MICROSTRUCTURE REFINEMENT FOR AL-0.4%SC ALLOY USING VARIABLE PULSING MAGNETIC FIELD (PMF) SOLIDIFICATION

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Abstract: *The industry of metals manufacturing is usually looking for realizing the highest quality of metals with the optimum mechanical characteristics. Therefore, various treatment methods were studied and performed in order to optimize the mechanical characteristics of different material by improving their microstructure. One of the most famous treatment processes performed by exposing the material to a magnetic field through the solidification procedure aiming to modify the material's microstructure. Therefore, the (Al-0.4%Sc) alloy was experimentally produced and examined undergoing the impact of the magnetic pulse field over the process of solidification. The various applied magnetic fields were identified according to several voltages produced by a magnetic field, they are (60, 80, 100 and 160 V). Energy dispersive x-Ray (EDX), scanning electron microscopy (SEM) and optical scanning processes were applied to inspect the microstructure of the examined samples (with and without exposing to the magnetic field). According to the obtained results, it has been inferred that the magnetic field has an obvious impact in eliminating the floating bifurcations in the examined sample and consequently improving the melting flow and the fractionation of the bifurcations. Whenever increasing the discharge voltage, a full equiaxed structure was obtained for the investigated alloy (Al-0.4% Sc). Hence, it has proven that the electromagnetic fields that subjected to the examined specimen have significant impacts on the grains' refining process and enhancing the propagation of solute toward the eutectic structure that promotes the mechanical characteristics and the microstructure of the whole specimen.*

1. INTRODUCTION

The process of metal solidification clarifies the liquid alteration concept from the state of liquid to the solid because of the reduction of liquid temperature [1]. The most popular methods of strengthening the Aluminum alloys is the addition of microalloying to dispense deposits well. Scandium is the most potent substance in Al alloys, because of its effective performance in multifold reinforcements [2]. Various studies have tested the alloys of the Al–Sc due to their behavior of sole solidification. it's greatly noticed that the solid hydrolysis solution of the Aluminum/Scandium supersaturated via the typical reaction of deposition to eventually generate precipitates of coherent, which includes a phase of steady L12 (Al_3Sc). The factor of lattice disparity (1.6 percent) of this phase with aluminum might generate a significant reaction of aging, even though Scandium has a low solvability relatively, and hence, a small portion of precipitation. The too-small Al3Sc sedimentation transfer the biggest strength increase in percentage (%) of different elements of alloying as via decreasing the grain size they supplemented to Al [1].

The solidification of the alloy in most cases happens with the circumstances of non-equilibrium. Hence, the latest microstructure might be irregular to that mainly estimated by the phase diagram of equilibrium. With regard to the alloys of the dilute Aluminium/Scandium at almost 100 °K rate of cooling; the temperature of the eutectic (fusion) reaction decreased by 3–4 °C whereas the composition of eutectic increased approximately from 0.6 wt-% to 0.7 wt-%. Moreover; the highest solid Sc solvability in aluminium raises to almost 0.6 wt-%. The solidification outgrowth can be managed by various techniques. The directional solidification (DS) is one of these technologies [3, 4]. It has been mentioned that mixing various metals causes a reduction in the temperatures of both melting (fusion) and freezing. At the precise mixture, the amount of drop in temperature becomes the most influencing factor, as it leads to the eutectic state [5].

This technology is a process of casting that manages the growth of the solidification microstructure to the ultimate form of the needed metal structure direction. It happens as the gradient of suitable thermal appeared in the existed gap between the hot and zone during the growth of the crystal. It can be aided in the prevention of the producing the grain boundaries essentially in the direction of perpendicular to the direction of dendritic growth. Other several technologies can be applied to recognize the refinement of grain in the processes of solidification. These technologies include; The refiners of external grain addition, using the solidification of rapid or cooling of rapid for the alloy to reach the heat rapid extraction away during the shaking of solidification or flipping the melt of solidifying during the vibrations of mechanical and/or electromagnetic, and the waves of Ultrasonic [6, 2]. The SC scandium is characterized by 3,000 kg/m^3 density and a 1450 °C melting temperate which considered high. Accordingly, the Scandium-based alloys are the proper selection for lightweight and high-temperature applications even though this metal has no commercial exploitation or global need. It has been assured that the interest in the usage of the scandium is increased as a component in the Aluminium alloys. However, the extraction of the scandium is so difficult, which increases its cost. The addition of scandium to the alloys of the Aluminium directly influences the grain features, where the SC of 0.4% will be combined with aluminium in this project with testing the process of solidification by a field of pulse magnetic to develop the structure of the grain. A work of experimental was chosen to inspect the alloy of Al-0.4%Sc microstructure subjected to the solidification of the PMF (pulse magnetic field) [7].

II. LITERATURE REVIEW

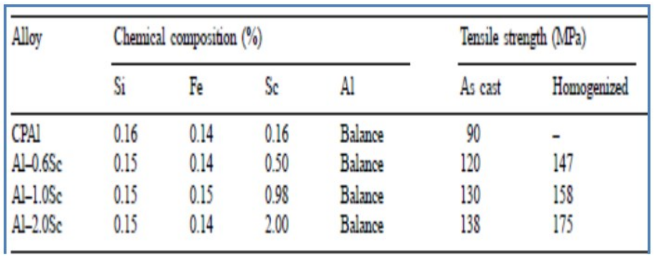
It has been proven that, the most proper method for microstructure solidification enhancement is obtained by increasing nucleation intensity and dominating the grain multiplication process. Additionally, it was stated that this is not the only followed method as there are more microstructures solidification engineering procedures without having any chemical intervention to take place as: nucleation advancement as well as separation procedure, grain growth within certain Mechanized force or substantive spheres. Other procedures shall be mentioned as electromagnetic stirring, alternate magnetic flux, electromagnetic pulse [8].

A research was aimed to study the resulted characteristics and microstructure for Al-4.5 wt-% Cu alloys, containing different rates of Scandium of (0.1, 0.2 and 0.4) wt-%. By applying the solidification process for these aluminium alloys, it is taking place under certain low cooling rates of (0.01, 0.08, 0.3 as well as 0.8) °C/s, additionally, the heating process was applied to accomplish this process. The heat treatment and solidification processes were accomplished by taking advantage of differential scanning calorimeter along with implementing a couple of heat treatment procedures. Mentioning the first technique, this followed procedure is depending on the traditional heat treatment by applying 18.5 h of dissolving under 535 °C, afterward, the cooling process is taking place, eventually, under 240°C, aging procedure is being implemented. On the contrary, the straight aging process was taking control of the solidified samples within the heat treatment process. Upcoming are some scenarios for reduced solidification processes: The Scandium process changed the grain morphology from ramifications (elongated dendrites) to balanced (equiaxed) construction without causing any internal change grain enhancements or even alloy refinement. The 0.4 wt-% Sc was clearly composited to the alloy; thus, a narrow solidification refinement was then observed within aging, this was alongside with solidification because of more Scandium quantities [9].

Another study investigated several Aluminium alloys with different SC rates (0.05, 0.1, 0.2, 0.4, 0.5, 0.7, 0.9 and 1.2) wt-%. This stage was performed by taking advantage of melting Aluminium separately by Aluminium mixture of 2.12 wt-% Sc alloy for a period of around 60 min. on 720 °C using an isolated furnace accompanied by graphite. Such process was only introduced to examine the impact of the solidification process on the microstructure of different Al–Sc alloys. to avoid oxidation at this phase, researchers try to cover melted alloy using the dry argon. Al–Sc casting specimens were produced by pouring the melted alloy through cylindrical-shape steel moulds. Al–Sc alloys were also introduced by (ICP- AES) which is an abbreviation for “Inductively coupled plasma atomic emission spectroscopy”. In order to study the influence of particle sedimentation for alloy’s mechanical performance, this effect was detected through aluminium-SC alloys with (0.4, 0.7, 1.2 and 1.6) wt% of Sc. The above particles were heated under 640 °C for 120 min. in an attempt to solidify this mixture. In addition, at different temperature degrees of (250, 300, 350, 400, 450, and 500), these samples were put under artificial aging process for multiple recorded timings in minutes (1, 2, 3, 5, 9, 17 and 33) min. furthermore, another timing was measured by hours as (1, 4, 10, and 19) hrs. by examining the aluminium grains’ microstructure after enhancing by involving Scandium solidification. It has been concluded that, the grain size of the specimens with 0.1% Sc by weight was increased by the soluble effects which took place to limit the grain enhancements. For the Al- Scandium results, the first material phase was noticed á-Al, however, it was let to raise internally to shape massive vertical grains after being primarily nucleated on the wall of the mould. At the same time, the Sc percentage was increased out of 0.1 to hit 0.5% by weight, the internal microstructure for the alloy changed from huge columnar grains to narrow sizes equiaxed grains, as presented in upcoming graph indicates [10].

By examining the effect of varying the Sc rate on the obtained characteristics of the AL-SC alloys experimentally. it was resulted that optimizing the ductility (tensile strength) of the AL-SC alloys could be realized by increasing the scandium content, as represented in table 1 [11].

Table 2: Characteristics of various AL-Sc alloys [11]



Alloy	Chemical composition (%)				Tensile strength (MPa)	
	Si	Fe	Sc	Al	As cast	Homogenized
CPAl	0.16	0.14	0.16	Balance	90	-
Al–0.6Sc	0.15	0.14	0.50	Balance	120	147
Al–1.0Sc	0.15	0.15	0.98	Balance	130	158
Al–2.0Sc	0.15	0.14	2.00	Balance	138	175

A. Microstructure factors that enhance the mechanical characteristics.

The main microstructure factor that can enhance the mechanical characteristics for the metal alloys is the size of the grains, this factor is controlled the mechanical performance of the metal alloys. This relation can be expressed by Eq. 1 [12];

$$\sigma_y=\sigma_0+k_m d^{-12} \qquad \text{Eq. 1 [12]}$$

The above equation's symbols are defined as follows: the factor 5Øß$_{\text{5ØfÜ}}$ stands for the yield strength, about the second parameter which is 5Øß$_0$, it refers back to the initial constant for material strength, and the 5ØXÜ$_{\text{5ØZÜ}}$ goes back to the material constant. The final d factor is a symbol for diameter of the grain. It is very obvious from the last stated equation that the relation between grain size square root and the yield strength is inversely proportional, by other words, whenever the grain size increases, the yield strength directly decreases. The process for enhancing the grain particular is by nucleation and taking control of the growth operation over solidification [12].

The morphology for grain microstructure is considered a proper method to identify the mechanical characteristics through as-cast conditions, also the casting deficiency is taking place alongside this morphology. These kinds of deficiencies are performing random microstructure the thing that induces the mechanical characteristics. These casting deficiencies are changing the fatigue life cycle as well as the internal microstructure toughness rate for metallic alloys, it could be achieved by concentrating the stress load and minimizing the effective space. The mechanized characteristics for the fatigue strength are: toughness rate accompanied with tensile, these two factors are bonded together with a directly proportional relation with volume ratio because of that utmost area or size ratio of deficiency that depends on the volume ratio of deficiency. The microstructure elements which are also considered as the casting deficiency core are [13];

The Chemical solutes separation, this procedure is applied for alloys super cooling, this process is identified by the non-uniformity of the chemical mixture, this is occurring because of solutes rejecting that takes place inside the inter-dendritic soluble for the solid.

- The Volumetric reduction for metallic alloys through the solidification process; this happens as a result of reducing the volume form the solid state to the liquid state.
- The Porosity effect; this defect can be defined as the gaps inside solid alloys (metal) along with the solidification, which is usually happening because of the inappropriate feeding [14].
- Effects of hot tears, these chemical defects usually defined as the internal or external cracks that spread randomly. these cracks are occurring after alloying the metal due to the weakness of the metals while they are hot. This phenomenon was noticed at interdimeric areas or at grain borders.
- Bubbles, this defect occurs because of the appearance of the bubbles of gas inside the liquid via the solidification, when finalizing the solidification, the metal is then refusing gas in bubbles, this leads to porosity formation and/or pore.

As per the aforementioned, to enhance the mechanical characteristics of the metal alloys, the microstructure for equiaxed grain are preferred than columnar grain. furthermore, the global uniformly structure is preferred than the dendritic microstructure.

B. The microstructure characteristics variation due to the Magnetic pulse solidification.

Aa previous aforementioned, to improve the mechanical characteristics for various alloys and metals, it is important to achieve the good crystalline grain size. thus, multiple reviews were introduced to study and control the size of grain. For these reviews, very different methods were followed in order to improve the grain size as the inoculant's addition, utilizing the magnetic field and supersonic field [15, 16]. The most common method is the PMF (an abbreviation for pulsed magnetic field) [17]. Different researches targeted to examine the impact of PMF on the metal specially on the grain enhancement for grains [18].

The electronic back dispersion diffraction, laser focal microscopy and optical microscopy have been used to inspect the impact of the magnetic pulse welding on the microstructure of several Al-Mg alloys. These welded joints were implemented using many voltages (4×10^3, 4.5×10^3 and 5×10^3) Volts, and these voltages were determined by the Al and Mg regions in addition to the welding interface. It was noted that the waves became smoother and steadier when the voltage increased. Moreover, the grain size was significantly refined. while the grain size increased at high voltage due to increasing the space to the welding interface. Dynamic recrystallization may be the main reason behind the noticeable gradual improvement of the grains adjacent to the welding interface, as the high performance of recrystallization of various Mg and Al grains is observed near the welding interface [19].

It has been mentioned that the behaviour of smelting alloys during the solidification can be controlled by using the magnetic fields, as a result of improving process performance in addition to the qualified products. Whereas, during the application of the magnetic field, smelting can occur in the air instead of the mold as it has been entrenched by Lorentz's good strength, which enables high purity products to be obtained. In addition, the magnetic field can be applied to provide an eco-friendly process. Despite the actual income of the melted agitation, which applies to the production of the desired mixture during the growth of semiconductor crystals [20].

III. METHODOLOGY

The main target of this project is to study the impact of the microstructure of the Aluminium alloy of 0.4 wt-% Scandium (Al-0.4%Sc) by applying the PMF with disparate voltages or fluxes. This inspection was implemented experimentally under conditions of controlled heat during the solidification of the alloy at various conditions. At the following section, the methodology of experimental examining of this alloy will be specified;

A. Test procedure

The alloy (AL-0.4%Sc) was investigated experimentally. This investigation was implemented with particular examining procedure, as stated below. where the alloy samples were prepared experimentally using several raw materials combinations. With regard to preparing of the samples, they were prepared performing the next steps:

- The raw materials of both Sc and Al were collected. 100g of Sc and 400g of Al were received from the lab of the university.
- In order to remove the humidity of the samples, they were dried, where the existence of the humidity in the sample surfaces might cause problems through melting as (Al oxidizing) that might lead to undesirable characteristics.
- Melting Scandium with Aluminium in a specialized insulated furnace, connecting to a temperature transducer to control alloy temperature. The temperature of the furnace was increased to 660 °C for the purpose of melting the metals.
- The collecting of the samples was performed by a vacuum tube directly connected to chamber of melting. And next the cooling of the samples was via papers of ceramics.
- The samples were examined experimentally under various conditions through the solidification. These various conditions contain examining the microstructure of the initial sample before any treatment. Additionally, the sample should examined under the impact PMF of (60, 89, 100 and 160) Volts. In order to study the microstructure, the following techniques will be applied;
- The optical scanning, which gives a 2D images of microstructure of the sample.
- SEM, which gives a detailed-2D images of microstructure of the sample and the sample phases.
- EDX, which gives the sample elemental composition and its stages.

The difference between the conditions studied is the amount of the magnetic field used for solidification. It is worth noting that the increase in magnetic fields leads to an improved crystalline structure, as the stated in the section of literature review. However, the effective implementation for the inspection of microscopic is mainly reached via the properties optimization of the material surface using the techniques of surface finishing as (Grinding, Etching and Polishing). Consequences collected were analysed to inspect the microstructure for various samples containing: (Size of Grain) the grain can be inspected by the factor of magnification. (Content of Material and Orientation of Grains): the orientation angles of the various grains.

IV. RESULTS AND ANALYSES

A comprehensive demonstration, examination and explanation to the resulted data from laboratory microstructure examination considering AL-0.4 %Sc samples under the impact of different magnetic wave conditions, taking into consideration that the wave magnetic fields were implemented in the entire solidification procedures of the alloy samples. The preceding examination is composed of information related to the initial sample investigations outcomes which were offered for the purpose of comparison. The results of investigated samples under the impact of varying magnetic field fluxes which were offered to illustrate the impact of executing different magnetic fields on the solidified microstructure of the specimen being examined. The mentioned investigation was executed by utilizing optical scanning together with SEM for 2D demonstration of the outcomes where the primary composition was given. In addition to EDX examination for presenting the composition in 3D form. Intending the comparison, a preliminary test was executed to investigate the solidification microstructure for the initial specimens before applying any type of magnetic field in the entire solidification process. Figure 1 and figure 2 represent the collected 2D profiles for the macro structure and microstructure of the specimen via optical and SEM examinations consecutively. It was observed that the AL-0.4 % specimen has a basic structure of dendrite grain that has big grain size. A comprehensive exhibition of such grains was illustrated in the SEM results which evidently offered the direction of the grain growth as well as introducing the essential intermetallic stages of the grey stages, bulk period, matrix stage and white phase. The features of granule scattering are clearly illustrated in such figures. Dendritic grains increase upwardly counter to the direction which caused the development of essential dendritic structure with high heights.

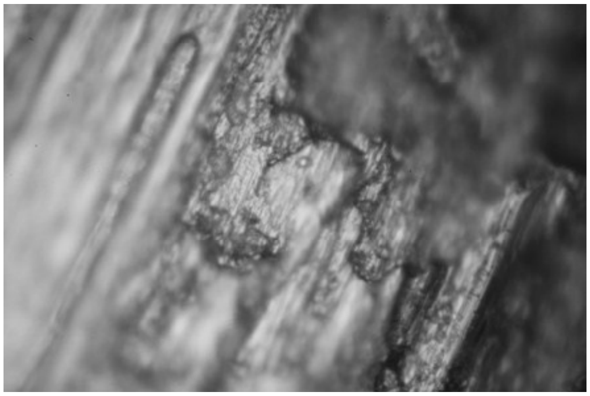


Figure 1: The optical scanning results of the original specimen x800.

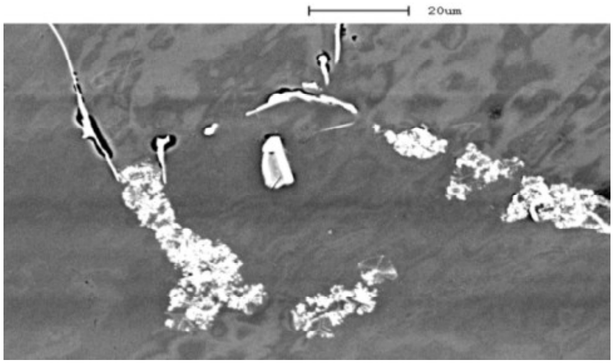
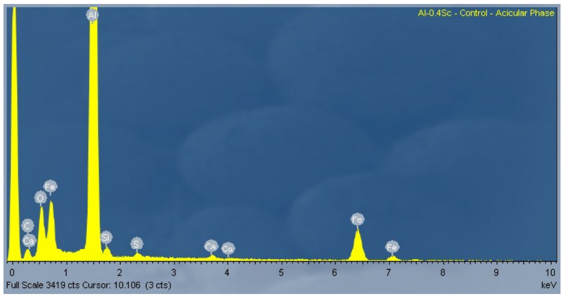
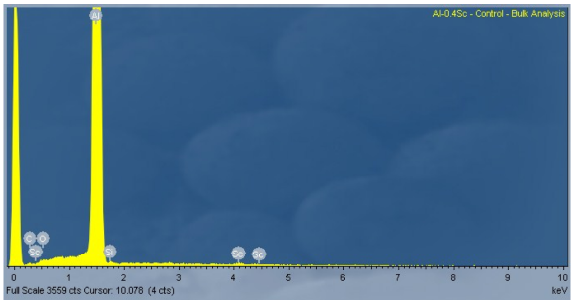


Figure 2: The SEM image of the specimen x1000.

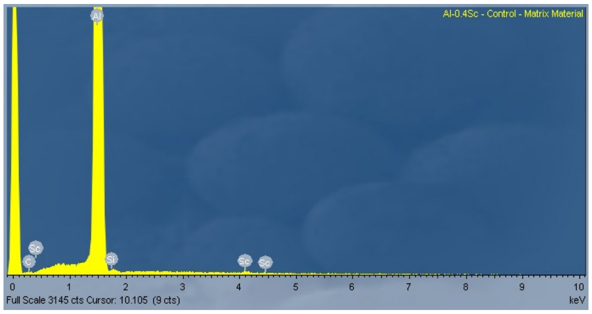
As said earlier, the basic phases of the alloy are shown in SEM images like the grey phase, bulk stage, matrix stage and white stage, are composed of essential elements. The constituent components of these stages were investigated through energy dispersive means and the outcomes shown in figure 3, where the majority of the phases exist. This stage explains the individual composition of the specimen as a whole that consists of aluminium, silicon, oxygen and carbon.in the grey phase, compositions of aluminium and iron were very high.in the matrix-black stage, the main existing element is aluminium while at the white stage Al and Sc are the major elements that existed.



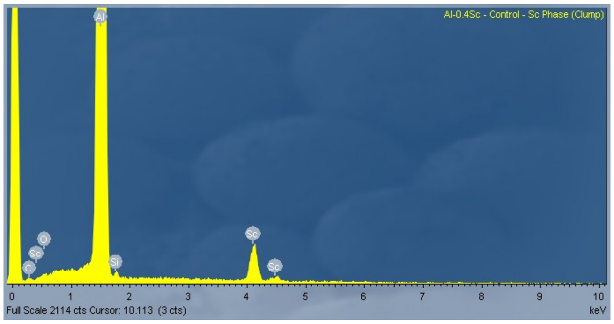
A. The grey stage.



B. The bulk stage.



C. The matrix stage.



D. The white stage

Figure 3: EDX results of the original specimens.

It has been suggested an optimization methodology for the original specimen, the initial specimen of the microstructure is to be attained by exposing to a magnetic field of 60 V, in the solidification process to modify its microstructure. Modifications in the solidified microstructure while applying the magnetic field are shown in figures 4 and figure 5. the optical scanning results illustrated that, dendrite grain development direction is lowered and their heights declined. This can be explained by the production of Lorentz force within the material due to the executed magnetic field where Lorentz force destroyed the formed dendrites. The adjustments in the materials stages are plainly shown in the SEM pictures which also show decline in the size of grains.

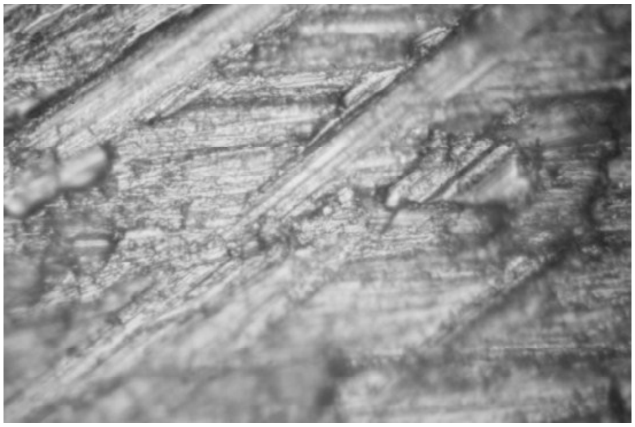


Figure 4: The optical scanning results of the specimen when applying 60V-magnetic field x800.

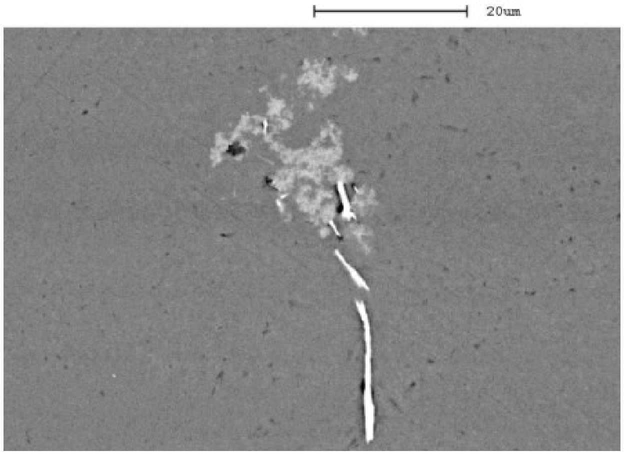


Figure 5: The SEM image of the specimen when applying 60V-magnetic field x1000.

Optical scanning and SEM resulted image when applying a magnetic field of 80 volts are represented in figure 6 and figure 7. It has been observed a decrease in the length and scattering in the structure of the grain. The observed porosities on the initial specimens were as well reduced.

Figure 6: The optical scanning result when applying 80V-magnetic field.

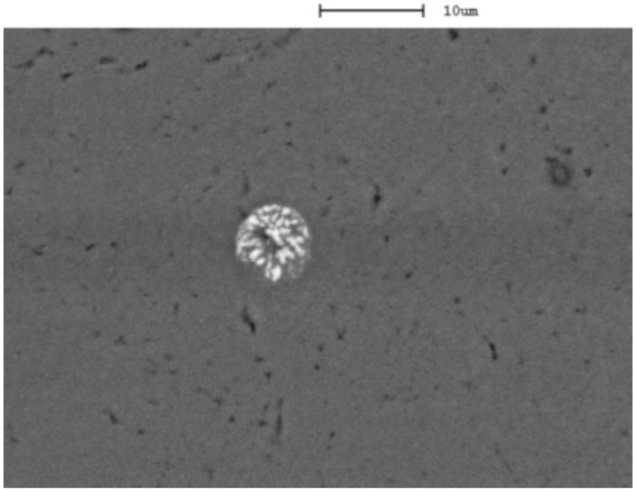


Figure 7: The SEM image of the specimen 1000 when applying 80V-magnetic field x2000.

The primary composition of the material stage varies since there diffusion changed in SEM investigations. With reference to the results of EDX, the levels of Fe dropped in bulk and C stages. Additionally, the levels of Scandium increased in the structure and Scandium stage which is exhibited in white in SEM pictures.

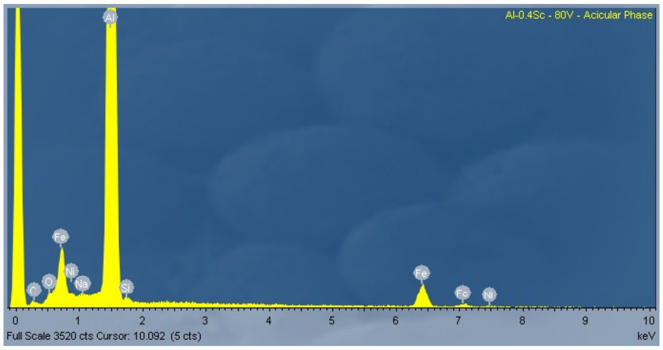


Figure 8: The acicular stage.

For more exanimations to the impact of raising the magnetic field fluxes, in the solidification process, a 100 V magnetic field was implemented. The optical scanning and SEM results in figure 9, 10 and 11 illustrate a plain scattered diffusion of dendritic grains in the minor structure which suggests that a lot of enough Lorenz force was executed to the microstructure and damage the dendrites leading to formation of tiny grains cuboid like structure was seen at increased accuracy of the SEM pictures which explains the rise in the Sc levels in the specimen.

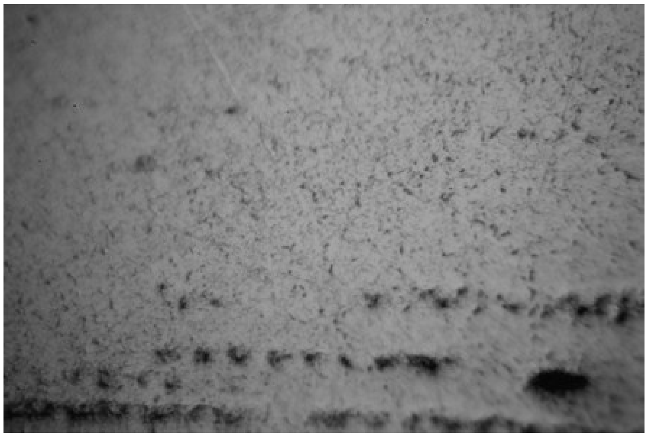


Figure 9: The optical scanning results of the specimen when applying 100V-magnetic field x800.

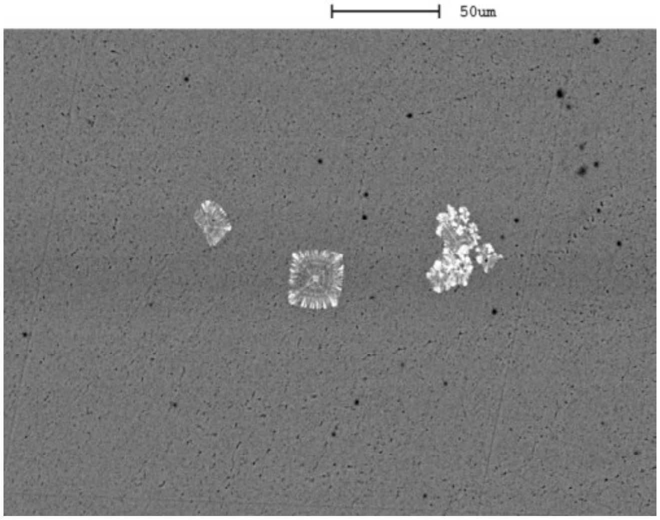


Figure 10: The SEM image of the specimen when applying 100V-magnetic field x1000.

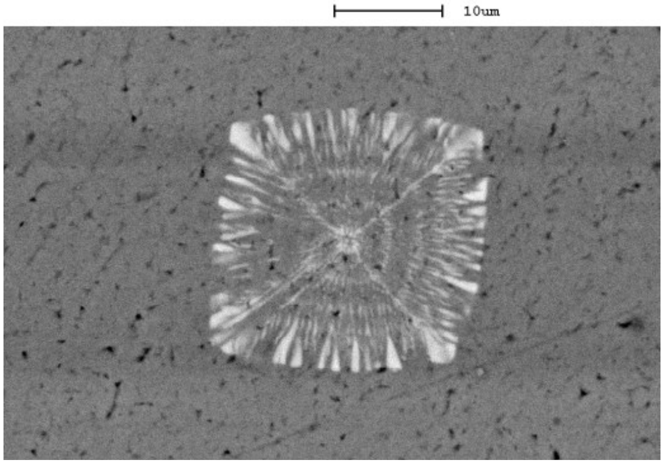


Figure 11: The SEM image of the specimen when applying 100V-magnetic field x2000.

EDX investigations aims to give an explanation on the change in the primary compositions of different stages as illustrated in the upcoming figure. A great increase in Sc levels was noted in the structure and the Sc stage. A rapid increase in Nickel and Fe is evident in the cuboid stage.

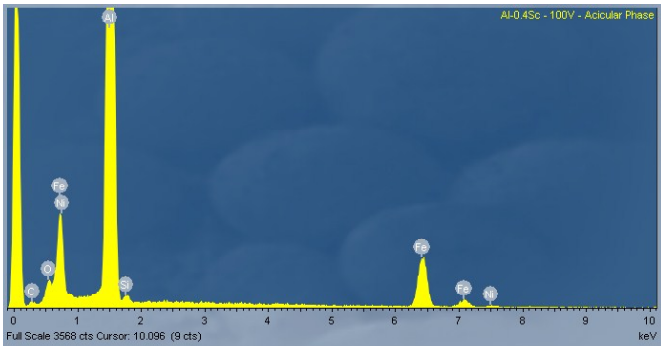


Figure 12: The cuboid stage.

Another rise in the executed voltage of a magnetic field was implemented and examined to illustrate its impact in the solidified microstructure. At dissemination of around 160 volts, essential dendrites develop in a scattered manner and are not visible in other locations in the specimen structure. This leads to grains purification alongside the generation of equalised dendrite grains on the specimen's structure. The comprehensive outcomes attained from SEM investigations illustrated that the executed electromagnetic waves greatly affected the solute distribution in the entire solidification process which thereafter affects the eutectic microstructure creation. Optical & SEM pictures attained at a voltage of 160 are demonstrated in figure 13 and figure 14.

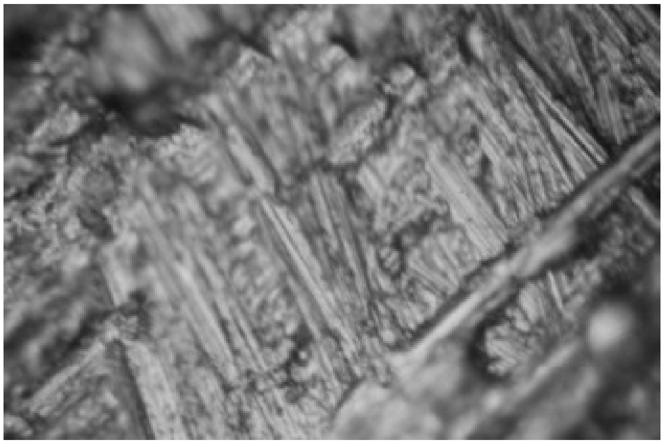


Figure 13: The optical scanning results of the specimen when applying 160V-magnetic field.

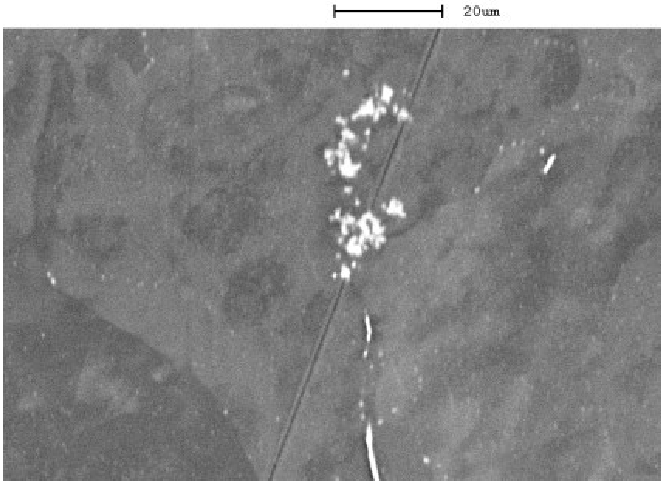


Figure 14: The SEM image of the specimen when applying 160V-magnetic field.

V. DISCUSSION OF ALL RESULTS

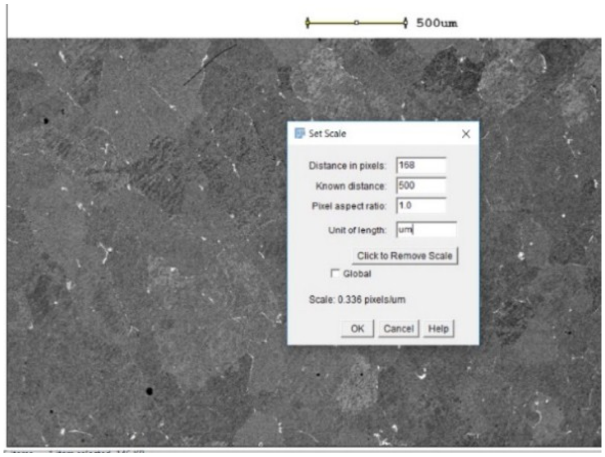
The results showed the microscopic structure that was achieved through the optical scanning process. The SEM and EDX tests on the original specimen show its construction before treatment. The results showed that the common dendrite matrix is where these bifurcations are combined. Large grains are formed with relatively large pores within the matrix structure. SEM results showed that the matrix is made of different physical stages from the bulk stage, acicular phase, matrix phase and Sc-clump stage. The key elements differ at these stages as EDX probes are used to present the existing components. In general, although the stage shows the components in the sample as a whole that is generated from Aluminium, oxygen, carbon nickel and Scandium. Likewise, Al is the primary component that increases in the matrix phase, while Al and Sc are the primary elements that increase in the white phase. In the acicular stage, there was an increase in the elements of Al and Fe.

The impacts of executing various PMF's adjustments for basic dendritic particulates were compared to the initial specimen. The executed voltages include; (60, 80,100 & 160) volts. At each voltage level, a high induction current together with high and adequate Lorentz forces are made within the Aluminium amalgamate due to pressure impact in executing wave magnetic fields. Lorentz force destroyed the dendrites' structure and thereafter causing a scattered diffusion in the dendrites. Also, purification, microstructure improving, mechanical efficiency enhancement and equalized matrix was attained. A lot of maximization was attained at these construction criteria as the executed voltage rose. In the undertaken examination in this research project, a PMF mechanism is brought on board as a universal means for creating the minor defection, microstructure together with the alloy of (Al-0.4 % Sc). The Specimen was then examined with no subjection to any magnetic field in the entire process of solidification, this was used as the control sample. Thereafter, it was examined upon executing a magnetic flux at varying intensities by adjusting the voltage levels, the voltage levels include; (60, 80, 100, and 160) volts. The impact of executing pulse magnetic field was tested through optical scanning, SEM and EDX microstructure examination procedures, the results found to be contrasted with the control specimen for the purposes of testing the impact of the PMF.

Through analyzing the attained results, it was concluded that subjecting a specimen to high levels of the magnetic field; caused a considerable change in the arrangement of solid to liquid together as compared to the control specimen. Also, an overall feature was seen in relation to grain purification when a specimen was subjected to a magnetic flux.

When the subjected voltage in the magnetic flux was increased, A tilt in the compass of lamellar eutectic development and a decline in the rough eutectic lamellar interspacing in the entire solidification process was observed that led to the production of a material possessing greater strength. When a low voltage of 60 volts was executed, a notable impact on configuration and dispersion in strengthened grains of the made mixtures is demonstrated.

By comparing the microstructure of the examined specimen made of the alloy (Al-0.4 % Sc), it has resulted that by increasing the voltage of the magnetic flux; the 3-dimensional morphology of the minor pores changed its dendrite construction to relatively equiaxed construction. The major cause for such change is because of the presence of forced convection introduced by the executed PMF damages the dendrites, pure sizes of grains, it also supplied the feed liquid and at the end cause a decline in the volume fraction of pores and improving the mechanical characteristics of the specimen. Regarding the size of grains and the volume proportion of pores at its basic stage, the two are dropped since PMF voltage rose. Dimensions of grains at different voltage levels were calculated by the image J (Fijii software). Enlargement scale must be modified according to the requirements stated at the microstructure capturing stage as illustrated in figure 15 below that demonstrates changes in the scale of the control specimen. Seven segment techniques were employed in order to establish the mean grain radius; therefore 7 segment means were executed by producing seven established lines and establishing intersections in every line. Figure 16 below exhibits specimens for controlling the specimen. The mean radius size is found as the overall length for various specimens with regards to the numerical value of intersections.



Distance in pixels: 168
Known distance: 500
Pixel aspect ratio: 1.0
Unit of length: um
☐ Global
Scale: 0.336 pixels/um

Figure 15: Adapting the microstructure scale of the control specimen.

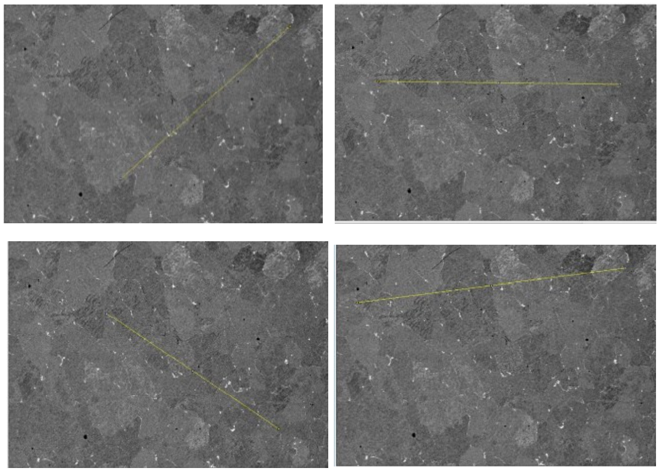


Figure 16: The segment lines of the control specimen.

According to the mentioned methodology, it was established that the mean grain radius was 90.30 ìm for set control specimen, size of grains at various magnetic fields were attained through the same steps using the used software, the size of the grain was greatly purified when a voltage of 60V was applied, it was observed that radius of the grain of the control specimen was 90. 30 ìm but upon applying a voltage of 60 V the grain size decline to a radius of 59.7 ìm .the impact of increasing the PMF is evidently seen in the table below(30, at 80 volts the diameter dimensions were further scaled-down as compared to the 60 V magnetic field to the radius of around 43.08 ìm .the mean dimeters for the grains were calculated for the remaining voltages of (100, 120, 140 and 160) volts and the diameters were (66.69, 58.04, 47.57 and 32.87) ìm respectively, according to these outcomes, the impact of executing magnetic fields on the microstructure can be clearly investigated. Figure 17 illustrates the grain size at different voltages to elaborate more on the scaling of the grain size.

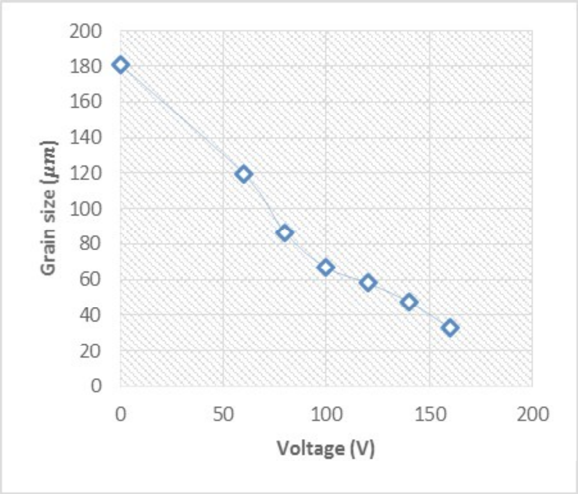


Figure 17: Grain refining against the executed volt.

In order to prove attained outcomes for this research as well as to adequately appreciate the contributions made by PMF, outcomes were contrasted with the existing research papers established of related projects. a special investigation with the objective of examining the pre-existing relationship between the size of grains and the volume fraction of pores in various conditions was conducted. The results were well demonstrated from the figure18 below. it was observed that amplifying intensity of executed magnetic flux caused a stepwise decline in volume proportion of minor pores together with a decline in grain diameter. in addition, the PMF found to have a unique function in grain purification and in enhancing incoming force. Actually, particulate purification was led to pile feeding promotion. Specifically, when the solid portion exceeds the minimum value, the dendrites begin forming a uniform network while grains become so large such that the tiny grains are able to easily pass within the entire dendrite network. As a result of this, the bigger gains are leave-pinned in the solidified skeleton together with an immature structure in the inlet channel. When magnetic flux is executed, the solidified skeleton is likely to get damaged due to applied Lorentz force in the entire process of solidification as well as purification of grain sizes.in addition, due to the stirring effects of the magnetic field; the particulate dispersion becomes more consistent and this is responsible for the consolidated equiaxed particles other than solidified skeleton such that, the molten metal can freely move to the front section of the surface by escalating feeding capacity and lowering the volume proportion. Also, repression of shrinkage in a magnetic field flux greatly led to different factors undermining grain purification, the improved feeding force that is introduced through the magnetic field together with their joined influence.

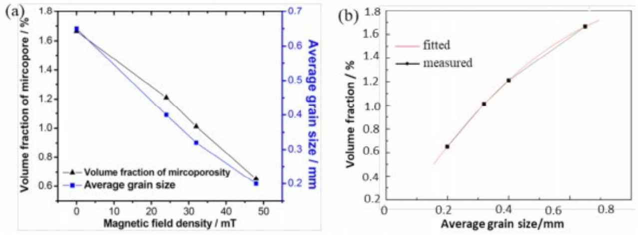


Figure 18: The effect of PMF on the grain size and micro-pore volume proportion in Al alloy .

VI. CONCLOUSIONS

the process of solidification plays a key role for all metals in adapting their mechanical characteristics, where various mechanisms can be utilized to regulate the solidification procedures like regulating rapid cooling or utilization of mechanical solidification mechanisms such as PMF. With regards to the previous studies, it was established that increasing the magnetic field flux, provide more purified grains. this resulted in the production of materials with good mechanical features. In this study; a laboratory task was embraced with initial samples prepared by melting the alloy while considering the various factors as illustrated in the experimental section. The initial specimen was treated by subjecting it to varying magnetic field flux and its impact on the solidification process of its microstructure examined thereafter compared with the initial instance by optical scanning, SEM and EDX evaluation criterion.

As per the attained results, in the presence or absence of magnetic field flux, it is generalized that, the microstructure of the initial specimen is found to be greatly dendritic alongside the big size of particles together with high porosity that compromised the mechanical properties. Since this specimen is treated by subjecting it to PMF at various fluxes, it was established that the subjection of Lorenz force to the dendrites rose when the voltage was amplified such that a lot of dendrites were damaged and proportionately improving the solidification process of the microstructure to form an equiaxed structure. an increase in voltage resulted in more improvements attained. PMF can be the optimum technique to enhance the performance of the produced metal and alloys.

In the future, it is recommended to investigate the reaction of different alloys subjected to different magnetic flux, in order to confirm the effectiveness of the stated curing method for all manufactured alloys.

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