A Project Report on Microstructure Of Al-Si Alloy

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Abstract

Through this project, we are able to gain a better understanding of the hardness properties and microstructure of A356 and A390 alloys, which will be useful for both practical applications and future research. The final microstructure was affected by the casting process using a mild steel mold. Precise specimen preparation was ensured by a digital hot mounting machine and bakelite polymer. While polishing required a multi-step procedure using a polishing wheel machine, specialty cloth, spray, and diamond pastes, grinding required a methodical approach using emery papers.

Using an optical microscope, microstructural examination of A356 and A390 revealed unique grain structures and eutectic formations. Vickers hardness testing gave important details about variations in hardness, highlighting the effect of rolling. The results help material engineers, researchers, and industries using Al-Si alloys by adding a great deal to our understanding of these alloys.

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1. Introduction

The project's results add to our understanding of the complex microstructure and hardness properties of A356 and A390 alloys. This information helps identify possible directions for future study and is essential for maximizing their performance in real-world applications. This study effort demonstrates the relationship between casting procedures, specimen preparation methods, microstructure, and hardness, providing useful information for material engineers, scientists, and Al-Si alloy users in many industries.

1.1 Al-Si Alloy overview

Al-Si alloys, also called aluminum-silicon alloys, combine silicon's and aluminum's beneficial qualities. This class of alloy is highly regarded for its superior thermal conductivity, corrosion resistance, and strength-to-weight ratio. A356 has excellent cast and weldability and is mostly used in automotive applications. Conversely, A390, which has been enhanced with extra elements such as copper, has improved mechanical qualities and can be used in applications that need higher strength.

1.2 Significance of Microstructure and Hardness Analysis

Optimizing the performance of Al-Si alloys in practical applications requires a thorough understanding of their microstructure and hardness. Mechanical properties are determined by the microstructure, which is shaped by the alloy composition and casting techniques. Hardness measurements, on the other hand, reveal the material's resistance to deformation. In order to shed light on the distinctive qualities and possible uses of A356 and A390 alloys, this project seeks to understand the complexities of their microstructure and hardness.

1.3 Rationale for the Study

The need for a thorough examination of A356 and A390 alloys to close the knowledge gap between theory and practice is the driving force behind this study. Through analyzing the casting procedures, preparing specimens with care using metallographic techniques, and performing in-depth microstructural and hardness analyses, we hope to add to the foundational knowledge needed by industries, researchers, and engineers that work with Al-Si alloys.

1.4 Objectives of the Project

The following are the project's main goals:

- Examining the A356 and A390 alloys' microstructure and hardness properties.
- Examining the impact of alloy composition and casting techniques on microstructural characteristics.
- Analyzing the changes in hardness in various alloy regions, paying particular attention to rolling's impact.

2.Casting processes

2.1 Overview of Casting Process:

A key manufacturing procedure that is essential to shaping metallic components, particularly alloys like A356 and A390, is casting. This section offers a thorough analysis of the casting procedure used to create these alloys, emphasizing how important it is in determining the alloy's final microstructure and characteristics.

By pouring liquid metal into a mold, it is transformed into a solid state during the casting process. This process makes it possible to create complex components with precise geometries for Al-Si alloys, which is important in industries where precision and complexity are critical.

2.2 Importance of Casting in Shaping A356 and A390 Alloys:

Because the casting process can accurately reproduce complex structures, it is crucial in shaping A356 and A390 alloys. Casting helps A356—a material that is extensively used in the automotive industry—maintain complex designs and produce superior surface finishes. Because A390 has improved mechanical properties, it needs to be cast in a way that maintains those qualities while forming the desired shape.

The alloys' microstructure is significantly impacted by the rate of cooling during casting. To guarantee uniform grain formation and avoid flaws like porosity, a regulated cooling rate is necessary. The complex relationship between the cooling rate, the casting process, and the resulting microstructure for A356 and A390 is examined in this section.

2.3 Role of Mild Steel Mold in Microstructure Formation:

One important factor affecting the rate of cooling and, in turn, the microstructure of the cast alloy is the material selection for the mold. Because of their superior thermal conductivity, mild steel molds are frequently used to extract heat from molten metal efficiently. Grain formation and controlled solidification are the outcomes of this.

Regarding A356 and A390, the mild steel mold is an essential tool for forming the alloys into parts with specific microstructures. The material of the mold allows for controlled cooling, which guarantees that the resulting microstructure satisfies the necessary application requirements and desired mechanical properties.

2.4 Comparison of Casting Processes for A356 and A390:

Both A356 and A390 can be cast using the same basic procedure, but because of their distinct compositions, casting requires some special considerations. A 356 alloy, which is well-known for its castability and weldability, gains from a casting method that prioritizes mold fillability and fluidity to produce complex designs. Conversely, A390—which has been strengthened with copper—needs a casting procedure that balances cooling rates to prevent rapid solidification and maintain mechanical properties.

This section explores the subtleties of casting procedures specific to each alloy, addressing any issues or factors that are particular to A356 and A390. The complexities of casting provide us with information about the early phases of alloy formation, which paves the way for further investigations into microstructure and hardness.

3.Metallographic Mounting

3.1 Purpose and Significance of Metallographic Mounting:

An essential step in getting specimens ready for microstructural analysis is metallographic mounting. The goal and importance of metallographic mounting are thoroughly examined in this section with reference to the analysis of A356 and A390 alloys.

Encasing specimens in a transparent, long-lasting material for later sectioning and polishing is the main goal of metallographic mounting. By preserving the microstructure without distortion, this process makes it possible to observe it accurately using a variety of microscopy techniques. The significance is in the ability to obtain polished specimens that allow for accurate analysis and interpretation and reveal the true nature of the alloy's internal structure.

3.2 Bakelite Polymer: A Suitable Embedding Material:

The embedding material is a crucial element in metallographic mounting, and bakelite polymer is selected for this project due to its appropriateness. One kind of phenolic resin that has many benefits is bakelite. Because it is thermosetting—it hardens irreversibly when heated—the embedded specimens are stabilized. Its smooth surface can be easily achieved by polishing it, and its transparency makes it possible to observe the microstructure with clarity.

The thermal stability of bakelite polymer is especially important in metallography because mounting requires high temperatures. Its capacity to endure these temperatures without endangering the specimen's structural integrity guarantees that the microstructure will not change and will accurately reflect the alloy's true properties.

3.3 Digital Hot Mounting Machine: Achieving Consistent Mounting Conditions:

To obtain consistent and repeatable results in the metallographic mounting process, a sophisticated device known as the digital hot mounting machine is used. An extensive description of the machine and its function in guaranteeing accuracy in mounting conditions is given in this section.

In order to embed the specimen, the digital hot mounting machine first heats the bakelite polymer to the proper curing temperature and then applies pressure. The digital control system makes it possible to precisely control the pressure and temperature, guaranteeing consistency across a number of specimens. Achieving uniform mounting conditions is crucial, as deviations may result in microstructure distortions and artifacts.

Through the use of a digital hot mounting machine, the project minimizes variability and improves the dependability of subsequent microstructural analyses by guaranteeing that every specimen goes through the same mounting procedure. One important feature of scientific research is reproducibility, which is enhanced by the machine's ability to maintain a controlled environment during embedding.

4. Grinding

4.1 Role of Grinding in Specimen Preparation:

A crucial stage in getting specimens ready for microstructural analysis is grinding. This section goes into great detail to explain the grinding process and how important it is to attain clarity and precision when observing A356 and A390 alloys.

There are several uses for grinding when preparing specimens. First, it ensures uniform thickness by leveling the mounted specimen's surface. This consistency is important because any deviations could make it difficult to see microstructural details during later polishing steps. Second, grinding exposes the desired areas of the specimen for microscopic examination by removing excess material. Lastly, the specimen's surface is refined through grinding, which prepares the way for later polishing steps.

4.2 Grinding Mediums:

Grinding media are silicon carbide (SiC), aluminium oxide (Al_2O_3), emery (Al_2O_3-Fe_3O_4), and diamond particles. All except diamond are generally bonded to paper or

cloth backing material of various weights in the form of sheets, disks, and belts of various

sizes. The abrasives may be used also in t h e powder form by charging the grinding

surfaces with loose abrasive particles

4.3 Development of a Detailed Flowchart for Grinding:

A comprehensive flowchart that shows the progression through different grit sizes of emery papers is developed in order to maintain a methodical and controlled approach to the grinding process. This flowchart outlines each step of the grinding process and acts as a visual guide.

Particle Size vs. Common Grit Sizes for Abrasive Papers

GRIT NUMBER		
European (P-grade)	Standard grit	Median Diameter, (microns)
60	60	250
80	80	180
100	100	150
120	120	106
150	150	90
180	180	75
220	220	63
P240	240	58.5
P280		52.2
P320	280	46.2
P360	320	40.5
P400		35
P500	360	30.2
P600	400	25.75
P800		21.8
P1000	500	18.3
P1200	600	15.3
P2400	800	6.5
P4000	1200	2.5

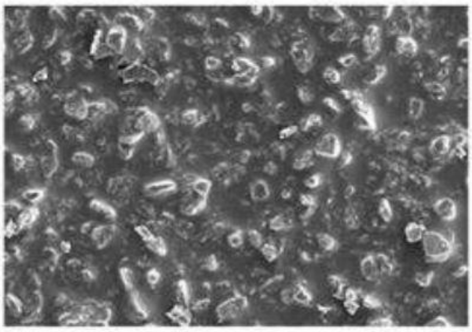


Figure SEM micrograph of 600 grit SiC Abrasive Paper (original mag. 150x)

The flowchart starts with coarse grit sizes and advances to finer ones gradually. Finer grits help create a smoother surface, while coarser grits effectively remove material and flaws. The flowchart guarantees a methodical approach, averting mistakes and guaranteeing that every sample experiences an identical grinding procedure.

4.4 Impact of Grit Sizes on Specimen Quality:

The prepared specimens' quality is greatly influenced by the grit sizes selected during the grinding process. This section examines the effects of varying grit sizes on the surface properties and overall quality of the specimen.

Lower Grit Numbers: Coarse grits work well for quickly leveling the surface and removing material. They usually range in grit number from 60 to 120. They might, however, leave deeper scratches behind, necessitating additional grinding with finer grits to smooth the surface.

Medium Grits (Grit Numbers 180–400): Medium grits are the middle ground between surface refinement and material removal. They help to smooth the specimen in preparation for subsequent stages of finer grinding, which are started by the coarse grits.

Fine Grits (Higher Grit Numbers): The purpose of fine grits, which start at 600 and go up, is to minimize scratches and refine the surface. They help achieve a mirror-like finish, which is essential for observing microstructural details clearly in subsequent microscopy.

5. Polishing

5.1 Overview of the Polishing Process:

After grinding, polishing is the refinement step, and it is crucial to getting specimens ready for in-depth microstructural examination. This section offers a thorough examination of the polishing procedure, illuminating the tools and supplies used to give specimens of A356 and A390 alloys a mirror-like sheen.

5.2 Polishing Equipment:

Polishing Wheel Machine: A key piece in the polishing procedure is the polishing wheel machine. The specimen is usually pressed onto a revolving wheel in this configuration. The material of the wheel, rotation speed, and pressure used all affect how well the wheel polishes. This apparatus enables precise and reliable polishing, guaranteeing consistency among various specimens.

5.3 Polishing Materials:

Cloth: The polishing wheel is used in conjunction with a specialized cloth. The composition of the cloth, which is frequently composed of felt or synthetic fibers, affects how well it polishes overall. It helps to remove any last traces of surface imperfections and acts as a carrier for the polishing compounds.

Spray: To lubricate, cool, and improve the effectiveness of the polishing compounds, a polishing spray is applied during the process. In order to maintain the specimen's ideal temperature and avoid structural alterations, the type of spray used can affect the frictional heat produced during polishing.

Diamond Pastes: A vital component of polishing compounds, diamond pastes come in a range of grit sizes. Fine diamond particles suspended in a carrier medium make up these pastes. The diamond paste's grit size influences the final smoothness of the surface and establishes the amount of abrasiveness.

5.4 Importance of Careful Polishing:

To achieve a mirror-like finish on specimens, careful polishing is essential. In this step, any remaining grinding marks or scratches are removed from the surface through further refining. A mirror-like finish is essential for obtaining unobscured and clear microstructural observations; it is not just an aesthetic requirement.

The process of meticulous polishing involves several steps, whereby the surface irregularities are reduced with each iteration using finer polishing compounds. This meticulous attention to detail guarantees that there are no artifacts in the polished final specimen that could jeopardize the precision of microstructural analyses.

5.5 Polishing's Effect on Microstructure:

The final microstructure of A356 and A390 alloys is greatly influenced by the polishing procedure. By eliminating surface flaws, the internal structure of the alloy can be more clearly seen under a microscope, revealing its true nature.

When undergoing microscopic analysis, the mirror-like finish that is attained through careful polishing helps to improve contrast and resolution. Grain boundaries, phases, and any other microstructural details that are crucial to comprehending the material's properties must be clearly visible.

Study of Microstructure

6.1 Overview of Microstructural Examination:

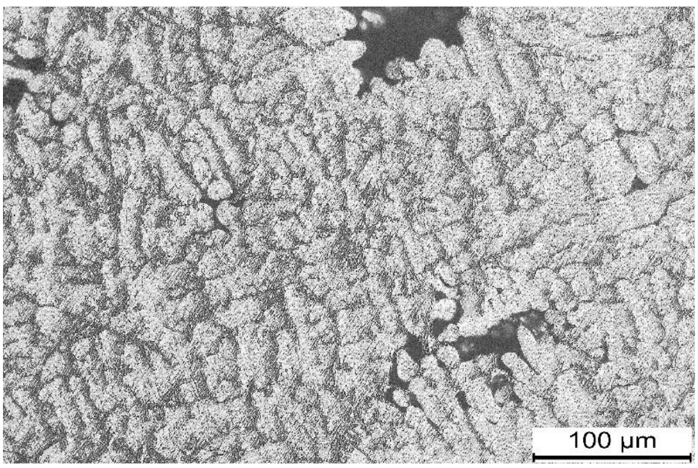
Understanding the characteristics and behavior of materials begins with an understanding of their microstructure. We begin a thorough optical microscope analysis of the A356 and A390 alloy microstructures in this section. We hope to decipher the complex details governing these alloys' mechanical properties and performance through this examination.

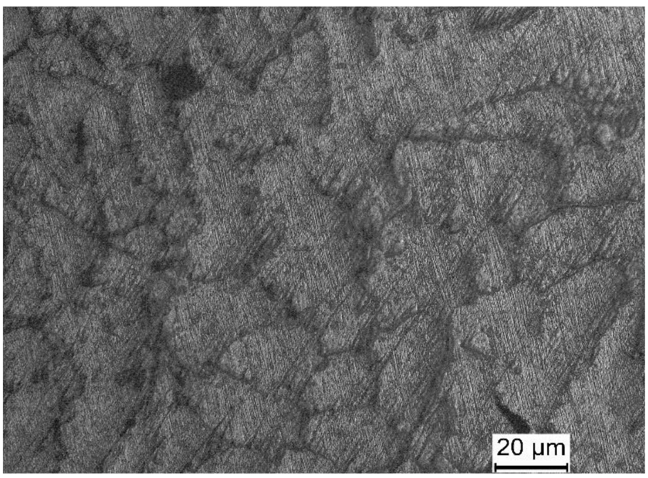
6.2 Microstructural Analysis Setup:

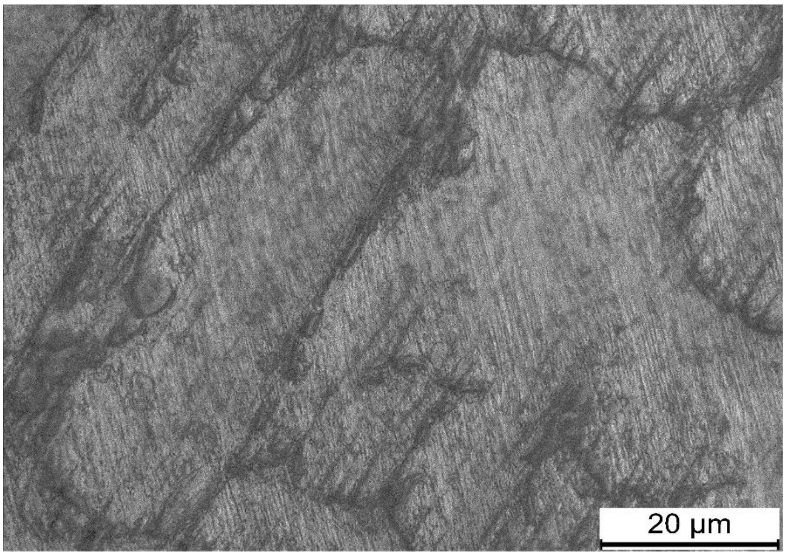
The specimens are now ready for microstructural analysis after being painstakingly prepared by the casting, metallographic mounting, grinding, and polishing procedures. Our main tool is the optical microscope, which offers the clarity and magnification required to view features at the microscopic level.

6.3 Grain Structure:

A356 Alloy:

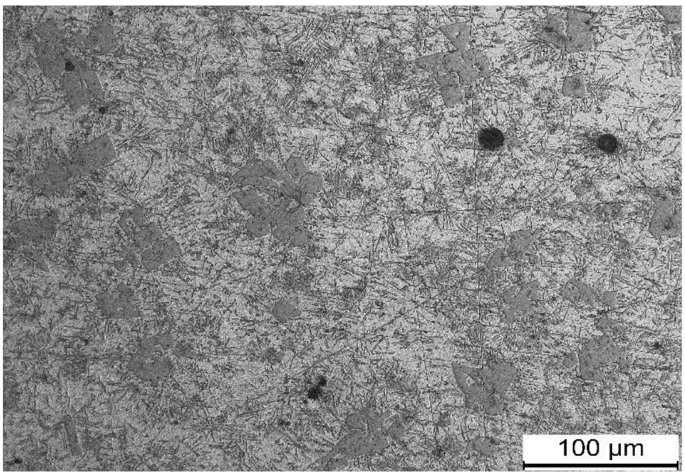


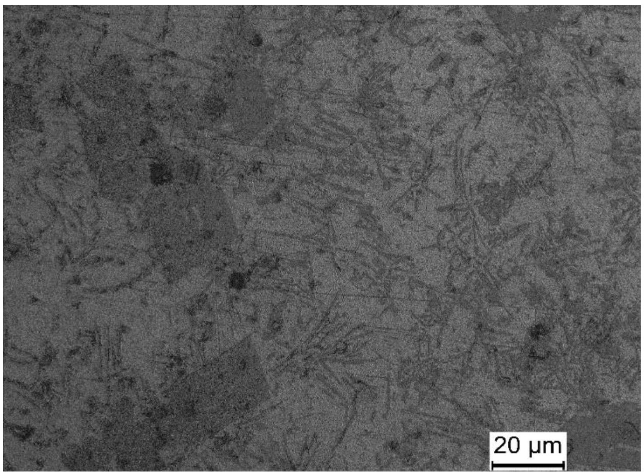


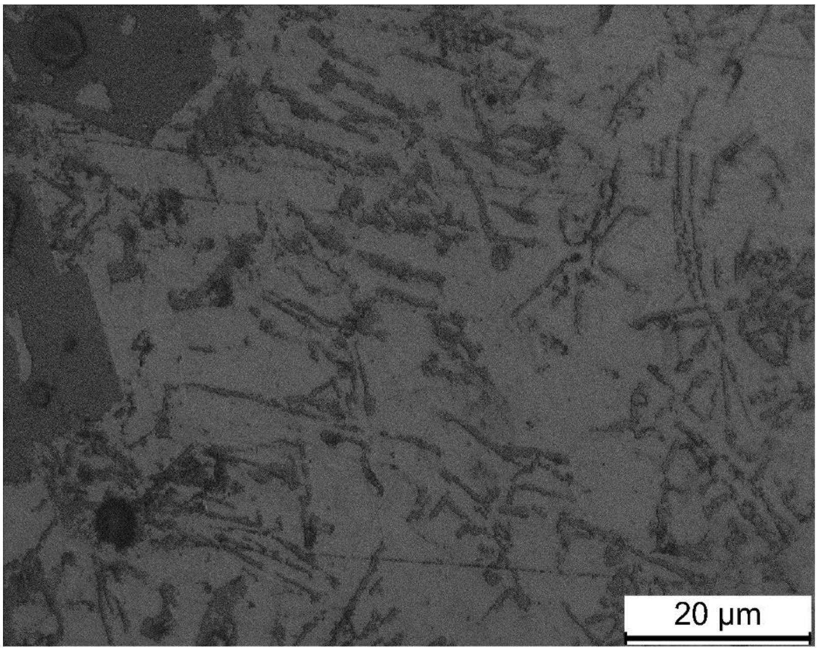


Equiaxed grains give A356 a unique grain structure when examined under an optical microscope. Equiaxed morphology, which produces similar-sized and shaped grains, is indicative of a balanced cooling rate during solidification. The alloy's isotropic qualities, which depend on the uniform distribution of grains, make it appropriate for uses where reliable mechanical behaviour is essential.

A390 Alloy:







On the other hand, under magnification, A390, which has been enhanced with copper, displays a refined grain structure. By influencing the nucleation and growth of grains, copper is added, resulting in a more regulated solidification process. Strength and wear resistance are two of A390's improved mechanical qualities that are a result of its refined grain structure.

6.4 Grain Organization:

A390 Alloy:

Equiaxed grains give A356 Alloy its unique grain structure when examined under an optical microscope. Equiaxed morphology, which produces similar-sized and shaped grains, is indicative of a balanced cooling rate during solidification. The alloy's isotropic qualities, which depend on the uniform distribution of grains, make it appropriate for uses where reliable mechanical behavior is essential.

A390 Alloy:

On the other hand, under magnification, the copper-enriched alloy A390 displays a refined grain structure. By influencing the nucleation and growth of grains, copper is added, resulting in a more regulated solidification process. Strength and wear resistance are two of A390's improved mechanical qualities that are a result of its refined grain structure.

6.5 Formations Eutectic:

A356 Alloy: Silicon particles embedded in the aluminum matrix give A356 eutectic formations their unique characteristics. Under a microscope, the silicon particles and aluminum form a eutectic phase that contrasts noticeably. The hardness and wear resistance of the alloy—two important characteristics in automotive applications—are influenced by the size and distribution of these eutectic formations.

The alloy A390 has a distinct eutectic morphology due to its copper content. The superior mechanical properties of the alloy are partly attributed to the copper-rich phases that form alongside the aluminum matrix. The eutectic formations present in A390 are essential in augmenting its strength and thermal conductivity, rendering it appropriate for use in scenarios necessitating resilient performance.

6.6 Microstructural Analysis Synopsis:

In conclusion, a variety of features, including eutectic formations and grain structure, have been revealed by optical microscope microstructural analysis of A356 and A390 alloys. Every feature that has been noted is important and affects the mechanical qualities and functionality of these alloys. This thorough examination paves the way for additional research into the connection between A356 and A390's final behavior in real-world applications and their microstructure and processing parameters.

7 Hardness Test:

7.1 Overview of Hardness Testing:

One of the most important techniques for determining a material's resistance to deformation is hardness testing. This section explores how the A356 and A390 alloys are tested for Vickers hardness. We also understand the alloys' behavior under applied loads, paying particular attention to areas where silicon concentration has an impact, and we identify how rolling affects the hardening process.

7.2 Vickers Hardness Testing Procedure:

Using a diamond indenter to make a square-shaped impression on the material's surface, the Vickers hardness test is based on the indentation principle. The ratio of the applied force to the indentation's surface area yields the hardness. Preparing the specimen, applying a controlled load, and measuring the resulting indentation are the steps in the testing process.

7.3 Table for Hardness test :

For A-356:

S.no	Diagonal X(μm)	Diagonal Y(μm)	Force (gf)	Hardness (HV)
1.	86.6	84.5	200	51
2.	88.3	85.8	200	49
3.	93.4	88.3	200	45
4.	93.4	90.9	200	44

Mean Hardness: 47.25 HV

For A-390:

S.no	Diagonal X(μm)	Diagonal Y(μm)	Force (gf)	Hardness (HV)
1.	62.0	59.9	200	100
2.	67.1	65.4	200	85
3.	67.5	70.9	200	77
4.	51.0	54.4	200	134

Mean Hardness: 99.0 HV

7.4 Inference from hardness Test:

A390 Al-Si alloys tend to be harder on average than A356 alloys. One common explanation for A390's higher hardness than A356 is that it contains more copper. It is well known that copper makes a substantial contribution to the hardness and strength of Al-alloys. Together with other alloying elements, the copper-rich phases that form in the microstructure of A390 produce improved mechanical properties that make it appropriate for applications requiring higher levels of hardness and strength.

7.5 Difference in Hardening Between Rolled and Without Rolled Sample:

Without Rolling: The alloy maintains its as-cast microstructure when rolling is not done. The distribution of silicon particles and the general casting conditions have the biggest effects on the hardness. If the microstructure is not varying locally, the alloy might show isotropic hardness.

Rolling: Rolling causes deformation that adjusts the distribution of eutectic phases and aligns grains. Anisotropic hardness is the result, in which the orientation with respect to the rolling direction determines how the material responds to applied loads. Increased hardness is a result of rolling-induced work hardening.

Conclusion:

8.1 Overview of the Main Results:

The thorough examination of the hardness and microstructure of A356 and A390 alloys has provided insightful information about the complex world of aluminum-silicon alloys. By means of painstaking specimen preparation, optical microscopy, and Vickers hardness testing, we have gathered copious amounts of data that advance our comprehension of these materials.

- ### Microstructural Examination:

The alloy A356 has silicon eutectic formations and equiaxed grain structures. The isotropic properties of the alloy are influenced by the uniform distribution of grains and the existence of phases rich in silicon, which makes it appropriate for applications requiring both complex designs and dependable mechanical performance.

A390 Alloy: This copper-enriched alloy has a finely tuned grain structure and unique copper-rich eutectic formations. Improved strength, wear resistance, and overall mechanical performance are facilitated by these microstructural characteristics.

- ### Hardness Evaluation:

A356 Alloy: The distribution of silicon particles in A356 largely determines the alloy's degree of hardness. The hardness values are in harmony with the properties of the alloy, achieving a balance between mechanical properties and castability.

A390 Alloy: A390 has higher hardness values due to its higher copper content. The alloy's strength and wear resistance are greatly enhanced by the phases rich in copper, which makes it ideal for uses requiring exceptional mechanical qualities.

8.2 Significance of the Research:

This study is important because it advances our knowledge of A356 and A390 alloys from an academic perspective as well as from a practical one. Our explanation of the subtle differences in hardness and microstructural characteristics lays the groundwork for making well-informed choices when choosing and designing alloys.

- **Intellectual comprehension**

Our understanding of the unique characteristics, eutectic formations, and grain structures of A356 and A390 has been enhanced by the comprehensive microstructural analysis.

The results of the hardness tests give quantitative information about the mechanical properties of these alloys and reveal how resistant they are to deformation.

- **Real-World Optimization**

For engineers and metallurgists choosing materials for particular applications, the research's findings have practical ramifications.

The focus on the variations in hardness between A356 and A390 offers recommendations for alloy optimization according to the intended mechanical characteristics for a particular application.

8.3 Concluding Remarks:

In summary, the study of A356 and A390 alloys has advanced our knowledge of these materials academically and opened doors for real-world engineering and metallurgical applications. We are at the intersection of design optimization, carefully considered alloy selection, and the quest of material performance excellence thanks to the marriage of the insights obtained from microstructural analysis and hardness testing. The insights gained from this study will surely influence aluminum-silicon alloys going forward, opening up new avenues and paving the way for developments across a range of sectors.

Reference :

- Materials and Design, Investigation of microstructures and mechanical properties of A356 aluminum alloy, By Wenming Jiang, Zitian Fan, Defeng Liao, Dejun Liu, Zhong Zhao, Xuanpu Dong, journal homepage: www.elsevier.com/locate/matdes
- Preparation of Cast Aluminum-Silicon Alloys

By: George Vander Voor
Published by Buehler, a division of Illinois Tool Works

- METALLOGRAPHY AND MICROSCOPY by PKJ
- https://www.sciencedirect.com/topics/engineering/aluminum-silicon-alloy
- https://www.phase-trans.msm.cam.ac.uk/abstracts/M7-8.html