JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF MATERIAL SCIENCE AND ENGINEERING

CHAIR OF METALLURGICAL ENGINEERING

MASTER OF SCIENCE PROGRAMME IN METALLURGICAL ENGINEERING

IMPROVING PURITY AND CONDUCTIVITY OF SCRAP MELTED ALUMINUM CONDUCTOR BY USING PRE-MELT AND IN-MALT TECHNIQUE

A thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Metallurgical Engineering

By Ismail Kamil Worke

January, 2021

Jimma, Ethiopia

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By

Ismail Kamil Worke

Advisor Dr. Prabal Dasgupta

Co-advisor Dr. Olu Emmanuel Femi

January, 2021

Jimma, Ethiopia

Declaration

I. All activities mentioned in this research paper performed by Ismail Kamil Worke under super vision of Dr.prabal Dasgupta. The experimental part of this research was conducted in BMET Cable Industry in Department of quality control lab. This research is my own original work and has not been presented for a degree in any other university

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Candidate	Signature	Date

II. Supervisor(s): This research has been submitted for examination with my approval as a university supervisor

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As members of the examining board of MSc. thesis, we certify that we have read and evaluated the thesis prepared by **Ismail Kamil Worke**. We recommend that the thesis could be accepted as a partial fulfillment of the requirements for the Degree of Masters of Science in Metallurgical Engineering.

Name of the chairman	Signature	Date
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Name of External Examiner	Signature	Date
Dr. Georgies Mene	[signature]	27/11/2020
Name of Internal Examiner	Signature	Date
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Acknowledgement

First of all, thanks to our almighty Creator for his endless support throughout my whole life. Then I would like to thank BMET Cables industry, which offers a great opportunity to work in their company.

I would like to express my deepest gratitude to my **Principal advisor Dr. Prabal Dasgupta** [PhD**]** and for his unreserved advice, skillful and technical guidance and support, and cooperation extended with nice approach that I received throughout my thesis work, starting from proposal to the completion of my thesis. Without his advice the accomplishment of this thesis would have been impossible.

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My heart pulsates with the thrill for tendering gratitude to those persons who helped me in my research work till the completion of the project. The pleasant point of presenting a report is the opportunity to thank those who have contributed to build my knowledge

Last but not the least, I would like to extend my heartily thanks to all my family members for their strong advice and all round supports they provided me to complete the thesis in time.

All those who contributed in one-way or other to the successful realization of this study deserve deepest appreciation

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LIST OF ACRONYMS AND ABBREVIATIONS

IEC	International Electrical Commission
UTS	Ultimate Tensile Strength
S/mm	Siemens per millimeter
MPa	Mega Pascal
Gm	gram
MJ	Mega Joule
Kg	Kilo gram
IACS	International Annealed Copper Standard
DC	Direct Current
Mu	Actual mobility

Abstract

Aluminum recycling has a number of key environmental and economic benefits. With this energy and cost saving in mind, BMETcable industry now has target increasing its usage of secondary materials and its profit. However, the accumulation of impurities in this recycled materials stream may provide a significant compositional barrier to its goals. A number of studies and literature suggest that accumulation of unwanted elements are big problem for the case of aluminum, the list of problematic impurities is quite large, including but not limited to Si, Mg, Ni, Zn, Pb, Cr, Fe, Cu, V, and Mn. The removal of unwanted elements in the scrap stream is dictated by energy considerations of the melt process. Compared to many metals, it is challenging to remove tramp elements from aluminum. Therefore, with no simple thermodynamic solution, producer must identify strategies throughout the production process to migitate this elemental accumulation. This dissertation provides different methods of aluminum purity improving method in BMET Cables industry and took apart in improving purities of scrap melted aluminum conductor by using two stages that are pre-melt treatment such as hand sorting, magnetic separation, air separation and hot separation and in-melt treatment fluxing and refining methods are used

CHAPTER ONE

1 INTRODUCTION

1.1.Background

Aluminum recycling has a number of key environmental and economic benefits, compared to other high volume materials, aluminum production has one of largest energy difference between primary and secondary production: 186 MJ/kg for primary compared to 10–20 MJ/kg for secondary [1]. With energy and cost saving in mind, many producers now have targets of increasing their usage of secondary materials. However, the accumulation of impurities in this recycled material stream provides a significant, long-term compositional barrier [2]. A growing number of studies and literature suggests that accumulation of unwanted elements is a growing problem, in all recycled material stream. In the case of aluminum, the list of problematic impurities is quite large, including but not limited to Si, Mg, Ni, Zn, Pb, Cr, Fe, Cu, V, and Mn [4, 5]. In addition to those impurities some oxides may serve as inclusion and inhibit the flow of electron and hence reduce the electrical conductivity. Metal recycling is a metallurgical process and is therefore governed by the laws of thermodynamics. The removal of unwanted elements in the scrap stream is dictated by the energy consideration of the melt process. Compared to many metals, aluminum presents a high degree of difficulty in the removal of tramp elements. Therefore, with no simple thermodynamic solution, producers must identify strategies throughout the production process to mitigate this elemental accumulation. There are a variety of solution to deal with the negative impact on recycling due to accumulation of undesired elements, such as resents a trade-off between cost and improvement in scrap recycling potential [9]. The most commonly employed technology for impurity removal is gas fluxing, which involves the use of chlorine and argon injected into the aluminum melts through gas injection lances. Fluxing with an inert gas alone is completely ineffective for removing impurities and actually increased the non-metallic impurity levels of a melt due to splashing and the exposure of the metal to air [2]. The chlorine reacts with the alkali metals lithium, sodium, and calcium, and it also helps in achieving beneficial phase separation between the liquid metal and solid inclusions. In primary and mill products operations, chlorine additions are on the order of only a couple percent, the rest being an inert gas such as nitrogen or argon, but in secondary aluminum processing, the chlorine concentration can be as high 90% manly because chlorine is the most potent and economical reducant of magnesium [3].

1.1.1. Pre-melt technologies

While physical separation technologies can be applied to a wide range of scrap streams, they are typically used for scrap that has been shredded [9]. The majority of automotive scrap, for example, goes through some sort of shredding process before being sold to secondary re-melters. These automotive hulks will be a focus of many of the upgrading technologies as they make up a large portion of end-of-life recycled scraps [18]. Pre melt technology includes the following process.

1.1.2. Magnetic separation

Magnetic separation is a way to separate the non-ferrous and ferrous scrap components. As the scrap nears the magnets, the ferromagnetic portion mainly steel and some iron is attracted to the magnet and pulled out [18].

1.1.3. Air separation

The light weight component of the scrap will separate by this technology. In vertical air separation system, the recycled material stream is fed through a column with air pushing up ward, the heavy metals are collected at the bottom and the materials are pushed through various feeds further [18].

1.1.4. Color sorting (hand sorting)

Color sorting or hand sorting takes advantage of the color and weight difference between scraps to separate zinc, copper, brass, and stainless steel from aluminum in non-ferrous scrap stream. The most basic application of hand sorting a prevalent practice in countries with low labor costs [6].

1.1.5 Melt technologies

Once scrap materials enters the furnace, physical separation technologies can no longer be applied. Technologies aimed at removing impurities from the melt are quite prevalent.

Melting is a metallurgical process and is therefore governed by the laws of thermodynamic and the removal of unwanted elements in the scrap stream is dictated be energy consideration of the melt process. In the case of aluminum, the thermodynamic barrier to the removal of most elements is quite large. Selective melting, or sweating is often performed to separate contaminating metals that have not been removed by physical separation techniques, particularly when metal parts are welded together [17, 18, 19].

Products of the company AAC, AAAC, copper solid, copper flexible, fiber optics and all types of energy and telecom cables. Currently the company is covering 60% of energy cable needs of the country

Possible existing problems in the company

Parameters	Company product	IEC standard
Purity	98.0 % Al max	99.5% Al
Conductivity	32 S/m	35.67 S/m
Tensile strength	145-178Mpa	103-150 Mpa
Elongation	1-15 %	1-18 %

Table1.1 Shows Possible existing problems in the company

1.2. Justification of the study

Metal contains free electron but those free electrons are confined within the metal unless an electrical field is applied. Then free electron travel through the metal and connected conductor. Electron mobility is hampered if electron undergoes collision with impurities. That is why presence of impurities lowers the conductivity of a metal. As a matter of fact electrons are scattered by impurities atoms and as a result electrical conductivity of a metal is decreased. Conversely resistivity increases. Electrons are also scattered by phonons (lattice vibration) .As the temperature is raised lattice vibration is also increase resulting greater concentration of phonon. These phonons can scatter free electrons and hence the electrical conductivity is lowered. This present research study removing impurities from scrap melted aluminum conductor during melting and before melting in order to decrease resistance and to increase conductivity of the conductor.

1.3.Research Question / Hypothesis

Pre-melt technology and in-melt technology uses to remove impurities from scrap melted aluminum conductor and minimizations of impurities leads to increase electrical conductivity and to decrease electrical resistance.

1.4. Statement of the problem

Aluminum and aluminum alloy conductors are the preferred and dominant conductors in several areas of power transmission and distribution. The major areas dominated by aluminum and aluminum alloy conductors are non-insulated overhead power transmission, insulated overhead power transmission and non-overhead power distribution. But the quality of aluminum conductivity depends on its purity. According to IEC standard aluminum that has 99.5% of Al purity has highest conductivity which is 35.67 S/m or 62% of copper conductivity in ICAS but in BMET Cables industry highest aluminum rod conductivity recorded as 32 S /mm or 54% of copper conductivity in IACS. This is due to highest impurity content of aluminum conductor. This research was aimed to take apart in improving impurities of aluminum by pre-melt technology such as hand sorting, hot separation, magnetic separation and in-melt technology such as fluxing in order to increase its conductivity.

1.5. General Objective

Improving electrical and mechanical properties of scrap melted aluminum conductor by using different technique

1.6.1 Specific Objective

- Removing impurities from scrap melted aluminum conductor.
- Determining compositions of the sample.
- Measuring the electrical resistance and conductivity of the conductors.
- Determining tensile strength of the conductor.

CHAPTER TWO

2 LITERATURE REVIEW OF THE PROBLEM

The removal of unwanted elements in the scrap stream is dictated by the energy considerations of the melt process. Compared to many metals, aluminum presents a high degree of difficulty in the removal of tramp elements. Therefore, with no simple thermodynamic solution, producers must identify strategies throughout the production process to mitigate this elemental accumulation. There are a variety of solutions to deal with negative impact on recycling due to accumulation of undesired elements each resents a trade-off between cost and improvement in scrap recycling potential [9].

The most commonly employed technology for impurity removal is gas fluxing, which involves the use of chlorine and argon injected into the aluminum melts through gas injection lances. Fluxing with an inert gas alone is completely ineffective for removing impurities and actually increased the non-metallic impurity levels of a melt due to splashing and the exposure of the metal to air [2]. The chlorine reacts with the alkali metals lithium, sodium, and calcium, and it also helps in achieving beneficial phase separation between the liquid metal and solid inclusions. In primary and mill products operations, chlorine additions are on the order of only a couple percent, the rest being an inert gas such as nitrogen or argon, but in secondary aluminum processing, the chlorine concentration can be as high 90% manly because chlorine is the most potent and economical reducant of magnesium [3].

2.1. Salt fluxing

Nikajima etal.have analyzed the distribution tendency of allying element among gas, slag and metal phases in pyro metallurgical recycling process of aluminum. Steel, Copper, Lead, zinc, Magnesium, and Titanium by evaluating the quantitative removal limits of impurities thermodynamically taking into account all relevant parameters such as the total pressure, the activity coefficient of the target impurity, the temperature, the oxygen partial pressure, and the activity coefficient of product. In regard to aluminum recycling, their results show that Be, Ca, and Mg can be removed by oxidation and Cd, Hg, and Zn can be eliminated by evaporation, but the removal of the other 39 elements, including Cu, Si, Fe, and Mn is difficult since these have a strong tendency to remain in the melt phase. Many alloying elements are difficult to remove from aluminum products, including aluminum alloy scrap, because aluminum has a high ionization tendency and thermodynamic reactivity. Accordingly, when the oxidation method is employed for the removal of impurities from aluminum scrap, aluminum tends to be preferentially oxidation into the slag. While aluminum is known as a well recycled material in term of quantity, there is a risk of contamination by alloying elements in its recycling. Hence, avoiding the contamination by alloying elements is crucial for sustainable recycling of aluminum alloys.

Salt flux treatment of aluminum scrap is a technological option to remove alloying elements or to extract aluminum from aluminum products. Fluxes based on a mixture of molten salts are often utilized in the processing of molten aluminum. They are used in a passive role to protect the metal from oxidation and sometimes in an active role to remove the additive elements as impurities from molten aluminum. Fluxes are mainly blends of chloride and fluoride salts with additive to instill specific properties. Most fluxes are based on a mixture of NaCl and KCl. Aluminum recovery during remelting process of aluminum scrap from turning process and aluminum composite enhanced by use of NaCl-KCl based flux. Also, separation and recovery of aluminum alloys from aluminum dross was reported with utilization of BaCl2-NaCl-NaF flux. Salt flux is useful and convenient for effective aluminum remelting. A limited number of reports are available concerning impurity removal from aluminum by salt flux such as distribution of Mg and Zn between KCl-NaCl and KCl-NaCl-AlCl3 melt and molten Al. The most common technology aimed at removing impurities from the melt is simple fluxing. For the treatment of aluminum and its alloys, various molten-metal process steps are necessary in addition to melting and alloying. Historic practice, such as fluxing, de oxidation, degassing, and grain refining, are being used in addition to newer in-melt technologies, such as metal degassing, fluxing, and filtration. The term fluxing is used to represent all additive to, and treatment of, molten aluminum in which chemical compounds are used. These compound are usually inorganic and may perform several function, such as degassing, damaging, cleaning, and alloying. Fluxing also includes the treatment of inert or reactive gases to remove inclusions or gaseous impurities.

Fluxes are used to remove oxide build-up from furnace walls or to eliminate and or to reduce oxidation. While fluxes require energy, they are effective in lowering the aluminum content of the dross or mush, and the amount of aluminum that is skimmed from the furnace can be substantially reduced. Fluxing is when various compounds usually inorganic salts, chemicals, and gases are added to reduce oxidation, encourage certain elements to migrate into the dross, or top layer of the melt, increase the fluidity or wettability of the melt which facilitates the separation of inclusions, and to remove hydrogen, nitrogen gas, and calcium ,sodium ,magnesium ,lead and tin [18, 19]. Different fluxes have four uses in aluminum scrap. First they form low-melting, high fluidity compound, for example NaCl-KCl mixture. Second, they decompose to generate anions, such as nitrates, carbonates, and sulfates, which are capable reacting with impurities in the aluminum scrap. Third, they act as fillers to lower the cost per kilogram, provide a matrix or carrier for active ingredients, or adequately cover the melt. Fourth, they absorb or agglomerate reaction product from the fluxing action. The use of salt fluxes fall into five categories: covering, cleaning, drossing, refining, and wall-cleaning.

2.1.1 Cleaning fluxes

Cleaning fluxes facilitate keeping furnace or crucible walls above and below the melt line free of build-up. Build-up begins as a composite of metallic aluminum and oxide, so that it initially can be loosened and dispersed with exothermic fluxes.

2.1.2 Drossing fluxes

Drossing fluxes are designed to promote separation of the aluminum- oxide dross layer from the molten metal. The drossing fluxes are used to great advantage to reduce the rich metallic content of drosses that may contain up to 60-80% free metal. The drossing fluxes are designed to react with metallic aluminum to generate heat. Drossing fluxes usually need to be mixed into the dross layer. After a flux is used, a quiescent time for the bath is recommended to allow adequate settling of heavy inclusions or floating out of lighter-density fluxing salts and flux-wetted inclusions. Optimal settling time may vary from 5-10minutes for a small crucible melt to 1-2hr for 50 tone furnace.

2.1.3 Refining fluxes

Refining fluxes contain compounds that break down and are thermodynamically favorable to react with certain metallic elements in the aluminum. For example, certain chlorine-containing compounds will react with molten aluminum containing Mg, Ca, Li, Na, and K to form compound that will partition to dross phase, where they can be removed by skimming.

2.1.4 Cover fluxes

Cover fluxes can be spread over the melt, while drossing fluxes usually need to be mixed into the dross layer. After a flux is used, a quiescent time for the bath is recommended to allow adequate settling of heavy inclusions or floating out of lighter-density fluxing salts and flux-wetted inclusions. Optimal settling time may vary from 5-10minutes for a small crucible melt to 1-2hr for 50 tone furnace. An important factor is the flux's melting and reaction temperature range. A cover flux should be liquid at melt temperatures, and drossing or exothermic flux should ignite. An exothermic wall cleaning flux is typically applied when the walls are as hot as possible to aid heating and softening of oxide buildups.

2.1.5 AlF3Alkali-fluoride salts

AlF3 alkali fluoride salts act as surfactants, decreasing the surface tension between the flux and the metal and between the flux and oxide. AlF3 removes Ca, Sr, Na, and Mg and compounds releasing chlorine remove Ca, Li, Mg, and Sr.

2.1.6 NaCl-KCl based flux

NaCl-KCl based flux forms eutectic at temperature 665ºc common cover flux contains about 47.7%NaCl, 47.5%KCl, and 5% fluoride salt. A low melting point is important since it will improve the fluidity of the flux. Magnesium may be removed by chlorine or an aluminum-fluoride-containing flux. Flux based on a NaCl-KCl mixture may be used to cover and protect the metal from oxidation and to recover aluminum from dross, more reactive. [25]

2.2. High purity aluminum properties

Pure aluminum has many outstanding attributes that lead to a wide range of applications, including:

- Good corrosion and oxidation resistance
- High electrical and thermal conductivities
- Low density
- High reflectivity
- High ductility and reasonably high strength
- Relatively low cost

Aluminum is a consumer metal of great importance. As a result of a naturally occurring tenacious surface oxide film, a great number of aluminum alloys have exceptional corrosion resistance in many atmospheric and chemical environments.

It corrosion and oxidation resistance is especially important in architectural and transportation applications. On an equal weight and cost basis, aluminum is better electrical conductor than copper. Its high thermal conductivity leads to applications such as radiators and cooking utensils. Its low density is important for hand tools and all forms of transportations, especially aircraft. Wrought aluminum alloys display a good combination of strength and ductility.

Aluminum alloys are among easiest of all metals to form and machine. The precipitation hardening alloys can be formed in a relatively soft state and then heat treated to much higher strength level after forming operations are complete. In addition, aluminum and its alloy are not toxic and are among the easiest to recycle of any of the structural materials. Aluminum is a light weight metal with a density of 2.70 g/cm3 and moderately low melting point of 655 degree celicus. Since it has a face-centered cubic crystalline structure, the formability is further of aluminum and aluminum alloys is good. The good formability is further aided by its rather low work-hardening rate. Aluminum alloys are classified as either wrought or cast alloys. Some of the wrought alloys are hardened by work hardening, while other are precipitations hardeneble.

2.2.1. The Dc Resistivity of Metals

The customary approximation used in the discussion of the resistivity of metal is Mathiessen's rule.

Matthiessen's rule- the statement that the electrical resistivity p of a metal can be written as

$\rho=\rho L+\rho i$, where pL is due to scattering of conduction electron by lattice vibrations and pi to scattering by impurities and imperfections'. If the impurity concentration is small, pi is temperature independent [21].

Impurity level of aluminum is directly related to the electrical resistivity (and conductivity) of aluminum.

The resistivity of a pure metal is increased by impurities due to the lattice distortion that affects electron scattering that is partially responsible for the electrical conducting property of the metal.

Matthiessen's rule shows the dependency of electron mobility of electron scattering contributions from impurities and lattice phonon. Electron mobility defines electrical conductivity and resistivity [21].

CHAPTER THREE

3. METHODOLOGIES

3.1 Descriptions of the research area.

Bmet cable industry is one of the biggest companies in the country and established in 2014 by Turkish investors by the capital of 3billion Ethiopian birr. Currently the company is covering 60% of country cable needs in telecom and energy sector. To carry out this research, typical materials were used, appropriate tools and equipment and also relative sampling methods chosen.

3.2 Materials

Aluminum scrap: aluminum scrap was taken from scrap storage in the company. Company is collecting the scrap from different parts of the country and most scrape are derived from domestic used materials and used aluminum cable.

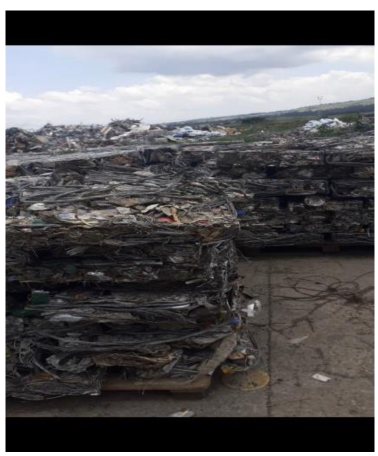

Figure3.1 Shows aluminum scrap

Salt flux: covering flux with composition

NaCl=47.5 %wt, KCl=47.5 %wt, NaF=5%

Aluminum fluoride (AlF3) flux and hexachloroethane (C_2Cl_6) flux

According to utigard, flux containing fluorides, it injected into the melt and mixed well in it. Flux envelops the oxides and fluorides then form a mixed oxide phase. This leads to disintegration into individual pieces oxides. These fragments oxide mixed phases have the ability to float, because their density is considerably lower, than the density of molten aluminum. This results in a slag having a low metal content.

Not, that the density of pure oxides is almost equal to the melt density and so they have practically no opportunity to emerge.

Fluxes like hexachloroethane (C_2Cl_6), enter under the melt surface, it forms bubbles, which reduce the hydrogen content in the melt.

Refining flux with the composition NaCl 40% by weight, KCl 30% by weight, NaF 10% by weight, Na3AlF_6 20% by weight and all salt flux bought by the company through purchasing department.

Figure3.2 Shows salt flux

3.2.1 Equipment

Air separator used to separate aluminum scrap from dust and light-weight materials. Air separator is available every place of the company because the company has installed air channel everywhere and connected with compressor.

Hot separator used to separate low melting materials with aluminum scrap.

Magnetic separator used to separate magnetic materials with aluminum scrap such as iron. And we used small magnetic bars which is available in the company

Furnace used to melt aluminum scrap and the furnace called high-efficient aluminum melting furnace can melt up to 3-ton aluminum scrap per hour. Melting furnace uses 80%oil and 20% pressure and burning rate is 98%.

Figure 3.3 Shows high-efficient aluminum melting furnace

Holding furnace used to hold the melt which transferred from aluminum melting furnace and used for fluxing and slag removing.

Figure3.4 Shows melt holding furnace

Resistance measuring machine this machine used to measure resistance of aluminum conductor by using four-point probe method. The electrical resistivity of conductive rod can be determined by four-point probe method. Four copper wires are stretched across the opening of a non-conductive material glued in place parallel and precisely-known separation between the two inner wires. All four wires then are connected to individual copper terminal blocks. The two outer leads are connected to a precision current source and the two inner leads are used to measure voltage drop. The sample rod is laid across the lead wire. Ohms low (V=IR) allows the resistance to be determined. Conductivity is calculated from the measured resistance and dimension of the conductor.

Figure3.5 Shows resistance measuring machine (resistomatt).

Electronic balance electronic balance used to measure 1meter cute aluminum conductor to calculate diameter of the conductor.

Figure3.6 Shows electronic balance

Spectra analysis machine used to analysis of composition of the scrap melted aluminum conductor.

Figure3.7 Shows spectro lab

Tensile testing machine used to measure tensile strength and elongation of the sample and the machine called universal tensile testing machine.

Figure3.8 Shows tensile testing machine

3.3. Methods

In this section the sequential methodology starting from the material collection to casting of the aluminum conductor is presented.

Scrap collection and scrap selection

Aluminum scrap was collected from scrap storage area. For the purpose of observing the effect we tried to select the same types of aluminum scrap. After finishing of pre-melt techniques that are hand sorting, air separation, hot separation and magnetic separation, scrap is bunched by bunching machine in order to make easy in furnace feeding. And next to pre-melt treatment was in-melt treatment such as fluxing the melt and skimming the slag.

Slag removing

Slag was removed at 660 ℃ and it was done before transferring the melt into holding furnace.

Fluxing the melt

Fluxing was done in holding furnace by using aluminum fluoride and hexachloro ethane tablet after fluxing skimming was done. Salt flux was added into the melt by using metal handle and the melt stirred after stirring skimming was done.

Refining the melt

Refining was done by using flux with composition NaCl 40%, KCl 30% , NaF 10% , $Na3AlF_6$ 20%
.

Casting the melt

After 4hr left the melt casting and extrusion drowning into 9.5mm diameter conductor rod was done.

After all melting and casting finished characterization of the sample was done. To compare the result and identify the effectiveness of this research we took five samples from the company casting technique and five samples took from treated casting and we analyzed for 10 samples.

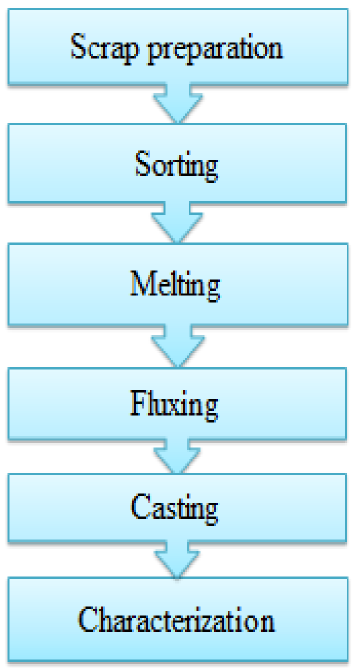

Figure3.9 Showa all process of scrap melting

3.4 Material preparation and Testing

Generally, the following tests are performed to obtain effects of impurity in aluminum electrical and mechanical properties.

- ✓ Spectra analysis
- ✓ Resistance testing
- ✓ Weight measuring
- ✓ Conductivity calculation
- ✓ Tensile testing
- ✓ Elongation testing

3.4.1 Spectra analysis

Spectra analysis done by a machine called spectra lab. Spectra lab is an instrument by which use to identify elements present in sample and quantify their amount. The sample placed between two graphite arc electrode and spark of high voltage is allowed to pass through. As a result, electrons in the different elemental atoms are exited. They absorb energy and are raised to higher energy level but that is temporarily. Soon electrons in the elemental atoms go down to lower energy level releasing energy in the form of radiation. Each element gives rise to different spectra (frequency) lines with different intensity. From observed line frequency and intensity, we can quantify the amount percentage in which different elements are present.

Procedure for spectra analysis

- ✓ Preparing aluminum sample from casting
- ✓ Grinding and polishing
- ✓ Run the machine
- ✓ Print compositions of the sample from computer and printer

3.4.2 Resistance testing

Resistivity of Pure aluminum has a resistivity of 2.64×10^{-8} Ωm at 20°C with a mean temperature coefficient over the range 0–100°C of 4.2×10^{-3}/°C. Thus it has about 66% of the conductivity of pure copper or 66% of that of the International Annealed Copper Standard (IACS) at 20°C. The density of aluminum is 2.7 compared with 8.9 for copper and hence, weight for weight, the conductivity of aluminum is 2.1 times that of copper and exceeds that of all known materials except the alkali metals. and conductivity measurement (21).

Resistance measurement done by using resistomatt four pro and conductivity was measured by using area and diameter calculation from 1m cut sample Diameter calculated by using caliper and measured weight.

Procedure for resistance testing

Tow meter aluminum conductor prepared

Sample placed in measuring bridge

Resistance read from resistomatt display

Figure3.10 Shows resistance testing procedure

3.4.3 Conductivity calculation

Pure aluminum has electrical conductivity at room temperature about 38 million Siemens per meter. But the existence of different impurity decreases electrical conductivity of aluminum.

Procedure for conductivity calculation

- ✓ Measuring 1-meter sample and cut
- ✓ Placing in electronic balance
- ✓ Weight read and multiply by 0.471 and powering ½
- ✓ Diameter is obtained from above calculation
- ✓ Calculating area from diameter
- ✓ Conductivity =length/(resistance x area)

Figure3.11 Shows conductivity calculating steps

3.4.3 Tensile testing

Tensile properties indicate how the material will react to forces being applied in tension. A tensile test is fundamental mechanical test where a carefully prepared specimen is loaded in very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and reduction in area, tensile strength, yield point, yield strength and other tensile properties. Tensile strength is the maximum engineering stress level reached in a tension test. The strength of a material is its ability to withstand external forces without breaking. In brittle materials, the UTS will at the end of the linear-elastic portion of the stress-strain curve or close to the elastic limit. In ductile materials, UTS will be well outside of the elastic portion into the plastic portion of the stress-strain curve. On the stress-strain curve above, the UTS is the highest point where the line is momentarily f lat. Since the UTS is based on the engineering stress, it is often not the same as the breaking strength. In ductile materials strain hardening occurs and the stress will continue to increase until fracture occurs, but the engineering stress-strain curve may show a decline in the stress level continue to increase until fracture occurs. This is the result of engineering stress being based on the original cross-section area and not accounting for the necking that commonly occurs in the test specimen. The UTS may not be completely representative of the highest level of stress that a material can support, but the value is not typically used in the design of components anyway. For ductile metals the current design practice is to use the yield strength for sizing static component. However, since the UTS is easy to determine and quite reproducible, it is useful for the purpose of specifying a material and for quality control purpose. On the other hand, for brittle materials the design of a component may be based on the tensile strength of the materials.

Procedure for tensile testing

- ✓ Preparing 40mm sample
- ✓ Placing universal tensile testing machine
- ✓ Adjusting diameter and area
- ✓ Run the machine up to sample fracture
- ✓ Read tensile value from the graph

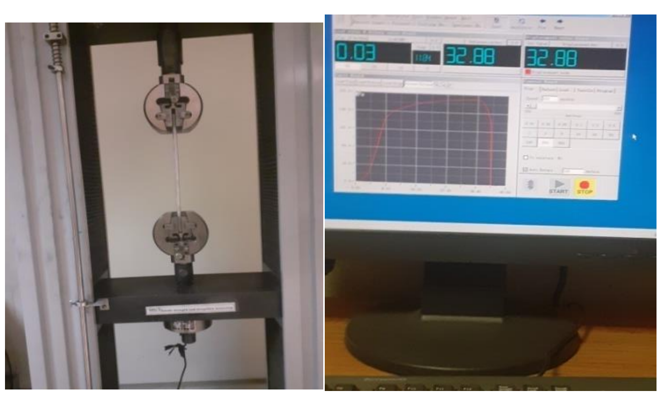

Figure3.12 Shows all tensile testing procedure

3.4.4 Elongation testing

The ductility of a material is a measure of the extent to which a material will deform before fracture. The amount of ductility is an important factor when considering forming operations such as rolling and extrusion. It also provides an indication of how visible overload damage to a component might become before the component fracture. Ductility is also used a quality control measure to assess the level of impurities and proper processing of a materials. The conventional measures of ductility are the engineering strain at fracture usually called elongation and the reduction of area at fracture. Both of these properties are obtained by fitting the specimen back together after fracture and measuring the change in length and cross-sectional area. Elongation is the change in axial length divided by the original length of the specimen. It is expressed as percentage; because an appreciable fraction of the plastic deformation will be concentrated in the necked region of the tensile specimen.

The value of elongation will depend on the age length over which the measurement is taken. The smaller gage length the greater the large localized strain in the necked region will factor into the calculation.

Procudure for elongation testing

- ✓ Marking 20cm in sample that prepared for tensile test
- ✓ After tensile test measure the length of the sample
- ✓ Calculating elongation by using elongation formula
- ✓ Elongation =(final length-inithal length)/initial length

Figure3.13 Shows elongation measuring procedure

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Spectra analysis result

The company melts aluminum scrap without any treatment except slag removing in different temperature. But in our research we treated the scrap melt in two ways before melt and in melt processes and to see the difference we analyzed both treated and non-treated sample from both sample. We analyzed five samples from both treated and non-treated sample aluminum conductor rod.

Impurities	Fe	Si	Cu	Mn	Mg	Cr	Zn	Al
Sample 1	1.37	0.661	0.197	0.137	0.128	0.193	0.3	96.7
Sample 2	0.0797	0.865	0.193	0.09	1.05	0.035	0.0382	97.5
Sample 3	0.658	0.418	0.033	0.018	0.596	0.0769	0.102	98.0
Sample 4	0.617	0.477	0.0412	0.01	0.682	0.0353	0.158	97.9
Sample 5	0.229	0.5	0.0426	0.464	0.0229	0.0017	0.3	97.6

Table4.1 Shows spectro result for scrap melted aluminum in the company

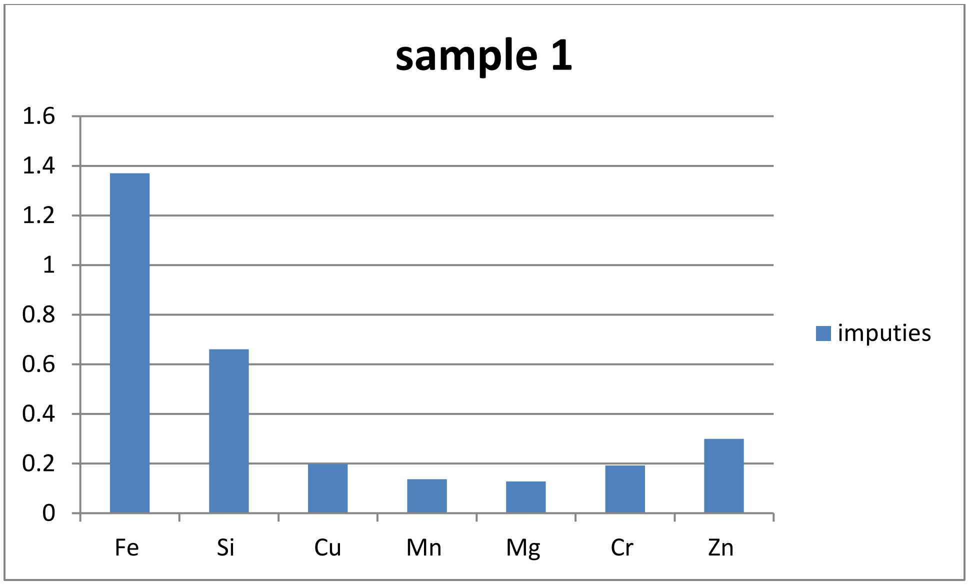

Figure4.1 Shows impurity level of sample one for company sample

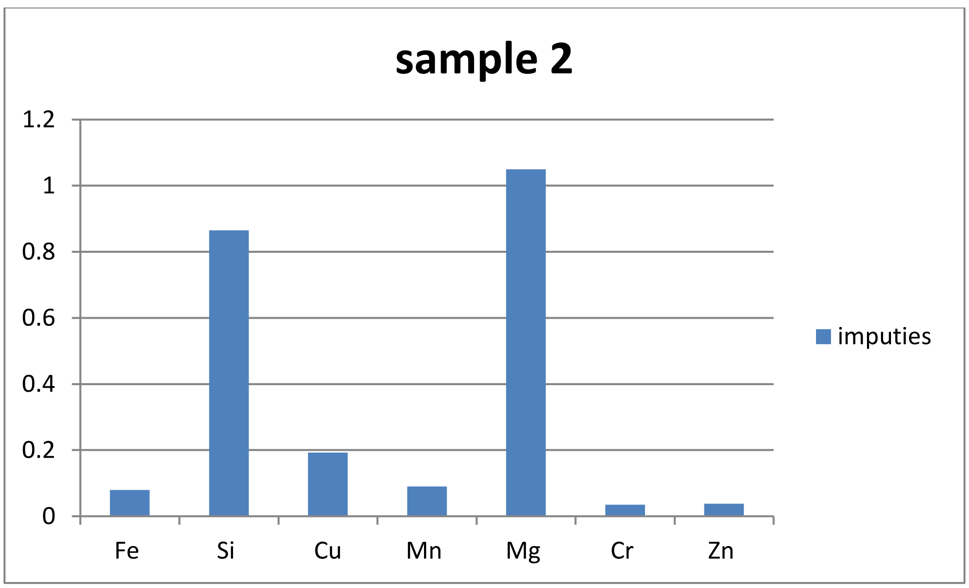

Figure4.2 Shows impurity level of sample tow for company sample

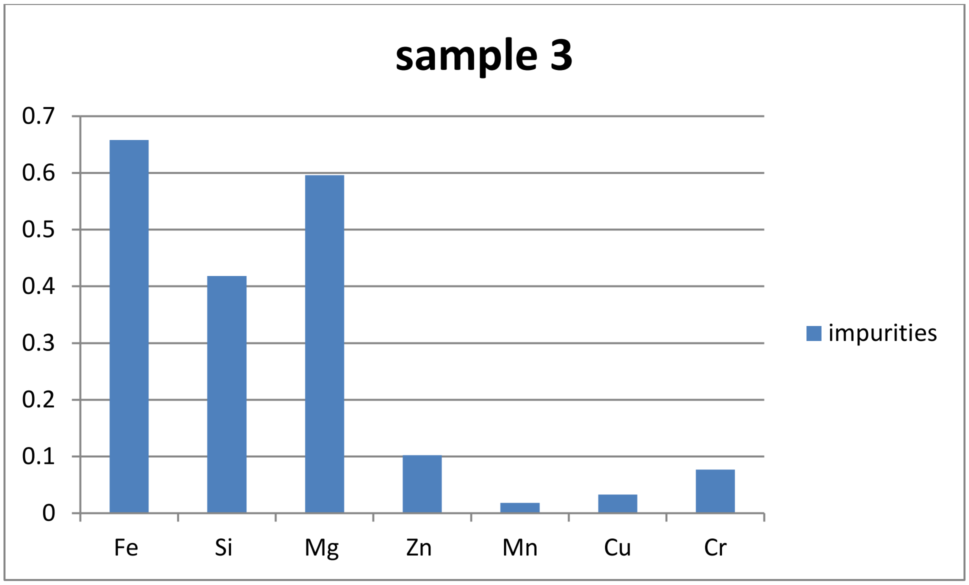

Figure4.3 Shows impurity level for sample three of company sample

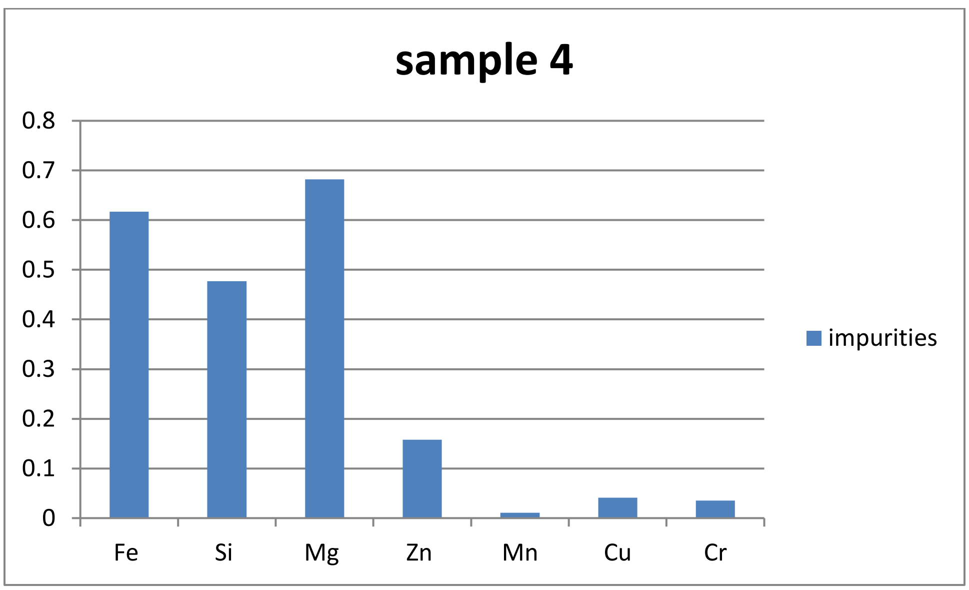

Figure4.4 Shows impurty level for sample four of company sample

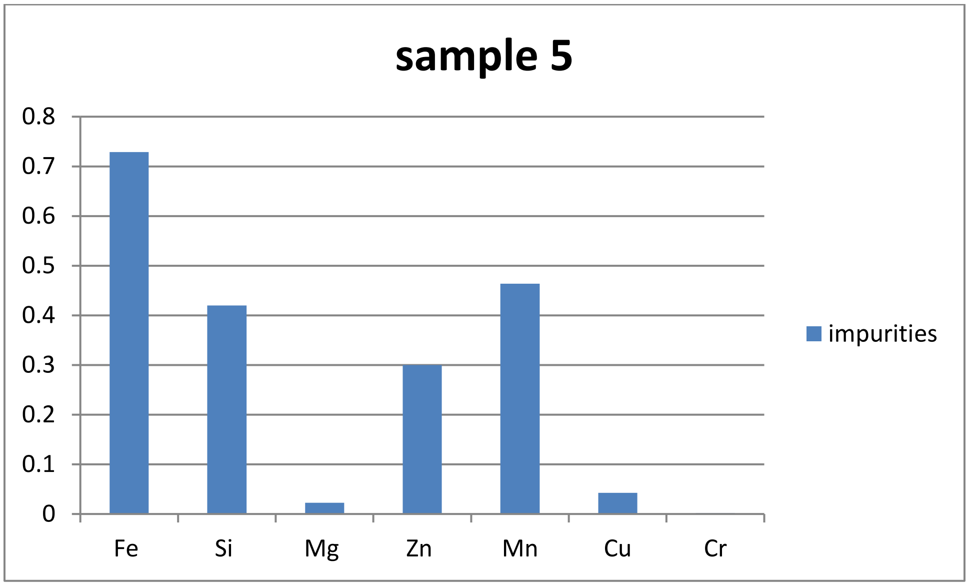

Figure4.5 Shows impurity level for sample five of company sample

Spectra result for testing samples table below shows spectra result for testing sample this testing sample is treated in different ways such as pre-melt treatment and in-melt treatment. For all sample we used almost the same types of scrap.

Impurities	Fe	Si	Cu	Mn	Mg	Cr	Zn	Al
Sample 1	0.637	0.391	0.0054	0.0161	0.524	0.0617	0.121	98.1
Sample 2	0.0585	0.652	0.018	0.499	0.153	0.0009	0.0788	98.2
Sample 3	0.0552	0.645	0.155	0.489	0.154	0.00095	0.0818	98.4
Sample 4	0.375	0.336	0.0466	0.0112	0.290	0.033	0.090	98.7
Sample 5	0.290	0.455	0.0066	0.0055	0.269	0.0086	0.0641	98.8

Table4.2 Shows spectro result of scrap melted aluminum conductor for testing sample

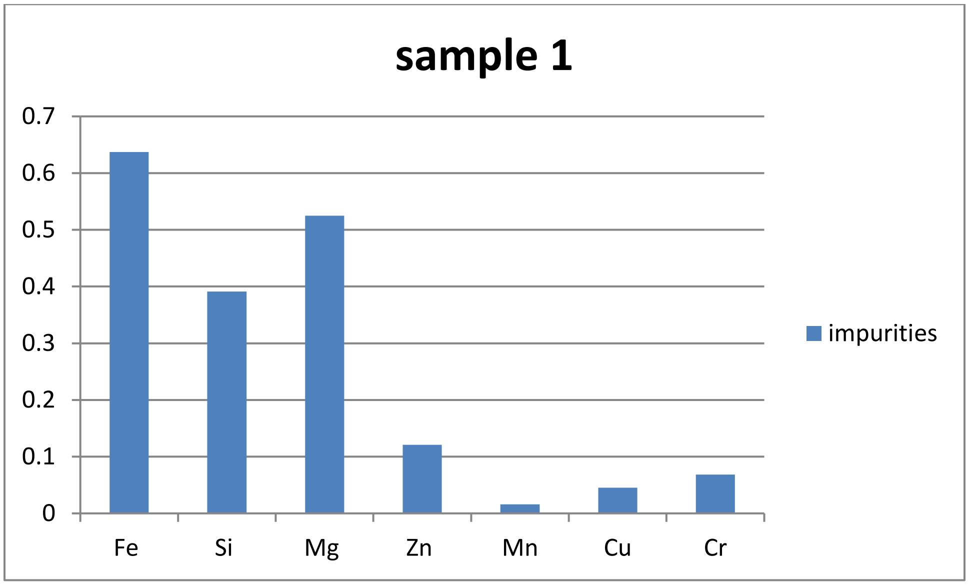

Figure4.6 Shows impurity level for sample one of testing sample

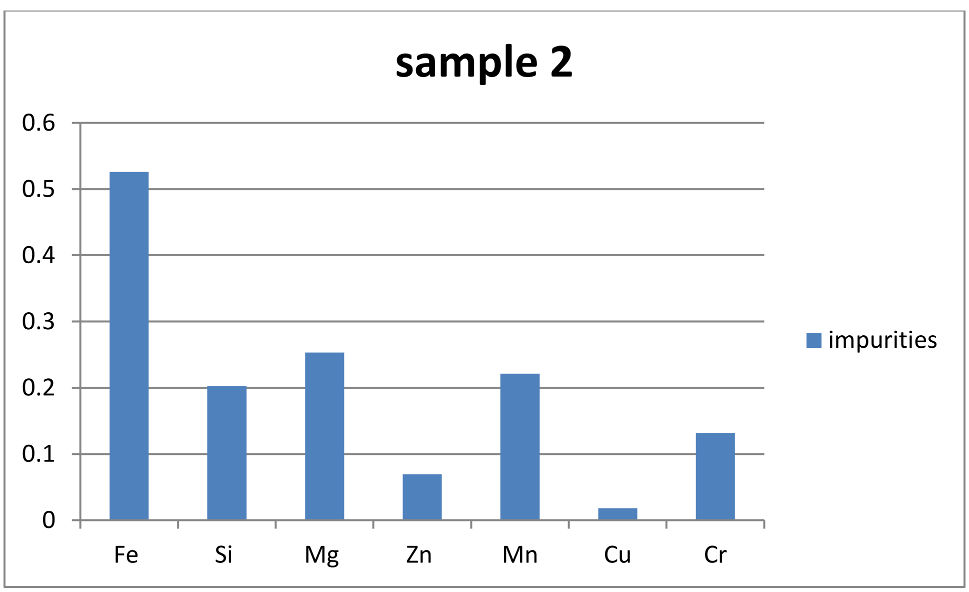

Figure4.7 Shows impurity level for sample two of testing sample

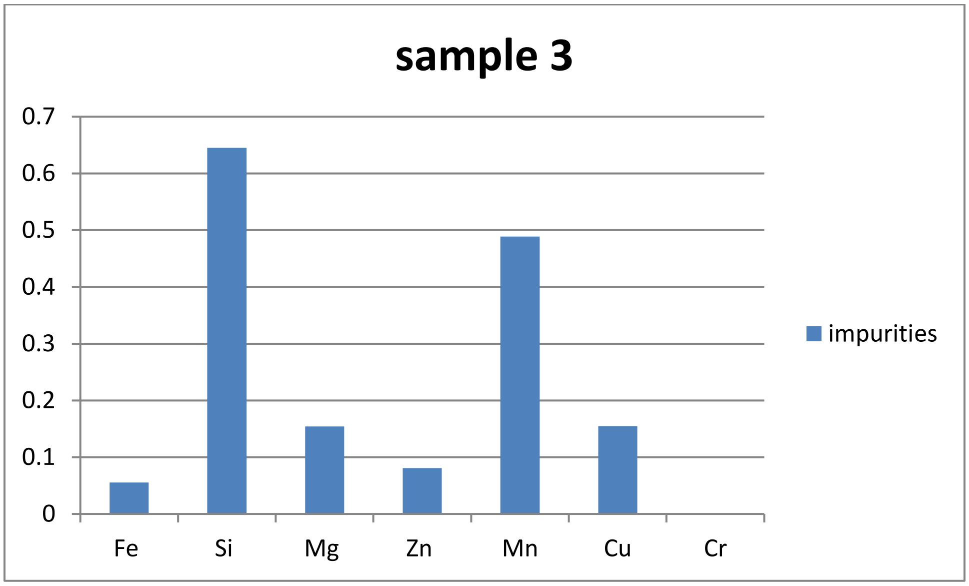

Figure4.8 Shows impurity level for sample three of testing sample

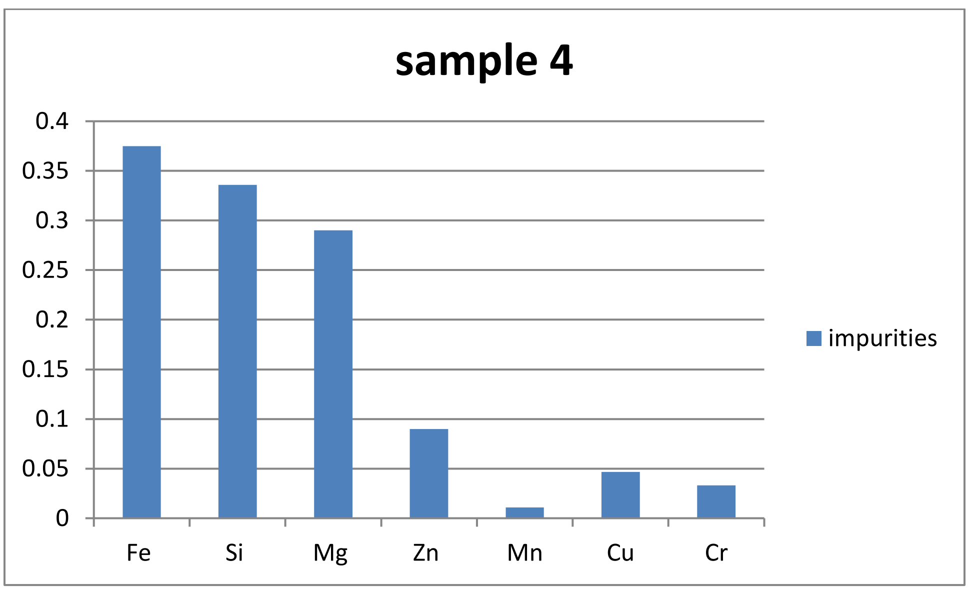

Figure4.9 Shows impurity level for sample four of testing sample

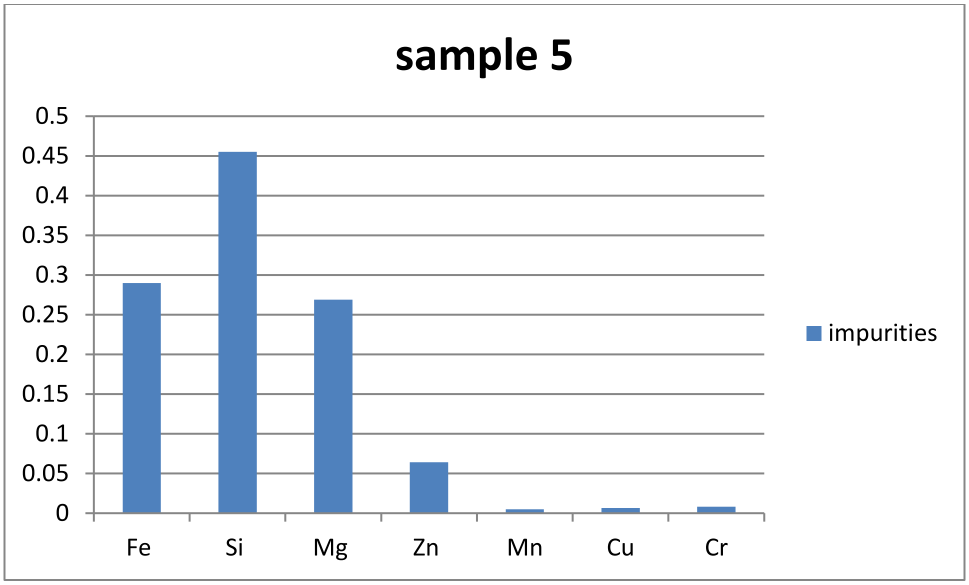

Figure4.10 Shows impurity level for sample five of testing sample

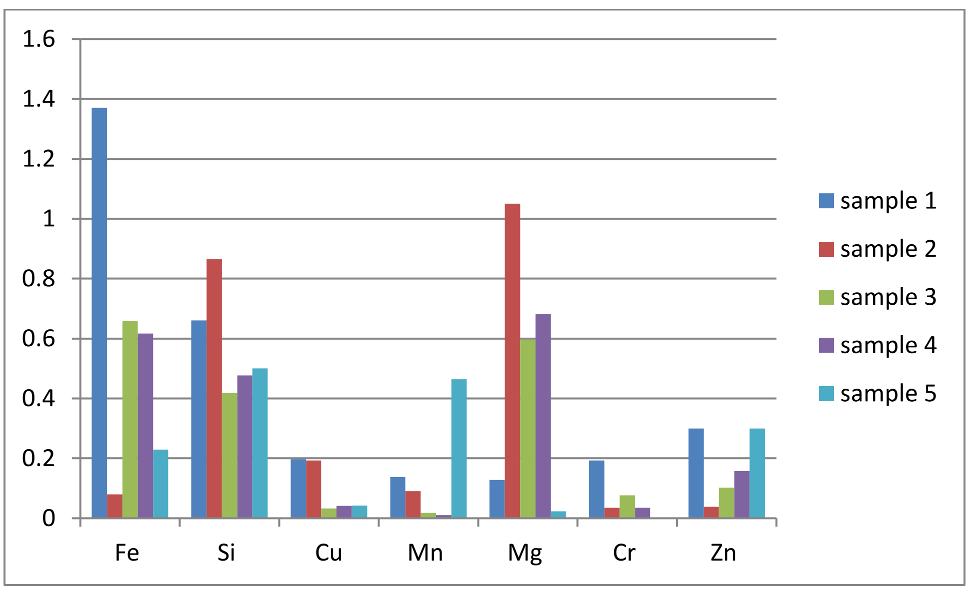

Figure4.11 Shows impurity level for all sample of company cable sample

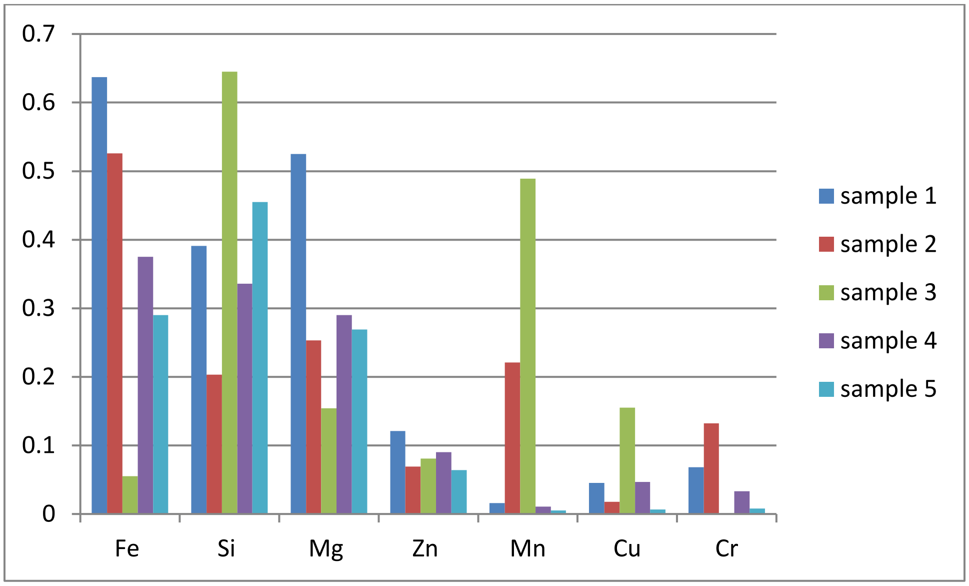

Figure4.12 Shows impurity level for all sample of testing sample .

4.2 Resistance measurement result

Electrical resistance is a property of all materials by a measure of which it opposes electrical current. It is defined as R=V/I where V= applied potential (voltage)and I=current strength in ampere. But resistance depends on the cross section, purity and length of an uniform conductor.

R=rhoXl/a

Where l=length of the conductor

a=area of cross section

rho=resistivity or specific resistance

so rho=RX(a/l) in other word resistivity is the resistance of a conductor whose length and area of cross section =1 this fundamental property of all metals resistivity increase with temperature. For pure metal resistivity at a given temperature is constant. Mathiessens rule is concerned with electron mobility which in turn decides electrical conductivity and resistivity of metals. Electrical conductivity of a metal can be well explained in the light of free electron model of metals .metal contains free electron but those free electrons are confined within the metal unless an electrical field is applied. Then free electron travel through the metal and connected conductor. Electron mobility is hampered if electron undergoes collision with impurities. That is why presence of impurities lowers the conductivity of a metal. As a matter of fact, electrons are scattered by impurities atoms and as a result electrical conductivity of a metal is decreased. Conversely resistivity increases. Electrons are also scattered by phonons (lattice vibration) .as the temperature is raised lattice vibration is also increase resulting greater concentration of phonon. These phonons can scatter free electrons and hence the electrical conductivity is lowered.

Mathiessens rule 1/mu=1/mu impurities+1/mu lattice

mu=actual mobility

mu impurities=is the mobility that electrons would have if there were impurity scattering

mu lattice=is the mobility of free electron if there were scattering by phonon or lattice vibration.

But the research aim is to identify effects of impurities in electrical conductivity so we have used constant temperature for all samples which is 20 degrees Celsius.

Due to improvement of purities of aluminum rod conductor also electrical resistance and electrical conductivity has improved. Electrical conductivity increased due to electrical resistance decrease. Electrical resistance is not only depending on purity but also it depends on temperature and rod length. For this analysis we used constant temperature and length for all samples.

Sample no.	Resistance result (Ohmkm)
1	0.4366
2	0.4247
3	0.4157
4	0.4146
5	0.4273

Table4.3 Shows electrical resistances of aluminum rod conductor of company sample

Sample no.	Resistance result (Ohmkm)
1	0.4116
2	0.4113
3	0.4098
4	0.4080
5	0.4075

Table4.4 Shows electrical resistances of aluminum rod conductor of testing sample

Conductivity is defined kappa=1/rho its unit is Siemens per meter and conductivity decrease with increase temperature. Due to decreasing of electrical resistance of the rod conductivity is increased. Electrical conductivity of the material mainly depends on purities of the materials and electrical resistance of the materials. Highest conductivity that the company obtained from scrap melt was 32S/mm, but in this research highest conductivity obtained from the scrap is 33.251S/mm. But international electrical commission (IEC) standard is 38millions/m. Even thou the research is not fulfill the IEC standard but it can be improving by repetition and by improving of scrap selection.

Sample no.	Conductivity result(S/m)
1	31.041S/mm
2	31.907S/mm
3	32.S/mm
4	32.09S/mm
5	32.1S/mm

Table4.5 Shows conductivity result of aluminum conductor result of bmet cable sample

Sample no.	Conductivity result(s/m)
1	32.93S/mm
2	32.949S/mm
3	33.07S/mm
4	33.2101S/mm
5	33.251S/mm

Table4.6 Shows conductivity result of aluminum conductor result for testing sample

To calculate electrical conductivity, we have used weight of the rod in order to get proper diameters of the rod. Weight and diameter has directly relationship. Electrical resistance increases when diameter decreases.

Conductivity=L/RA

Where L=length of the rod, R=resistance from resistomatt read, A=area of the conductor which calculated from diameter of the rod

Sample no.	Resistance (ohm/km)	Diameter (mm)	Area (mmsq)	Conductivity(S/m)
1	0.4366	9.657	73.242	31.041
2	0.4247	9.534	71.354	31.907
3	0.4157	9.608	72.466	32
4	0.4146	9.534	71.35	32.09
5	0.4273	9.63	72.9	32.1

Table4.7 Shows electrical resistance and electrical conductivity of all aluminum rod for company samples

Sample no.	Resistance (ohm/km)	Diameter (mm)	Area (mmsq)	Conductivity(S/m)
1	0.4116	9.583	72.089	32.93
2	0.4113	9.608	72.467	32.949
3	0.4098	9.608	72.5009	33.07
4	0.4080	9.608	72.466	33.2101
5	0.4075	9.681	73.606	33.251

Table4.8 Shows electrical resistance and electrical conductivity of all aluminum rod for testing sample

4.3 Weight result

Aluminum is light weight metal but the existence of heavy elements affects the weight of aluminum. The existence of heavy elements also it is a reason to have high weight. Table below shows weights of aluminum rod conductor for one-meter sample. Weight used to calculate diameter, diameter used to calculate area and area used to calculate electrical conductivity of the rod.

Sample no	Weights of the sample for one meter per gram
1	198 gm
2	198gm
3	197gm
4	198gm
5	198gm

Table4.9 Shows weight of one meter sample for aluminum conductor rod for company sample

Sample no	Weights of the sample for one meter per gram
1	197gm
2	198gm
3	196gm
4	196gm
5	196gm

Table4.10Shows weight of one meter sample for aluminum conductor rod for testing sample

4.7 Tensile testing result

Tensile strength or ultimate tensile strength (UTS) is the maximum that material can withstand before breaking down is known tensile strength of material. In ductile materials UTS is higher than brittle materials. UTS is obtained from the engineering stress-strain. The highest point in the curve indicates the UTS of the materials. Tensile strength depends on impurities that found in the material. Pure aluminum has Mpa less tensile strength than impure aluminum. The existence of elements like iron makes to have high tensile strength but pure aluminum has high electrical conductivity and low tensile strength.

Sample no.	Tensile strength result(Mpa)
1	178 Mpa
2	166 Mpa
3	158 Mpa
4	145 Mpa
5	156 Mpa

Table4.11 Shows tensile strength of aluminum rod conductor of company sample.

Sample no.	Tensile strength result(Mpa)
1	155 Mpa
2	146 Mpa
3	152 Mpa
4	149 Mpa
5	148 Mpa

Table4.12 Shows tensile strength of aluminum rod conductor of testing sample.

4.8 Elongation result

Elongation was measured using the same experiment i.e engineering stress-strain curve. Let the initial length of the test piece be L. After breaking tow broken parts are joined and its length measured. Let the final length l. Then the percentage elongation is defined as e=(l-L)/L x 100.it is a measure of ductility of materials. Higher the percentage elongation grater will be its ductility. For cable industry aluminum ductility must be high in order to draw into the wire by using extruder drawing machine. Elongation can be affected by the existence of impurities by making the material brittle.

Sample no.	Elongation result in %
1	7.5
2	15
3	10
4	15
5	14

Table4.13 Shows elongation result of company sample

Sample no.	Elongation result in %
1	15
2	16
3	15
4	17.5
5	17

Table4.14 Shows elongation result of testing sample

CHAPTER FIVE

5. CONCLUSION & RECOMMENDATION

5.1 Conclusion

High purity aluminum conductor obtained by using pre-melt and in- melt treatment technology. Scrap melted aluminum conductor can be improved its electrical and mechanical properties by using different method such as pre-melt and in-melt treatment. Pre-treatment method uses to decrease impurity containing scrap from charging into the furnace by using different separation methods. Elements like iron and silicon is not possible to improve in-melt treatment and it can be eliminating by using pre-melt treatment. Using salt flux in aluminum scrap melt has significant values in order to improve aluminum purity and its properties like electrical and mechanical properties. Salt flux improves purity by removing elements from the melt by thermodynamic process and by preventing the melt from oxidation. Electrical conductivity improved from improvement of purity. Mechanical properties like tensile strength and elongation depend on the existence of different element. Element like iron affects tensile strength of aluminum. Fluxes such as NaCl-KCl used for covering the melt and it prevent aluminum scrap melt from oxidation in melting furnace and also it used to remove elements like calcium from the scrap melt in holding furnace. Aluminum fluoride flux used to remove some elements like calcium, magnesium and sodium. Hand separation and magnetic separation used for separate aluminum from iron and other heavy metals. Air separation used to separate lightweight materials from the scrap and hot separation used to separate low melting materials.

5.1.1 Possible causes of the problems

- ✓ Existence of different types of impurities
- ✓ Such as Fe, Ca, Mg, Mn, Si, Cr, etc

5.1.2 Remedies

1. Pre-melt technology

- ✓ Hand sorting
- ✓ Air separation
- ✓ Hot separation
- ✓ Magnetic separation

2. In-melt technology

- ✓ Fluxing
- ✓ Refining

5.2 Recommendation

Since the time know the company melts aluminum scrap without any treatment except removing the slag in different temperatures because of that scrap melted aluminum rod not satisfy any standard. The company uses IEC (international electro technical commission) standard as a reference but in this reference the purity of aluminum should be 99.5 and more and conductivity should 35S/m for the production of 1350 pure aluminum conductor. As we analyzed in this research the conductor which produce in the company is not fulfill the above standard and the company is known importing the conductor rod from outside to fulfill the standard. The company is covering its aluminum need by importing pure aluminum rod from outside the country and uses by mixing with scrap melted aluminum rod to satisfy customer need and the company is losing many things. For example, to fulfill customers need resistance of the cable is the company is covering by production of extra diameter of the wire. When the company uses extra diameter also they use extra weight. Even if they are gating the scrap in chip price they should improve their products in order to keep their customer and to gate more profit**.** This research tried to show improving of scrap melted aluminum conductor in simple way especially pre-melt treatment is easy for the company**.**

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