CHAPTER-3

Experimental Programme

The main objective of the present investigation is to understand the effect of oscillation during the solidification on mechanical properties and microstructural characteristics of A356 and A319 aluminum casting. The experimental results were compared with that of the properties of the stationary casting and the conclusions were derived. The detailed experimental procedure involved in each stage of this experimental work are briefed in the following sections. To achieve the main objectives of the present experimental investigation, the experimental research work was planned in the following sequence mentioned below:-

1. Literature Reviews(Based On Aluminum Alloy Casting Under Mold Oscillation)
2. Design and development of a reliable experimental setup for casting under oscillatory condition.
3. Selection of work material for casting
4. Preparation of casting under stationary and oscillatory conditions.
5. Fabrication of test specimens for tensile, impact and hardness tests from casting.
6. Preparation of test specimens for microstructure study.
7. Characterize and correlate the observed results by using microstructure and software like metallurgical plus.

8. Compare the tensile fracture of oscillatory casting with stationary prepared casting.
9. Compare all the results of mechanical properties of oscillatory casting with that of stationary prepared casting.
10. Compare all the results of metallurgical properties of oscillatory casting with that of stationary prepared casting

3.1 Block Diagram of Experimental Work Plan

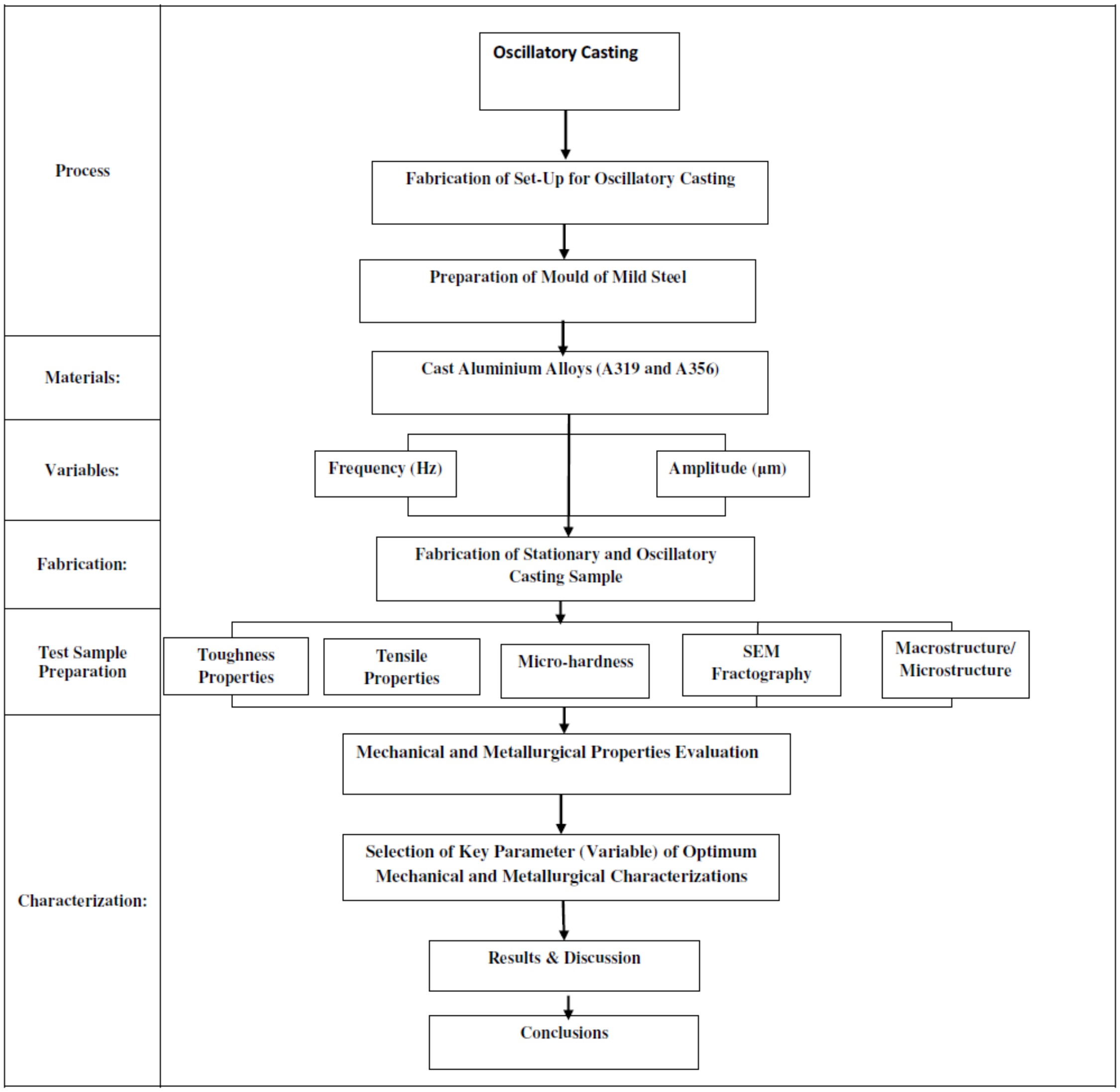

Figure 3.1 Block diagram of Work Plan

3.2 Design and development of a reliable experimental setup for casting under oscillatory condition.

For casting the work pieces under stationary and oscillatory conditions .a setup was designed and fabricated **Figure 3.2**, is the schematic diagram of the set-up.

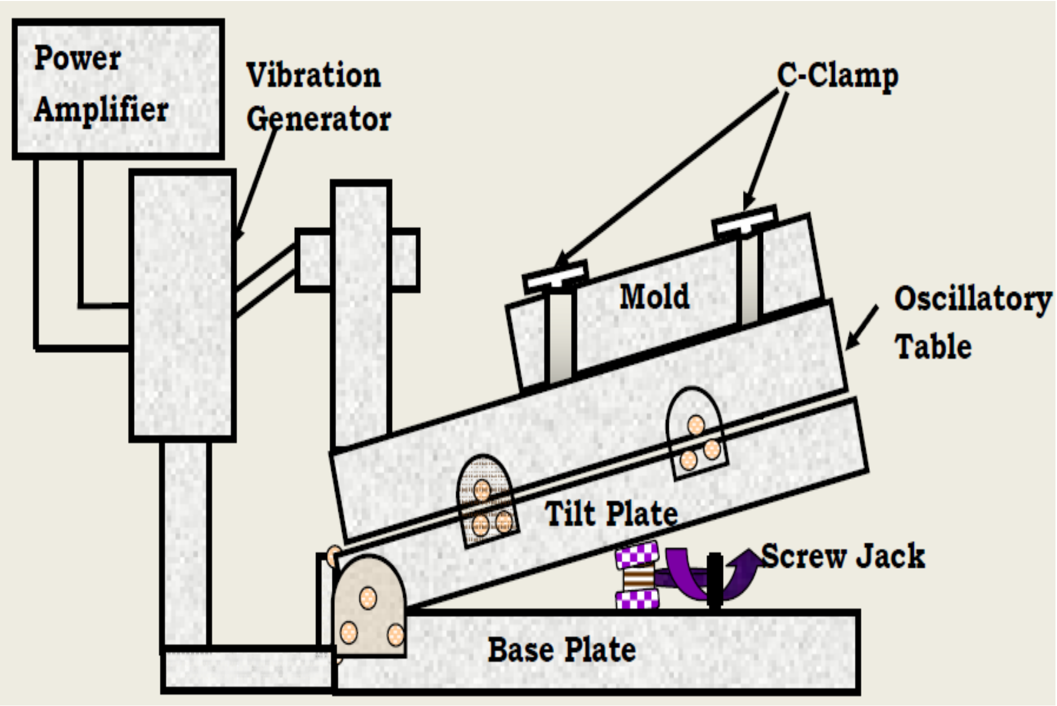

Figure 3.2 Schematic diagram of the Set Up

3.2.1 Descriptions of the Set-Up

One square plate of 16cmx16cm of mild steel was welded at 90° to four plates of 4cm x16cm each in order to make the mold. 1 cm thick square mold (16cmx16cmx4cm) of mild steel directly placed on oscillatory table of set-up and was held by C-Clamps. Vibration exciter was rigidly coupled to oscillatory table. During the solidification of casting, molds were oscillated at different oscillatory amplitudes in the range 0-20μm with constant frequency of 100Hz of oscillation developed through set-up shown in

Figure no: 1. Frequency and amplitude can be measured with the help of vibration pick-up and vibration meter respectively . Vibration meter has capability to measure the displacement range 0 to 1000 micron) and frequency range 0 to10KHz.During the casting mould were oscillated at different frequencies and amplitudes of vibration with the help of an audio oscillator/power amplifier and vibration exciter.

3.2.2 Fabrication of the Set-Up

Fabrication of the set-up shown in **Figure 3.2** consists of machining of base plate, oscillatory table, turning of two mild steel shafts and device for coupling the exciter to the oscillatory table rigidly. The base plate consists of four square hollow rods(two rods of 560mm x 40mm x 40mm and other two of 410mm x 40mm x 40 mm dimensions) which were machined on a planer. These rods were welded together at right angle to make rectangular skeleton structure of 640mm x 410mm x 40mm. To give proper height and alignment with oscillator, hollow square rods of 40mm x 40mm were used on each side. The rod was straightened in the fitting shop. Eight holes of 20mm diameter each drilled for fixing four bearing blocks. These bearing blocks have 25mm internal bearing fixed. Two mild steel shafts were turned to the size of 25mm diameter and 410mm length on a center lathe. The oscillatory table was machined to the final size of 380mm x 300mm x 10mm. The table was made flat in the fitting shop and an ‘L’ plate with both base and vertical plates of 100mm x 50mm x 5mm area with a 10mm hole was bolted to it. The hole was provided to rigidly couple the oscillatory table to the vibration exciter with an aluminum bolt. After joining two bolts, the flatness and perpendicularity of the two plates were checked.

Oscillatory table rests on two shafts which were mounted on the bearing over the base plate.

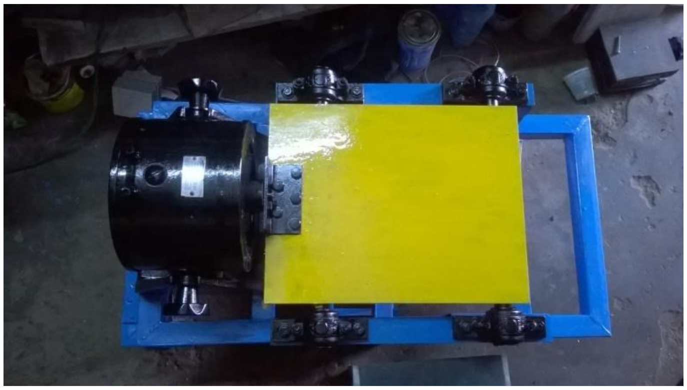

Figure 3.3 Photograph of Developed Set Up

a) **Specification of Exciter**

Vibration Generator(Exciter)

Make :	Messelektronik Dresden RFT(Made in Germany)
FABRNAR:	21001
Type :	11077VEB
Frequency Range	1 Hz to 10 KHz
Wave From	Sinusoidal

b) **Specification of Vibration Pick Up**

Vibration Pick Up

Make :	Industrial Electronics Pvt.Ltd., Bangalore
Type	CVP 3001
S.No.	529
Range, Displacement	1 to 10000 microns
Frequency	0-10KHz
Accuracy	+2%

3.3 Selection of work material for casting

A356 and A319 alloy are taken as the work material for investigation in the experimental work. Aluminum alloys are widely used in automotive manufacturing, especially aluminum–silicon (Al-Si) , and aluminum –Silicon-Copper alloys due to their low density, high strength/weight ratio and excellent castability. These alloys are appropriate for use in components such as cylinder heads, pistons and cylinder blocks. The microstructure of Al-Si and Al-S- Cu alloys consists of a mixture of a primary phase and a eutectic phase of various elements such as eutectic silicon and other intermetallic compounds. Depending on the weight percentage of the base material, Al-Si and Al-S-Cu alloys contain varying amounts of elements such as zinc, magnesium and iron. The size, shape and distribution of the Al-Si, Al-Cu, Al-Si-Cu and Mg-Si second phases have a considerable effect on the mechanical properties of the alloys. Ideally, the globular microstructure of the primary phase a-Al is surrounded by a layer of eutectic mixture. The eutectic mixture layer acts as a bond between the components of the primary phase and enables the primary phase to resist an exerted external force.

3.3.1 Characteristics of the material used to make the Casting

Chemical analysis was performed using a foundry master spectrometer of flat cylindrical specimens (3 cm of diameter and 5 mm of thick each) taken from the base material of A319 and A356, in order to check their chemical composition. In **Table 3.1** and **Table 3.2**, the results of the analysis are shown, noting that the major elements identified in the specimen can confirm that the materials used were A319 and A356 respectively.

Si	**Fe**	**Ni**	**Cu**	**Mg**	**Zn**	**Sn**	**V**
7.16	**0.14**	**0.043**	**0.077**	**0.35**	**0.064**	**0.073**	**0.013**

Table 3.1 Chemistry of Base A356 Aluminium Alloy

Si	**Fe**	**Mn**	**Cu**	**Mg**	**Ti**	**Zn**	**V**
5.78	**0.43**	**0.29**	**3.75**	**0.05**	**0.03**	**0.06**	**0.011**

Table 3.2 Chemistry of Base A319 Aluminium Alloy

3.3.2 Thermo-physical Properties and Compositions of A319 and A356 Aluminum Alloy

A319 Alumnium Alloy		**A356 Aluminium Alloy**	
Solidus Temperature	723 K	Solidus Temperature	831 K
Liquids Temperature	869 K	Liquids Temperature	876 K
Latent Heat	400 J/g	Latent Heat	429 J/g
Density at Melting Point	2.5328 g/cm^3	Density at Melting Point	2.362 g/cm^3
Composition	Si=6.1% Fe=0.68% Mg=0.3% Cu=3.01% Mn=0.32% Zn=0.71%	Composition	Si=6.9% Fe=0.08% Mg=0.34% Ti=0.013%

Table 3.3 Thermo-physical Properties and Compositions of A319 and A356 Aluminum Alloy , Bakhtiyarov, S. I., et al. [123]

3.4 Preparation of casting under stationary and oscillatory conditions.

3.4.1 Melting and Casting

In the present investigation, melting of alloys were carried out in pit furnace. The A319 and A356 aluminum alloys were melted in a graphite crucible in a pit furnace. It is taken out and degassed using the required quantity of degassing powder of HexaChloro Ethane in order to remove the dissolved hydrogen gas, oxides and coal ash in the surface of the molten metal. Aluminum alloys will absorb or dissolve harmful quantities of hydrogen from atmosphere during melting and pouring. If the molten metal reaches the approximate pouring temperature (≈700°C), subsequent cooling and solidification will result in gas evolution, pinholes, and microscopic gas porosity. So degassing is performed to minimize these defects. The presence of oxides and coal ash in the surface of the molten metal are skimmed. Then the molten metal is poured into the mold cavity at a temperature approximately of 700 ºC. During the solidification of casting mold were oscillated at different frequencies (0 Hz,100 Hz,200Hz 300Hz and 400Hz) with amplitudes of 5µm, 10µm and 15µm of vibration with the help of an oscillator/ power amplifier and vibration exciter.

Figure 3.4Experimental Set-Up

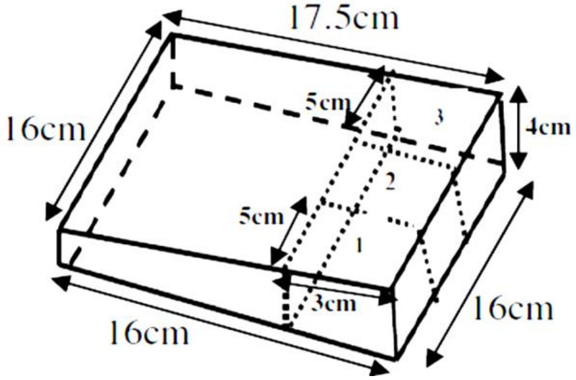

Figure 3.5 Casting sample with sectional test bar

3.5 Fabrication of test specimens for tensile, impact and hardness tests from casting

3.5.1 Fabrication of Tensile Test Specimen

The tension test specimens were prepared from the casting workpieces as per ASTM specifications. The circular cross-section test pieces were machined on a lathe machine. Shape of the ends was made to suit the gripping device of the tensile testing machine. End portion was kept long enough for proper gripping. The test specimen was long enough to ensure that the necking does not take place near the ends. All the surface irregularities were removed through machining of test specimen and finally with the help of emery paper original dimension was obtained.

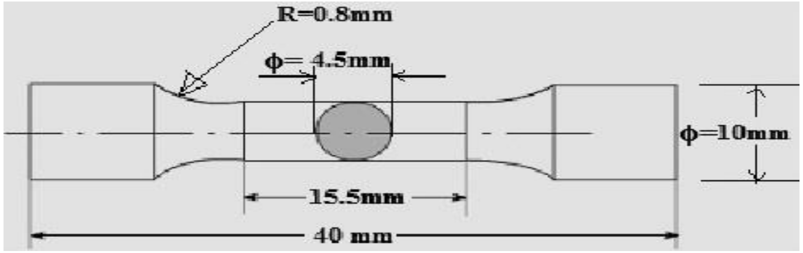

Figure 3.6 Tensile Test Specimen

3.5.2 Fabrication of Impact Test Specimen

Several methods have been developed for the determining the impact properties of cast metals. The two most widely used are the Izod and Charpy tests. The charpy test is most commonly used to evaluate the relative toughness or impact toughness of the materials and as such is often used in quality control applications where it is fast and economical test. The notched bar test has been devised to give a definite indication of behavior of the materials under dynamic condition of loading. The charpy test pieces were prepared on a shaper and a milling machine. The charpy test involves striking a suitable test piece with a striker, mounted at the end of a pendulum. The test piece is fixed in place at both ends and the striker impacts the test piece immediately behind a machined notch. A weight swung against the specimens and the impact value was obtained for each specimen .The average value of three such reading were taken for stationary and oscillatory conditions of the casting specimen. The charpy test specimens normally measure 55mm x10mm x10mm and have "V" notch across one of the larger faces.

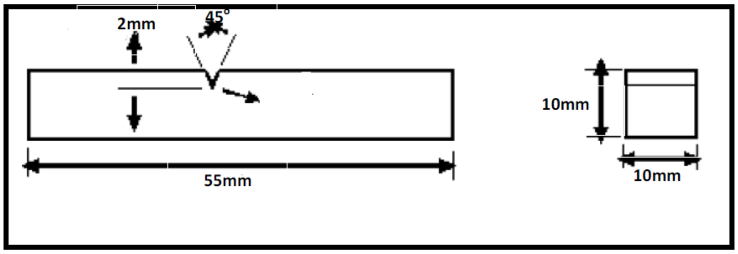

Figure 3.7 Charpy Impact Test Specimens

3.5.3 Fabrication of Micro-Hardness Test Specimen

The micro hardness tests are used to determine the resistance of a material to deformation. This tests can be performed on a macroscopic or microscopic scale. The metals indentation hardness correlates linearly with tensile strength. This important relation permits economically important non destructive testing of bulk metal deliveries with lightweight, even portable equipment, such as automatic Vickers micro hardness testers. The controlled test force the specimen is pressed with the indenter with a dwell time of 10 to 15 seconds. The indenter is removed forming an indent in the sample that appears square shaped. The size of the indent is determined optically by measuring the two diagonals of the square indent. The Vickers hardness number is obtained by the test force divided by the surface area of the indent. The average of the two diagonals is used in the formula to calculate the Vickers hardness. The application and removal of the load is controlled automatically.

The Vickers micro hardness H V is calculated by using formula

$H\ V = 1.854F / d^2$

Where F is load applied in kgf,

d is mean of the two diagonals, d1 and d2 in mm

HV is Vickers hardness, Dwell time = 10seconds

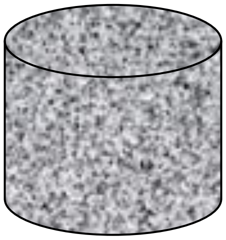

Figure 3.8 Micro-Hardness Specimen

3.5.4 Preparation of test specimens for microstructure study

A carefully prepared specimen and magnification are needed for microscopic examination. Proper preparation of the specimen and the material’s surface requires that a rigid step-by-step process be followed. The first step is carefully selecting a small sample of the material to undergo microstructure analysis with consideration given to location and orientation. It is followed by sectioning, mounting, grinding, polishing and etching to reveal accurate microstructure and composition.

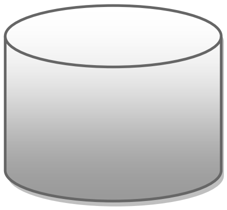

Figure 3.9 Microstructure Specimen

3.6 Characterize and correlate the observed results by using microstructure and Dewinter Material plus software

The microstructural analysis is done with the help of Dewinter inverted trinocular metallurgical microscope of DMI – Prime Model as shown in Figure 4.14. Dewinter Material plus software incorporated with the optical microscope was used to capture and analyze the images. Microstruture photograph captured from different location of test specimen at 100 magnifications. From the captured image ASTM micro grain size number, n was measured with the help of Micromeasurement and Image Analysis Software (**Dewinter Material plus software)** from the measured ASTM grain size number (n), the average grain size diameter was calculated using equation given below:

$$D=359e^{-354(n)}$$

Where, D is the average grain diameter and n is the ASTM grain size number. Similarly, silicon particles size, aspect ratio, average area of silicon particle, Roundness of silicon particle and dendrite arm spacing (DAS) were measured.