MODELLING AND EXPERIMENTAL INVESTIGATION OF ALUMINIUM ALLOY PRODUCT USING SAND CASTING

Dissertation-1 Report

Submitted in partial fulfillment of the requirement for the award of Degree of

MASTERS OF TECHNOLOGY

IN

MANUFACTURING ENGINEERING

By

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "Modelling and Experimental Investigation of Aluminium Alloy products using Sand Casting" in partial fulfillment of the requirement of the award of the Degree of Master of Technology and submitted to the Department of Manufacturing Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of Mr. Mahipal Singh(Assistant Professor) and Dr. Nav Rattan (Assistant Professor), Department of Manufacturing Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

30 November 2017

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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The external viva-voce examination of the student was held on successfully ________________

Signature of Examiner

ACKNOWLEDGEMENT

At this pleasing moment of having completed my dissertation-1 report, I wish to convey my sincere thanks and gratitude to the Head of Department Mr Jaswinder Singh, who provided me with all facilities.

With deep sense of gratitude, I would like to express my earnest and sincere thanks to my supervisor Mr Mahipal Singh and my co-supervisor Dr. Nav Rattan for their constructive suggestions, guidance & encouragement during my dissertation work.

ABSTRACT

Defects in casting are not accidents but they usually occur when some steps or parameters in manufacturing cycle are not properly controlled. Some of the foundry industries however ignore rather than optimizing them to meet production targets within time. A defect in a casting may be a cause of various parameters and if not optimized the rejections may increase up to 50% which is nowadays an ever present problem to the foundry industry. Hence, the aim of this research work is to optimize various parameters of sand casting by both experimental approach and simulation approach by using a computer simulation software for modeling comparing both the results which can result into best optimization technique minimize defects in casting with good quality of sand cast products.

Keyword: Casting Defects, Process Parameters, Casting Simulation Software, Optimization, High Quality Production.

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CHAPTER 1

INTRODUCTION

1.1 Sand Casting

The main purpose for every foundry company is production of high quality metal castings with minimal rejections so that they could satisfy needs and requirements of customer in the global market (Narayanaswamy. C & Natarajan.K, 2016). Growth in and foundry company depends upon skilled and experienced workers and techniques used by them in casting.

The various components of sand casting are shown in figure 1 and also process of sand casting when the mould is opened and closed. The various components of sand casting process involves Ladle, Molten Metal, Cope, Drag, Pouring Cup, Sprue, Parting Line, Runner, Gates, Chaplets, Cavity, Core, Riser. Casting is known as one of the oldest processes for the production of metallic components. The first metal casting was done during the period of 4000-3000 BC using stone and metal moulds. The molten metal in casting is poured into a cavity; later the molten metal takes the shape of the cavity after solidification and then removing the solid component as the molten metal solidifies (Sulaiman, S., & Hamouda, A. M. S, 2004). This process of casting starts with

- Placing a pattern with a desired shape in the sand to make an imprint.
- Incorporating a Gating system.
- Pouring of the molten metal to fill the mould cavity.
- Allowing the molten metal to cool till it solidification.
- Breaking off the sand mould and removing the casting.

As we know that one of the earlier metal shaping process used until today is casting. Also less weighed parts having complex shapes can be manufactured effectively by casting process than any other manufacturing processes. In which Sand Casting is used widely process in casting for production of cheap components. Sand Casting is used about 60% among overall production of casting, rest 40% is equally distributed by all other processes in casting. Also using sand casting process both ferrous and non-ferrous metals can be casted (Choudhari, C. M. et.al, 2013; Mohammad, V. M.et.al, 2016).

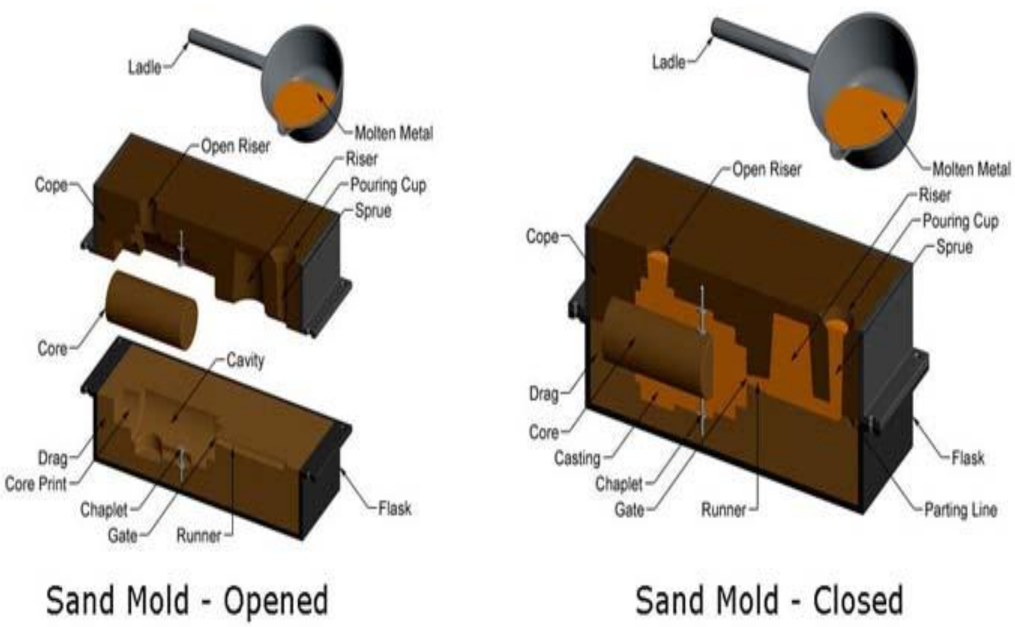


Figure: 1 Sand casting mould (Source: www.custompartnet.com/wu/sandcasting)

Both aerospace and automobile industries use sand casting process for manufacturing different components because of its low cost of raw materials, low consumption of fuel, low emission damaging the environment and good casting ability of a wide variety of alloys (Mugeri, H.et.al, 2017). This process of sand casting allows the cast product to solidify first and the breaking the mould of sand by removing the cast product. Green sand is a mixture of water, sand grains, clay and other materials is often used for moulding throughout the sand casting process. It is one of the most extensively used manufacturing process for high production of casting parts that cannot be produced through any other manufacturing process. Each of the materials from the above combination plays an important role in reducing and controlling casting defects. If any of these materials are out of optimum value it may lead to defects in casting. (Said. R. M.et.al, 2017; Guharaja.S.et.al, 2006).The process of sand casting involves various parameters which if not optimized may lead to casting defects simultaneously affecting the quality of casting components produced.

1.2 Casting Parameters: In this study there are many attempts made in optimization of different casting parameters like Pouring temperature, rate of solidification, cooling rate, moisture content, Sand Binder ratio, permeability, mould hardness, Compression Strength, Aging temperature, Wall Thickness, etc. (Mugeri.H.et.al, 2017; Datau S.G.et.al, 2012; Narayanaswamy. C & Natarajan. K, 2016).These parameters of sand casting after optimization improve quality of sand casting. Optimization of sand casting process parameters include various techniques such as Taguchi methods, ANOVA Methods, Response Surface Methodology (RSM), Minitab Analysis, Microstructural Analysis, PROCAST Simulation, ANSYS Simulation, MAGMA soft Simulation etc. (Choudhari.C.M.et.al, 2013;Weldeanenia.K.G.et.al, 2016; Narayanaswamy. K, 2016). Response Surface Methodology (RSM) consists of fitting of data and experimental design methods finding relation between design variables and responses (Chen.W.J.et.al, 2016). The techniques with optimized parameters improve the quality reducing the rejections in sand casting process.

1.3 Mechanical properties: The most common element is known as aluminium which exists in the form of aluminium oxide in the earth's crust (Datau S.G.et.al, 2012). Aluminium has different physical and mechanical properties such as good electrical conductivity, brighter colour with low weight, high thermal conductivity and high corrosion resistance (John.O.et.al, 2011). Similarly aluminium alloy casting has mechanical properties such as ultimate tensile strength, impact strength, hardness, percentage elongation, solidification time, etc. There is requirement of high mechanical properties in most of aluminium alloy castings.

Similar to Aluminium alloys nowadays Magnesium alloys have wide applications in spacecraft, aircraft, transportation, electronics, military and automotive industries (Zhang.H.et.al, 2016; John.O.et.al, 2011).They have higher strength with lower density and having excellent Machinability. Magnesium alloys are also known to exhibit excellent corrosion resistance and creep resistance both at elevated and room temperatures with defect less& high quality castings in foundries (Li, Y.et.al, 2016). However Magnesium alloys cannot used above elevated temperature of 175^0C due to low thermal stability. But using Gadolinium which is a rare earth metal increases thermal stability of aluminium alloys enhancing Ultimate Tensile Strength and Yield Strength (Liu, S.et.al, 2015).

1.4 Casting Defects: Nowadays every foundry industry is aiming to produce defect free castings with high quality and low cost of production to satisfy customer needs. Poor quality production of casting includes a number of process parameters and also mechanical properties of material (Narayanswamy.C & Natarajan. K, 2016).The defects in the casting include blow holes, mismatch, misrun, micro porosity, penetration, shrinkage, inclusions, flash or fin, crushes, run out and drop. These casting defects do not occur accidentally but through error practices in step by step operations involved in the process of casting that leads to defective parts after the casting process, which is the big problem faced by the casting industry.(Narayanaswamy. C & Natarajan. K 2016; Kamble.B.S, 2016). A defect in the casting can be a cause of various physical, thermal, metallurgical, mechanical and environmental factors which if not prevented can increase the percentage of rejections in casting by 50% (Kamble.B.S, 2016). Hence our aim is of setting optimum process parameters through which there will be minimized defects with good quality castings.

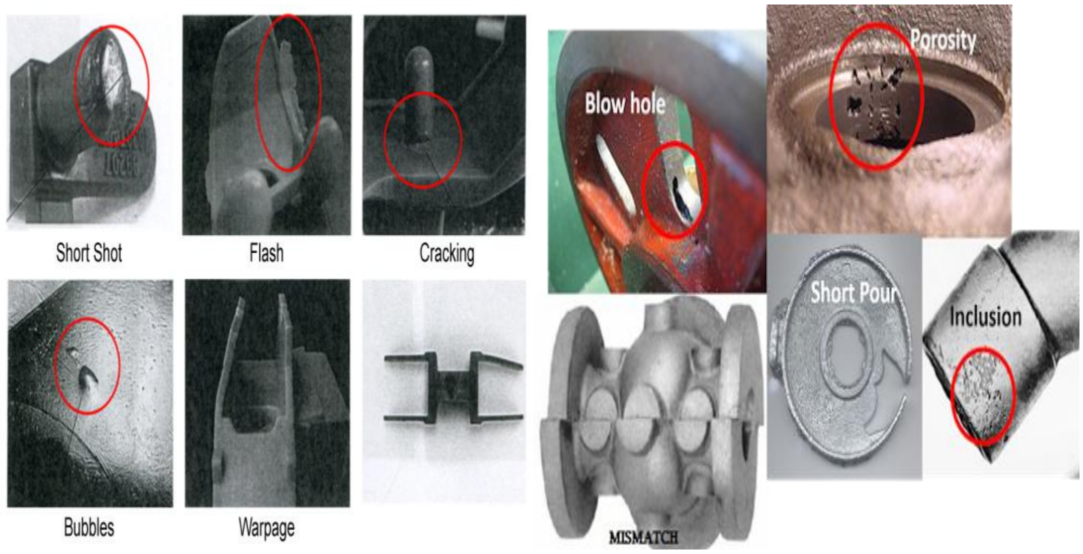


Figure 2: Some of the defects in sand casting (Source: https://me-mechanicalengineering.com/probable-causes-suggested-remedies-various casting-defects)

Figure 2 shows some of the defects in the sand casting process which mainly includes blowholes, sand inclusions, mismatch, cracking, short pour, flash, porosity, warpage, short shot, bubbles, etc. in which most of the defects can be controlled by setting of optimum process parameters in the sand casting process. Blowhole is a very common defect in casting which happens when gas is trapped during solidification of the molten metal. In case of neglecting such rejections will lead to low production with increasing percentage of defects and rejections in the casting process (Kamble, B. S, 2016). Permeability is a measure of the flow capacity of a porous media to emit gases from an object. Considering permeability which decreases with the decrease in the grain size. Maximum permeability helps in removing the gases from the mould through the sand grains (Said. R. M.et.al, 2017).

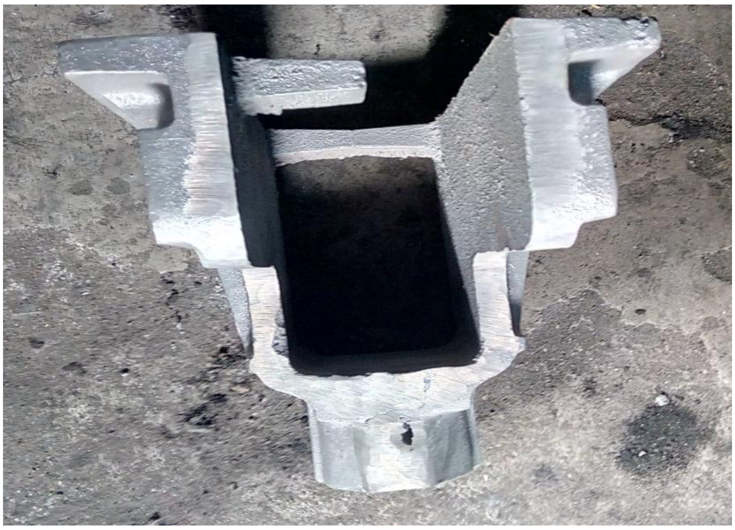


Figure 3: Blowhole defect found in LM 13 Aluminium Alloy

Figure 3 explains about the defect of blowhole found in LM 13 Aluminium alloy in a S.S Metal Castings, Pune which is a very common defect in casting which happen when gas is trapped during solidification of the molten metal.

1.5 Simulation: Nowadays computer simulation in casting is becoming more significant. Simulation is an imitation of a real process by using a set of mathematical equations implemented in a computer program (Dabade U. A.et.al, 2013; Sulaiman, S., & Hamouda, A. M. S, 2004). Most of the simulation in casting is carried through some of the simulation software's like Procast, Magma soft, Z-cast, Ansys, etc.In this research we are going to perform modelling using casting simulation software and validate the experimental results with the simulation results.

CHAPTER 2

2.1 LITERATURE REVIEW

This literature review below illustrates us about different research work done by various researchers on analysis of casting defects and effect of casting parameters on mechanical properties of different alloys by optimising their parameters leading to high quality castings by reducing defects the sand casting with minimum number of rejections by application of various experimental, analysis and simulation techniques.

N. Ducic et. al (2017) used Genetic algorithm to optimize the geometry of the gating system maximizing the rate of filling. The optimized ingate cross section and height are $300mm^2$& 110mm increases the rate of filling raising the casting quality and less molten metal consumption.

Rahaini Mohd Said. et. al (2017) conducted 2^k Factorial design with 16 levels of optimised process parameters. Optimal Green sand composition are 100g silica sand, 21g bentonite, 6.5g water and 6g coal dust getting optimum permeability number of 598.3GP minimizes occurrence of defects by improving quality of sand casting.

Mugeri et al. (2017) used the technique of Magma soft simulation to minimize the defects in casting by considering filling temperature and pressure with 5 test samples of different wall thickness. They also concluded that Fillability increases as wall thickness increases due to reducing heat transfer of molten metal and mould. Wall thickness lowers backpressure that increases flow of molten metal at high pressure.

Sanitas A & Coniglio N (2017) showed that correlation between molten metal temperature and casting roughness values of Zr refined ZE41 Mg alloy cast in 3D printed Furan sand moulds. Roughness value drops when temperature of molten metal is 908K and solid fraction of 0.22. Mold Cavity filled at last has lowest roughness values.

Misal Gandhi & Dr. Piyush Jain (2017) in their review paper showed imposing Mechanical Vibrations, cooling rate increases at the top, middle and bottom area. At 0 Hz it is observed that cooling rate is fastest at the bottom area and middle area has slowest cooling rate. The pouring temperature should be kept from 650^0-800^0C.

Joseph B &Reyaz H (2017) in their research paper showed that Chromium is used as a substitute to titanium. Microstructure and mechanical properties were studied increasing addition of chromium to 0.23%.Casting with 0.20% chromium gave highest mechanical properties showing high hardness and UTS of 57HB and 229Mpa than compared to titanium.

Narayana Swamy.C & Natarajan.K (2016) carried out the study of various casting defects for one year from April 2014 to March 2015 in Ammarun Foundries, Coimbatore saying that the percentage of these casting defects vary from 12.87% to 15.02%. They investigated that the quality of casting depends on quality of sand, method of operation, quality of molten metal and environmental conditions, etc.

Bhushan Kamble (2016) in his review paper carried a research on various casting defects and their causes. He concludes that rejection in casting just won't happen usually but due some wrong steps taken in the cycle of manufacturing a casting product which can result to about nearly 50% of rejections if not controlled.

Himanshu.K &B.Ravi.(2016) showed effect of molding parameters on mechanical properties is done by Taguchi method. Optimization of mould parameters have been considered such as curing time 4h, 2.4% binder and 40GFN gives highly dimensional quality parts.

V.M.Mohammed et al.(2016) applied Taguchi's method to sand casting process with optimised parameters reduces rejections in Al-Si alloy casting also by setting the parameters such as Pouring temperature 690^0C and Holding time 4min if are optimised reduces the rejections in casting.

Narayanaswamy, C., &Natarajan, K. (2016) carried out experiments by FMEA Techniques, ANOM and setting of process parameters is done to minimize casting defects**.**Optimum parameters like pouring temperature 1460^0C, inoculants 0.3, moisture content 3.1%, and Sand binder ratio 60:0.1 were observed.

Li, Y.et al. (2016) took Mg ingot melted with Gd, Zr, Y at 730-780 ^{0}C with chemical composition taken under ICP-AES analysis with preheating temp of mould sand 70^0C, pouring temperature 750^0C & Flame retardant 1 % with OM,XRD.As pouring temp increases from720-780^0C, fluidity of Mg alloy increases them decreases. Increasing preheating temp of moulding sand from 40-110^0C leads to improvement in fluidity. Flame retardants added to Mg alloy has neglected effect on micro structure with average grain size of 52µm.

Wen-Jong Chen & Cai-Xuan Lin. (2016) proposed Taguchi and ANOVA the process parameters in a gating system of sand casting. The CBQPSQ algorithm reduces filling time, solidification time and oxide ratio that improves casting quality of Al A356 Alloy

Zhang H. et al. (2016) showed composition detection by Atomic emission spectrometry, solution treatment carried out by water quenching. Vickers hardness test and XRD & TEM. High hardness (HV 108.8) for 100Hrs obtained when specimen peak-aged at 200^0C. Solution treatment done at 525^0C for 6Hrs and aging treatment at 250^0C for 10Hrs, desired ductility and strength is obtained.

Weldeanenia K. G & Abebe A. T (2016) in their research paper used the Orthogonal array, Taguchi method, ANOVA method on the process parameters of 46MnSi4 and effects were analysed using Minitab software .Also optimization of parameters such as pouring time 82 sec, pouring temperature 1672^0C, size of runner $62cm^2$ using various methods was carried out to improve quality of casting.

Liu S. J. et al. (2015) showed that chemical composition determined by POES. Solution treated by T4 quenched at 60-80°C.Vickers hardness carried at 0.5kg of loading, tensile properties determined by tensile testing machine and microstructure observed by OM,SEM. Study of micro structural and mechanical properties of given alloy is done by SEM, OM, tensile and Vickers test. Optimization of ageing parameters done at 220^0C for 16h. Ultimate Tensile strength, elongation and yield strength was 280Mpa, 7.5% & 175Mpa.

Jun, M. E. I. et al. (2014) carried out refining of given alloy with gas bubbles and flux, microstructure, tensile fracture and chemical composition, Phase composition done by SEM, Age hardening, XRD & OM. Age hardening at 250 ^{0} C & plastic elongation of alloys gives high strength and better ductility. By T6 heat treatment minimum secondary cracks were seen. Increase in EL & UTS through 2%JDMJ flux refining process.

Uday A & Rahul C (2013) in their research paper used a new method for casting defect analysis is proposed and studied that is combination of (DOE) and Computer aided Casting Simulation for rejection analysis of defects related to sand moulding, methoding, filling and solidification. Optimized level of process parameters obtained by Taguchi method are moisture content 4.7%, green compression strength 1400 gm/cm^2, permeability number 140 and mould hardness number 85. Rejection reduced from 10% to 3.59%.

C.M.Choudhari et al.(2013) carried out Simulation using ANSYS software by optimising of riser and sleeve dimensions and increase in feed efficiency of casting. Also by using optimum riser dimensions of 50mm and sleeve thickness 5mm with trails carried out increases the yield of casting and minimizing solidification defects.

Datau S.Get al. (2012) varied the mould temperature and pouring temperature the mechanical properties such as impact tensile strength, hardness were studied. Also it was found that there is increase in ultimate tensile strength, elongation, hardness with the increase in the pouring and mould temperature and decrease in runner size.

Pang, S., et al. (2012) carried out thermal analysis which results in increase of cooling rate decreasing solidification and Solidus temperature. Vickers hardness test enhances hardness with increasing of cooling rate. Tensile properties of UTS & TYS of GW103K alloys first increases then it decreases. AGS of α-Mg decreases from 59µm to 39µm. Cooling rate was 0.7^0C/s for a thickness §=30mm.

Magdalen Nowak & Haribabu Nadendla. (2012) carried out Investigation through Grain refining, Thermal analysis, Micro structural analysis, and ultimate tensile Strength and Vickers hardness test. Low cooling rate ($0.03\text{-}100^0$/s) with novel grain refiner (Al-Ti-B) can be used to produce complicated parts with thin walls with high strength, hardness and ductility.

John O. Kareem & Idusuyi, N. (2011) proposed ANOVA technique to analyse effects of sand casting parameters on ultimate tensile strength. Parameters such as mould temperature and pouring temperature influence the ultimate tensile strength of Al-alloy up to 90% and should be optimised.

Merlin, M., & Garagnani, G. L. (2009) concluded that Tensile Strength tests, T6-heat treatment, Taikai Analysis were performed on both full cores & empty cores.T9-heat treatment improve ductility of Al alloys and in Taikai analysis, empty cores reduces production cost, weights, time over full cores.

S. Guharaja& A Noorul (2006) used Taguchi methods at 3 levels of process parameters of range of moisture content 2.6%-3.0%, green strength 650-950 gm/cm^2, mould hardness number 70-90 and permeability number 235-275.Optimised parameters of spheroid graphite cast iron casting are moisture content 2.6%, green strength 950 gm/cm^2, permeability number 235 and mould hardness number 80; this improves productivity of castings by increasing stability of casting process.

Meneghini, A., & Tomesani, L. (2005) in their research paper carried outinvestigation with HTC of A356 alloy was done with 2 K-type thermocouples, on 3 types of casting chills& on casting chill interface **.**Cu chills have greater cooling effect (4-8 kW/m^2K) at 375-400^{0}C, Al chills at (3-6 kw/m^2K) at400-420^{0}C & Grey C.I chills at(1-2 kW/m^2K) at 490-530^{0}C.

Sulaiman & Hamouda (2004) in their research paper carried out Simulation model of 2-ingate mould and 3-ingate mould of sand casting were made and thermal analysis was done. Comparing modelling with experimental results, the experimental temperature curves are generally higher than modelling for mould because of trapped air and porosity of sand mould.

2.2 SCOPE OF STUDY

Aluminium alloy has high strength; high corrosion resistance with low coefficient of thermal expansion having advantages of good bearing and wear resistance

In the current era best sand casting techniques will result in better casting and quality parts with higher production at minimal cost with less defects just by optimization of the sand casting process parameters like pouring temperature, permeability of sand, volatile content and Grain Fineness Number of the aluminium alloy material.

This aluminium alloy due to its good mechanical and physical properties can be used in packaging purpose in pharmaceutical industries. Also in automobile and manufacturing industries for manufacturing of sheaves for lifting purpose and manufacturing of Petrol and Diesel Engine pistons. Nowadays aluminium alloy has also been used in manufacturing of exhaust fan blades in hotels and home appliances is a good option to save electricity using low power consumption due to its light weight and wear resistance

CHAPTER 3

OBJECTIVES

1. To perform the modelling and simulation of sand casting process using simulation software.
2. To study the effect of process parameters on mechanical properties of aluminium alloy sand cast.
3. To optimize the process parameters for aluminium alloy sand casting process.

CHAPTER 4

MATERIALS AND METHODOLOGY

4.1 MATERIALS:

Various Grades of Aluminium Alloy with Specifications

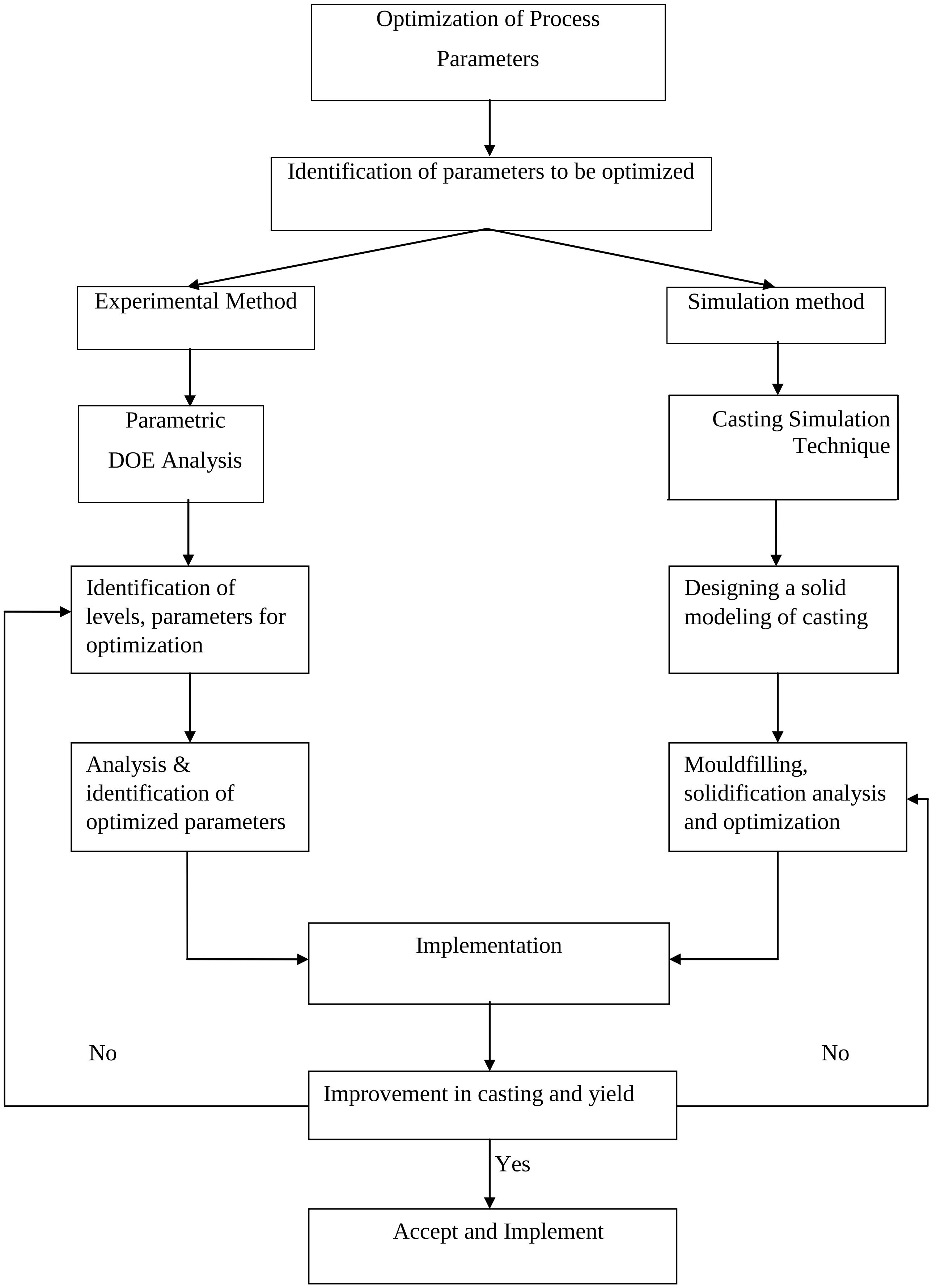
LM 0	Food Factories, Chemical & Electrical Industries manufacture components by using this LM 0 alloy by using sand casting process.
LM 2	Die casting is done by preferring this grade of alloy.
LM 4	This grade of alloy has good mechanical properties as increase in its heat treatment increases
	Its strength and hardness with its good scope in industries.
LM 5	With its good resistance to corrosion it has its scope in marine industries.
LM 6	Castings with complex shapes, good ductility and resistance to corrosion use this alloy.
LM 9	It has good scope in die castings with increase in heat treatment increases its tensile strength.
LM 12	With sufficient heat treatment high resistance to shock and strength can be achieved.
LM 13	Used for manufacturing of petrol and diesel engine pistons, sheaves and other engine components having high strength and good corrosion resistance.
LM 16	With certain limit of heat treatment it is used to make complex sand castings.
LM 20	It has more machinability compared to LM 6 for all types of die castings.
LM 21	Its proof strength and machinability is more than LM 4.
LM 22	It has wide application in casting of chills with good ductility at required heat treatment.
LM 24	Castings with huge, complex shapes, good ductility and resistance to corrosion use this alloy.
LM 25	Strength at required heat treatment with good resistance to corrosion uses this alloy.
LM 26	Manufacturing of petrol and diesel engine pistons as an alternative to LM 13
LM 27	Used as an adaptable alloy and as LM 21 alternation.
LM 28	Used for manufacturing of pistons.
LM 29	Except has low coefficient of thermal expansion with similar properties to LM 28.
LM 30	It has good resistance to wear with its wide application in die casting industries.

Company Name: SS Metal Castings, Pune, Maharashtra

4.2 METHODOLOGY:

Methodology is a theoretical and systematic analysis of methods that are applied in a particular field of research. It is a combination of principles and theoretical analysis associated with the branch of research study. It comprises concepts such as qualitative and quantitative techniques, theoretical model and phases offering an understanding of which method are to be used.

4.3 FLOW CHART



GANTT CHART:

Sr.no	Description	Sep 17	Oct 17	Nov 17	Dec 17	Jan 18	Feb 18	Mar 18	Apr 18
1.	Literature Review								
2.	Simulation								
3.	Experimental Work								
4.	Analysis of the result								
5.	Report Writing								

CHAPTER 5

EXPECTED OUTCOME

1. To optimize the process parameters of sand casting like pouring Temperature, permeability of sand, Grain Fineness Number, Volatile content.
2. To improve the quality of casting using good quality of aluminium alloy for casting purpose
3. Comparing the results of modelling and experimental work of the aluminium alloy and validate both the results.

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