Development of the Corrosion Deterioration Inspection Tool for Transmission Tower Members

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Abstract

Recently, interests for maintenance of transmission tower are increasing to extend life of structures and reduce maintenance cost. However, existing classical diagnosis method of corrosion deteriorated degree on the transmission tower steel members, visual inspection, has a problem that error often due to difference of inspector's individual knowledge and experience. In order to solve the problem, this study carried out to develop the corrosion deterioration inspection tool for transmission tower steel members. This tool is composed of camera equipment and computer-aided diagnosis system. We standardized the photographing method by camera equipment to obtain suitable pictures for image processing. Diagnosis system was designed to evaluate automatically degree of corrosion deterioration for member of transmission tower on the basis of the RGB color image processing techniques. It is anticipated that developed the corrosion deterioration inspection tool will be very helpful in decision of optimal maintenance time for transmission tower corrosion.

Keywords: Transmission tower, maintenance, corrosion deterioration inspection, RGB, color image processing

I. INTRODUCTION

The transmission tower is constructed and managed in various atmospheric environments during long-period of time, therefore, deterioration is occurred through the main cause of atmospheric pollution. The main member of most of the supports for the transmission tower is steel, and to minimize the deterioration, basically the method of hot dip galvanizing treatment is applied, and in the case of the hot dip galvanizing losing its original function, the painting repair is enabled additionally by the middle molding painting on the surface of the member. Generally, the deterioration of the transmission tower member not only results in the difficulty of maintenance and repair of the facility, but it also inhibits the reliability on the power supply, and becomes an important reason in reducing public safety. Therefore, to enable the economic and reliable management of the transmission tower, the condition of deterioration must be evaluated precisely, and at the same time, maintenance such as timely and rational repair and reinforcement are required.

For the transmission tower member currently under operation, the standard index for reading the deterioration level is partially set, and for the inspection method of deterioration to determine the performance of the maintenance, visual inspection is mostly performed. This visual inspection includes the irrationality of the inspector's personal experience and own decision being greatly reacted in reading the level of deterioration in the transmission tow member. Also, quantitative analysis on the deterioration is difficult to disable efficient response to the determination of the maintenance period. To solve these problems in this study, the inspection tool for the quantitative analysis on the corrosion and deterioration level, and enabling objective reading of the level of deterioration on the transmission tower member was developed.

II. THEORETICAL BACKGROUND AND STUDY TREND

According to the use of the transmission tower, when the hot dip galvanizing is corroded on the member, coating is performed on the surface of the steel surface to prevent additional corrosion. This is a chemical or electrical blockage of the material and environment of the steel to prevent from corrosion. Currently, coating is the most widely used method, occupying approximately 65% of the cost for measures to corrosion. The reason that coating is widely used is because it does not require special tool for the coating to enable construction on the field, and it's also low cost and can maintain the eco-friendly appearance. However, the durability of the coating and film are limited, therefore coating must be performed regularly after certain period.

Thus, as the importance of coat management on the steel structure is recognized, studies on the maintenance method of economic coating were performed. Various applicable coating methods according to the characteristics of the exposed atmospheric environment were set, and the service life of each costing were evaluated to analyze the life-cycle cost to evaluate the economic feasibility of maintenance [1]. Especially, grade was defined in advance on the level of occurrence and progression of the corrosion on the transmission tower, and rational method of repair according to each corrosion grade were planned to analyze the coating repair cost during the life-cycle, and as a result, it showed that over 2 times the cost was added according to the difference of repair period for each corrosion grade [2]. Therefore,

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Table 1. Criteria of deterioration grade for hot dip galvanizing member

Grade	External characteristics
1	· Shows bright gray color · Surface is satisfactory with no discoloration and corrosion
2	· Shows faint rust according to the exposure of galvanizing alloy layer, and also shows light yellow color on the overall surface · The area rate of the discolored site into red or black is within 10%
3	· The alloy layers on all sides are exposed · Beginning to show red color, and spots of rust or local corrosion has occurred · The area rate of the rust within the 1.0 m size of the member is within 20%
4	· The alloy layer and the steel member are exposed in wide areas to have change into red and black color · The area rate of the rust within the 1.0 m size of the is between 20~40%
5	· The steel member is shown wider than in grade 4 of deterioration level, and noticeable black discoloration has occurred · Area rate of rust in the 1.0 m size of the member is over 40%

Table 2. Criteria of deterioration grade for painted member

Grade	External characteristics
1	· Shows the unique color (Green, orange, etc.) of the initial painted member · The surface condition is satisfactory, and has no discoloration, crack, exfoliation, swelling and basic material exposure
2	· Shows slight discoloration on the painted member, but the surface condition is satisfactory in overall, and the area rate of damage such as crack, exfoliation, swelling and exposure of the basic material are less than 5%
3	· Crack, exfoliation, swelling and exposure of the basic material are occurred on the surface of the painted member · There are also corrosion on the basic material exposed · The area rate of damage within 1.0 m size of the length in the member is less than 20%
4	· Crack, exfoliation, swelling and exposure of the basic material are widely occurred on the surface of the painted member · There are corrosion also on the basic material exposed · The area rate of damage within 1.0 m size of the length in the member is between 20~40%
5	· Crack, exfoliation, swelling and exposure of the basic material are occurred on the surface of the painted member much wider than grade 4 of the deterioration level · There are corrosion also on the basic material exposed · The area rate of damage within 1.0 m size of the length in the member is over 40%

in the management and maintenance of the existing transmission tower, precise verification of the deterioration condition on the member is an important procedure to secure the safety and also the economic feasibility. In correspondence to this, various techniques were developed to inspect and diagnose the corrosion and deterioration level of the existing transmission tower and the steel structure. Basically, the evaluation standard through visual inspection on the corrosion and coating deterioration of the steel structure was established [3]-[6]. Also, the technique of using ultrasonic waves to measure the deterioration level on the painted member was introduced [7]-[9]. Moreover, for the hot dip galvanizing member, the electro-magnetic thickness tester and the handheld X-Ray fluorescence analysis system were used to effectively measure the residual thickness of the hot dip galvanizing film [10]. Especially, from the image filmed with CCD (Charge Couple Device) camera on the inspection and diagnosis site of the steel structure to image processing the deterioration such as the steel corrosion and exfoliation of the coating, techniques for the quantitative evaluation of the level of deterioration were developed to be actually applied on the inspection and diagnosis of the steel girder bridges [11][12]. Also for the transmission tower, studies regarding the reading on deterioration through HSV and Lab color space digital image processing were partially conducted [13][14].

However, the existing techniques of inspecting and diagnosing the level of corrosion and deterioration on the structure have limitations in use to be applied direction on the judgement of deterioration on the transmission tower. In other words, visual inspection is not possible for quantitative evaluation on the deterioration reading, and the residual thickness measurement using non-destructive tool has high precision in measurement, but has only sectional result on the member of inspection. Therefore, in the case of performing the inspection on the overall structure, it has the problem of low efficiency in the inspection and diagnosis work. According to these conditions, the deterioration evaluation technique through the digital image processing is recently being applied, but it was mostly on the steel girder bridges, and the image processing technology is optimized on the deterioration characteristics on the painted member, therefore, it is impossible to be applied in members treated with hot dip galvanizing coating such as the transmission tower. Also, the existing digital color image processing based transmission tower deterioration evaluation technology that was developed is an image processing technology considering the deterioration characteristics of the hot dip galvanizing member, but in the case of performing the repair on the coating according to the elapse in the use of the transmission tower, it is difficult to provide proper inspection and diagnosis result on the deterioration condition of the painted member.

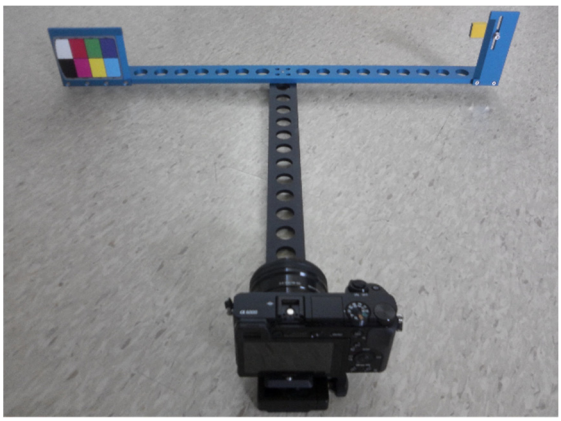
III. DEVELOPMENT OF THE CORROSION AND DETERIRORATION INSPECTION TOOL

In this study, according to the deterioration condition evaluation standard of the transmission tower by KEPCO, the inspection tool that can enable quantitative analysis on the steel corrosion and coating deterioration on the hot dip galvanizing coating and painted member of the transmission tower in use, and provide objective evaluation on the level of deterioration was planned. To utilize the RGB color value on the transmission tower member corrosion and coating deterioration to evaluate the level of deterioration on the transmission tower based on the digital color image processing, the camera equipment and the computer-aided diagnosis system of corrosion and deterioration were developed.

A. Standard of deterioration grade decision on the transmission tower

The criteria of deterioration on the transmission tower can differ according to each country or the subject of maintenance. In KEPCO, the color change characteristics on the surface of the steel according to the deterioration of the hot dip galvanizing coating and painted member of the transmission tower are used to select the member subjected for anti-corrosion coating, and the condition of corrosion is diagnosed and evaluated according to

(a)



(b)

Fig. 1. Camera equipment for corrosion deterioration inspection tool. (a) safety inspection scene, (b) camera equipment.

the overhead transmission operating work standard [15].

Table 1 is the standard of anti-corrosion coating in the overhead transmission operating work standard, and shows the external condition according to the process of corrosion on the hot dip galvanizing member of the transmission tower. Table 2 shows the external characteristics according to the process of corrosion on the painted member of the transmission tower, and the deterioration level is classified as 1 (good) to 5 (poor) according to each external condition to perform the diagnostic evaluation.

B. Development of the corrosion & deterioration imaging tool

As shown in Table 1 and Table 2, the deterioration of the transmission tower is determined according to the rust within 1.0m of the member width or by the area rate of damage, therefore, the imaging tool of deterioration level evaluation on the transmission tower must be developed to always take the image of 1.0 m in width of the member. However, as shown in Fig. 1(a), climbing up the transmission tower and taking the image of 1.0 m in length at once is very difficult, therefore, in this study, 0.5 m of the member length was filmed in sequence as shown in Fig. 1(b) to plan the diagnosis and evaluation of the deterioration level on the transmission tower.

As shown in Fig. 1(b), the camera equipment was developed in blue rectangular frame form to automatically extract the ROI (Region of Interest) on the filmed member of the transmission tower through the image processing technology. For the width of the transmission tower member, the location was set by the

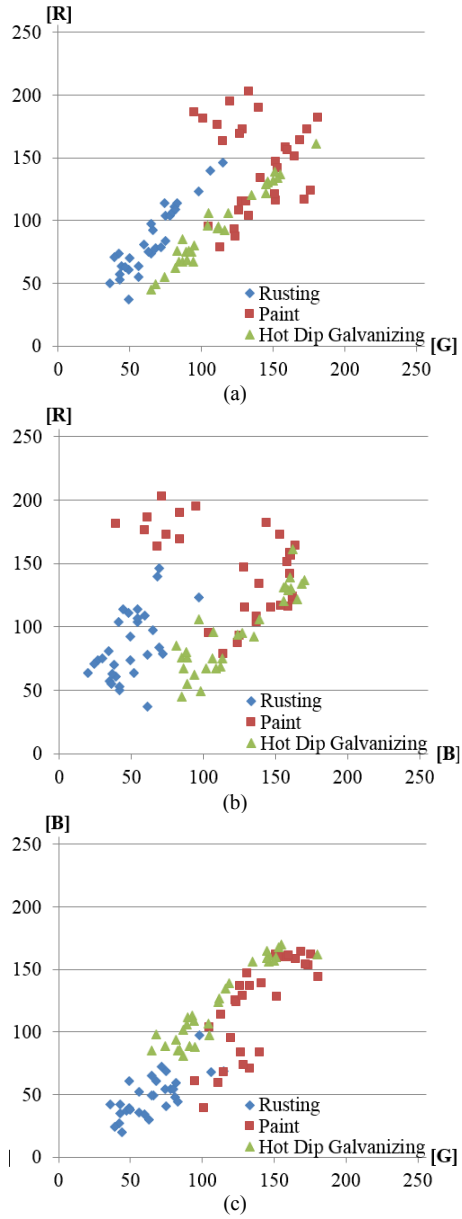


Fig. 2. RGB value of transmission tower steel member. (a) R-G Axis, (b) R-B Axis, (c) B-G Axis

Table 3. RGB value analysis of transmission tower steel member

Division	Rust			Painting			Hot dip galvanizing coating		
	R	G	B	R	G	B	R	G	B
Maximum value	146	115	97	203	181	164	161	180	170
Minimum value	37	36	20	79	95	39	45	65	81
Average	85	65	49	144	139	122	96	112	123
Variance	719	386	273	1,229	554	1,412	946	937	949
Standard deviation	27	20	17	35	24	38	31	31	31

yellow marker on the right side of the rectangular frame to be processed into an image. Especially, the color chart on the left side of the rectangular frame provides the standard value of RGB for calibrating the distortion in the image according to the change in illumination.

Magnet was installed on the bottom of the rectangular frame to enable convenience in operating the camera equipment, and the digital camera support was able to be attached and detached from

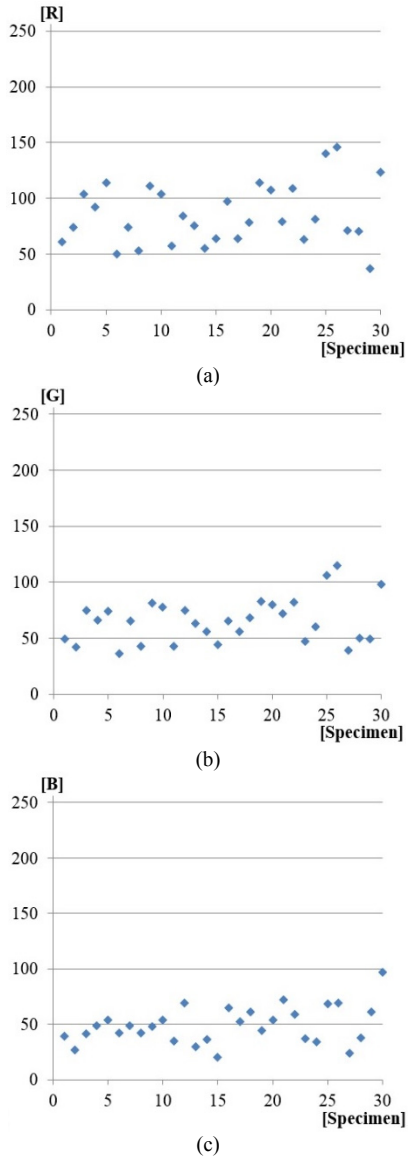


Fig. 3. RGB value of rusting for transmission tower steel member. (a) R value, (b) G value, (c) B value.

the center of the rectangular frame. The digital camera applied on the camera equipment is attached to the vertical support in the center of the rectangular frame to take the image of the transmission tower member in the equal angle of view and ration in a certain distance, to secure the constant, standardized image of deterioration.

C. Development of the corrosion & deterioration color image processing technique

By using the discoloration characteristics of the member surface according to the deterioration of the hot dip galvanizing coating and painting of the transmission tower to perform the color image processing for the evaluation of deterioration level, the color characteristics of the rust, painting and the hot dip galvanizing coating must be secured. In this study, the deterioration image of members in 30 transmission towers in use were filmed to analyze the RGB color value of the rust, painting and hot dip galvanizing coating, and the result is show in Fig. 2 and Table 3.

As shown in Fig. 2 and Table 3, The RGB value of rust can be distinguished to the RGB value of hot dip galvanizing coating

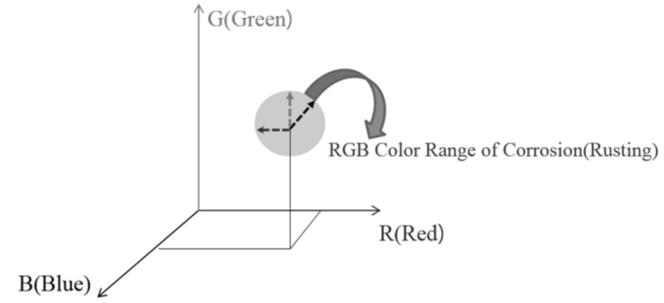


Fig. 4. Color image processing solution of corrosion deterioration for transmission tower steel member.

Fig. 5. Architecture of computer-aided diagnosis system for transmission tower steel member.

Table 4. System development and operation environment

Division	Contents
Development tool	· Language : C++ (MS Visual Studio 2010)
	· DBMS : MS-SQL
Operating environment	· OS : Windows Server 2012
	· WEB Server : Tomcat 7.x
H/W	· IBM-PC Compatible

and painting. Also, the painting applied on the transmission tower are various, including green, orange, white and ivory according to its purpose, therefore, the RGB value is dispersed widely. Fig. 3 shows the dispersion status of the RGB value on rust. Therefore, regarding the color image processing for determining the level of deterioration level on the transmission tower, the key is to use the RGB value per pixel of the deterioration image of the hot dip galvanizing coating and painting on the member in Fig. 4 to select and extract the RGB value of the rust or painting based on the Table 3 result.

D. Development of the corrosion & deterioration diagnosis system

From the deterioration image of the hot dip galvanizing coating and painted member of the transmission tower, the color image processing corrosion & deterioration diagnosis system was planned for determining the level of deterioration. Also, the system was developed to be usable in web-based Windows environment to improve the use accessibility. The development and operating environment of the corrosion & deterioration diagnosis system is shown in Table 4 and Fig 5.

Fig. 6 shows the procedure of determining the level of deterioration on the transmission tower steel member by the color image processing based corrosion & deterioration diagnosis system. The process of determining the level of deterioration on

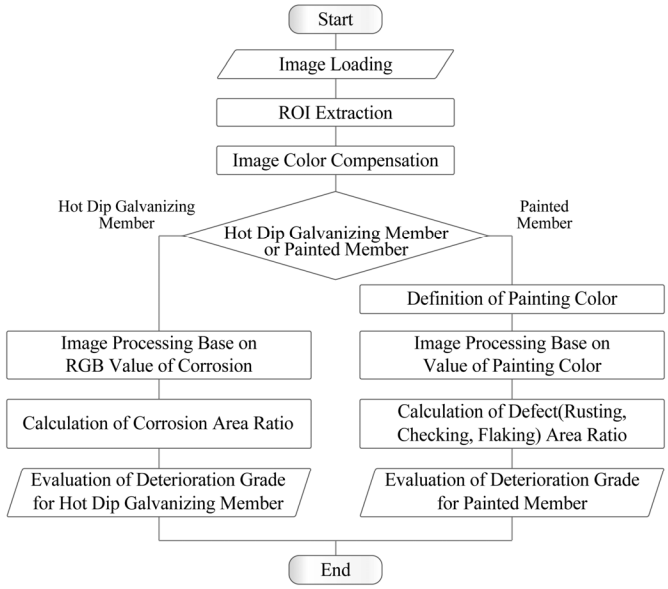


Fig. 6. Flow chart on the computer-aided diagnosis system of corrosion deterioration.

the transmission tower steel member by the corrosion & deterioration diagnosis system is separated between the hot dip galvanizing coated member and the painted member, but the main processing procedure are the same. In other words, the deterioration image of the transmission tower steel member is taken to be inputted in the corrosion & deterioration diagnosis system, and the ROI is extracted from the image that was inputted. On the ROI, RGB chart is used to perform image calibration, and the hot dip galvanizing coated member and the painted member are divided to perform the color image processing. The area rate of rust and damage are calculated, and the level of deterioration is determined by the criteria of deterioration grade on the hot dip galvanizing coated member and the painted member.

The reason that the decision procedure of deterioration level on the hot dip galvanizing coated member and the painted member is divided is because the RGB value of the hot dip galvanizing coated member and rust are inherent, but the RGB value of the painted member exists diversely according to the applied paint. Therefore, in the color image processing for the deterioration level evaluation of the transmission tower painted member, the procedure of defining the RGB value of the paint is required, and based on the RGB value of the paint determined, to perform the color image processing, the damaged site can be processed into an image.

The cases of the result of determining the deterioration level of the hot dip galvanizing coated and painted transmission tower steel member using the corrosion & determination diagnosis system developed in this study are shown in Fig. 7 and Fig 8. As show in Fig. 7, the deterioration image of the hot dip galvanizing coated and painted transmission tower steel member acquired from the camera equipment was performed with digital color image processing to convert the rust region pixel into red and the normal region into yellow to enable intuitive recognition on the region of deterioration. Also, in the digital deterioration image, the number of pixel on the red was divided with the number of pixel on the overall deterioration image to calculate the area rate of the rust. As shown in Table 1, the grade is determined by the criteria of deterioration level on the transmission tower of

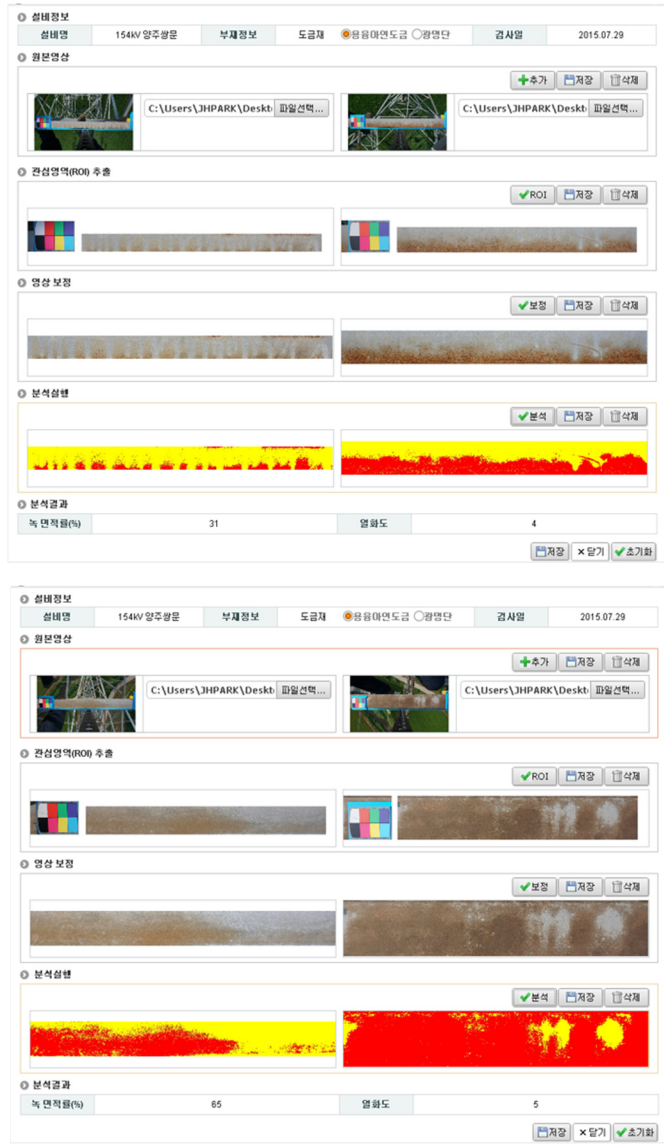


Fig. 7. Analysis result of corrosion deterioration for transmission tower hot dip galvanizing member.

KEPCO. For the transmission tower painted member shown in Fig. 8, the damaged region of rust, crack, exfoliation and swelling from the original color of coating and painting are past processed into red to calculate the area rate, and as shown in Table 2, the grade is determined by the criteria of deterioration level.

IV. CONCLUSIONS

In this study, the evaluation technique of the deterioration condition on the transmission tower in the overhead transmission operating work standard by KEPCO was used to develop an inspection tool that can enable quantitative analysis of the steel corrosion and damage in the paint on the hot dip galvanizing coated and painted transmission tower steel member, and also evaluate the level of deterioration on the transmission tower objectively. The inspection tool was composed of the corrosion & deterioration image camera equipment that can secure the standardized deterioration image on the transmission tower steel member, and the corrosion & deterioration diagnosis system

Fig. 8. Analysis result of corrosion deterioration for transmission tower painted member.

processing the color image and evaluating the deterioration level based on the RGB characteristic value of the rust, hot dip galvanizing coating, and painting from the deterioration image of the hot dip galvanizing coated and painted transmission tower steel member.

As a result of using the developed corrosion & deterioration diagnosis system to test the decision on the level of deterioration on the hot dip galvanizing coated and painted transmission tower steel member, the area rate of rust and the deterioration level were able to be evaluated quantitatively from the deterioration image of the hot dip galvanizing coated member. Also, from the deterioration image of the painted member, damages such as rust, exfoliation and swelling were processed into color image, and the deterioration level based on the area rate of damage were determined.

The color image processing deterioration level evaluation technique based on the RGB characteristic value of the rust, painting and hot dip galvanizing coating applied on the development of the corrosion & deterioration inspection tool of the transmission tower steel member is expected to be applied in expansion to inspecting and diagnosing the corrosion of similar steel structure and the deterioration condition on the painting. To enable this, it is considered that criteria of deterioration level on each facility subjected for inspection and diagnosis must be established in advance.

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