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Analysis of Tensile Strength Characteristics of ACSR due to White Rust

백화현상에 따른 ACSR 송선선로의 인장강도 특성 분석

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Abstract

In this study, a tensile test, one of the mechanical tests, was performed with the collected natural aging ACSR. In order to be used as basic data for predicting the replacement cycle of ACSR, the tensile strength with the normal cables was compared for cables which was caused white rust due to exposure of the hard-drawn aluminum wire surface. Among the ACSR wires collected from various regions, white rust was found on the surface of the small wire, and by checking the tensile strength of them, we would like to suggest the criteria for the ACSR replacement cycle, focusing on changes in mechanical properties.

Keywords: *ACSR, White rust, Tensile strength*

I. Introduction

Electrical (Contents) The original purpose of electric power transport cable should have sufficient mechanical strength to resist external impulse caused by gusts, snowfall and etc. Therefore, the mechanical design could be applied when manufacturing the overhead cable is determined to have sufficient support for various natural disasters at a predictable level.

Aluminum stranded conductor steel reinforced cable(ACSR) is the most commonly used wire for transmission lines, and it is coated with zinc at the center and aluminum wire is connected to the outside. In addition, mechanical properties of ACSR are required more than electrical properties since ACSR is installed outdoors and is exposed to pollution, heavy snow, sunlight, etc., and is always subjected to vibration or external force due to wind.[1-2] However, the number of natural disasters and its intensity have increased recently at the national scale, accidents may occur due to loss or damage of cable, and the pattern of accidents varies depending on the environment, location, and type of load.

In Korea, ACSR began to be installed in the 1970s and the number of cable that have passed the life limit is gradually increasing, so it is urgent to establish standards for residual life and replacement time. In addition to natural deterioration, if the ACSRs are exposed to the outside for a long time due to pinhole phenomena and peeling of the cover caused by trees, white rust occurs on the surface of the aluminum wires[3].

The white rust is a phenomenon in which aluminum conductors surrounding the outside of ACSR are oxidized, and it has been reported that the resulting mechanical tensile strength tends to decrease algebraically. Therefore, the white rust is directly related to the lifespan of the ACSR [4], and measures such as replacement and reinforcement of the ACSR are required due to changes in characteristics, but few research results have been reported at home and abroad. Therefore, since there is no exact replacement standard, research on this is urgently required.

In this study, among the ACSR (AW-OC 58,95 and OC 58,95) determined to be defective, peak stress due to tensile test was observed, and the effect of the white rust on the strength change of the ACSR was confirmed.

II. Experiments

A. Sample preparation and tensile test

A tensile test sample was manufactured for power distribution ACSRs collected directly from various fields(branches of KEPCO), and a tensile test was conducted by applying the test method specified in the specification.

MTS system was used to measure the tensile load, which is a mechanical characteristic experiment of ACSR, and figure 1 shows the tensile test readiness. A tensile test sample has a structure in which six wires surround one steel wire in a spiral shape, and it is very difficult to fix all of them at once while cutting wires due to a lack of clear bonding force between them. Both ends of test sample with cement inserted between the steel wires was manufactured and

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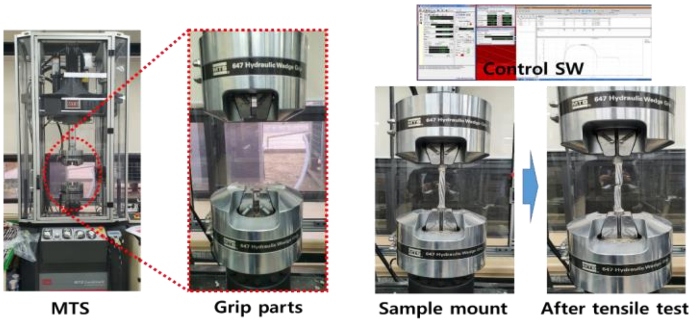

Fig. 1. Preparing for MTS and tensile test

applied to the grip of the MTS since steel wires or aluminum wires may be significantly deformed due to excessive external force in the grip during the tensile test.

In order to observe the surface change of the ACSR in which normal ACSR and white rust-occurred ACSR, a cross-section of the ACSR was obtained by cut off machine (ATM, Brillant 220), and then cross sectional images were observed using a scanning electron microscope SEM (JEOL, JSM-6300) and an energy dispersive X-ray spectroscopy (EDS).

In the case of MTS system operation, after fixing both ends of the ACSR sample to the MTS using a V-shaped wedge-type hydraulic grip as shown in the figure above, the tensile test was carried out at a rate of 1 cm per minute.

III. Result and Disccussion

The ACSR collected at the actual site(branch of KEPCO) were manufactured as shown in the image of figure 2 for tensile testing.

Each sample was cut to a length of about 30cm, and both ends of the sample were designed to serve as a grip part by attaching steel collets containing cement. The table below shows the tensile load criteria according to the type of ACSR.

Peak stress graphs of the ACSR samples tested according to the above tensile load standards are shown as follows.

As a result of the tensile load test, peak stress values above standards of nominal cross-sectional area were recorded in all samples classified into good samples (black, red) and poor samples (green, blue), respectively.

From the graph above, it can be assumed that even if the condition of the sample observed with the naked eye is confirmed to be poor, it may not be related to the tensile load. The results of the experiment under the same conditions for all collected samples are shown in the following tables (table 2, 3). Tables 2 and 3 were determined visually positive and negative, respectively, and the results were represented as good or reduced tensile strength values compared to the standard value of peak stress.

Among the ACSR samples, defectives were classified based on the case where damage to the ACSR cover due to deterioration and pinhole phenomenon was visually observable. In table 3, tensile strength value lower than the reference value was confirmed in the four samples(No. 8,10,15 and 16).

Therefore, photographs of covering and wire appearance for the four defective samples were observed as follows.

As a result of the tensile test for the defective samples, it was confirmed that all four samples with a lower peak stress level than the reference value had partial damage already to the appearance. Considering the tensile strength measurement results and the above

Fig 2. The ACSR samples collected from various sites(branch of KEPCO)

TABLE 1
ACSR tensile load standards

Nominal cross section (mm^2)	Wires configuration # of wires	Wires configuration St (mm)	Wires OD (mm)	Insulation thickness (mm)	Total OD (mm)	Tensile load [kN(kgf)]	Tensile load [Mpa]
ACSR/AW-OC 160	18	1/3.2	15.4	4.0	23.4	30.20 (3,080)	297.92
ACSR/AW-OC 95 ACSR-OC 95	6	1/3.5	12.0	3.5	19.0	23.14 (2,360)	231.43
ACSR/AW-OC 58 ACSR-OC 58	6	1/3.5	9.7	3.0	15.7	18.63 (1,900)	186.32

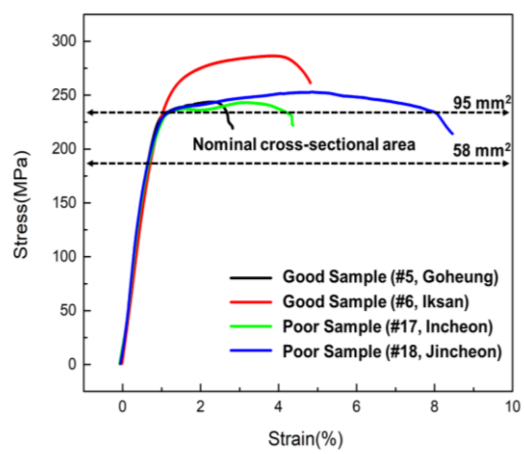

Fig. 3. Results of test(peak stress) graphs of ACSR

exterior photographs (fig 4), it is believed that the sample had defects in internal steel wire in advance (before the test) due to partial damage to the wire surface. Alternatively, since the tensile characteristics of the wire are partially affected not only by the steel wire but also by the surrounding wires, it is considered that the partially damaged wires may affect the tensile test results. In addition, considering that the tensile load is satisfied by 110% or more than standard value despite the damage observed visually, it is believed that the tensile strength remains normal if there is no direct damage or defect in the steel wire.

TABLE 2
ACSR samples that has been tested positive

No.	Classification: Collection location (KEPCO branch)	Classification: Detailed location	Classification: Year of use	Type	Nominal cross section (mm²)	Peak Stress (MPa)	Result (Compared to standard value)
1	Gangseo-yangcheon	Residential	Unknown	ACSR-OC	58	203.83	good
2	Gochang	Mountain	20~30	EW	32	301.37	good
3	Goheung	Coast	10~20	ACSR-OC	95	256.25	good
4	Sunchang	Residential	10~20	EW	58	243.79	good
5	Goheung	Mountain	Unknown	EW	58	286.56	good
6	Iksan	Downtown	10~20	EC	58	308.96	good
7	Iksan	Industrial area	10~20	EC	58	196.74	good
8	Jincheon	Industrial area	20~30	EW	58	252.44	good

TABLE 3
Table of tensile test results for specimens collected by classifying them as defective

No.	Classification: Collection location (KEPCO branch)	Classification: Detailed location	Classification: Year of use	Type	Nominal cross section (mm²)	Peak Stress (MPa)	Result (Compared to standard value)
1	Uiseong	Downtown	Under 10	ACSR AW-OC	58	254.38	Good
2	Pohang	Coast	20~30	ACSR AW-OC	95	278.52	Good
3	Gurye	Mountain	10~20	ACSR AW-OC	58	234.41	Good
4	Jungseon	Mountain	Under 20	ACSR AW-OC	58	205.89	Good
5	Jeju	Residential	Under 20	ACSR AW-OC	58	231.21	Good
6	Jungseon	Mountain	Unknown	ACSR AW-OC	58	203.83	Good
7	Paju	Mountain	20~30	ACSR-OC	58	231.44	Good
8	Dongducheon	Industrial	Unknown	ACSR-OC	58	144.03	23% Reduced
9	Gurye	Mountain	10~20	ACSR-OC	58	251.45	Good
10	Cheonan	Residential	10~20	ACSR AW-OC	58	173.35	7% Reduced
11	Sunchang	Residential	Under 10	ACSR AW-OC	58	263.58	Good
12	Jeju	Outdoor	10~20	ACSR AW-OC	58	205.96	Good
13	Yangsan	Mountain	10~20	ACSR AW-OC	58	233.18	Good
14	Uiseong	Downtown	20~30	ACSR-OC	95	230.13	Good
15	Daejeon-Sejong-Chungnam	Mountain	20~30	ACSR-OC	95	210.79	9% Reduced
16	Tongyeong	Industrial	20~30	ACSR-OC	95	205.96	11% Reduced
17	Incheon	Residential	Unknown	ACSR AW-OC	58	252.92	Good
18	Jincheon	Industrial	20~30	EW 58	58	243.21	Good

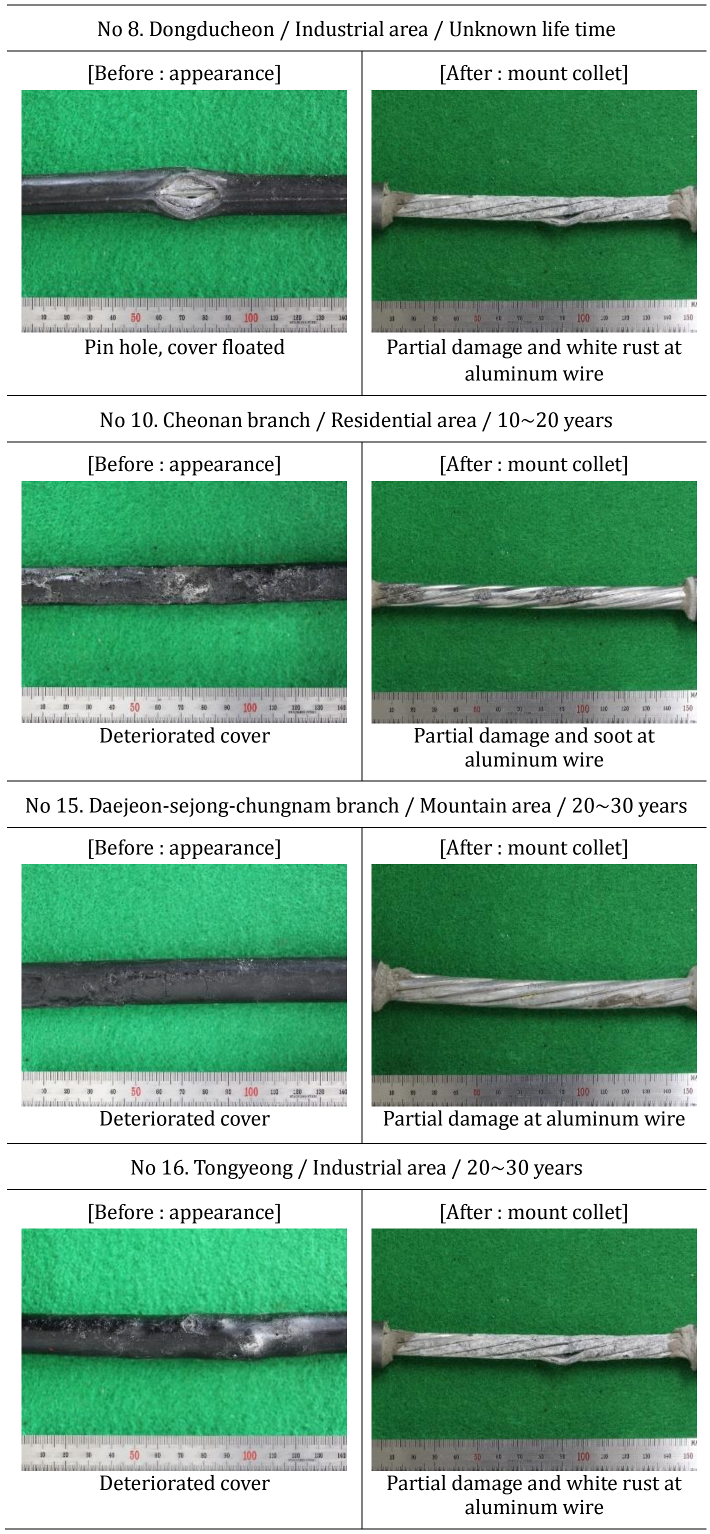

Fig. 4. before(left) and after collet mount(right) images of samples which had lower peak stress level than the reference

From the table 2, it was confirmed that the tensile test results of the samples which were visually checked as positive were all good.

As a result of analyzing the normal samples and partial white rusted wires using SEM and EDS (Fig 5), it was observed that the samples with partial white rusted wires had significantly more oxygen species than the oxygen molecules present on the surface of the normal ACSR.

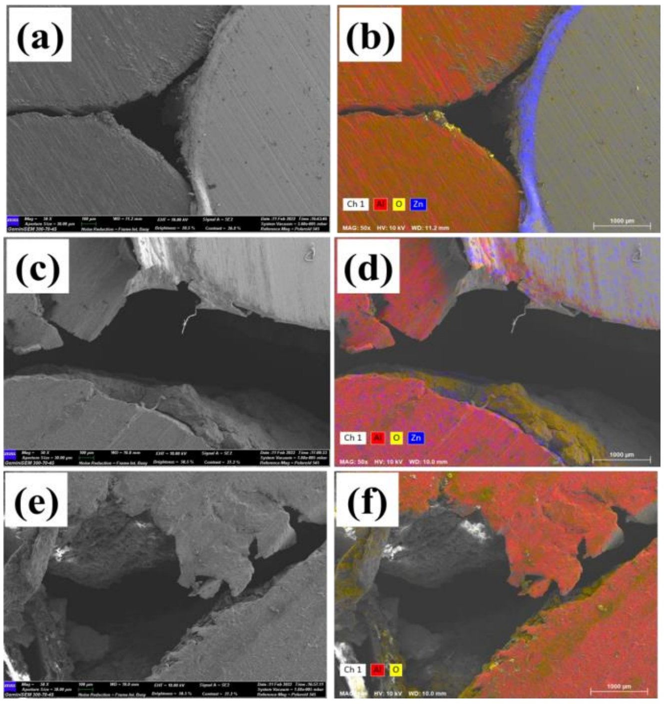

Fig. 5. SEM(left) and EDS mapping analysis(right) images of ACSR

Figure 5 shows SEM (left) and EDS (right) images of the cut surface of the sample determined as normal (a, b) and defective samples (c~f) respectively. In the case of normal sample, it was verified that aluminum wire (yellow color) exists next to steel wire (blue part in EDS image) coated with zinc on the right side of each image.

Figure 5 (c~f) shows the SEM and EDS results of the sample recording the normal tensile strength among the samples judged to be defective. In fig 5(d), it can be seen that the zinc coated part has been completely removed unlike the normal sample, it could be confirmed that the oxide species are significantly greater than that of the normal samples through the yellow colored portion(fig 5d,f) of the EDS images.

The reason why the difference in tensile strength was not discovered even though a part coated with zinc was removed and an oxide species were increased more compared to the positive sample is that the wire was not damaged in advance and the mechanical strength of the steel wire was maintained. Furthermore, the reason that the tensile strength is maintained above a reference value even though the surrounding wire is partially white rusted(corroded) could be seen that the steel wire contributes the most to determining the mechanical strength of the ACSR.

In the case of four samples whose peak stress values were confirmed to be 7~23% lower than the standard, it is believed that the surface of each sample has already affected the steel wire regardless of the type of sample, place of use, and year of use. The tensile strength is considered to remain normal enoughfully even if the ACSR has not been directly damaged or defected, so it is necessary to reflect changes in the mechanical strength of the steel wire rather than small wires in establishing wire removal standards. In addition, in order to establish a more specific standard, it is thought that additional research should be conducted to track changes in surface corrosion or strength of small wires and steel wires in various environments for a long time.

IV. Summary

In summary, we collected ACSR wires that had been exposed to various environments across the country for a long time and performed tensile tests on positive and defective samples. As a result, it was confirmed that the tensile load standard was not satisfied only in the case of samples with partial damage to the sample wire regardless of the exposure environment and the elapsed year. Additionally, in the case of some white rusted samples, it is confirmed that the tensile strength is still maintained upward, and thus it is determined that the mechanical strength of the steel wire should be an important indicator for determining the life of the ACSR rather than the surrounding wires.

Although the ACSR currently used in the field is enough to satisfy KEPCO's technical standards, there is loss in the event of serious natural disasters. In the event that such an accident occurs severely by region, it is believed that applying technical standards differently according to the area will be an economical and reasonable preventive measure in the long term operation of power distribution.

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