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# Enhancement of Fluidity and Mechanical Properties of Al – Si cast Alloy

G V Karthikeya, K Ch Apparao,

***Abstract: The aim of the study is to investigate the fluidity and mechanical properties of the Al-Si alloy by varying the copper content at three different temperatures with the effect of grain refinement. In this present examination a humble endeavour has been made to know the properties with an ease strategy for sand casting system. Al- Si aluminium alloy is chosen as the base material and copper powder; grain refinement and scrap were added as the compositions. The investigation has been furnished by variying the weight percentage of copper (0-4%), scrap (20-40%) and grain refinement (0-0.4%). Test examples were exposed to various testing conditions and properties have been upgraded. The tensile strength of the material increases with increase of percentage of copper content and the fluidity is balanced by addition of grain refinement. The comparison between microstructure images at 0% copper and 4% copper shows the variation of grain sizes.***

***Keywords - Al-Si alloy, sand casting, metal composite, mechanical properties, grain refinement***

## I. INTRODUCTION

Light Alloys with phenomenal explicit quality find expanding applications in the car businesses and aviation. With oil costs at a noteworthy high and worldwide worry about vehicle discharge, the attention on vehicle assembling is moving thus to lightweight materials to decrease the fuel utilization [1]. Assessments given by the International Aluminum Institute speak to that each kilogram of a heavier material that is supplanted by aluminum in a vehicle brings about the decrease of 22 kilograms of carbon dioxide over the life expectancy of a vehicle. The development of the light composites in car applications has been assessed at 12% in the course of the most recent decade and is required to increment at the pace of 15% in the coming decade [2]. Aluminum alloys are extensively utilized as a fundamental lattice component in composite materials. Aluminum composites for its light weight, has been in the net of analysts aimed at upgrading the innovation. The composite material has great normal for hardness, opposing wear obstruction and rigidity because of good quality and less weight the composite material assume an imperative job in engineering field [3-4].
Aluminum is one of the most significant metals utilized by present day social orders.

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***** Correspondence Author
**G V Karthikeya**, Mechanaical Engineering, Institute of Aeronautical Engineering, Hyderabd - India. Email: karthikeyagageera96@gmail.com.
**K Ch Apparao***, Mechanaical Engineering, Institute of Aeronautical Engineering, Hyderabd - India, Email: kchapparao@gmail.com .



Aluminum's mix of physical properties brings about its utilization in a wide assortment of items, a considerable lot of which are irreplaceable to current life. Among business aluminum casting alloys, those with silicon as the major alloying component just called as Al-Si cast alloys is the most significant one fundamentally due to its phenomenal casting attributes. Expansion of Si to unadulterated aluminum gives high ease, great nourishing attributes, low shrinkage and great hot breaking opposition. The high solidarity to weight proportion is one of the most intriguing trademarks include. The properties of Al-Si alloy make them prominent in different applications including the automotive, aerospace and defense industries. Throughout the years, these Al-Si combinations have been uncommonly created to satisfy the expanding needs of the present business, which has brought about the generation of littler, lightweight segments to agree to the property, natural and different particulars. Further, the attractive mechanical properties in these alloys can be acquired by advancing procedure parameters during Casting and controlling compound structure [5-6]. In the present period, Sand Casting procedure has been utilizing quickly in the large scale manufacturing of car parts; since they can deliver unpredictable shapes with a high level of precision and repeatability and surface completion with smooth or finished surface. By weight, 90% of all molded Al castings are produced using Al-Si based combinations by Die Casting forms. Castings with huge grains have poor castability and mechanical properties contrasted with those with fine equiaxed grains. The ordinarily utilized grain purifier intended for aluminum combinations is Al-5Ti-B ace composite and its utilization as grain refiner is settled and the exploration has been seriously done throughout the previous five decades. The Al-5Ti-1B ace compound is exceptionally strong grain purifier for consistent and semi-persistent castings of fashioned alloys, whose Si substance is under 2 wt. %, yet neglects to meet the desires on account of Al-Si cast composites, where the substance of Si is over 4 [7-8]. The reason is that the dissolved Si will collaborate with Ti to frame titanium silicide's (i.e. TiSi, $TiSi_2$, and $Ti_5Si_3$), which drains the Titanium content in the soften, subsequently hindering the grain refining proficiency of the ace compound. This wonder is known as poisoning effect [9-10] To beat this poisoning effect, various attempts were made extensively, but fails to meet the expectations. But Nb –B master alloy [11] effectively enhances the grain refinement effect of Al-Si alloys. For the present examination, Ferro Niobium (FeNb) and Carbon (C) made Al-3.5FeNb-1.5C master alloy and Cu alloying element additions have been considered for the studies on the enhancement of mechanical properties and fluidity properties of Al -12Si alloy [12].

## II. MATERIALS AND METHODOLOGY

The materials used for experiment are:

- Al-Si Aluminum alloy
- Copper Powder
- Grain Refinement

### *Al-Si Aluminum Casting Alloy (Al – 12Si)*

Al-Si compound is basically a hypoeutectic Al-Si amalgam (commonly comprises of 11.5wt% Si, under 12.6wt% Si of eutectic piece) with low copper substance to grant it the incredible property of erosion opposition under both standard barometrical and marine conditions. The chemical composition of Al 356 alloy has given below

**Table 1. Composition of Al356 alloy (mass fraction, %)**

| GB | USA | Si | Mg | Mn | Cu | Ni | Zn | Ti | Fe |
|---|---|---|---|---|---|---|---|---|---|
| LM25 | AA356 | 6.5-7.5 | 0.2-0.6 | 0.3 | 0.2 | 0.1 | 0.1 | 0.08 | 0.5 |

### *Copper Powder*

The copper powder is utilized in the electrical and the gadgets ventures in view of its superb electrical and warm conductivities. Alloyed with tin, zinc, nickel and different components, copper in powder structure is utilized in auxiliary parts and rubbing materials.

Copper powders are produced by many processes, including chemical precipitation, electrolytic deposition, oxide reduction, water atomization, gas automation, and jet milling. Accordingly, copper powders are commercially available in a wide range of particle shapes and sizes.

### *Master alloy preparation*

In the present investigation, Al-3.5FeNb-1.5C grain purifier was manufactured by an immunization method in the melting furnace. Aluminum (99.9% unadulterated) ingot, initiated carbon powder (~150 µm) and ferroniobium (60% Nb) metal have been utilized as crude materials. Initially, 1 kg aluminum ingot was softened in a graphite die at 900ºC and idled 60 minutes. At that point, the preheated actuated carbon powder enveloped by an aluminum paper has been put in to the liquid metal at 1.7 wt.% of C and following 4-5 minutes, 7.7 wt.% of FeNb metal was mixed to the dissolve. Then the liquid metal has been taken in to metallic die and allowed to solidify. Then the solidified master alloy has been considered for experimental work.

## III. EXPERIMENTAL PROCEDURE

Al-Si Aluminum alloy Ingots were taken and are cut into equal number of portions. This cutting operation is done in the hydraulic cutting machine. Equal numbers of portions are cut by hydraulic cutting machine. The material is sent to composition testing to confirm whether it is Al- Si alloy or not.

A three level OA with 9 test runs has been chosen for the present examination. The task of casting process parameters (A to D) to sections is given in table 2. Following the $L_9$ OA series a table is prepared with the process parameters [13].

Table. 2 clearly says the amount of compositions to be added with varying temperature. Calculations are done for converting percentile into weights (in grams).

**Table 2. Design of Experiments**

| Exp . no | Process Parameters | | | |
|---|---|---|---|---|
| | Temperature A | Addition of Scrap B | Grain Refinement C | Addition of Copper D |
| 1. | 720 | 0 | 0 | 0 |
| 2. | 720 | 20% | 0.4% | 2% |
| 3. | 720 | 40% | 0.8% | 4% |
| 4. | 750 | 0 | 0.4% | 4% |
| 5. | 750 | 20% | 0.8% | 0 |
| 6. | 750 | 40% | 0 | 2% |
| 7. | 780 | 0 | 0.8% | 2% |
| 8. | 780 | 20% | 0 | 4% |
| 9. | 780 | 40% | 0.4% | 0 |

Accordingly, all the calculations are done for the addition of Copper, Grain refinement and scrap. A total of 9 experiments are done each of different compositions. The copper is added in the form of powder, and then 2%-4% copper powder is calculated in grams and packed separately for each experiment. In the same way 0.4%-0.8% of Grain refinement is calculated in grams and packed separately for nine different experiments. 20%-40% of scrap is taken from the same Al-Si alloy and then required amount of scrap is calculated in grams and packed separately for nine different experiments.

For the fluidity studies, a spiral pattern made of wood is chosen for the mould. This pattern is used for the fluidity test. Sand casting process is chosen. A spiral mould and a shaft mould is prepared. The Al-Si alloy is made to melt in the core furnace and then calculated amount of scrap, copper and Grain refinement are added and are stirred well. The temperature of the alloy is measured by using a k-type thermocouple. At $720^0$C the melted Al-Si alloy with composition is made to mould in the design patterns. The same procedure is done at three different temperatures 720, 750 and 780 $^0$C. At these temperature spiral mould and a shaft mould are prepared. The amount of passage of the melted material in the spiral mould says the amount of fluidity the material process. The shaft mould is used to know the tensile properties and the hardness of the material.

The cylindrical rods are machined for the tensile test specimen by following the ASTM E-8M standards. The tensile specimen was prepared by measuring a length of 200mm and 20mm diameter with a gauge length of 60mm.

The machined tensile test specimen was tested for tensile test in a tensile test machine. The tensile test machine is connected to the computer which shows the maximum load, tensile strength and yield strength with a graph. The same procedure is repeated for all the nine experiments and then the hardness test is done. The specimen used for tensile test is used for the hardness test. A length of 5-10mm and 20mm diameter is cut and used for the hardness test.

## IV. RESULTS AND DISCUSSIONS

Following are the tests completed to check the mechanical properties and fluidity studies of Al- Si Aluminum alloy metal composites.

(a) Tensile test Results
(b) Fluidity test Results
(c) Microstructure Results

***(a) TENSILE TEST RESULTS***

Tensile quality is an estimation of the power required to dismantle something to the point before it breaks. Tensile test is finished utilizing Universal Testing Machine (UTM) figure 1. The Specimen utilized according to ASTM E8 standard. The specimen made of (Al-Si) Aluminum alloy metal having composites 0-4% copper powder, 20-40% scrap and 0.4-0.8% Grain refinement is used for tensile test.

**Fig. 1: Universal Testing Machine**

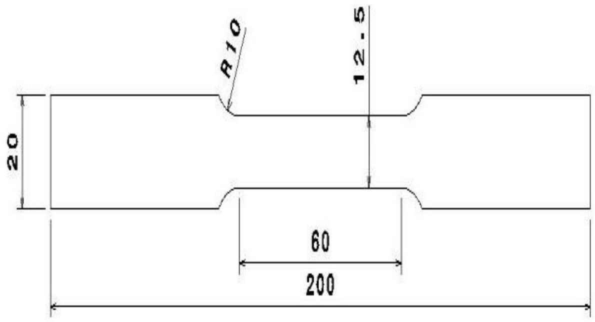


Fig. 2: Schematic illustration of tensile test

***Al-Si alloy with 0% Copper powder***

The figure demonstrates the example when testing.


**Fig. 3: Tensile test specimen at 0% Cu.**

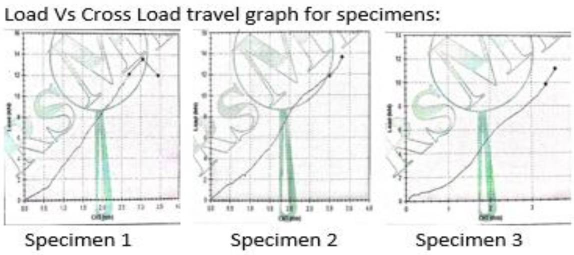


**Fig. 4: Load vs Cross Load graphs**

The figures show the results of tensile test. The composition of the test specimens is given in table 1. Fig 3 shows tensile test specimen before and after testing and the Fig 4 shows the graphs of load vs cross load of tensile test specimen. Maximum load, tensile strength and yield stress values are given in table 3.

**Table 3. Tensile test report**

| S.No | Specimen ID | Load at Breaking Point | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) |
|---|---|---|---|---|
| 1 | 1 | 11 KN | 98 | 109 |
| 2 | 2 | 13 KN | 95 | 110 |
| 3 | 3 | 11 KN | 90 | 90 |

***Al-Si alloy with 2% Copper powder***

Fig 5. demonstrates the example when testing. The composition of the test specimens were given in table 2. The values obtained from testing are given in table 4

**Table 4. Tensile test report**

| S.No | Specimen ID | Load at Breaking Point | Yield Stress ($N/mm^2$) | Tensile strength ($N/mm^2$) |
|---|---|---|---|---|
| 1 | 4 | 13 KN | 93 | 108 |
| 2 | 5 | 8 KN | 88 | 101 |
| 3 | 6 | 13 KN | 98 | 107 |


**Fig. 5: Tensile test specimen at 2% Cu.**

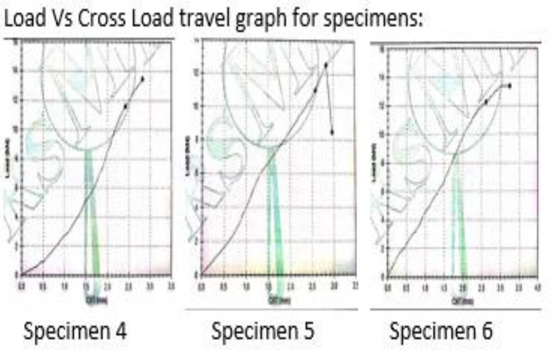


**Fig. 6: Load v's Cross load graph at 2% Cu**

***Al-Si alloy with 4% Copper powder***

The composition of the test specimens was given in table 2.

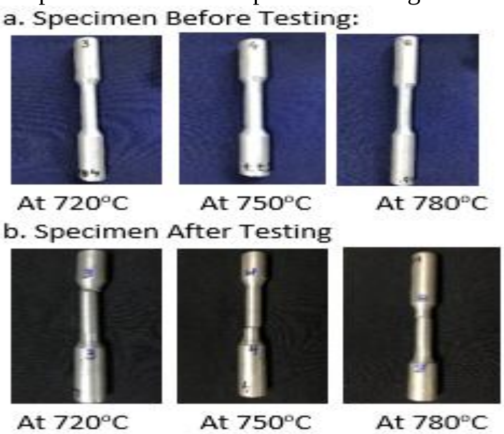


**Fig. 7: Tensile test specimen for 4% Cu**

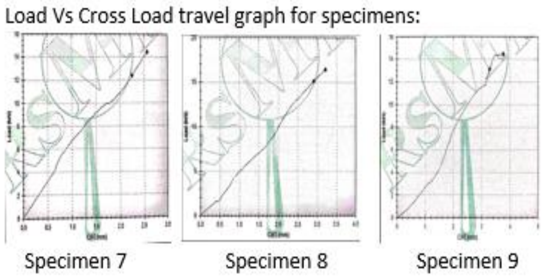


**Fig. 8: Load v's Cross load graphs for 4% Cu**

The values obtained from testing are given in table 5. The figure demonstrates the example when testing.

**Table 5. Tensile test report**

| S.No | Specimen ID | Load at Breaking Point | Yield Stress ($N/mm^2$) | Tensile Strength ($N/mm^2$) |
|---|---|---|---|---|
| 1 | 7 | 14 KN | 100 | 117 |
| 2 | 8 | 16 KN | 121 | 131 |
| 3 | 9 | 14 KN | 105 | 116 |

### (b) FLUIDITY TEST

In our work we used a spiral pattern for fluidity test. The below figure shows the spiral pattern which was used in this work

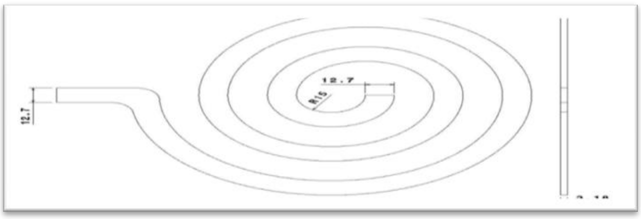


**Fig. 9: - Single spiral of 3.18mm thick, 12.7mm width and 940mm length**

The dimensions of the spiral pattern are 940mm length, 3.18mm thickness, 12.7mm width with radius 15mm at the center. The amount of fluidity the material process is known by the amount of molten material passes through the mold. This can be properly known by measuring the total length of the specimen after the casting. The fluidity testing is done at three different temperatures $720^0$, $750^0$, $780^0$ by varying copper, scrap, grain refinement in it.

***At 0% copper***

Below figure shows the fluidity test castings of Al-Si alloy with 0% copper powder in it

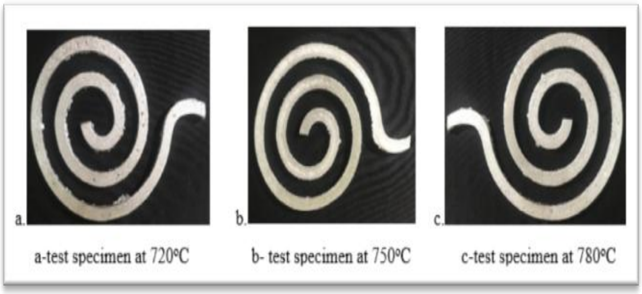


**Fig. 10: Specimen at 720, 750 and 780°C for 0% Copper**

The above figure shows the three different metal composition test specimens for fluidity test. The metal composition of these specimens was given in table 2. The below table shows the total length values of the test specimen at different temperature.

**Table 6. Fluidity values of the metal composite specimen**

| S. No | Specimen ID | Pouring temperature | Total length |
|---|---|---|---|
| 1 | 1 | 720 | 91 |
| 2 | 2 | 750 | 92 |
| 3 | 3 | 780 | 93 |

***At 2% copper***

Below figure shows the fluidity test castings of Al-Si alloy with 2% copper powder in it.

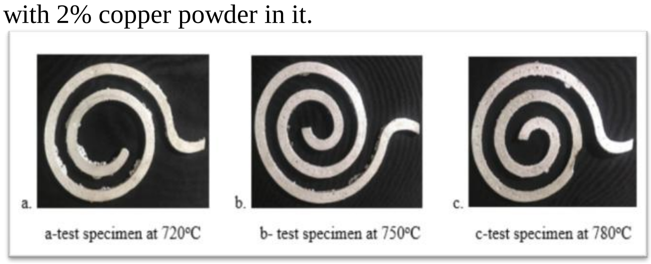


**Fig. 11: Specimen at 720 , 750 and 780°C for 2% Copper**

The below table shows the total length values of the test specimen at different temperature.

**Table 7. Fluidity values of the metal composite specimen**

| S. No | Specimen ID | Pouring temperature | Total length |
|---|---|---|---|
| 1 | 4 | 720 | 80.5 |
| 2 | 5 | 750 | 92 |
| 3 | 6 | 780 | 93.5 |

***At 4% copper***

Figure shows the fluidity test castings of Al-Si alloy with 4% copper powder in it.

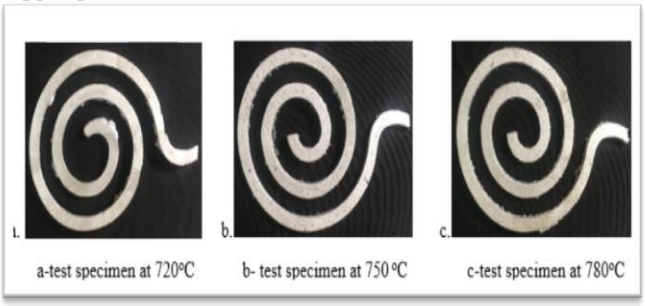


**Fig. 12: Specimen at 720, 750 and 780°C for 4% Copper**

The table 8 shows the total length values of the test specimen at different temperature.

**Table 8. Fluidity values of the metal composite specimen**

| S. No | Specimen ID | Pouring temperature | Total length |
|---|---|---|---|
| 1 | 7 | 720 | 93.5 |
| 2 | 8 | 750 | 94 |
| 3 | 9 | 780 | 93.5 |

**(c) MICRO STRUCTURE RESULTS**

Specimens are machined as per ASTME 112 standards. The specimens are polished and then etched using HF. The equipment used in this process is a Metascope Metallurgical Microscope. The images are taken with a 100x magnification. Figures below shows the microstructure image of a composite metal alloy with varying copper content in it.

***At 0% copper powder***

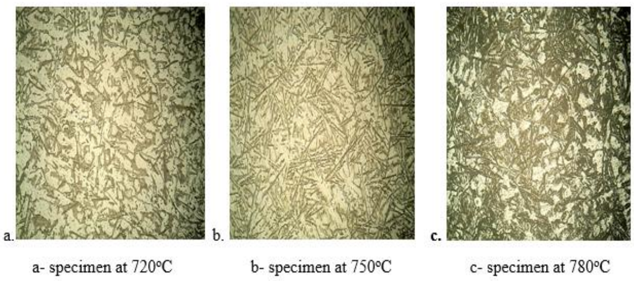


**Fig. 13: Microstructure of a sand cast Al metal composite with 0% of copper.**

Figure 13 shows the microstructure of an Al-Si alloy with 0% copper in it. The grain sizes of specimens at three different temperatures($720^0$c,$750^0$c,$780^0$c ) is 62±3 µm.

***At 2% copper powder***

Figure 14 shows the microstructure of an Al-Si alloy with 2% copper in it. The grain sizes of specimens at three different temperatures($720^0$c,$750^0$c,$780^0$c ) is 51±3 µm.

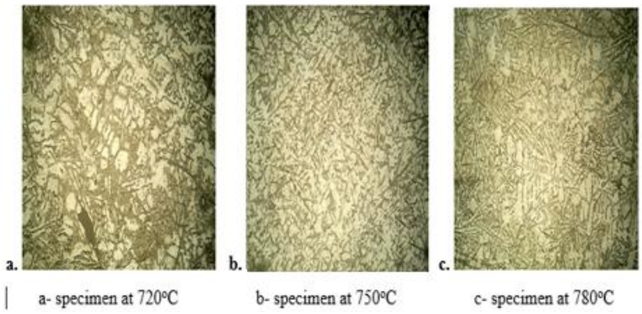


**Fig. 14: Microstructure of a sand cast Al metal composite with 2% of copper.**

***At 4% copper powder***

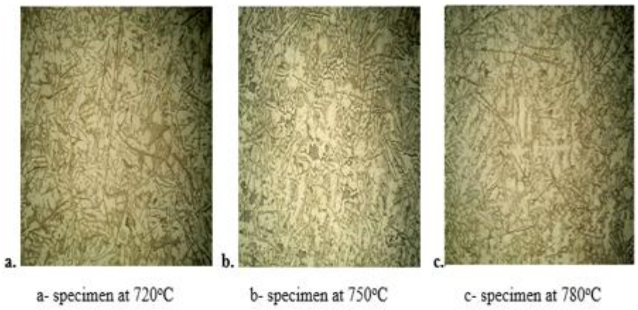


**Fig. 15: Microstructure of a sand cast Al metal composite with 4% of copper.**

The above figure shows the microstructure of an Al-Si alloy with 4% copper in it at three different temperatures. The grain sizes of specimen at three different temperatures ($720^0$c,$750^0$c,$780^0$c) is 22±3 µm.

## V. CONCLUSIONS

- Enhancement of Mechanical properties such as tensile strength of Al-Si alloy has been observed by the addition of Cu powder particularly at 4% of the Cu weight percentage.
- The addition of Copper also leads to lower the fluidity of the Al-Si alloy. But the fluidity is enhanced by addition of grain refinement at 0.4% of grain refinement.
- There is no effects on the fluidity properties of Al-Si alloy with the addition of scrap.
- From the microstructures it has been observed that grain sizes have been decreased from 0% copper to 4% copper weight percentage. Particularly the smaller grain structure has been observed at 4% copper and 750°C.
- Enhances properties such as Tensile strength and fluidity have been observed mainly at 750°C with 4% copper addition compared to other two temperatures.

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## AUTHORS PROFILE

**G V Karthikeya** studying as M Tech student in CAD-CAM from Mechanaical Engineering, Institute of Aeronautical Engineering, Hyderabd – India. He has done his M Tech thesis work on Enhancement of Mechanical Properties of Al-Si cast Alloys. He has published his research paper in one International Conference conducted at Singapore.

**Dr. K. Ch Apparao** is Associate Professor in Department of Mechanical Engineering at Institute of Aeronautical Engineering College, Hyderabad. He has obtained his Ph.D Degree (2018) from NIT, Manipur and actively involved in teaching and research in the direction of manufacturing science for last nine years. His research interests are in the Manufacturing Science, Metal Casting, Grain refinement and Composites. He has authored and co-authored more than 12 research papers in reputed national/international conferences and 7 peer-reviewed journal papers, which includes publications in Springer and Elsevier journals.