A PROJECT REPORT

ON

MINIMIZATION OF DEFECTS IN ALUMINIUM ALLOY CASTING USING GDC

Submitted by

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In partial fulfillment for the award of the Degree

Of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

UNDER THE GUIDANCE

Of

Prof. ATUL MESHRAM

DEPARTMENT OF MECHANICAL ENGINEERING

ANJUMAN-I-ISLAM

KALSEKAR TECHNICAL CAMPUS NEW PANVEL,

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CERTIFICATE

This is to certify that the project entitled

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

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APPROVAL OF DISSERTATION

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(Internal Examiner) **(External Examiner)**

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Date: ___________

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ABSTRACT

In the present world with the increasing use of Aluminium alloy wheels in automotive industry the Aluminium foundry industry had to focus on the quality of the products. The quality of a foundry industry can be increased by minimizing the casting defects during production.

Aim of the current study is to study the production line of an aluminum alloy wheel manufacturing industry and to improve the quality of production using quality control tools. This study shows the systematic approach to find the root cause of a major defects in aluminium castings using defect diagnostic approach as well as cause and effect diagram. Casting defect analysis is carried out using techniques like historical data analysis, cause-effect diagrams, design of experiments and root cause analysis. Data from X-ray inspection (Radiographic Inspection) have been collected along with the production parameter data. Using check sheets data has been collected and all the defects have been studied. Using Pareto chart major defects in the aluminium castings were noted. The major defects for the rejections during production were identified as shrinkages, inclusions, porosity/gas holes and cracks. Each defect is studied thoroughly and the possible causes for the defects are shown in Fishbone Diagrams (Cause Effect Diagrams). As the shrinkages mainly occur due to lack of feedability during the fluid flow the stalk changing frequency is noted along with the shrinkages defects and a relation is drawn between them. As hydrogen forms gas holes and porosity in the aluminium castings the amount of hydrogen present in the molten metal is studied by finding specific gravity of the samples collected. The molten metal temperature effects the amount of the hydrogen absorbed by it. .So the effect of molten metal temperature on the specific gravity of the sample collected have been shown in a graph and the optimum value for molten metal temperature was found out.

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Chapter 1
INTRODUCTION

Aluminium alloy wheels are manufactured through low pressure die casting method. It has been lately developed to enable the production of castings that are flawless, have very thin sections, and register a yield approaching even in metals such as aluminum and magnesium. The mould which is made in the metal (usually cast iron/ die steel) is filled by upward displacement of molten metal from a sealed melting pot or bath. This displacement is effected by applying relatively low pressure of dry air (0.5 ~ 1.0 kg/mm2) on the surface of molten metal in the bath. The pressure causes the metal to rise through a central Ceramic riser tube into the die cavity.

The dies are provided ample venting to allow escape of air, the pressure is maintained till the metal is solidified ; then it is released enabling the excess liquid metal to drain down the connecting tube back in to the bath. Since this system of upward filling requires no runners and risers, there is rarely any wastage of metal. As positive pressure maintained to force the metal to fill the recesses and cavities, casting with excellent surface quality, finish and soundness are produced. Low pressure on the metal is completely eliminates turbulence and air aspiration.

1.1 Manufacturing processes

Manufacturing refers to the processes of converting the raw materials into useful products.This is normally accomplished by carrying out a set of activities such as product design, selection of raw material, and materials processing.

Following are the 4 types of manufacturing processes

1.Machining-

Machining is any of various processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process.

2.Joining -

Every joining approach has particular design needs, while certain joint needs may propose a particular joining approach.

3.Forming-

Metal forming is the approach of creating the metallic components by deforming the metal.Bending, spinning, drawing, and stretching are a few important metal forming process in manufacturing.

4.Casting-

Casting is a manufacturing process in which a solid is dissolved into a liquid, heated to appropriate temperature (sometimes processed to change its chemical formula).

1.2 CASTING

Casting is a manufacturing **process** in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a **casting**, which is ejected or broken out of the mold to complete the **process.**

These are the types of casting,

1. Sand Casting
2. shell and mould casting
3. Plaster mould casting
4. ceramic mould casting
5. vacuum casting
6. permanent mould casting
7. Die casting.

1.3 Die Casting

Die casting is a metal casting process that is characterized by forcingmolten metal under high pressure into a mold cavity. The mold cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mold during the process.

Types of die casting processes,

1. Cold chamber die casting.
2. Gravity die casting.
3. Low pressure die casting.
4. High pressure die casting.

1.4 DIE CASTING GRAVITY

Aluminium alloy wheels are manufactured through low pressure die casting method. It has been lately developed to enable the production of castings that are flawless, have very thin sections, and register a yield approaching even in metals such as aluminum and magnesium.

The mould which is made in the metal (usually cast iron/ die steel) is filled by upward displacement of molten metal from a sealed melting pot or bath. This displacement is affected by applying relatively low pressure of dry air (0.5 ~ 1.0 kg/mm2) on the surface of molten metal in the bath. The pressure causes the metal to rise through a central Ceramic riser tube into the die cavity. The dies are provided ample venting to allow escape of air, the pressure is maintained till the metal is solidified ; then it is released enabling the excess liquid metal to drain down the connecting tube back in to the bath.

Since this system of upward filling requires no runners and risers, there is rarely any wastage of metal. As positive pressure maintained to force the metal to fill the recesses and cavities, casting with excellent surface quality, finish and soundness are produced. Low pressure on the metal is completely eliminates turbulence and air aspiration.

Chapter 2

GDC DEFECT.

A *casting defect* is an undesired irregularity in a metal casting process. Some defects can be tolerated while others can be repaired, otherwise they must be eliminated.

They are broken down into five main categories:

1. gas porosity.
2. shrinkage defects mold material defects.
3. pouring metal defects
4. metallurgical defects

2.1 GAS POROSITY

Gas porosity is the formation of bubbles within the casting after it has cooled. This occurs because most liquid materials can hold a large amount of dissolved gas, but the solid form of the same material cannot, so the gas forms bubbles within the material as it cools. Gas porosity may present itself on the surface of the casting as porosity or the pore may be trapped inside the metal, which reduces strength in that vicinity. Nitrogen, oxygen and hydrogen are the most encountered gases in cases of gas porosity. In aluminum castings, hydrogen is the only gas that dissolves in significant quantity, which can result in hydrogen gas porosity. For casting that are a few kilograms in weight the pores are usually 0.01 to 0.5 mm (0.00039 to 0.01969 in) in size. In larger casting they can be up to a millimeter (0.040 in) in diameter.

Gas porosity is one of the most significant problems in die casting. High gas content eliminates heat-treating or welding steps and makes the strength of the casting unpredictable.

Here are three major sources of gas porosity in die-castings:

1. Trapped air
2. Steam
3. Gas from lubricant

To prevent gas porosity the material may be melted in a vacuum, in an environment of low-solubility gases, such as argon or carbon dioxide, or under a flux that prevents contact with the air. To minimize gas solubility the superheat temperatures can be kept low. Turbulence from pouring the liquid metal into the mold can introduce gases, so the molds are often streamlined to minimize such turbulence.

2.2 Factors Affecting GAS POROSITY

1. Pouring mould temperature
2. Preheat temperature
3. Degasification time & defects
4. Die coat material
5. Die coat thickness

2.2.1. POURING MOULD TEMPERATURE

Pouring temperature generally varies from 650 to 800 degree Celsius. When we pour aluminum alloy then its fluidity is completely dependent upon pouring temperature. Therefore, growth rate of fluidity above 735 °C is lower than between 695 °C and 735 °C.

2.2.2.PREHEAT TEMPERATURE

Preheating in the gravity die casting is done to remove the possibility of formation of temperature gredients. A significant precondition for the production of high quality castings is keeping an optimum temperature of the respective parts of the mould cavity surface.

2.2.3.DEGASSING TIME & MATERIAL

The gas used for degasification is mostly argon and nitrogen which are inert gases. After melting the molten metal should go in to "degassing process". In this method, an inert gas like argon or nitrogen is injected into the flow of molten metal through injection nozzles. The hydrogen diffuses into the bubbles. The gas is bubbled through molten aluminum to remove absorbed hydrogen. The amount of hydrogen is reduced gradually.

2.2.4.DIE COAT THICKNESS AND MATERIAL

Die coat in the gravity die casting in order to obtain smooth surface finish and to avoid direct exposure of mould to the molten metal in order to avoid direct chilling Effect. The material used for die coating is generally calcium carbide and silicon mixture and graphite

2.2.5.DEGASIFICATION & DEFECTS

Degasification mainly eliminates the unwanted gases from the mould by bubbling at the bottom of the container and it controls the porosity to a much larger extent.

Chapter 3
MATERIAL SURVEY

The commercial aluminium silicon alloy A356 was used in this experimental work. The chemical composition of the alloy used in present work shown below:

Table 1material composition

MATERIAL	%
Al	**91.623**
Si	**7.121**
Fe	**0.481**
Mn	**0.235**
Mg	**0.463**
Cr	**0.005**
Zn	**0.019**
Ni	**0.0**
Ti	**0.014**
Pb	**0.010**

Chapter 4
Methodology

The experimentation work is performed in an alloy wheel industry manufacturing Alloy wheels of A356. The company manufactures wheels of various models and supplies to the leading automobile manufacturing companies. The model for analysis is selected after the discussion with the technical team of the company. The company follows the laid down systematic procedure for the manufacture for wheels. Around 30% fresh ingots and 70% chip, rejected wheels, rings and sprues are used for melting in gas fired furnace for around 1 hour so that the temperature of the melt reaches 750 – 780 ^{0}C. The melt is then transferred to the holding furnace for the alloy preparation. Then Fluxing powder is added to remove dross from the melt known as “Fluxing”. Nitrogen gas is then purged into the melt to remove gas in the form of bubbles and slag is taken to the surface. This is known as “degassing”. Skimming is done so that the metal is free from dross and slag. Melt is then hold for some time before it is poured in the die of gravity die casting machine to make alloy wheels. Here along with the alloy wheels, tensile test bars are casted with the same set of parameters. The wheels and tensile test bars will then be heat treated (T6) and sent for further machining.

Defect Diagnostic Approach

1. Defect analysis in casting defects is carried out using techniques like
2. Historical data analysis
3. Cause-effect diagrams
4. Design of experiments
5. Root cause analysis
6. Identifying the casting defect correctly is the first step in the defect analysis.
7. Then the identification of the sources of the defect is to be made.
8. By taking the necessary corrective remedial actions defects can be controlled.
9. Implementation of wrong remedial actions makes the problem complicated and severe.
10. The major rejected aluminium alloy wheel castings was analyzed using “Defect diagnostic approach” as shown

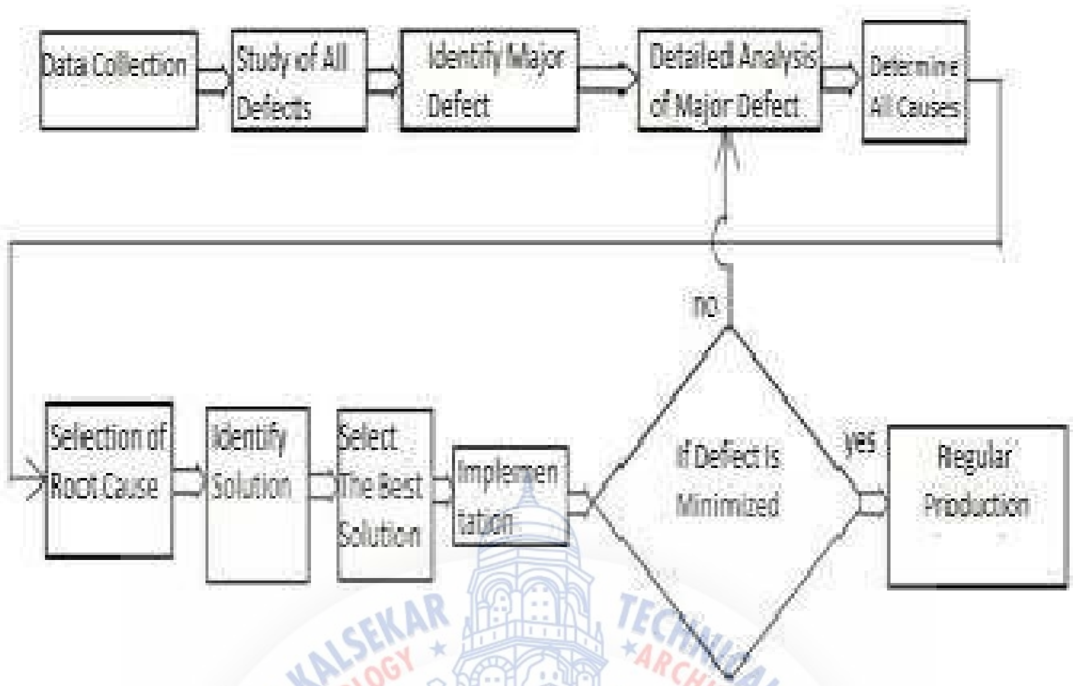


Figure 1 Defect Diagnostic Approach

Chapter 5
ANALYSIS

Historical Data Analysis

To find the rejections in castings, data for occurrence of defects for one year was collected from one of leading Al alloy wheel casting industry. Using historical data analysis [2], check sheets have been prepared which helps to identify occurrence defects in aluminium alloy castings. Using check sheets data collection is simple and it also helps in spotting problem areas by frequency of location, cause and type of defects. The details are shown in Table 4.1.

DEFECT	REJECTED QUANTITY	cum %	DEFECT	REJECTED QUANTITY	cum %
SHRINKAGE	4078	39	MISMATCH	84	97
POROSITY	2610	64	GRINDING SHADE	69	98
CRACK	1410	77	HALF CYCLE	51	98
INCLUSION	984	86	BELOW RANGE	46	99
UNFILLING	413	90	EJECTOR PIN DEPRESSION	42	99
PROFILE DAMAGE	194	92	DENTS	35	100
DISTORTION	181	94	ABOVE RANGE	22	100
METAL STICKING	155	95	MESH	12	100
GAS HOLE	122	97	WITHOUT MESH	5	100

table 4.1

Pareto Diagram for Defects

Using the data collected for different casting defects pareto diagram have been drawn as shown in Figure 4.1

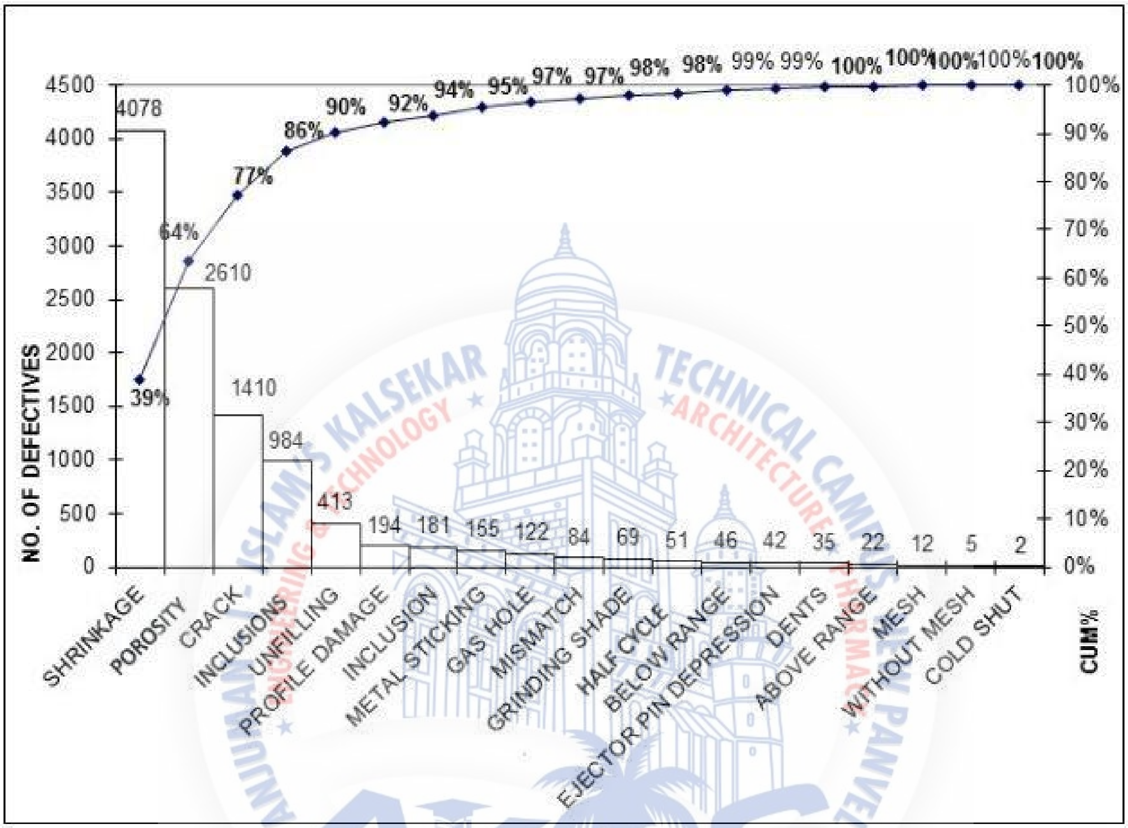


Fig 4.1

Using pareto chart shown in Figure 4.1, we can conclude that the major causes for the rejections in Al alloy wheel castings were due to

1. Shrinkages
2. Air leak
3. Crack
4. Inclusions etc.

DETAILED ANALYSIS OF THE MAJOR DEFECT - SHRINKAGES

Shrinkages

1. The following points describe how shrinkages occur in castings
2. Shrinkage occurs during solidification as a result of volumetric differences between liquid and solid state. For most aluminum alloys, shrinkage during solidification is about 6% by volume
3. Lack of adequate feeding during casting process is the main reason for shrinkage defects.
4. Shrinkage is a form of discontinuity that appears as dark spots on the radiograph.
5. It assumes various forms, but in all cases it occurs because the metal in molten state shrinks as it solidifies, in all portions of the final casting
6. By making sure that the volume of the casting is adequately fed by risers, Shrinkage defects can be avoided.
7. By a number of characteristics on radiograph, various forms of shrinkages can be recognized.

Types of shrinkages

1. Cavity
2. Dendritic
3. Filamentary
4. Sponge types

Shrinkage Cavity

1. The following points explain how shrinkage cavity occurs in castings ● It appears in areas with distinct jagged boundaries.
2. When metal solidifies between two original streams of melt coming from opposite directions to join a common front, cavity shrinkage occurs as shown in Figure 4.2.
3. It usually occurs at a time when the melt has almost reached solidification temperature and there is no source of supplementary liquid to feed possible cavities.

Dendritic Shrinkage

This type of shrinkage can be identified by seeing distribution of very fine lines or small elongated cavities that may differ in density and are usually unconnected as shown in Figure 4.3.

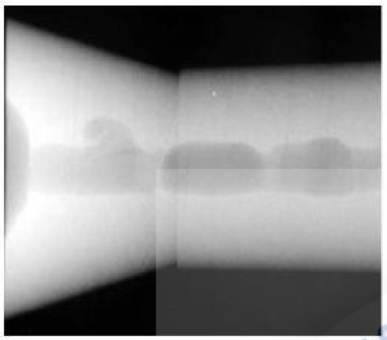


Figure 4.2. Shrinkage cavity [5]

Figure 4.3. Dendritic shrinkage [5]

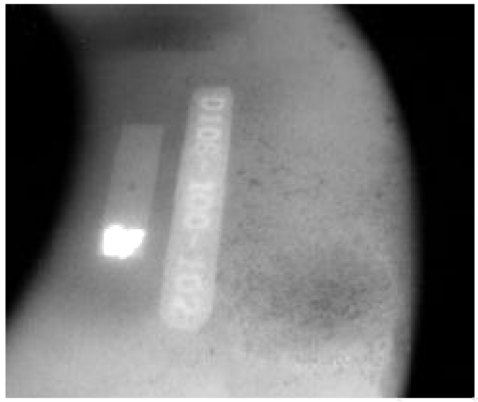
Filamentary Shrinkage

This type of shrinkage usually occurs as a continuous structure of connected lines of

1. Variable length
2. Variable width
3. Variable density

Sponge Shrinkage

1. Sponge shrinkage can be identified from areas of lacy texture with diffuse outlines as shown in Figure 4.4.
2. It may be dendritic or filamentary shrinkage.
3. Filamentary sponge shrinkage appears more blurred as it is projected through the relatively thick coating between the discontinuities and the film surface. Figure 4.4.



Fish Bone Diagram for Shrinkage

Fish bone diagram helps in following ways

1. Once a defect has been identified, potential causes of this undesirable effect has to be analyzed.
2. Fishbone Diagram (Cause Effect Diagram) is a useful tool in finding potential causes.
3. By using this fishbone diagram, all contributing factors of defects and their relationship are displayed in a place.
4. It identifies areas of problem where data can be collected and analyzed. The fish bone diagram for shrinkages is shown in Figure 4.5.

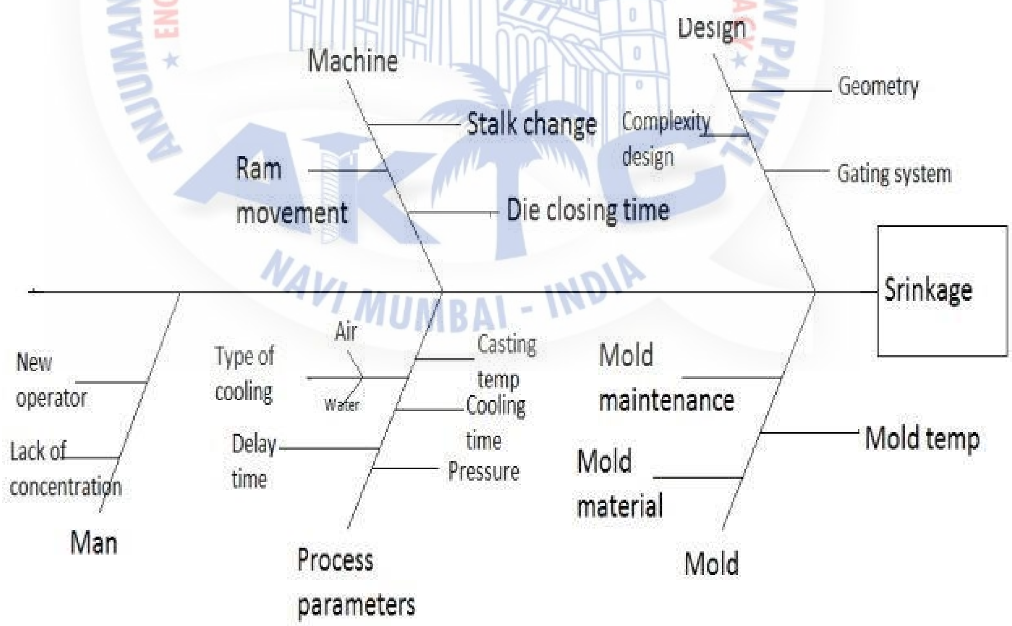


Figure 4.5. Fish bone diagram for shrinkages

Classification of Shrinkage Defects

1. The shrinkage defects were classified according to the area of defect ➔ Hub shrinkage Shrinkage in the hub region of the wheel around gate.
2. Spoke shrinkage Shrinkage happens in joint area between spoke and rim.
3. Rim shrinkage It happens in rim flange area which is the farthest from the gate.
4. Various parts of a wheel is shown in Figure 4.6.

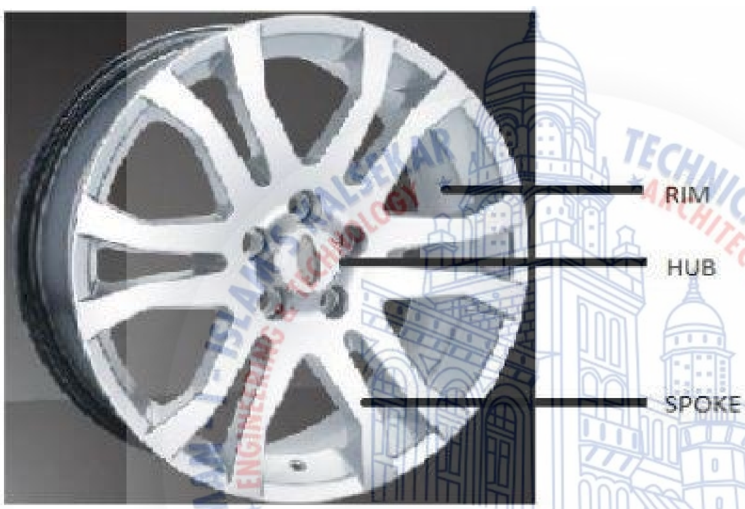
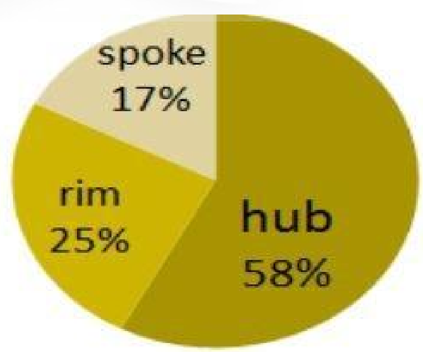


Figure 4.6. Wheel of an automobile [12]

Data has been collected using check sheets shown in Table 4.2. The no of rejections due to various shrinkages have been noted and is shown in pie charts shown in Figure 4.7.

M/C No	Mould	Defects		
		Shrinkages		
		HUB	RIM	SPOKE
1	XYZ	487	210	147



Using histogram as shown in Figure 4.8. It was noted that the hub shrinkages were more compared to rim and spoke shrinkages

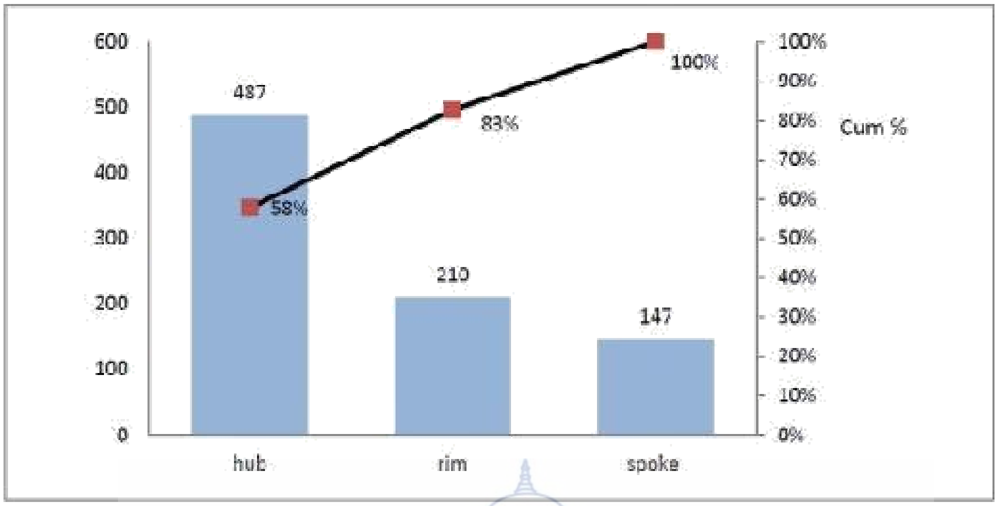


Figure 4.8. Histogram for shrinkage defects

Conclusion

Hub part is the last solidified part of the wheel. Most of the shrinkages occur in the hub region due to the lack of feeding during the solidification.

. Hub Shrinkage:

It is because of in sufficient feeding of molten metal.

Spoke Shrinkage:

It is because of formation of hot spot in the junction, where greater volume of liquid metal will flow. It may be external or internal.

Rim Shrinkage:

It happens in rim flange area which is the farthest from the gate.

It also occurs when rim thickness is less.

Stalk

It is a refractory tube, through which the molten metal aluminum finds its way into mold cavity when holding furnace is pressurized. It is basically steel pipe as welded to a flange. The steel tube is wound with refractory material. It is fitted in to the central hole of holding furnace as shown in Figure 4.9.

Effect of Salk Change on Shrinkages

Observation:

The shrinkage % and the stalk changing frequency were collected. Both are related using histogram as shown in Figure 4.10.

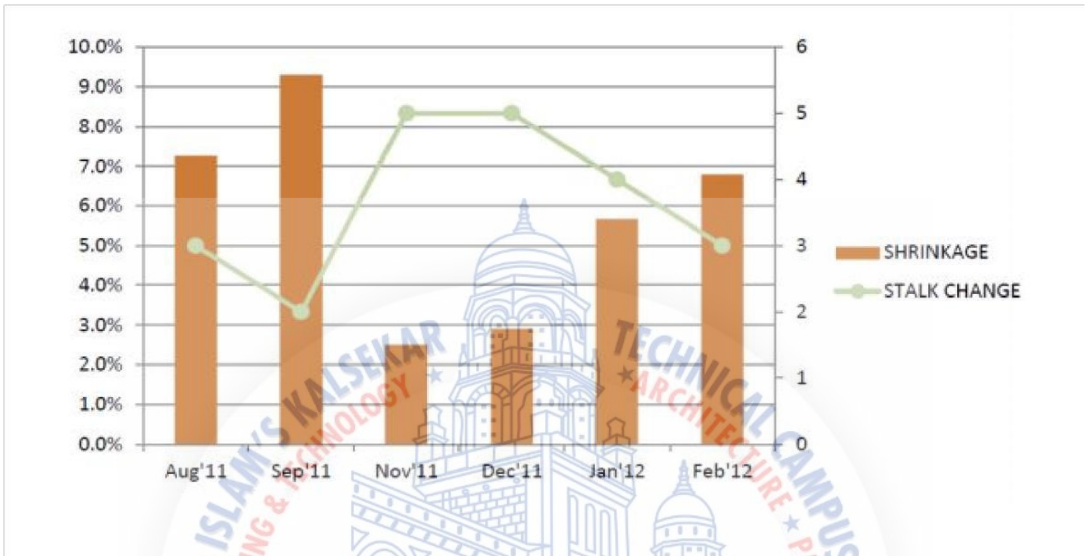


Figure 4.10. Histogram for stalk change & shrinkages

Conclusion

With the use of histograms as shown in Figure 4.10, it was noted that the shrinkage % decreases with the increase in stalk change frequency.

DETAILED ANALYSIS OF THE MAJOR DEFECT -CRACKS

Cracks

The following points explain the formation of cracks

1. Cracks are irregular shapes formed when the molten metal pulls itself apart while cooling in the mould or after removal from the mould as shown in Figure 4.11.
2. Hot tear occurs when the crack appears during the last stages of solidification .If hot tear occurs the crack faces are usually heavily oxidized [9].
3. Hot tear commonly occur in metals and alloys that have a wide freezing range, and the isolated regions of liquid become subjected to thermal stresses during cooling and fracture results.

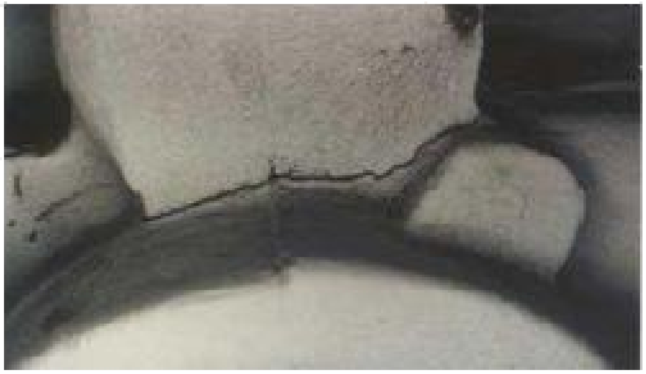


Figure 4.11. Crack in casting [5]

The causes for hot tearing are

1. Thermal contraction
2. Liquid film distribution
3. Liquid pressure drop
4. Vacancy supersaturation

Crack can propagate through

1. Through liquid film by sliding
2. By liquid film rupture
3. By liquid metal embrittlement
4. Depending on the temperature range it occur through liquid film or solid phase.
5. It occurs when there is diffusion of vacancies from the solid to the crack.

Conditions for Formation of Crack are

1. When thermal stress exceeds rupture stress of the liquid film
2. . • When critical value for cavity nucleation is reached when pressure drops over mush.
3. When strain rate reaches a critical value and it cannot be compensated by much ductility liquid feeding .
4. When insufficient feeding is there in the vulnerable temperature range.
5. When thermal stress exceed local critical stress.
6. By liquid flow and mush ductility thermal strain cannot be accommodated.

The actual hot tearing mechanism occurs on two scales:

1. Microscopic

- Crack nucleation and propagation
- Stress concentration
- Structure coherency
- Wet grain boundaries

- lack of feeding stress
- Lack of strain or
- Strain rate imposed on the structure
- The scales during equi

Figure 4.12. Different length scales of equiaxed dendritic solidification along with suggested hot tearing mechanisms [5]

axed dendritic solidification is shown in Figure 4.12.

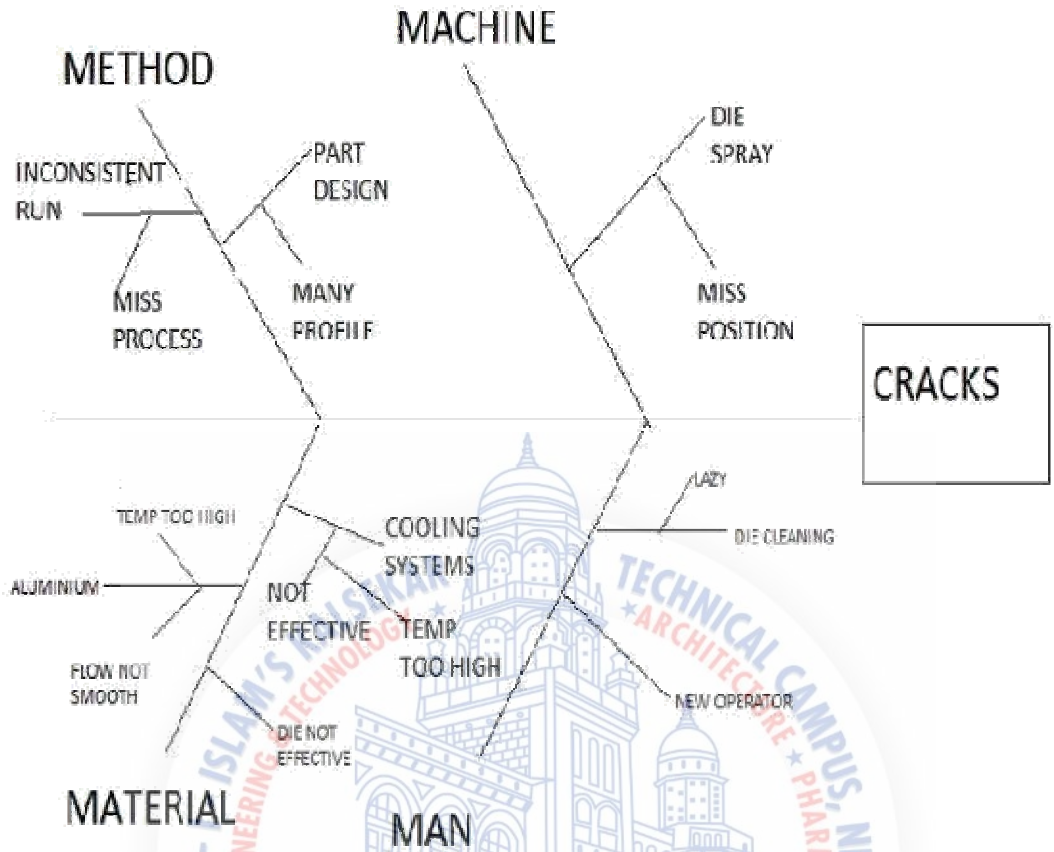
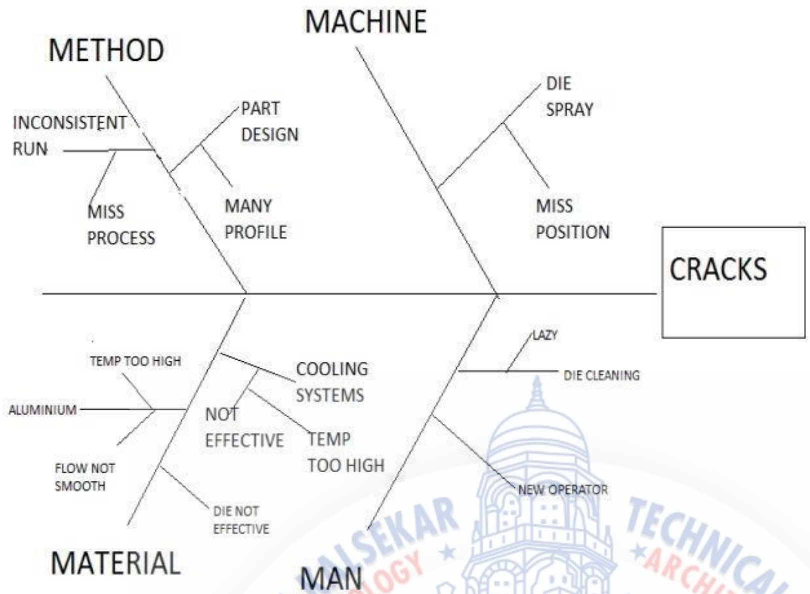


Figure 4.12. Different length scales of equiaxed dendritic solidification along with suggested hot tearing mechanisms

Cracks mostly occur in hub region of the wheel it may internal or external. These are irregular shape cracks formed when the metal pulls itself apart while cooling in the mould or after removal from the mould.

Fish Bone Diagram for Cracks



DETAILED ANALYSIS OF THE MAJOR DEFECT -POROSITY

Porosity

3. The following points explain how pinhole porosity occur in castings.
4. The main reason of gas holes and porosity defects is the trapped hydrogen gas in the molten metal during casting.
5. Increase in hydrogen content will increase the porosity in the casting and the pore size.
6. Main factor of gas porosity during solidification is the dissolved hydrogen level in melts and it has to be avoided otherwise it will significantly decrease the mechanical and surface finish properties of the final casting product.
7. When aluminium combines with the water vapor in the atmosphere hydrogen gas is released.
8. 2Al+3H2O6H+ Al2O3
9. Liquid aluminium dissolves the hydrogen generated in the process.
10. Solubility of gaseous hydrogen decreases when aluminum solidifies so aluminum alloys release excessive amount of hydrogen gas during Solidification from liquid state to liquid state. This results in porosity defects which distributes throughout the solid metal.
11. Size of pore increases with increase in initial hydrogen content.

The following are the Sources of hydrogen in molten aluminum

1. Humidity in atmosphere
2. wet metallic charge
3. wet furnace lining (crucible, transfer ladles)
4. wet foundry instruments
5. wet fluxes
6. furnace fuel combustion products which contains hydrogen
7. Hydrogen Concentration Measuring

Melt quality can be known by measuring hydrogen content. The simple way of indirectly measuring the hydrogen content of the melt is to measure its specific gravity. Molten metal is collected in a sample and casted. The specific gravity is measured by weighing the sample in air and water (Archimedes Principle)

. $Sg = Wa/ (Wa-Ww)$

Where, Sg is the specific gravity of sample.

Wa is the weight of the sample noted keeping it in air.

Ww is weight measured by keeping the sample in water.

The volume of hydrogen can then be determined by $H2 = (Sg - SgT)$. Where, SgT is theoretical specific gravity of the alloy

Degassing

Molten aluminum is extremely reactive, so when it comes in contact with moist air or wet tools, the water decomposes to release hydrogen in the melt. Excessive quantities of this dissolved gas have a well-documented detrimental effect on the mechanical properties of the final aluminum castings. What is also well known to anyone making castings is that dissolved gas has an overriding effect on the distribution and amount of porosity and shrinkage. Dissolved hydrogen levels must be controlled to minimize scrap. To control gas in aluminum, metalcasters must accomplish two things:

1. Prevent and minimize introduction of hydrogen in the melt.
2. Measure and remove the hydrogen prior to pouring.

. After melting the molten metal should go in to “degassing process”. In this method, an inert gas like argon or nitrogen is injected into the flow of molten metal through injection nozzles. The hydrogen diffuses into the bubbles . The gas is bubbled through molten aluminum to remove absorbed hydrogen. The amount of hydrogen is reduced gradually. This bubbling action of inert gas through spinning rotor helps oxide particles to float to the surface. It also creates a large number of small bubbles of gas that are mixed with the liquid alloy. Rotory degassing method is shown in Figure.

Degassing fluxes are added to remove hydrogen from the molten metal as well as to lift oxides and particles to top of the bath so that they can be removed

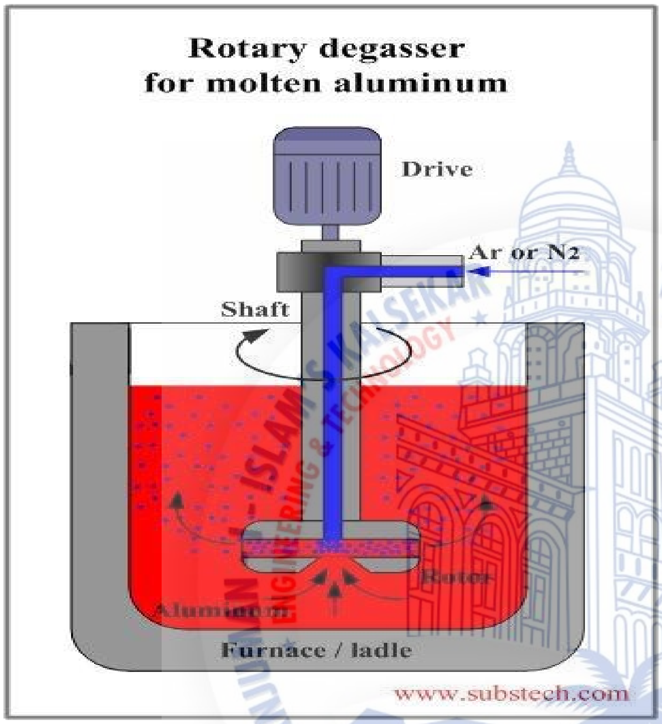


FIG. DEGASSING USING ROTARY MOTION

Chapter 6

Design of Experiment

Introduction to TAGUCHI METHOD

In recent years, it has been shown that the reliability of mechanical properties of aluminium castings can be significantly increased by simple alterations to the design of their filling alloy systems. Metal casting process considered to be one of the largest industries in the manufacturing sector.The mechanism of degradation involves the entrainment of the surface oxide film. If the surface film is entrained during pouring, the metal folds and mutually collides, the surface film contacting dry-side to dry-side, giving an unbounded interface consisting of opposed ceramic-to-ceramic faces. These double films with their central unbonded interface are submerged to act as cracks in suspension in the liquid metal.

The presence of bifilm cracks in the metal has numerous consequences: the unbonded interface can be opened by the inward diffusion of gas, thus initiating gas porosity. Alternatively, they can be pulled apart by shrinkage stresses to initiate shrinkage porosity or hot tearing.

Gravity casting has been one of the most traditional and simplest ways of casting metals and alloys. It is practical and economical. However, it has few disadvantages besides its common use.

1. trial-and-error approach :

performing a series of experiments each of which gives some understanding. This

requires making measurements after every experiment so that analysis of observed data will allow him to decide what to do next - "Which parameters should be varied and by how much". Many a times such series does not progress much as negative results may discourage or will not allow a selection of parameters which ought to be changed in the next experiment. Therefore, such experimentation usually ends well before the number of experiments reach a double digit! The data is insufficient to draw any significant conclusions and the main problem (of understanding the science) still remains unsolved.

2. Design of experiments :

A well planned set of experiments, in which all parameters of interest are varied over a specified range, is a much better approach to obtain systematic data. Mathematically speaking, such a complete set of experiments ought to give desired results. Usually the number of experiments and resources (materials and time) required are prohibitively large.

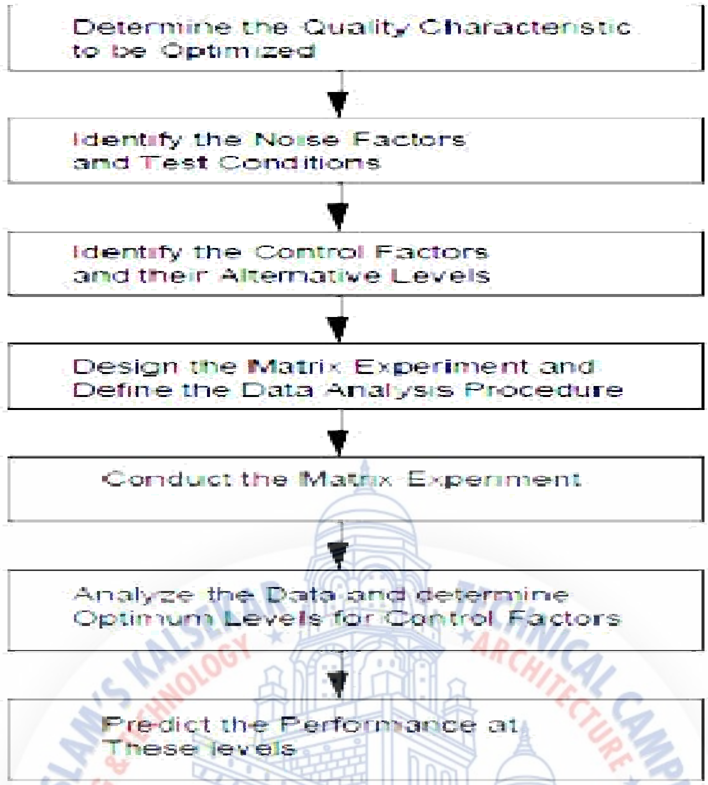
Often the 30

experimenter decides to perform a subset of the complete set of experiments to save on time and money! However, it does not easily lend itself to understanding of science behind the phenomenon. The analysis is not very easy (though it may be easy for the mathematician/statistician) and thus effects of various parameters on the observed data are not readily apparent. In many cases, particularly those in which some optimization is required, the method does not point to the BEST settings of parameters. A classic example illustrating the drawback of design of experiments is found in the planning of a world cup event, say football. While all matches are well arranged with respect to the different teams and different venues on different dates and yet the planning does not care about the result of any match (win or lose)!!!!

Obviously, such a strategy is not desirable for conducting scientific experiments

3. TAGUCHI Method :

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on " ORTHOGONAL ARRAY " experiments which gives much reduced " variance " for the experiment with " optimum settings " of control parameters. Thus the marriage of Design of Experiments with optimization of control parameters to obtain BEST results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.



Taguchi's Parameter Design Approach

Design of experiments techniques, specifically Orthogonal Arrays (OAs), is employed in Taguchi's approach to systematically vary and test the different levels of each of the control factors. Commonly used OAs includes the L4, L9, L12, L18, and L27. The columns in the OA indicate the factor and its corresponding levels, and each row in the OA constitutes an experimental run which is performed at the given factor settings. Selecting the number of levels and quantities properly constitutes the bulk of the effort in planning robust design experiments.

	Factors		
Run	A	B	C
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1

(a) $L_4 (2^3)$ array

	Factors						
Run	A	B	C	D	E	F	G
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

(b) $L_8 (2^7)$ array

	Factors			
Run	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

(c) $L_9 (3^4)$ array

The quality characters, which were selected to influence the gravity die-casting process from Al-Si-Mg alloys, are as follows:

- Solidification time of alloys
- Tensile strength of castings
- %Elongation of castings
- Hardness of castings

The parameters, which influence the performance of the gravity die casting process, are:

Alloy composition

- **---- Al**
- **--- Si**
- --- Mg
- --- Fe
- Gravity die-casting--- Pouring temperature of the metal
- --- Degasification
- --- Preheating temperature of the mould

The selected levels for the chosen control parameters are summarized in Table-2. The orthogonal array (O.A), L9 was selected for the present work. The parameters were assigned to the various columns of O.A. The assignment of parameters along with the OA.

FACTOR	Symbol	Level – 1	Level – 2	Level-3
ALLOY COMPOSITION	A	1	2	3
POURING TEMPERATURE OF MELT, ^0C	T	675	700	725
MOULD PRE-HEAT TEMPERATURE, ^0C	P	200	300	400
Degasification with Tetrachlorethane, %	D	0.75	1.00	1.25

Table-3. Orthogonal Array (L_9) and control parameters

Treat No.	A	T	P	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Orthogonal arrays are special standard experimental design that requires only a small number of experimental trials to find the main factors effects on output. Before selecting an orthogonal array, the minimum number of experiments to be conducted is to be fixed based on the formula below

N Taguchi = 1+ NV (L – 1)

N Taguchi = Number of experiments to be conducted

NV = Number of parameters L = Number of levels In this work

For Ex….

NV = 3 and L = 3,

Hence N Taguchi = 1+ 4 (3-1) = 9

Hence at least 9 experiments are to be conducted. Based on this orthogonal array (OA) is to be selected which has at least 9 rows i.e.,9 experimental runs. The following standard orthogonal arrays are commonly used to design experiments:

Level Arrays: L4, L8, L12, L16, L32

Level Arrays: L9, L18, L27

Level Arrays: L16, L32

6.2.ARRAY SELECTOR TABLE

↓levels→parameters

	2	3	4	5	6	7	8	9	10	11	12
2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16
3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27
4	L16	L16	L16	L16	L32	L32	L32	L32	L32		
5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50

L9 Arrays

Experiment No.	Factor A	Factor B	Factor C	Factor D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Experimental Setup

Factors and their Levels

TREATMENT CONDITION	POURING TEMPERATURE	DEGASSING TIME	HOLDING FURNACE VOLUME
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Factors	**A**			**B**			**C**		
Parameters	**Pouring Temperature, PoT**			**Degassing Time, DgT**			**Volume in Holding Furnace (H.F.) of 500 kg, VoH**		
	(^{0}C)			(minutes)			Volume in H. F.		
Levels	1	2	3	1	2	3	1	2	3
	700^{0}C	720^{0}C	740^{0}C	5 Minutes	10	15	Start, S (Full)	Mid, M (Half)	End, E (Finishing)

Heat Treatment (T6)

The heat treatment of cast aluminium alloys is carried out to increase their strength and hardness and to change their physical, mechanical and metallurgical properties. T6 Heat Treatment includes Solution treatment followed by precipitation (age) hardening produces the highest strength and mechanical properties (tensile and yield strength) while retaining ductility (elongation). Precipitation (age) hardening stabilizes the properties.

Heat Treatment includes water quenching at 537 ±5^{0}C for a cycle time of 4 Hours after reaching temperature, in a continuous monitoring. Aging Owen temperature at 155 ±3^{0}C for 1hr 30 minutes, after reaching temperature.

TC	PoT (^{0}C)	DgT (minutes)	VoH (S,M,E)
1	700	5	S
2	700	10	M
3	700	15	E
4	720	5	M
5	720	10	E
6	720	15	S
7	740	5	E
8	740	10	S
9	740	15	M

Density

The buoyant force on a submerged object is equal to the weight of the fluid displaced. This principle is useful for determining the volume and therefore the density of an irregularly shaped object by measuring its mass in air and its effective mass when submerged in water (density = 1 gram per cubic centimeter).

Buoyant force is given by:

$F_b = g \rho V$ (1)

$F_b = W_a - W_f$ (2)

Where,

F=Buoyantforce

g=Acceleration due to gravity

ρ = Density of the fluid

V = Volume of the object inserted into the fluid

F_b is the Buoyant force

W_a = the Normal weight of the object when it is in air

W_f = the Apparent weight of the object when it is immersed in the fluid Using **(1) = (2)**

$$g \rho V = W_a - W_f$$

ρ = (Wa–Wf)/ gv.................... Density by Archimedes Principle

DI TESTER-

PROCESS OF DENSITY TESTING

Scope:

Density is the mass per unit volume of a material. Specific gravity is a measure of the ratio of mass of a given volume of material at 23°C to the same volume of deionized water. Specific gravity and density are especially relevant because plastic is sold on a cost per pound basis and a lower density or specific gravity means more material per pound or varied part weight.

Procedure:

There are two basic test procedures- Method A and Method B. The more common being Method A, can be used with sheet, rod, tube and molded articles. For Method A, the specimen is weighed in air then weighed when immersed in distilled water at 23°C using a sinker and wire to hold the specimen completely submerged as required. Density and Specific Gravity are calculated.

Data:

Specific gravity = a/[(a + w)-b]

a = mass of specimen in air.

b = mass of specimen and sinker (if used) in water.

W = mass of totally immersed sinker if used and partially immersed wire.

Density, kg/m3 = (specific gravity) x (997.6)

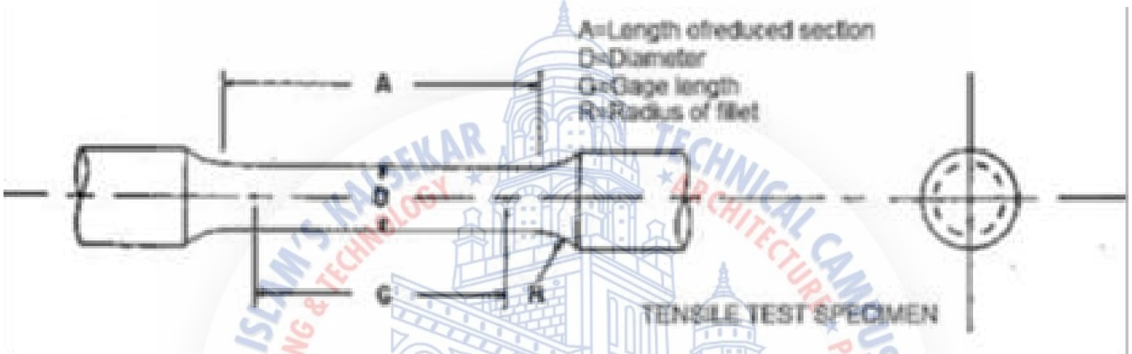
BAR NO.	**Density, g/cm^3**
1	2.66
2	2.64
3	2.632
4	2.65
5	2.62
6	2.61
7	2.63
8	2.62
9	2.59

WITH DEGASSING

WITHOUT DEGASSING

Tensile & Hardness Tests

Brinell hardness tests were carried out for all test bars with 5 mm ball indenter and 250 kg preload. The tensile test for all six sets of readings were also carried out and readings for Yield strength, Ultimate Tensile Strength and % Elongation were noted it a table

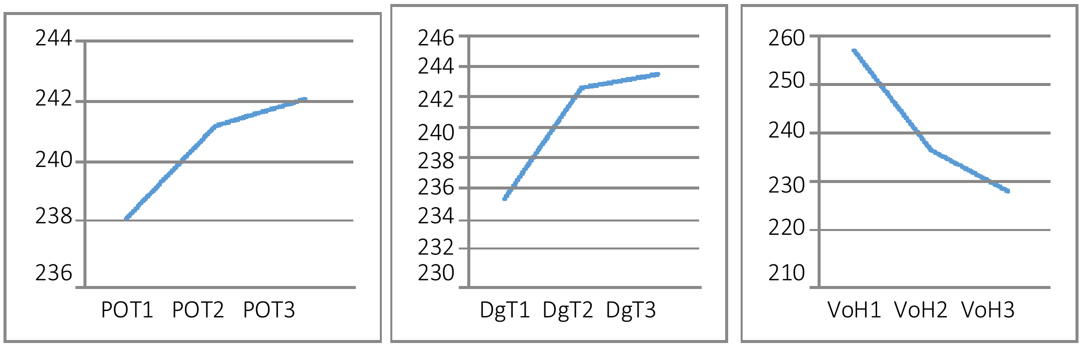

A=Length ofreduced section
D=Diameter
G=Gage length
R=Radius of fillet
A
D
G
R
TENSILE TEST SPECIMEN

Tensile test Results are tabulated as below:

ANOVA Table for UTS

Factors & Levels L9 DoE			UTS			
PoT	DgT	VoH	UTS-A	UTS-B	UTS-C	
1	1	1	245.275	242.26	246.275	733.81
1	2	2	237.779	236.7	238.9	713.379
1	3	3	230.148	230.8	234.148	695.096
2	1	2	232.246	235.623	237.2	705.069
2	2	3	226.622	223.2	228.5	678.322
2	3	1	260.104	262.34	264.45	786.894
3	1	3	223.877	226.71	227.43	678.017
3	2	1	265.258	262.85	263.25	791.358
3	3	2	234.524	237.52	236.78	708.824
						6490.769

	TOT RESP	avg resp=TOT/9
POT1	2142.285	238.0316667
POT2	2170.285	241.1427778
POT3	2178.199	242.0221111
DgT1	2116.896	235.2106667
DgT2	2183.059	242.5621111
DgT3	2190.814	243.4237778
VoH1	2312.062	256.8957778
VoH2	2127.272	236.3635556
VoH3	2051.435	227.9372222



Graphs: Factor Levels Vs UTS

Pouring Temperature, Degassing Time & Volume of Holding Furnace is SIGNIFICANT

CONCLUSION

The study was carried out to understand the effect of bifilms on the quality of castings. Parameters affecting porosity in A356 alloy by GDC was identified and experiments were performed and the results are discussed.

The tensile test bars and Reduced pressure samples were made. Tensile tests were performed on test bars. Density of the test bars were also found by Archimedes principle.

Taguchi's Design of Experiments gave the experimental data obtained for the test bars. Tensile tests were performed on the test bars and density test by Archimedes principle gave us following results:

1. Pouring Temperature, Degassing Time & Volume of Holding Furnace is SIGNIFICANT

Interpretation from result: UTS depends on PoT, DgT and VoH and the optimum levels are PoT at Level 3, DgT at level 3 and VoH at level 1

2. Pouring Temperature, Degassing Time & Volume of Holding Furnace is SIGNIFICANT

Interpretation from result: Density depends on PoT, DgT and VoH the optimum levels are PoT at Level 1, DgT at level 3 and VoH at level 1

It is concluded that the all 3 factors are contributing and more the density, lesser will be the porosity hence improved strength is obtained.

Confirmatory Run gave us the same results

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