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The Effect of The Melts shear DC Cast Over Aluminium alloy 6xxx

Galin Shlyakhov

Collage of engineering, American International University of Management and Technology, Hawaii

Abstract—**An experimental work was investigated in this project to assess the effect of The Melts shear DC cast over aluminum alloy 6xxx, where the microstructure and hardness analysis was obtained. The samples of 6082 Al-alloy was received from the university lab for both normal DC cast and Melts shear DC cast with dimensions 12mmx8mmx8mm . The hardness of the Melts shear Dc cast is higher than Normal DC cast, where the high hardness for the Melts shear DC can be explained according to the finest of its grains. Two types of heat treatment were used for both types of samples which are the aging and solution heat treatment. The solution heat treatment was obtained at temperature 500C for 6 hours, and the aging heat treatment was obtained for different temperatures (150C,200 C and 250C). The results shows the optimum heat treatment can be used to improve the hardness is aging heat treatment at temperature 200 C for 6 hours.**

Keywords—microstructure, Melts shear, normal DC, hardness

I. INTRODUCTION

Nowadays, there is a high demand for Aluminium alloys in structural applications such as automotive, aerospace, constructions, and consumer electronics. This is due to the good properties of aluminium alloys. These properties have drawn the attention of several manufacturing sectors to replace their products' materials with AL-Alloys. For example, there is a widespread tendency toward replacing steel with Al-Alloys. The only problem with that are the high cost requirements of the production of AL-Alloys. Despite this fact Al-Alloys have low weight, the great performance of corrosion, and very high strength. An example of mechanical properties of 6082 are: (Density=2.7007(kg/cm^3), Thermal conductivity=169.891-219.859(W/mK), Modules of elasticity=70000MPa, yield tensile strength=240Mpa, and elongation at break= 6-9%) [2]. Moreover, 6000 series alloys are generally used in wrought conditions as much as other Al-alloys due to their suitability by heat treatment processing. Nevertheless, convent ally this needs a DC casting, rolling , and annealing manufacturing ways which require a high cost and time. In this experimental project, a full analysis and examination of a new route of shear assisted casting of 6082 Al-alloy is going to be undertaken under consideration to estimate the mechanical properties, performance of corrosion, microstructure, and heat treatability of the new introduced process shear assisted casting). Furthermore, the microstructure property and heat treatability of the melt shear processed alloy will be compared against conventionally processed alloy to identify the benefits or drawbacks of the new processing rout [3].

Aluminium can be easily deformed without occurrence of any failure. This advantage allows for aluminium alloy to be easily formed by machining, extruding, rolling, drawing, machining as well as other mechanical processes. Furthermore, it can be used in cast process to produce high tolerance casting. Cold working, heat-treating as well as alloying can be used to enhance the aluminium properties. The tensile strength for the pure aluminium metal is 90 MPa and it can typically be increased to more than 690 MPa for heat-treatable alloys [1].

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TABLE 1: MECHANICAL PROPERTIES OF ALUMINIUM ALLOYS [1]

Mechanical Property	Value
Tensile Strength	300 Min MPa
Proof Stress	255 Min MPa
Hardness Brinell	91 HB
Elongation A50 mm	9 Min %

The Al alloys 6xxx series are produced basically for extrusion process. For 6xxx alloys, the type 6082 with high percent of magnesium content as well as silicon is actually the strongest alloy that can be used for several applications in aircraft, building as well as automotive industry. Moreover, the surface zone for the previously mentioned alloy, when it produced using the direct chill casting (DC), has very important role in the extruded materials quality. Even the use of air–slip method in the direct chill casting can improve the quality of the surface for some extent; there are large different variations in the surface appearance as well as the surface defects may be found in the alloy. Furthermore, the surface segregation depth could be considered as very important factor for the surface quality as well as can be also defined as layer in that the contents of the alloy different from the bulk content [1]

Direct-chill casting technique consists of the mould which cooled by water as well as can be closed by bottom block which placed at the closed at the bottom. Melt feed to the mould cavity from the top side and the bottom block is drawing the solid billet to the down, when the casting melt feed as well as speed rate were balanced in this way as in order to hold a constant melting level inside the mould. Moreover, the heat can be extracted to the billet solid part by water spraying onto the billet surface as it is already drawn down, and then the billet should be immersed into a water pit for more intensifying of the cooling.

The DC-casting advantages are its ability of billet producing of very fine as well as homogenous structures as well as high surface quality, while being efficient as well as cost effective. Furthermore, because of the thermal gradient is very high between the surface and the center of the billet that produced from the cooling mechanism, a lot of problems can happen during the process of DC casting like the bleed-outs, severe macro-segregation, coarse columnar microstructure, hot tearing as well as the crack that resulted from the large thermal stress [6].

intensive shearing melt of DC Casting process can be achieved when the high shear device is submerged in the sump as illustrated in the following figure. The device used for high shear is a mechanism of rotor–stator, when the rotor having a lot of blades is rotating at very high speed within a cylindrical stator as well as several small holes [7].

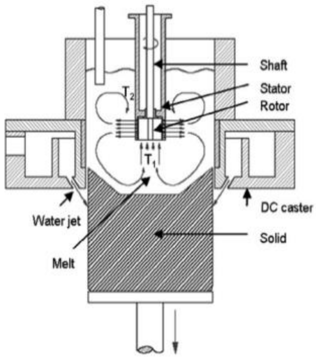

Figure 1: Schematic show the DC new casting technique by submerging the device of high shear rotor–stator in a sump of a conventional DC casting setup [7].

The main advantage of the previous high shear equipment is that provides a very useful combination of the distributive as well as dispersive mixing actions and keeps the melted surface very stable for avoiding the possibility of oxides entrainment as well as increased the intake hydrogen from the atmosphere. Moreover, the high shear device applications in the chill casting method have the following effects [8]:

- Firstly, the action of dispersive mixing will disperse oxide films as well as inclusions in the melt material into individual as well as fine particles, eliminating/ reducing their harmful and bad effects on the processes as well as quality of castings.

- Secondly, the action of distributive mixing can be provide a uniform melt in the sump, homogeneous chemical composition as well as uniformly distributed as well as well dispersed heterogeneous sites of nucleation.

- Finally, the interaction of the macroscopic flow of melt, for example, the paths of laminar flow paths as illustrated in figure 1 as well as the front solidification can be provided a shallower as well as

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flatter sump profile as well as the ability of increasing the cast speed.

According to [9] the uniform as well as fine microstructure is desired for aluminium billets that produced by the process of direct-chill (DC) casting. Generally, this can usually be achieved by the addition of grain refiner during the process of DC casting. The physical approach was demonstrated in this paper for refining the grain of DC cast billets. The process of intensive melt shearing was applied to the direct-chill casting by submerging high shear rotor–stator device in DC caster sump. It was also observed that DC casting process with the intensive melt shearing was achieved by the reduction of one order grain size without adding chemical grain refiners.

By adding such fine as well as equiaxed grain structure, the Al alloy can be enhanced by the heterogeneous nucleation for the Al billets can be enhanced as well as grown under the conditions of reduced gradient temperature as well as increased growth velocity. By the static mould experiments help with the melt intensive shearing, such equiaxed as well as fine grain structure for the Al billets may be attributed to improve the heterogeneous nucleation as well as grow with the conditions of reduced temperature gradient, increased growth velocity as well as solute redistribution. It was believed that the dendrite fragmentation can play role through the DC casting steady state when using intensive melt shearing[9].

Different heat treatment methods can be used for 6802 aluminium alloys [14] which are:

- Homogenisation – the process of segregation removal by heating the produced pieces after casting process.
- Age hardening or precipitation (alloys 6XXX, 7XXX as well as 2XXX).
- Annealing – this process can be used after the operations that have cold working for softening work-hardening alloys (3XXX, 5XXX as well as 1XXX).
- Heat treatment by solution before the precipitation hardening alloys ageing.

This project aims to compare 6082 alloy manufactured through melt shear DC cast and Conventional DC cast in terms of microstructure, property and heat treatability of the alloy to investigate if the new manufacturing method improves the microstructure and property of the alloy.

II. EXPERIMENTAL METHOD

a. Samples preparation for microscopy

The samples of 6082 Al-alloy was received from the university lab for both normal DC cast and Melts shear Dc cast with dimensions 12mmx8mmx8mm.

The Automatic Buehler mounting press machine was used where each sample was mounted with black conductive material, then the Grinding was obtained using (LabPol-5) grinding machine. The Silicon Carbide foils (SiC) were used for the grinding and the types are from coarsest to the finest, it's worth to mention that, the grinding process is used to obtain specimens with flat surface, where different grit sizes (SiC foils) were used, which are (120grit, 500grit, 800grit, and 1200grit). The water was used to remove the remaining scratches during the grinding process. After each step the specimens are cleaned by water and ethanol. The Etching of samples was obtained using chemical solution contains:

- 100mL water.
- 4g Potassium permanganate.
- 1g NaOH.

Actually the HF solution which should be used for Etching is hydrofluoric acid where this chemical solution is very dangers so the previous solution was recommended by the supervisor.

b. Microscopy of samples

The Optical microscope was used to study the microstructure for microscopy of samples, where the capturing magnification was (20μm, 50μm, and 100μm)m the microscopy of samples was obtained before and after heat treatments.

The grains size was measured using linear intercept method, therefore, seven random lines were drawn on the image of microscopy, and the ratio of number of intercepts to lines length was evaluated.

c. Heat treatment experiments

Two types of heat treatment were obtained which are solution heat treatment and aging heat treatment. 32 specimens were treated using solution and aging heat treatment (16 specimens for normal DC Cast and other

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specimens for Melts shear DC cast) , for solution heat treatment ,the specimens were treated at temperature 500℃ for 6 hours. The specimens were treated using aging heat treatment for different temperature and time as shown in the following table.

TABLE2: THE HEAT TREATMENT CONDITIONS FOR AGING HEAT TREATMENT

Temperature (℃)	**Time (hours)**
150	3,6,9,12,16,18, 20,22
200	2, 4, 6, 8,12
250	2, 3, 4, 6,8, 10

It's worth to mention that; the samples were protected from oxidation using graphite powder. After heating the samples for the suggested time, samples were qunshed to be cooled down, where the quenching is rapid cooling heat treatment , the quenching is used to get fine grains with high hardiness. After heat treatment the samples were investigated for microstructure and hardness testing.

d. Hardiness testing

The hardness testing was obtained using INNOVA testing rig where two specimens were tested before the heat treatment (Melt shear Dc and normal DC cast) also the Hardness of samples measured after heat treatment . the hardness was measured for Vickers hardness.

III. RESULTS AND DISCUSSIONS

a. Microstructure and hardness of DC cast samples with and without melt shearing.

The results for the microstructure was obtained for the normal DC cast and Melts shear Dc cast, Figure (2) shows the microstructure of the normal DC cast where the images were captured at different zooming (20μm) the size of grain boundaries is larger than the grains of the Melts shear Dc cast as shown in figure (3), this point validated that; the Melts shear Dc cast has finest grains than the normal DC cast.,

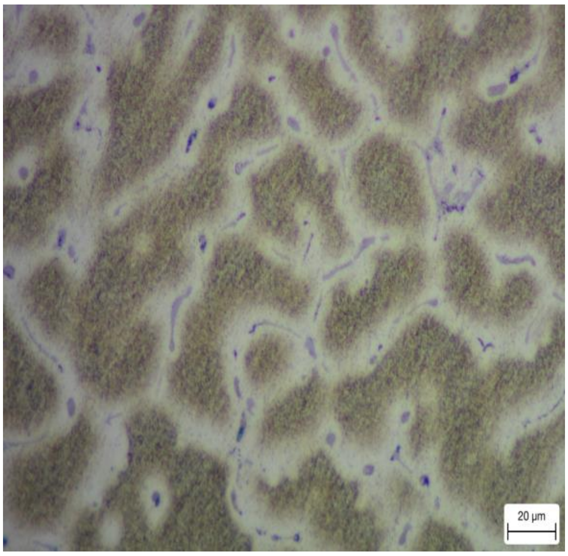

Figure 2: The microstructure of normal DC cast. (the grains are Al and the second phase in the grain boundary are complex eutectic of Mg2Si and Si)

The grains size was measured using intercept method, the grain size for Melts shear DC cast about 3.5μm, and 5.6 μm for the normal DC Cast.

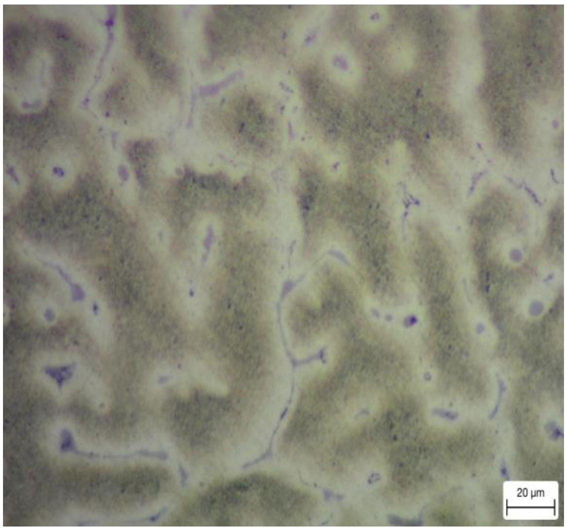

Figure 3: The microstructure of Melts shear Dc cast (the grains are Al and the second phase in the grain boundary are complex eutectic of Mg2Si and Si).

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As mentioned before ,the hardness testing was obtained using INNOVA testing rig ,Two specimens were tested before the heat treatment; the results for the hardness are 82.93 for the normal DC Cast and 97.97 for the Melts shear DC cast. It can be noted the hardness of The Melts shear Dc cast is higher than normal DC cast, where the high hardness for the Melts shear Dc can be explained according to the finest of its grains.

b. Microstructure evolution following solution treatment and aging

The following figures show the microstructure when solution heat treatment was implemented.

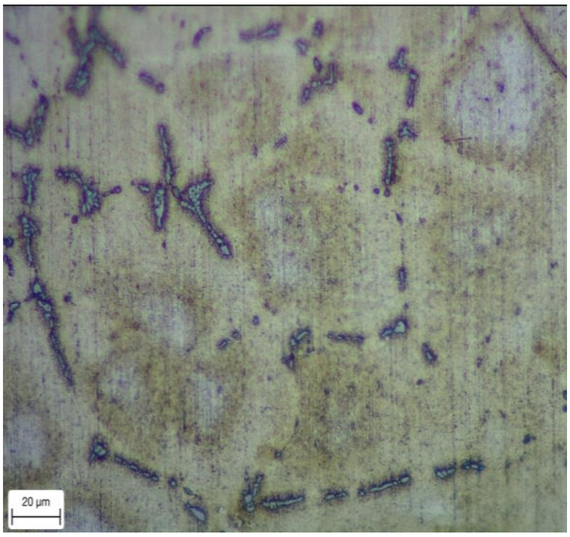

Figure 4: The microstructure of Melts shear DC cast sample after solution treatment. the grains are Al and the second phase in the grain boundary are complex eutectic of Mg2Si and Si

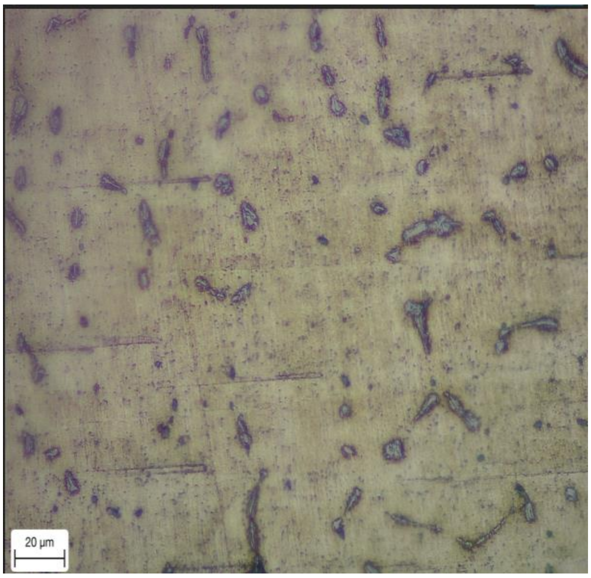

Figure 8: The microstructure of the normal DC Cast sample after solution treatment. the grains are Al and the second phase in the grain boundary are complex eutectic of Mg2Si and Si)

Using intercept method the average grain size for the Melts shear DC cast about 4.1μm, and 6.2 μm for the normal DC Cast. As shown the grain size of the Melts shear is less than the normal DC cast.

For aging heat treatment, the microstructure of the different specimens are shown in figure 6 and 7 where the grain size were measured using intercept techniques, the grain size for Melts shear DC cast about 2.9μm, and 4.3 μm for the normal DC Cast. As shown the grain size of the Melts shear is less than the normal DC cast.

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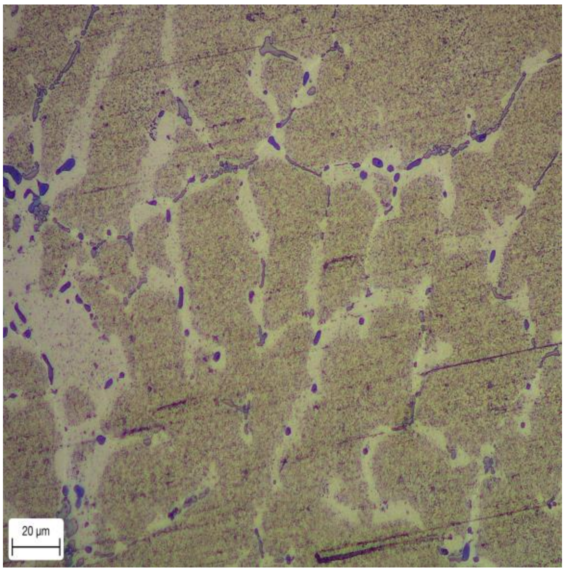

Figure 6: The microstructure of Melts shear DC cast (aging treatment 10hrs). the grains are Al and the second phase in the grain boundary are complex eutectic of Mg2Si and Si)

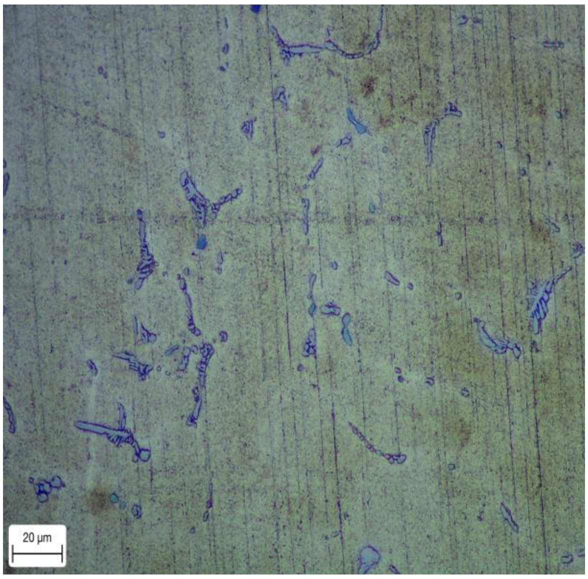

Figure 7: The microstructure of normal DC cast for aging treatment /10hrs(aging treatment 10hrs). the grains are Al and the second phase in the grain boundary are complex eutectic of Mg2Si and Si)

c. Hardness evolution through heat treatment with and without melt shearing.

The hardness of the specimens after solution heat treatment was recorded as 67.23 for Normal DC Cast and 71.51 for Melts shear DC Cast as shown in table 3.

TABLE3: THE HARNESS OF SAMPLES BEFORE/AFTER SOLUTION HEAT TREATMENT

	Hardness before heat treatment (HV)	**hardness after solution treatment (HV)**
Normal DC Cast	82.93	67.23
Melt shear DC Cast	97.97	71.51

The hardness was measured for different normal DC cast samples at the different temperature and times and plotted as shown in figure (10).

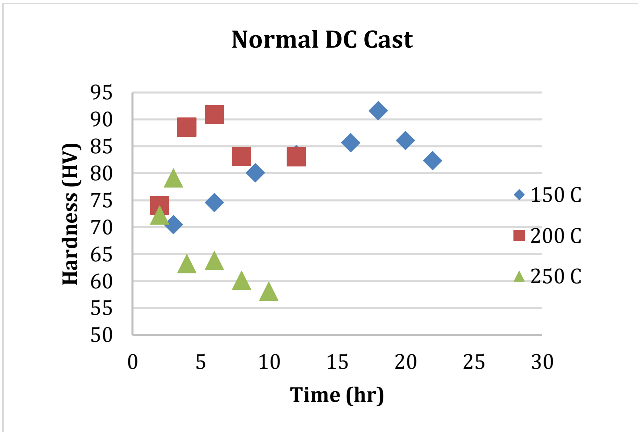

Figure 10: The hardness of the normal DC cast

According to the results of the hardness the optimum value of hardness at each temperature for the normal DC cast is shown in the following table.

Table .3: the optimum time for aging treatment (Normal DC)

Temperature (°C)	Time (hours)	Hardness (HV)
150	18	91.6
200	6	90.86

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250	3	79.12

The same procedure was used for the Melts shear DC where the hardness (HV) was plotted vs. heat treatment time as shown in figure (11)

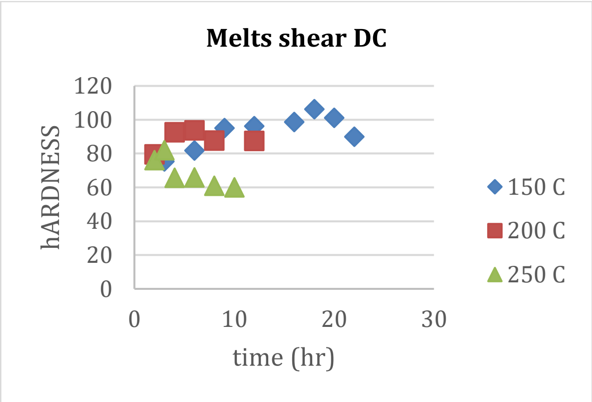

Figure 11: The hardness of the normal DC cast

The optimum value of hardness at each temperature is shown in the following table.

Table .4: the optimum time for aging treatment (Melts shear DC)

Temperature (°C)	Time (hours)	Hardness (HV)
150	18	106.21
200	6	93.63
250	3	81.99

d. Influence of melt shearing on microstructure, property and heat treatability

By comparing the difference optimum times for each experiment it can be concluded the optimum time to achieve high hardness is 6hr at temperature 200C. The hardness of specimens for aging heat treatment also are higher than the values of hardness of solution heat treatment. Table (5) shows the fitting equations for the different experimental measurements where these equations can be used in future by other researchers to find the value of hardness based on the heat treatment time.

Table .5: the fitting equations

(°C)	Case	Hardness (HV) Where t: the time(hours)	R^2
150	Normal DC	$-0.0083t^3 + 0.2202t^2 - 0.2496t + 69.702$	94.07
200	Normal DC	$0.1687t^3 - 3.8903t^2 + 26.368t + 35.285$	98.91
250	Normal DC	$0.1357t^5 - 4.0204t^4 + 44.826t^3 - 232.39t^2 + 549.81t - 396.42$	99.05
150	Melts shear DC	$9E\text{-}05t^6 - 0.0078t^5 + 0.2517t^4 - 4.021t^3 + 32.798t^2 - 123.61t + 241.05$	99.89
200	Melts shear DC	$0.1472t^3 - 3.3898t^2 + 22.946t + 45.876$	93.87
250	Melts shear DC	$0.1377t^5 - 4.0671t^4 + 45.2t^3 - 233.53t^2 + 550.13t - 391.06$	99.91

As shown before the Melts shear DC has hardness higher than the normal DC , where other researches were obtained to discuss the influences of heat treatment and Meltsheaing on the mechanical properties of AL-6082 such as [4] who studied the influence of the temperature of solution heat treatment on the mechanism as well as ageing kinetics for the two commercial types of wrought aluminium alloys 6082 as well as 6005 was also analyzed. Moreover, the alloys were exposed to heat treated -T4 process at wide temperature ranges from 510°C to 580°C as well as then making the process of natural ageing at the room temperature. Furthermore, Brinell hardness test was conducted on the alloys to examine the effect of time of ageing on the behavior of precipitation hardening. The aluminium alloys microstructure changes were followed ageing during 120 hours was inspected by metallographic as well as transmission electron microscopy. The other objective of this investigation is to specify how extrusion process affected on the mechanical properties as well as the microstructure of the previous aluminium alloys. The tensile tests were conducted for this purpose. The following table shows the mechanical properties 6082 alloy.

According to previous studies it can be concluded:

- The investigated hardness for 6082 alloy can generally be more sensitive for the cooling conditions and to the

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homogenization time. The highest hardness has been acquired in the cooled water.

- It found that a higher Rm value was got after the process of extrusion forging than the as-cast state process.
- It was found that the Mg2Si compound is readily precipitates after the solution treatment during the cooling process. Furthermore, the distribution as well as amount of particles is depending on the variant of cooling process. Very fine Mg2Si dispersed precipitates were found in the air cooled samples.
- The ageing hardness as well as kinetics for the studied 6005 aluminium alloy was not depending on the temperature of the heat treatment solution.

The effect of Melt shearing also can be noted according to [12] who studied the process of melt shearing refines the SDAS as well as the grain size for aluminium alloys 6802. When the cooling rate is increased, the SDAS as well as grain size for aluminium alloys 6802 are refined. The process of melt shearing can improve the aluminium 6802 alloys as well as the intermetallic particles of Al6Fe. Furthermore, the hardness is decreased when increasing the times as well as cooling rate of the melt shearing process[12].where the periodic melt shearing as well as cooling rate effect on the aluminium 6802 alloys was investigated. The examinations of the microstructure were made by X-ray diffraction, scanning and optical. The result of this experiment suggested that the melt shearing higher than the point of melting can generally refine the structure for the alloy as well as improve the intermetallic morphology phases and; the refinement the can be increased by increasing the shearing time. Moreover, when the cooling rate is increased by reduced sections, . The hardness test results presented that increasing the cooling time as well as rate for the melt shearing can reduce the aluminium 6802 alloys hardness.
Other researchers focused on the influence of heat treatment on the normal DC cast like [1]who studied the Characteristics of tension elongation and strength of normal DC cast, s6 however the maximum tensile strength obtained 90% of the identification because the initial alloy Mg content was lower than the commercial identification. Also , the normal cast 6082-T6 strengths surpassed overall the T6 strength goals of the described alloy however as a result of porosity that is produced through elementary melting over resolution of the treatment of heat as well as the eutectic current fine intermetallic needles, the elongation accomplished 36% of the lowest demand. The 7075 Normal cast produced strength surpassed the demand as well as the maximum tensile strength accomplished 97% of the identification; although the elongation obtained 46% of the lowest demand likewise as a result of the porosity of elementary melting that produced over the operation of resolution heat treatment.
According to [14] the effect of solution treatment was investigated using AL6082, , this process was compared with the procedure of conventional rolling to evaluate variations in the terms of mechanical properties, texture as well as the resulting microstructure.
In order to limit or avoid the recovery occurrence, all the rolling were produced at the room temperature. as well as micro-hardness tests were conducted also to check the texture. Moreover, the investigations of the experimental tests showed that asymmetric rolling process in the regime of SPD must readily be promoted the produced ultrafine grain structure as well as the texture different compared with the conventional rolling process.

IV. Conclusion

The conclusions can be summarized as following points:

- Aluminium 6xxx alloy has medium strength properties as well as has good corrosion resistance. Furthermore, it has also the highest strength and it is considered a structural alloy.
- The 6082 alloy is commonly used in plate form for machining process.
- The samples were prepared to testing using mounting, grinding, polishing, and finally Etching.
- The proposed chemical solution for HF solution which should be used for Etching is hydrofluoric acid which is very dangers acid, so the an alternative chemical solution was used
- .The results for the microstructure before heat treatment shows that; the size of grain boundaries for normal DC cast is a larger than the grains of the Melts shear DC cast.
- Two methods of heat treatment were obtained which are the solution heat treatment and aging heat treatment.
- It can be noted the hardness of The Melts shear DC cast is higher than normal DC cast, where the high

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hardness for the Melts shear DC can be explained according to the finest of its grains.

- The hardness of the specimens after solution heat treatment was recorded as 67.23 for Normal DC Cast and 71.51 for Melts shear DC
- For aging heat treatment the optimum temperature was selected is 200C for 6 hours, where the hardness of specimens for aging heat treatment also is higher than the values of hardness of solution heat treatment.

V. Recommendations for Future Works

The researcher recommends the following points for any development in this field.

- Studying the effect of cooling temperature after heat treatment, also the type of coolant.
- Preparing tensile testing for the samples after heat treatment to measure the tension characteristics and compare it with the mechanical properties before treatment.
- Studying the cold work of the samples before and after each type of heat treatment. Acknowledgement

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