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An Application of Solenoid Eddy Current Sensor for Nondestructively Inspecting Deterioration of Overhead Transmission Lines due to Forest Fires

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산불에 의한 가공송전선의 열화특성을 비파괴적으로 검출하기 위한 솔레노이드 와류센서의 응용

김성덕, 김영달, 정동화

Abstract

This paper describes several performances and nondestructive inspection for deterioration due to forest fires in overhead transmission lines. After discussing corrosion mechanism such as atmospheric and galvanic corrosion for aged ACSR conductors and its detection for them are presented. Through impedance analysis of a solenoid coil, it is shown that the eddy current sensor may be available to inspect severe fault or local corrosion. As the solenoid coil changes its impedance when the test conductor is inserted into the coil, it can be possible to measure deterioration degree caused by forest fires. Tensile strength, extension rate and sensor impedance are tested for some samples degraded by artificial fire. As increasing blazed period to some extent, the strength of aluminum strand begins to be reduced remarkably, while galvanized steel strand holds the similar strength to the initial value, despite of appearing a little loss of zinc layer. In general, it is shown that the sensor impedance would be increased while the tension load of conductor is reduced and the extension rate is contrarily increased. Therefore, the sensor output could exhibit the changes of mechanical performances, and would be used to detect such deterioration caused by forest fire in ACSR conductors built on the ridge of mountains. Finally, it was verified that the solenoid coil could be applicable to obtain any crucial inform for serious deterioration due to forest fires.

국문요약

본 논문에서는 산불에 의한 가공송전선의 열화에 대한 몇 가지 특성들과 비파괴 검사를 다룬다. 노화된 ACSR 도체에 대한 대기부식과 전해부식과 같은 부식기구를 설명한 후에 부식검출에 대해서 기술한다. 솔레노이드 코일의 임피던스 해석을 통하여 와류센서가 도체의 심한 결함과 국부부식을 검사하는데 유용하게 사용될 수 있음을 확인하였다. 시험 도체를 코일 내부에 삽입한 경우에 센서코일의 임피던스가 변하므로, 산불에 의해 초래된 열화 정도를 측정하는 것이 가능하였다. 인공화염에 의해 열화된 몇 개의 시료들을 사용하여 인장강도, 신장율과 센서 임피던스가 측정되었다. 화염 기간을 어느 정도 증가시키면, 알루미늄 소선의 인장은 현저하게 감소하기 시작하나 아연도금 강소선은 약간의 아연층이 부식되지만 인장은 초기와 유사하게 유지하였다. 일반적으로 도체의 인장하중이 감소하고 반대로 신장율이 증가하면 센서 임피던스는 감소하는 것을 알 수 있었다. 따라서, 센서의 출력은 도체의 기계적 특성 변화를 나타내므로 이 센서는 산 등성이에 가설된 ACSR 도체에 대해 산불로 인한 열화상태를 검출하는데 이용할 수 있다. 결국, 산불에 의한 심한 열화상태에 대한 중요한 정보를 얻는데 솔레노이드 코일을 응용할 수 있다는 것을 확인하였다.

1. Introduction

Deterioration of ACSR (Aluminum Stranded Conductors Steel Reinforced) in transmission and distribution power lines would slowly progress by various factors such as material components, manufacture methods, installed environment and so on. Especially, ACSR which consists of galvanized steel strands and aluminum ones, shows more complex corrosion mechanisms than any other power lines of Aluminum or Copper Conductors. In general, overhead power lines may be attacked by atmospheric corrosions such as galvanic corrosion, crevice or fatigue corrosion[1~3].

In most power companies over the world, they have different refurbishment criteria established by themselves. Most of these criteria are determined by the elapsed years of the lines, or load rate, line status and power quality[4,5]. Sometimes, one of them would be to test several mechanical or electrical performances of jumper wires removed in the lines. Therefore, the aged overhead lines in service may be often refurbished by the decision of managers through the results obtained from line inspectors. Of course, there is no criterion for refurbishing line conductors degraded by forest fires.

Beside natural deterioration or corrosion, forest fires would sometimes give serious trouble in holding the stability of overhead power lines built along the ridge of mountains. Forest fire is usually accompanied by high temperature, humidity, smoke, dust and flame and further it may progress shortening status between each conductor. Therefore, transmission conductors installed across mountains would often occur any troubles to supply stable power. Especially, the tensile strength of conductors after putting out fire may be reduced remarkably so that it should be made any assessment for whether those conductors would be still stable or replaced someday later. However, there has been no trial for inspecting such phenomenon due to forest fires. It may be impossible to select a correct time to refurbish aged overhead lines because most power companies could not have a suitable common criteria for the refurbishment period based on the remain life of operating power lines. However, such decision in order to replace old conductors gives only a possibility by using the factors described above, but these are not always absolute. Therefore, it must be only used in refurbishing line conductors via probability concepts.

In practice, it is seemed that the end of the life of power lines is directly given by the tensile loss of conductors. Hence, to know mechanical or electrical stability of the line, the tensile strength of power lines may be precisely tested. This must be impossible in reality techniques and then, we should find out any other method to know or estimate the tensile strength of power lines in service, without removed the overall spans or cut jumper wires off. In this research, we try to search any inspecting method to assess overhead power lines degraded by forest fires under several experimental tests and analysis. Mechanical and material performances for artificial fire test samples are examined and furthermore, a nondestructive test (NDT) using a solenoid coil is also suggested.

2. ACSR and Forest Fire

2.1 Corrosion of ACSR

As shown in Figure 2.1, general ACSR conductor consists of hot-dip galvanized steel strands in the inner layer and hard-drawn aluminum conductors in the outer layer. Aluminum strands are used to conductors to transfer power energy, while steel strands take charge of the most tensile strength of ACSR. The surface of

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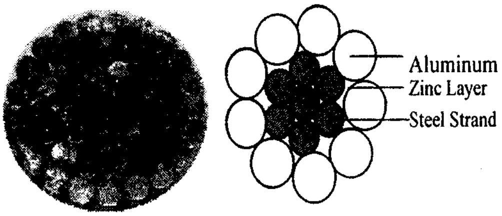
steel strand is galvanized in order to prevent atmospheric corrosion and the galvanizing layer also presents iron-zinc alloy because it is made to hot-dip, which the depths of both zinc coating and iron-zinc alloy are approximately 20[um].



(a) 480[㎟] (b) schematic diagram

Figure 2. 1 ACSR 480[㎟]

Aluminum strands in the outer layer of ACSR are directly exposed to the atmosphere. Even through aluminum is an active metal with high affinity to oxygen, it has high corrosion resistance in the air because a film oxide formed on its surface protects the aluminum strands. At the initial stage when ACSR is exposed to the atmosphere, aluminum strand becomes to corrode rapidly. In any cases, however, its corrosion rate decreases with the lapse of time. Hence, aluminum usually appears a high corrosion resistance[1,6].

Galvanizing layer on the surface of steel strand moderates the rate of corrosion of galvanized steel strands as it may be directly exposed in air or humidity and it has strong chemical affinity with oxide ions. Overhead ACSR conductor has a good condition to penetrate humidity or water into the strands. Furthermore, there are dust or pollutants in the contaminant air and these would be formed to electrolytes so that the corrosion rate of zinc layer becomes high. After corroded zinc layer, aluminum strands in the inner layer are directly contacting with bare steel strands and then, they would be attacked by galvanic corrosion, especially in coastal areas where salt is carried by wind. In conclusion, main factors caused to deterioration in overhead ACSR are atmospheric corrosion and galvanic corrosion[7].

2.2 Forest Fire

Most of transmission lines in domestic area have been built along the ridge of mountains and therefore, they would be always exposed in any weakness situation for bush fires. Especially, it is always dry weather in spring and, so most forest fires would be occurred between the end of March and the middle of April.

Before analyzing any forest fire effect on ACSR conductors, it is necessary to understand physical and chemical performances for them. The prediction of forest fire propagation consists in finding the motion of the forest fire front. This prediction is a more complex problem than droplet evaporation because it deals with modeling difficulty in its own. Propagation model depends on the scale of forest description: vegetation where we distinguish the thickness of vegetation stem, or forest where we consider a particle of forest as composed of vegetal species and air. The forest is then seen as a porous media with micro-structure, for which there is a local thermodynamic non equilibrium between the phases[8,9].

The equation system fund can be simplified using the small vegetation cover thickness compared with the length of forest fire extension. The vegetal cover, which composes the forest, can be seen as a boundary layer for the outside hydrodynamic problem. This layer is a curved surface that owns a lot of material properties at this scale.

Forest fires itself are very complex because they include a lot of physical and chemical factors, so that it could not be easy to analyze any effectiveness of transmission lines or equipment caused by them. In practice, as general forest fire is carried out together flame, high temperature, humidity and smoking, there may occur any metallic variation due to quenching, melting or heating in the transmission conductors. In particular, ACSR consists of 3 different metals such as aluminum, zinc and ferrous so that such behaviors could be analyzed under general concepts for blaze fires.

2.3 Deterioration Detection

It may be available to choose a magnetic detecting method with a solenoid coil such that local or global corrosion in aged ACSR conductor can be detected nondestructively. Of course, such coils were proposed to inspect severe corrosion or zinc loss of ACSR in transmission lines.

A corrosion detector for inspecting deterioration in overhead power line was initially studied by J. Sutton and K.G. Lewis at CERL in the middle of 1980s[10]. They suggested a special magnetic coil sensor to detect the zinc loss of ACSR. There were several reports to have used such corrosion detector in England, Australia and Canada[11,12].

Another corrosion detector similar to that of CERL was made an attempt in Japan in the early stage of 1990s[13]. They tried to detect the loss of the cross section area of aluminum conductor in transmission lines exposed to a coastal area for a long period. However, it was too heavy to install on the overhead line that it may be failed to develop a suitable instrument.

There has been no consideration in detecting the deterioration or corrosion in transmission and high voltage distribution lines installed in domestic area until the middle of 1990. In recent years, as increasing air pollution in the north-east area and conductors built about 30~40 years ago, there occurred accidents by the severe loss of the tensile load in transmission line and therefore, KEPCO (Korea Electric Power Corporation) have becoming consideration to seek any prevention such accidents. In KEPRI (Korea Electric Power Research Institute), a preliminary study to develop to detect the internal corrosion in ACSR was carried out during 1995~1999[14,15]. As the result, detecting method, sensor structure and deterioration phenomenon for overhead grounded wires of ACSR, were studied. In recent year, a developed corrosion detector is testing in the field. Although there has been several trials in inspecting corrosion or deterioration in aged transmission lines, no research has been in detecting physical deterioration due to forest fires. However, we will examine an NDT inspection method using a solenoid eddy current sensor through several tests for artificial fire conductors.

3. Solenoid Eddy Current Sensor

3.1 Impedance Analysis

Eddy current method which sensor is implemented by using a probe coil or an encircling coil has been widely applied in nondestructive test of conductive materials. Thus many instruments have been developed and used in various industrial fields. Eddy current testing could be possible for all conductive materials and then includes the inspection of the dimension of the test materials, the measurement of the thickness of metallic plates or non-metallic coating, and the assessment corrosion, deterioration or other metallic properties. An important advantage of eddy current testing compared with other testing methods is that there is no need for physical contact with the surface of the object under testing and further its measurement speed is rapid[16,17]. If forest fire would change any material and electromagnetic properties of the conductors, it seems to be used a solenoid coil in order to inspect such variations, as applying it to detect corrosion of aged power conductors.

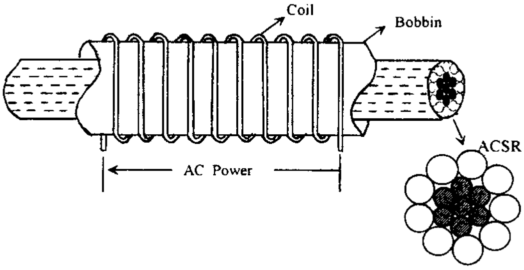


Figure 3. 1 Schematic diagram of solenoid eddy current sensor

As shown in Figure 3.1, a solenoid having a conducting material at the longitudinal axis such as

ACSR conductor is excited by an alternating current. It is assumed that there is no search coil or probe to detect dimension of the testing material. In this sensor, thus, the electromagnetic performance of the material would appear as the impedance variation of the coil itself.

The solenoid coil has a finite length ℓ and its effective radius is a. It is assumed that the test conductors contain 2 kinds of metals, S_1 and S_2, which have homogeneous and cylindrical structure for the simplicity of analysis. S_1 and S_2 have n_1 and n_2 strands, respectively and each conductivity and relative permeability are defined as σ_1, σ_2, μ_{r1} and μ_{r2}.

If applying an alternating current $i(t) = i_o e^{j\omega t}$ to the solenoid coil, the solenoid coil inside would be formed to equivalent magnetic flux under the assumption that the bobbin length is infinite. Since magnetic flux does not attenuate in air, eddy current could not be generated in air-cored coil and then, sensor impedance is given as follows

$$\dot{Z}_0 = R_0 + j\omega L_o \qquad (1)$$

where R_0 and L_0 denote the resistance and the inductance of the coil, respectively. If coil turns is small, the resistance R_0 may be negligible.

If any conductors are inserted into the sensor, the conductor is induced any eddy current dependent upon electromagnetic property of the conductor. As the eddy current flux reduces the main magnetic flux, the overall magnetic flux of the coil also reduces and the, the impedance of the coil becomes to change, corresponding to the eddy current generation. Let the sensor impedance in the presence of the conductor inside the sensor be

$$\dot{Z} = R + j\omega L \qquad (2)$$

In general, conductor in magnetic field generates eddy current flux, which is dependent upon the standard penetration depth of magnetic flux defined as[33]

$$\delta = \frac{1}{\sqrt{\pi\sigma\mu_0\mu_r f}} \qquad (3)$$

where f denotes source frequency. Here, letting the magnetic flux in air gap and the conductors be ϕ_G and ϕ, respectively, and assuming all strands are isolated electrically. Then, the total magnetic flux, ϕ_T, can be written by

$$\phi_T = n_1\pi b_1^2\overline{B_1} + n_2\pi b_2^2\overline{B_2} \qquad (4)$$

where $\overline{B_1}$ and $\overline{B_1}$ denote the mean magnetic flux density for S_1 and S_2 . Defining $\overline{B_1}$ and $\overline{B_1}$ as magnetic flux density of free space and coil, respectively, we can obtain the following relation

$$\widehat{\mu_T} = \sum_{i=1}^{2} n_i\eta_i(\widehat{\mu_i} - 1) + 1 \qquad (5)$$

where $\widehat{\mu_T} \equiv \overline{B_T}/B_0$ and $\widehat{\mu_i} \equiv \overline{B_i}/B_o\ (i=1,\ 2)$. Further, η_i denotes the fill factor for each conductor in S_1 and S_2 and defined as

$$\eta_i = (b_i/a)^2 \qquad (6)$$

From Eq. (5), $\widehat{\mu_i}$ is a complex variable determined by the magnetic flux penetration effect and then it can be rewritten as $\widehat{\mu_i} = \widehat{\mu_i^R} - j\widehat{\mu_i^I}$. Hence, substituting this relation into Eq. (5) leads to

$$\widehat{\mu_T} = \sum_{i=1}^{2} n_i\eta_i(\hat{\mu}_i^R - 1) + 1 - j\sum_{i=1}^{2} n_i\eta_i\hat{\mu}_i^I \qquad (7)$$

Since the impedance of solenoid coil is proportional to magnetic flux linkage, the impedance ratio could be equivalent to Eq. (6), $\widehat{\mu_T}$. This equation is so called as the normalized impedance with dimensionless[3]. Finally, assuming that R_0 in Eq. (1) is negligible gives

$$\omega L/\omega L_0 = \sum_{i=1}^{2} n_i\eta_i(\hat{\mu}_i^R - 1) + 1 \qquad (8)$$

$$(R - R_0)/\omega L_0 = \sum_{i=1}^{2} n_i\eta_i\hat{\mu}_i^I \qquad (9)$$

It is noted that the equations for the normalized impedance are closely related to the fill factor. Therefore, the cross section area, diameter, conductivity or permeability of the material could be estimated by using Eq. (8) and (9)[34,35]. Most of NDT apparatus with a solenoid coil to measure such performances of metallic conductors are virtually utilized by these relations.

Analytic results shown in this section are only available in understanding solenoid sensor applications under several assumptions. One is that all strands are electrically isolated each other and then, generation of eddy currents for them would be independent. On another important thing is that it may be easy to analyze galvanizing layer correctly.

3.2. Numerical Analysis and Experiment

To examine impedance results in Section 1, the test sample is assumed to be similar conductor to an ACSR 480[㎟] with 3 aluminum strands layers(45 strands) and 7 steel strands. Aluminum and steel strands have radius, 3.7 and 2.47[mm], respectively. Furthermore the conductivity of aluminum and steel strand is assumed to be 35 and 5[MS/m], respectively and the relative permeability of steel strand is $\mu_r=40$. For the purpose of numerical analysis, the mean diameter and length of a solenoid coil are given as 51 and 100[㎜]. In this numerical result, we did not consider the variation of eddy currents due to contacting with each strand. Moreover, it is also assumed that there does not exists any zinc layer on the steel strands.

Figure 3.2 demonstrates normalized impedance for several cases, where "Steel Strands" denotes the case of existing only 7 steel strands, and "Conductor" means the case of 7 steel strand and 45 aluminum strands like ACSR 480[㎟] conductor. Further, "Aluminum 1 Layer" and "Aluminum 2 show the cases that aluminum strands are 9 and 16 together with 7 steel strands. In general, normalized impedance is determined by ferromagnetic strands because of the permeability. If the exciting frequency is infinite, normalized impedance converges to $(0,\ 1-\sum_{i=1}^{2} n_i\eta_i)$. Hence, it can be easily known that the cross section area of strands may be detected by using such property.

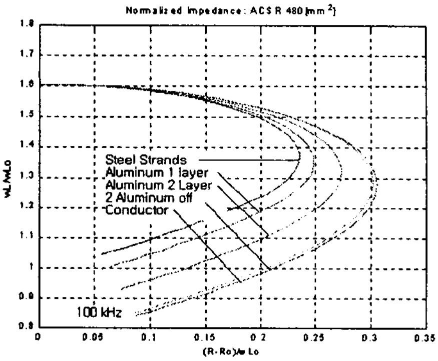


Figure 3. 2 Performance of normalized impedance

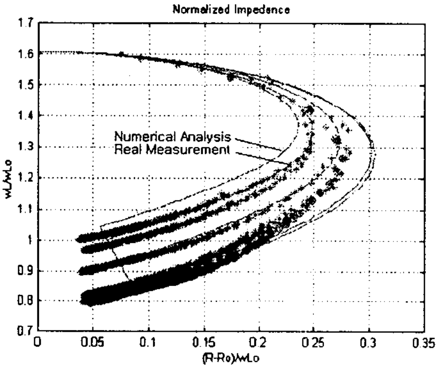


Figure 3. 3 Measurement of normalized impedance

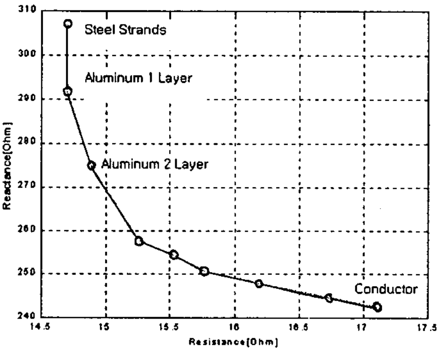


Figure 3. 4 Variation of aluminum strands

To verify the effectiveness of numerical result, a new ACSR 480[㎟] conductor is tested under the assumptions as given in Figure 3.2. Figure 3.3 shows the property of normalized impedance obtained by measurement data. From this result, we can see a similar performance between the numerical result and the measuring data, despite all strands of the conductor are not exactly isolated and there exits galvanizing layer on the surface of steel strands. Typically, if strands are contacting with each other, the eddy currents of conductor would be reduced. However, zinc layer on the steel strand may not be affected the impedance of coil because aluminum strands in the outer layer closely contacted.

According to numerical analysis, the fill factor is closely correlated to the variation of the impedance of solenoid coil only if steel strands are not change. However, it is only an ideal case. In practice, impedance property when varying aluminum strands for ACSR 480[㎟] shows as given in Figure 3.4. Although deterioration with age or due to forest fire is caused by complex factors, its degree can not be perfectly quantified by using impedance data. However, it would be sometimes possible from such impedance to obtain any inform for deterioration or corrosion under suitable assumptions.

4. Deterioration Characteristics and Its Detection

4.1 Experimental Condition

As mentioned before, forest fire has complex physical and chemical factors so that it would not be easy to obtain their exact modeling. The propagation of forest fire is characterized by a nonlinear coupling. We may have a bad knowledge of forest media properties, and initial conditions of forest fire propagation. Moreover, several probabilistic factors make it difficult to perform forest fire test. However, it may be possible to know any result for metallic variations after blazed fires.

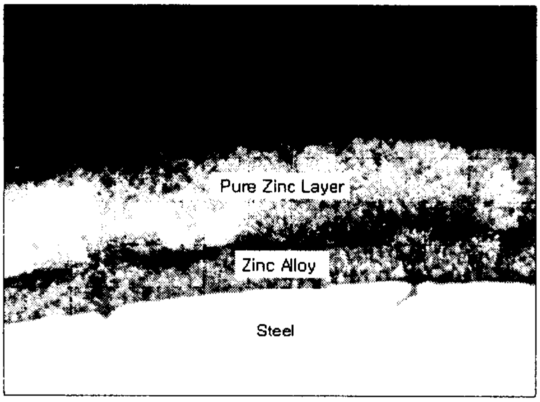
It is desirable to use any suitable method in analyzing material variations in transmission lines due to forest fires or inspecting such deterioration by using any NDT test. One of them is to estimate strength reduction or electrical variations based on analyzing several material and mechanical characteristics for various conductors collected such deteriorated conductors after putting out forest fires. However, there have not been any research data and further, we have not many samples due to fire. Therefore, we primarily try to prepare several conductors under testing by artificial flame and to obtain physical performances.

First, some samples for ACSR 480[㎟] under new condition was heated by using gas burner for 3 minutes interval. After slowly cooling them in ambient temperature, impedance of the solenoid coil as given in Section 3.2 is measured for each conductor. ACSR 480[㎟] consists of 3 aluminum layers which has 25, 16 and 9 strands, respectively, and 1 galvanized steel core and 6 steel strands layer. For each layer, 3 strands are tested to obtain tensile strength and a part of them is used to examine microscopic phenomena and material components.

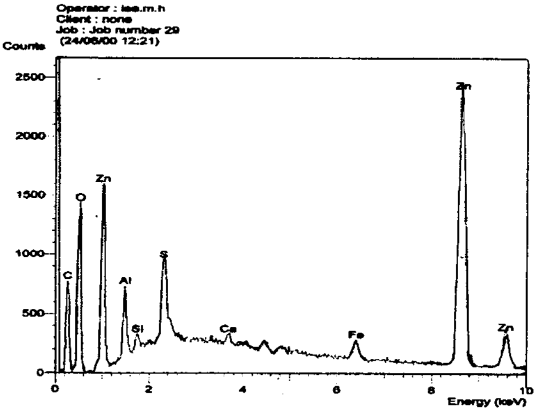
4.2 Metallic Properties

To identify deterioration due to fire flame, we use SEM (scanning electron microscopy) and EDX (energy dispersion x-ray analysis) for a blazed conductor for 10 minutes heating. EDX results are given for the surface layers of the strand and micrographs of SEM are given to the cross section portion of each strand.

For a general galvanized steel strand under new condition, it exhibits approximately 20~30[㎛] pure zinc layer and about 20[㎛] zinc alloy. Its components are chiefly Zn and a little oxide. However, as we can see from Figure 4.1(a) for a blazed galvanized steel strand, the depth of pure zinc layer compared with a new strand shows an increased shape to 2 times. This is due to oxidization of pure zinc with oxygen in air. Further, high temperature may lead to melt a little amount of aluminum strand in the interior strand. A part of oxidized zinc would break away from the steel strand to the outer aluminum layers. As you can see from EDX graph in Figure 4.1(b), there exists Al, C, Fe, S except for Zn on the surface of the galvanized steel strand. Such oxidized zinc would reduce both electrical performance and corrosion resistance.



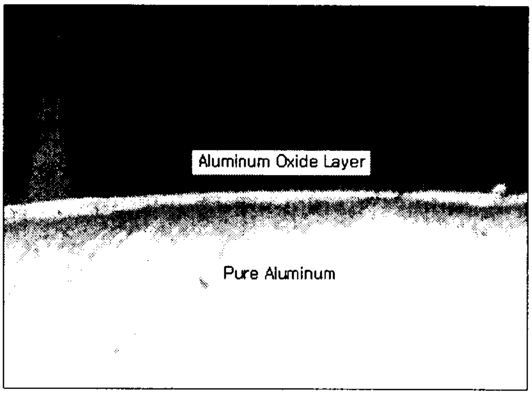
(a) cross section



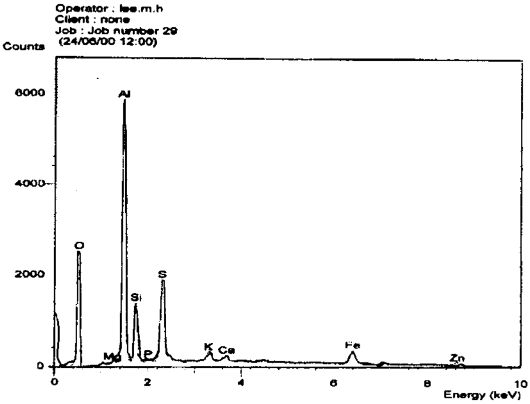
(b) EDX

Figure 4. 1 Galvanized steel strand by blaze fire

Figure 4.2 shows cross section and EDX graph for blazed aluminum conductor. Although a new aluminum strand has mainly pure aluminum, the surface of blazed strand is formed to aluminum oxide layer and it includes such minor components as Si, S, Fe and Zn besides Al. It is obvious that a part of degradation components would appear to the surface of aluminum layer while the galvanized steel strand in the inner layer is degraded by blaze fire. Finally, the effective cross section area of aluminum would be reduced due to fire heating.



(a) cross section



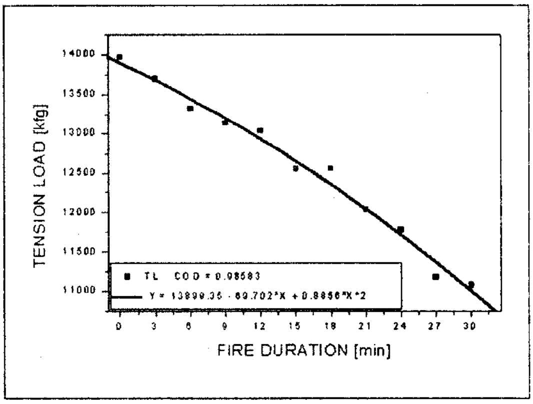
(b) EDX

Figure 4. 2 Aluminum strand by blaze fire

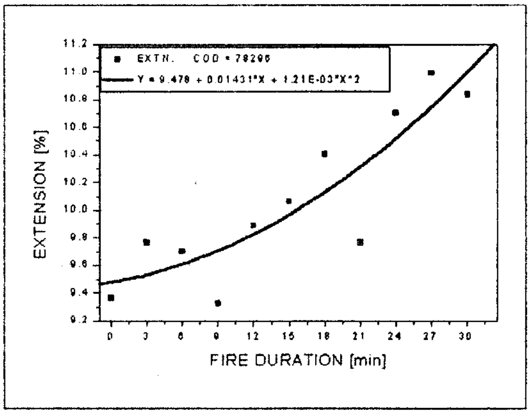
4.3 Estimation of Strength

In general, it may be assumed that most of metals would become less strength after heating flames with high temperature. As discussed in Section 4.2, fire flames are directly contacting with the surface of conductor so that aluminum strands in the outer layer would be more lost their strengths than the other layer.

Based on experiments, for steel core and strands, there almost appears no changes in strength because outer 3 aluminum layers in this conductor could prevent to invoke flame and temperature into the center. In contrary to steel strands, we could easily know that there appears apparently loss of strength in aluminum layers. As one's expectation, all layers show reduction phenomena of mechanical strength according to increasing fire duration. In particular, strength of the outer layer would be reduced remarkably. All aluminum strands in ACSR 480[㎟] take 64[%] charge for ultimate tension load and so they show most reduction of tension load due to fire. In general, extension rates in most metals by heat may be increased and then, ACSR conductors due to blaze fires are also to increase their extension rates.



(a) tension load



(b) extension rate

Figure 4. 3 Mechanical performances

To examine whether solenoid sensor would be used to estimate any deterioration of blazed ACSR, we determine some relations between ultimate tension load, extension rate and fire duration. Let tension load be sum of test data in every strand and extension rate define as an average value for all strands.

Figure 4.3 demonstrates mechanical properties corresponding to fire duration. As ones expectation, it can be easily shown that the strength is reduced while the extension is increased, corresponding to fire duration. Especially, the estimation curves have good coefficient of determination (COD) and then, the strength reduction or the extension increment in ACSR conductors is closely correlated to fire duration. Based on these results, it can be verified that overhead ACSR conductor built along the ridge of mountains would be affected by forest fire and its strength may be more reduced than that before firing.

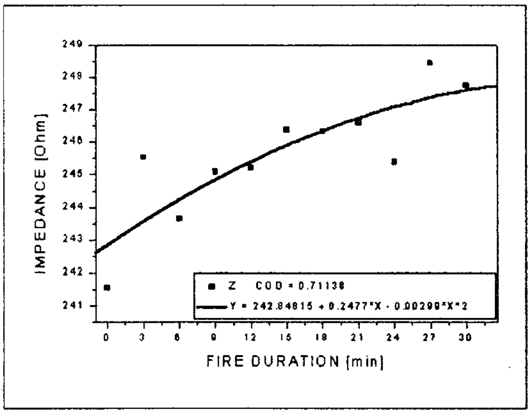
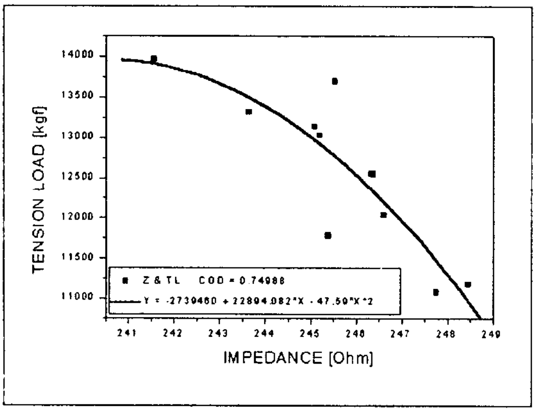


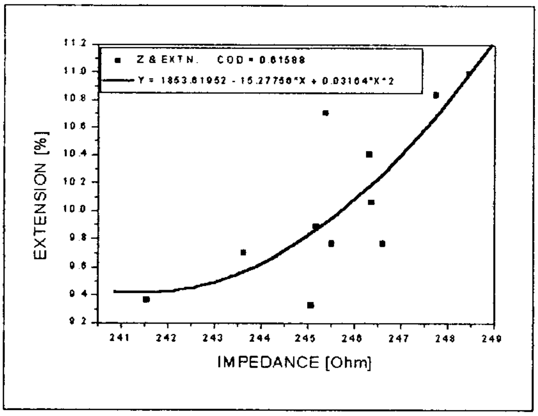
Figure 4. 4 Sensor impedance for flame duration

Although the mechanical performances for artificial test samples may change, it is more important to inspect such variations by any NDT method without cutting off the test conductors from the transmission lines. One method is to use a solenoid coil as discussed in Chapter 3. Figure 4.4 illustrates the property of impedance magnitude related to fire duration. From this result, it can be known that longer fire duration shows larger impedance magnitude. Such behavior implies that the conductor would be oxide due to flame and then, aluminum oxide could be reduced the conductivity as well as mechanical strength of conductor.

As the strength, extension rate and sensor impedance corresponding with fire duration have relatively good correlation, there may also show well relations between impedance and mechanical performances of conductor. Such results are shown in Figure 4.5.



(a) tension load



(b) extension rate

Figure 4. 5 Mechanical performance estimates by sensor impedance

From Figure 4.5, the estimated functions for tension load, y_t and extension rate, y_e corresponding to impedance magnitude, x, are given by

$$y_t = -47.59x^2 + 22894x - 2739460 \qquad (10)$$

$$y_e = 0.0316x^2 - 15.2776x + 1853.6195 \qquad (11)$$

As CODs from Figure 4.5 are given to 0.75 and 0.62, respectively, it is obvious that the solenoid sensor can be used to detect mechanical strength loss of ACSR due to forest fire. Finally, if a suitable eddy current sensor would be designed and implemented, such mechanical performances as severe faults or deterioration of ACSR caused by forest fires could be effectively inspected.

5. Conclusions

Several performances for deterioration in overhead transmission lines due to fires are discussed in this paper. Atmospheric and galvanic corrosion for aged ACSR conductor and its detection for them are presented. A method to inspect deterioration for blazed conductors by using solenoid eddy current sensor is also discussed. As the solenoid coil changes its impedance when the test conductor is inserted into the coil, it can be possible to measure deterioration degree caused by forest fires. For some samples degraded by artificial fire, tensile strength, extension rate and sensor impedance are tested. For the initial stage of exposure time of gas fire, aluminum strand in the outer layer shows a little more strength than that of new strand but galvanized steel strand holds the similar strength despite of appearing a little loss of zinc layer. However, as increasing blazed period to some extent, the strength of aluminum strand begins to be reduced remarkably. In general, the sensor impedance is increased if the tension load of conductor is reduced or the extension rate is increased. Therefore, it can be verified that the sensor output could exhibit the changes of mechanical performances, and would be used to detect such deterioration of ACSR conductors due to forest fire.

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