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Use of waste for the manufacture of Electric Power Transmission Wires

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ABSTRACT

Aluminum and its alloys considered one of the most important engineering materials used in the industry is widely as the main material for overhead power wires because of its good electrical conductivity and lightweight, where its uses in increased steadily recently the urgent need for products and low density suit technological progress, due to the large increase in the prices of metals used in the engineering industry during the last two decades has become there is an urgent need to obtain engineering materials from (waste) and in particular that contain aluminum and its alloys. The current study conducted for the first time in Iraq, where it has been exploited waste represented soft drinks cans and scrap electric wires damaged and recycled to obtain alloy optimal standard specifications at the lowest cost and utilization in the manufacture of wire and used in power transmission lines. Adopted the current study Use Artificial Ageing treatment to improve the performance of the alloy base (A) and to evaluate the performance of the alloy (A) conducted several tests, including tests (hardness - electrical conductivity - tensile - optical microscopy imaging).

Keywords: *soft drink cans, scrap wire damaged*, *electrical conductivity*, *hardness*, *tensile*, *Artificial Ageing.*

1. INTRODUCTION

The requirements of the human and diversity as a result of economic and social developments and on the track appeared lifestyles new contributed to increasing the quantity and quality of waste generated daily has become an urgent need to need to adopt scientific methods in waste management and the development of radical solutions to them through a focus on reducing the amount of waste and handled in a manner sound.

So to achieve the production of environment-friendly have been taken approach (waste recycling) mainly optimization in improving the physical and mechanical properties of the electric power transmission wires.

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 [1].

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 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 .[2] 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, Another way to classify scrap sources is according to the products in which the metal was used before it became a waste. The main aluminum scrap sources in this sense are vehicles, metal products for construction, cables and wires, electrical and electronic equipment and packaging [3]. All aluminum products can be recycled after use. Every two out of three aluminum cans produce being the recycling process either at local recycling centers, community drop-off sites, recycling bins, Aluminum cans from these sources are then gathered at large scrap processing compounds, scrap aluminum is then transported to the scrap compounds where it is checked and sorted to determine its composition and value, If the scrap is of unknown quality, the scrap aluminum will first be passed through large magnets to remove any ferrous metal, Then they are condensed into briquettes or bales and ship off to aluminum companies for re-melting, depending upon the type of contamination present, the condensed cans will be shredded, crushed and stripped off their interior and external lacquer via a burning process, Then the shredded pieces of aluminum cans are loaded into melting furnaces, where the recycled metal is blended with new aluminum, The molten aluminum is then poured into ingots, the ingots are fed into rolling mills that reduce the thickness of the metal, the metal is then coiled and shipped to can manufacturers who produces can bodies and lids, they in turn deliver cans to beverage companies for filling, the new cans are then ready to return to store shelves in less than 60 days [4].

2. EXPERIMENTAL

This section deals with smelting and casting operations and the preparation of test samples Alloy (A) used in the current research, which comprise of (50%soft drink cans, 50%scrap wire damaged).

Table (2.1) includes a chemical analysis of alloy used in the current search (as cast)

Elem.	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	B	V	Zr	Al
% wt	0.195	0.418	0.122	0.588	1.12	0.016	0.004	0.050	0.013	0.002	0.008	0.001	Rem

Conducted several Heat transaction of the alloy (A) included:

- Homogenizing treatment (500C°) and duration (10hr).
- Solution heat treatment (500C°) and duration (1hr).
- Artificial Ageing at isothermal ageing temperature (175 Cº) and different times (1-5-10-20-30-50 hr.) after solution treatment.

This work also included the following tests:

- Electrical conductivity test, which was conducted simultaneously with heat treatments.
- Way Vickers hardness test (HV), which was conducted simultaneously with heat treatments.
- Tensile test.
- Examine the microscopic structure of the samples.

2.1 Alloy Preparation

Was prepared quantities of empty soft drinks cans and scrap wire damaged and cleaned by washed and dried and then weighing by the corresponding quantities decided to get the required percentages weighted. For melting the components of alloys were used electric ovenworks in the field (0-1350 C°).

The process of melting and casting Includes melting quantities of soft drinks cans back-to-back graphite crucibles capacity (1kg) and then remove the slag resulting from the smelting process, where the cleaner has been added slag (CaCo3) and repellent before casting process gases few minutes, After this is done casting molten output of the cans after the removal of slag in a metal mold was preheated to a temperature of (200-300 Cº) and then is cast out of the mold and cooled to be weighing a sensitive balance and according to the required percentage weighted and is Melting scrap wire damaged alternately by weighted percentage and after the complete of the smelting process is added by a cast resulting from cans where they are mix and move it by molten ceramic rod in order to avoid pollution of the molten Bay is the elements required to ensure melting and molten homogeneity. Finally made the casting process very rapidly in metal molds that have been pre-heated to temperatures of up to (200-300 Cº) to avoid solidification of molten quickly when touching the wall of the mold and get rid of the cold casting defects.

2.2 Homogenizing Treatment

Conducted treatment homogenizing 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 Cº), Then samples were cooled inside the oven slow cooling to room temperature, and the table (2.1) shows the homogenizing treatment conditions.

Table (2.2) shows homogenizing treatment conditions for samples hardness and electrical conductivity.

Alloy code	Condition
A_1	Homog. at (500 Cº) for (10hr) + R.T

Homg. = Homogenization.

R.T = Room Temperature.

2.3 Specimens Preparation

After the end of treatment homogenizing been cutting castings to samples in the form of tablets in diameter (30mm) and thickness (9mm), Then conducted the process of grinding of the samples for the purpose configured to operations of measuring hardness, electrical conductivity and examining the microstructure, and now the process of using paper grinding of carbide silicon with gradients (180-400-600-800-1000-1200-1500-2000-3000),), then the polishing process was conducted using a mechanical polishing device used in this process alumina powder, water, and after the end of each stage of the smoothing or polishing samples washed with distilled water and dried hot air stream.

2.4 Tensile Test Specimens

After finishing smelting and casting operations and homogenizing has been manufacturing tensile test specimens under standard (A 370 – 05 ASTM) and fig. (2.1) shows the dimensions of the test specimen tensile.

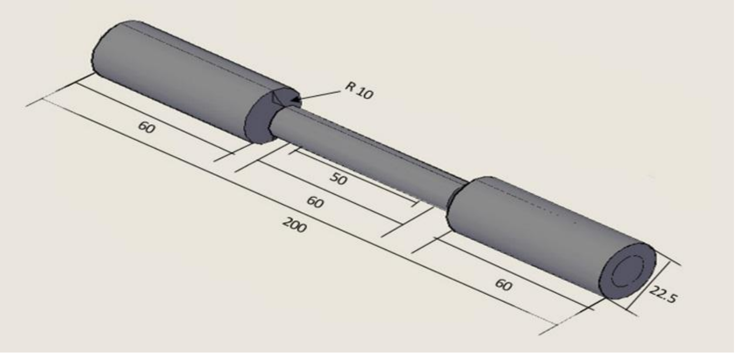

Fig. (2.1) Diagram of tensile specimen used in the tensile test.

2.5 Solution Heat Treatment

These include treatment develop samples within furnace and heating to a temperature of (500 C^o) while keeping the samples at this temperature for a period of (1hr), then the samples were put out with cold water and too quickly.

Table (2.3) shows Solution heat treatment conditions and quenching for the samples hardness and electrical conductivity.

Alloy Code	**Condition**
A_2	**S.H.T at (500 C^o) for (1hr) + W.Q**

S.H.T = Solution heat treatment.
W.Q = Water Quenching.

2.6 Artificial Aging

Conducted artificial aging treatment of samples at a constant temperature (175 C^o) where included:

- Solution heat treatment conducted at temperature (500 C^o) and the period of stay (1hr).
- Quenching of the samples with cold water and too quickly.
- Samples Heating at a temperature (175 C^o) and different times (1, 5, 10, 20, 30, 50 hr.).

Table (2.4) shows artificial aging treatment conditions for samples hardness and electrical conductivity for different times.

Alloy Code	Condition
A_3,A_4,A_5,A_6,A_7,A_8	S.H.T at (500 C^o) for (1hr) + W.Q + Aging at (175 C^o) for (1-5-10-20-30-50 hr.) respectively.

2.6 Hardness Test

Was this test to samples used in this research before and after conditions of transactions thermal and mechanical to be an indication of changes to holds in the mechanical properties and physical properties of samples, which were calculated (Vickers-Micro - hardness) for all samples used in the research using the device type **(DIGITAL DISPLAY MICROHARNESS TESTER – MODEL HVS – 1000, SERIAL NO. 0006)** and was load applied (200gm) and the download time (20 sec) each point represents schemes exist on the relationship between hardness - time rate for three or more readings to different regions of the sample.

2.7 Electrical Conductivity Test

Considered this test indicative of changes in the physical properties and mechanical has been conducting this test using a device type (SIGMASCOPE® SMP 10) by (Standard measurement according to ASTM E 1004 and DIN EN 2004-1.), the measured electrical conductivity is expressed as a percentage of the International Annealed Copper Standard (IACS%). In addition, represent every point on the charts the relationship between conductivity - time rate for three readings or more to different regions of the sample and from both sides of the sample.

3. RESULTS

3.1 Hardness

Fig. (3.1) the relationship between hardness and ageing time for the alloy (A) used in the current research through artificial aging treatment at a temperature (175C^o) where increasing hardness very quickly to reach (80.4 kg/mm^2) during the time of (5hr.) nearly, the appear hardness peak (85.6 kg/mm^2) to this alloy after (20hr.) of aging, Note that hardness of the alloy in the homogenized state (as homogenized) before the treatment solution and quenching is (67 kg /mm^2).

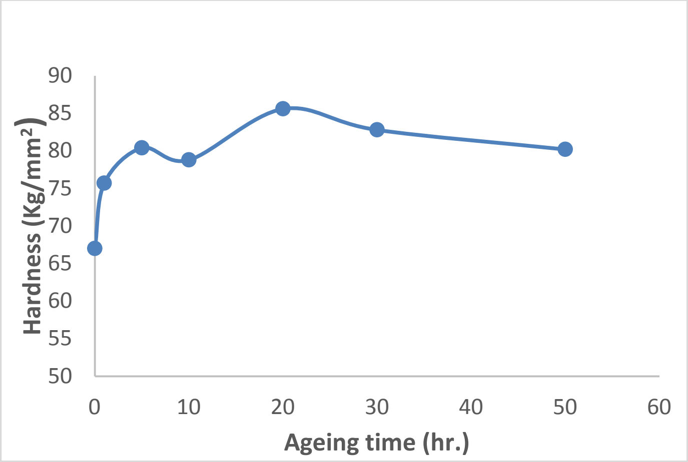

Fig. (3.1) shows the relationship between hardness and aging time at temperature (175 Cº) of the alloy (A)

3.2 Electrical conductivity

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 sample (**A$_6$**) has the highest electrical conductivity(40.4 IACS%) compared with other samples as shown in the table (3.1) Which represents the electrical conductivity readings for the samples.

Table (3.1) shows the electrical conductivity of the samples before and after conduct heat treatment.

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%	31	33.6	38.3	40	36.6	38.2	40.4	39.5	40

The following figure shows Effect of aging time on electrical conductivity for the alloy (A) at temperature (175C°) and for different times.

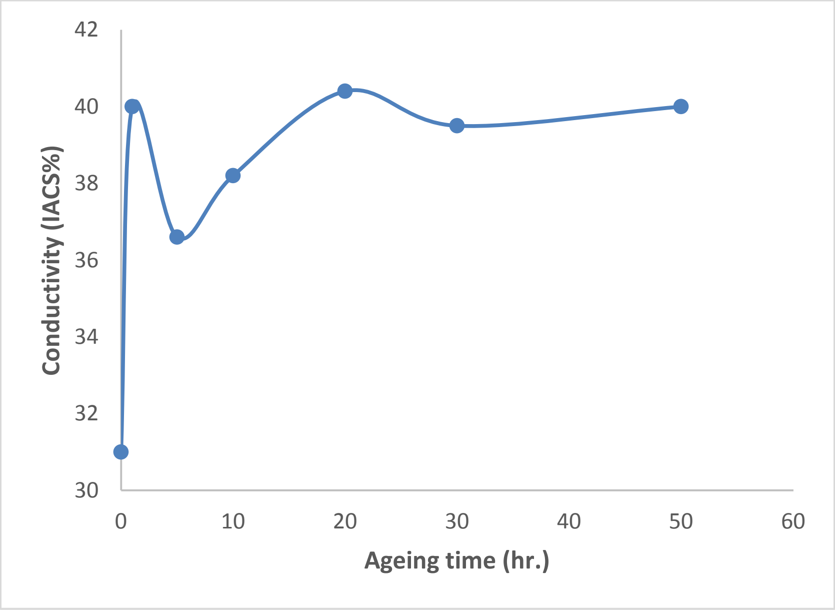

Fig. (3.2) shows Effect of aging time on electrical conductivity for the alloy (A) at temperature (175C°) and for different times.

3.3 Tensile Test

The table (3.2) shows values (tensile strength, yield strength, elongation) of the alloy (A) as cast.

Alloy code	condition	Tensile strength (Mpa)	Yield strength (Mpa)	Elongation (%)
A	As cast	165	69	17.5

The table (3.3) shows values (tensile strength, yield strength, elongation) of the alloy (A) after an artificial aging treatment at a temperature of aging (175 Cº).

Alloy code	Conduction	Tensile strength(Mpa)	Yield strength(Mpa)	Elongation (%)
A6	Homg. at (500 Cº) for (10hr) + R.T+S.H.T at (500 Cº) for (1hr.) +W.Q.+A.A.at (175 Cº) for (20hr.).	285	141	14

The table (3.4) shows the Mechanical and physical properties of alloy (A) after artificial aging treatment.

Alloy code	Electrical conductivity (IACS %)	Tensile Strength (Mpa)	Yield strength (Mpa)	Hardness Kg/mm^2	Elongation (%)
A6	40.4	285	141	85.6	14

3.4 Optical microscope imaging

Some of the samples was filmed before and after heat treatment conducting to examine the microstructure, where fig. (3.3) shows the microscopic structure of the alloy (A) after the Casting, While the fig. (3.4) shows the microscopic structure of the alloy itself after homogenizing treatment, either Fig. (3.5) shows the microscopic structure of the alloy (A) after conducting artificial aging treatment at a temperature (175 Cº) and aging time (20hr.).

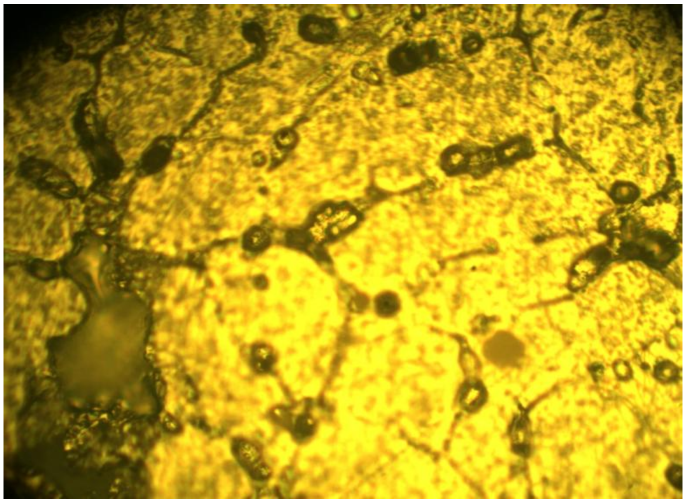

Fig (3.3) shows microstructure of alloy (A) after the Casting (base alloy), 4ooX

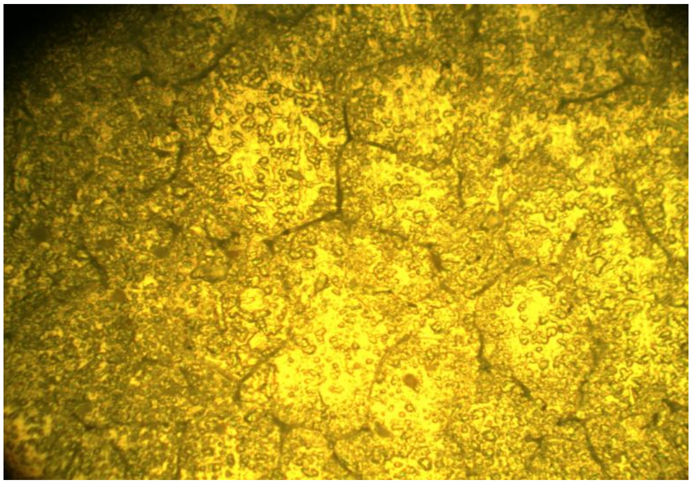

Fig (3.4) shows microstructure of alloy (A1) after homogenizing treatment, 4ooX.

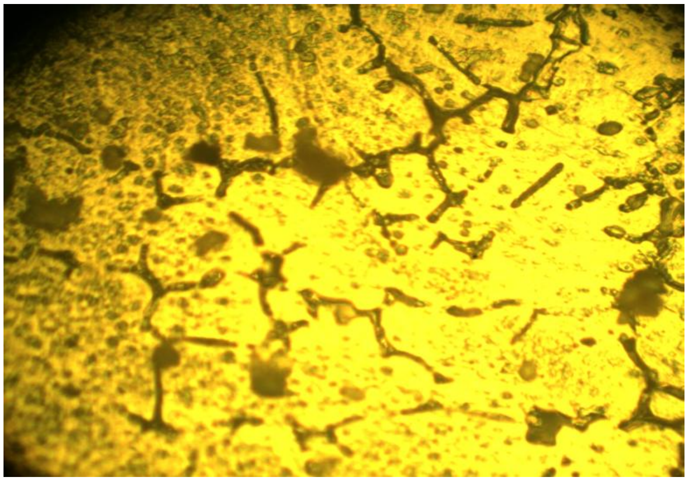

Fig (3.5) shows microstructure of alloy (A6) after artificial aging treatment at a temperature of (175 C°) and aging time (20hr.), 4ooX.

4. DISCUSSION

4.1 Effect of artificial aging on hardness

The behavior shown by alloys (A) through the process of aging artificial temperature (175C$^{\circ}$) shown in fig. (3.1) and from the note for the hardening fast followed decrease in the values of hardness, where they appear alloy (A) a rapid increase in the value of hardness which is getting by (13%) approximately during the first hour of aging, and the proportion of (20%) approximately during the first five hours of aging.

Studies show the emergence of peak hardness secondary after longest aging times, has been reaching the peak due to the use long aging times reach (50hr.) as shown in fig. (3.1) i.e. obtain of seconds hardness phase where you start hardness to rise again until reaching the peak hardness to start after decreasing due to over ageing condition **[5].**

Fig. (3.1) shows the emergence improvement ratio in peak the hardness of this alloy compared with the hardness obtained after solution treatment and quenching, where the ratio of improvement of the alloy (A$_6$) compared with (A$_1$) (28%).

The explanation is essential for continued rapid hardening for alloys was introduced by **[5],** Where it was proposed that rapid hardening related partly rapid Docking for quenching gaps and collected to form rings dislocations, and entirely to reaction these dislocations with atoms dissolved causing blocking early dislocations that work gaps pools and thus the number of quenching gaps will be reduced significantly in the phase matrix.

The contribution to hardness depends on the coherency of the precipitate with the matrix, size and distribution of the precipitates and the proximity of the particles. In general, the increase in hardness depends on the variation in the stress fields in the vicinity of the precipitate. After quenching from solid solution, the alloy contains regions of solute segregation. This clustering produces local strain, which results in an increase in hardness **[6]**.

The increase the speed of hardening return a primarily to provide high temperature (i.e. greater driving force for diffusion) and thus to increase the hardness values, as the aging process depends on Process of nucleation and growth, which in turn affected by temperature, Therefore, the choice of optimal aging temperature for any alloy depends on many factors, including the chemical composition and the cooling rate and its ability to solidification and mechanical thermal transactions**[7] .**

Based on the foregoing, the researcher pointed **[8]** Aging trials between (150◦C) and (200◦C) showed that peak hardness values could be obtained after aging at (175 ◦C) for (8 hr.) As compared to the fast over aging at 200 ◦C and slow hardening at (150 ◦C) We can say that the optimal aging temperature for industrial use is ((175 ◦C).

4.2 Effect of artificial aging on electrical conductivity

Fig. (3.2) effect of aging time on the electrical conductivity of the alloy (A) at a temperature (175 °C) and for different times, and the note from the figure that the electrical conductivity of the sample (A6) is the highest compared with those of other samples, Where we note the emergence of a high improvement in the electrical conductivity of the alloy (A6) compared with the electrical conductivity obtained after casting,, where the percentage of improvement in the electrical conductivity (30%) of the alloy (A6) compared with the ingot (A).

The behavior of alloy in terms of increased conductivity because electrical conductivity increases with increasing ageing 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 ageing proceeds, thus minimizing their scattering effect **[6].**

The behavior shown by alloy (A) through the process of aging artificial temperature (175 °C) shown in fig.(3.2) 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 (29%) after (1 hr.) of aging and conductivity values begin to this alloy decreasing after the passage of (5 hr.) of aging to then begin to rise and stabilize at (10 hr.).

Studies in this field that there are two opposite effects 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 **[9 ,10].**

4.3 Effect of artificial aging treatment on the mechanical properties

Table (3.2) show tensile test results for alloy (A) as cast, while the table (3.3) shows the results of the test tensile after conducting the treatment of artificial aging at aging temperature (175 C°), where increased values tensile and yield strength of the alloy (A) was the ratio of improvement in tensile and yield strength for alloy (A_6) compared with the alloy (A) is (72.7%, 104%) respectively.

The essential explanation to increase the tensile strength and yield of the alloy after conduct artificial aging treatment compared with alloys in the cast condition (as cast) is due to the fact that quenched specimens consisted mainly of widely spaced dislocations which were pinned by solute cluster or GP zones which were formed during quenching **[11].**

Researcher pointed **[12]** the (5xxx) series alloys derive their strength from the solid solution strengthening due to magnesium. Other alloying elements such as chromium, manganese, and zirconium are added for the control of grain and sub grain structures, which also contribute to strengthening, The other hand, has pointed out the grain boundaries revealed two types of grain boundary precipitates:

- Large cuboidal Al6Mn precipitates.
- Small, Mn containing precipitates.

The large precipitates, which are present in all of the alloys, are used for control of sub grain and grain structures during alloy processing; the small Mn-containing precipitates result from the aging treatments and are not observed in the as-rolled and annealed alloys.

Thus, these precipitates can be considered is responsible for the increased strength of these alloys.

Foregoing can be said that there are two main factors that contribute to increased resistance of these alloys, the first contribution to strengthening is from both sub grain and grain boundaries which act as a point of blocking the movement of dislocations, and the second contribution is from dislocation networks where they accumulate these dislocations often slip levels at points disabling such as grain boundary and secondary phases, and these dislocations collected at disability produce inversely stressful or reaction works to resist another dislocations movement along the slip and slip direction.

4.4 Photo in Optical Microscope

Were photographed some samples of the alloy before conduct heat treatment any directly after the casting process (as cast) and after treatment of homogenizing and artificial aging, fig. (3.3) shows the microstructure of the alloy base (A) after the casting where the observed shape and particle size equal axes almost as well as the presence of precipitate on the grain boundary and in the form of black dots, either fig. (3.4) explains the microstructure of the alloy (A_1) after homogenizing treatment at temperature (500 C°) and time (10 hr.) which different from the alloy base (A) in the form and particle size and distribution where we note the disappearance of the black dots as a result of the treatment of homogenizing and to lead to dissolve some formative phases and rich impurities and precipitate on the grain boundary, Fig. (3.5) shows the microstructure of the alloy (A_6) after ageing at temperature (175 C°) and a time of aging (20 hr.) where observed some large black dots and precipitates on the grain boundary.

5. CONCLUSIONS

1. The current study is one of the recent studies prospects in Iraq**,** where the exploitation of waste from soft drinks cans and scrap wire shabby and use them in the

manufacture of wire for use in power transmission lines.

2. Mechanisms used to improve the performance of alloy was simple and inexpensive.
3. Showed artificial aging treatment at a temperature (175 Cº) and for different times of improvement in hardness values of the alloy (A6) compared with the hardness obtained after solution treatment and quenching, where the ratio of improvement of the alloy (A6) compared with (A1) (28%).
4. Showed the results of the test tensile after conducting the treatment of artificial aging at temperature (175 C°) Increase in values tensile and yield strength of the alloy (A) was the ratio of improvement in tensile and yield strength for alloy (A6) compared with the alloy (A) is (72.7%, 104%) respectively.
5. Showed artificial aging treatment at a temperature (175 Cº) and for different times of improvement in electrical conductivity values of the alloy (A6) compared with the electrical conductivity obtained after casting, where the ratio of improvement of the alloy (A6) compared with (A) (30%).

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