is B_p, scale parameter θ_q is as follows:

$$\theta_q=\frac{MTTF_q}{\Gamma(1+\frac{1}{\beta})}=\frac{B_p}{[-\ln(1-p)]^{1/\beta}}$$

where β: Shape parameter, : Gamma function

If number of specimens tested simultaneously in accelerated service life test is n (sample size) and confidence level is CL, t_n which is MTTF test time to pass reliability certification test can be determined as follows:

$$R(t_n)=e^{-(\frac{t_n}{\theta_q})^\beta}=(1-CL)^{\frac{1}{n}}$$ and

$$t_n=\theta_q\left(\frac{-\ln(1-CL)}{n}\right)^{\frac{1}{\beta}}=\frac{B_p}{n^{1/\beta}}\left[\frac{\ln(1-CL)}{\ln(1-p)}\right]^{1/\beta}$$

First of all, accelerated service life test time for grade 1 heavy duty coating paint was (where scale parameter: β = 1.1,[1)] confidence level: CL = 80%, guaranteed service life: B_{10} = 15 years, sample size: n = 10(2set)):

MTTF test time:

$$t_n=\frac{B_p}{n^{1/\beta}}\left[\frac{\ln(1-CL)}{\ln(1-p)}\right]^{1/\beta}=\frac{15}{10^{1/1.1}}\left[\frac{\ln(1-0.8)}{\ln(1-0.1)}\right]^{1/1.1}=19.671$$

(yr) As acceleration factor (AF) obtained from test was 41.7, accelerated service life test time was: Accelerated service life test time:

$$\frac{19.671(yr)\times 365(day)\times 24(hr)}{41.7}=4{,}132.325(hr)$$ equal to around 690 cycles when converted to number of cycles of composite cycle weather-resistance test (1 cycle = 6 hours).

Therefore, accelerated service life test time was converted to number of cycles of combined cyclic anti-corrosion test (1 cycle = 6 hours) and if heavy duty coating showed no faults for 690, 460, 230 cycles (total of fault element less than 20), B_{10} of 15 years (Grade 1), 10 years (Grade 2) and 5 years (Grade 3) were regarded as guaranteed at confidence level of 80%.

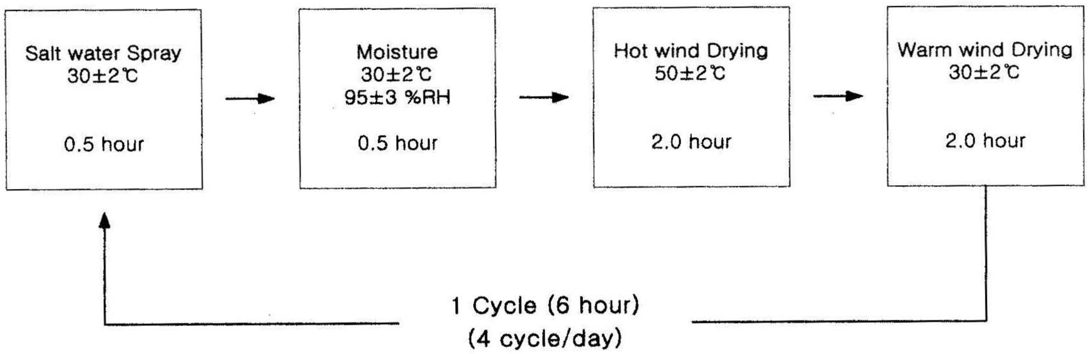
3.5 Validation of correlation of accelerated service life test factor

As the accelerated weathering test factor and accelerated service life test factor were all based on data from Japan, those factors will be validated against local meteorological conditions in the outdoor exposure test site under construction in Seosan, Chungnam Province. To provide an overview of the planned outdoor exposure test, duration of exposure will be equal to warranty period of each heavy duty coating being tested and test specimen will be positioned at 30 degree angle to horizontal plane. Also, since results of outdoor exposure test are known to vary, depending on the time when the test starts and deterioration gets aggravated from Spring to Summer, start of outdoor exposure will be scheduled for some time during May in this study.

4. Conclusions

1) Accelerated weathering test of heavy duty coating was conducted in compliance with KS R 4069 and JIS K 5400 and the duration of accelerated weathering test was 1,250 hours for Grade 3 products (guaranteed service life of 5 years), 2,550 hours for Grade 2 products (guaranteed service life of 10 years and 3,750 hours for Grade 1 products (guaranteed service life of 15 years).

2) Accelerated service life test was conducted only on products that passed basic performance test and weathering resistance test. The accelerated service life test was configured to be a combined cyclic anti-corrosion test composed of salt spray, hot wind drying, moisturizing and warm wind drying cycle and the test was done in com-



Schematic diagram of combined cyclic anti-corrosion test

pliance with provisions in ISO 11997-1 and ISO 11997-2.

3) To assess durability and reliability of heavy duty coating, accelerated service life test was conducted by composite cycle tester and Grade 3 paints iterated 230 cycles, Grade 2 460 cycles and Grade 1, 690 cycles to assess their characteristics.

4) If tested heavy duty coating satisfied criteria of basic performance test and weathering resistance test and the total of fault element factor identified in accelerated service life test was less than 20, Grade 3 paint was found to guarantee B_{10} of 5 years, Grade 2 10 years and Grade 1 15 years at confidence level of 80%.

Acknowledgement

I deeply appreciate contributions rendered by JPIA and Suga Weathering Technology Foundation in support of this study.

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