

Effect of homogenizing and artificial aging treatment on electrical conductivity of the wire recycled from waste

Hussein Ali Alwan¹, Haidar A.H. al-Jubouri², Abbas Khammas Hussein³

Abstract—The aim of this study is to investigate the effect of homogenization and artificial aging treatment at isothermal temperature (180 °C) for various periods of time (1,5,10,20,30 and 50 hr.) on electrical conductivity of as-cast (A-B-C) alloys, where it has been exploited waste represented carbonated beverages cans and scrap electric wires damaged and recycled to obtain optimal alloy standard specifications and utilization in the manufacture of wire and used in power transmission lines, addition of boron (3%) in aluminum melts significantly decreases impurities (Ti, V and Zr) (as solute), boron can combine with even trace amounts of transition elements to form insoluble boride compounds thus lowering the transition metal impurity content in the metal, the borides can then be separated by precipitation, add boron leads to a significantly improvement in the electrical conductivity of the aluminum commercial, showed artificial aging treatment at a temperature (180 °C) improvement in electrical conductivity value of the alloy (C6) compared with the electrical conductivity of the alloy base (A), where the percentage of improvement in the electrical conductivity of the alloy (C6) at aging time (20hr.) is (56.8 %) compared with the electrical conductivity of the alloy base (A). Generally showed artificial aging treatment conducted at temperature (180 °C) for various periods of time improvement in the values of electrical conductivity of the alloys (A,B,C) compared with the values of the electrical conductivity of the alloy as is cast.

Index Terms — Carbonated beverages cans, Scrap wire damaged, artificial aging, Homogenizing, Solution heat treatment, Electrical conductivity, waste, recycling, boron treatment.

1. INTRODUCTION

THE term "Heat Treatment" for Aluminum alloys is frequently restricted to the specific operations employed to increase strength and hardness for wrought and cast alloys. These usually are referred to as the "heat-treatable" alloys to distinguish them from those alloys in which no significant strengthening can be achieved by heating and cooling [1].

The precipitation-hardening process generally involves the following three basic steps:

- ❖ Solution heat treatment, or homogenization, is the first step where the alloy is heated between the solvus and solidus temperatures and soaked until all of the soluble phases are dissolved and a homogeneous solid-solution structure is produced.
- ❖ Quenching is the second step where the solid solution is rapidly cooled to a lower temperature, usually room temperature. This forms the formulation of a supersaturated solid solution (SSSS) since the solubility of one or more alloying elements in aluminum decreases with decreasing temperature.

- ❖ The final step in the precipitation hardening process is aging that allows controlled decomposition of the supersaturated solid solution (SSSS) and the formation of strengthening precipitates [2].

Ageing of the quenched alloy at room temperature is known as natural ageing while at elevated temperatures is known as artificial ageing. Precipitation in solid solution occurs when the solubility of solute decreases with decreasing temperature. The precipitate of the second phase should be coherent in nature. The object of age hardening is to create in a heat-treated alloy a dense of fine dispersions of precipitated particles in a matrix of deformable metal. The precipitate particles act as obstacles to dislocation motion and thereby strengthen the heat-treated alloy [3].

Aluminum recycling has a number of key environmental and economic benefits. Compared to other high volume materials, aluminum production has one of the largest energy differences between primary and secondary production: 186 MJ/kg for primary compared to 10–20 MJ/kg for secondary [4].

Aluminum has physical characteristics that make its recycling economically attractive. A primary incentive for recycling metals is that the process used to produce a given mass from recycled scrap consumes less energy than producing the same mass from virgin ore. It is estimated that to produce a given mass of aluminum from recycled scrap requires only 5% of the energy necessary to produce the same mass from virgin ore [5].

The key benefit of recycling is that it reduces the amount of waste that needs to be buried or burned. In the case of aluminum, there is also another advantage. If old soda

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cans were simply buried, new cans would have to be made from new aluminum that would have to come from aluminum ore, Therefore, recycling aluminum has an economic advantage as well as an environmental one. Not all materials are economically advantageous to recycle. Plastic, for example, is often cheaper to produce from raw materials than it is to recycle. So, while plastic is endlessly recyclable, it is often burned or simply buried because it is not cost-effective to recycle. Other constraints also make materials such as green glass less desirable to recycle. It is not that the glass cannot be endlessly recycled, it is because the color of glass cannot be changed once it is green, it will be green forever[6].

One way of classifying scrap is to distinguish it according to its source; from the aluminum processing (new scrap), and scrap from products after their use (old scrap).

New scrap is generated during the initial manufacturing processes. All secondary aluminum residues are treated by refiners or remelters. The composition of new scrap is well known and in principle, new scrap does not need any pretreatment process before it is remelted.

Old scrap is collected after a consumer cycle, either separately or mixed, and it is often contaminated to a certain degree, depending highly on its origin and collection systems[7].

Current research aims to exploit and take advantage of waste in the manufacture of wire transfer of electrical energy using carbonated beverages cans and scrap wire

2. Alloy B (40% Carbonated beverages cans– 60% Scrap wire damaged-Zr).
3. Alloy C (40% Carbonated beverages cans– 60% Scrap wire damaged–Zr-B).

TABLE 2.1 WEIGHTING RATIOS OF THE ALLOY USED IN RESEARCH.

Composition Alloy	C.B.C wt. %	S.W.D wt. %	Zr wt. %	B wt. %
A	40	60	–	–
B	40	60	0.12	–
C	40	60	0.12	3

C.B.C: Carbonated Beverages Cans

S.W.D: Scrap Wire Damaged

A different heat treatment of samples included:

- Homogenizing treatment (500°C) and holding time (5hr.).
- Solution heat treatment (500°C) and holding time (1hr.).
- Artificial ageing at isothermal ageing temperature (180°C) and different times (1-5-10-20-30-50 hr.) after solution treatment.

This work also included electrical conductivity test, which was conducted simultaneously with heat treatments.

TABLE 2.2 THE CHEMICAL ANALYSIS OF ALLOYS.

Compo. Alloy	Si%	Cu%	Fe%	Mg%	Mn %	Ti%	Cr%	Zn%	Ni%	Pb%	V%	B%	Sn%	Zr%	Al%
A	0.185	0.125	0.411	1.14	0.581	0.011	0.014	0.043	0.004	0.008	0.007	0.0024	0.001	0.0016	rem.
B	0.136	0.070	0.313	0.620	0.342	0.007	0.010	0.036	0.003	0.004	0.005	0.0028	0.001	0.1011	rem.
C	0.130	0.51	0.304	0.352	0.278	0.002	0.007	0.020	0.001	0.002	0.002	0.0246	0.001	0.0488	rem.

damaged as a basic material for the production of

Quantities of empty soft drinks cans and scrap wire

alloys. In addition to study the effect of artificial aging treatment on electrical conductivity of the alloys.

2. EXPERIMENTAL

This section deals with melting and casting operations and the preparation of test samples of the alloy used, which include:

1. Alloy A (40% Carbonated beverages cans– 60% Scrap wire damaged).

damaged were prepared to be and cleaned by washing and dried and then weighing by the corresponding quantities of alloying elements to get the required percentages weighted. For melting the components of alloys an electric furnace was used, type (MARIO DIMAIO-20122 MILANO No.5332 - Italy) works in the field (0-1350 °C). The protection of some of the added elements of molten (Zr, B) packaging the aluminum foil before the addition of a guarantee of entry molten and

Immersed it by contact with oxygen. The process included a smelting and casting the following steps:

1. melting quantities of carbonated beverages cans alternately in graphite crucibles capacity (1kg) and then remove the slag resulting from the smelting process, where the cleaner has been added slag (CaCO₃) and repellent gases before casting process few minutes.
2. Casting molten output of the cans after the removal of slag in a metal mold was preheated to a temperature of (200-300 °C) and then is cast out of the mold and cooled to be weighing a sensitive balance and according to the required percentage weighted.
3. Melting scrap wire damaged alternately by weighted percentage and after the completing of the smelting process is added by a cast resulting from cans, then mix of molten and move it by ceramic rod to ensure melting molten and homogeneity.
4. Add zirconium for molten consisting of (carbonated beverages cans - scrap wire damaged) with the continued move of molten to ensure the spread of zirconium atoms and get homogenization for molten, and repeated the same process for the boron powder.
5. Continuing mixing of molten for up to five minutes to ensure complete melting.
6. Complete the casting process very rapidly in metal molds that have been pre-heated to temperatures of up to (200-300°C) to avoid solidification of molten quickly when touching the wall of the mold and get rid of the cold casting defects.

2.1 Homogenizing Treatment:

Conducted homogenizing treatment to get rid of whimsical formative semi dissolved and rich impurities deposited on the border crystalline, conducts such treatment develop castings inside a container filled with powder alumina to reduce oxidation and developed the container in turn electric oven works in temperatures from (0-1200 °C), Then samples were cooled inside the oven slow cooling to room temperature.

TABLE 2.3 HOMOGENIZING TREATMENT CONDITIONS FOR ELECTRICAL CONDUCTIVITY SAMPLES.

Alloy Code	Condition
A ₁ ,B ₁ ,C ₁	Homogenizing at 500°C for 5hr. + R.T

R.T: Room Temperature.

2.2 Solution heat treatment:

After homogenizing treatment was conducted solution heat treatment samples electrical conductivity by placing the samples in the same furnace used for the treatment of homogenizing that was used with furnace device calibration temperature type (YANGMING-MODEL XMTA-6311).This treatment included developing samples within furnace and heating to a temperature of (500 °C) while keeping the samples at this temperature for a period of (1hr). then the samples were quickly put out in cold water.

TABLE 2.4 SOLUTION HEAT TREATMENT CONDITIONS AND QUENCHING FOR THE SAMPLES ELECTRICAL CONDUCTIVITY.

Alloy Code	Condition
A ₂ ,B ₂ ,C ₂	S.H.T at 500°C for 1hr. + W.Q

S.H.T = Solution Heat Treatment.

W.Q = Water Quenching.

2.3 Artificial Aging treatment:

Conducted artificial aging treatment of samples (A, B, C) at a constant temperature (180°C) included:

1. Solution heat treatment conducted at temperature (500 °C) and the holding time is (1hr.).
2. Quenching of the samples with cold water as quickly as possible.
3. Samples heating at a temperature (180°C) and different holding (1, 5, 10, 20, 30, 50 hr.).

TABLE 2.5 ARTIFICIAL AGING TREATMENT CONDITIONS FOR

SAMPLES ELECTRICAL CONDUCTIVITY FOR DIFFERENT TIMES.

Alloy Code	Condition
A ₃ ,B ₃ ,C ₃	Homog. at 500 °C for 5hr. + R.T +S.H.T at 500°C for 1hr. + W.Q + Aging at 180°C for 1hr.
A ₄ ,B ₄ ,C ₄	Homog. at 500 °C for 5hr. + R.T +S.H.T at 500°C for 1hr. + W.Q + Aging at 180°C for 5hr.
A ₅ ,B ₅ ,C ₅	Homog. at 500 °C for 5hr. + R.T +S.H.T at 500°C for 1hr. + W.Q + Aging at 180°C for 10hr.
A ₆ ,B ₆ ,C ₆	Homog. at 500 °C for 5hr. + R.T +S.H.T at 500°C for 1hr. + W.Q + Aging at 180°C for 20hr.
A ₇ ,B ₇ ,C ₇	Homog. at 500 °C for 5hr. + R.T +S.H.T at 500°C for 1hr. + W.Q + Aging at 180°C for 30hr.
A ₈ ,B ₈ ,C ₈	Homog. at 500 °C for 5hr. + R.T +S.H.T at 500°C for 1hr. + W.Q + Aging at 180°C for 50hr.

Fig. 2.1 Electrical Conductivity device

Homog: Homogenization

2.4 Electrical conductivity test:

This test was conducted in the company in the general company for examination and rehabilitation engineering - Baghdad using a device type (SIGMASCOPE® SMP 10) as shown in Fig 2.1 which measures the electrical conductivity using the eddy current method according to (ASTM E 1004 and DIN EN 2004-1.) where used samples in the form of discs with a diameter (35 mm) and thickness (10 mm) for all alloys used in this research before and after conditions of transactions thermal, and considered this test indicative of changes in the physical and mechanical properties installation and the microstructure, the measured electrical conductivity is expressed as a percentage of the International Annealed Copper Standard (IACS%), were performed all conductivity tests at room temperature. The test instrument was calibrated using copper standards, prior to commencement as well as during the conductivity measurements, has been drawing the relationship between the values of electrical conductivity and time for different conditions through which alloys to know the behavior of alloys by different thermal transactions. In addition, every point on the chart represents the relationship between conductivity - time rate for three readings or more to different regions of the sample and from both sides of the sample. The figure (2.1) shows the electrical conductivity device.

3. RESULTS

3.1 Electrical conductivity

Table 3.1 represents the electrical conductivity readings for the samples where electrical conductivity was measured for the samples before and after conduct heat treatment and periodically as a measure of the changes taking place and found that the alloy (C) has the highest electrical conductivity compared with other alloys (A,B).

TABLE 3.1 ELECTRICAL CONDUCTIVITY OF THE SAMPLES ALLOYS.



A	Code name	A	A1	A2	A3	A4	A5	A6	A7	A8
	condition	as cast	H	H+S	1hr.	5hr.	10hr.	20hr.	30hr.	50hr.
	IACS%	32	34.5	39.1	41.2	37.7	39.5	41.6	40.5	41.3
B	Code name	B	B1	B2	B3	B4	B5	B6	B7	B8
	condition	as cast	H	H+S	1hr.	5hr.	10hr.	20hr.	30hr.	50hr.
	IACS%	40.8	43.7	42.3	44.6	44.9	44.5	44.1	42.9	42.6
C	Code name	C	C1	C2	C3	C4	C5	C6	C7	C8
	condition	as cast	H	H+S	1hr.	5hr.	10hr.	20hr.	30hr.	50hr.
	IACS%	45.8	49.8	49.4	49.2	48.5	48.8	50.2	49.9	49.2

H + S = Homogenization + Solution Heat Treatment.

The figures (3.1),(3.2),(3.3) shows effect of aging time on electrical conductivity for the alloys (A),(B),(C) at temperature (180°C) and for different times.

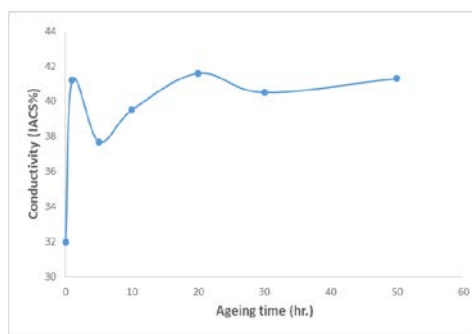


Fig. 3.1 Effect of aging time on electrical conductivity for the alloy (A) at temperature (180°C) for different times.

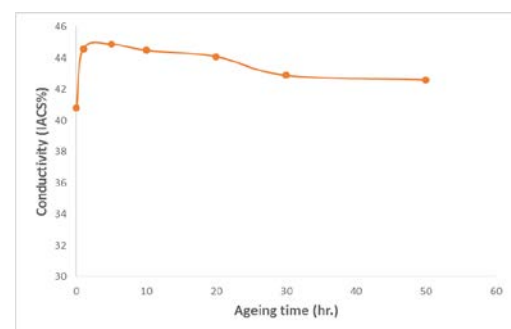


Fig. 3.2 Effect of aging time on electrical conductivity for the alloy (B) at temperature (180°C) for different times.

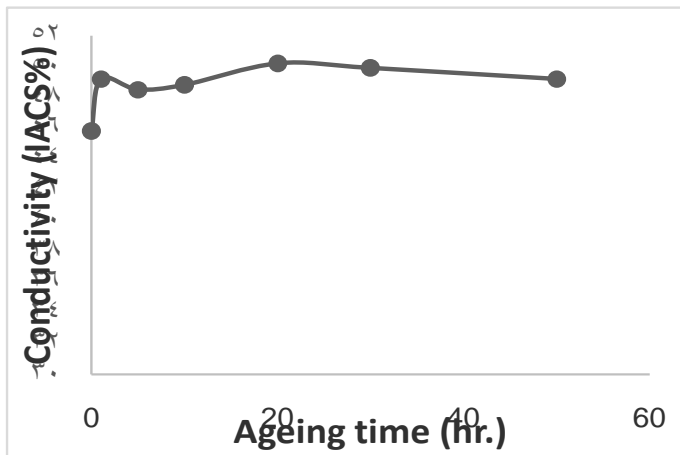


Fig. 3.3 Effect of aging time on electrical conductivity for the alloy (C) at temperature (180°C) for different times.

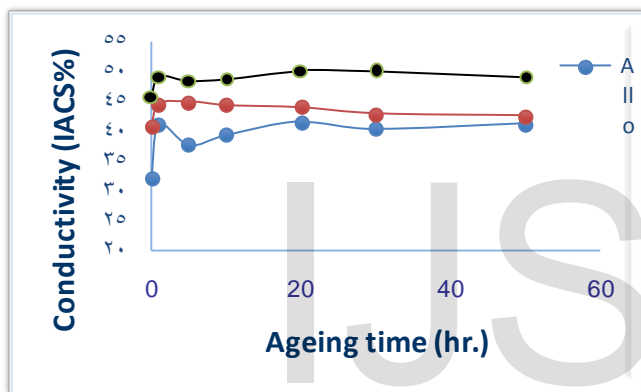


Fig. 3.4 Effect of aging time on electrical conductivity for the Alloys (A, B, C) at temperature (180°C) for different times.

4. DISCUSSION

4.1 Effect of homogenizing treatment on the electrical conductivity

Fig. 3.5 shows values of the electrical conductivity of the alloys (A,B,C) after a homogenizing treatment temperature (500°C) and the holding time (5 hr.) and we note that the alloy (C) has the highest conductivity, where the values of conductivity (34.5, 43.7, 49.8 IACS%) of the alloy (A,B,C), respectively. The ratio of improvement in the electrical conductivity of the alloy (C) after a homogenizing treatment compared with alloy (as cast) is (8.7 %), and alloy (B) compared with alloy (as cast) is (7.1 %), either alloy (A) was the ratio improvement in the electrical conductivity is (7.8 %) compared with the electrical conductivity of the alloy (as cast), either the ratio of improvement in the electrical conductivity of the alloy (C) compared with alloys (A,

B) is (44.3 %, 13.9 %) respectively, this is due to the fact that the electrical conductivity of the alloy monotonously increases with increasing homogenization temperature and time [8]. Most aluminum alloys are typically subjected to a homogenization heat treatment after casting. The primary goals of this treatment is to eliminate the consequences of micro segregation, reduce Mn in solid solution and obtain desirable particle size distributions, including fine dispersions and coarser constituents, these particles and dispersions have a strong influence on the alloy, and especially the

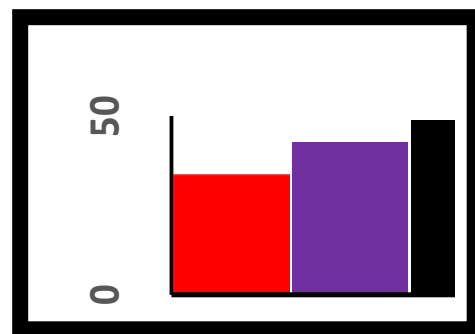


Fig. 3.5 Electrical conductivity for the alloys (A, B, C) when homogenizing treatment at a temperature (500 °C) and time (5hr.).

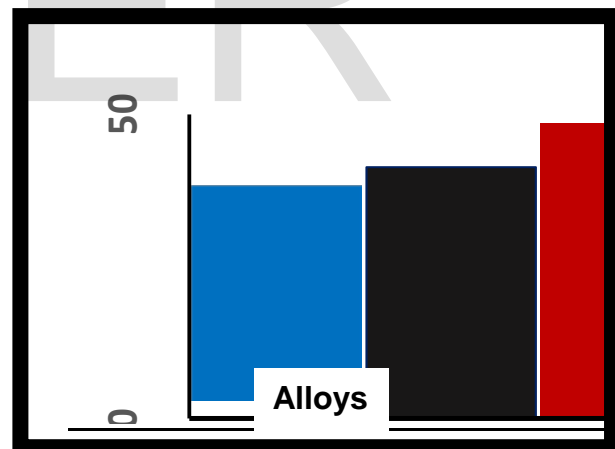


Fig. 3.6 Electrical conductivity for the alloys (A, B, C) when solution treatment at a temperature (500 °C) and time (1 hr.).

Recrystallization kinetics, texture development, grain size and mechanical properties of the alloy. This is why the homogenization procedure is important with regard to the control of the microstructure evolution [9,10,11,12,13]. They found that the conductivity reached a maximum at around 500-530 °C due to dissolution of dispersions with the increased solubility for Mn in solid

solution. But when the temperature was increased to 600 °C the conductivity increased even more due to growth of constituent particles [9]. The depletion of the matrix solid solubility decreases the ability of electron scattering in the alloy, resulting in the electrical conductivity increased [8]. The essential explanation for the different values of the electrical conductivity of the alloy through homogenizing treatment pointed out by the researcher [14]. Depending on Mathiessen theory to calculate the electrical resistance of the alloy as follows:

$$\rho = \rho_0 + \Delta\rho_s + \Delta\rho_p + \Delta\rho_v + \Delta\rho_d + \Delta\rho_g$$

Where:

$\Delta\rho_s$ = electrical resistance caused by the solid soluble atoms.

$\Delta\rho_p$ = electrical resistance caused by the precipitated phase.

$\Delta\rho_v$ = electrical resistance caused by the vacancy.

$\Delta\rho_g$ & $\Delta\rho_d$ = electrical resistance caused by the grain boundaries and dislocations, respectively.

Many researches [15, 16, 17] have pointed out that the most influencing factor for electrical resistance is $\Delta\rho_s$, followed by $\Delta\rho_p$, $\Delta\rho_g$, $\Delta\rho_v$ and $\Delta\rho_d$. This is because the scattered ability to electron caused by the solute atoms that distort the aluminum matrix lattice is much greater than that caused by others, such as the precipitate phases. In the condition of direct chill casting, most of Mg, Mn, Sc and Zr elements are solution in the aluminum matrix, which raises $\Delta\rho_s$, so the conductivity of the alloy is very low. During homogenization, supersaturated solid solution is decomposed and $Al_3(Sc, Zr)$ and Al_6Mn particles precipitated. Thus, the solid solution depletes and $\Delta\rho_s$ greatly decreases. At the same time, the precipitation of $Al_3(Sc, Zr)$ and Al_6Mn particles causes additional scattering and gives the increment of the electrical resistance $\Delta\rho_p$, but in the whole, the electrical conductivity of the alloy will increase along with the precipitation of $Al_3(Sc, Zr)$ and Al_6Mn . And the more the precipitates, the greater the electrical conductivity of the alloy.

4.2 Effect of artificial aging treatment on electrical conductivity

Fig. 3.4 effect of aging time on the electrical conductivity of the alloy (A, B, C) at a temperature (180°C) and for different times, and the note from the figure that the electrical conductivity of the alloy (C) is the highest compared with those of other alloys (A, B), where the values of electrical conductivity are (41.6, 44.9, 50.2 IACS %) of the alloys (A, B, C) respectively. The ratio of improvement in the conductivity of the alloy (A) is (30%) compared with the electrical conductivity of the alloy (A) at aging time (20 hr.). The behavior shown by

alloy (A,B,C) through the process of aging artificial temperature (180°C) shown in Fig. 3.4 where we note an increase in the electrical conductivity of the alloy followed by stabilization in the values of conductivity, showing the alloy (A) increase in conductivity which increasing by (28.7%) after (1hr.) of aging and conductivity values begin to this alloy decreasing after the passage of (5hr.) of aging to then begin to rise and stabilize at (10 hr.).

The behavior of alloy in terms of increased conductivity because of electrical conductivity increases with increasing aging time. The reason of the increase in electrical conductivity is thought to be the purification of the matrix by means of segregation of the solute atoms and formation of semi-coherent metastable phase. As the rate of precipitation is accelerated, the foreign atoms that act as scattering centers of electrons segregate from the aluminum matrix at an enhanced rate. Equilibrium precipitates are larger particles and increase in size as aging proceeds, thus minimizing their scattering effect [18]. Studies in this field that there are two opposite effects which contribute to the variations in electrical conductivity. The annihilation of vacancies during the recovery and the decrease of dislocation density during the recrystallization increase conductivity. On the other hand, the dissolution of soluble precipitate phases (i.e. Mg removing to solution) decreases conductivity [19,20].

While the alloy (B) shows an increase in the conductivity of which increasing by (9.3 %) after (1 hr.) of aging to stabilize after the conductivity values of this alloy, the difference in electrical conductivity between the as-cast and maximum value is 2.3 MS m⁻¹ (4.1 IACS%) at aging temperature (180 °C), while other researchers pointed [17] that difference in electrical conductivity between the as-cast and maximum value for Al-0.1%Zr at aging temperature (425 - 450°C) is 3.6 ± 0.1 MS m⁻¹ (6.1 IACS %).

The ratio of improvement in the electrical conductivity of the alloy (B) at aging time (5 hr.) is (10 %) compared with electrical conductivity of the alloys (B).

The effect of presence zirconium in the alloy (B), a refers to the research results reached by the Willey's divided into two groups the first one is the influence of the presence of zirconium in the solid solution, which causes a significant decrease of aluminum's resistivity, and the other is its presence in the precipitates (intermetallic phase Al_3Zr). According to Willey, the Zr influence in the solid solution equals 17 nm/% mass, and in the precipitates – only 0.4nm/% mass [29].

The role played by the (Zr) through its presence in a solid solution (Al_3Zr) is to reduce the electrical resistance, which results in an increase in the electrical conductivity of the alloy.

Fig. 3.4 shows that the alloy (C) shows an increase in conductivity which increases by (7.4%) during the aging time (1hr.) to stabilize after the electrical conductivity with increasing aging time, from other hand the ratio of improvement in the conductivity of the alloy (C₆) is (9.6%) compared with the electrical conductivity of the alloy (C) at aging time (20 hr.).

That alloy (C₆) has to the highest conductivity (50.2 IACS %) at the time of aging (20 hr.) is attributable to the role of boron in increasing the electrical conductivity of the alloy. Boron treatment is widely used to remove transition metals Ti, V and Zr for electrical conductive grade (Al), addition of (B) in (Al) melts significantly decreases these impurities (as solute) to several parts per million (ppm) even when the original concentrations are already low, (B) can combine with even trace amounts of transition elements to form insoluble boride compounds thus lowering the transition metal impurity content in the metal. The borides can then be separated by precipitation. While this process is particularly effective for removing Ti, V and Zr, it has substantially no effect on the removal of other common impurities such as Fe, Si and Cu [22]. Al-B alloy has primarily two stable phases as (AlB₁₂) and (AlB₂), AlB₂ has hexagonal closed packed crystal structure, whereas (AlB₁₂) has tetragonal crystal structure [23].

Boron has been added by (3%) to alloy (B) to produce alloy (C) for the purpose of improving the electrical conductivity through the combination of boron with the trace amounts of transition elements (V, Ti, Cr, Zr) to form insoluble compounds, note that the maximum ability for soluble boron in aluminum is (0.022%) [24]. And by noting table 2.2 which shows the chemical analysis of alloys, we find lower ratios weighted transition elements (V, Ti, Cr, Zr) when adding boron to the alloy (B). The process has been found to be useful in treating commercial (Al) of a purity of (99.4%) and higher [25]. This is different to what researcher reached where boron was added to alloy (B) containing commercial aluminum of a purity is less than (99.4%).

The reactions depend upon diffusion of the impurities in the aluminum melt and the availability of boron/aluminum borides. It has been reported that these reactions of boron with transition metals are fast enough that 70% of increase in electrical conductivity is achieved in the first couple of minutes. Further increase in electrical conductivity is quite slow and takes more than two hours, i.e. after the heavy boride particles settle at the bottom of furnace. Studies have shown that solution thermodynamics and the detailed reaction mechanisms of the borides formed in aluminum melts are not well-understood [26].

5. CONCLUSIONS

1. The use of carbonated beverage cans and scrap wire dilapidated as a basic material for the production of alloys.
2. For achieving these purposes, the best use of available resources has been the adoption of the principle of (recycling) for reaching the optimum alloy for use in the manufacture of electric power transmission wires.
3. Adding two (Zr) and (B) element pursuant to a significant leap in improving the physical properties of the alloy.
4. The main use of Al-B master alloys is to improve the electrical conductivity.
5. The ratio of improvement in the electrical conductivity for Alloy (C) is (44.3 %) compared with (A) and (13.9 %) compared with alloy (B) when conducting homogenizing treatment at temperature (500 °C) and time (5 hr.).
6. The study proved that it is possible to add boron to commercial aluminum with least purity (99.4%) and this is different to what reached by other researchers.
7. The study proved that the addition boron contributed to improving the electrical conductivity of the commercial aluminum by combining with trace amounts of transition elements (Ti, V & Zr) to form insoluble boride compounds.
8. The ratio of improvement in the conductivity of the alloy (A₆) is (30%) compared with the electrical conductivity of the alloy (A) at aging time (20 hr.), either ratio of improvement in the electrical conductivity of the alloy (B₄) at aging time (5 hr.) is (10 %) compared with electrical conductivity of the alloys (B), and the ratio of improvement in the conductivity of the alloy (C₆) is (9.6%) compared with the electrical conductivity of the alloy (C) at aging time (20 hr.).
9. Showed artificial aging treatment at a temperature (180 C°) and for different times of improvement in electrical conductivity values of the alloy (C₆) compared with the electrical conductivity obtained after casting, where the ratio of improvement of the alloy (C₆) is (9.6 %) compared with (C), while the ratio of improvement in the electrical conductivity of the alloy (C₆) is (56.8 %) compared with the electrical conductivity of the alloy base (A).

10. Showed artificial aging treatment conducted at temperature (180 °C) and different times improvement in the values of electrical conductivity of the alloys (A,B,C) compared with the values of the electrical conductivity of the alloy as is cast.

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