PAPER NAME

Effect of Mechanical Vibrations In Sand Casting of Alumunium Alloy Using Organ ic Binders

AUTHOR

Ragib Rownak Safayet Mahmud

WORD COUNT

15956 Words

CHARACTER COUNT

85683 Characters

PAGE COUNT

69 Pages

FILE SIZE

8.5MB

SUBMISSION DATE

May 18, 2022 3:05 PM GMT+6

REPORT DATE

May 18, 2022 3:08 PM GMT+6

● 24% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

- 15% Internet database
- Crossref database
- 12% Submitted Works database
- 11% Publications database
- Crossref Posted Content database

● Excluded from Similarity Report

- Bibliographic material
- Cited material
- Manually excluded text blocks
- Quoted material
- Small Matches (Less then 8 words)

Islamic University of Technology

Department of Mechanical and Production Engineering

EFFECT OF MECHANICAL VIBRATIONS IN SAND CASTING OF ALUMINUM ALLOY USING ORGANIC BINDERS

A Thesis by
SAFAYET MAHMUD
RAGIB ROWNAK

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Bachelor of Science in Mechanical Engineering

May (2022)

EFFECT OF MECHANICAL VIBRATIONS IN SAND CASTING OF ALUMINUM ALLOY USING ORGANIC BINDERS

SAFAYET MAHMUD, 170011003, 2017-18
RAGIB ROWNAK, 170011019, 2017-18

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Bachelor of Science in Mechanical Engineering

DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

May (2022)

CERTIFICATE OF RESEARCH

This thesis titled "EFFECT OF MECHANICAL VIBRATIONS IN SAND CASTING OF ALUMINUM ALLOY USING ORGANIC BINDERS" was submitted by SAFAYET MAHMUD (170011003) and RAGIB ROWNAK (170011019) has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science in Mechanical Engineering.

Supervisor

Prof. Dr. Md. Anayet Ullah Patwari
Professor
Department of Mechanical and Production Engineering (MPE)

Head of the Department

Prof. Dr. Md. Anayet Ullah Patwari
Professor

Department of Mechanical and Production Engineering (MPE)
Islamic University of Technology (IUT)

DECLARATION

I hereby declare that this thesis entitled "EFFECT OF MECHANICAL VIBRATIONS IN SAND CASTING OF ALUMINUM ALLOY USING ORGANIC BINDERS" is an authentic report of our study carried out as a requirement for the award of degree B.Sc. (Mechanical Engineering) at Islamic University of Technology, Gazipur, Dhaka, under the supervision of [Prof. Dr. Md. Anayet Ullah Patwari], Professor, MPE, IUT in the year 2022

The matter embodied in this thesis has not been submitted in part or full to any other institute for award of any degree.

Safayet Mahmud

170011003

Ragib Rownak

170011019

Acknowledgments

First of all, I am grateful to ALLAH (SWT), the most benevolent and kind to provide me the strength and ability to write this dissertation. I want to thank my project supervisor, Prof. Dr. Md. Anayet Ullah Patwari, for his strong and patient support through unpredictable problems during the project and his precious advice when I faced difficulties. His generosity, kindness and strong supervision during work made me feel less stressed in confronting unexpected troubles and be more productive in my personal life. I would also like to thank Mr. Shah Alam Bhuiyan & all the lab instructors for their immense support throughout the project.

In the next step, I would like express my deep acknowledgment to my father and mother for their continued support and dedication towards my higher study.

ABSTRACT

This paper represents a systematic finite element analysis to evaluate the various mechanical vibration impacts on sand mold casting during aluminum alloy cooling. In general, the mold materials govern the molten metal filling of the cavity in a smooth, uniform, and complete manner. Two distinct types of binding materials were used in this study. As a sand binding material, rubber seed oil and cottonseed oil were utilized. The bottom gating system is adopted because of its low gas entrapment and low surface defect features. Experimentation with several binders at various mechanical vibrations was carried out, as well as computational analysis to determine the best mechanical vibration range for the binders utilized. Following the application of mechanical vibration, the coarser dendrites transformed into fine equiaxed grains, and the size, morphology, and distribution of the -Al primary phase and eutectic silicon particles, as well as the SDAS, were all significantly improved. The mechanical properties and density of A356 aluminum alloy improved significantly as a result, with the tensile strength, yield strength, elongation as well as hardness of the sample with 40 mm wall thickness measured to be 35% higher, 42% higher, 63 percent higher, and 29% higher than those of the conventionally cast sample under the T6 condition. The degree to which mechanical vibration had an effect on the microstructure and mechanical properties of the material increased as the wall thickness increased. Following the application of mechanical vibration, the coarser dendrites transformed into fine equiaxed grains, and the size, morphology, and distribution of the -Al primary phase and eutectic silicon particles, as well as the SDAS, were all significantly improved. The mechanical properties and density of A356 aluminum alloy improved significantly as a result, with the tensile strength, yield strength, elongation as well as hardness of the sample with 40 mm wall thickness measured to be 35% higher, 42% higher, 63 percent higher, and 29% higher than those of the conventionally cast sample under the T6 condition. The degree to which mechanical vibration had an effect on the microstructure and mechanical properties of the material increased as the wall thickness increased. The best binder was chosen based on the rate of cooling at a certain mechanical vibration range. Solid works were used to create a CAD model and a fluid flow study was performed to confirm the impact. The simulation parameters and boundary conditions were taken from an existing model. The actual experimental situation results and CFD modeling both were to demonstrate which binder is the most effective and at what mechanical vibration range does the binder cool more quickly.

Keywords: Casting, mold, vibration, oils, organic, binders.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

Nomenclature

CFD	Computational fluid dynamics
DOE	Design of Experiment
HTBS	Horizontal tempering and bending system
PDSA/ PDCA	Plan-do-study-act/ Plan-do-check-act
SMED	Single-Minute Exchange of Die
SD	Shape Defects
FRD	Filling Related Defects
SRD	Shape Related Defects
VSM	Value stream mapping
BB	Bottom Board
USL	Upper specification limit
LSL	Lower specification limit
q	Heat transferred per unit time (W)
A	Heat transfer area of the surface (m^2)
h_c	Convective heat transfer coefficient of the process
T	Absolute temperature
CFX	Computational Fluid Simulation
CAD	Computer Aided Design
ANSYS	Analysis of Systems
C&D	Cope & Drag

Chapter One

Introduction

1.1 Introduction:

Sand mold casting is a type of metal casting that uses sand as the mold material. The sand-casting process is used to make more than 72%[1] of all metal castings. Sand casting is one of the most common and straightforward casting techniques. Sand casting not only allows manufacturers to create new products but also allows them to save money. Sand casting provides low-cost products, but it also has additional advantages. Most types of sand casting are also possible. Depending on the type of sand used for the molds, different metals will be cast. The sand is combined with an appropriate bonding agent. Typically, the mixture is moistened to develop the mold's strength and plasticity, usually with water, but sometimes with other ingredients to make the aggregate mold smooth, uniform, and consistent. Results are controlled by the mold materials. The best binders used at different mechanical vibration is dictated by the rate of cooling of the molten metal poured in the mold which in turn controls the quality of the end product. Various studies have been carried out to determine the efficiency of various binders at various mechanical vibrations. In sand casting, we mostly use aluminum as it is one of the most abundant metals on planet earth. Aluminum is the world's most abundant metal and the third most frequent element. It accounts for 8%[1] of the earth's crust. Aluminum is the most extensively used metal due to its flexibility. After steel, there is aluminum. Around 29 million tons of aluminum are produced each year. It is in high demand throughout the world. It's frequently alloyed with zinc, magnesium, silicon, copper, lithium, manganese, etc. There are about 305 wrought alloys[2] for aluminum, of which 51 are used commonly. Aluminum and its alloys have a wide range of characteristics that make aluminum the most cost-effective, versatile, and appealing material that can be utilized for a variety of applications, e.g., from ductile and soft foil to various technically challenging applications. Aluminum has several unique features like strong heat conductivity, corrosion resistance, electrical conductivity, ease of manufacture, lightweight, and vibrant color as well as texture. It is one of the most important manufacturing processes in which liquid metal is poured into the mold cavity and allowed to cool or solidify in that cavity, which is one of the most important manufacturing processes. Because of its simplified procedure, the casting process is the most cost-effective of all the manufacturing methods. The flow behavior of the molten metal, as well as other process parameters, influences the quality of the cast. Casted products account for more than 80% of all products manufactured today. Temperatures in the range of 649C to 750C[3] are used to cast aluminum alloys. A knowledge of the melting temperature of the metal or alloy in question is required calculate the corresponding pouring temperature. Another important factor to consider when casting is the temperature at which the material is poured. As a result of rapid solidification of the riser at lower pouring temperatures than the optimum value, the casting mold not be complete using the solidification of the directional solidification to be interrupted. Mold shrinkage and wrapping are caused by pouring at a temperature higher than the optimum value, which is determined by the manufacturer. Fayomi et al.[1] explored the use of native oils, such as groundnut oil, cottonseed oil, and palm oil, in combination with Nigerian clay and silica sand to produce foundry cores of various compositions. The mechanical features of Expendable Foundry Sand Cores were studied by Nuhu Ademoh[4]. He bonded kaolin clay composites and grades 1 and 4 Gum- Arabic Popoola et al using molasses, starch, and other binders and investigated the effect of binders on core strength in metal casting with the effects of binders such as bentonite and cassava starch on the molding properties of silica sand. Abid Bin Rashid also did a comparison and CFD verification of binder effects in a sand mold casting of the aluminum alloy using clay, oil, and molasses as binders.

In the production of machine components or parts, the core plays a critical role in the process of metal casting. Cores are used to support all of the cavities created during the metal casting process. Core binding materials are numerous, and the mode of casting determines which material is used in both ferrous and non-ferrous foundries, depending on the application. Oils are among the most important binders in industrial applications. Vegetable, mineral, and marine oils have all been used as core binders in this formulation. The drying ability of these materials determines their application. As a result of its ability to absorb oxygen during curing, the drying property of the oil is what determines the backed strength of a core made of oil sand. The level of oxygen absorption by the oil is a direct indicator of the drying power of the oil, and it is determined by the degree to which the fatty acids have been saturated with oxygen. Oils are classified into three categories based on this scale: drying, semi-drying, and non-drying. In recent years, the use of vegetable oils has become increasingly popular due to the low cost of the oils and the long bench life, and excellent core properties [6, 7, 8, 9]. Soybean, cottonseed, groundnut, shear butter palm, and palm kernel oils are among the vegetable oils that can be found in abundance locally. Investigations into these oils have revealed that soybean oil can achieve a backed strength of 700kN/m^2 when used in conjunction with other oils. Using clay as an additive, Anobiidae reported a backed strength of 742kN/m^2 using a formulation consisting of 3 percent soybean oil, 1.5 percent clay, 7 percent water, and 85.5 percent sand [10]. According to Akor's research into the use of soybean oil sludge as a core binder for foundry sand, baa lacked the strength of 587kN/m^2[5] was achieved in a formulation consisting of 3 percent soybean oil sludge, 0.5 percent cassava starch, 7% water, and 89.5 percent sand. In the foundry industry, the development of oil-sand cores using locally sourced raw materials will be an important contribution, according to several studies. The major issue is the limited supply of these vegetable oils, which is a result of the high demand for them from the food and cosmetic industries. As a result, there is a pressing need for research into non-consumable vegetable oil sources for use in casting technology.

Rubber seed oil and cottonseed oil is a non-consumable vegetable oil that has little or no use in human nutrition due to their high acidity. The purpose of this research is to develop oil-sand cores by using rubber seed oil as a binder. We are wasting rubber seeds in our plantations, particularly in the southern part of Nigeria. The success of the work will allow local foundries to maximize the utilization of this readily available raw material, minimize waste, remain competitive, and reduce pollution while remaining economically viable.

1.2 Research Problem Statement:

The authors of this research used rubber seed oil and cottonseed oil as sand binder materials and conducted a systematic finite element analysis to determine the most effective binder in sand mold casting for aluminum cooling through analytical and simulation methods. The goal was to find the best organic binder that can be used instead of inorganic binders.

In most of the modern sand-casting methods, we see the use of inorganic binders. The problem with modern sand-casting methods is that for the use of these inorganic binders the environment is heavily polluted because of these binders. Most binders are not biodegradable and harm the environment in more ways than imaginable. Because of the nature of its work and the environment in which it operates, the sand-casting industry is frequently accused of polluting the environment. Some of the environmental issues associated with the industry include the release of harmful and poisonous gases, the generation of dust and particles, and the generation of waste pollutants.

The government and sand-casting industry associations have established a number of standards and guidelines to assist the industry in combating pollution by controlling emissions and appropriately disposing of pollutants. Many environmental legislations have been proposed by the government, all of which will have a significant impact on the way foundries conduct their operations in the future. Businesses must be aware of the various laws and regulations that apply to their operations, as well as the actions that must be taken to ensure compliance. The functioning of a foundry involves several interconnected and complex operations that necessitate skill and prudence to produce high-quality castings. Final casting quality is restricted in the foundry sector due to the numerous variables and sophisticated production procedures that are employed. Consequently, in sand casting foundries, defect reduction continues to be the primary goal to be achieved.

1.3 Goals and Objectives:

This is the case in this the goal is to reduce the pollution done by sand casting through using organic binders and concerning foundries, process knowledge is critical to boost production by lowering the number of faults in sand castings. This involves the strategy to acquire information, a System of conceptualization and analysis to determine the varying process variables that are related to a certain product. Characterization of final goods is important. The thesis gives an overview of the lit-on process knowledge in the manufacturing industry. concentrating on the sand-casting method that can help to encourage the use of organic binders. It then investigates the possibility of applying this paradigm specifically to the sand-casting industry to reduce its negative environmental impacts.

The primary goal of this initiative is to increase the competitiveness of the casting sector to reduce environmental pollution through the use of organic binders.

1.4 Scope and limitation of the study:

Modern methods for producing casting products include the use of sand molds, dies, centrifuge casting, and metal molds, among other things. Castings made with sand molds exhibit a variety of microstructures that are dependent on the average shape, size, and distribution of sand grains, as well as the alloy compositions used in their production. Additionally, these factors influence the permeability, refractoriness, and surface finishing of all castings. The rising cost of new sand, combined with the increasing difficulty of disposing of solid waste, is forcing foundrymen to pay more attention than they have in the past to developments in sand reclamation and reutilization for lower pollution. The foundry industry generates a variety of byproducts, the most significant of which is "spent sand," which accounts for the majority of the total volume.

Molding sand is combined with a binder and additives to form a composite material. The characteristics of the residuals vary from foundry to foundry and are dependent on the type of metal that is poured, the type of casting process used, the technology used, and the type of finishing process used in the casting. Foundry waste sand is physically suitable for a wide range of applications /I-7/, even though the long-term environmental effects have not been thoroughly investigated. To make beneficial use of waste sand, it is necessary to conduct detailed physical and chemical characterization of the waste material. The results of waste characterization should include the identification of hazardous wastes, the determination of disposal requirements, and other issues. The issue of recycling foundry sand is dominated by economic and environmental considerations. Because landfilling is becoming more expensive and regulations are becoming more stringent, the currently accepted practice of dumping spent sand in landfills is becoming an economic burden for foundries. Furthermore, issues of technical and economic feasibility are raised for foundries that wish to make use of their spent sands beneficially. The foundry waste sands can be put to work through reclamation or other forms of constructive application. Money saved during the process may be used to fund future production.

For a better product and fewer defects, this research of ours introduces mechanical vibrations to improve the efficiency of the overall process of sand-casting methods and also shows the viable replacements of inorganic binders with organic binders.

1.5 Methodology of the study:

Because of the low gas entrapment and low surface defect characteristics, a bottom gating system was adopted. The author also did a computational analysis to get the best result at a specific mechanical vibration range. Solid works were used to create a CAD model, and an Ansys workbench was used to conduct a fluid flow (CFX) analysis. A real-world experimental condition was used to extract simulation parameters and boundary conditions. The rubber seed oil has a faster cooling rate compared to cottonseed oil found from the CFD simulation analysis. Mechanical vibration, ultrasonic vibration, and electromagnetic vibration are the three primary types of vibration. Mechanical vibration is the simplest because its parameters are more easily controlled. An increasing number of studies examine the effects of electromagnetic and ultrasonic vibrations on casting materials and products.

1.6 Contribution of the study:

Metal sand casting is one of the most common types of metal casting, accounting for a large proportion of the total weight of all cast prototypes. During the sand-casting process, a metal is heated to the point where it melts, allowing the chemical composition of the metal to be altered. As soon as the material has reached its liquid state, the molten metal is poured into an aluminum sand mold that has been shaped to the exact specifications of the prototype that is being built. The advantages and disadvantages of this casting type, as with other forms of casting, are partially dependent on the knowledge and experience of the designer, as well as the care with which they complete the process. Before beginning any casting project, it is critical to carefully consider the functional requirements of the part to be cast, as well as how the specific casting method will contribute to the achievement of those requirements. For this reason this paper analyses various significant process parameters of the sand-casting processes using organic binders. An attempt has been made to obtain optimal settings of the green sand-casting process to yield the optimum quality characteristics of sand castings. The process parameters considered are: green strength, moisture content, permeability, and mold hardness. The effect of selected process parameters and their levels on the casting defects and the subsequent optimal settings of the parameters have been accomplished using mechanical vibration. The result indicates that the selected process parameters significantly affect the casting defects. The estimation of the optimum performance characteristics of organic binders in sand casting at the optimum levels of parameters with various mechanical vibrations is done in this paper and the results are verified by confirming with practical experiments that can be done in the future. This research is targeted to help reduce environmental pollution caused by sand castings and shows a replacement of inorganic binders that are being used in sand casting methods today.

1.7 Thesis Organization:

In chapter 1, the introduction has been given to highlight modern sand-casting methods and the importance of sand casting. The types of binders being used and also the pros and cons of the modern methods being implemented. The research on which topic of sand casting is done. The scope of the research and its contribution to and-casting industries.

In chapter 2, a literature review of the other research similar to the topic and the past research done on this topic is highlighted.

In chapter 3, the experimental design used in this research is shown and the reason of choosing the model is explained with detailed pictures and a flow chart of the process is shown of how the experiments are conducted.

In chapter 4, the methods used to collect data and the results of the data are shown in tables signifying the promises of this research.

In chapter 5, the conclusion of the research and the future scope and recommendations are explained with the references that helped with the research.

Chapter Two

Literature Review

2.1 Introduction:

Sand casting is the most widely used metal casting method in the industrial sector, accounting for more than 70%[6] of all metal casting jobs. Because of its low cost, and is an ideal choice for applications ㉛ in the manufacturing industry. The size of a sand casting can range from a micron to a kilometer, depending on the material used. Pump housings, engine blocks, cylinder heads, machine tool bases, and valves, to name a few applications, are manufactured utilizing the sand-casting method in modern manufacturing.[3] This mixture of water and clay is frequently used to hold together the ㊵ sand that is utilized in the casting process, according to the manufacturer. Sand accounts for 89 percent of the total volume, clay accounts for 7 percent, and water accounts for 4 percent. You may make gigantic, complex-shaped pieces in large quantities using the casting technique, and they will have properties that are not possible to achieve using any other method. Among the many procedures involved in the production of casting are the following: mold-making, (57) melting, pouring, solidification, fettling, cleaning, inspection, and the elimination of faulty castings. Consequently, if these faults are not remedied, a significant amount of time and money will have been squandered from the idea of the product and the casting through to final manufacturing and distribution. Instead, the issue originates from the inappropriate technique in which the mold was prepared in the first place. Although a multitude of casting procedures are well-known, sand casting is the most often used since it is the simplest and least expensive of the options available. While it is natural for a cast product to have some faults, there is a way to decrease these imperfections before to finishing process.[7] Read on to learn more. While conducting this study, we hope to use different types of the bi the so that preparing the mold for reuse will be easier and more cost-effective, rather than having to produce the sand-casting mixture from scratch each time.

Part of our research involves identifying methods for reducing sand waste during the casting process, as well as determining whether it is possible to reuse molds. This includes the usage of binders that can be utilized to remold the preceding cast into another design with new specifications, as well as the repurposing of existing molds, which we're currently investigating. On average, we may expect a 38.75 percent[8] reduction in the amount of waste material generated, which will translate into increased efficiency and less time spent on the task at hand. Our investigation aids us in the identification of the most effective binder for use in the composition of molding sand. In the development of sand molds, an innovative and more effective approach has been discovered that results in better sand castings with fewer flaws and a cheaper total cost of production while providing better sand castings.[3]

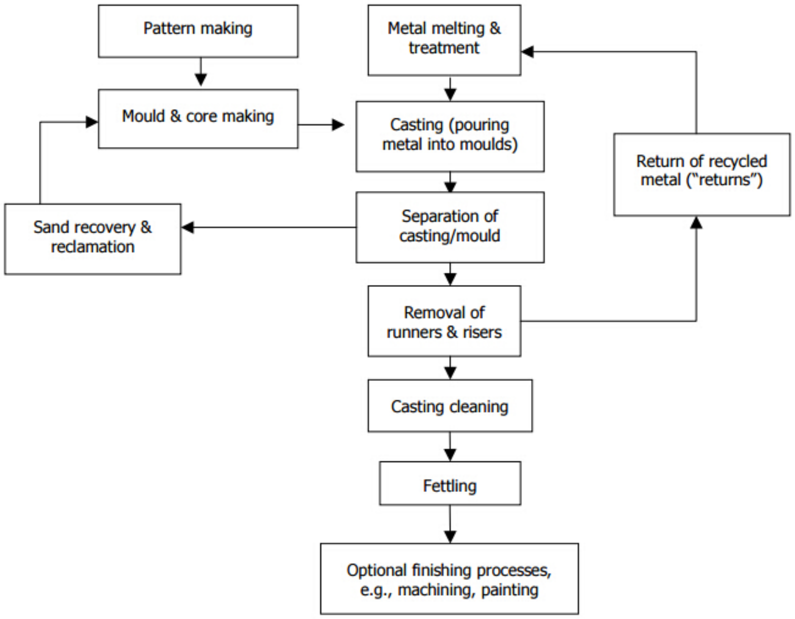
2.2 Detail List of Review:

The use of specific binders will aid in the production of the highest-quality sand molding composition possible, which will be used both to reuse previously used molds and for the purpose of metal alloys with fewer defects and greater precision, which is one of the primary issues in sand casting. Aside from that, we intended to include mechanical vibration in our experiment to see what kind of effect and improvement might be achieved when mechanical vibration was used during the solidification process of metal casting. ANSYS 2021 R2 was used for all of our simulations and tests, and we carried out all of our data collection in the lab.

2.2.1 Casting Process & Defects

One of the most common causes of casting problems is a variation in the parameters of the casting process. It is necessary to regulate the process parameters to ensure that there are no faults present. It is critical to understand the impact of process parameters on casting as well as the influence they have on defects in order to process parameters. A large number of researchers have used a variety of instruments to aid in the reduction of flaws in manufacturing processes, which has resulted in a reduction in the number of defects. In addition to the additional information, a concise summary will be provided. Narayanswamy and Natrajan[9] conducted an investigation that occurred dissevering process. The four types of flaws that could occur are filling-related defects (FRD), shape-related defects (SRD), thermal defects (TD), and appearance-related errors. This causes the rejection percentage to fluctuate from 12.86 percent to 15.01 percent[10] on a month-to-month basis as a result of the issues. A few examples of filling-related flaws include sand inclusion, uneven surface, scabbing, blow holes, chill blow, clay ball hole, blowholes, and pin holes, amongst holes things. Every pinhole is an example of a filling flaw. The occurrence of other types of sand faults, such as mold lift, mold breakage, and shift, are also possible. One type of issue is a DBS blast core that has gone missing, while another is swelling in the area. It is critical to pay close attention to any defects in the filling during the investigation because of the wide variation in sand quality. Mold-making and melting operations have the potential to introduce shape-related, appearance-related, and thermal defects into the finished product, depending on the process used. The ability to produce high-quality castings that meet the needs of customers while utilizing modern processes and appropriate approaches is an asset to the foundry industry. Among the conclusions they reached as a result of their investigation was that sand, operating method, metal quality, and environmental variables all had an impact on the overall quality of the castings they produced.

The steps involved in the casting process a. shown the in following figure[7];



Defects occurred in the casting process are broadly classified as,

Casting Defects		
Surface defect	Internal Defect	Visible Defects
Blow, Scar, Blister, Drop, Scab, Penetration, Buckle.	Blowholes, Porosity, Pinholes, Inclusion, Dross.	Wash, Rattail, Swell, Misrun, Cold shut, Hot tear, Shrinkage.

As a result of his investigation into TSB casting, Dr. Shivappa D.N[2] discovered that the following factors contribute to casting rejections: sand drop, blowhole misfit, and oversize. The sand drop factor was found to be the most common. It has been discovered that certain parts of the body appear to be more sensitive to these defects than other parts of the body, according to research. Defects were investigated and the reasons for their existence were discovered through the application of a methodical methodology; the results were published in the scientific journal Science. Because of mold growth in the areas around the chiller, mold interface, sleeve, and breaker core, which were not properly cleaned after being cleaned incorrectly, the sand drop was caused by a sand avalanche. Blowing holes develop around long members as a result of the gating design's inability to completely stop the flow of water. Castings that don't match up are the fault of the locators and cores that were used in the casting process. Most of the time, lifting and bulging in the mold cavity responsible for the excessive casting size. If you are experiencing sand drop issues, make sure to thoroughly clean the mold before closing it. You should also use shell core instead of no no-baker, place pads on the bottom face of the mold, and redesign your loose piece design in toxoid core crushing during the manufacturing process. Modify the loose piece design in order to possibility of core crushing to avoid the loose piece design to prevent core crushing from occurring. (iv) Core Crushing: Modify the loose piece design to prevent core crushing from occurring. In Blow Hole, the gating system will be modified so that the flow offs are connected directly to the top surface of the long member, rather than through the bottom surface (ii). Three of the locators are metallic, whereas the other three are self-locating, which creates an inconsistency in the set of locators. It is necessary to securely fasten the molds in order for them to withstand pressure if the molds are going to be enlarged (iv). During four months of production testing in the foundry, the above-mentioned corrective procedures were evaluated and validated.

The findings of the study indicated that the rejection rate for die castings had decreased by a statistically significant amount.[11]

Joshi and Jugulkar[12] are two of the most talented athletes in the world (three) We used the Pareto principle and a cause-and-effect diagram to discover and analyze the various flaws and causes of those flaws that result in component rejection at each stage of the manual casting process. If the casting problem can be identified and corrected as soon as possible, the process of corrective action becomes much simpler. It is explained in this document how to identify the root cause of errors that occur as a result of manual processes. It was discovered that the manual metal casting procedures were carried out with a high degree of carelessness and negligence. To reduce total rejection by more than 30%, it is recommended and implemented that such remedial measures be implemented. When automation is used, it has been shown to reduce error rates by as much as 70%. According to the findings of this comprehensive study, casting faults can be controlled through the use of effective tooling and process analysis. An investigation into the casting flaw Jadhav B. and Jadhav S. [6] have focused their attention on the cold shut. Operations such as pattern creation and mold creation are just a few of the many processes that go into the casting process. There are dozens more. It is nearly impossible to produce a casting that is completely free of flaws. A single factor or a combination of factors may be responsible for the occurrence of the defect. These factors can be mitigated through the use of a well-organized process. The purpose of this article is to discuss the analysis and reduction of casting defects. Grey cast iron is used in construction. In a car, a Grade FG150 cylinder block was cold-shut. As demonstrated in this study, regulating the alloy composition and pouring temperature can help to reduce the number of defects. A quality control methodology is a tool that is used to analyze and reduce errors. Some of the methodologies used are the check sheet, Pareto analysis, cause-and-effect diagram, flow chart, scatter diagram, histogram, and control chart.

Jain and Rajput[13] investigated the application of seven quality control strategies to eliminate defects in aluminum alloy, and their findings were published in the journal Quality Control. Their investigation into the root cause of large flaws in aluminum castings included the application of a defect diagnostic technique as well as a cause-and-effect diagram, both of which were used in their investigation. To achieve more precise and effective feedback control during the casting of aluminum alloy wheels, a process model for the production line was developed, which was previously impossible. Using this diagram, it is possible to identify problems, as well as the underlying causes of those problems and possible solutions to them. A study conducted by the University of California found that shrinkage, fractures, and inclusions were the most common reasons for rejection in para to graphs. According to the check sheets, a significant proportion of the rejections were due to a variety of shrinkages that were discovered. By a significant margin, hub shrinkages outnumbered rim and spoke shrinkages in the histograms. When it comes to 3-cylinder metric block casting, Vante and Naik[13] are particularly concerned with improving control to overcome the problem of dimension deviations. The use of quality control equipment helps to raise the overall standard of a manufactured good by ensuring that it meets specified specifications. Tools for quality control such as the Pareto diagram (cause-and-effect diagram), brainstorming, and why-why analysis are some of the methods that have been implemented. It will be possible to improve process management with the help of this methodology if it is implemented. Once the root causes of a problem have been identified, it is possible to develop a long-term solution. The successful application of the remedies will result in a reduction in casting rejections as well as an improvement in casting quality in the castings that are produced. Dr. Mench and Dr. Kinagi[14] used tools from the design of experiments and failure mode and effects analysis to analyze casting flaws such as cold shut and blow holes in their research (FMEA). It is possible to identify potential causes of failure and their consequences, as well as appropriate actions to improve quality and productivity, by utilizing the FMEA tool and Pareto analysis. The Taguchi method, which is a variation of the DOE approach, is being used to optimize the parameters of the sand-casting process. We used a Taguchi-based[15] L9 orthogonal array for experimental purposes. The mean (ANOM) plots produced by this array were analyzed using Minitab software, which is included with the package. It was used to optimize the inoculants (0.3), moisture content (3.3), and sand-binder ratio (3.3) at temperatures of 13800°C and 14400°C[16], respectively, for the experiments, which were carried out at temperatures of 13800°C and 14400°C (60:1). After investigating casting flaws, Sushil Kumar et al[17] concluded that Six Sigma, or the (DMAIC) method to parameters, can improve quality at the lowest possible cost while maintaining or improving productivity. It is possible to identify signal variables with optimal values to reduce the impact of noise on response characteristics. When they conducted a case study on green sand castings, they discovered that they could reduce the number of casting faults by refining the process parameters used in these castings. In addition to green strength (1990 g/cm2) and moisture content (4.0 percent), pouring temperature (14100C), and mold hardness numbers vertical and horizontal (72 and 85)[18], the optimal parameters for the green sand-casting method were determined through experimentation.

2.2.2 Reclamation and Utilization of Foundry Waste Sand

As a result of the aforementioned factors, foundrymen are being compelled to pay greater attention to sand recovery and reuse to combat rising sand costs and the challenges associated with solid waste disposal. Byproducts from foundries include a wide range of materials, the most common of which is "spent sand," which is used in the production of a wide range of other goods.[19]

Molding sand that has been treated with additives will be described in the following manner: Each metal pour, casting method, the technology used, and finishing process in a category is distinguished from the others by a distinct set of characteristics that are unique to that category. It is still unclear what the long-term environmental consequences of foundry waste sand will be, and scientists are baffled as to why. Before waste sand can be used to determine whether or not it is beneficial to the environment, it is necessary to describe it in terms of its physical and chemical characteristics. The waste characterization should be used to detect potentially hazardous wastes and to select the most appropriate disposal option for each type of waste produced. Recycled casting sand is used in the manufacturing of new products for a variety of reasons, including economic and environmental concerns. Foundries are already suffering financial losses as a result of the practice of disposing of waste sand in landfills, while at the same time they are experiencing an increase in the number of restrictions on how they can dispose of waste. Aside from that, foundries wishing to make use of waste sand must overcome a variety of technological and economic challenges. Foundry waste sand, as stated by Kashyap and Chakrabarti[20], has the potential to be recovered or utilized profitably in a variety of applications, including concrete casting. Other options include using the money saved for the castings' production or reinvesting the money saved in other projects. Dry reclamation and wet reclamation are the two techniques they use to respond to this question. It is more common to use a dry reclamation method[21].

2.2.3 Usage of organic oils as the binder in casting

When working in the foundry industry, it is possible to employ a wide range of different types of oils, including those obtained from marine sources as well as those derived from mineral deposits and vegetable sources, among other sources. Even though this ingredient is incredibly popular in both the culinary and cosmetic industries, the market currently has an unsatisfactory supply of it available. It is therefore necessary to conduct an additional study into the use of non-consumable vegetable oil sources as core oils in casting methods. According to the authors (International and Of, 2014)[22], a mixture of cassava starch, water, and silica was tested as a core binder for rubber seed oil and was found to be successful. A combination of cassava starch, water, and silica was evaluated as a core binder for rubber seed oil. The results showed that the combination was effective. To get an appropriate baked strength of $1829 kN/m^2$,[22] a mixture of 3% rubber seed oil, 7% water, 0.5 percent cassava starch, and 89.5 percent sand can be used to form an optimal composition. To get an appropriate baked strength of $1829 kN/m^2$,[22] a mixture of 3% rubber seed oil, 7% water, 0.5 percent cassava starch, and 89.5 percent sand can be used to form an optimal composition.

Rubber Seed Oil

Cotton Seed Oil

Palm Oil Fuel Ash

Corn Starch Oil

Soya Bean Oil

Fig 2.1: Organic Binders

2.2.4 The estimation of the ability to reclaim molding sands with biopolymer binders

Organic binding materials based on synthetic resins, on the other hand, when burned, emit a significant number of dangerous pollutants into the environment, even though they have excellent technical properties in and of themselves.[23] Recently discovered results are leading to a gradual substitution of binders obtained from petroleum-based resources with polymer bio composites derived from renewable resources. This is being accomplished through scientific research currently available. Biodegradable goods can be manufactured using aliphatic polyesters such as polylactide, polycaprolactone, polyhydroxyalkanoates, and aliphatic-aromatic polyesters, which include polylactide, polycaprolactone, polyhydroxyalkanoates, and aliphatic-aromatic polyesters. Aliphatic polyesters, such as polylactide, polycaprolactone, polyhydroxyalkanoates, and aliphatic-aro As a result of these improvements, there has been an increase in the amount of attention that is being devoted to particular sorts of materials. According to the Journal of Engineering (2011)[24], one of the most important areas of inquiry in this sector is the use of biopolymers as mold sand binders in the manufacturing process. Currently, the vast majority of studies authored by contemporary authors are concerned with the technical qualities of sand, as well as its environmental influence. T The authors study how moldable sands can be recovered from waste streams by using biopolymer binders in the process. In the publication, the biopolymer binders are discussed in detail as well.

2.2.5 Usage of ANSYS as simulation software

Casting is a manufacturing process that can have a wide range of faults, including shrinkage porosity, sink, cavity, and partial filling, when used to create complicated shapes from various materials in large quantities. Modifying the (72) feeding system design is essential for new castings or castings with a high rejection rate. High-quality castings depend on a well-designed feeding mechanism. As part of the system design process, you must decide where the risers should go and how many risers you want to utilize. Flowability and turbulence can be affected by the gating system, which regulates the flow of molten metal. Metallurgists, casting engineers, and physicists regard the solidification of metals as a marvel of ultimate consequence, affecting ⑰ casting quality, material yield, and cycle time. By using casting simulation software and an intelligent feeding approach, the number of casting flaws can be minimized. Thermal changes and heat transmission in the solidification of a casting can be simulated using AUTO Cast[24] (Demo). It aids the user in visualizing a certain casting's solidification process. With the simulation program, a user may be guided through the process of creating gating and riser designs, and visual outputs can be generated to identify potential issue locations and flaws in a casting. In the trial casting stage, it can help cut the lead time and reduce casting losses. We are constrained by the cube's gating system in the demo version of AUTO Cast. Gating system design and ANSYS simulations of casting solidification processes are discussed in this research.

2.2.6 Effect of Mechanical Vibration in Sand Casting

Specifically, the characteristics of sand-casting alloys are researched to determine if mechanical mold vibration has an impact on the performance of the alloys under investigation. Porosity in A1100 alloy castings is caused by a substantial and apparent feature of the alloy that causes the issue to arise in their castings. Incorporating the technique outlined by [24] into metal molding alloys results in an improvement in their quality while simultaneously lowering the amount of porosity and internal faults in the alloys produced. Mechanical vibration is used to cast the aluminum alloy A1100 in the sand, which is a high-performance alloy with excellent corrosion resistance. With the help of mechanical mold vibration, we have been able to determine the shape of eutectic silicon in alloy A1100 in this study.[25]

The mechanical and metallurgical characteristics of an A1100 sand cast alloy that has been subjected to vibration are compared to the mechanical and metallurgical characteristics of an A1100 sand cast alloy that has not been subjected to vibration to determine if an increase or improvement in mechanical and metallurgical attributes has occurred. During the sand-casting process for alloy A1100, mechanical vibration occurred, which resulted in considerable improvements in the alloy's properties and attributes, which were previously unreachable. In recent years, the quality and qualities of A1100 alloy have improved, allowing it to be used in a larger range of machinery and vehicles while simultaneously enhancing the price-benefit ratio of the material and lowering its cost.[26]

2.3 Selection of Methods:

Our findings from several articles and journals enabled us to develop accurate methods for each step of the experimental process, which we then implemented. One of our key objectives was to collect the sand from the foundry garbage that was generated throughout the construction process. We have determined that dry reclamation and wet reclamation are the most appropriate ways of implementation for this stage as the principal techniques of implementation. The extraction of organic bi-product binders from the waste stream was our next objective. As a result of the ease with which they can be obtained in the industry and the fact that they have the best binding strength, we have restricted our research to only rubber seed oil and cottonseed oil for our trials. In the current research, the emphasis is on the use of mechanical pressing to extract oil from rubber seeds, as well as the kinetic analysis of the acid esterification process, both of which are now under examination. After being crushed, dried, and mechanically pressed, rubber seeds were removed from their shells and used as rubber substitutes. Our other binder, which is extracted from the seed of the plant using mechanical or chemical means, such as solvent extraction, is bound together with other vegetable oils, such as cottonseed oil, to form a strong bond. Cottonseed oil is obtained by the solvent extraction process, which is the most widely used method in the commercial production of the oil.

Ansys Library provided experimental reference values for this investigation, which were derived from a variety of sources, including Rubber Seed Oil: Properties, Uses, and Benefits and Rubber Seed Oil: Properties, Usage, and Benefits.

Our studies, which included the impact of different binder oils as well as the influence of mechanical vibration, were modeled and observed using the ANSYS 2021 R2 software.

Chapter Three

RESEARCH/EXPERIMENTAL DESIGN

3.1 Introduction:

As sand binder materials, the authors of this study used rubber seed oil and cottonseed oil, and they conducted a systematic finite element analysis to determine the most effective binder for aluminum cooling in sand mold casting through analytical and simulation methods. A bottom gating system was chosen due to the low gas entrapment and low surface defect characteristics of the material being used. In addition, the author performed a computational analysis to obtain the best possible result within a specific mechanical vibration range. It was necessary to use Solid Works to create the CAD model, and an Ansys workbench was used to conduct a fluid flow (CFX)[27] analysis on the model. To extract simulation parameters and boundary conditions, a real-world experimental condition was used to generate them. When compared to cottonseed oil, which was discovered through CFD simulation analysis, rubber seed oil has a faster cooling rate. Computational fluid dynamics (CFD) is the most widely used tool for simulation and analysis in the engineering field. The simulation of the flow field characteristics inside the turbo machined out using a numerical CFD tool in three dimensions. The use of CFD simulation makes it possible to see the flow conditions inside a centrifugal pump in real-time. The present paper describes the head, power, and efficiency of the pump, as well as the performance of the pump as measured by the ANSYS CFX-14, a computational fluid dynamics simulation tool, in detail. Flow phenomena such as cavitation flow, which can occur in either the rotating runner-impeller or the stationary parts, are strongly represented in these simulations. The transient three-dimensional (3D) hydrodynamic model based on the kinetic theory of granular flows was used to predict the behavior of horizontal solid-liquid (slurry) pipeline flows. We compared the outcomes of computational fluid dynamics (CFD) simulations performed using the ANSYS-CFX commercial CFD software package with the results of experimental data sets available in the literature. Ito investigate the effect of the in-the volume of the in-situ solid, time-averaged solids concentration profiles, pa, article, and liquid velocity profiles, as well as frictional pressure loss, the simulations were conducted. It was discovered that there was excellent agreement between the model predictions and the experimental data. Using both experimental and numerical results, we can conclude that the particles are asymmetrically distributed in a vertical plane, with the degree of asymmetry increasing with particle size. Once the particles have grown to a sufficiently large size, the concentration profiles are solely dependent on the volume fraction of in situ solids. In contrast to commonly used correlation-based empirical models, the present CFD model does not rely on experimentally determined slurry pipeline flow data for parameter tuning, and as a result, it can be considered superior to those models. The paper emphasized the systematic modeling of hydrodynamic damping on the complex-shaped valve using the computational fluid dynamic software ANSYS-CFXTM, which is not a practice that is commonly used. Small-scale testing using a free-decaying experiment was used to verify the theoretical models obtained from ANSYS-CFXTM during the developmental stage for initial design and prototype testing. The simulation results are shown to be consistent with the experimental results. According to the proposed method, the valve's hydrodynamic damping coefficients could be determined.[21]

Consumable vegetable oils are the most widely used binders in the foundry industry, out of all the oils available, including those from marine, mineral, and vegetable sources. Because of the high demand from the food and cosmetic industries, their supply is limited in the meantime. It is, therefore, necessary to investigate the use of non-consumable sources of vegetable oils as core oils for use in casting technology. Rubber seed oil was tested as a core binder in foundry sand, which was composed of a mixture of cassava starch, water, and silica. The results were promising. The maximum baked strength of 1829kN/m2 was achieved in a mixture consisting of three percentages of rapeseed oil, seven percentages of water, one percent of cassava starch, and eighty-nine percent of sand. The foundry industry generates several byproducts of which the largest volume is "spent sand". Molding sand is mixed with binder and additives. The characteristics of the residuals vary from foundry to foundry and depend on the type of metal being poured, the type of casting process, the technology employed, and the type of finishing process.[28] Foundry waste sand is physically suitable for many applications although long-term environmental effects are not well documented. The beneficial use of waste sand requires specific physical and chemical characterization of the waste material. Results of waste characterization should identify hazardous wastes, and determine disposal needs and other issues. This waste can be reduced when using the organic binders as these binders degrade faster. Thus, this thesis implies the use of mechanical vibrations on organic binders in sand casting processes to increase overall efficiency to replace them with inorganic binders

3.2 Experimental Setup:

The experiment was carried out using sand molds. In turn, rubber seed oil and cottonseed oil were used as mold binding materials. The fundamentals of the molds' compositions and the percentages of the binding materials in the mold are shown in Table 1.

The molds have a circular cross-section at the gate. A pattern for the cast product was created first. Then it was made out of wood. Based on that pattern, a mold was created. The bottom gating system was used to ensure that inside the mold cavity, the molten metal flows without turbulence. The riser, basin, and gate were all installed and standard formulae were used to ensure the best results in casting for excellent quality with no flaws. The sand mold process is depicted in part in the following illustration

Rubber seed Oil Bonded Molding Sand		Cottonseed Oil Bonded Molding Sand	
Molding Sand constituent	Weight percentage	Molding Sand constituent	Weight percentage
Silica Sand	80	Silica Sand	81
Rubber seed oil	16	Cottonseed oil	15
Wood flower	2	Wood flower	2
Parting Materials (Chalk Powder)	2	Parting Materials (Chalk Powder)	2

[29]Table 3.1: Composition of rubber seed oil bonded and cottonseed oil bonded molding sand

A K-type thermocouple (CD-XMTA-1001)[2] was used at a specific point on the mold to measure the temperature of the molten metal. A digital temperature meter was used to take the temperature reading.

This meter can give you an accurate temperature reading in the range of 0 to 999C[14]. The drag flask is set up on the board of directors. Dry facing sand is sprinkled over the board to provide a smooth finish. It is possible to locate the pattern's drag half on the moldboard. Dry-facing sand will provide a non-sticky layer on top of the concrete. Afterward, molding sand is poured in to completely cover the pattern created with the fingers, and the drag is filled. Hand rammers are then used to compact the sand in the drag until it is tightly packed. Peen hammers (which are used first, close to the drag pattern), as well as but hammers (which are used for surface ramming), are employed. The ramming must be done properly, that is, it must not be too hard or too soft. Ramming that is too soft will result in a weak mold that will not produce a good imprint of the pattern. The use of excessive force during ramming will prevent gases and air from escaping, resulting in the formation of bubbles in the casting and the formation of defects known as "blows." Furthermore, the fabrication of runners and gates will be time-consuming. With a straight bar known as a striking the excess sand is leveled/removed from the ramming after it has been completed. A series of vent holes are cut into the drag that text extends the full depth of the flask and into the pattern to aid in the removal of gases during the pouring and solidification processes. This is accomplished through the use of a vent rod. The finished drag flask is now constructed upside down, revealing the pattern underneath. The drag pattern is then placed on the cope half of the pattern with the help of locating pins. Pins are also used to locate the cope flask, which is another important component. The dry parting sand is sprinkled liberally all over the drag surface as well as on the design pattern. A sprue pin, which is used to create the sprue passage, is located a short distance from the pattern edge. The riser pin is positioned in the proper location. The filling, ramming, and venting of the cope are all accomplished in the same way. To pour the liquid metal, the sprue and riser are removed, and a pouring basin is created at the top of the cylinder. The pattern from the cope and drag has been eliminated. With a gate cutter, you can create runners and gates by cutting the parting surface of the parting surface. A gate cutter is simply a piece of sheet metal that has been bent to the desired shape. The core to create a central hole is now placed into the mold cavity in the mold. Drags in the core prints and rests there. The mold has been assembled and is ready to be filled. It is nothing more than the fundamental design that is required to construct a smooth and proper filling of the mold cavity of the casting that is free of discontinuities, voids, and solid inclusions during the casting process. This method of setting up the gate system ensures proper and smooth filling of the casting cavity by forcing the pure molten metal to flow into the ladle and the casting cavity through a gating system. A lot of this depends on the layout of the gating channels as well, including the direction and placement of the runner, the sprue, and the ingates. The mold cavity must be filled with a clean metal in orthent the entry of slag and inclusions into the mold cavity, which in turn reduces the surface instability of the finished product. If the mold has a smooth filling, it will aid in reducing the bulk turbulence in the mold. If the casting fill is uniform, it indicates that the casting fill has been done in a controlled manner. Complete filling of the cavity results in a metal that is thin and has the least amount of resistance at the end sections.[8]

3.2.1 Materials:

Sand, rubber seed oil, and cassava starch are some of the raw materials that were used in this investigation. Rubber seed oil is a non-consumable vegetable oil that has little or no use in human nutrition due to its high acidity. The purpose of this research is to develop oil-sand cores by using rubber seed oil as a binder.[30] We are wasting rubber seeds in our plantations, particularly in the southern part of Nigeria. For local foundries to maximize the utilization of this locally available raw material, minimize waste, remain competitive, and be economically viable, the success of the work must be demonstrated. The sand collected was washed to remove clay and organic matter, then sun-dried sundried before being sieved through a set of sieves to remove any remaining particles. The mixture was stirred for 80 minutes at a constant temperature of 55 degrees Celsius[29] to allow the solvent to force oil out of the solid cells and into the solvent. The mixture was filtered and distilled to cover the solvent as well as the oil that had been produced. After that, the oil was dried in the oven for two hours at a constant temperature of 105 degrees Celsius to produce.

The casting metal chosen was aluminum. The aluminum was melted at a temperature of over 700-750 °C in a crucible furnace. The molten metal was formed after the metal was melted and a ladle was used to pour the metal into the mold’s basin. Following the pouring, a temperature reading was taken. The experiments were carried out again after changing the binding materials It was made certain that initial operating conditions and overall environmental conditions were the same in the experiments.[22]

After that, cooling curves were generated. For the experiment, a commercially available Aluminum grade was used. The following are the properties of the Aluminum used in the experiment:

Properties	Values
▪ Molar Mass	▪ 26.98 g mol^{-1}
▪ Specific heat capacity	▪ 1047 J Kg^{-1} K^{-1}
▪ Density	▪ 2750 Kg m^{-3}
▪ Thermal conductivity	▪ 180 Wm-1K
▪ Dynamic viscosity	▪ 0.0025 Kg m-1s^{-1}
▪ Thermal coefficient of expansion	▪ 4x10-5 K^{-1}

Table 3.2: Properties of Aluminum used in the experiment[25]

3.2.2 Part Selection:

In this research, we used a master acuter valve. The braking system of a car is intricate and complicated. Unlike the common misconception, braking systems are comprised of much more than just calipers and rotors. In a vehicle's braking system, one of the most important components is the acuter valve. Being aware of the function and significance of your brake acuter valve is critical to understanding how your car works and determining when it should be serviced by a professional technician or mechanic. The braking system of a car is intricate and complicated. Unlike the common misconception, braking systems are comprised of much more than just calipers and rotors. The proportioning valve is an extremely important component of a vehicle's braking system. Being familiar with the function and significance of your brake acuter valve is critical to understanding how your car operates. The acuter valve is typically used to connect the master cylinder to the rest of the braking system, but it can also function independently of the master cylinder in some instances. A properly functioning front-to-rear bias valve, also known as brake balance, is required for optimal performance. It is a spring-loaded component that is activated when fluid pressure builds as a result of pressing the brake pedal all the way. The plunger of the valve then comes loose, allowing fluid to rush into the calibrated range. This causes the spring to be compressed, and the plunger to become obstructed, preventing fluid from passing through. It is critical for safe and dependable braking performance that the pressure is distributed evenly between the front and rear wheels of your vehicle.[28]

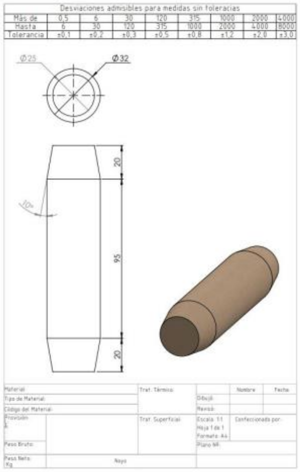
Figure 3.1: Master Actuator valve

The presence of a brake proportioning valve in your brake system is advantageous because it allows you to better control brake balance. If your proportioning valve is not working properly, your rear brakes may receive an excessive amount of pressure during rapid deceleration. A properly functioning proportioning valve ensures that your rear brakes do not lock up when you apply the brakes hard. When driving any car, but especially in pickup trucks with light backends, this is essential. The purpose of taking this part in the research is because it is made by traditional sand-casting methods using inorganic binders. This thesis highlights the fact of producing this part more efficiently with less pollution by using organic binders and applying mechanical vibrations to the toe mold.

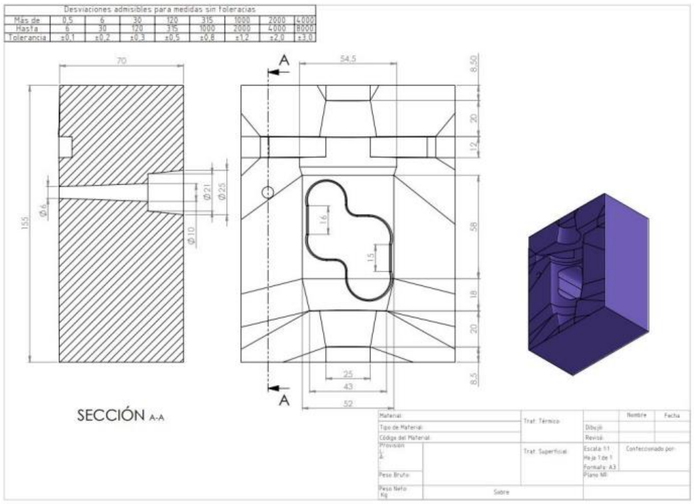
In the experiment on sand casting, we looked for suitable parts which are produced using the sand-casting process and available in the consumer market. After some lookups and research, we came up with a simplified CAD model of a master cylinder actuator system which is heavily used in the automotive industry. The following flow chart shows the selection, modeling, prototyping, and, casting process of the selected part for our experiment.

2D Sketch Parts

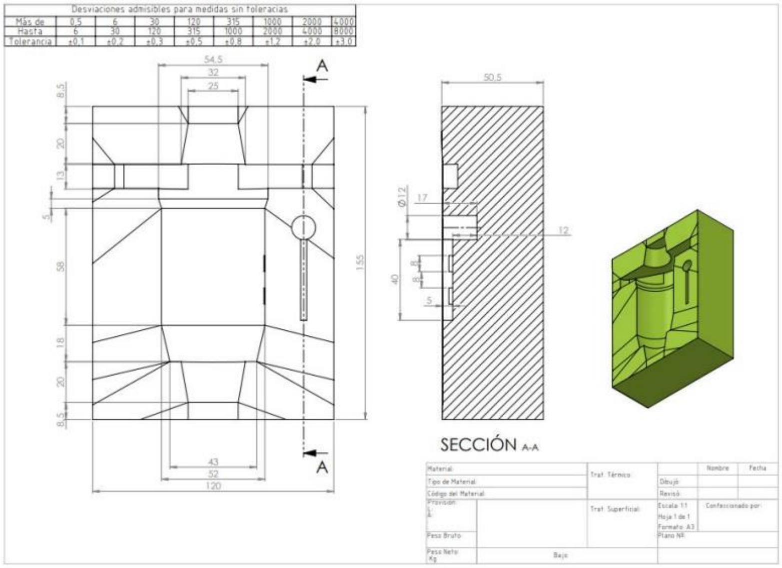
Inside Die:



Upper Section:



Lower Part:



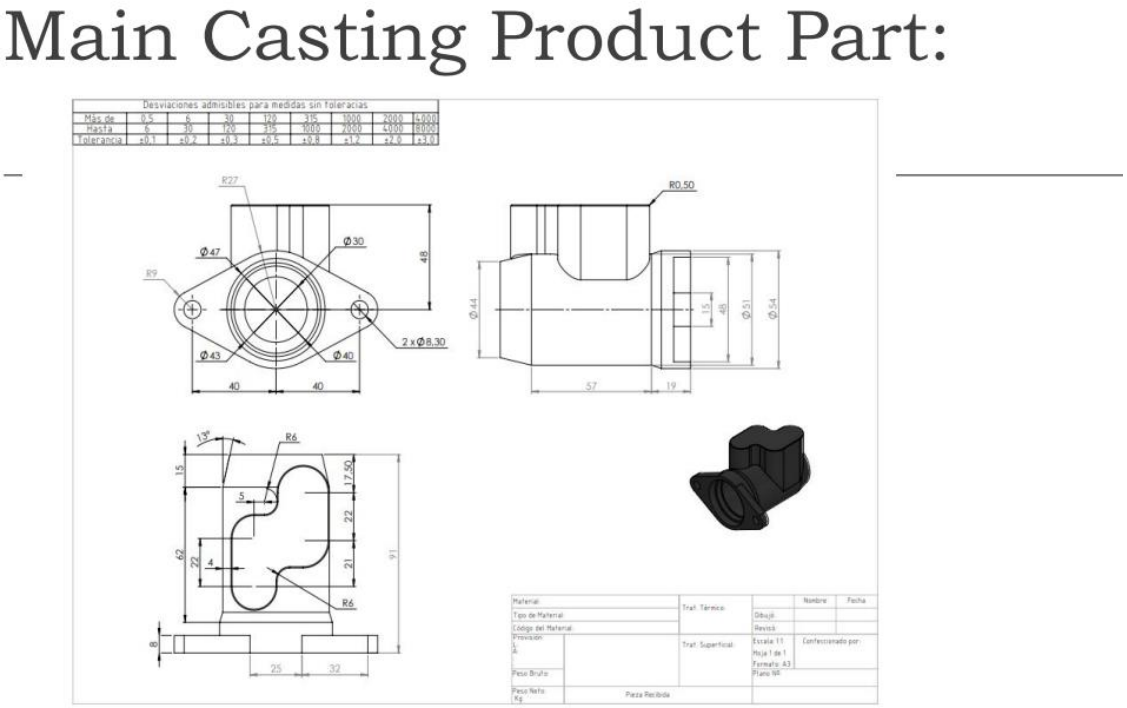


Fig 3.2: 3D Design of the CAD Model

We used Solidworks 2020 to make the mold to fit the acuter valve inside with proper gating systems and with cope and drag. The properties of the CAD model are given below:

Mass = 13829.34 grams

Volume = 1920741.11 cubic millimeters

Surface area = 162312.42 square millimeters

Center of mass: (millimeters)

X = 11.48

Y = 151.96

Z = 139.88

Getting closer to the mold cavity, the total cross-sectional area decreases. The restrictions in the metal flow are responsible for maintaining backpressure. The flow of liquid (in terms of volume) is nearly equal from all gates. Beausite sprue is always full, back pressure assists in reducing aspiration. Because of the restrictions, the metal flows at a high velocity, causing more turbulence and increasing the likelihood of mold erosion and erosion. Within the sprue and the gate, the velocity of liquid metal is uniform across the cross-section. In reality, the velocity of a fluid in contact with any solid surface is zero, with the maximum velocity occurring at the axis of the conduit.[11]

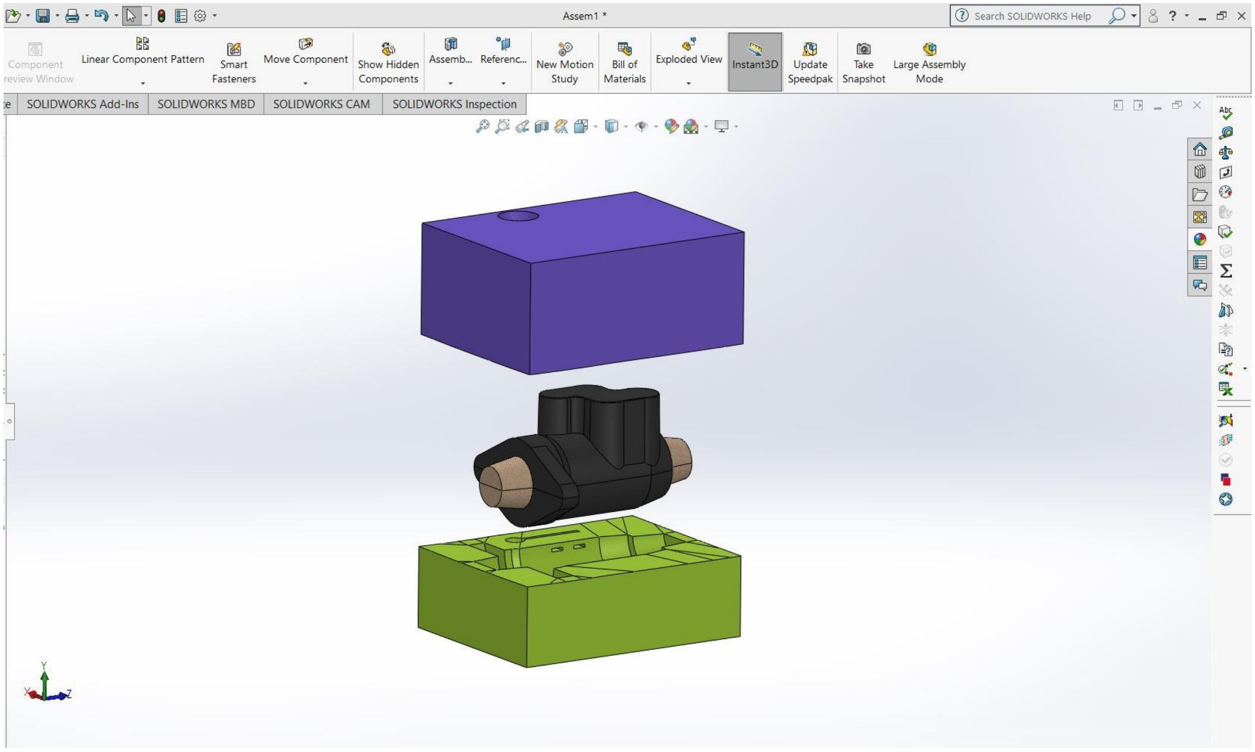


Figure 3.3: CAD Part with cope and drag

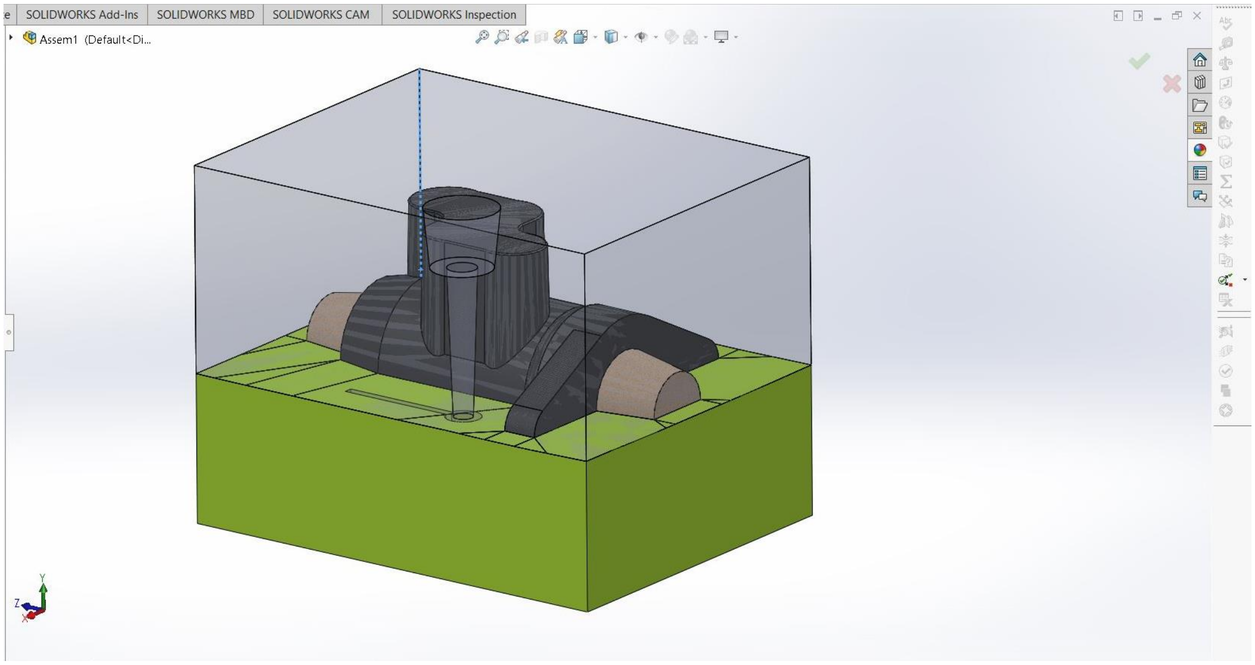


Figure 3.4: Casting assembly with runner and gating system

The distribution of velocity within the conduit is determined by the shape of the conduit as well as the nature of the flow (i.e., turbulent or laminar). Furthermore, the assumptions are made that there are no frictional losses in the discussion thus far.

3.3 Framework for Data collection:

To verify the results of the experimental setup for the sand mold casting process for various binders. Ansys CFD was used to simulate the situation. N.A. Chowdhury et al. [5] followed the same approach for casting with a permanent mold. Initially different parts of the body are modeled geometrically. However, while most computational fluid dynamics ③ (CFD) simulations are based on Reynolds-averaged Navier-Stokes (RANS) turbulence models, it is becoming increasingly clear that certain classes of flows are better covered by models in which all or a portion of the turbulence spectrum is resolved in at least a portion of the computational domain. According to this paper, such methods are referred to as ③ Scale-Resolving Simulation (SRS) models. There are two primary reasons for preferring SRS models over RANS formulations: first, they are more accurate. To begin with, ㊷ the need for additional information that cannot be obtained from a RANS simulation is one of the primary reasons for using SRS models. Examples of this include acoustics simulations in which the turbulence generates noise sources that cannot be accurately extracted from RANS simulations, for example. There are also multi-physics effects such as vortex cavitation, where the unsteady turbulence pressure field is the cause of cavitation, which can occur in unsteady mixing zones of flow streams at different temperatures and can result in material failure. SRS may be required in such situations even if the RANS model is capable of computing the correct time-averaged flow field in principle. The second reason for employing SRS models has to do with the accuracy of the models. When it comes to accuracy, it is well known that RANS models have their limitations in certain flow situations. RANS models have demonstrated their superiority primarily for wall-bounded flows, where the calibration according to the law of the wall provides a solid foundation for further refinement after the initial calibration. The performance of RANS models is significantly less consistent when dealing with free shear flows. The types of flows that can occur include simple self-similar flows such as jets, mixing layers, and wakesimpingeging flows, flows with a lot of swswirlsmassively separated flows, and many others.Becauset RANS models typically have limitations in terms of covering the most fundamental self-similar free shear flows with a single set of constants, it is unlikely that even the most advanced Reynolds Stress Models (RSM) will be able to provide a reliable foundation for all such flows shortly introduction to RANS modeling. Because the largest turbulence scales in free shear flows are typically on the order of the shear layer thickness, it is typically much easier to resolve the largest turbulence scales in free shear flows. In contrast, in-wall boundary layers, the turbulence length scale near the wall becomes extremely small when compared to the thickness of the wall boundary layer (increasingly so at higher Re numbers). Large Eddy Simulation (LES) is severely restricted as a result of this, as the computational effort required is still far more than the computing power currently available to the industry. As a result, hybrid models, in which large eddies are resolved only away from walls and the wall boundary layers are covered by a RANS model, are currently being developed. Detached Eddy Simulation (DES)[11] and Scale-Adaptive Simulation (SAS) are two examples of global hybrid models[27]. The Shielded Detached Eddy Simulation (SDES) and the Stress-Blended Eddy Simulation (SBES), both proposed by the ANSYS turbulence team, are examples of more recent advancements in the field. The sprue, basin, riser, and other components of the mold were created. Solid works were used to create the design, which was then assembled while keeping the same hydraulic diameter to maintain the same flow characteristics at all times at the model's corresponding points. Points were then generated on surfaces such as inlet, opening, and the fluid domain is followed by an opening and a wall. For the meshes, tetrahedral meshes were created for cavities and patterns in the mold. The standard of the experiment is checked to get the best results, the meshes were double-checked and fine-tuned to gain optimum conditions. Finally, mesh files were created. Ansys CFX can use the cfx format for further analysis. The figures show an enlarged view of the generated mesh. A model with a variety of material properties and the flow chart's boundary conditions were followed. Figure 4 depicts the sand-casting process. The worth of various boundary conditions and parameters are also considered as shown in table 3:

Parameters	Value
pouring temperature	700-750°C
Inlet temperature	710°C
Pressure	1 atm
pouring speed	2.6 cm/s

Table 3.3: Simulation parameters

The following Tetrahedral mesh was generated in ANSYS from the experimental assembly;

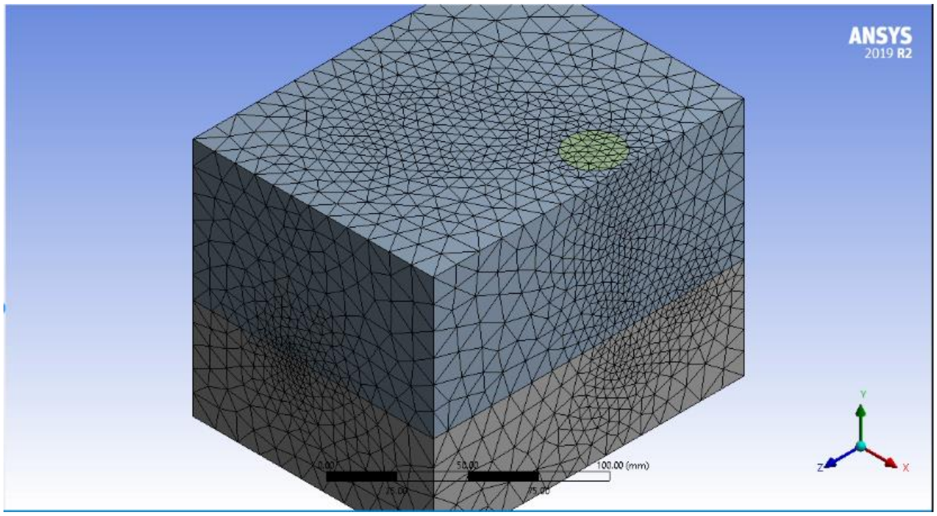


Fig 3.5: Tetrahedral mesh of the experimental assembly

After refining the mesh in ANSYS Fluent, we conducted 4 simulations for each type of binder oil, one without any vibration force and the rest three with the various frequency of vibration resulting in a total of 8 experimental simulations. The simulations were plotted and compared for the result and discussion.

The baking process resulted in a significant increase in the strengths as the baking time was increased. As the percentage of oil in the mixtures was increased, the strengths of the mixtures increased dramatically, demonstrating that the oil has a binding effect on the core mixtures. The oil's binding ability is a result of the polymerization of unsaturated oil molecules that occurs under the influence of oxygen during the manufacturing process. The oxygen comes from the air blown into the oven by the built-in fan, and it acts as a catalyst for the polymerization process. The process is referred to as thermo-oxidative polymerization in this case. Additionally, it can be seen from the results that, for all percentages of oil additions and baking times, there was a significant increase in the strengths with increasing baking time when the cookies were baked. As the percentage of oil in the mixtures was increased, the strengths of the mixtures increased dramatically, demonstrating that the oil has a binding effect on the core mixtures. The oil's binding ability is a result of the polymerization of unsaturated oil molecules that occurs under the influence of oxygen during the manufacturing process. The oxygen comes from the air blown into the oven by the built-in fan, and it acts as a catalyst for the polymerization process. The process is referred to as thermo-oxidative polymerization in this case. Additionally, the results show that for all percentages of oil additions and baking times, the results are the same.

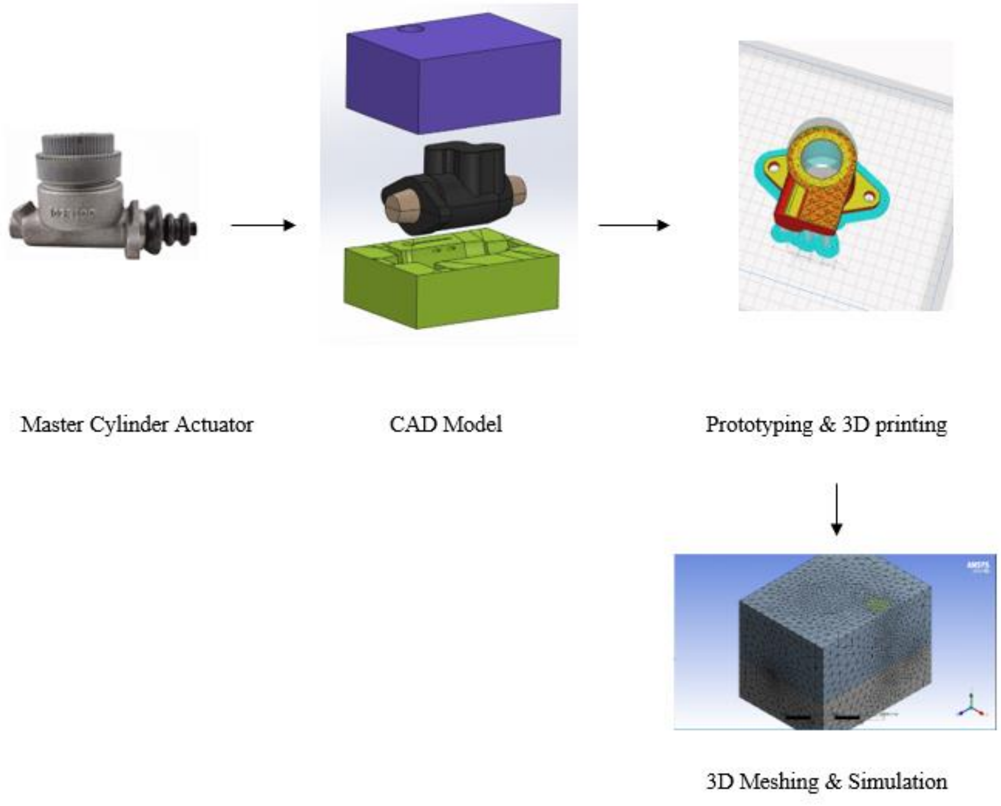


Figure 3.6: The sequence of the experimental process

Chapter Four

4 DATA GENERATION/COLLECTION, ANALYSIS, AND DISCUSSION

4.1 Introduction

Two stages of experimentation were used in our data collecting and analysis. The first step is simulating and conducting experiments with product binders such as rubber seed oil and cottonseed oil, respectively. This stage involves the introduction of mechanical vibration into the solidification process, which is simulated and seen using the ANSYS 2021 R2 simulation and observation program. Finally, we present our final results and discussion, which include rigorous simulation through trial and error, and a comparison of the outcomes to determine whether mechanical vibration is a viable choice or not. To achieve the best possible outcomes, we have employed the trial-and-error method to determine the most suitable region of mechanical vibration as well as the binder qualities. A huge number of iterations were performed, and tabulations and graphs were created to compare one pie to another.

4.2 Data Collection:

Our first set of data collection was regarding the properties of our two binders, rubber seed oil, and cottonseed oil. The properties used in the experimental setup are tabulated below for reference;

Property Name	Rubber Seed Oil *
Color	Golden Yellow
Viscosity (mm^2/s)	40.86
Density (gm/cm^3)	0.857
Specific Gravity	0.91

Moisture Content (weight, %)	1.73
High Heating Value (MJ/Kg)	36.1-44
Kinematic Viscosity (mm^2/s)	6-66

Table 4.1: Properties of Rubber Seed Oil used in the experiment

Property Name	Cotton Seed Oil *****
Color	Dark Brown
Viscosity (mm^2/s)	62
Density (gm/cm^3)	0.917
Specific Gravity	0.88
Moisture Content (weight, %)	0.52
High Heating Value (MJ/Kg)	40.13
Kinematic Viscosity (mm^2/s)	33.5

Table 4.2: Properties of Cotton Seed Oil used in the experiment

Our second step of data collection included the properties of Aluminum 1100 which was used as the casting metal during the experiment. The properties used in the experiment are tabulated below for reference;

Properties	Values
Pouring Temperature	700-750 °C
Inlet Temperature	710 °C
Pouring Speed	2.6 cm/s
Pressure	1 atm
Molar Mass	26.98 gm/mol
Density	2750 Kg/m^3
Specific Heat Capacity	1047 J/Kg/K
Dynamic Viscosity	0.0025 Kg/m/s
Thermal Conductivity	180 W/m/K
Thermal Coefficient of expansion	$4*10^{-5}$ K^{-1}

Table 4.3: Properties of Aluminum 1100 used in the experiment

These data sets were used to complete the first step of our investigations. To ensure the correctness of the experiment, several simulations and trial-and-error methods were used. The simulation of metal casting in the mold cavity, as well as the examination of attributes and outcomes such as density, porosity, viscosity, turbulence, thermal conductivity, and so on, were all included in our experiment. Listed below for your convenience are all of the visual examinations of the experiments;

4.2.1 Density Analysis:

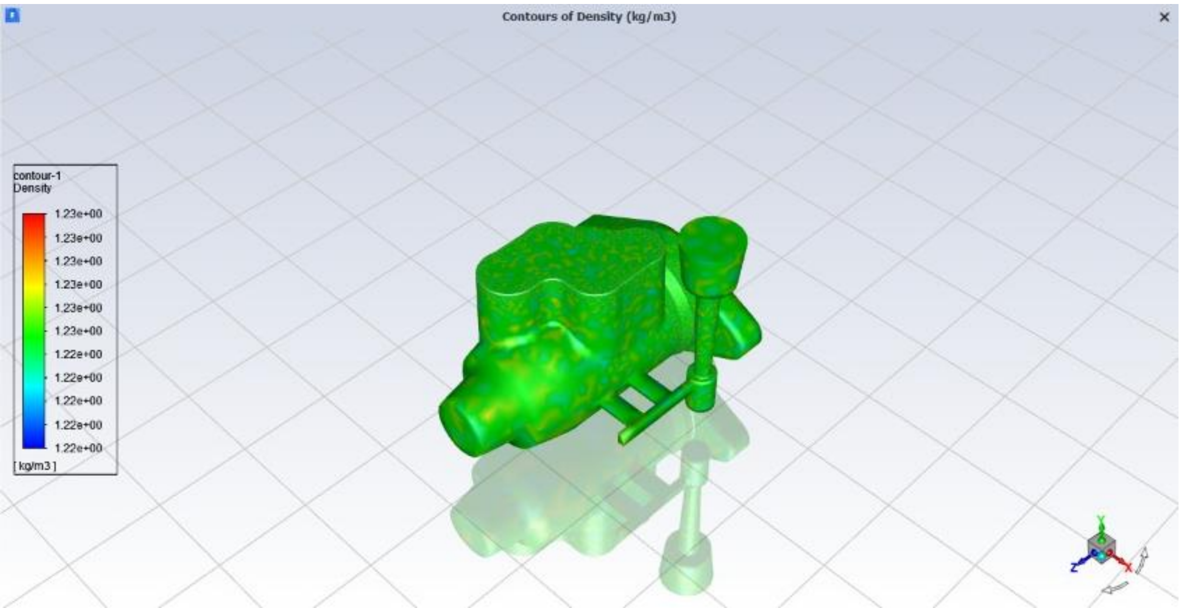


Fig 4.1: Density Analysis of Rubber Seed Oil

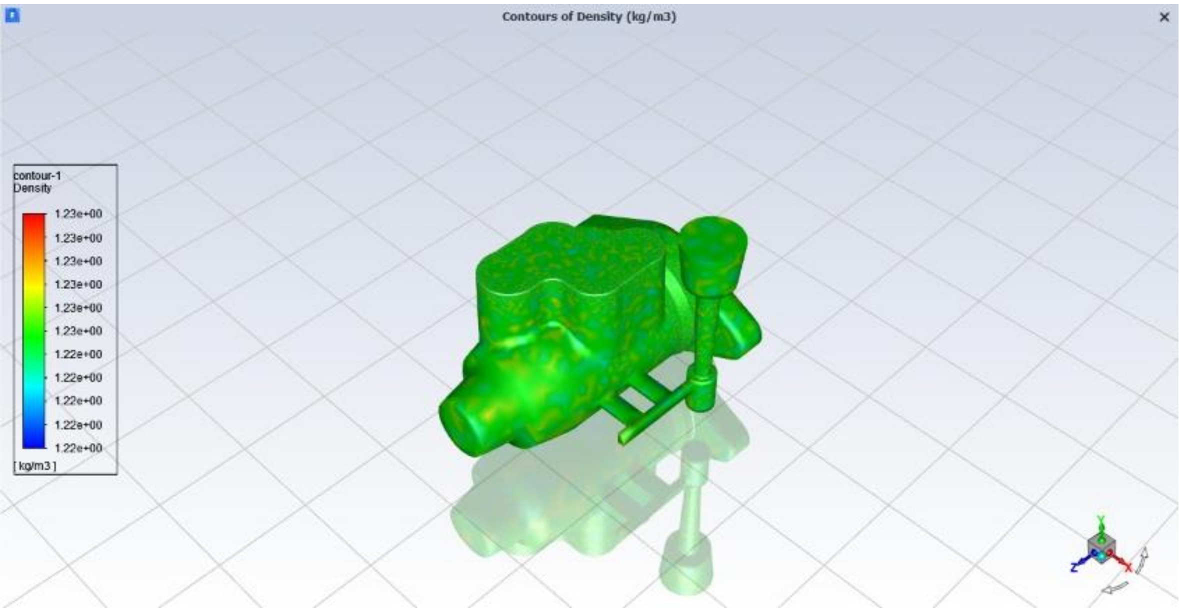


Fig 4.2: Density Analysis of Cotton Seed Oil

4.2.2 Molecular Viscosity Analysis

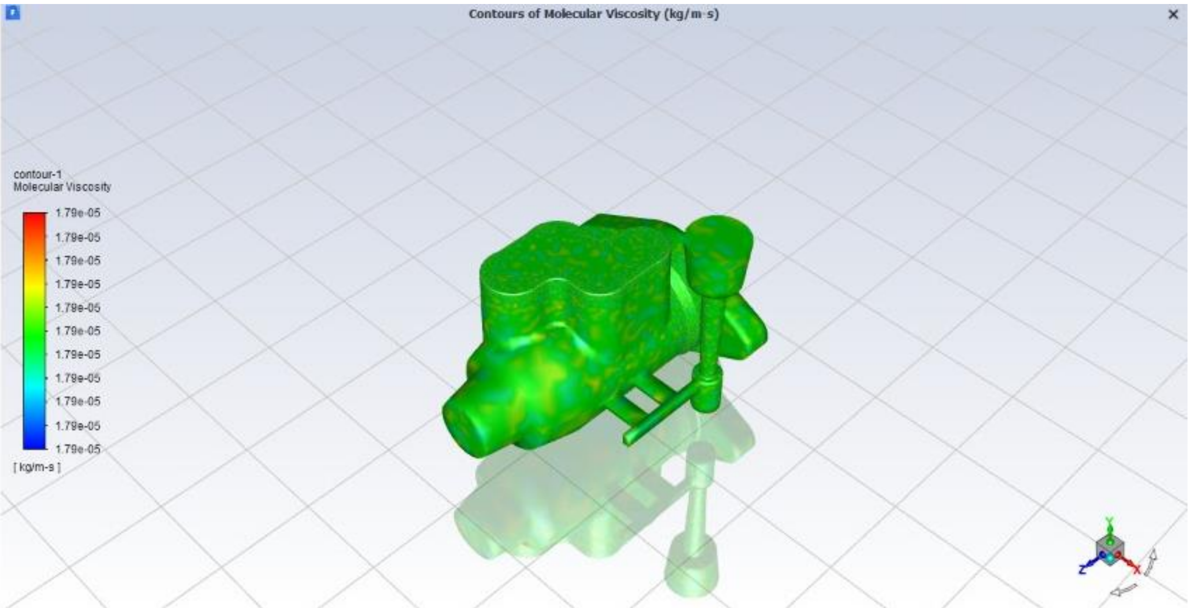


Fig 4.3: Molecular Viscosity Analysis of Rubber Seed Oil

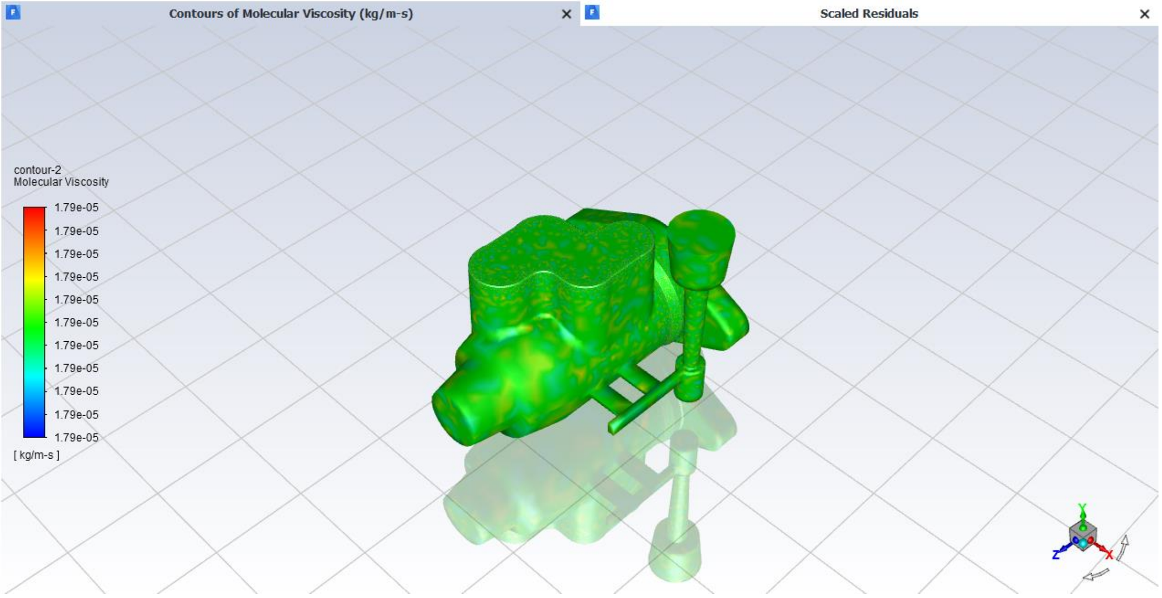


Fig 4.4: Molecular Viscosity Analysis of Cotton Seed Oil

4.2.3 Mass Imbalance Analysis:

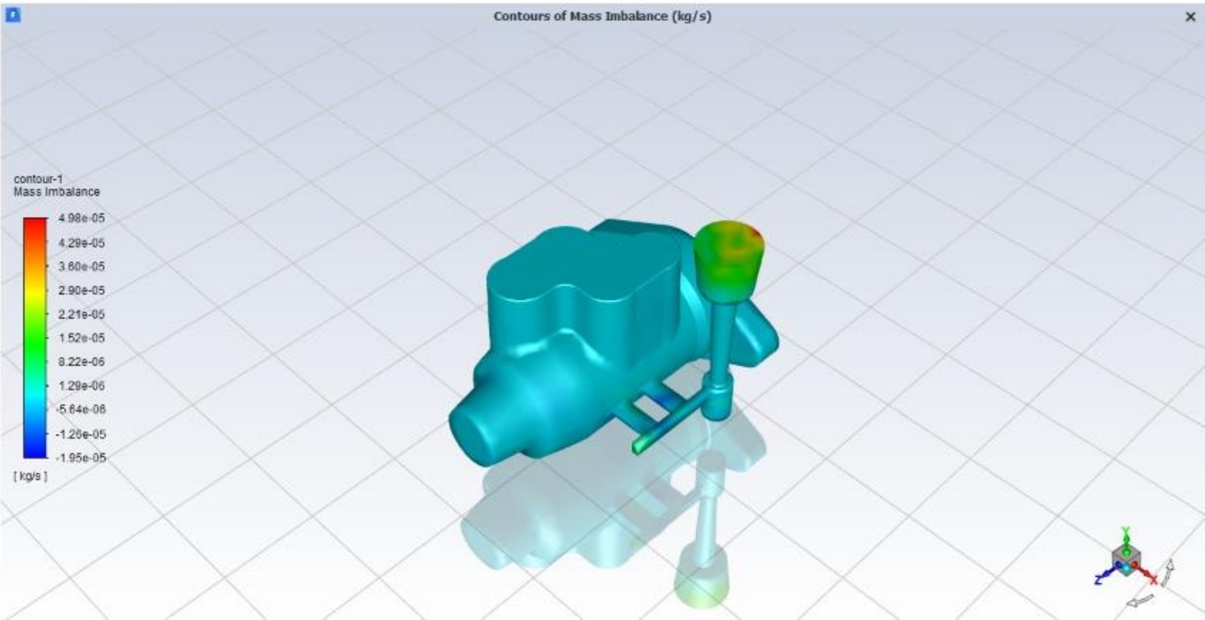


Fig 4.5: Mass Imbalance Analysis of Rubber Seed Oil

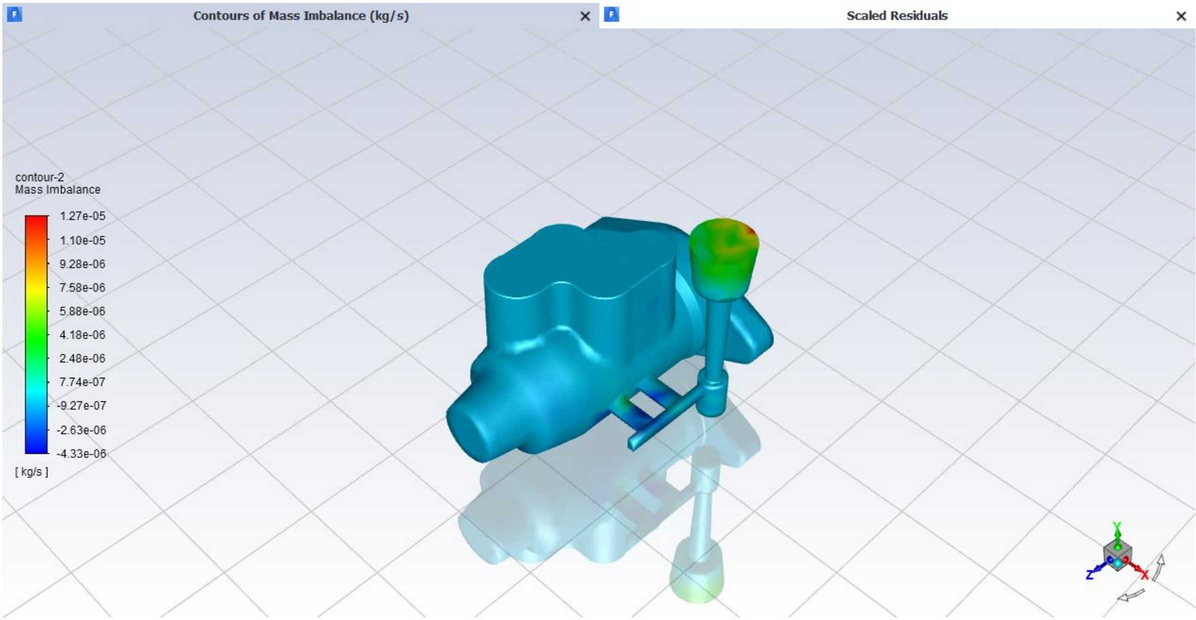


Fig 4.6: Mass Imbalance Analysis of Cotton Seed Oil

4.2.4 Shear Stress Analysis:

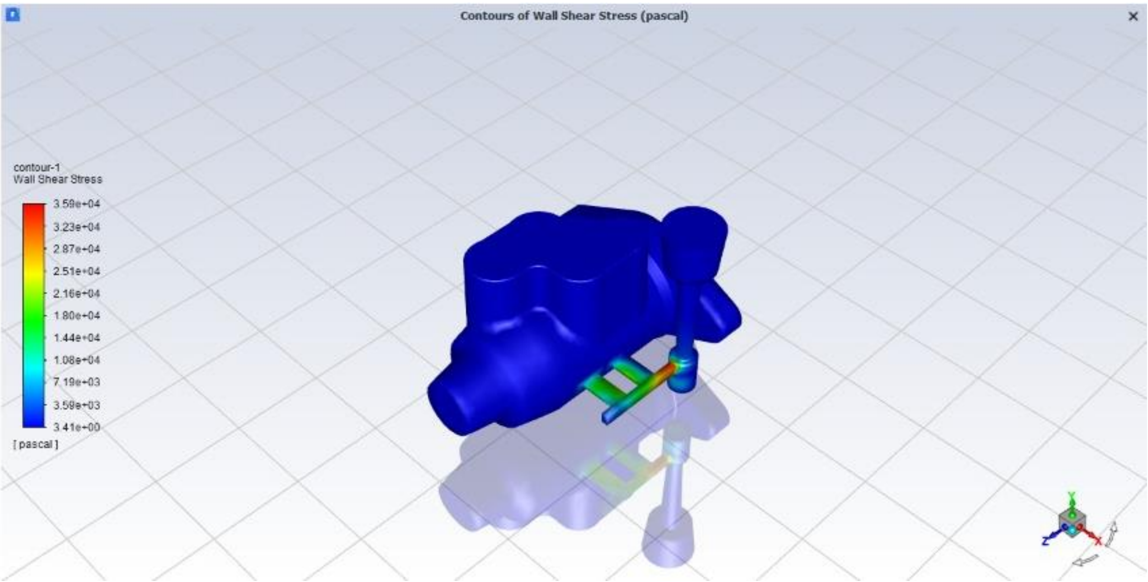


Fig 4.7: Shear Stress Analysis of Rubber Seed Oil

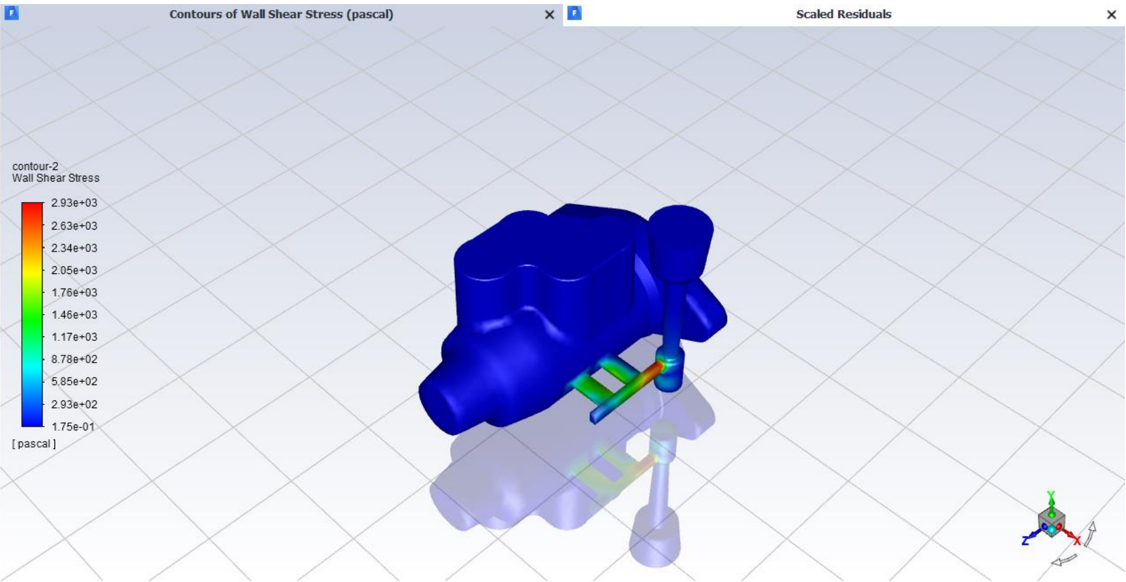


Fig 4.8: Shear Stress Analysis of Cotton Seed Oil

4.2.5 Turbulent Kinetic Energy Analysis

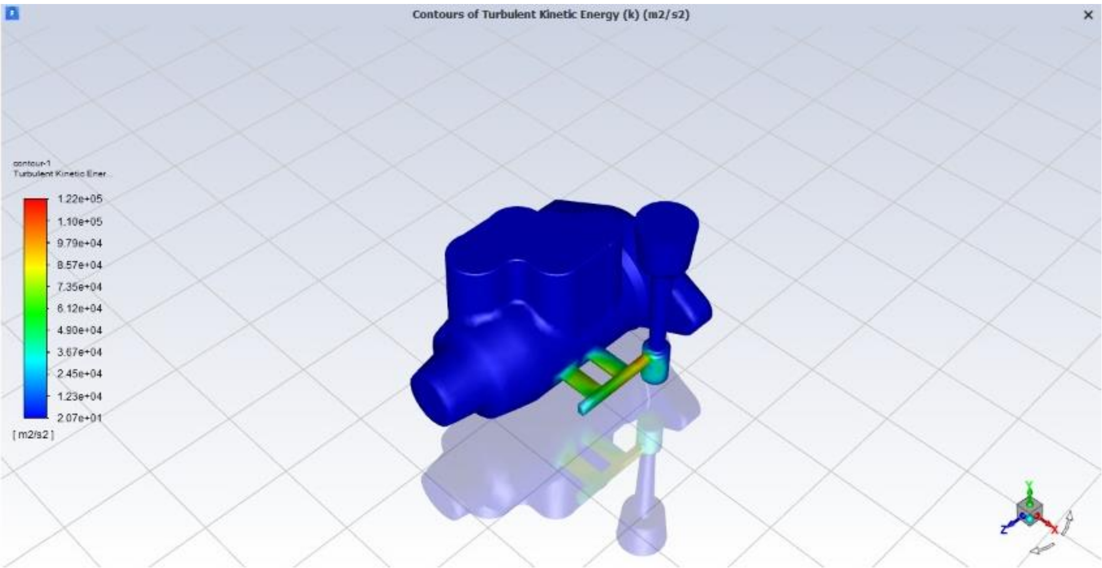


Fig 4.9: Turbulent Kinetic Energy Analysis of Rubber Seed Oil

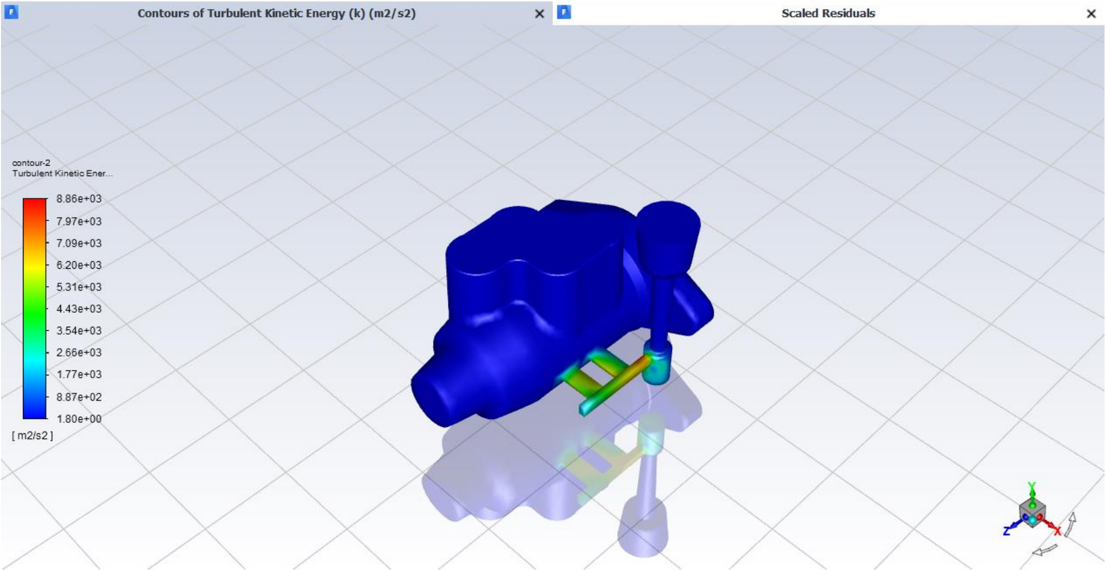


Fig 4.10: Turbulent Kinetic Energy Analysis of Cotton Seed Oil

4.2.6 Total Pressure Analysis

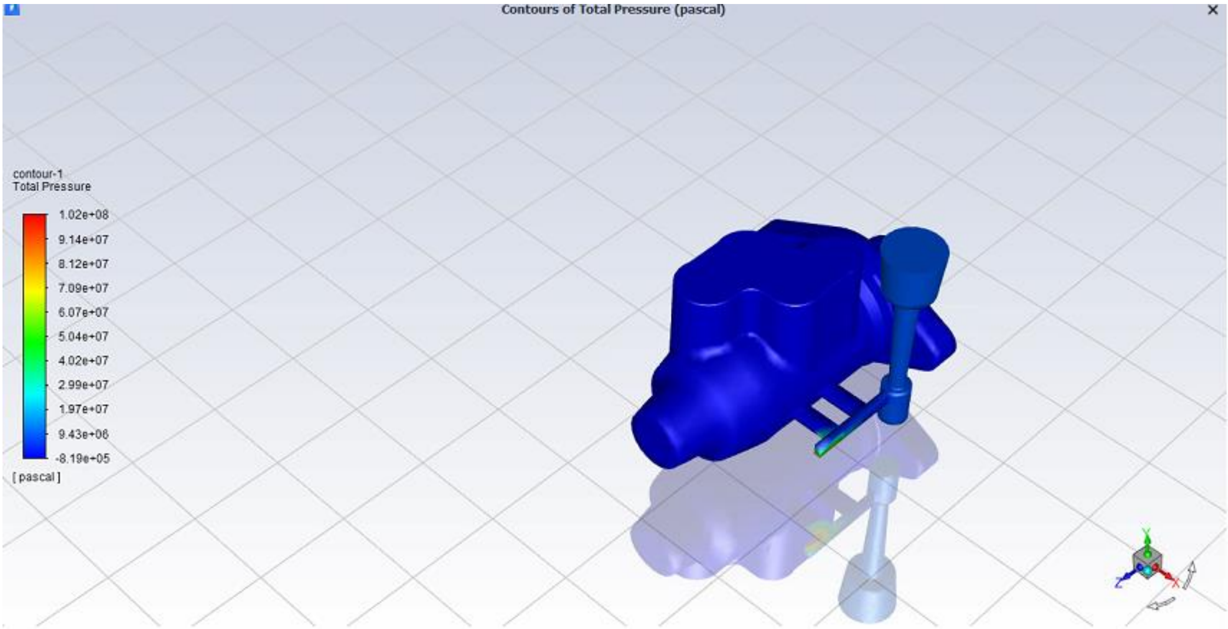


Fig 4.11: Total Pressure Analysis of Rubber Seed Oil

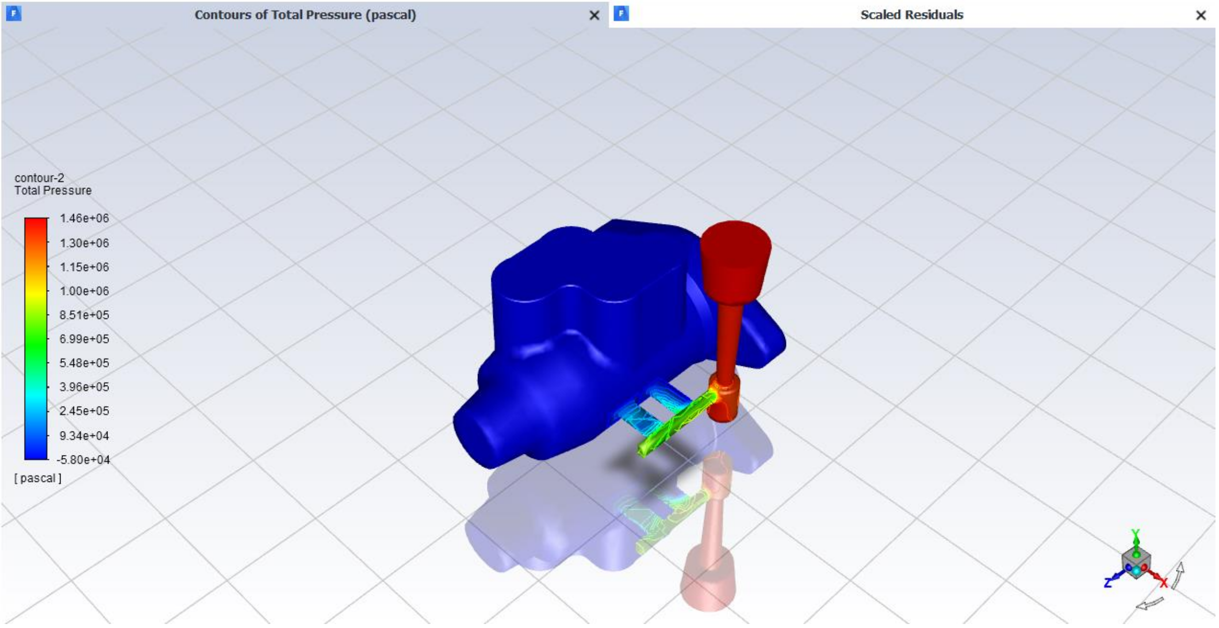


Fig 4.12: Total Pressure Analysis of Cotton Seed Oil

4.2.7 Mechanical vibration in sand casting

It is demonstrated in this experiment that mechanical mold vibration increases the density and elongation of the cast component and that the influence of mechanical mold vibration on a sand-casting alloy A1100 is examined. The A1100 alloy is cast in a sand mold to achieve the desired shape. When the cast begins to solidify, mechanical vibration is produced in the process.

After that, the alloy is dimensionally sliced and the surface is smoothed using a lathe machine, which produces the final product. The Rockwell and Brinell tests are used to determine hardness and stiffness. During the casting process, the results of the tests are recorded to determine whether or not there is an increase in the mechanical qualities and characteristics of the A1100 alloy when mechanical mold vibration is applied. The mechanical vibrational force was applied from the bottom surface of the sand-casting mold uniformly for optimum results.

4.2.8 Viscosity Analysis of Rubber Seed Oil:

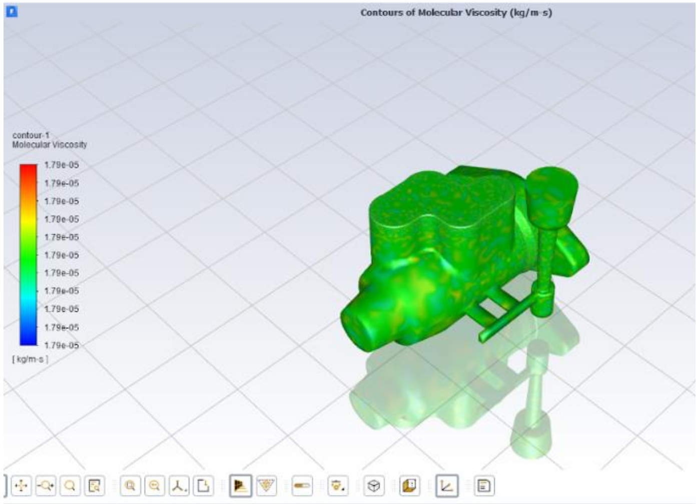


Fig 4.13: Before any vibration

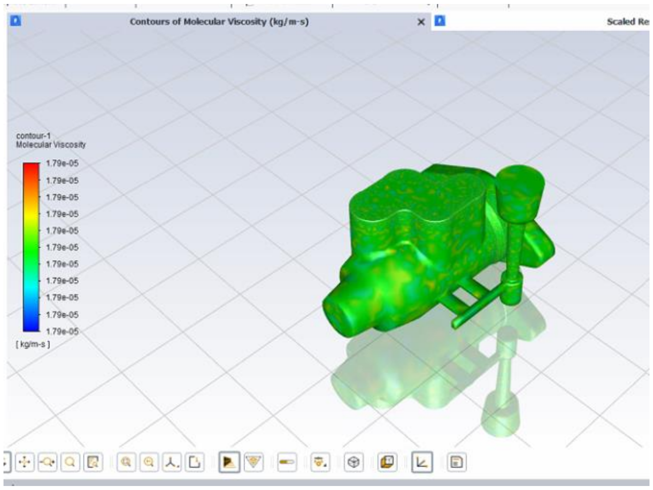


Fig 4.14: After applying 30hz mechanical vibration

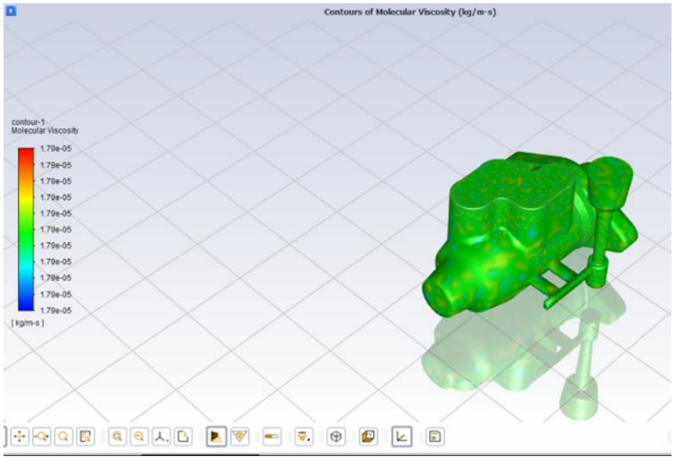


Fig 4.15: After applying 40hz mechanical vibration

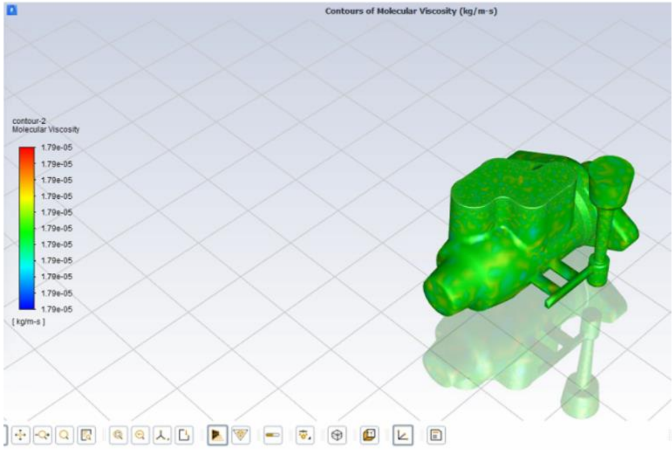
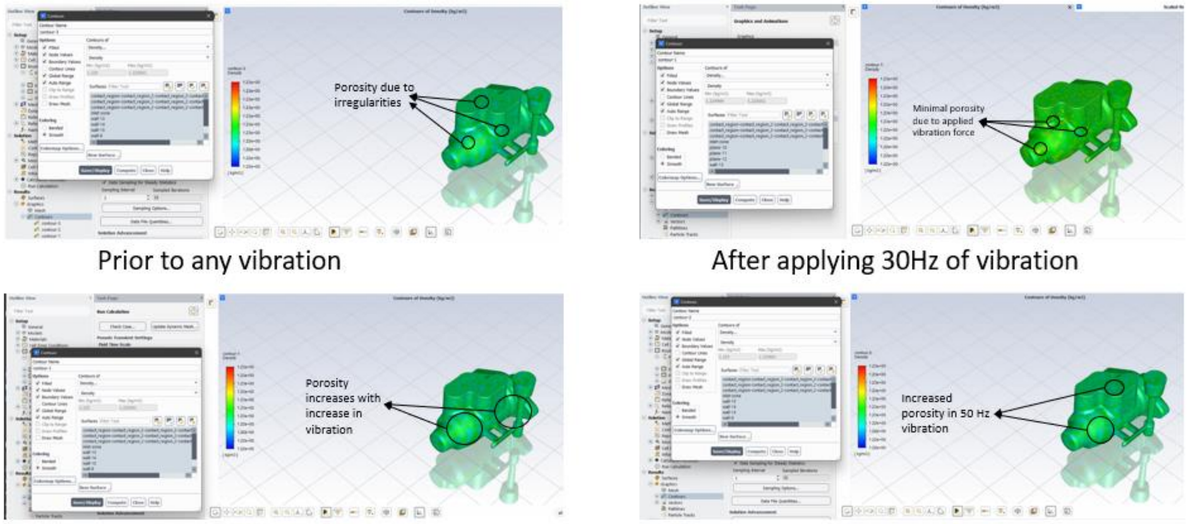


Fig 4.16: After Applying 50hz mechanical vibration

Rubber Seed Oil Density:



Porosity due to irregularities

Minimal porosity due to applied vibration force

Porosity increases with increase in vibration

Increased porosity in 50 Hz vibration

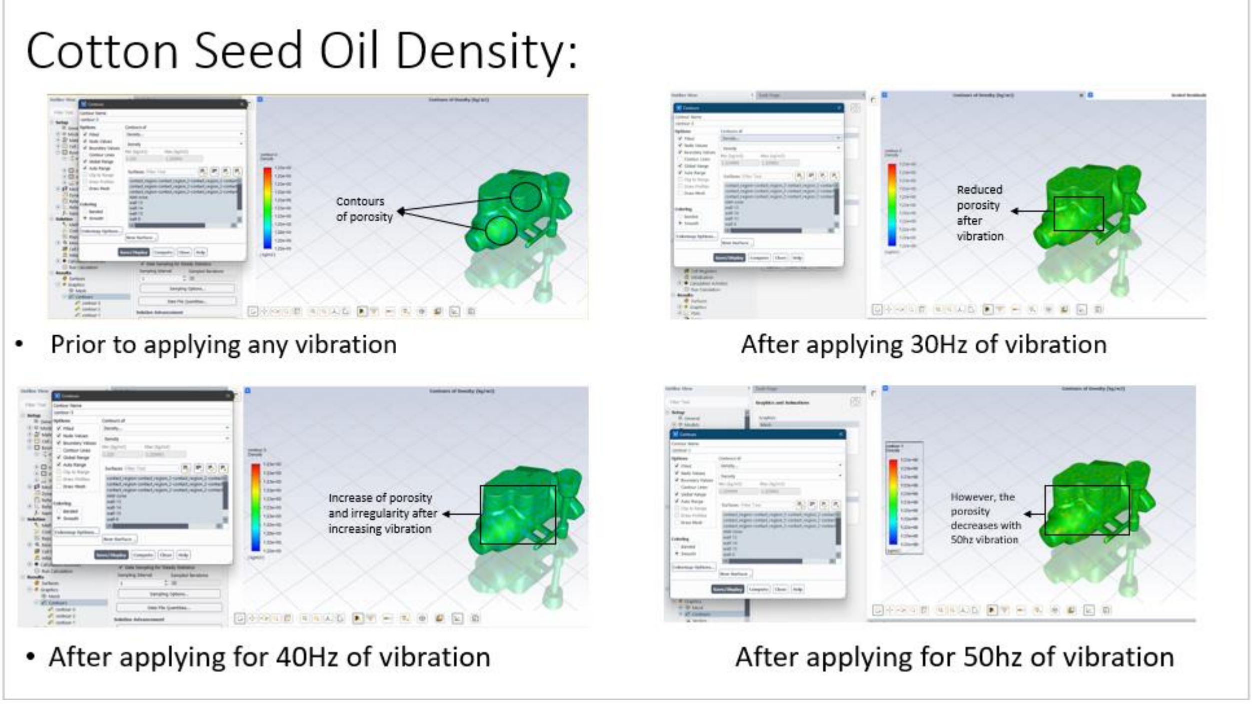
- Prior to any vibration

After applying 30Hz of vibration

- After applying 40Hz of vibration

After applying 50Hz of vibration

Fig 4.17: Comparison of density of rubber seed oil binder casting



Cotton Seed Oil Density:

Contours of porosity

- Prior to applying any vibration

Reduced porosity after vibration

After applying 30Hz of vibration

Increase of porosity and irregularity after increasing vibration

- After applying for 40Hz of vibration

However, the porosity decreases with 50hz vibration

After applying for 50hz of vibration

Fig 4.18: Comparison of density of cottonseed oil binder casting

Cotton Seed Oil Viscosity Analysis:

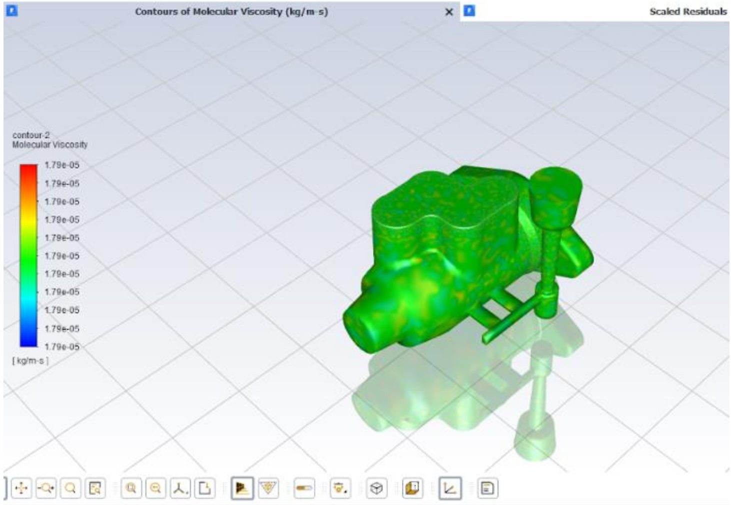


Fig 4.19: Before any mechanical vibration

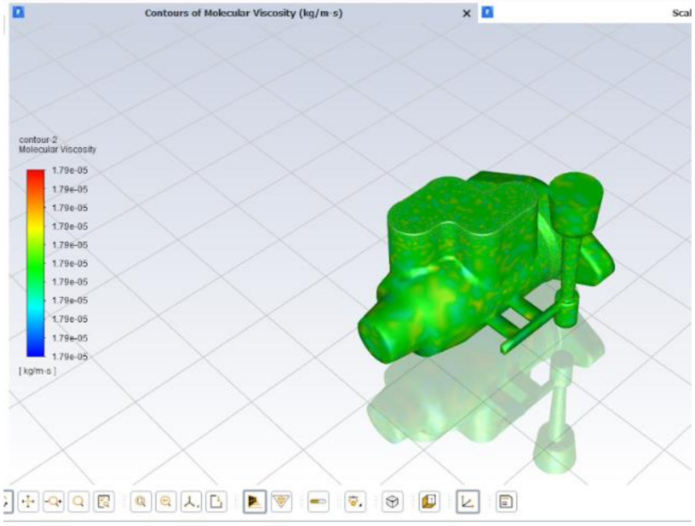


Fig 4.20: After applying 30hz mechanical vibration

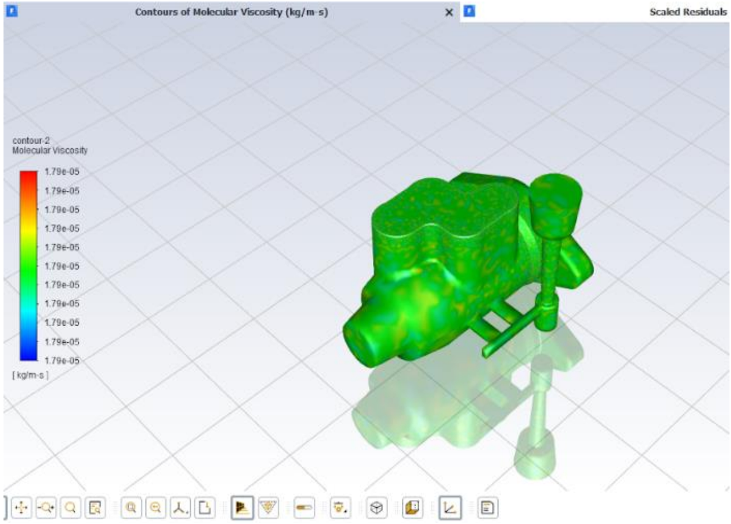


Fig 4.21: After applying 40hz mechanical vibration

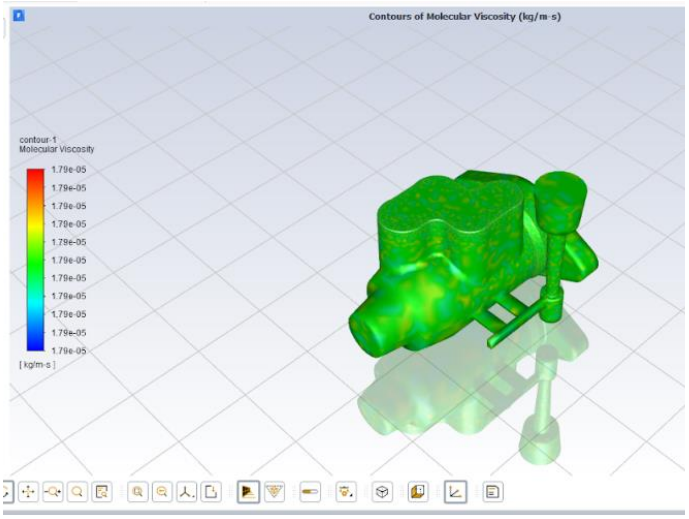


Fig 4.22: After applying 50hz mechanical vibration

4.3 Result Analysis:

When used for the sand casting during the solidification of the alloy, vibration played a vital role in increasing the quality of the cast. The findings reveal a reduction in porosity, hot tearing, degassing, pipe formation, and solidification time of the casted alloy, as well as a reduction in solidification time.

From our experimental data and statistics, we come to the following conclusions;

- For Rubber Seed Oil: Viscosity is best in the 40hz region & Density is best in the 30hz region
- For Cotton Seed Oil: Viscosity is best in the 40hz region & Density is best in the 40hz region.

The result findings are illustrated in a graph form in the following graphs:

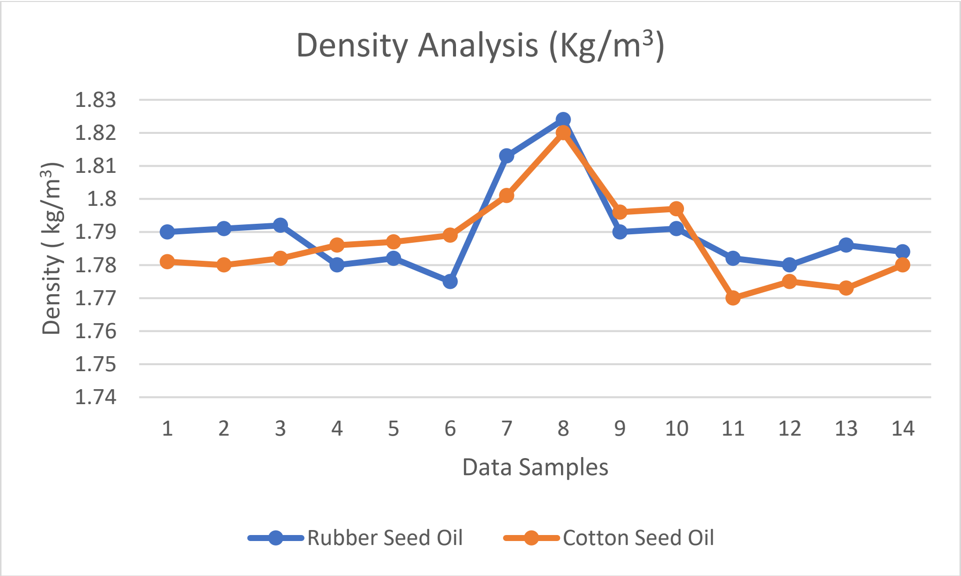


Fig 4.23: Density Analysis of Rubber Seed oil & Cotton Seed Oil

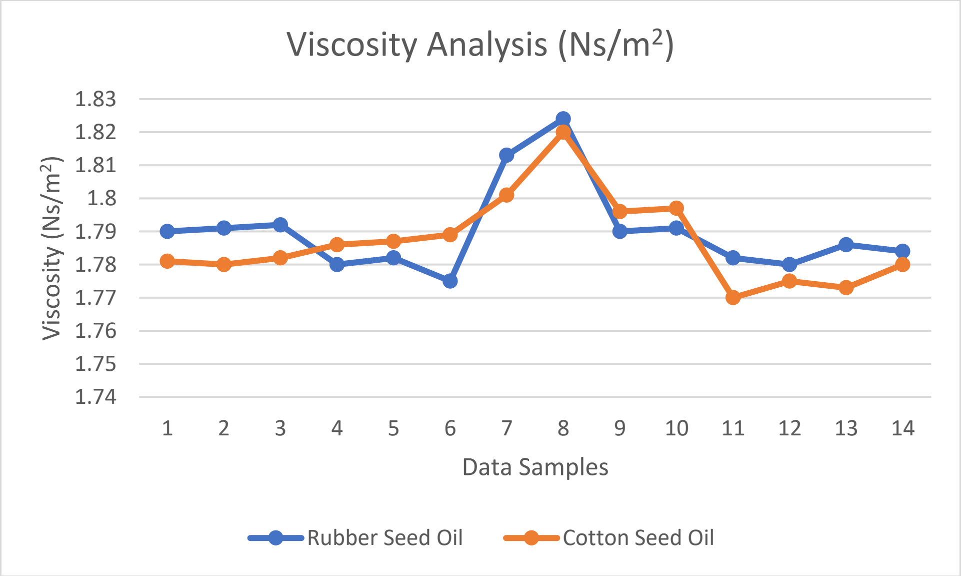


Fig 4.24: Viscosity Analysis of Rubber Seed oil & Cotton Seed Oil

4.4 Discussion:

The effects of mechanical vibration frequency and amplitude on solidification filling, microstructure, and mechanical characteristics of cast A1100 alloy have been investigated. Results show that the solidification filling capacity of A1100 alloy is at its best when the mechanical vibration frequency is 40 Hz and the mechanical amplitude is 1.0 mm; the length, width, and aspect ratio of beta Magnesium Aluminate in A1100 alloy decrease first, and then increase with the increase of mechanical vibration frequency, and gradually decrease with the increase of mechanical amplitude; the minimum value was obtained when the mechanical vibration frequency was 40 Hz and the mechanical amplitude was 1 mm; and the For cast A1100 alloy, the tensile strength, and yield strength are now 143.4 MPa and 121.6 MPa, respectively. These values correspond to mechanical vibration characteristics that are adequate for the alloy's casting process.

Because of this study, it has been discovered that solidification simulation may be used to monitor and visualize a casting's freezing development from the inside out, as well as to identify a casting's ultimate frozen areas, hot spots, and metal flow rate, among other important characteristics. This mechanism was determined to be insufficient for thick casting components owing to the large number of solidification flaws that were discovered inside the casting during its testing. In the planned or horizontal gating and feeding system, where gates and risers had been placed symmetrically and flow was uniform, it was simple for gases to be released into the environment. As a result of using this method, casting rejects due to gating and feeding system-related faults has been reduced by 30 percent, according to the company. Foundries must concentrate on process improvement to get a competitive advantage in today's highly competitive industry. Improved production techniques, improved plant maintenance procedures, improved product quality, and the most efficient use of limited resources are all necessary for sand casting foundries to maintain a competitive advantage in their markets. Process expertise may be especially important in sand casting foundries to overcome the limitations of the technology in contrast to other metal production techniques. The goal of this study was to define and demonstrate the significance of process information for defect reduction in sand casting foundries, specifically mechanical vibration. The capacity to comprehend and use process knowledge is critical to the improvement of business processes and processes in general.

For A1100 alloy casting, mechanical vibration plays an important role in increasing the alloy's mechanical and metallurgical properties, as compared to casting without mechanical vibrations. As a consequence, the industrial and vehicle sectors may make better use of this alloy.

Chapter Five

CONCLUSIONS AND RECOMMENDATIONS

The authors investigated the effect of mechanical mold vibration on the casting characteristics of Al-based alloys and found that it had a negative effect. To investigate the effect of mechanical vibration on hot tearing, grain refinement, and mechanical properties of aluminum alloy A1100, the alloy has been selected as the subject of the study. It is discovered from the results that mechanical mold vibration has a significant impact on sand casting as well as on improving the mechanical and chemical properties of A1100 alloy during the casting process. The authors of this research used rubber seed oil and cottonseed oil as sand binder materials and conducted a systematic finite element analysis to determine the most effective binder in sand mold casting for aluminum cooling through analytical and simulation methods. Because of the low gas entrapment and low surface defect characteristics, a bottom gating system was adopted. The author also did a computational analysis to get the best result at a specific mechanical vibration range. Solid works were used to create a CAD model, and an Ansys workbench was used to conduct a fluid flow (CFX) analysis. A real-world experimental condition was used to extract simulation parameters and boundary conditions. The rubber seed oil has a faster cooling rate compared to cottonseed oil found from the CFD simulation analysis, so it's the best binder at 50hz.

5.1 Conclusion:

The authors looked into the effect of mechanical mold vibration on the casting characteristics of aluminum-based alloys and discovered that it hurt the casting characteristics. The alloy A1100 has been chosen as the subject of the study to investigate the effect of mechanical vibration on hot tearing, grain refinement, and mechanical properties of aluminum alloy A1100. The findings reveal that mechanical mold vibration has a significant impact on sand casting, as well as on improving the mechanical and chemical properties of A1100 alloy during the casting process, as demonstrated by the experiments. As sand binder materials, the authors of this study used rubber seed oil and cottonseed oil, and they conducted a systematic finite element analysis to determine the most effective binder for aluminum cooling in sand mold casting through analytical and simulation methods. A bottom gating system was chosen due to the low gas entrapment and low surface defect characteristics of the material being used. In addition, the author performed a computational analysis to obtain the best possible result within a specific mechanical vibration range. The proposed work is concerned with compiling a list of some of the alternative sources that could be used as binding materials in the production of green sand casting. To a certain extent, the consumption of silica sand can be reduced by substituting it with suitable organic materials without sacrificing quality, and the cost of casting production can be reduced as a result of this reduction. The health risks associated with silica sand in foundries can also be avoided if the sand is replaced with silica-free minerals that are combined with the appropriate binder and additives. Furthermore, it is possible to avoid relying on a single source for casting production, which allows for greater flexibility in selecting different organic binding materials, thereby reducing the demand for a particular material. The construction aggregates will be tested for use in green sand mold production in conjunction with silica sand to determine whether they can be used to replace silica sand in some proportions or to a certain degree of fullness in the sand mold. Further, waste powders such as fly ash, tamarind powder, coconut shell powder, and other waste materials such as tailing sand, chromite sand, olivine sand, alumina, and other waste materials such as tailing sand, chromite sand, olivine sand, alumina, and other waste materials such as fly ash, tamarind powder, and coconut shell powder can be mixed in appropriate proportions with different combinations. It was necessary to use Solid Works to create the CAD model, and an Ansys workbench was used to conduct a fluid flow (CFX) analysis on the model. The systematic finite element analysis was carried out to identify the most effective binder among clay, molasses, and oil in sand mold casting for the cooling of aluminum alloy. The results were presented in the form of graphs. Experimental evidence and CFD simulation both demonstrated that clay was the most effective binder in situations where cooling is more rapid. As a result, it can be concluded that clay can be used as an effective binder in the sand mold casting process. To extract simulation parameters and boundary conditions, a real-world experimental condition was used to generate them.

From the findings, the following conclusions can be drawn:

1. Porosity, hot tearing, solidification time, and pipe formation were all reduced as a result of mechanical mold vibration during the casting of the A1100 alloy.
2. Mechanical vibration during the solidification of the casting revealed that a shift in the dendrite coherency point towards a lower temperature, as well as an increase in grain refinement and compactness, resulted in improved rigidity and hardness of the A1100 alloy.
3. The test of the A1100 alloy cast under the influence of vibrations revealed an increase in tensile strength and ductility of the alloy under consideration.
4. When A1100 alloy is cast in a sand mold and the vibration is applied, surface imperfections are reduced, resulting in improved surface finishing and a smoother surface, as well as a reduction in corrosion of the alloy cast in the mold.
5. The shape of aluminum alloy castings gradually becomes complete as the frequency of mechanical vibration increases, and the filling area of the castings gradually increases as the frequency of mechanical vibration increases. When the frequency of mechanical vibration is 100 Hz, the casting surface of aluminum alloy castings has a more complete shape and a clearer profile than when the frequency is 50 Hz. The shape of the casting surface of aluminum alloy castings becomes more complete as the mechanical amplitude is increased, and the filling area increases gradually until the maximum value is reached when the mechanical amplitude is 1.0 mm.
6. When the mechanical vibration frequency is 50 Hz, the phase-in aluminum alloy has the smallest length, width, and aspect ratio of any phase in the material's history. When the frequency of mechanical vibration is increased further, the phase of -Mg17Al12 coarsens in the opposite direction of the frequency increase. Mechanical vibration frequency increases, and the tensile strength and yield strength of aluminum alloy increase first and then decrease, with the maximum values of tensile strength and yield strength being 143.4 MPa and 121.6 MPa, respectively, when the mechanical vibration frequency is 50 Hz. When the mechanical vibration frequency is 40 Hz, the maximum values of tensile strength

and yield strength are 143.4 MPa and 121.6 MPa, respectively.

7. The increase in mechanical ⑤ amplitude can refine the -Mg17Al12 phase in the alloy, causing its shape to become more spherical as a result of the refinement. The mechanical amplitude of the alloy increases gradually as the ⑤ tensile strength and yield strength of the alloy increase. The tensile strength and yield strength of the alloy increased by 17.9 percent and 10.3 percent respectively when the mechanical amplitude was one millimeter as opposed to 0.2 millimeters when the mechanical amplitude was one millimeter.

In ⑬ this study, it was discovered that solidification simulation allows for and visualizes the progressive freezing of a casting from the inside to the outside environment, as well as identifying the ⑬ last solidified regions, hot spots, metal flow rate, and other relevant parameters. Because numerous solidification defects were discovered within the casting in this instance, the ⑬ vertical gating and feeding system was deemed unsuitable for thick casting components. In the proposed ⑬ horizontal gating and feeding system, gates and risers were placed symmetrically and the flow was uniform; gases were easily released into the atmosphere as a result of this. The percentage of castings rejected ⑬ due to gating and feeding system-related defects has been reduced by 30% as a result of the use of the casting simulation method. In today's competitive economy, foundries must concentrate on process improvement to gain a competitive advantage. ㉒ Improved production processes, improved plant maintenance processes, improved product quality, and proper utilization of resources, particularly scarce resources, are all examples of what it means to have a competitive advantage in sand casting foundries. Process ㉒ knowledge could be extremely important for sand casting foundries to overcome the limitations of the technology when compared to other metal manufacturing techniques. It was the goal of this paper to define process knowledge and to demonstrate its significance for ㉒ defect reduction in sand casting foundries, specifically through mechanical vibration. Understanding and putting process knowledge into action are critical for process improvement.

① Finally, it is concluded that mechanical vibrations during sand casting of A1100 alloy play a significant role in improving the mechanical and metallurgical properties and characteristics of the alloy when compared to the alloy cast without mechanical vibration during the process of casting.

As a result, this alloy can be used more effectively and efficiently in the machinery and automobile industries.

5.2 Future Recommendations:

More tensile tests should be performed with different alloys and casting conditions to compare the change in biofilm index with mechanical properties. The establishment of a map between biofilm index and RPT density, illustrating the contours of strength and ductility, would be a worthwhile goal.[14]

Under reduced pressure conditions, the effects of organic binders on the structure and pore morphology should be investigated.

To determine how many samples should be taken from a melt to obtain a reliable assessment of the quality of the melt, a statistical technique will be used to analyze the RPT test results obtained from the thesis and with the data that will be collected from the future tests to analyze RPT results.

The effects of different core materials on the microstructure and mechanical properties of aluminum casting products have been investigated in this research. The Al casting samples and cylinder head were fabricated with organic and inorganic binder cores, respectively, and their microstructures and mechanical properties were evaluated to determine their effectiveness. The mechanical properties of the Al casting samples fabricated with an inorganic core were found to be superior to those of the Al casting samples fabricated with an organic core in terms of tensile strength and elongation, as compared to the organic core-fabricated samples. Because the Al casting samples contained a small number of pore defects and had a fine microstructure when compared to the Al casting samples fabricated using an organic core, this was the case. In addition, the use of organic cores has significantly reduced harmful gas emissions and environmental pollution and so in the future by applying mechanical vibration the efficiency of organic binders.

References:

[1] A. P. Popoola and O. S. Fayomi, “Accessing the performance of binders on core strength in metal casting,” *Int. J. Phys. Sci.*, vol. 6, no. 34, pp. 7805–7810, 2011, doi: 10.5897/IJPS11.1144.

[2] G. Sridhar, G. K. Ananda, H. Ramesha, and D. Shivappa, “Thermal Optimization for Al12SiMg with Influence of Magnesium Oxide Particulate Composites,” *Mater. Today Proc.*, vol. 18, pp. 3160–3166, Jan. 2019, doi: 10.1016/J.MATPR.2019.07.191.

[3] B. Saadatfar, R. Fakhrai, and T. Fransson, “Conceptual modeling of nano fluid ORC for solar thermal polygeneration,” *Energy Procedia*, vol. 57, pp. 2696–2705, 2014, doi: 10.1016/J.EGYPRO.2014.10.301.

[4] A. Steel, C. Limited, and N. a Ademoh, “Evaluation of the Foundry Properties of River Niger Sand Behind,” vol. 3, no. 1, pp. 75–83, 2008.

[5] M. A. Tarar, A. H. Khan, Z. ur Rehman, S. Qamar, and M. N. Akhtar, “Compatibility of sunflower oil with asphalt binders: a way toward materials derived from renewable resources,” *Mater. Struct. Constr.*, vol. 53, no. 3, 2020, doi: 10.1617/s11527-020-01506-8.

[6] M. M. Khan, M. Singh, S. M. Mahajani, G. N. Jadhav, and S. Mandre, “Reclamation of used green sand in small scale foundries,” *J. Mater. Process. Technol.*, vol. 255, no. 2010, pp. 559–569, 2018, doi: 10.1016/j.jmatprotec.2018.01.005.

[7] S. Martinez, G. Michaux, J. L. Bouvier, and P. Salagnac, “Numerical investigation of the energy performance of a solar micro-CHP unit,” *Energy Convers. Manag.*, vol. 243, Sep. 2021, doi: 10.1016/j.enconman.2021.114425.

[8] S. C. Somé, V. Gaudefroy, and D. Delaunay, “Effect of vegetable oil additives on binder and mix properties: laboratory and field investigation,” *Mater. Struct. Constr.*, vol. 49, no. 6, pp. 2197–2208, 2016, doi: 10.1617/s11527-015-0643-1.

[9] “Control Of Heat Generation During Composting | BioCycle.” https://www.biocycle.net/control-of-heat-generation-during-composting/ (accessed Mar. 31, 2022).

[10] E. C. Okonkwo, M. Abid, and T. A. H. Ratlamwala, “Effects of synthetic oil nanofluids and absorber geometries on the exergetic performance of the parabolic trough collector,” *Int. J. Energy Res.*, vol. 42, no. 11, pp. 3559–3574, Sep. 2018, doi: 10.1002/ER.4099.

[11] P. R. Spalart, “Strategies for turbulence modelling and simulations,” *Int. J. Heat Fluid Flow*, vol. 21, no. 3, pp. 252–263, 2000, doi: 10.1016/S0142-727X(00)00007-2.

[12] S. A. Yaro and M. U. Suleiman, “CASSAVA / GUINEA CORN STARCHES AND SOYBEAN OIL AS CORE BINDERS IN SAND CASTING OF ALUMINIUM SILICON (AL-Si) LLOY Journal of Engineering and Technology (JET) Vol . 1 No . 1 August,” *J. Eng. Technol. (JET) Vol . 1 No . 1 August 2006*, vol. 1, no. 1, pp. 47–55, 2006.

[13] “Process Flow Chart of Sand Casting [6] | Download Scientific Diagram.” https://www.researchgate.net/figure/Process-Flow-Chart-of-Sand-Casting-6_fig3_282391639 (accessed May 10, 2022).

[14] R. P. Merchán Corral, “Thermodynamic optimisation of thermosolar hybrid Brayton cycle plants,” 2020, doi: 10.14201/GREDOS.145409.

[15] C. Sithole, K. Nyembwe, and P. Olubambi, “Process knowledge for improving quality in sand casting foundries: A literature review,” *Procedia Manuf.*, vol. 35, pp. 356–360, 2019,

doi: 10.1016/j.promfg.2019.05.052.

[16] "Product Standardization - Disadvantages & Advantages of Product Standardization." https://www.marketing91.com/what-is-product-standardization-uses-and-advantages/ (accessed Mar. 25, 2022).

[17] O. S. Vaidya and S. Kumar, "Analytic hierarchy process: An overview of applications," *Eur. J. Oper. Res.*, vol. 169, no. 1, pp. 1–29, Feb. 2006, doi: 10.1016/J.EJOR.2004.04.028.

[18] Z. Wang, "Design of the Concentration System," *Des. Sol. Therm. Power Plants*, pp. 225–318, 2019, doi: 10.1016/B978-0-12-815613-1.00004-3.

[19] H. Zhou, A. Meng, Y. Long, Q. Li, and Y. Zhang, "Classification and comparison of municipal solid waste based on thermochemical characteristics," *J. Air Waste Manag. Assoc.*, vol. 64, no. 5, pp. 597–616, 2014, doi: 10.1080/10962247.2013.873094.

[20] S. Chakrabarti, S. P. Kashyap, B. Sahoo, A. Sen, and M. Verma, "Subleading soft theorem for multiple soft gravitons," *J. High Energy Phys.*, vol. 2017, no. 12, Dec. 2017, doi: 10.1007/JHEP12(2017)150.

[21] Maciej Serda, "Synteza i aktywność biologiczna nowych analogów tiosemikarbazonowych chelatorów żelaza," *Uniw. śląski*, pp. 343–354, 2013, doi: 10.2/JQUERY.MIN.JS.

[22] T. International and J. Of, "Evaluation of Rubber Seed Oil as Foundry Sand-Core Binder in Castings," pp. 20–28, 2014.

[23] S. Shaaban, "Analysis of an integrated solar combined cycle with steam and organic Rankine cycles as bottoming cycles," *Energy Convers. Manag.*, vol. 126, pp. 1003–1012, Oct. 2016, doi: 10.1016/j.enconman.2016.08.075.

[24] S. K. P. Kumar, "Effect of Mechanical Mould Vibration on the Properties of Sand Casting Aluminium (A-1100) Alloy," *Int. J. Eng. Res. {&} Technol. ISSN*, vol. 07, no. 06, pp. 370–374, 2018, [Online]. Available: www.ijert.org.

[25] P. Karunakaran and C. Jegadheesan, "Investigation of the properties of moulding sand with waste powder from steel industry," *Eur. J. Sci. Res.*, vol. 77, no. 1, pp. 5–13, 2012.

[26] P. Kumar and J. H. Han, "Packaging materials for non-thermal processing of food and beverages," *Emerg. Food Packag. Technol.*, pp. 323–334, 2012, doi: 10.1533/9780857095664.3.323.

[27] Y. Egorov, F. R. Menter, R. Lechner, and D. Cokljat, "The scale-adaptive simulation method for unsteady turbulent flow predictions. part 2: Application to complex flows," *Flow, Turbul. Combust.*, vol. 85, no. 1, pp. 139–165, Jul. 2010, doi: 10.1007/S10494-010-9265-4.

[28] N. Pan, S. Wang, and C. Shen, "A fundamental study on characteristic of thermoacoustic engine with different tilt angles," *Int. J. Heat Mass Transf.*, vol. 74, pp. 228–237, Jul. 2014, doi: 10.1016/j.ijheatmasstransfer.2014.03.019.

[29] R. A. M. Napitupulu, S. Ginting, W. Naibaho, S. Sihombing, N. Tarigan, and A. Kabutey, "The effect of used lubricating oil volume as a binder on the characteristics of briquettes made from corn cob and coconut shell.," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 725, no. 1, 2020, doi: 10.1088/1757-899X/725/1/012010.

[30] "Rubber seed oil: Properties, uses and benefits." https://www.researchgate.net/publication/325952720_Rubber_seed_oil_Properties_uses_and_benefits (accessed May 07, 2022).

● 24% Overall Similarity

Top sources found in the following databases:

- 15% Internet database
- 11% Publications database
- Crossref database
- Crossref Posted Content database
- 12% Submitted Works database

TOP SOURCES

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

	Source	
1	ijert.org Internet	2%
2	theijes.com Internet	2%
3	download.hangtuah.ac.id Internet	1%
4	islamicuniversity on 2022-05-10 Submitted works	1%
5	Jinxia Chen, Xu Chen, Zhiming Luo. "Effect of mechanical vibration on ... Crossref	1%
6	Wenming Jiang, Zitian Fan, Xu Chen, Benjing Wang, Hebao Wu. "Combi... Crossref	1%
7	Landmark University on 2020-09-29 Submitted works	<1%
8	bayerojet.com Internet	<1%

9	Sourav Kayal, B.K. Chakrabarti. "Reclamation and Utilisation of Foundr... Crossref	<1%
10	ingentaconnect.com Internet	<1%
11	insightsociety.org Internet	<1%
12	N Prabhushankar, N Balaji. "Various Alternative Sources for Silica Sand... Crossref	<1%
13	Sachin L. Nimbulkar, Rajendra S. Dalu. "Design optimization of gating a... Crossref	<1%
14	University of Malaya on 2015-08-11 Submitted works	<1%
15	doaj.org Internet	<1%
16	data.nanet.go.kr Internet	<1%
17	Riga Technical University on 2022-01-19 Submitted works	<1%
18	The Engineering College on 2018-07-17 Submitted works	<1%
19	UNITEC Institute of Technology on 2020-11-16 Submitted works	<1%
20	rroij.com Internet	<1%

21	Kalekudithi Ekambara, R. Sean Sanders, K. Nandakumar, Jacob H. Mas... Crossref	<1%
22	Cindy Sithole, Kasongo Nyembwe, Peter Olubambi. "Process knowledg... Crossref	<1%
23	iosrjournals.org Internet	<1%
24	jmsa.hrbeu.edu.cn Internet	<1%
25	islamicuniversity on 2022-05-18 Submitted works	<1%
26	ansys.com Internet	<1%
27	iosrjen.org Internet	<1%
28	arc.aiaa.org Internet	<1%
29	Liverpool John Moores University on 2020-08-06 Submitted works	<1%
30	Shinas College of Technology on 2019-07-03 Submitted works	<1%
31	Universiti Teknikal Malaysia Melaka on 2021-01-14 Submitted works	<1%
32	Middle East Technical University on 2022-01-31 Submitted works	<1%

33	p2pays.org Internet	<1%
34	University of Illinois at Urbana-Champaign on 2022-02-07 Submitted works	<1%
35	Emirates Aviation College, Aerospace & Academic Studies on 2021-0... Submitted works	<1%
36	ijsrd.com Internet	<1%
37	Peng Wang, Zhengfan Zhang, Chuangxin He, Xin Wen, Yingzheng Liu. "... Crossref	<1%
38	Visvesvaraya Technological University on 2015-05-04 Submitted works	<1%
39	dspace.knust.edu.gh Internet	<1%
40	Edith Cowan University on 2017-10-27 Submitted works	<1%
41	core.ac.uk Internet	<1%
42	Filipe Fabian Buscariolo, Felipe Magazoni, Marc Wolf, Flavio Koiti Maru... Crossref	<1%
43	Higher Education Commission Pakistan on 2020-11-04 Submitted works	<1%
44	Wuttichai Roschat, Theeranun Siritanon, Boonyawan Yoosuk, Taweesa... Crossref	<1%

45	Arati Sridharan, Jit Muthuswamy. "Chapter 4-1 Quantitative Assessme... Crossref	<1%
46	Northern Consortium UK on 2019-12-02 Submitted works	<1%
47	University of Glasgow on 2013-04-19 Submitted works	<1%
48	University of Strathclyde on 2022-04-13 Submitted works	<1%
49	scilit.net Internet	<1%
50	Glenelg High School on 2022-01-22 Submitted works	<1%
51	Myanmar Noble College on 2018-03-15 Submitted works	<1%
52	oceanrep.geomar.de Internet	<1%
53	mdpi.com Internet	<1%
54	Sheffield Hallam University on 2014-12-10 Submitted works	<1%
55	Felix E. Okieimen, C. Pavithran, Isiaka O. Bakare. "Epoxidation and hydr... Crossref	<1%
56	coursehero.com Internet	<1%

57	D. Benny Karunakar, G. L. Datta. "Prevention of defects in castings usin... Crossref	<1%
58	La Salle Academy on 2013-04-21 Submitted works	<1%
59	NIT Imphal on 2019-05-12 Submitted works	<1%
60	Nagarajan Jeyakumar, N. Bose. "Effect of Diglyme on the performance,... Crossref	<1%
61	National Institute of Technology Karnataka Surathkal on 2013-08-22 Submitted works	<1%
62	Saginaw Valley State University on 2018-02-12 Submitted works	<1%
63	Tshwane University of Technology on 2019-08-17 Submitted works	<1%
64	University Tun Hussein Onn Malaysia on 2015-06-30 Submitted works	<1%
65	University of Technology, Sydney on 2020-05-02 Submitted works	<1%
66	p2pays.org Internet	<1%
67	Asian Institute of Technology on 2012-11-23 Submitted works	<1%
68	Grötzbach, G.. "Challenges in low-Prandtl number heat transfer simulat... Crossref	<1%

69	M. Satyanarayana, C. Muraleedharan. "A comparative study of vegetab... Crossref	<1%
70	Middle East Technical University on 2022-01-31 Submitted works	<1%
71	Sushil Kumar. "Design for Six Sigma to optimise the process paramete... Crossref	<1%
72	University Tun Hussein Onn Malaysia on 2017-01-05 Submitted works	<1%
73	University of Queensland on 2017-05-02 Submitted works	<1%
74	Xiaolong Gong, Wenming Jiang, Shengli Hu, Zhiyuan Yang, Xinwang Li... Crossref	<1%
75	manualzz.com Internet	<1%
76	psasir.upm.edu.my Internet	<1%
77	repositories.lib.utexas.edu Internet	<1%
78	ujcontent.uj.ac.za Internet	<1%
79	worldwidescience.org Internet	<1%
80	irjet.net Internet	<1%

● Excluded from Similarity Report

- Bibliographic material
- Cited material
- Manually excluded text blocks
- Quoted material
- Small Matches (Less then 8 words)

EXCLUDED TEXT BLOCKS

isone of the most important manufacturing processes in which liquid metal is pour...

www.ijert.org

is one of the most importantmanufacturing processes

www.ijert.org

Core binding materials are numerous, and the mode of casting determines

theijes.com

average shape, size, and distribution of sand grains

www.ijert.org

Vegetable, mineral, and marine

theijes.com