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The Effects of Electric Pulse Modification on Eutectic Al-12.6%Si alloy.

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Abstract: *Al-Si alloy at eutectic region as the research object, Electric pulse modification (EPM) were used to achieve simultaneous refinement and modification of eutectic silicon phase, in order to analyze the mechanism of electrical pulse modification to the alloy and analyzed how the EPM affects the solidification structure and the corresponding properties. We get the conclusion by observing the microstructure of the sample, measuring the hardness, calculating the volume fraction and the average size of primary silicon at different pulse frequency and voltage. By using this process the particle size of primary silicon was reduced from 50 µm to a range of 5-20µm and the shape changes from acicular to fine fiber when compared with the conventional casting process. Also, the result of mechanical test showed that the hardness increase from 105HV-156HV with the change in pulse voltage at 700V peak value it therefore increased with 49% and at 1000V decline to 144HV with increased by 37% with homogeneous distribution of eutectic silicon.*

Key words: *electric pulse modification; Al-Si alloy; microstructures; primary Silicon phase;*

I. Introduction

The Al-Si alloys are the largest group of cast alloys due to their excellent castability. Addition of Si increases the fluidity and decreases the solidification shrinkage, resulting in an increase in castability [1]. A further advantage is that Si can be added without increasing the density of the alloy. Si increases the strength and stiffness, but reduces the ductility. Commercial Al-Si casting alloys have Si concentrations in the range of 5 to 23wt% [2]. Three different microstructures form depending on the Si concentration, i.e. the alloy can be hypoeutectic, eutectic or hypereutectic. The microstructure of the hypoeutectic alloys consists of α-Al dendrites which solidify first followed by the Al-Si eutectic. Eutectic Si in Al–Si foundry alloys has often a very coarse and plate like morphology, leading to poor mechanical properties, particularly ductility [3]. Primary Si particles form first in hypereutectic alloys followed by the Al-Si eutectic. The Si concentration of alloys used in the automotive industry often ranges between 5 and 10 wt% and they are frequently used in applications such as engine blocks, cylinder heads and wheels. Typical applications are cylinder liners, pistons and piston rings. However, the form, size and distribution of the primary crystal silicon in the solidification structure impact seriously the mechanical properties. The Si particles have a plate-like morphology in unmodified aluminum alloys, which act as crack initiators and have a negative influence on ductility [4]. The alloy ductility can be improved by changing the morphology of the Si towards a more fibrous form.

Physical approaches to the refinement of primary Si, including ultrasound [5, 6], electromagnetic stirring [7] and electromagnetic vibration [8] have been attempted with limited success. Treatments are localized within the melt and take of the order of ten minutes even within very small quantities of liquid. Therefore, a postulated, but representative model proposed by Wang [9] attempted to account for the operating mechanism of electric pulse modification (EPM) from only phenomenology and DLVO theory of colloids [10]. Using this technology the primary Si is improved in a certain degree through the electrical pulse modification on the melt [11-14].

Previous study of Al-Si alloy was fragments. Based on the previous experiments on Al-22%Si alloy, the influence of static duration on solidification structure is analyzed by high-frequency and high-voltage EPM at different pulse temperatures. The study aims at analyzing the mechanism of EPM on hypereutectic Al-Si alloy solidification structure and its inoculation fading. And also pulse temperature is one of the important factors to influence the modification effect [15].

Therefore, this paper is aim to analyze how does the electric pulse modification affects the solidification structure and the corresponding properties, which is expected to establish the relationship between the Si addition and the EPM response.

II. Materials and methods

Al-Si alloy in 8kw silicon-carbide were molten with the high purity graphite as the crucible material. After the temperature is up to a certain degree and insulated for 30min, and subsequent de-aeration with pure nitrogen, two columnar graphite electrodes with size of φ5 × 200mm will vertically inserted 50mm into the metal mold. The EP parameters were optimized as follows, 1000V peak voltage, 15Hz frequency and 30s treating time and taking a permutation of the parameter accordingly. Then the molten alloy was poured into a φ80 mm × 120 mm metal mould by manipulator at room temperature after 30s by EPM duration as in the (Fig. 1) below

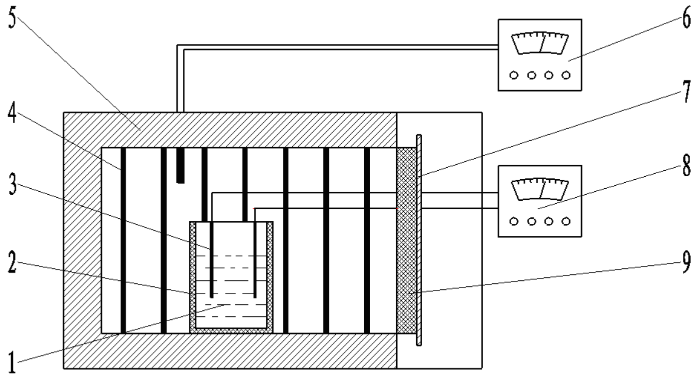


Fig. 1 EPM Process on Molten Alloys

1. Melt 2. Graphite crucible
2. Electrode 4. Element 5. Electric furnace 6. Temperature Controller 7. Metal board 8.EPM device 9.asbestos

The specimen used for micro-analysis were the central section being cut at 15mm from the bottom of the ingots and grand mechanically on 200,400,600,800 and 2000Cw grid or sand papers, polished and etched with reagent HCL or 0.5%HNO_3 solution at room temperature for 30s. Axiover200MAT metallurgical microscope was used to observed the samples microstructure and test the volume fraction of the primary silicon phase. J-2000N electron microscope was also used for microstructure observation to the former microstructure sample with HV-1000 micro-hardness instrument to test the micro-hardness..

III. Results and discussion

3.1 Microstructure

Typical resulting microstructures for Al-12.6wt%Si samples are shown in Fig.2. The sample has a microstructure characterized by an Al-rich dendritic matrix (α-Al phase) and a eutectic mixture in the inter-dendritic region formed by silicon particles, which are coarse and distributed in a flake-like morphology which are compared with treated and untreated by Electric pulse modification (EPM) with different pulse parameter at 750^{o}C of which Fig.2 (a) is the structure without being modified by EP.

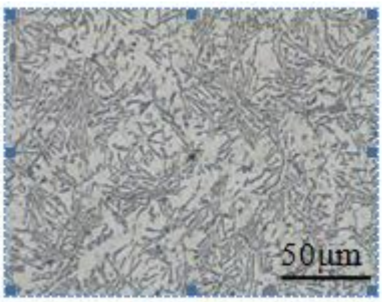


Fig. a

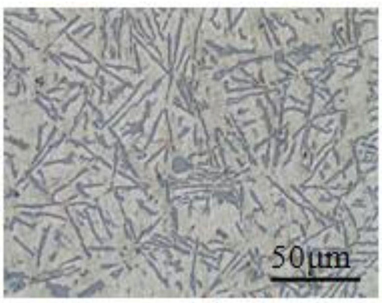
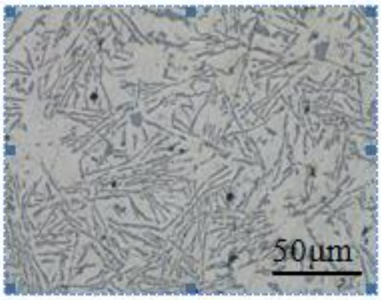


Fig. b



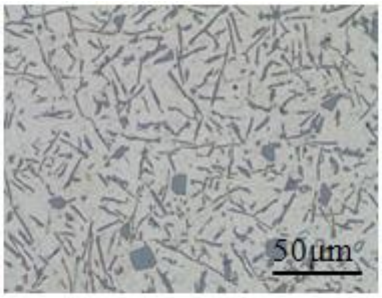
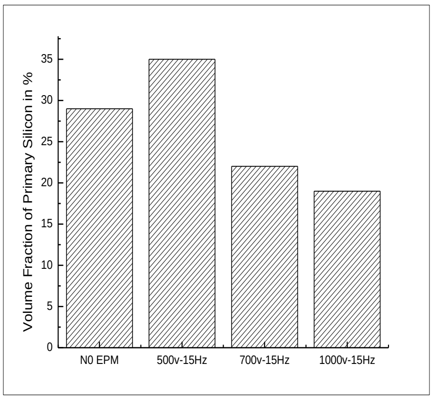


Fig. c Fig. d

Fig.2 Al-12.6%Si alloy Microstructure with different pulse parameter at specified temperature of 750°C in (a) Without EPM (b) 500V 30S 15Hz(c) 700V 30s 15Hz (d) 100V 30s 15Hz.

The Fig.2(a-d) above shows the microstructure of Al-12.6%Si alloy which comprises of treated and untreated sample, from (a) above the Primary silicon tends to assume different morphologies like massive crystals of geometric star like or dendrite shape and grow to some certain extent. After the dendrites impinge upon each other its mobility is restricted, inter-dendrite networks of eutectic silicon distributed in the matrix with the segregation state. It is well known that the dendritic refinement improves mechanical properties [16]. .In (Fig. 3b&c) contain coarse primary Si and eutectic Si morphology and (d) shows the refinement of eutectic silicon particles, the silicon has acicular and small amount of flake shape in (b) and the structure of (c) changes in size and size spacing, in (d) It is clearly observed that the resulting sample in Fig (d) exhibits a very refined microstructure neither porosity nor cracks have been observed on the treated surface, it has more fine grains. Therefore the convenient cast Al-12.6%Si treated with Electric pulse contained refined primary Si particles with avarege size of 5-20μm which changes from acicular to fine fibre shapes and are uniformly distributed in the matrix.



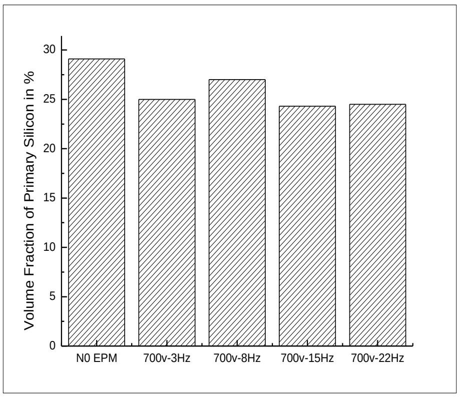
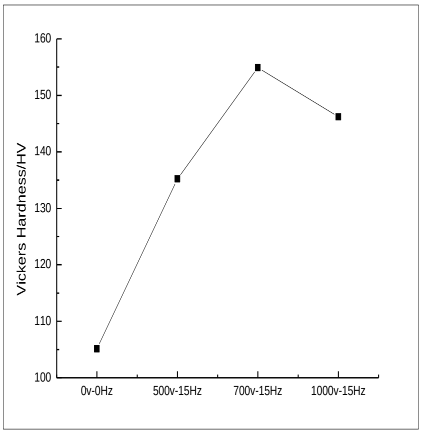


Fig 3(a) Fig 3(b)

Fig.3 (a) Shows the Volume Fraction of Primary Silicon at Primary Silicon at different Voltage in 750°C.

Fig.3 (b) Shows the Volume Fraction of Different Voltage in 750°C

From Fig.3 above shows the Volume fraction of Primary Silicon phase of treated and untreated samples, the primary silicon with size range of 5-20μm and the eutectic silicon with needle-like of range 5-50μm and eutectic spacing at the least value of 20μm or less in fig.(2). In fig.3(a) without EP treatment the Volume fraction of the sample is about 29.10% , when EP was applied at 500V-15Hz the Volume rapidly increased to 35.08% without time difference its increased with 20%, after the voltage increased to 700V-15Hz the volume fraction reduced to 22.52% and finally to 20.26% at 1000V which decreases to 24%. These shows that the volume fraction of the silicon phase changes with the change in pulse voltage its increases with the increasing voltage and then decrease with increase in pulse voltage, in Fig.3 (b) in an untreated sample is about 29.10%, when EP was applied with varying frequency it decreases and increases in the same manner which shows the effect of EP with the changes of certain parameters.



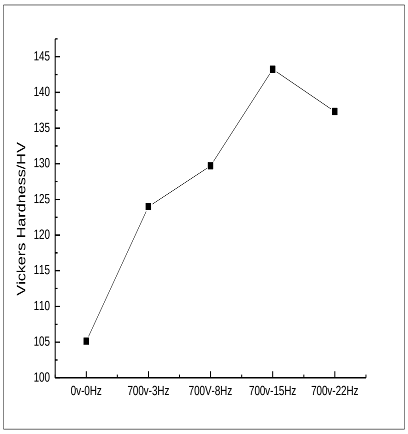


Fig 4(a) Fig 4(b)
Fig.4 (a) Shows the Vickers Hardness test with different Fig.4 (b) with the same frequency different
Voltage at 750°C.Voltage same frequency at 750°C.

3.2 Mechanical Property

Considering the Vickers Hardness test in the diagram (a) above which indicate that the hardness is at lower level without EPM in 105HV, hardness increases to 135HV when the Voltage is 500V-15Hz, with the increase in Voltage there is corresponding increase in hardness up to 156HV this indicate that the pulse Voltage and hardness are nearly proportional up to 700V-15Hz point and then start to decline to 144HV when the pulse Voltage was increased to 1000V with same frequency. This shows that the higher the Voltage the higher the thermal vibration in the melt, with increase in pulse voltage the number of primary silicon crystals increases and the range size of primary crystal silicon is 5-20µm with a blocky shapes which distributed uniformly. Grain was refined and its size change from 50µm to a range of 5-20µm which has many advantages to improved mechanical properties, better feeding during solidification, reduced and more evenly distributed shrinkage porosity, better dispersion of second phase particles, better surface finishing and other desired properties. The detail analysis was when the pulse Voltage was 1000V, the size of primary silicon reach up to 50µm which increases to 50%, at 500V the shape of eutectic aluminum-silicon was acicular, were the pitch distance was in range of 20-30µm the lower the pulse Voltage the more evenly distributed. At 700V the hardness of the matrix reached to peak at about 156HV which was related to matrix solubility and the shape of the silicon reduce to fibrous shapes. Meanwhile, pulse frequency also influence the silicon phase, at 700V-3Hz hardness increased with change in frequency but has no effect compared to change in pulse voltage as in fig.4(a) reaching up to 700V-15Hz peak then decline at 700V-22Hz, the width of the primary silicon was clearly decreased to its half. At constant Voltage with increasing frequency, the hardness of the matrix increases continuously and then decreases when it reaches 15Hz. This indicate that the electric pulse change the melt structure of Al-12.6%Si alloy that leads to an increased in Si-Si clusters, thus allowing the changes in the number of primary silicon and the distribution of atom clusters of the eutectic silicon was obviously changed. Therefore changes in the matrix hardness were related to the effects of the solute distribution of atoms alloy element.

IV. Conclusions

A study was carried out to investigate the influence of Electric Pulse Modification on Eutectic Al-12.6%Si alloy, its Microstructure analysis, Vickers hardness and the Volume fraction of the melt, the result shows that:

1. Electric Pulse is an efficient and physical technique to control the morphology and size of primary silicon grains, refinement and distribution of inter-metallic phases which promotes eutectic silicon modification.
2. The morphology of eutectic silicon was modified from dendrite shape in the samples without Electric Pulse to a coarse acicular plate like shapes and finally into a fibrous at 700v and 750°C.
3. Electric Pulse, changes the melt structure of Al-12.6%Si which leads to increased of Si-Si cluster thus allowing the change in the number of primary silicon and the distribution of atom cluster of eutectic silicon also changed.
4. Besides refinement, size and size spacing between eutectic silicon in Fig.2(c) decreased, and that effect increased with the increased in pulse processing Voltage.

Acknowledgments

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