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# Alüminyum Alaşımlı Tellere Isıl İşlem Uygulanması ve Bu Tellerle Üretilen Tam Alaşımlı AAAC İletkenlerle Geleneksel ACSR Örgülü İletkenlerin Karşılaştırılması

**Ebru KISTI[1]*, Erhan SAYIN[2], Necati OCAK[3], Ahmet FEYZİOĞLU[4]**

[1,2,3]Emta Conductor &Cable, Osmaniye, Turkey
[4]Marmara University, Faculty of Technology, Department of Mechanical Engineering, İstanbul, Turkey

[1]https://orcid.org/0000-0001-6907-7530
[2]https://orcid.org/0000-0002-6145-5688
[3]https://orcid.org/0000-0001-8494-5789
[4]https://orcid.org/0000-0003-0296-106X
*Sorumlu yazar: ebrukisti@gmail.com.tr

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**ÖZ**

Geleneksel ACSR iletkenleri, alüminyum tellerin çelik bir çekirdek üzerine bükülmesiyle oluşturulur. Çelik çekirdek akım taşımaya katkı sağlamaz ve sadece taşıma amaçlı kullanılır. Hat ağırlığının artmasında çelik kısmın rolü büyüktür. Hat ağırlığının artması ile daha kısa mesafelerde daha uzun direkler kullanılır ancak taşıma görevini üstlendiği için çelik özden vazgeçilemez. Günümüzde ACSR konvansiyonel iletkenine alternatif arayışları hızlanmıştır. Bu alternatiflerden biri de AAAC'dir (Tam alüminyum alaşımlı iletkenler). AAAC'de bulunan teller özel alaşımlı üretim ile sertleştirilmiş olup, merkezde taşıyıcı olarak çelik öz ihtiyacını ortadan kaldırır. Alüminyum havai hat iletkeni üretilirken alüminyum külçeler ergitme fırınlarında eritilip, dinlenme fırınlarına alındıktan sonra içine Si, Mg gibi alaşım elementlerinin belirli oranlarda ilave edilmesinden sonra bakır bir kalıba dökülerek katılaştırılır. Refrakter yolluklardan geçerek haddeleme işleminden sonra 9,5 mm veya 12 mm Alüminyum Alaşımlı çubuk (filmaşin) yarı mamülleri üretilmektedir. Üretilecek havai hat iletkeni için standartlarda belirlenen çapta tel üretilirken, 9,5 mm veya 12 mm Alüminyum çubuk (filmaşin) yarı mamul çekme işleminde belirli bir küçültme oranı ile inceltilir ve istenilen çapta alüminyum tel elde edilir. Çekme işleminde filmaşin, makineye ve üretilecek nihai ürüne uygun bir indirgeme oranı ile haddelenir. Üretilen teller standartlardaki adım oranı ile bir araya getirilerek bir iletken oluşturulur. Üretilen alüminyum alaşımlı telin, mekanik ve elektriksel özelliklerini kazanmak için ısıl işlem fırınlarında belirli bir zaman ve sıcaklıkta ısı uygulanır. Bu çalışmada uygulanan ısıl işlem süresi ve derecesi dikkate alınarak ısıl işlem öncesi ve sonrası özellikler karşılaştırılacak ve ısıl işlemin tele etkisi deneysel çalışmalarla gösterilecektir. Alaşımlı tellerden yapılmış AAAC 774 AL7 iletkeni ile çelik çekirdek üzerine örülmüş alüminyum tellerden yapılmış ACSR Pheasant iletkenlerinin mekanik ve elektriksel testleri yapılacak ve hat seçiminde bazı parametreler dikkate alınarak iki iletken karşılaştırılacaktır.

# Application of Heat Treatment to Aluminum Alloy Wires and Comparison of Full Alloy AAAC Conductor Manufactured with These Wires and Conventional ACSR Stranded Conductors

**Research Article**

**ABSTRACT**

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Conventional ACSR conductors are formed by stranding aluminum wires over a steel core. The steel core does not contribute to current carrying and is used only for carrying purposes. The steel core has a great role in the shedding of the line weight. With the increase in line weight, longer poles are used at shorter distances, but it cannot be abandoned because it undertakes the transport task. Nowadays, the search for alternatives to the ACSR conventional conductor has accelerated. One of these alternatives is AAAC (Full aluminum alloy conductors). The wires in AAAC are hardened with special alloy production and eliminate the need for a steel core as a carrier in the center. While producing the aluminum overhead line conductor, after the aluminum ingots are melted in the melting furnaces and taken to the resting furnaces, after the addition of alloy elements such as Si, Mg in certain proportions, it is solidified by pouring it into a copper mold through refractory runners, and after the rolling process, 9.5 mm or 12 mm Aluminum Alloy rod (wire rod) semi-finished products are produced. While producing wire in the diameter determined in the standards for the overhead line conductor to be produced, 9.5 mm or 12 mm Aluminum rod (wire rod) is thinned with a certain reduction ratio in the semi-finished drawing process, and aluminum wire of the desired diameter is obtained. In the drawing process, the rod is rolled with a reduction ratio suitable for the machine and the final product to be produced. The wires produced are brought together with the step ratio in the standards to form a conductor. In order to gain the mechanical and electrical properties of the produced aluminum alloy wire, heat is applied at a certain time and temperature in heat treatment furnaces. Considering the heat treatment time and degree applied in this study, the properties before and after the heat treatment will be compared and the effect of the heat treatment process on the wire will be shown with experimental studies. Mechanical and electrical tests of AAAC 774 AL7 conductor made of alloy wires and ACSR Pheasant conductors made of aluminum wires knitted on steel cores will be carried out and the two conductors will be compared considering some parameters in line selection.

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## 1. Introduction

In the continuous casting line fed with aluminum ingots, the aluminums are melted and liquefied. If the alloy is desired to be produced, 6000 series alloying elements such as Si-Mg are added at the rates determined according to the product desired to be obtained, while the aluminum in liquid form is taken into the quenching furnace. Alloyed liquid is transmitted to the copper wheel with the help of aluminum refractory runners (Figure 1).

**Figure 1.** Melting and resting furnaces

Here the liquid metal, which solidifies by cooling the copper wheel with water with the help of nozzles, is processed in the rolling unit and shaped to produce 9.5 mm aluminum alloy rod.

In order to produce the wire with the diameter specified in the standards for the overhead line conductor to be produced, 9.5 mm aluminum/alloy rod semi-finished product is used in the wire drawing process. In alloy production, 9.5 mm aluminum alloy rod is heat-treated at 550 -580 °C for 6-8 hours in order to increase the machinability of the semi-finished product, and then used in the wire drawing process.

The 9.5 mm aluminum/alloy rod semi-finished product given to the wire drawing machines is passed through the rolling series adjusted at a certain reduction ratio according to the wire diameters that make up the final product desired. Since no heat is applied during this process, it is called cold forming. The wires produced after this process are wound on bobbins to be used in the next stranding process.

Aluminum alloy wires produced using a heat-treated 9.5 mm aluminum alloy rod cannot provide the minimum conductivity required by the standard at the end of the drawing process (Figure 2).

**Figure 2.** Heat treatment applied to aluminum wires

Wires are stranded in stranding machines according to the number of wires, number of layers and wire diameter specified in the standards, forming conductors.

In this study, conductivity, elongation and strength values from mechanical and electrical tests will be tested before and after the heat treatment applied for alloy wires and the results will be compared. After the evaluation of the compliance of the results with the standard, the importance of the time and temperature values of the applied heat treatment will be emphasized and it will be shown that the application is in the optimum range as a result of the experience obtained from the previous processes. AAAC 774 AL7 conductor, which is approximately the same diameter as the ACSR Pheasant conductor, which is the most used in high voltage transmission lines in Turkey, and which is preferred abroad, will be tested and its properties will be compared.

## 2. Material and Methods

### 2.1. Comparison of the values of aluminum alloy wires before and after heat treatment

Aluminum alloy wires can not meet some desired mechanical and electrical properties at the end of the wire drawing process. The main purpose of heat treatment of alloy wires is to obtain the values given in the standards and/or specifications. For AAAC 774-AL7 conductor, 4.02 mm AL7 wire will be produced in wire drawing process by using 9.5 mm aluminum alloy rod. The specifications of 4.02 mm AL7 wires given in the BS EN 50183 standard Table 1 (Table 1) (BS EN 50183:2000 Standard).

**Table 1.** Properties of 4,02 mm AL7 wire after heat treatment (BS EN 50183 Table 1)

| TYPE | NOMINAL CONDUCTIVITY (%IACS) | DIAMETER RANGE (mm) | MINIMUM TENSILE STRENGTH ($N/mm^2$) | MINIMUM ELONGATİON (250 mm) (%) | MAXIMUM RESISTIVITY (Mean of a lot) nΩ.m |
|---|---|---|---|---|---|
| AL7 | 57.5 | 4.00 – 5.00 | 255 | 3.0 | 30.0 |

The tests to be compared for 4.02 mm AL7 before and after heat treatment are the diameter, tensile strength, elongation and conductivity tests specified in the BS EN 50182 standard Table 1 (Table 1).

Diameter measurement test: The diameter will be the average of two readings taken at right angles to each other at the same location, rounded up to two decimal places of one millimeter. Diameter tolerance for wires over 3mm is ±1% (BS EN 50183:2000 Standard).

Strength and elongation test: A force is applied to the wire by the wire drawing device until the wire breaks. The breaking strength is determined by dividing the breaking force by the initial cross-sectional area. The elongation at break is calculated with the wire length and initial length information after breaking.

Conductivity test: In order to calculate the conductivity value, the resistivity of the conductor must be calculated first. Resistivity is calculated according to the formula in 1.1.

The volume resistivity is defined as the resistance of a conductor of unit length and unit cross-sectional area. Its value at a reference temperature to is calculated from the following formula (1.1):

$$\rho(to) = \frac{\mathrm{A}(to)\mathrm{x}\mathrm{R}(to)}{L(to)} \tag{1.1}$$

where:

ρ(to) = volume resistivity at the reference temperature *to*

R(to) = resistance between the ends of the gauge length of the specimen at the reference temperature *to*

A(to) = cross-sectional area of the specimen at the reference temperature *to*

L(to) = gauge length of the specimen at the reference temperature *to*

(IEC 60468 Method of Measurement of Resistivity of Metallic Materials, 1st Edition, January 1974, Page 7)

According to the determined diameters of the cylindrical aluminum wires, the cross-sectional area is calculated according to the formula 1.2;

$$\mathrm{A(to)} = \frac{\pi \mathrm{x} D^2}{4} \tag{1.2}$$

A(to) cross-sectional area of the specimen at the reference temperature to ($mm^2$) and D represents the diameter of the conductor (mm).

The rated d.c. (direct current) resistance of the conductor up to three determination figures in Ω/km at 20°C is based on the resistivity value and the nominal diameter of aluminum-clad steel and aluminum wires for calculation purposes (BS EN 50182:2001 Standard).

The conductivity calculation is calculated with reference to the resistivity of the annealed copper defined in the standards. The conductivity unit is IACS (International Annealed Copper Standard). Resistivity of annealed copper is accepted as 17.241 n.ohm.mt 100% IACS in conductor standards. After calculating the resistivity, the inverse ratio is established by taking the resistivity value of 17.241 n.ohm.mt versus the 100% IACS conductivity value as a reference.

In the first study, the strength, elongation and conductivity values of the wires will be compared before and after heat treatment. The applied heat treatment time has been determined by the experience learned from the previous productions. It is also possible to determine these values using artificial intelligence.

### 2.2. Comparison of steel core aluminum conductors and full aluminum alloy conductors in transmission lines

In order for the conductors to be used in power transmission and distribution lines to provide the required performance, they must meet some requirements according to the line characteristics. Some of these features are;

a. Conductivity
b. Unit Weight
c. Conductor Diameter,
d. Deflection,
e. Mechanical Strength

*a) Conductivity*

The conductive material to be used in overhead lines should have high conductivity, that is, low resistance. Because it is desired that the power loss in the lines during transmission is minimal (Havai Enerji Hatları, 2011).

*b) Specific weight*

One of the most important factors affecting the conductor in terms of mechanical strength is the weight of the conductor. The specific gravity has a great effect on the mechanical stress of the conductors. For this reason, the specific gravity of the conductors used in overhead lines should be small. Due to its low specific weight, economy is provided in mast and overhead line hardware materials (Havai Enerji Hatları, 2011).

*c) Conductor Diameter*

The larger the conductor diameter, the greater the ice load, wind load and tensile force on the conductor. In conductors with larger diameters, more snow and ice loads are accumulated, and the wind effect becomes larger. This adversely affects the mechanical strength of the conductor (Havai Enerji Hatları, 2011).

*d) Deflection*

In high voltage power transmission lines, the sagging of the conductor stretched between two poles due to its own weight and the snow and ice loads accumulating on it is called deflection. The length of the distance between the poles where the conductor is used, the weight of the conductor, the wind and ice loads on the conductor, etc. increase the deflection (Havai Enerji Hatları, 2011).

*e) Mechanical Strength*

Overhead line conductors are always exposed to external influences and loads caused by them. The loads (snow, ice, wind) that may come to the overhead lines and their own weight must be able to be safely carried by the conductor (Havai Enerji Hatları, 2011).

In the second study, the effects on the line parameters will be examined by applying the diameter measurement, mass per unit length, complete resistance and complete breaking tests to the steel core aluminum conductor ACSR Pheasant and the full aluminum alloy conductor AAAC 774 AL7. The properties of the conductors in the standard are given in BS EN 50182 standard Table F.37 (Table 2) and BS EN 50182 standard Table F.25 (Table 3).

**Table 2.** AAAC 774-AL7 technical specifications ( BS EN 50182 Table F.37)

| CODE | WIRE DİAMETER (mm) | CONDUCTOR DIAMETER (mm) | MASS PER UNIT LENGTH (kg/km) | RATED STRENGTH kN | DC RESISTANCE Ω/km |
|---|---|---|---|---|---|
| 774-AL7 | 4.02 | 36.2 | 2139.8 | 197.43 | 0.0397 |

**Table 3.** ACSR PHEASANT technical specifications (BS EN 50182 Table F.25)

| OLD CODE | WIRE DİAMETER (mm) | CONDUCTOR DIAMETER (mm) | MASS PER UNIT LENGTH (kg/km) | RATED STRENGTH kN | DC RESISTANCE Ω/km |
|---|---|---|---|---|---|
| FA 405 PHEASANT | 3.90 – Al 2.34 – St | 35.1 | 2423.8 | 196.36 | 0.0448 |

Tests for AAAC 774 and ACSR Pheasant Conductor;

1-Conductor diameter measurement: Conductor diameters will be measured using caliper.

2-Conductor resistance: Conductor resistance will be made with a device capable of measuring the complete resistance.

3-Mass per unit length of conductor: Conductor weight will be measured using a digital scale. The conductor length will be measured using a tape measure. Conductor unit weight will be calculated by dividing the measured weight of the conductor by its measured length.

4-Tensile strength test of the conductor: The conductors are completely connected to the breaking test device and the load is applied to the conductor until it breaks. The force value given by the device at the moment it breaks gives the breaking strength in tensile.

The devices used in the experiments and the calibration status of the devices are given in Table 4.

**Table 4.** Devices used in tests and calibration status of devices

| TEST DESCRIPTION | EQUIPMENT DESCRIPTION | MARK-SERIAL NO | CALIBRATION RANGE |
|---|---|---|---|
| Diameter Measurement | Digital Micrometer | Mitutoyo 85014274 | 04.08.2021-04.08.2022 |
| | Digital Caliper | Mitutoyo 09030184 | 04.08.2021-04.08.2022 |
| Resistance Measurement | Resistance Measuring Device | Burster 2316-397492 | 17.08.2021-17.08.2022 |
| Mass per unit length of conductor | Digital Balance | Dikomsan KD-KCS-6000 64403 | 16.08.2021-16.08.2022 |
| | Meter | Fisco EMT-ŞMT-00 | 04.08.2021-04.08.2022 |
| Tensile strength test of the conductor | Horizontal Breaking Machine | Baykon 1526001H6 | 17.08.2021-17.08.2022 |

## 3. Results and Discussion

In the works to be done;

1- The strength elongation and conductivity values of 4.02 mm AL7 wire to be used in the production of AAAC 774 AL7 conductor will be compared before and after heat treatment, and the effects of heat treatment on the alloy wire will be examined.

2- For ACSR Pheasant conductor and AAAC 774 AL7 conductor, diameter, mass per unit length, complete resistance measurement and tensile breaking strength tests will be performed. Two conductors will be compared by considering some parameters in line selection.

Conductors manufactured with wires that are hardened by heat treatment have the same cross-section as ACSR, but have higher strength, more energy carrying capacity and are lighter. On the other hand, its price is higher than ACSR. However, despite this, it has started to find widespread use because it compensates for this with its ability to transport more energy in the 2-3 year term. ( Karabay et al., 2005)

The International Energy Agency announced that world energy consumption has increased by 45% since 1980 and will be 70% higher by 2030. The energy policy of the future will be on the triad of saving, energy efficiency and renewable energy.(İşler, 2009)

Although the investment cost of AAAC alloy conductors is higher than ACSR conventional conductors, it provides advantages in the long run thanks to its contribution to energy efficiency.

### 3.1. Properties of aluminum alloy 4.02 mm AL7 wires before and after heat treatment

Heat treatment was applied to 4.02 mm Al7 coils between 180 °C and 190 °C for 8 hours. 61 wires to be used in the conductor were numbered starting from 1 and tests were carried out before and after heat treatment.

*Resistivity*

The resistivity of the wires was calculated by measuring the resistance values before and after the heat treatment (Table 5).

The resistance value of wire number 1, measured at 1 meter length before heat treatment, is 2.491 mΩ/m (Figure 3).

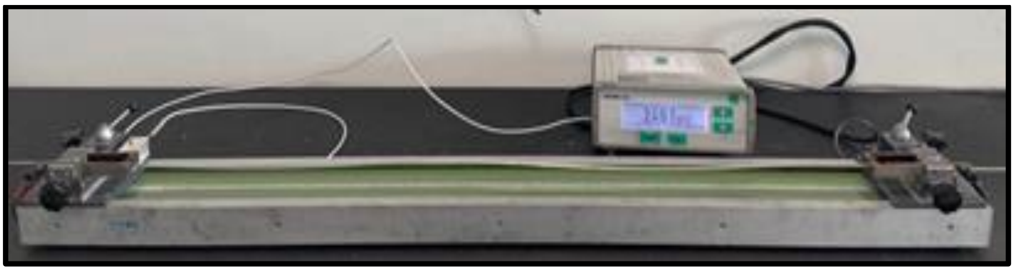

**Figure 3**. 4,02 mm alloy wire resistance measured before heat treatment

Cross-sectional area of wire 4.02 mm (S) (Formula 1.2 has been applied.);

$S= (\pi \times (4.02)^2 )/4 = 12.69\ mm^2$

Resistivity value (ρ) (Formula 1.1 has been applied);

$\rho = (2.491\ m\Omega \times 12.69\ mm^2 )/ 1\ m = 31.611\ n\Omega\ m$

17.241 nΩ m resistivity ——— %100 IACS conductivity

31.611 nΩ m resistivity ——— Conductivity value

*There is an inverse proportion between conductivity and resistivity.*

Conductivity value = (17.241 x100) / 31.611 = 54.54 IACS

The resistance value of wire number 1, measured at 1 meter length after heat treatment, is 2.345 mΩ/m (Figure 4).

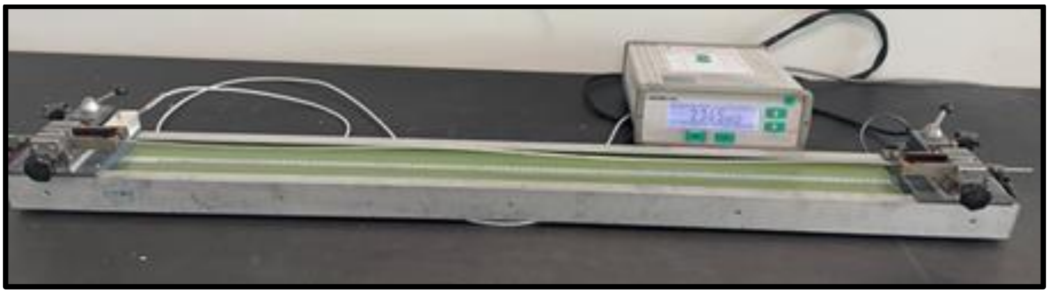

**Figure 4**. 4.02 mm alloy wire resistance measured after heat treatment

Cross-sectional area of wire 4.02 mm (S) (Formula 1.2 has been applied.);

$S= (\pi \times (4.02)^2 )/4 = 12.69\ mm^2$

Resistivity value (ρ) (Formula 1.1 has been applied.);

$\rho = (2.345\ m\Omega \times 12.69\ mm^2 )/ 1\ m = 29.758\ n\Omega\ m$

17.241 nΩ m resistivity ——— %100 IACS conductivity

29.758 nΩ m resistivity ——— Conductivity value

*There is an inverse proportion between conductivity and resistivity.*

Conductivity value = (17.241 x100) / 29.758 = 57.94 IACS

**Table 5.** 4.02 mm AL7 Aluminium alloy wire before and after heat treatment conductuvity test results

| *No* | **4.02 mm Al alloy wire before heat treatment Conductivity (%IACS)** | **4.02 mm Al alloy wire after heat treatment Conductivity (%IACS)** |
|---|---|---|
| 1 | 54.54 | 57.94 |
| 2 | 54.80 | 57.83 |
| 3 | 54.65 | 57.86 |
| 4 | 54.78 | 57.65 |
| 5 | 55.77 | 58.03 |
| 6 | 54.49 | 57.88 |
| 7 | 54.73 | 57.66 |
| 8 | 54.37 | 57.73 |
| 9 | 54.62 | 57.85 |
| 10 | 54.75 | 57.78 |
| 11 | 54.52 | 57.77 |
| 12 | 54.69 | 57.62 |
| 13 | 55.58 | 57.98 |
| 14 | 54.61 | 57.82 |
| 15 | 54.73 | 57.85 |
| 16 | 54.67 | 57.92 |
| 17 | 54.77 | 57.67 |
| 18 | 54.65 | 57.72 |
| 19 | 54.83 | 57.85 |
| 20 | 54.76 | 57.63 |
| 21 | 55.47 | 57.86 |
| 22 | 54.66 | 57.75 |
| 23 | 54.38 | 57.68 |
| 24 | 54.57 | 57.77 |
| 25 | 54.69 | 57.82 |
| 26 | 54.71 | 58.05 |
| 27 | 54.28 | 57.59 |
| 28 | 54.84 | 57.83 |
| 29 | 54.21 | 57.73 |
| 30 | 54.64 | 57.91 |
| 31 | 54.48 | 57.66 |
| 32 | 55.69 | 57.94 |
| 33 | 54.62 | 57.76 |
| 34 | 54.86 | 57.85 |
| 35 | 54.45 | 57.92 |
| 36 | 55.21 | 57.70 |
| 37 | 55.48 | 58.15 |
| 38 | 54.69 | 57.92 |
| 39 | 55.27 | 57.85 |
| 40 | 54.53 | 57.73 |
| 41 | 54.86 | 57.68 |
| 42 | 55.23 | 58.10 |
| 43 | 54.47 | 57.98 |
| 44 | 54.21 | 57.71 |
| 45 | 55.17 | 57.85 |
| 46 | 54.67 | 57.93 |
| 47 | 54.91 | 57.78 |
| 48 | 54.03 | 57.94 |
| 49 | 54.95 | 57.76 |
| 50 | 54.88 | 57.69 |
| 51 | 55.33 | 57.78 |
| 52 | 55.41 | 57.63 |
| 53 | 54.28 | 57.78 |
| 54 | 55.67 | 57.82 |
| 55 | 54.93 | 57.65 |
| 56 | 54.18 | 57.73 |
| 57 | 54.71 | 57.68 |
| 58 | 55.08 | 57.76 |
| 59 | 54.85 | 57.92 |
| 60 | 54.93 | 57.61 |
| 61 | 55.13 | 57.73 |

*Tensile strength*

The strength and elongation values of the wires before and after heat treatment (Table 6) were measured using a tensile tester (Figure 5).

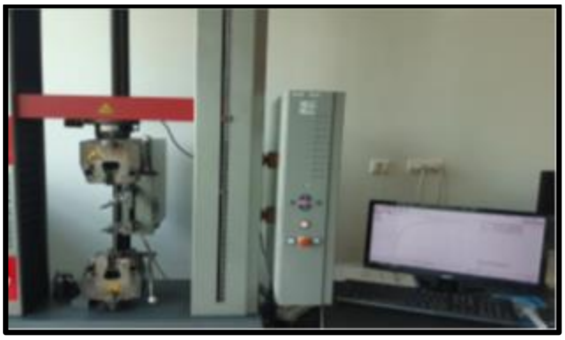

**Figure 5.** Tensile Tester

**Table 6.** 4.02 mm AL7 Al alloy wire before and after heat treatment tensile strength and elongation test results

| *No* | 4.02 mm Al alloy wire before heat treatment | | 4.02 mm Al alloy wire after heat treatment | |
|---|---|---|---|---|
| | **Tensile strength (MPa)** | **Elongation (%)** | **Tensile strength (MPa)** | **Elongation (%)** |
| 1 | 276 | 4.3 | 261 | 7.0 |
| 2 | 271 | 5.0 | 265 | 5.4 |
| 3 | 272 | 3.6 | 263 | 5.0 |
| 4 | 269 | 4.0 | 264 | 5.4 |
| 5 | 276 | 3.2 | 262 | 5.2 |
| 6 | 281 | 4.0 | 275 | 5.8 |
| 7 | 270 | 3.4 | 265 | 4.4 |
| 8 | 276 | 1.3 | 273 | 5.6 |
| 9 | 271 | 4,9 | 258 | 5.9 |
| 10 | 263 | 3.6 | 260 | 4.9 |
| 11 | 275 | 4.1 | 275 | 5.2 |
| 12 | 272 | 5.3 | 260 | 7.1 |
| 13 | 271 | 4.4 | 268 | 5.1 |
| 14 | 268 | 3.9 | 269 | 5.6 |
| 15 | 272 | 3.1 | 261 | 4.2 |
| 16 | 276 | 4.0 | 265 | 5.3 |
| 17 | 269 | 2.7 | 269 | 5.4 |
| 18 | 275 | 4.2 | 260 | 5.1 |
| 19 | 276 | 4.0 | 260 | 5.1 |
| 20 | 277 | 4.9 | 266 | 5.4 |
| 21 | 270 | 5.0 | 267 | 5.3 |
| 22 | 268 | 4.9 | 261 | 6.2 |
| 23 | 271 | 5.0 | 273 | 6.1 |
| 24 | 266 | 3.4 | 258 | 5.2 |
| 25 | 272 | 4.0 | 261 | 5.7 |
| 26 | 268 | 3.9 | 262 | 4.8 |
| 27 | 271 | 3.4 | 266 | 6.3 |
| 28 | 270 | 5.4 | 261 | 5.4 |
| 29 | 280 | 5.2 | 264 | 4.8 |
| 30 | 278 | 4.9 | 259 | 4.4 |
| 31 | 274 | 4.5 | 265 | 5.8 |
| 32 | 271 | 4.4 | 256 | 5.6 |
| 33 | 281 | 4.6 | 263 | 6.3 |
| 34 | 269 | 4.1 | 272 | 5.6 |
| 35 | 265 | 1.5 | 267 | 5.8 |
| 36 | 280 | 5.3 | 264 | 6.0 |
| 37 | 268 | 4.5 | 262 | 5.2 |
| 38 | 273 | 4.4 | 272 | 5.8 |
| 39 | 276 | 4.6 | 271 | 5.5 |
| 40 | 273 | 4.7 | 269 | 4.6 |

| | | | | |
|---|---|---|---|---|
| 41 | 277 | 3.9 | 268 | 5.6 |
| 42 | 266 | 1.4 | 272 | 5.8 |
| 43 | 268 | 5.1 | 262 | 5.5 |
| 44 | 267 | 5.0 | 264 | 5.0 |
| 45 | 267 | 5.0 | 264 | 5.5 |
| 46 | 279 | 4.6 | 274 | 5.5 |
| 47 | 269 | 4,9 | 268 | 5.1 |
| 48 | 271 | 4.2 | 262 | 5.5 |
| 49 | 279 | 2.7 | 264 | 5.8 |
| 50 | 270 | 4.7 | 267 | 5.7 |
| 51 | 259 | 1.9 | 275 | 6.8 |
| 52 | 271 | 3.7 | 264 | 4.0 |
| 53 | 272 | 4,5 | 269 | 5.9 |
| 54 | 272 | 4.9 | 268 | 4.9 |
| 55 | 266 | 2.5 | 269 | 4.5 |
| 56 | 271 | 3.2 | 260 | 5.7 |
| 57 | 274 | 5.1 | 259 | 6.1 |
| 58 | 277 | 3.4 | 273 | 6.6 |
| 59 | 275 | 4,1 | 263 | 6.1 |
| 60 | 281 | 6.0 | 271 | 5.6 |
| 61 | 278 | 3,8 | 265 | 4.2 |

### 3.2. AAAC 774 AL7 and ACSR Pheasant conductor tests

By taking samples from AAAC 774 AL7 conductor and ACSR Pheasant conductor (Figure 6), diameter, mass per unit length, complete resistance measurement and tensile strength tests were applied to the conductors.


**Figure 6.** AAAC 774 AL7 and ACSR Pheasant Conductor

#### 3.2.1. AAAC 774 AL7 and ACSR Pheasant conductor diameter measurement test

The diameter of the AAAC 774 AL7 and ACSR Pheasant conductors was measured using caliper. Conductor diameters should not vary by more than ± 1% for conductors greater than or equal to 10 mm (BS EN 50183:2000 Standard).

AAAC 774 AL7 conductor diameter measured 36.25 mm (Figure 7). ACSR Pheasant conductor diameter measured 35.15 mm (Figure 8).


**Figure 7.** AAAC 774 AL7 conductor diameter


**Figure 8.** ACSR Pheasant conductor diameter

### 3.2.2. AAAC 774 AL7 and ACSR Pheasant conductor complete resistance measurement

Conductor resistances were measured using a complete resistance measuring device (Figure 9). Conductor complete resistance should not be greater than the maximum resistance value given in the related standard.

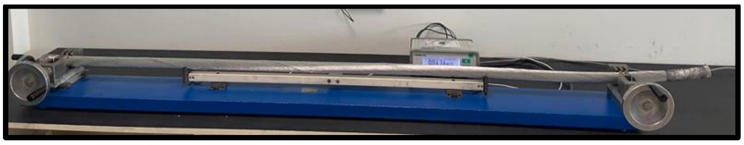

**Figure 9.** Complete resistance measuring device

ACSR Pheasant resistance value is measured as 0.0434 mΩ/m (Figure 10). (The maximum value given in the Table 3 ACSR PHEASANT Technical Specifications (BS EN 50182 Table F.25) is 0.0448 mΩ/m).

AAAC 774 AL7 conductor resistance value is measured as 0.0376 mΩ/m (Figure 11). (The maximum value given in the Table 2 AAAC 774-AL7 Technical Specifications (BS EN 50182 Table F.37) is 0.0397 mΩ/m).


**Figure 10.** ACSR Pheasant conductor resistance


**Figure 11.** AAAC 774 AL7 conductor resistance

### 3.2.3. AAAC 774 AL7 and ACSR Pheasant conductor measurement of mass per unit length

The product weight was measured in grams using a balance, and the conductor length was measured in mm using a tape measure (Figure 12). The unit weight was calculated by dividing the conductor weight by its length.

The mass of the conductor per unit length shall not vary by more than ± 2% of its nominal value (BS EN 50183:2000 Standard).

**Figure 12.** Measuring conductor length and weight

The ACSR Pheasant sample weight was 5414.5 g, and its length was measured as 2228 mm. Its unit weight is found as 2430.2 kg/km by dividing 5414.5 g by 2228 mm.
The weight of AAAC 774 AL7 sample was 4537 gr and its length was measured as 2120 mm. The mass per unit length is calculated as 2140 kg/km by dividing 4537 gr by 2120 mm.

### 3.2.4. AAAC 774 AL7 and ACSR Pheasant conductor tensile strength test

Complete breaking values of AAAC 774 AL7 and ACASR Pheasant conductors were determined using the complete breaking device (Figure 13).
Conductor complete breaking value should not be less than the minimum breaking value given in the standard.

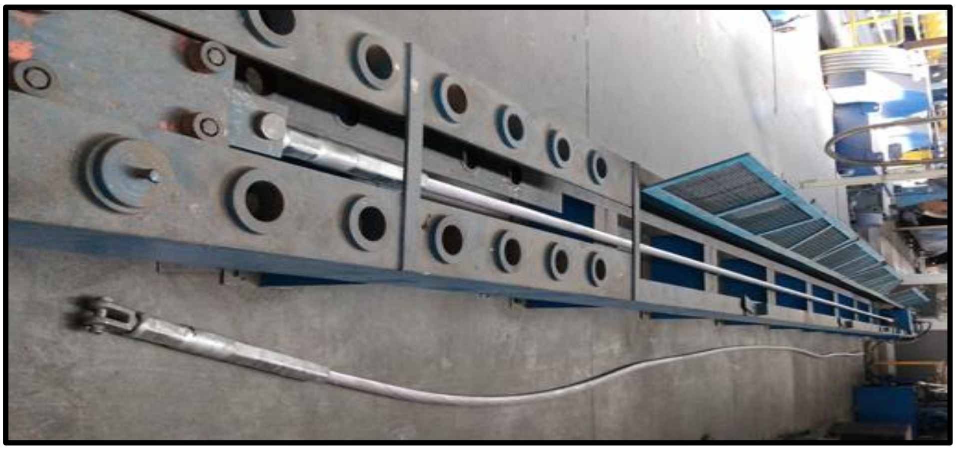

**Figure 13.** Tensile breaking strength test

As a result of the test, the ACSR Pheasant Breaking load was measured as 238.48 kN. (Minimum value given in EN 50182 Standard Table F.25 (Table 3) is 196.36 KN)
AAAAC 774 AL7 conductor breaking load is measured as 242.57 KN. (Minimum value given in EN 50182 Standard Table F.37 (Table 2) is 197.43 KN)

## 4. Conclusion

In the first study, the effects of heat treatment on the alloy wire were investigated by comparing the strength, elongation and conductivity values of 4.02 mm AL7 wire before and after heat treatment. For 4.02 mm AL7 wire, the minimum elongation required in the standard is 3%, the minimum strength is 255 MPa and the minimum conductivity is 57.5 IACS. Although the strength values before heat treatment are above 255 MPa, it is seen that the elongation values of some wires are less than 3%. It is seen that the conductivity values of 4.02 mm AL7 aluminum alloy wire are below the desired 57.5 IACS. In order to increase the low elongation values and low conductivity values, it is seen that the elongation and conductivity values are increased by increasing the elongation and conductivity values for 61 wires as a result of applying heat treatment to 4.02 mm AL7 aluminum alloy wire in the range of 185 ° C- 190 ° C for 8 hours. Although the strength values after the heat treatment decreased compared to the values before the heat treatment, it is seen that it is above 255 MPa, which is the lowest value required by the standard. It has been observed that heat treatment is required for aluminum alloy wires to comply with the standard.

In the second study, diameter, mass per unit length, complete resistance measurement and complete tensile strength tests were performed for ACSR Pheasant conductor and AAAC 774 AL7 conductor.

As a result of the conductor diameters test, the diameter was measured 36.25 mm for the AAAC 774 AL7 conductor and the diameter was 35.15 mm for the ACSR Pheasant conductor. Although the conductor diameters are almost the same, the ACSR Phesant conductor with a low diameter will be advantageous in energy transmission and distribution lines as it will be less exposed to wind and ice load than the AAAC 774 AL7 conductor.

As a result of the conductor resistance test, the ACSR Pheasant conductor total resistance value was measured as 0.0434 mΩ/m and the AAAC 774 AL7 conductor complete resistance value was measured as 0.0376 mΩ/m. The resistance of the AAAC 774AL7 conductor is very low compared to the ACSR Pheasant conductor. Since the line losses of the AAAC 774 AL7 conductor will be lower than the line losses of the ACSR Pheasant conductor, the AAAC 774AL7 conductor will provide an advantage in energy transmission and distribution lines.

As a result of the conductor mass per unit length test, it was measured as 2430.2 kg/km for ACSR Pheasant and 2140 kg/km for AAAC 774 AL7 conductor. It has been observed that the unit weight of AAAC 774 AL7 conductor is less than ACSR Pheasant conductor. Since the deflection performance of AAAC 774 AL7 conductor with lower unit weight will be better than ACSR Pheasant conductor, AAAC 774AL7 conductor will be advantageous in energy transmission and distribution lines.

As a result of the conductor complete breaking strength test, the ACSR Pheasant breaking load was measured as 238.48 kN and the AAAC 774 AL7 conductor breaking load was measured as 242.57 kN. Since AAAC 774 AL7 conductor has higher mechanical strength than ACSR Pheasant conductor, AAAC 774AL7 conductor will provide advantage in energy transmission and distribution lines.

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**Conflict of Interest Statement**

There is no conflict of interest in the content of this article.

**Author's Contributions**

The contribution of the author's is equal.

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