Effects of Dynamic Solidification on Properties of Die-Casted Alloys

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I am thankful to my Creator Allah Subhana-Watala to have guided me throughout this work at every step and for every new thought which You setup in my mind to improve it. Indeed, I could have done nothing without Your priceless help and guidance. Whosoever helped me throughout the course of my thesis, whether my parents or any other individual was Your will, so indeed none be worthy of praise but You.

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Abstract

Gravity die casting using low frequency (0-45Hz) mechanical vibration of aluminium alloys was conducted. In order to improve their microstructure and mechanical properties of aluminium alloys. the vibration given to the mould is in vertical axe. Columnar rod specimen of diameter (10mm, 15mm & 20mm) were produced in vibrating die to investigate the vibrational and cooling effect during casting. The acceleration during the experimentation ranges from 0.5g to 1.5g. During mechanical vibration the rate of cooling increase with increase in vibrational frequency. The dendrite produced in the outer casting region decresed by vibration, and with the increase in vibration frequency it also decreased. The main purpose of vibration is to increase the nucleation and thus produced more homogeneous metal structure. Grain analysis and other mechanical properties were investigated on samples with vibration and without vibration in order to realize the vibration effect.

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Chapter 1

Introduction

1.1 Background and Motivation

Casting is very old manufacturing process for the preparation of metal products, in which pure liquid metal is poured into the mold and allow it to solidify in cavity of that mould.. All of the manufacturing process related to casting. Casting process is very much cheaper due to its simplification and versatility of procedure. The good quality casting depends upon the flowability of molten metal and other process parameters involved in casting. The totality of features of metals and alloys begin to work by a very important operation, that of solidification. Dynamic Solidification is the process that gives required shape and structure to the products. Presently the solidification process has practiced a rapid development in casting specially for nonferrous alloys. [1]

Effect of external process parameters like material of mold, mechanical mold shaker and temp during pouring on wear & hardness resistance of AL-SI alloy. Different types of vibration are applied during solidification of metal casting. Several researchers studied the vibration effect on casting specially on microstructure and dendritic coherency of material, reduced porosity is the effect of of degassing in molten metal include refinement of grains, dendrite fragmentation. Current study recommends that, vibrate the casting mold till to solidify is one of the significant process for production of well improved morphology structure, reduced amount of shrinkage and. surface finish. Mold conditions such as frequency of vibration and pouring temperature, and other variables are reasons that would have a great influence on the properties and microstructure of the cast [2].

Aluminum is the most abundant and very common metal of the earth's listed in third very common material on earth that comprises of 8% of crust. Due to its flexibility and versatility, aluminum is the second most used material after steel grades, every year approximately 29 million tons of aluminum is required through globe. Its main alloy components with copper, zinc, magnesium, lithium, silicon and manganese. Aluminum has almost three hundred wrought alloys, 50 are used commonly in industries. The different properties of aluminum and its alloys make it more attractive, economical and versatile material to be used for wide range of purposes [3].

Vibration process is a supplementary method that is frequently useful during solidification of macro- and microstructures improvement and subsequently their mechanical properties. Vibrational phenomena work the treatment of cavitation produced during solidification and its attributes. The various ranges of aluminum temperature is between 649oC – 750oC. Pouring temperature has a major effect on production of good quality cast parts. Pouring temperature lower than the required optimum value, mould is not filled properly because riser is solidified earlier the casting which leads to misrun defect in casting. Pouring temperature exceeds than the optimum value, shrinkage in casting occurs and wrapping of mould [4].

Vibrational analysis is one of the most significant and cost-effective approach to melt processing methods using external fields. As studies shown in different researches that, the vibration dealing of different metallic melts has a numeral advantage, including dendrites destruction and degassing. grain size was reduced experimentally showing that to increase in vibrational frequency up to a certain level [5].

Die casting is most important and widely employed in mass production and manufacturing of various automotive and industrial components, where the core advantages are mass productivity of components with complex geometries and thin walls. Though, Die casting for aluminum alloys parts is restricted to a critical level due to defects and problems corresponding to material performance [6]. It is studied that the vibration and the distress of liquid melt during solidification can reduce the dendritic coherency and improve grain size. Many other vibration procedures such as ultrasonic vibration, mechanical vibration, and electromagnetic vibration and electromagnetic stirring have been established and testified to improve the grain size of castings. Though, the real-world application of procedures is very limited, because due to intricate process and expensive apparatus such as magnet coil, ultrasonic horn, and superconducting magnet [7].

1.2 Problem Statement

To minimize the defects during die casting which involves different process parameters. Quality of casting is influenced by varying process parameters, among these one have the most influence. Optimization of process parameters is necessary for casting.

1.3 Objective

The final goal consists in an improvement of the mechanical performance of die castings and at this purpose a non-dendritic microstructure is preferable The objective of this research is to analyze microstructure and strength of the ingots will be evaluated by optical microscopy and Tensile testing.

1.4 Scope

The scope of research is to develop defectless and stress free alloys using Mechanical vibration in mold.

1.5 Research Methodology

Qualitative research approach has been adopted in this thesis. A comparative analysis with master part (free of defects) alongwith its root cause analysis using Taguchi analysis vis-à-vis experimentation has been carried out after eradication of various defects based on Taguchi results.

The thesis is structured as following:

Chapter 1	Introduction
Chapter 2	Literature Review
Chapter 3	Materials and Methodology
Chapter 4	Testing and Sampling
Chapter 5	Results and discussions
Chapter 6	Conclusion & Future Works

Chapter 2

LITERATURE REVIEW

2.1 Background

The best procedure of essential deficiency identification in a casting is high recurrence vibrational examination as its breaking point changes smooth and rapidly in the beginning phases of deformity development. Mechanical vibration is straightforward one because of its simpler authority over its procedure control boundaries. A few scientists applied ultrasonic and electromagnetic vibration and investigate their impact on molding. Experimentation with mechanical mold shaking to modify the as-cast metallography structure of cast segments go back to late eighteenth century. The prior reviews found that use of mechanical vibration during hardening of steel caused refinement of austenite particles.

There are mainly three types of vibration.

1) Mechanical Vibration
2) Ultrasonic Vibration
3) Electromagnetic Vibration

2.2 Mechanical Vibration

2.2.1 Introduction

All in all, vibration is the movement of particles. Popular technique, the entire mold is put into vibration by mean vibration source. Even though the utilization of mechanical vibrations permits constrained degrees of freedom to the administrator, it is the most encouraging technique for applying vibrations to solidifying melt because of its straightforwardness and the toughness of the equipment required for generating vibrations.

2.2.2 Literature Review on Mechanical Vibration

Nagaraju et. al. [1] investigating that vibration mould during casting causes shrinkage of metal , surface finish, improved morphology, and a smaller chances of hot tearing. The work includes the result of vibrating during solidus of Al 356 for changed standards frequency at a static pouring temperature to understand the change in internal structure and mechanical properties. The Al 356 casting takes arranged in a lead mould with both conditions with/without shaking. dynamic incidences are varied from (0 - 20) Hz during the casting process. The test results

indicated critical refinement of grain and surprisingly perfection in micro hardness and compression strength of castings with motor shaking mold vibration during solidification.
Premvrat Kumar et. al. [3] examines the impact of mechanical mold vibrations on properties of sand casting of Aluminum A1100 is utilized for the mechanical vibration impact using sand mould technique. The impact of mechanical mold shaker on grain size, hot ripping and morphology of eutectic silicon A1100 are examined. The ultimate tensile strength of A1100 combination casted under the influence of vibrations indicated an expansion in rigidity and malleability of the composite.

Chen Jinxia et. al. [8] studied the impacts of mechanical mold vibration recurrence and breadth on microstructure, solidification filling, and mechanical properties of AZ91D combination were considered. The results indicated that when the mechanical vibration recurrence of 100 Hz and the mechanical abundancy of 1.0 mm, the solidification filling limit of AZ91D composite is the best; the width, length and perspective proportion of the β-Mg17Al12 in AZ91D amalgam decline first and then increment with the expansion of mechanical vibration recurrence, and step by step decline with the increment of mechanical sufficiency, the base worth was gotten when the mechanical vibration recurrence of 100 Hz and the mechanical plentifulness of 1.0 mm. As of now, the elasticity and yield properties of cast AZ91D are 143.4 MPa and 121.6 MPa.
Naoki Omura et. al. [9] examined the influence of mold vibration on micro and Marco properties of Aluminum (AC4C) Alloy Castings. In assessment with as cast the grains formed without vibration, becomes finer from inner side of the sample and columnar and open grains like structure in the outer region of specimen. The typical density of a sample increased by obligation the mechanical mould vibration. The defects in casting is reduced in each sample and became less in numbers due to increase of vibration frequency.
Aramide Fatai et. al. [10] studied effect of mould vibration during molten metal solidification in a die or sand casting mould the properties of an AZ-91 magnesium alloy was examined. The frequency during the test was range from (0 to 24) Hz and 2- vibrational powers; 5Volts- (peak to peak) & 10Volts- (peak to peak). Tests are performed on a sample like hardness test, tensile & impact test stood performed on the different trials. Enhancements were detected in the tests when the frequency of beginning ranges from (12-16 Hz). Therefore, decided that the mech vibration during metal solidification on different moulds shows some refinement effects

on the grain constructions & improvement in the mechanical properties of the sample. The best frequency for producing best mech vibration results is between 12 and 16 Hz.

S.S. Mishra et. al. [11] studied molten metal solidification during mould shaking of (Al-6wt%Cu) for diverse wavelengths ranges at a constant pouring temperature is inspected to recognize the change in internal structure and other techniques of casting process. The different frequencies ranges (40 - 150) Hz throughout the process. casting has performed with/without vibration to compare outcomes. The experimental results displayed vital grain modification and greatly development in hardness with mould shaking all through metal solidification.

2.3 Ultrasonic Vibration

2.3.1 Introduction

Since the thirty years of the only remaining century, because of the high effectiveness and straightforward adjustment, the ultrasonic technology has been generally applied in the biomedicine, science, substance building, and metallurgical industry. The utilization of ultrasonic melt treatment in the light alloys has uncovered wide possibilities in the microstructure control and execution improvement for metal and alloys.

2.3.2 Literature review on Ultrasonic Vibration

Gang Chen et al. [12] examined that confirm the possibility of casting technology using squeezed assisted ultrasonic. The outcomes show that Al-2024 composite part by an unpredictable form and great exterior class can be created by ultrasonic assisted squeeze, casting technique. when ultrasonic force expanding, the morphology of parts with squeezing casting were obviously refined. Mechanical properties, for example, plasticity and strength, were likewise improved ignorantly as the ultrasonic force expanding. At the point when the ultrasonic force was 1.8 kW, the ultimate tensile and yield strength and lengthening to break were (372, 246) Mpa and 8.5 percent by weight, which were upgraded by (20.8, 21.2 & 84.8) %, separately, contrasted with a customary squeeze cast part.

Dmitry Eskin et. al. [13] considered that temperature ranges from (720 – 670) and (710 – 670) °C respectively. The reduction in start of temperature yielded a wonderful change in the grain structure in any event, when the rod was presented without ultrasonic vibrations, with the normal grain, simultaneously the grain size acquired upon bar presentation with ultrasonic motions in a more extensive temperature extend was better than in a smaller temperature range.

Ripeng Jiang et. al. [14] investigated that Consequence and dynamic machine of ultrasonic vibration of 7050 aluminum solidification were brought out through introducing ultrasound by using (DC) casting into the semi continuous casting of aluminum composite and into alloy setting in a pot, results show that vibration applied by using ultrasonic refine the entire cross-segment of a billet and grains in the primary test and can build the cooling rate inside the temperature extend from 625 ◦C to 590 ◦C in the other one.

Abdulsalam Muhrat et. al. [15] studied that vibration by using ultrasonic horn (USV) was estimated in a lab-scale. Furthermore, the addition of (Ti–6Al–4V) sonotrode erosion and its involvement in refining the structure of grains were studied. The USV action improved the suspension of copper inside the molten solution and upgraded, the contribution of quality and grain refining, of the formed alloy meaningfully. However, the holding time is increasingly necessarily for the whole suspension of Cu, the parts of the cu dissolution were not continuous because of imperiled to the ultrasonic cavitation under the sonotrode.

YAO Lei et. al. [16] examined that erosion resistance, microstructure, and mechanical properties of the Mg-8Li-3Al combination under different power of ultrasonic horn vibration were explored. The fine structure is acquired particularly when the ultsasonic power is 170 Watts, and the purifying impact likewise shows signs of improvement with drawing out the ultrasonic treatment time. The consumption obstruction of the composite with power of 170 Watts of ultrasonic vibrator and applied for 90 s duration shows the improved obviously contrasted and the amalgam without ultrasonic vibration. The mechanical properties of blends with ultrasonic vibration are additionally both improved evidently. The tensile strength and prolongation of compound improve by (9.5 & 45.7) %, separately, with power of 170 Watts for 90 s.

Hanbing Xu et. al. [17] studied ultrasonic degassing using USV at a frequency of 20KHz & 1500 watts power in aluminum A356. Efficiency of degassing measured in different samples for pressure reduction. researcher suggested that ultrasonic vibration reduce permeability creation in aluminum alloys.

2.4 Electro-Magnetic Vibration

2.4.1 Introduction

An vibration called electromagnetic was attained by the mutual discontinuous magnetic field and a fixed magnetic field in a (DC) casting technique. use of electromagnetic field in direct chill casting procedure is also an active tool to alter microstructure characteristics. Development of (EMF) in the first 1970s the initial claim of electromagnetic field in DC of aluminium alloys.

2.4.2 Literature Review on Electromagnetic vibration

Yoshiki et. al. [18] studied that the As the name proposes, that electromagnetic vibrations ordinarily include two diverse force fields, to be specific a rotating electric field and a fixed attractive field. In the event that a fixed attractive field with an attractive transition thickness 'B' and a rotating electrical field with a recurrence 'f' and flow thickness 'J' is applied to a liquefy, at that point an electromagnetic vibrating body force with a thickness 'F' is incited inside the dissolve. This force 'F' sets the particles inside the soften into vibration movement with a recurrence equivalent to the recurrence of the substituting electrical field, and the particles vibrating opposite to the plane of vector J and B.

M Sayuti et. al. [19] Studied that Application of small electromagnetic vibration frequency can be used to grain refinement, avoid cracks, remove micro separation and expand the as-cast external superiority of alloys.

Shijie Guo et. al. [20] investigated impact of electromagnetic field upon macro separation in AZ-80 magnesium billet alloy, upper surface is meaningfully condensed by the electromagnetic frequency. Moreover, Increasing the motionless magnetic field, i.e., increasing the concentration of electromagnetic vibrational frequency uniform dispersals of the metal particles in the billet.

Ch. Vivs et. al. [21] studied that Broad refinement of particles has been seen in individually composites with expanding polarizing force. This examination displays that the mean grain size got by this vibrational method is consistently littler than that created by the as of late created CREM (carting, refining, electromagnetic) process.

Y Zuo et. al. examined that [22] ingots with 200 mm in measurement was prepared by electromagnetic field vibration influence of electric field vibration on the morphology was considered outcomes indicated that electromagnetic field shaking meaningfully disturbs the cementing conduct, exaggerated by electro-magnetic vibration during direct chill casting method, This research presents the DC casting novelty by using electro-magnetic vibration.

2.5 Literature review on Selected Materials

2.5.1 Aluminium Alloy 7075

R. Haghayeghi et. al. [6] studied that impact of ultrasonic vibrations preceding to high pressure of AA7075 Result propose decreases of up to 73% in grain estimate and up to 5% on porosity because of blow holes, The common place estimations of extreme Tensile pressure and yield pressure expanded separately to 590MPa and 502MPa and extension improved to 18% , The impact of relaxation time after ultrasonic vibrations analyzed and results demonstrates light grain size increment from 68 to 80 mm.

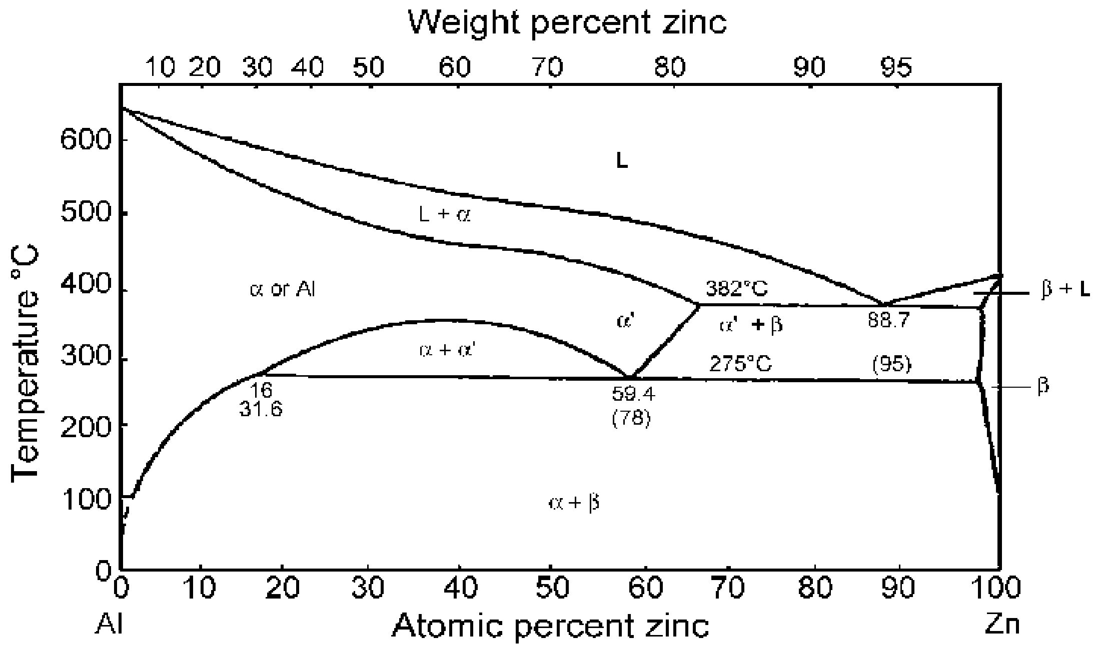

Figure 1 Al-Zn Phase Diagram

Xiao-Hui Chen et. al. [23] studied that the connection of dispersion and grouping level of researched by leading casting test. A hydrodynamic prototypical intended for computing the basic edge speed mandatory to thrust nanoparticles. Microstructural examines demonstrated that the subsequent microstructures of composites relied upon the size and level of nano-Al2O3 grouping.

Vinod Kumar et. al. [24] investigated that Tribological attributes of AA-7075 Treated over Casting using Ultrasound Technique. The test outcomes demonstrated that the expansion of TiB2 elements advances the Micrographs, stiffness. uncover the even circulation of TiB2 particles encompassed laterally the grain limits and this prompt better-quality mechanical properties. The decrease in the grain size and consistent dissemination of reinforcement particles.

Shaoming et. al. [25] studied that the impact of a small addition of strontium (Sr) expansion changes the mechanical and microstructures of Al-7075 Al amalgams was examined. The size of cast Al-7075 grain was purified from (157,115 , 108, and 105um) subsequent to including 0.05, 0.1, and 0.2 percent by weight. The uts expanded from 573 to 598 MPa and the yield lengthening to disappointment was raised from 19.5% to 24.9%. The small-scale hardness expanded from 182 to 195 Hv.

Peng-Xiang Zhang et. al. [26] investigated that, 7075 aluminum grid were created by ultrasonic vibration casting. Contrasted with the hardness of 7075 aluminum compound lattice (94.7 HV), the hardness of composites (113.8 HV) expanded 20% the hardness of Al2O3np/7075 composites under arrangement treatment (150.4 HV) at 480 0C for 5 h expanded 32% and the hardness of Al2O3np/7075 composites under ideal T6 heat treatment (173.5 HV) expanded 52%.

S.W. Kim et. al. [27] studied that the 7075 fashioned Al amalgam (Al–5.7 wt.% Zn–l.7 wt.% Cu–2.6 wt.%Mg) was readied utilizing the immediate squeeze process of casting. The miniaturized scale assemblies of cast squeeze applied with (25, 50 & 75MPa) could be liberated from the deformities that happen with unpressurized die cast blooms and turned out to be more polished and thicker than unpressurized casts. The hardness of 7075 composite matured at 120 and 18 ^{0}C was expanded with expanding applied weight because of the expansion in the nucleation site of middle of the road hastens.

HuaShan Liu et. al. [28] examined the Consequence vibration casting using ultrasonic technique on mechanical and microstructural properties of Al-7050 aluminum amalgam. At the point when matured at 120 ^{o}C, the UI compound arrives at its pinnacle quality after 8 h, with elasticity of 602 MPa, yield quality of 547 MPa and prolongation of 12.7%, individually, while the CI combination plate is with its rigidity, yield quality and stretching of (536 , 462)Mpa & 15.0%, separately, after pinnacle matured for 12 h.

balasubramanian. k et. al. [29] investigating Grain size and hot cracking in AA7075 Aluminum alloy. Vibratory Welding action was supported out in different ranges of frequency from 100 to 2050Hz using with/without weldments action linked together using cracking test of weld and description tests hardness measurements and micro structural analysis. Experimental test show that by put on vibration, hot cracking and other defects can be mostly removed in arc welding.

Qiong Wu et al. [30] investigated that the experimental and simulations on thin cylinder wall parts in aerospace using vibration controls through Preload test stage used to compute dynamic qualities of avionics insufficient parts under a confident preload is structured, and exploratory modular investigation of the parts is done. Common recurrence increments with expanding preload is summed up dependent on examination of the mathematical arrangements and exploratory arrangements of the self-motivated qualities, consequences of reproduction and trial, resizing compression to transformation the regular recurrence of parts is an exceptionally powerful way to deal with keep away from solid vibration of aviation slender walled workpieces.

2.5.2 Aluminium Alloy 5083

Shulin Lü et. al. [31] examined that the circuitous ultrasonic vibration technique, in which a metallic cup containing alloy the waves were horned outside the cup, was utilized for getting ready 5083 slurry, in this work. Results show that good quality slurry is obtained when the probe is immersed in slurry for fifty seconds, and the normal measurement and shape coefficient of essential - Al particles were 60 m and 0.54 individually. The elasticity and elongation of the rheo-diecasting tests were 283 MPa and 9% individually.

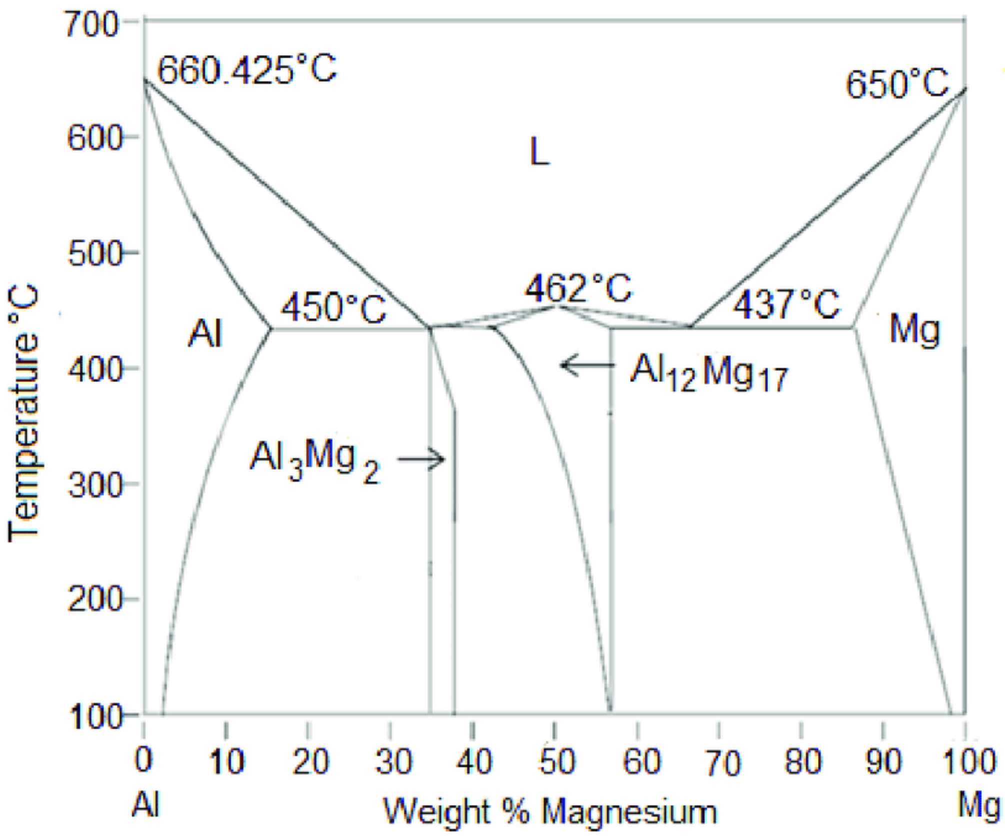

Figure 2 Al-Mg Phase Digram

Krishan Kumar et. al. [32] investigated that ultrasonic exciting gives a deviations in mechanical properties and microstructure characteristics of Al-5083 & Al-5083-TiC compounds. The ratio of attentiveness of Tic wide-ranging among (0-10) percent by weight of alloy. The microstructure of the aluminum alloy comprising TiC same and fine grain in the metal matrix composites and even dispersal in Al alloy matrix of TiC atoms.

R. S. Rana et. al. [33] studied Tribological conduct of AA-5083/Micron and Nano SiC composites manufactured by ultrasonic helped mix casting process. aluminum lattice composites manufactured utilizing conventional mix casting procedure normally present helpless dispersion of these particles inside the grid and high porosity.

Results discovered that at small load and smaller gliding distance amalgams with nano SiC show advanced wear resistance, though at greater load and extended sliding distance composites.

Mirela popescu et. al. [34] investigating the influence of rate of cooling on micro structure of 5083 aluminum conditional on chilling situations. The cooling curves were documented for diverse casting environments there were designed the cooling amount. The mechanical structural examines, completed by Image Pro-Plus 6.0 software, permitted both be painted structural accuracies of several situations for molding.

J.H. Lee et. al. [35] studied that squeeze-casting of secondary formed Al5083 alloy had been studied that of die form & pressure as functions. The macro reduction voids that were shaped like a hot spot can be removed by pressure of 100Mpa.

2.5.3 Aluminium Alloys 6061

P. Kumbhar et. al. [36] studied Vibrational Response and Mechanical Properties of silicon Aluminum Alloy 6061 Compound material was arranged by changing Sic (0%, 3%, 6%, and 9 %) by stirring technique. Ordinary rate Rockwell hardness, compressive strength and tensile strength were scrutinized. The outcome displays that, adding of sic in Al-matrix rises, stretchable strength, hardness, natural frequency, crushing strength and 9-wt. % presented extreme all mechanical properties.

Dinesh Kumar et. al. [37] studied the Ultrasonic Stir method for Casting is used to evaluate the Mechanical Properties of Al-6061. Compounds with normal dimensions of 40 nm and mass proportions (1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0) has been studied. The examinations of assets lead to the increase in ductile properties, hardness and crush strength with ultrasonic forming, qualified to even spreading of particles in Al-compound by ultrasonic vibrations at 20KHz.

Sharath N et. al. [38] investigated that Tribological Performance of Al-6061 Metal-Matrix Composites by Mixing Casting Techniques Al-6061 strengthened with graphite & boron fabricated particles by stir casting method, the reinforcing differ from (3%, 6% and 9%) by mass. Then were transferred into the molten metal to yield the specimen to required shape and size. The samples are subjected to several trials. And inspect the frictional and wear properties of composites by means of wear tester with varying load.

Santhosh Kumar Sape et. al. [39] shows Outcome of vibrating mould on Metallurgical &Mechanical Properties of Al-6063 alloy Casting. impact of shape vibration on casting during cementing of Al-6063 compounds for various estimations of frequencies at static pouring temperatures is researched to recognize the progressions in mechanical and microstructure of casting. The casting has been performed with & without vibrations. The frequencies changed from (0 to 40) Hz. A casting has been made without vibration too contrast the aftereffects of castings and vibration. The exploratory outcomes demonstrated noteworthy refinement of particles.

2.6 Deductions from Literature

After undergoing a thorough literature review, following can be deduced:

a. Most of the researchers have undertaken simulation-based optimization and not conducted thorough experimentation may be due cost effects.

b. Taguchi methodology has been adopted by most of the researchers due its suitability of application in optimization of sand-casting process.

c. Due to limited number of process variables in sand casting process, generally most of the researchers utilize similar process variables, while claiming enhanced quality and reduced rejections.

Chapter 3 MATERIALS AND METHOD

3.1 Methodology

The experimental research work has been done to study the required properties of Aluminum Alloy. Equipment and Mold has been prepared according to design. There are two sections of project evaluate the properties using vibratory mold and without vibration. The flow chart of the study and steps involved to carried out project is shown in Figure.

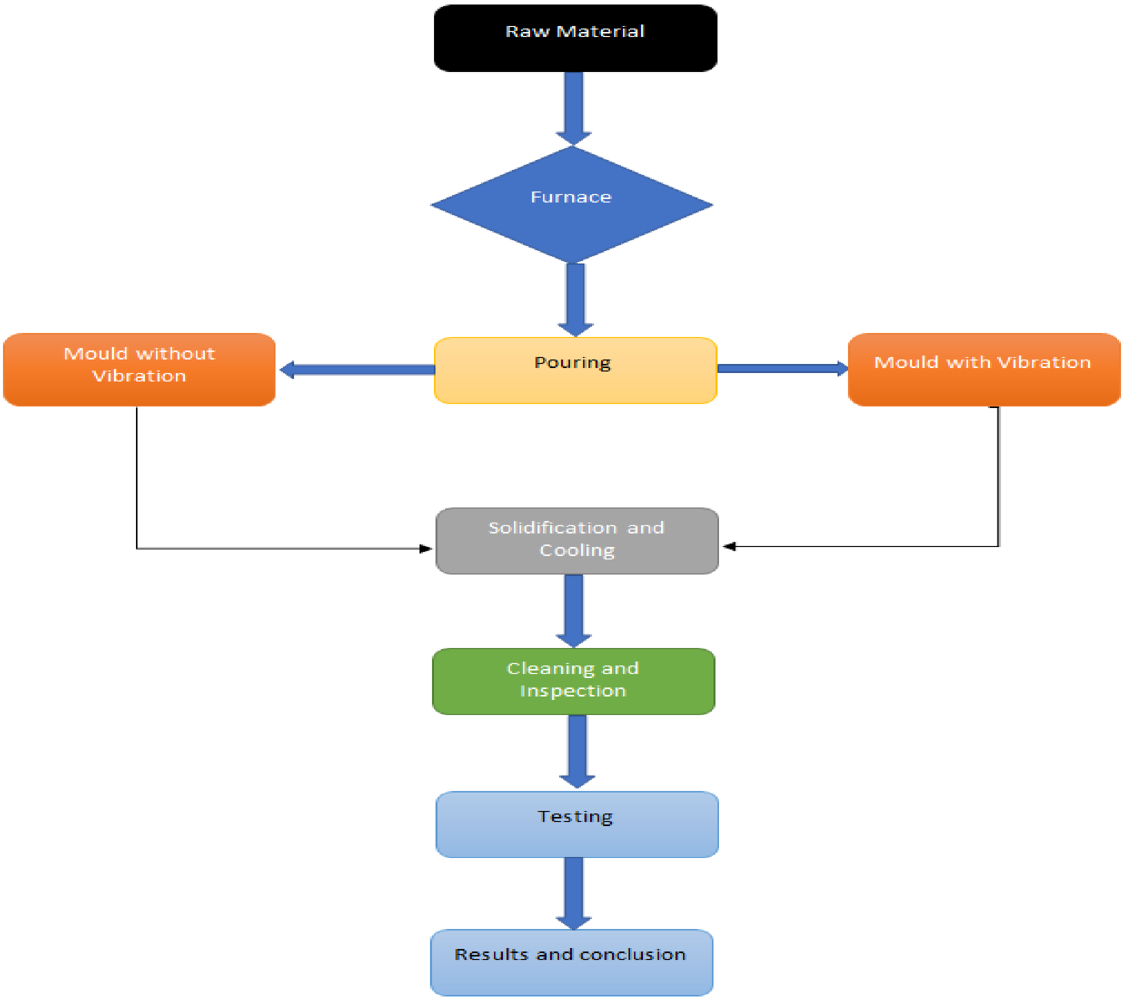

Figure 3: Flow chart for Vibration casting

The tensile and hardness test is performed on specimen to analyze the Mechanicl properties And physical properties while microscopic images are used to identify the morphology and measuring grain size.

3.2 Vibration Table Setup

Vibration table is designed for giving controlled vibrations to the die mold. It consists of motor three phase AC 220/440 Volt attached with Variable frequency drive (VFD) which gives required RPM of motor at desired frequency. The functional shaft at both ends, one of the ends is mounted by different eccentric rotating weights; these weights are used to achieve the desired acceleration in the form of g. Different masses is used to achieved required g values.

Vibratory Table consists of different parts including motor, base plate, vibratory plate, springs, VFD, sensors, fixture for mould and motor attachments. mould is attached with vibratory plate with the help of fixture and motor below the vibratory plate in horizontal axis (x- axis) so that vibration can be produced in vertical axis (z- axis). springs x4 of known stiffness is used to generate vibration. The compressive load test of spring is performed to measure the load vs linear compression values.

Load vs spring compression							
Compressive length (mm)	**166**	**150**	**140**	**135**	**125**	**110**	**100**
Load (kg)	**0**	**7.4**	**11.7**	**13.8**	**18.3**	**25.1**	**29.7**

Table 1 Load vs Deflection of Springs

The specifications of Mechanical shaker is as under.

Parameter	Specification
Frequency	8 to 47 HZ
Amplitude	2mm max
Maximum payload	500 Lbs
Maximum acceleration	2g max

Table: 2 Vibration Table Parameters

3.3 CAD Designing of Table

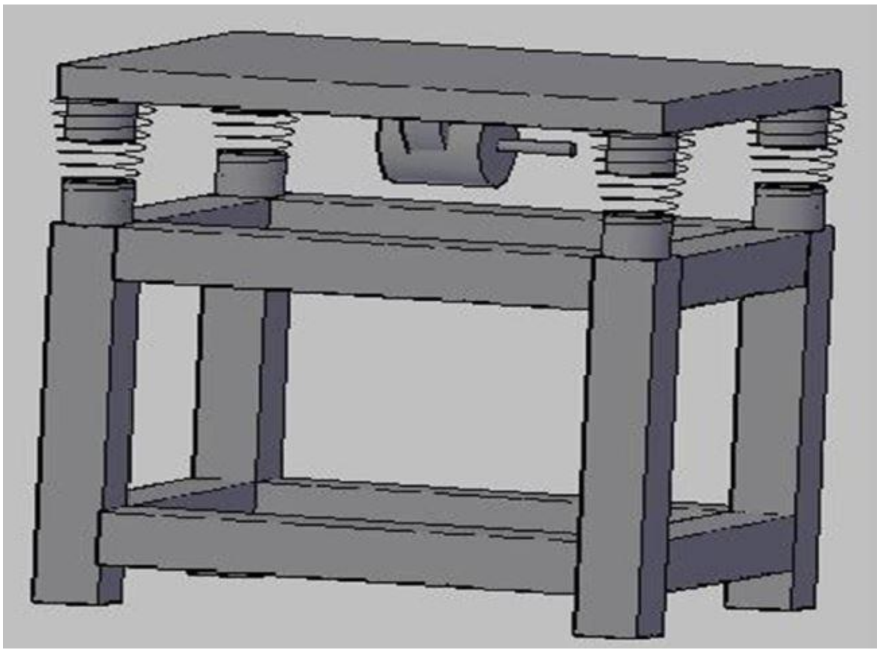

Figure 4: isometric view of CAD model

3.4 Data Acquisition

The amplitude produced during vibration is measured using the sensor IMU MPU6050. Which is a Micro Electro-Mechanical Systems (MEMS) comprises of three axis accelerometer & three-axis Gyroscope. which measures velocity, displacement and acceleration & several other constraints of a system as required. Arduino based microcontroller is programmed to read the values from sensor which is further displayed on monitor in the form of graph.

The second thing is to measure the cooling rate of the casting in the mould to get the required results. Two K-type thermocouples are attached with the mould to gather the temp data which is attached to the Arduino controller Which is programmed based and gives temperature value after 10 sec on monitor.

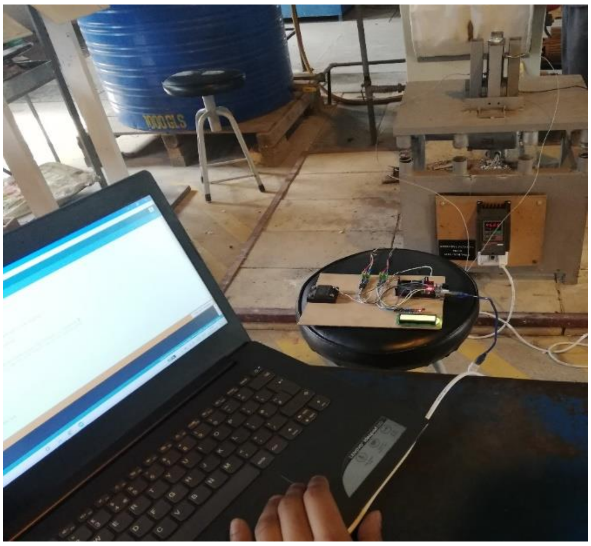

Figure 5: Data Acusition through arduino and sensors

3.5 Mould Designing

Die casting is fabricating process which produces complex metal parts using reusable molds, called dies. The die casting includes the utilization of a furnace, metal, die casting machine, and die. Metal, normally non-ferrous amalgam, for example, aluminum or zinc, is softened in the furnace and afterward infused into the dies in the die casting machine.

Permanent mould die made of mild steel is used for casting setup to prepare samples of cylindrical shape which are different in size. The diameters of die for different samples are 10mm,15mm and 20mm and the length of all samples is 100mm. the CAD model of die is shown below.

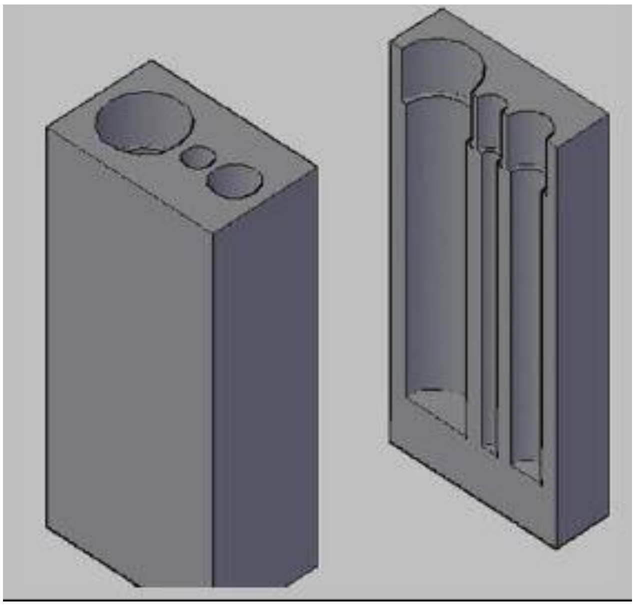

Figure 6: CAD Model of Die

3.6 Designing of Eccentric mass

Eccentric rotating mass equipment functioning based on the most vibration motors, with the exemption of linear resonant actuators. Number of times a complete cycle takes place in a second is called frequency measured in hertz (Hz). Vibration frequency is measured directly with the help of Rpms of motor. As the Motor speed at 220 V AC is 2800 RPMs to measure the variable rpm of motor use tachometer so the formula to calculate the frequency is as follow:

Frequency (f) =RPMs (Motor Speed)/60 ……………………… 3.1

So, for 2800 RPMs frequency is equal to 46.7 Hz. The vibration amplitude which is the characteristic which describes the severity of the vibration is the peak to peak value from the static position of table. Vibration Amplitude is measured directly with the help of dial indicator. The third parameter of vibration is measured in term of the acceleration which is calculated in "g" (one g is equals to 9.8 m/sec2). The vibration amplitude is a quantification of acceleration in term of g. Gravitational acceleration is calculated via specifically design electronics sensor system with shows the values in term of g‟s. Electronic sensor consists on a controller, accelerometer, amplifier, connecting wires and specifically generated software to display the values on computer screen. For verification of values of gravitational acceleration following calculation has been performed: The value of 'g' for an eccentric weight is calculated as follows:

$$F_c = m_e r w^2 \quad \text{……………………………………………………3.2}$$

Where F_c is called centripetal force, m_e is the mass of eccentric rotating semi-circle, r is the radius of center of mass for eccentric rotating mass calculated by $4r/3\pi$, and ω is angular frequency which is equal to $2\pi f$.

$$F_g = m_o g \quad \text{……………………………………………………3.3}$$

Whereas F_g is force due to gravitational potential energy, m_o is overall mass of the vibrating part and g is the acceleration. In case of eccentric rotating mass.

$$F_c = F_g \quad \text{……………………………………………………3.4}$$

By comparing Eq. 3.3 and 3.4

$$m_o g = m_e r w^2 \quad \text{……………………………………………3.5}$$

$$g = m_e r w^2 / m_o \text{……………………………………………3.6}$$

Calculated values are approximately closed to measured value of sensor system this calculation helps to design & manufacturing of the eccentric rotating mass for generation of required gravitational acceleration.

3.7 Material Selection

This research investigates and characterize the outcome of energetic solidification to measure the properties of Aluminum Alloys. In order to meet these objectives three different types of Aluminum Alloys are used.

3.7.1 Aluminium Alloy 7075

Aluminum alloy 7075, the major alloying component is zinc and other elements are in smaller portion. It is much stronger than other aluminum alloys, by means of toughness equivalent to numerous prepares, which has boundless machinability and fatigue strength, Because of its low density, high strength, thermal properties and its capacity to be exceptionally cleaned, 7075 is generally utilized in mold tool production. Chemical composition of 7075 is shown below in table.

AL 7075 Chemical composition								
Elements	Mg	Fe	Ti	Si	Mn	Zn	Cu	Al
wt.% composition	2.8	0.15	0.02	0.05	0.01	5.92	1.93	Balance

Table 3: Al-7075 Composition

3.7.2 Aluminium Alloy 5083

Aluminum alloy 5083 magnesium is the basic element of alloying, chromium and manganese is as major traces. Al 5083 is very much resistant by seawater and other chemicals. It is mostly used in welding process has exceptional strength after joining of metals. Mostly used in ship building for its corrosion resistance properties, rail roads, drilling, and pressure vessels. Chemical composition of Al 5083 is given below.

AL 5083 Chemical composition									
Elements	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Al
wt.% composition	0.05 to 0.06	0.10 to 0.12	0.40 to 0.45	4.90 to 4.91	0.48 to 0.40	0.40 max	0.15 to 0.16	0.25 to 0.26	Balance

Table 4: Chemical Composition of Al-5083

3.7.3 Aluminium Alloy 6061

Al 6061 T6 form has major alloying element contain silicon and magnesium. It has good mechanical properties such as extrusion and weldability. It is mostly for all types of general-purpose work. Chemical composition is as below.

AL 6061 Chemical composition									
Elements	Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr	Al
wt.% composition	0.88 to 1.20	0.4 to 0.8	0.70	0.15 to 0.40	0.250	0.150	0.150	0.04 to 0.35	Balance

Table 5 : Chemical Composition of Al-6061

3.8 Taguchi Method

Taguchi method for experiments design is an effective tool for creating orthogonal array for experiments, where multiple parameters are included in the process. This technique reduces significantly experimental time and cost very and improves reliability of the procedure. The L-9 orthogonal array selected by Minitab to perform the reduced experiment. The significant involvement of process limits have been measured for this method is size, Frequency and G-Value which are shown in table.

The current exploration as related with die casting process which includes different boundaries at various levels and influences the casting quality. Considering these highlights of Taguchi strategy, is utilized to lessen the level of dismissal because of molding related defects by setting the ideal estimations of the process boundaries of the die casting. This system accomplishes optimized process boundaries utilizing Taguchi is as given beneath.

a. The influencing process limits with their stages and accomplish the trial casting as per Taguchi method, then gathering information.

b. To investigate the information utilizing statistical tools. An anova acquired to decide the statistical criticalness of the boundaries. Means plots can be plotted to decide the favored degrees of boundaries considered for experimentation, Regression analysis is performed to determine the relationship between dependent and in dependent variables.

c. Select best levels of parameters and make validation experiments and implement the process.

	Parameters	Levels		
		1	2	3
A	**Material**	AL 7075	AL 6063	AL 5083
B	**Frequency (RPM/HZ)**	900/15	1800/30	2700/45
C	**Acceleration (g)**	0.5	1	1.5
D	**Size (mm)**	10	15	20

Table 6 : Process Parameters foor DOE Selection

3.9 DOE in minitab

The methodology described above based on process knowledge was manifested through modeling work using Taguchi's Design of Experiment by MINITAB software. Three process parameters with three levels of values were practically analyzed. The process parameters namely frequency, G-value and size were used to yield the result for analysis.

Selection of Taguchi's Orthogonal Array through Minitab Software as illustrated below.

Taguchi Design of Experiments				
Columns of L9(3^4) Array				
Sr.no	**Material**	**Size**	**Frequency**	**G Value**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 7 : Taguchi Design of Experiments

Taguchi Orthogonal Array for selected parameters

Taguchi Design of Experiments				
Columns of L9(3^4) Array				
Sr.no	**Material**	**Size**	**Frequency (RMPM/HZ)**	**G Value**
1	Al 7075	10	900/15	0.5
2	Al 7075	15	1800/30	1
3	Al 7075	20	2700/45	1.5
4	Al 5083	10	1800/30	1.5
5	Al 5083	15	2700/45	0.5
6	Al 5083	20	900/15	1
7	Al 6061	10	2700/45	1
8	Al 6061	15	900/15	1.5
9	Al 6061	20	1800/30	0.5

Table 8 : Taguchi Array for Selected Parameters

3.10 Experimental Procedure

Experimental procedure is performed in NUST Manufacturing Resourrce centre. Induction furnance "topcast" having power 45kva, max current 65A is used for melting the material. Crucible is used to pour the molten metal into the permanent mould and repeats the process 3 times for each material. one sample without vibration is also prepared for comparison. Then samples are removed from the die and cleaning for testing and further procedurs the pictures of complete process is shown below.

Experimental Procedure Pictures

Figure 7: (a) Melting in Furnace, (b) Pouring from Crucible to Pouring Cup, (c) Pouring through Pouring Cup in a die, (d) Vibration On, (e) data accusation through sensors, (f) Casted Parts

Chapter 4

Testing and Sample Preparation

4.1 Testing

There are two basics test process which is adopted to carried out this research project for acquiring results, which includes mechanical and physical properties. Second is the microstructure study with the help of optical microscope to learn the particle dispersion and consistency to describe the stages in the procedure.

4.2 Tensile testing

Tensile testing is used to find the mechanical characteristics of materials tensile specimens are prepared according to international standard which is ASTM E-8 (B-557M). Samples are prepared in the die mold then machined to dog bone shape using lathe machine as shown in figure below.

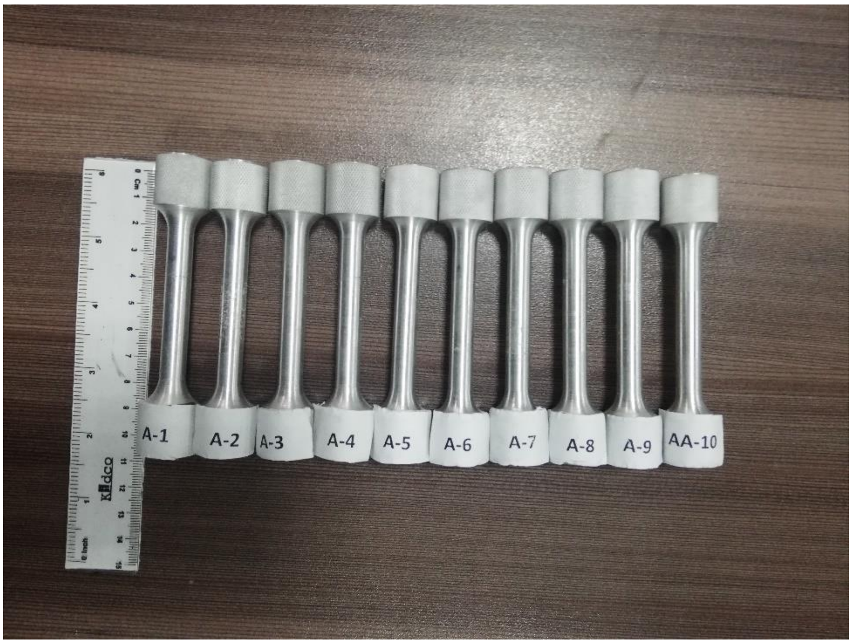

Figure 8: Tensile Sample Preparation

Tensile tests are performed in NUST school of materials Engineering by using a Shimadzu universal testing machine to find the tensile properties of aluminum alloy such as percentage elongation, yield stress and tensile strength. The strain rate for the aluminum alloys is 0.5mm/mm/min and the load are applied 20kn while performing this test as shown in figure below.

Figure 9: Tensile Testing Machine

4.3 Hardness test

Hardness test were completed by means of micro Vickers hardness machine at 200g applied load condition for all kind of alloys. The hardness is performed at three different points of top and bottom side of each sample. The average value is considered as the final value of overall sample. Micro Vickers were performed on Wolpert group model no 401MVD. Hardness can be measured according to the ASTM E-92-82. Different samples and machine is shown below.

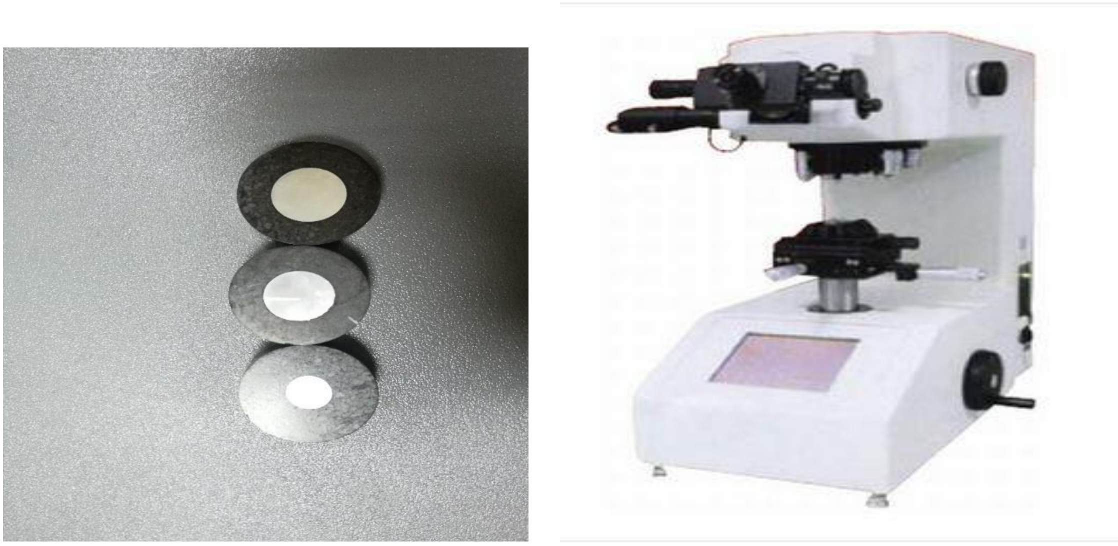

Figure 10 : (a) sample for Hardness (b) Micro Hardness Machine

4.4 Microstructure Analysis

Optical microscope in DME is used to examined the microstructures and grain size of samples at different magnification. Samples were prepared for microstructure analysis using different process are defined below. Samples were cut from top and bottom side of the cast part using EDM wire cutting machine then mounted using backlit powder, prepared sample and mounting machine as shown in figure below.

Figure 11: (a) Mounting Machine (b) sample preparation through backlit powder

The upper surface of the sample is finished level by an coarse emery paper mounted on rotary disc machine, these machines have variable speed according to smooth and rough grinding and armed with cooling accessories to confirm that during cutting to wash the abrasives particles from the moving belt or disc. During initial grinding of specimen it is in mind to avoid over overheating of the sample. Mounted samples are then grinding on automatic grinder to level the surface using grinding paper p600 to p400. The picture of grinder is shown below.

Figure 12: Manual Grinding Machine

Final finishing of samples is obtained by using diamond suspension of 1-micron size on a automatic polishing machine using polishing cloth on a polishing machine having rotating disc. Diamond suspension is usually used in combination with Fluids, to equally allocate the polishing particles over polishing cloth. To give mirror like presence to the samples polishing be done on automatic polisher using one micron polishing paper with diamond suspension of one micron. Which gives the clear and shiny surface just like the mirror.

Figure 13: Automatic Grinding and Polishing Machine

Chemical Etching is a process used to high lid internal structures of metals surfaces at very micro levels. Most of the metallurgical topographies are very small in size can't be seen with naked eyes only possible with optical magnification.

Clearly seen features of a sample must be refined to mirror-like surface, these very finely and polished samples gives a surface like a plain white field.

Etchants main purpose is to expose:

- the size and shape of boundaries (crystal structure defects)
- different phases present in metal (metal types in an alloy)
- additions (small quantities of non-metallics)
- Truthfulness of fuse points, mostly in electronic devices
- blows and cracks in welds
- Thickness, uniformity and quality of coating materials

Etchants used for aluminium alloys are shown below in table.

Materials	Echants						
	HF (48%)	HCL (con)	H2SO4 (con)	HNO3 (78%)	KMNO4	NaOH	D.Water
Al 7075	2ml	3ml		20ml			175ml
Al 5083					4g	2g	94ml
Al 6061	5ml		10ml				85ml

Table 9: Ecchtants for solution preparation percentage

Etch samples are then seen in the optical microscope infinity to capture the images in 20x these captures imgages are further use to measure the grain size using astm standard E-112 and the method applied is lineal intercept method (hynes).

4.4.1 Microscopy Images Aluminium 7075

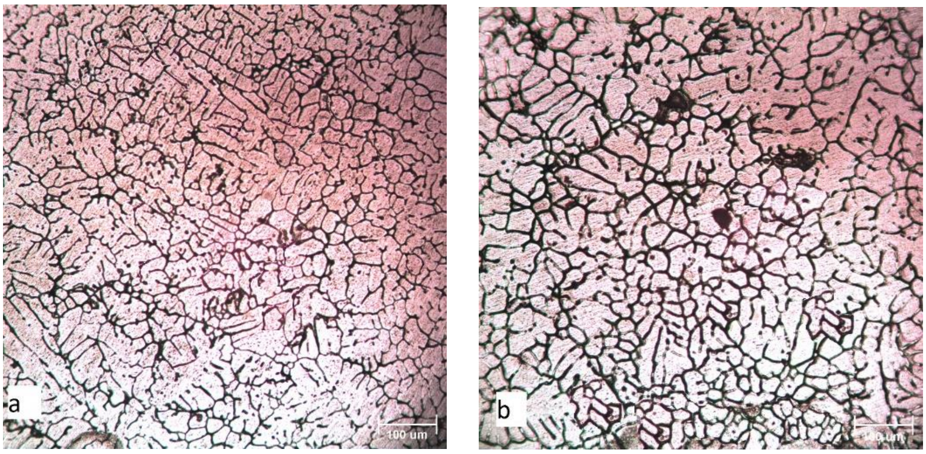

Figure 14 Run-1 a-Bottom sample, b-Top sample (Die size 10mm)

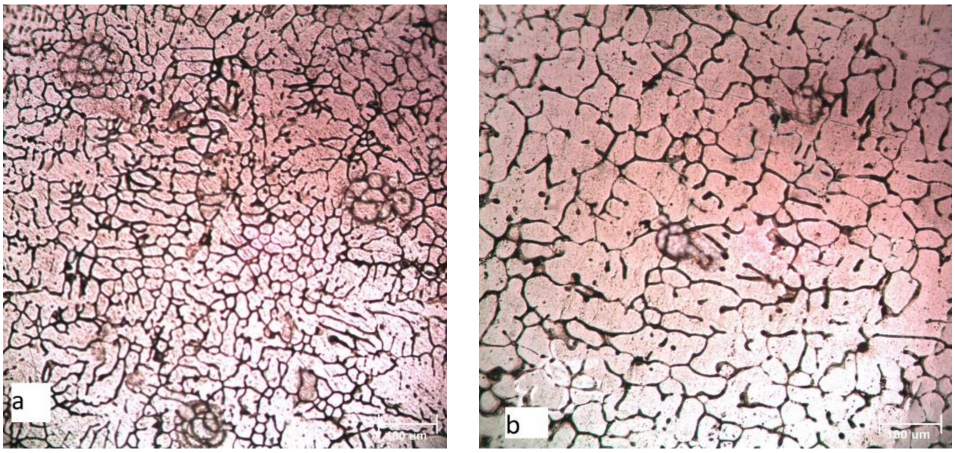

Figure 15-Run-2 a-Bottom sample,-b-Top sample (Die size 15 mm)

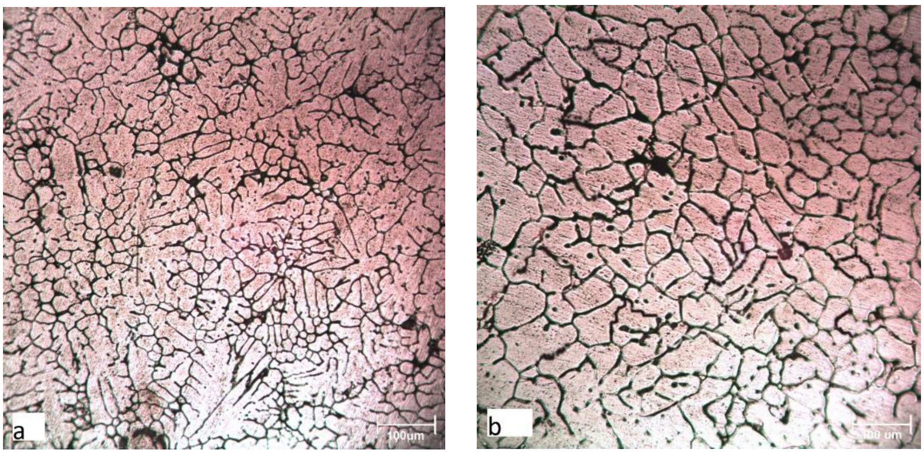

Figure 16- Run-3 a- Bottom sample,b-top sample (Die size 20 mm)

4.4.2 Microscopy images Aluminium 5083

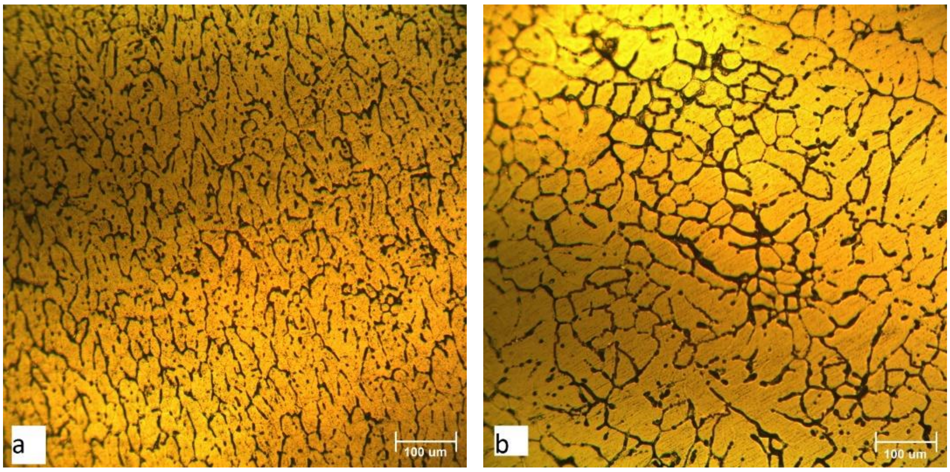

Figure 17- Run-4, a- Bottom sample, b- Top sample (Die size 10 mm)

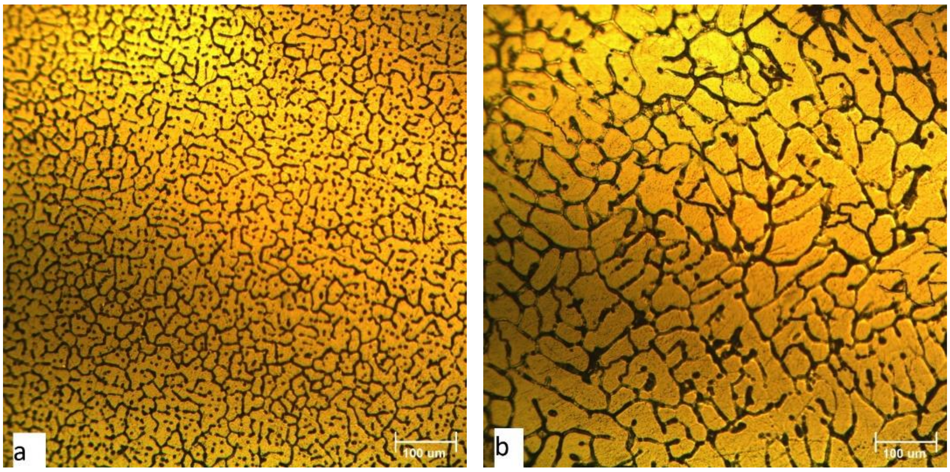

Figure 18-Run-5, a- Bottom Sample,b-top sample (Die size 15 mm)

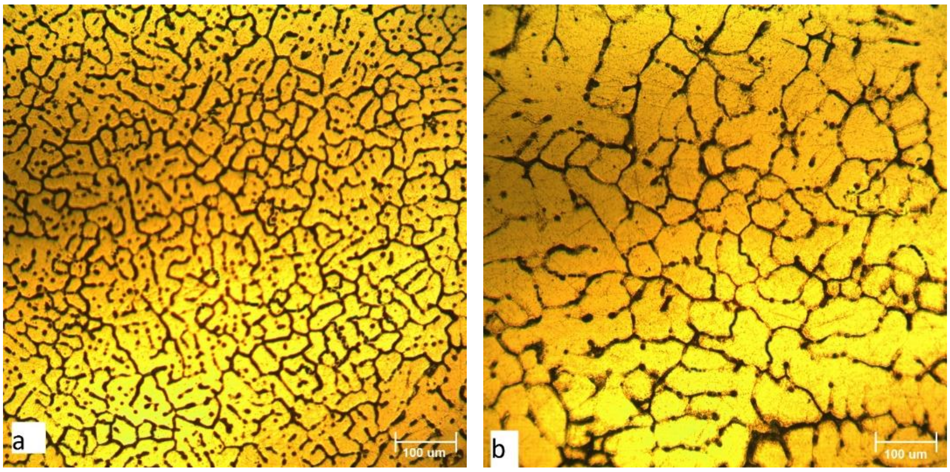

Figure 19-Run-6,a-Bottom Sample,b-top sample (Die size 20mm

4.4.3 Microscopy imagesAluminium 6061

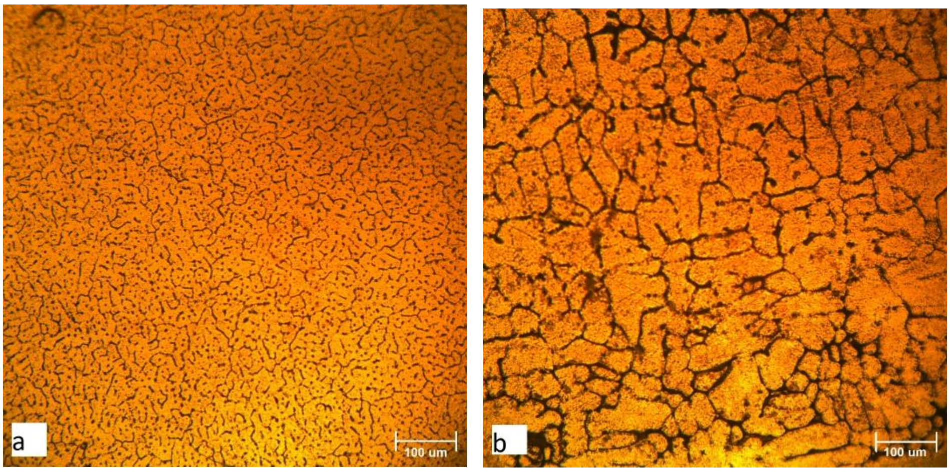

Figure 20-Run-7,a- Bottom Sample,b-top sample (Die size 10mm)

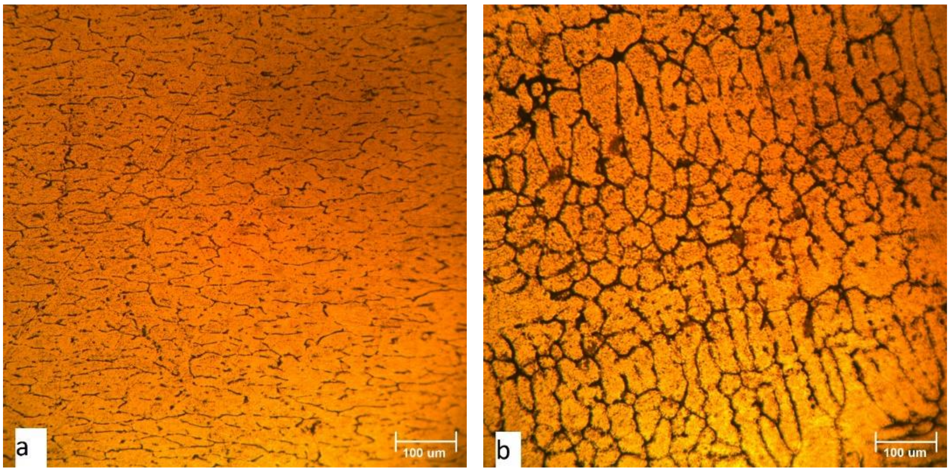

Figure 21-Run-8,a- Bottom Sample,b- Top sample (Die size 15mm)

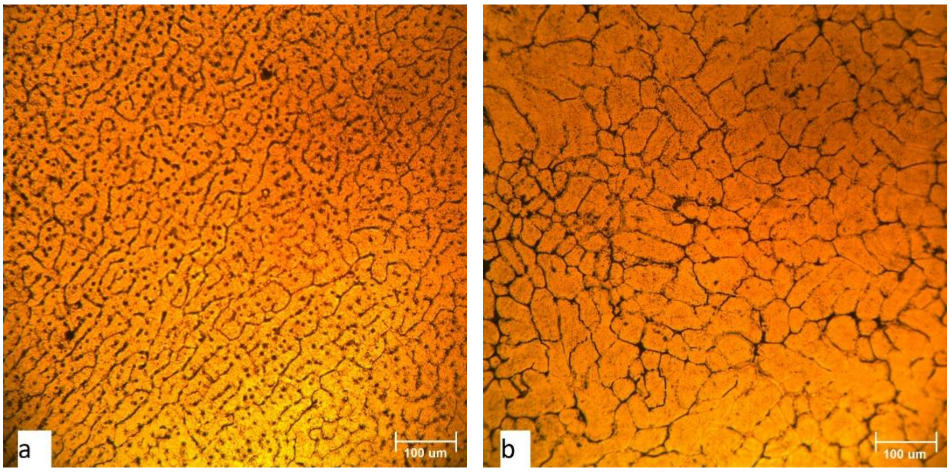

Figure 22-Run-9,a- Bottom Sample,b-top sample (Die size 20mm)

Chapter 5

Results and Discussion

Taguchi approach is reasonable in test plan for planning and creating vigorous items or procedures independent of variety in process boundary (inside set cutoff points) or variety in ecological conditions. For analysis the entire process parameters Taguchi method generally employs special designed orthogonal arrays with less trials. This strategy utilizes the signal to noise ratio for estimating the nonconformity of the superiority trademark from the ideal value since 'signal' speaks to the alluring value specifically mean for the output characteristics and 'noise' speaks to the undesirable value or standard deviation for the output characteristics.

5.1 Tensile strength

5.1.1 Tensile Test Results Casted samples

Run	Sample Id	Tensile Strength Mpa			
		x1	x2	x3	Avg Tensile Stress
1	A-1	183.2052	169.05	185.43	179.2284
2	A-2	175.1096	202.775	198.5	192.1282
3	A-3	178.8821	176.4	149.2	168.1607
4	B-1	151.37	123.0799	142.13	138.8599667
5	B-2	184.54099	148.7016	160.21	164.4841967
6	B-3	148.72	138.9559	130.9	139.5253
7	C-1	173.3022	182.4879	163.66	173.1500333
8	C-2	171.6514	151.2167	162.45	161.7727
9	C-3	194.2867	171.0226	173.2	179.5031

Table 10: Tensile test Results

5.1.2 Tensile Test Results (As cast) samples

Run	Sample Id	Tensile Strength Mpa
1	Ac-1	170.3539
2	Ac-2	180.1396
3	Ac-3	152.78
4	Bc-1	149.2521
5	Bc-2	181.0828
6	Bc-3	198.3737
7	Cc-1	138.6418
8	Cc-2	165.3836
9	Cc-3	93.05644

Table 11: Tensile Test Results As Cast Samples

Cooling curve of Die

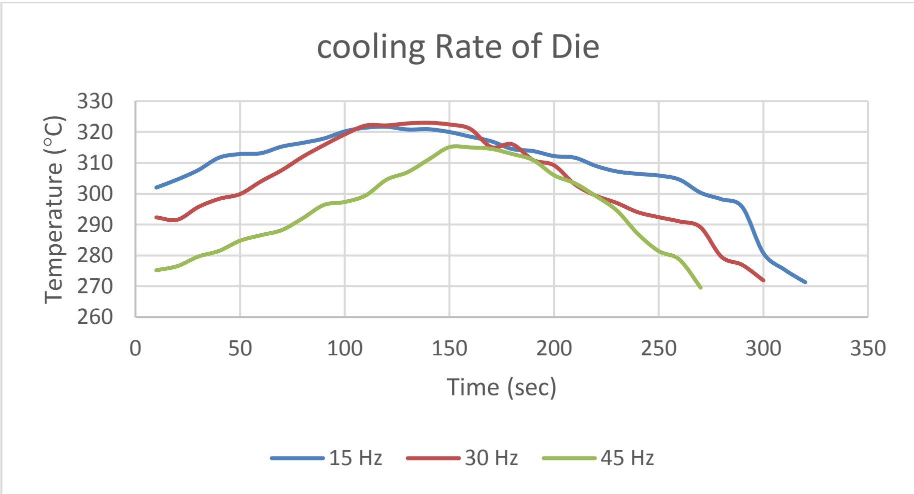

Figure 23 : cooling curve of Die

5.2 Hardness

5.2.1 Hardness Test Results

Run	Sample Id	Hardness (VHN)									
		x1			x2			x3			Average Hardness
		Top Avg	Bottom Avg	avg	Top Avg	Bottom Avg	avg	Top Avg	Bottom Avg	Avg	
1	A-1	97.4	107.4	102.4	109	112	110.5	111.3	128.7	120	111.0
2	A-2	89.5	111.6	100.55	105.1	121.9	113.5	116.9	122.1	119.5	111.2
3	A-3	111.5	113	112.25	111.8	123.2	117.5	114	131.1	122.55	117.4
4	B-1	102.3	107.3	104.8	101.2	104	102.6	97.4	102.6	100	102.5
5	B-2	92.1	95.5	93.8	93.8	97.4	95.6	95.69	98.81	97.25	95.6
6	B-3	97	101.84	99.42	90.7	95.72	93.21	91.99	94.1	93.045	95.2
7	C-1	79.9	81.2	80.55	79.1	94.5	86.8	85.29	86.81	86.05	84.5
8	C-2	82.9	87.2	85.05	71	88.1	79.55	80.15	83.35	81.75	82.1
9	C-3	80.1	85.1	82.6	74.5	85.9	80.2	76	80	78	80.3

Table 12 : Hardness Test Results

5.2.2 Hardness Test Results (As cast) Samples

Run	Sample Id	Hardness (VHN)		
		x1		Average Hardness
		Top Avg	Bottom Avg	
1	A-1	97.4	98.9	98.15
2	A-2	97.8	117.8	107.8
3	A-3	76.5	80.9	78.7
4	B-1	68.9	76.6	72.75
5	B-2	69.9	73.7	71.8
6	B-3	91.8	92.1	91.95
7	C-1	64.2	69.9	67.05
8	C-2	64.4	70.2	67.3
9	C-3	72.9	85.8	79.35

Table 13 : Hardness Test Result As Cast Samples

5.3 Grain size measurement (Linear intercept method)

5.3.1 Grain size Result casted samples

Run	Sample Id	Grain Size mIcron meter									
		x1			x2			x3			Avg Grain Size
		Top Avg	Bottom Avg	Avg	Top Avg	Bottom Avg	Avg	Top Avg	Bottom Avg	Avg	
1	A-1	21.88	15.91	18.895	23.7	14.6	19.15	19.2	17.21	18.205	18.75
2	A-2	37.83	25.22	31.525	31	23.2	27.1	33.9	27	30.45	29.69166667
3	A-3	33.33	20.9	27.115	30.9	22.8	26.85	32.1	25	28.55	27.505
4	B-1	35.15	25.93	30.54	31.9	26.5	29.2	33.81	27	30.405	30.04833333
5	B-2	38.88	21.72	30.3	33.2	24.61	28.905	30.9	22	26.45	28.55166667
6	B-3	35.9	26.42	31.16	33.4	23.5	28.45	37.1	24.12	30.61	30.07333333
7	C-1	37.84	28.57	33.205	35.66	27.51	31.585	41.32	29	35.16	33.31666667
8	C-2	36.84	27.45	32.145	39.88	28.12	34	33	30.1	31.55	32.565
9	C-3	33.83	26.77	30.3	35.32	25.11	30.215	29.65	27.39	28.52	29.67833333

Table 14: Grain size Measurement (Linear intercept method)

5.3.2 Grain Size Measurement (As cast) samples

Run	Sample Id	Grain Size mIcron meter		
		x1		Avg Grain Size
		Top Avg	Bottom Avg	
1	Ac-1	48.28	41.6	44.94
2	Ac-2	40.01	38.88	39.445
3	Ac-3	37.83	35.61	36.72
4	Bc-1	28.57	30.21	29.39
5	Bc-2	31.81	30.22	31.015
6	Bc-3	26.4	22.9	24.65
7	Cc-1	41.18	38.23	39.705
8	Cc-2	42.42	39.9	41.16
9	Cc-3	37.83	35.88	36.855

Table 15: Graain Size Measurement As cast Samples

5.4 Anova

ANOVA is a statistical analysis technique used to show the degree of significance and to check the impact of each variable factor on final casting product. The p-value is the measure of the significance level of each factor. If the p value is lower than 0.05, it represents s the power level has a statistically substantial effect on the responses.

5.4.1 ANOVA Results for Grain size Measurement

ANOVA Results for Grain Size Measurement Using Line Intercept Method

Source	DF	Contribution	Adj SS	Adj MS	F-Value	P-Value
Material	2	42.76%	198.03	99.013	47.8	0
Size	2	8.25%	38.21	19.104	9.22	0.002
Frequency	2	9.23%	42.75	21.374	10.32	0.001
Acceleration	2	31.71%	146.89	73.443	35.45	0
Error	18	8.05%	37.29	2.071		
Total	26	100%	463.16			

Table 16: Anova result for grain size measurement (Linear intercept method)

Level	Material	Size	Frequency	Acceleration
1	29.56	27.37	27.13	25.66
2	31.85	30.27	29.81	31.03
3	25.32	29.09	29.79	30.04
Delta	6.54	2.9	2.68	5.37
Rank	1	3	4	2

Table 17: Response Table For Means (Grain Size Using Line Intercept Method)

In anova individually factor, the software measures the normal characteristic of every factor at respectively level. In every feature, the Minitab software calculates the delta value, which avg response highest value subtract lowest response avg value for that factor. Delta values shows response from top to bottom is the rank order. Highest value of delta is allotted rank 1, and the rank 2 is allotted to the next respective value and so on.

S/N Ratio Calculation Grain Size measurement Using Line Intercept Method

Following is the table telling about the S/N ratios of the experimentation.

Material	Size	Frequency	Acceleration	Grain Size	S/N Ratio
7075	10	15	0.5	18.75	-25.46199
7075	15	30	1	29.69166667	-29.47015
7075	20	45	1.5	27.505	-28.79143
5083	10	30	1.5	30.04833333	-29.55815
5083	15	45	0.5	28.55166667	-29.1261
5083	20	15	1	30.07333333	-29.5702
6061	10	45	1	33.31666667	-30.46158
6061	15	15	1.5	32.565	-30.25948
6061	20	30	0.5	29.67833333	-29.4521

Table 18: S/N Ratio Calculation Grain size Measurement

Main Effect Plots (Grain Size Measurement Using Line Intercept Method)

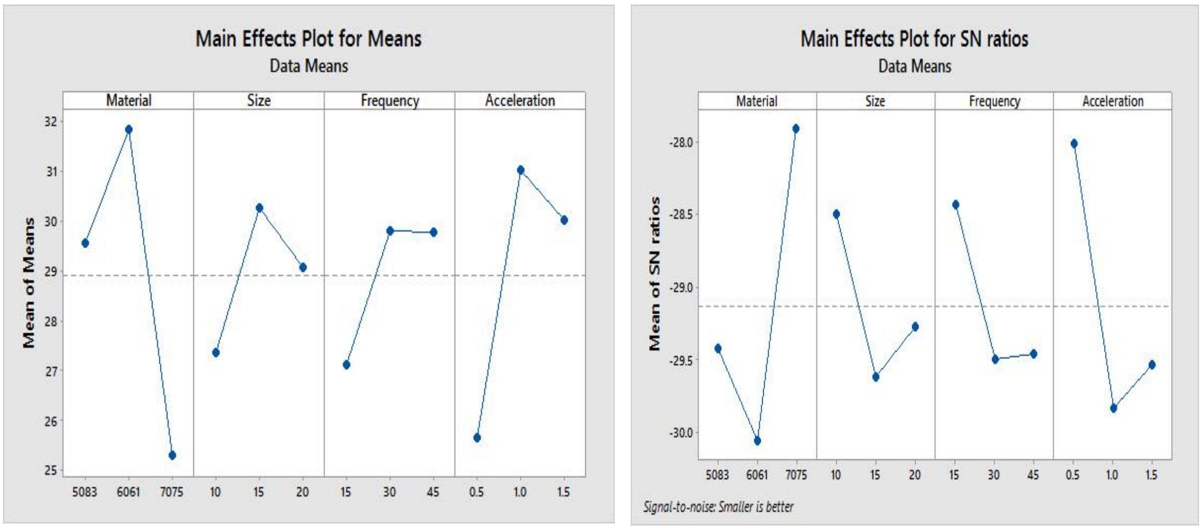

Figure 24: (a) Main effect plot for mean (b) Main effect plot for S/N Ratio

5.4.2 ANOVA Results for Hardness Measurement

Source	DF	Contribution	Adj SS	Adj MS	F-Value	P-Value
Material	2	65.05%	4288.92	2144.46	60.94	0
Size	2	5.82%	41.02	20.51	3.76	0.284
Frequency	2	7.86%	42.66	21.33	5.79	0.17
Acceleration	2	12.46%	122.81	61.40	10.26	0.02
Error	18	9.81%	488.99	27.17		
Total	26	100%				

Table 19: ANOVA Results for Hardness Measurement

Level	Material	Size	Frequency	Acceleration
1	97.75	99.30	96.10	95.63
2	82.32	96.28	98.01	96.96
3	113.19	97.68	99.15	100.67
Delta	30.87	3.02	3.05	5.04
Rank	1	4	3	2

Table 20: Response Table for mean of Hardness measurement

S/N Ratio Calculation for Hardness

Material	Size	Frequency	Acceleration	Hardness	SNRA1	MEAN1
7075	10	15	0.5	111.0	40.84934	111.9667
7075	15	30	1	111.2	40.85195	111.1833
7075	20	45	1.5	117.4	41.37908	117.4333
5083	10	30	1.5	102.5	40.2069	102.467
5083	15	45	0.5	95.6	39.6018	95.550
5083	20	15	1	95.2	39.5629	95.227
6061	10	45	1	84.5	38.5191	84.467
6061	15	15	1.5	82.1	38.2788	82.117
6061	20	30	0.5	80.3	38.0961	80.383

Table 21: S/N Ratio calculation for Hardness

Main Effect Plots for Hardness

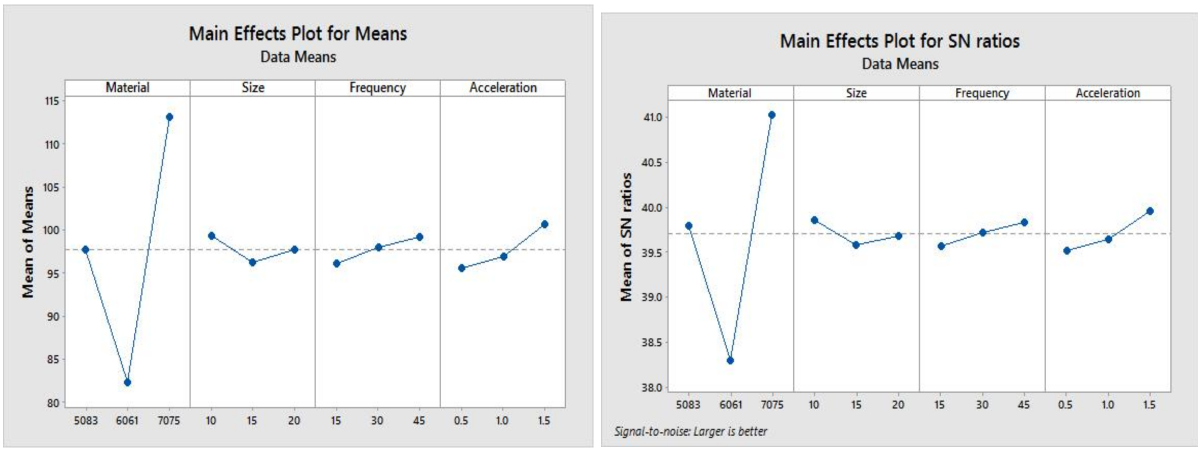

Figure 25: (a) Main effect plot for mean (b) Main effect plot for S/N Ratio

5.4.3 ANOVA Results for Tensile Strength Measurement

Source	DF	Contribution	Adj SS	Adj MS	F-Value	P-Value
Material	2	46.73%	5030.2	2515.1	14.58	0
Size	2	5.35%	575.5	287.8	1.67	0.217
Frequency	2	4.83%	519.5	259.7	1.51	0.249
Acceleration	2	14.24%	1532.5	766.3	4.44	0.027
Error	18	28.86%	3105.9	172.5		
Total	26	100%	10763.6			

Table 22: ANOVA Results for Tensile Strength measurement

Level	Material	Size	Frequency	Acceleration
1	147.6	163.7	160.2	174.4
2	171.5	172,8	170.2	168.8
3	179.8	162.4	168.6	156.3
Delta	32.2	10.4	10	18.1
Rank	1	3	4	2

Table 23:Response Table for mean of Tensile strength Measurement

S/N Ratio Calculation for UTS

Material	Size	Frequency	Acceleration	UTS	SNRA1	MEAN1
7075	10	15	0.5	179.228	45.046	179.228
7075	15	30	1	192.128	45.6166	192.128
7075	20	45	1.5	168.161	44.4245	168.161
5083	10	30	1.5	138.86	42.7529	138.86
5083	15	45	0.5	164.484	44.2194	164.484
5083	20	15	1	139.525	42.8577	139.525
6061	10	45	1	173.15	44.7427	173.15
6061	15	15	1.5	161.773	44.143	161.773
6061	20	30	0.5	179.503	45.0392	179.503

Table 24: S/N Ratio calculation for UTS

Main Effect Plots for uts

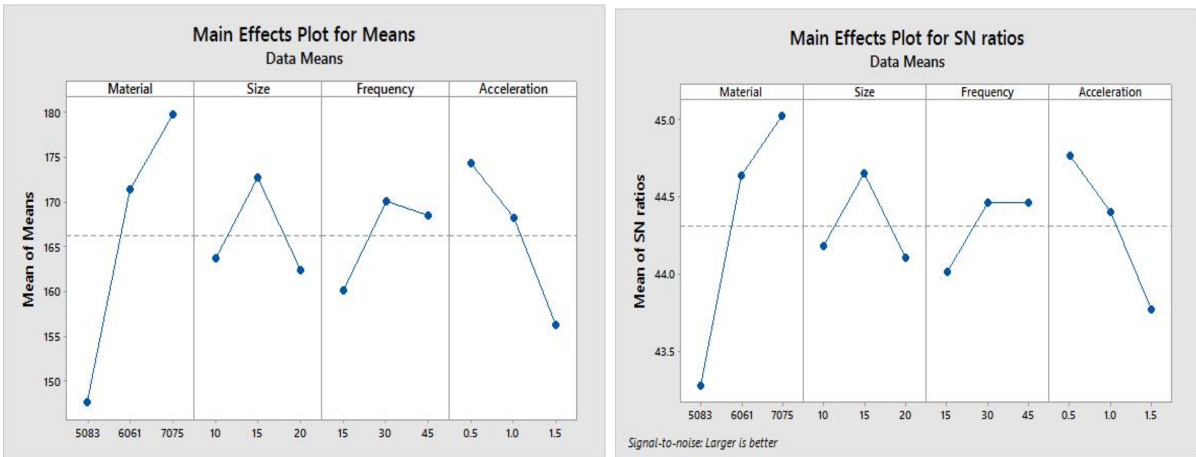

Figure 26: (a) Main effect plot for mean (b) Main effect plot for S/N Ratio

5.5 Confirmation Experiment vs As cast

5.5.1 Optical micrgraphs

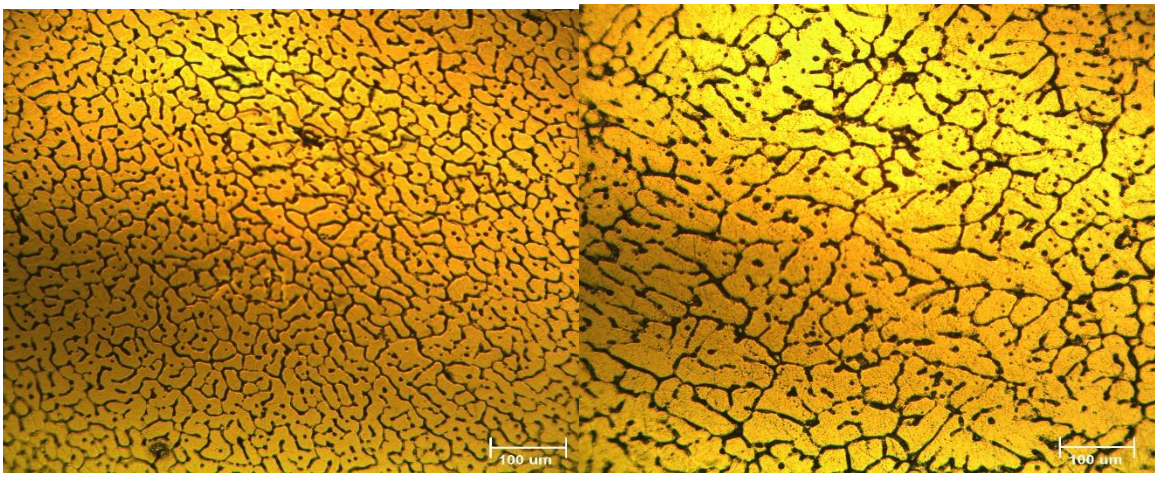

Figure 27 : Confirmation experiment Bottom and Top

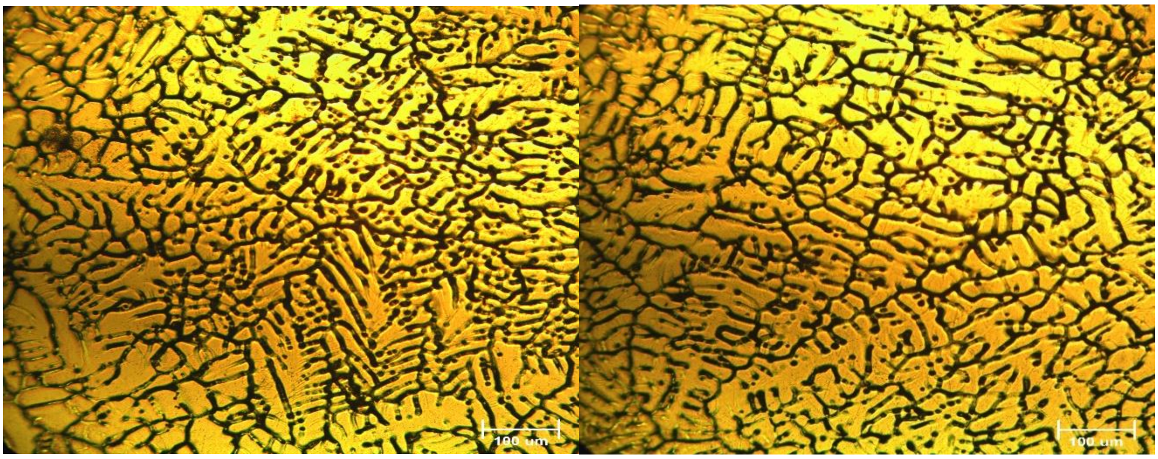

Figure 28 : As cast Bottom and Top

5.5.2 Confirmation Experiment Results

Experiment	**UTS (MPa)**	**Hardness (VHN)**			**Grain Size (um)**		
		Top	Bottom	Avg	Top	Bottom	Avg
Optimum	182.48	111.5	113	112.25	33.33	20.9	27.115
As-Cast	149.25	97.4	98.9	98.15	37.83	35.61	36.72

Table 25 Confirmation Experiment Results

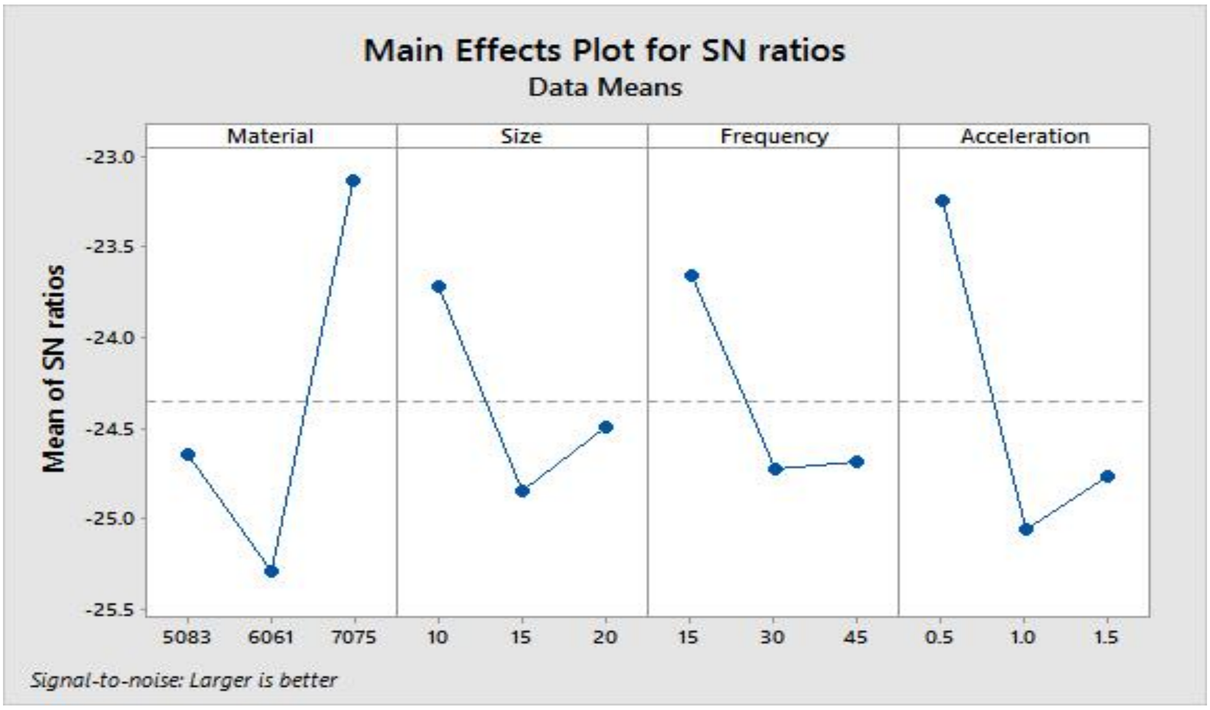

Figure 29 : S/N Ratio of confirmation Experiments

5.5.3 Optimum parameters

Material	Size	Frequency	Acceleration
Al-7075	10	15Hz	0.5g

Table 26 : Optimum Parameters

5.6 Discussion of Results

5.6.1 Frequency Effect

- The effect of frequency can be clear seen that at range 15Hz the average grain size is 27.13um, whens frequency is increased to 30Hz the average grain size increases to 29um and remains the same at 45Hz. It shows that lower frequency has better effect on grain size.
- Average hardness is 96.10Hv when frequency touches 15Hz and further increase in frequency from 30Hz to 45Hz the hardness slightly increases from 98.01Hv to 99.15
- At the frequency 15Hz the tensile strength is 160.2Mpa then further increase with frequency and becomes 170.2Mpa then slightly decrease with increased in frequency. This trend shows that two much increase in frequency can decrease in Tensile strength.

5.6.2 Die size Effect

- The effect of die size can play very effective role in grain size and other properties Avg grain size is 27.37um. when the die size increases to 15mm the grain size also increses and reaches to 30.27um and remains the same for next die size. This shows that when smaller grain size is requires smaller die is used decause in smaller die cooling rate is higher than other one.
- Average hardness is 99.30Hv when die size is 10mm and the harness is decreasing when size is 15mm then again slightly increased when the die size becomes larger.
- The average tensile strength of die size 10mm is 163.7Mpa and further increases as size increases, then drop down to 162.4Mpa when die size is 20mm. which shows die size also play an important role in tensile strength upto certain size.

5.6.3 Acceleration Effect

- Acceleration has also some effect grain size for g value 0.5g the grain size is much smaller which is 25.66um and then increases to 31.03um on 1.0g and furthers drop down to 30.04um when g increases to 1.5g.
- Average hardness is on increasing trend as acceleration increases fro 0.5g to 1.5g.
- Tensile strength and hardness has opposite effect of acceleration on each other.

Chapter 6 Conclusion and Future Works

6.1 Conclusion

The effect of mechanical permanent mold vibration is investigated on Al-based alloys it was found that impact of vibration parameters is effected upto specific range after which casting defects appears.

Taguchi was used to optimize the parameters and identify the best combination of parameters to improve the casting quality

- Mechanical vibration has greater effects on dendrite coherency on hypoeutectic alloy.it is believed that mechanical vibration has lower penetration defects which are mostly common as porosity and shrinkage in hypoeutectic alloy.
- Mechanical vibration has has refine the grain structure of hypoeutectic aluminum alloys and significantly reduced the diameter of grains.
- Mechanical properties of alloys can be improved without adding any additives or heat treatment process.
- During higher values of amplitude there is reduction in UTS and improvement in hardness value.
- Delayed in metal pouring causes drop in temperature ,which further arise incomplete filling of mold and others defects.

6.2 Future works

On the basis of research conducted, following future works are suggested:

- Others latest techniques like ultrasonic horn and electromagnetic vibration is used for further refinement and better results.
- Graphite mould for better results.
- Pressure die casting is recommended for better results.
- To further improve mechanical properties it is highly recommended to add additives like metal matrix composites ,phosphorous, etc
- It is recommend for further improvement in aluminum alloys hypereutectic alloys were used.

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