Rejection Analysis for Productivity Improvement in Foundry Technology

A Project Report

Submitted by

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BONAFIDE CERTIFICATE

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Pursuing Final B.E. - Mechanical Engineering at Kumaraguru College of Technology, Chinnavedampatti, Coimbatore has successfully completed their project titled **"Rejection Analysis for Productivity Improvement in Foundry Technology"** in our company. During the project work their conduct was good. We wish them all success for future endevours.

For Santhi Casting Works Pvt Ltd.

M. Yn Lopna

(Proprietor)

ABSTRACT

Casting is one of the cheapest and oldest methods of metal forming process. The casting industry produces about 75 million metric tons of cast components per year worth more than $150 billion globally. India stands 6th among its global competitors in the production of cast components with a production capacity 3.27 million tons per year.

Over the last decade, there has been a steady increase in the requirement of castings with stress on quality assurance, shorter lead-time, smaller lot size and competitive pricing. Assemblers are eliminating inspection of incoming goods and expect the suppliers to be responsible for the quality. In this industry the major loss in productivity is due to rejection caused by casting defects.

Pertaining to this problem, we have taken up the project entitled "Rejection Analysis for Productivity Improvement in Foundry Technology", with the investigations conducted in Santhi Casting Works Pvt. Ltd., Coimbatore.

When the loss of productivity was analyzed, it became evident that in spite of the vast technological developments in various engineering field, the foundries still follow only traditional methods in analyzing and controlling defects which may not give a permanent solution to prevent the loss of productivity. This has made us to select the statistical and logical approaches for casting defect analysis and control.

We have taken up a case study on two products (10TG Brake Drum and 608 Brake Drum) and adopted the non-traditional approaches. The adoption of statistical and logical approaches has been found to be very effective and it provided us a result of reduction in rejections from 7.16% to 4.23% in 10TG Brake Drum and from 7.59 % to 3.98 % in 608 Brake Drum. Through this project work, it has been proved that adopting non-traditional approaches will much effectively reduce rejections and improve the productivity in foundry industry.

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GCS	Green Compression Strength
DCS	Dry Compression Strength
SPC	Statistical Process Control
QC	Quality Control
AFS	American Foundrymen Society
fig.	Figure
psi	pounds per square inch
MT	Million Tons

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

1.1.1 Background of the Problem:

Foundry industry, one of the oldest industries in human society and is the cheapest process of metal forming compared to the other metal forming technologies. Mass production was considered to be an art rather than a science until recently, where the quality demands were being met by the skill of the labour involved rather than the proper application of technology. This trend is still prevalent in many of the local foundries.

But the rapid industrialization and growth in the other fields of engineering has placed stringent demands of quality and quantity on the foundries also. As a result vast developments and changes in the current process as well as production plans have become mandatory for any industry trying to compete globally.

1.1.2 Importance of Project:

A report published on the **"Indian foundry Journal"** reveals that in producing one million tons of castings, it is estimated that about 75000 tons of additional castings are made and scarped due to defects. The productivity loss also includes the machining cost in addition to the cost on casting it in foundry. Some times even entire batches of castings are returned to the foundry due to the problems exposed during machining. Also such rejects are to be considered as a major loss of manufacturing time, which has become one of the scarcest resources in any production industry.

In the view of the above mentioned problem, investigating castings defects in order to counter them will be seen playing a major role in improving the productivity of the foundry. Even a two or three percent reduction in rejects by proper elimination of defects will save a lot on resources such as salvage cost, man-hours, machine- hours etc., thereby improving productivity. This prime importance of the analysis of rejects and their consequent prevention has made us formulate this topic for our project work.

1.2 SCOPE OF THE PROJECT

The rate of newly emerging foundries and rate of increase in the turn over of existing foundries has gone up drastically in the past decades and the high level of competition persuaded the casting industry to concentrate on quality control. But, inspite of vast technological development in engineering field the foundry people are following only the traditional approach in analyzing and controlling defects which may not give a permanent solution.

In the view of this constraint, in this project we dealt about adoption of statistical approach for defect analysis and logical approach for defect identification and control.

The scope of our project is to complexly replace the traditional approach with the statistical and logical approach so as to achieve a permanent solution by adopting sequential methodology.

Though the modernization of foundries are not that viable for many small and medium scale casting industries, the adoption of the methodology we have followed will help a lot in improving productivity.

For our project, we have taken up a case study at Santhi Casting Works Pvt.Ltd. and used the statistical approach for analyzing rejection due to various categories of defect and adopted a logical approach in identifying causes and controlling the defects.

1.2 COMPANY PROFILE:

Santhi Casting Works Pvt.Ltd was initiated in the year 1971 at Kumarapalayam, Narasimmanaickenpalayam, Coimbatore in a small scale with just one unit. It was expanded in the year 1989 into two units and has received the coveted ISO 9002 certification. It has today, established itself as a leading manufacturer in Graded C.I, S.G Iron Castings and Non Ferrous Castings with its clientele comprising some famous names like, Ashok Leyland Pvt.Ltd, Hyundai Pvt.Ltd, V.G. Seviolaxmi Pvt.Ltd, Lakshmi Machine Works and M.M.Gears. The Foundry now has a maximum capacity of 750 Tons.

The Foundry specializes in manufacturing products like Brake Drums for Trucks and Cars, Clutch plates, Gear Box Cover, Automobile Spares, Gear End, Off End, and Textile Spares. It also produces a special nozzle and related parts for BHEL, Trichy. The Company also includes a machining unit for finishing the cast parts, and its finished products are normally taken directly to the assembly line of the client.

The available resources are,

- Induction Furnace (2.00 ton Capacity) 1 Nos
- Induction Furnace (1.00 ton Capacity) 3 Nos
- Induction Furnace (0.50 ton Capacity) 1 Nos
- Induction Furnace (0.25 ton Capacity) 1 Nos
- Arpa 300 BMD Simultaneous Jolt Squeeze 2 pairs
- Arpa 450 BMD Simultaneous Jolt Squeeze 1 pair
- CO_2 Core process 1 Nos
- Shell Core Shooter 2 Nos
- Cold Box Core Shooter 2 Nos
- Twin Table Shot Blasting Machine 2 Nos
- Metal Spectrometer 1 Nos

1.4 LITERATURE SURVEY

1.4.1 Defects in Castings:

Several types of defects may occur during casting, considerably reducing the total output of castings besides increasing the cost of their production. It is therefore essential to understand the causes behind these defects so that they may be suitably eliminated. Casting defects are those characteristics that create a deficiency or imperfection contrary to the quality classifications imposed by the design and the service requirements.

1.4.2 Classification of Defects:

Defects in castings may be of three basic types.

*(1) **Major defects**, which cannot be rectified, resulting in rejection of the casting and total loss. It includes the following defects,*

(a) Blow holes, gas holes, porosity, pinholes, and blisters.

(b) Scar, seams, plates, cold shots.

(c) Shrinkage cavities and depressions

(d) Hot tears and cracks

(e) Hardness defects –mass hardness, hard spots, chilled spots etc.

(f) Misrun and cold shuts

(g) Inclusions of dirt, slag and other materials

(h) Sand defects like erosion scabs, cuts, washers, expansion scabs, buckles, rat-tails, blacking scabs, pull downs.

(i) Mould metal reaction defects like sticker or rat, rough surface, metal penetration, fusion.

*(2) **Defects** that can be remedied but whose cost of repair may not justify the salvage attempt.*

*(3)**Minor defects**, which clearly allow the casting to be economically salvaged and thereby leave a reasonable margin for profits.*

1.4.3 Causes Of the Defects:

1) **The castings design** which includes pattern equipment flask equipment and gating, risering ,moulding sand cores.
2) **The methods of casting** that includes pouring practice melting and moulding practice.
3) **Faulty workmanship.**

1.4.4 Description of Defects:

Shift:

A shift results in a mismatch of the sections of a casting usually at a parting line. This defect is usually easy to identify. Unless the error caused due to mismatching is within the allowable variation on the casting, it cannot be rectified and the casting has to be scrapped. Misalignment of flasks is a common cause of shift. The defect can be prevented by ensuring proper alignment of the pattern or die parts, moulding boxes, correct moulding of patterns plates, and checking of pattern flasks, locating pins, etc, before use.

Warped Casting:

Warpage is an undesirable deformation in a casting which occurs during or after solidification. Large and flat sections or intersecting sections are particularly prone to warpage. A proper casting design can go a long way in reducing the warpage of the casting. A judicious use of ribs can prevent the warping tendency, but an incorrectly placed rib may worsen the defect.

The warpage may occur also due to,

(i) Too small flasks, which may cause rapid cooling of the edges.

(ii) Weak flasks, which may allow movement of the sand mould walls.

(iii) Insufficient getting system, which may not allow rapid pouring of metal.

(iv) Sand with too low green strength, which may cause it to move.

(v)Non-provision of chamber allowance on the pattern, wherever necessary.

Swell:

A swell is an enlargement of the mould cavity by metal pressure, resulting insufficient ramming of the sand. If molten metal is poured too rapidly, a swell may occur. Insufficient weighting of the moulds during pouring may also cause the cope to lift giving a swell.

Fin:

A thin projection of metal, no intended as part of the casting is called a fin. Fins usually occur at the parting of the mould or core sections. A 'run out 'of molten metal may be considered an extreme type of fin. Moulds and cores incorrectly assembled will cause fins. "Kiss Cores" of shorter length than necessary may also give rise to a fin. High metal pressures due to too long sprue or improper clamping of flasks may again produce the fin defect or, if the trouble is more critical, run-out may result in a weak spot and give rise to run-out, may result.

The pattern that is too large for a given flask or placed too close to the flask edge may result in a weak spot and give rise to run-out. Improper sealing of moulding joints may also produce run-outs.

Blowhole:

Blowholes are smooth and round holes clearly perceptible on the surface of the casting. They may be either in the form of a cluster of a large number of small holes having a diameter of about 3 mm or less or in the form of one large and smooth depression. Blowholes are caused in a casting by the generation and/or accumulation of gas or entrapped air in the mould cavity. Gas may accumulate when permeability of sand is low, such as when sand contains high moisture, sand grains are too fine, sand is rammed too hard, or when venting is insufficient. To prevent blowholes the moisture content in sand must be well adjusted, sand of the proper grain size should be used, ramming should not be too hard, and venting should be adequate.

Pinholes:

Pinholes are numerous holes of small diameter, usually less than 2 mm, visible on the surface of the casting. They are caused by the absorption of steel is poured from wet ladles or is not sufficiently degasified. The defect can be minimized by using good melting and fluxing practices, by reducing the moisture content of moulding sand and increasing its permeability, and by promising a faster rate of solidification.

Gas Holes:

Gas holes are those holes that appear when the surface of the casting is machined or when the casting is cut into section. If the core prints are of inadequate size, gap cannot escape from the mould as fast as it is generated in the cores. The accumulation of gas from the core may give rise to gas holes in the casting. Faulty and poor quality of metal, the lack of controlled solidification, and excessively moist sand may also create gas holes.

Shrinkage Cavity:

Shrinkage cavity is a void or depression in the casting caused mainly by uncontrolled and haphazard solidification of the metal. It may be due to wrong location or an improperly seized gating system, inadequate risers, or poor design of casting involving abrupt changes of sectional thicknesses. Shrinkage may also be produced of the pouring temperature is too high. The defect can be eliminated by applying the principles of directional solidification in mould design and by judicious use of chills, denseners and padding.

Porosity:

Porosity is also due to gas formation and gas absorption by the metal while it is poured. Metal may dissolve some gas or air from the mould or core faces. These gases are liberated later when the metal cools, leaving behind porosity in the casting. Obviously, the porosity defects may lead to leaking castings and reduce pressure tightness. Adequate fluxing of metal and controlling the amount of gas producing materials in the moulding and core making process can help in minimizing this defect.

Drops:

When the upper surface of the mould cracks and pieces of sand fall into the molten metal, "Drops" occurs. Sand having too low green strength, soft ramming or insufficient reinforcement of the mould may cause this defect.

Dirt:

Dirt generally appears in the form of foreign particles and sand embedded on the surface of the casting. The causes for this defect may be crushing of the mould due to mishandling, sand wash when the metal is poured because of low strength and soft ramming, insufficient fluxing of molten metal, and presence of slag in the mould due to its incomplete separation from molten metal.

Slag Holes:

These are smooth depressions or cavities on the upper surface if the casting or near it, usually near the gates and are produced when the slag tends to find its way into the mould cavity along with the molten metal. Incorrect gating system and poor fluxing of metal are mainly responsible for this defect.

Scabs:

Scabs are assorted of projection on the casting which occur when a portion of the mould face or core lifts and the metal beneath in a thin layer. Scabs can be recognized as rough, irregular projection on the surface containing embedded sand.

Scabs are of two types:

(i) Expansion scabs.

(ii) Erosion scabs.

An expansion scab is caused by the expansion of the layers of the sand mould. It may occur on any part of the mould, but more often it is found where the sand gets strongly heated, such as the top face of the mould which gets heated first by the radiation of heat from the molten metal rising upwards and then by actual contact with the molten metal. Heating by radiation causes a thin outer layer of sand to dry up and expand, leaving the interior green. This local expansion subjects the layer to serve and it eventually cracks.

Molten metal enters through the crack and flows behind the layer of sand. It appears as a shallow flat topped projection on the casting

An erosion scab may occur when metal where metal has been agitated or has partly eroded the sand, leaving behind a solid mass of sand and metal at the spot where erosion took place. The sand that is eroded may find its way to the top part of the mould as dirt inclusion. Erosion scabs may thus be caused by hard and uneven ramming, improper selection of gates such that metal impinges on the mould or core and its flow is not streamlines, too high a moisture content in sand, too low permeability of sand, intermittent pouring of metal, or insufficiently baked cores or moulds.

Hot Tears:

Hot tears are internal or external ragged discontinuities or cracks on the casting surface, caused by hindered contraction occurring immediately after the metal has solidified. They may be produced when the casting is poorly designed and abrupt sectional changes take place, no proper fillets and corner radii are provided, and chills are inappropriately placed. Hot tears may also be caused when the mould and core have poor collapsibility or when the ramming is too hard and the casting is thereby under severe strain during cooling. Incorrect pouring temperatures and improper placement of gates and risers can also create hot tears. Methods to prevent hot tears may entail improving the casting design, achieving directional solidification and even rate of cooling all over, selecting proper mould and core materials to suit the cast metal and controlling the mould hardness in relation to other ingredients of sand.

Cold Shut and Misrun:

A cold shut is a defect in which a discontinuity is formed due to the imperfect fusion of two streams of metal in the mould cavity. The defect may appear like a crack or seam with smooth rounded edges. A Misrun casting is one that remains incomplete due to the failure of metals fill the entire wall thickness, ... slow and intermittent pouring, poor quality of metal cavity is not completely filled because of insufficient metal, the defect is called "Pour short".

1.4.5 Analysis of the Defect:

When a defective casting is produced it is necessary to analyze or observe them to determine the causes for their occurrence, so as to identify critical errors in the process. Such a thorough analysis can bring out possible solutions for the eradication of such defects and is sure to improve the productivity of the foundry.

Often, there are a large number of inter-related factors affecting the occurrence of any defect and it becomes difficult to determine the exact causes. In order to assist analysis of defects cause and effect diagrams can be prepared showing major causes and all the possible reasons for those causes.

1.4.6 Inspection of Castings:

Two basic objectives of inspection are

(1) To reject castings that fail to meet the customers' requirements.

(2) To serve as a means of maintaining the quality of workmanship and materials used in the foundries.

Inspection of castings broadly covers a large number of methods and techniques used to check the quality of castings. These methods may be classified into five categories.

1. Visual inspection
2. Dimensional inspection
3. Mechanical and chemical testing
4. Flaw deduction by non-destructive methods.
5. Metallurgical inspection

CHAPTER 2

SELECTION OF PRODUCT

2.1. DEFINING THE PROCESS OF SELECTION

The process of identifying appropriate product plays an important role in making the case study effective. This is because a case study done on inappropriate product would drastically vary the scope of project providing erroneous study parameters. So appropriate identification for, synchronizing the project case study along with the scope of project becomes essential.

The project identification involves the following three steps,

(1) Setting up criteria for project selection,

(2) Product data collection (based on criteria)

(3) Selection of product variety.

2.2. SELECTION CRITERIA

The various criteria on basis of which product for the case study is to be selected has been identified keeping in mind, the project in phase with its scope.

2.2.1 The Selection Criteria with Its Influence:

The various criteria selected based on the requirement of project are as follows,

(1) Frequency of rejections:

REASON - The man hour, machine-hour, post-machining cost & time

(2) Weight of the product:

REASON - To reduce the wastage, so as to control the product yield cost and to improve casting yield

(3) Number of defects encountered:

REASON - Based on consideration of making the analysis effective and to expand the scope to be generalizing it for all foundries.

(4)Production consistency:

REASON- The study can be applied only if the production rate per month is consistent during the period of study, which includes, period of observation before and after recommendations. As a result the product selected has to be produced in batches that are constant through out the period of study

2.3. PRODUCT DATA COLLECTION

Data on product is collected based on the above mentioned criteria and products are short-listed based on the suitability to the problem considered.

2.3.1 First Stage of Selection:

The short listed products have production for the next six months consistently. Also these products have been identified to be involved with a number of complications and more number of rejection causing defects.

The preliminary short list covers the following products;

- Sump
- Gearbox Cover
- Brake Drums
- Face Plates
- Pulley
- Clutch Plates
- Textile Spares
- Gear End
- Off End

2.3.2 Second Stage of Selection:

In second stage of selection, the criterion of "REJECTION FREQUENCY" has been given prime consideration. In consultation with Plant Production Manager and in reference to past rejection report, the products with high rejection frequency along with the data on the above mentioned four selection parameters has been listed in table below

Table 2.1 PRODUCT SELECTION

S.No	Product	Frequency of Rejection	Weight of product (kg)	No. of defects encountered	Production per month
1.	Sump	4.28	41	177	4158
2.	10TG Drum	7.16	60	211	2940
3.	End Bearing	-	230	-	5
4.	608 Drum	7.59	54	223	3181
5.	MXI Drum	8.4	12	205	2450

*Values are the average for one month

2.4 PRODUCT SELECTION

The final selection of product has been based on the criteria of "PRODUCT WEIGHT" so as to benefit the industry in saving the scrap cost (or) salvage loss. Also the defect variety has been taken into account along with the process involved so as to make analysis effective. The products chosen for the case study are as follows,

1. **10TG Brake Drum (S-1869122)**
2. **608 Brake Drum (S-1860822)**

The products are selected with similarity so as to make the process analysis easier and simpler. Also the rejection frequency is comparatively more (around 7% and 8% respectively).

These two products are the part of automobile braking. These brake drums are used in drum brake assembly for braking in the vehicle. The customer of the product is Ashok Leyland Pvt. Ltd.

The products are represented in the following photographic figures,

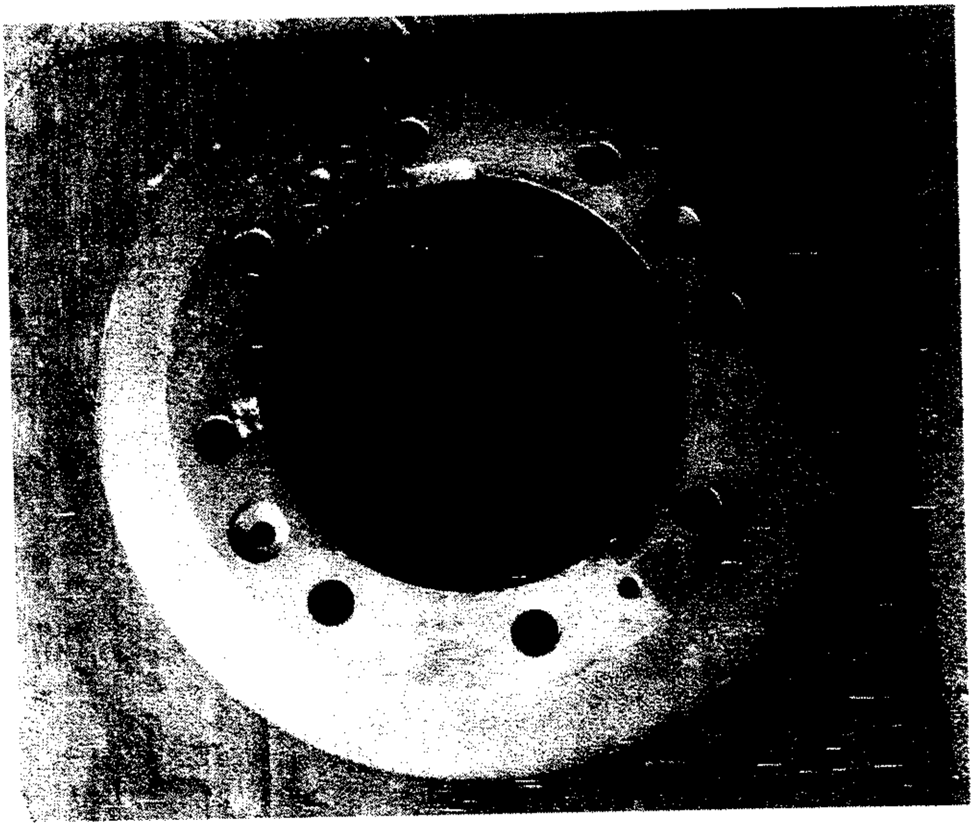


FIGURE 2.1 FRONT VIEW OF 10TG BRAKE DRUM

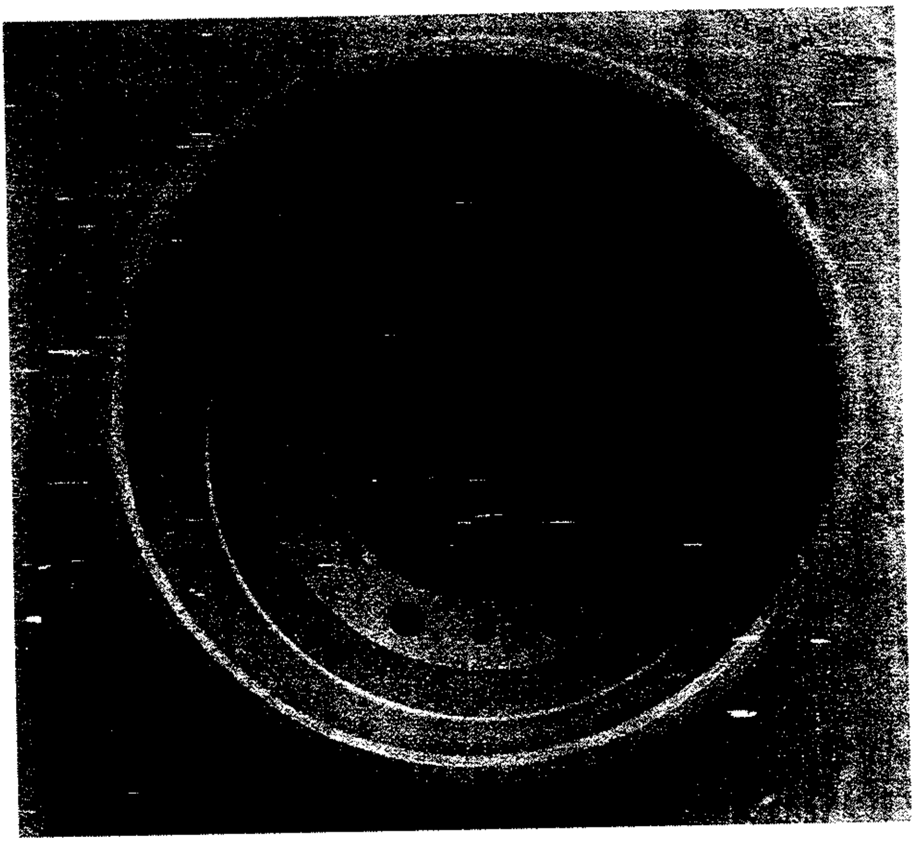


FIGURE 2.2 REAR VIEW 10TG BRAKE DRUM

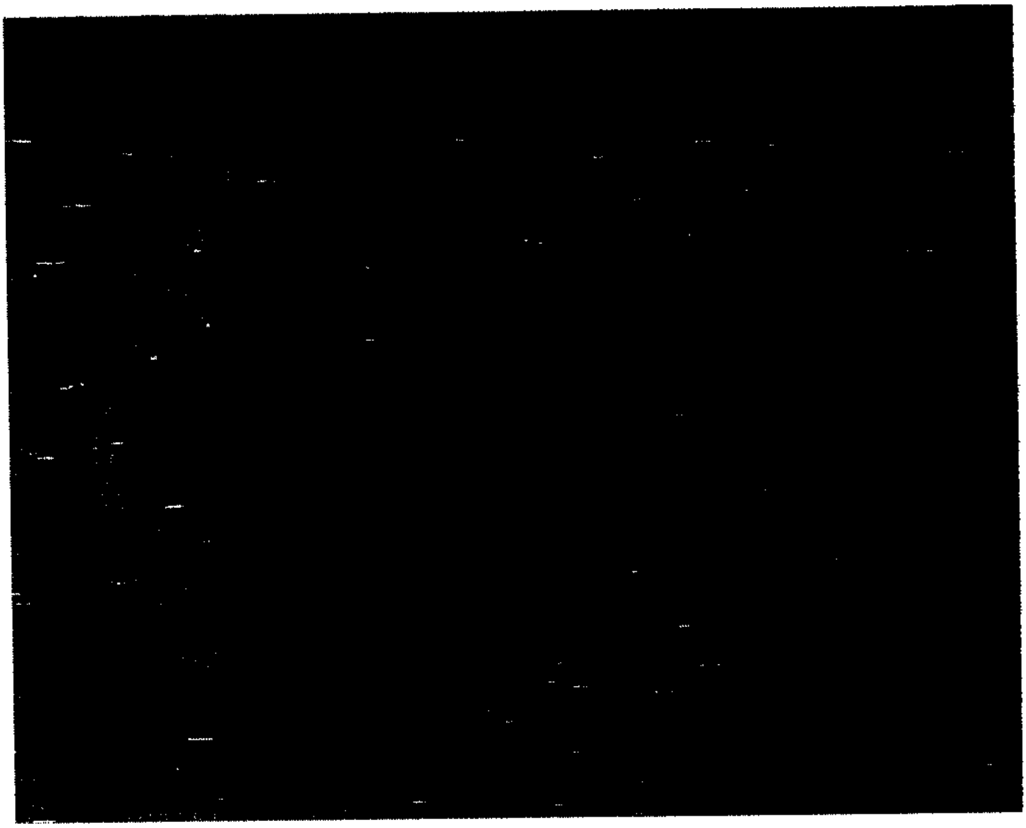
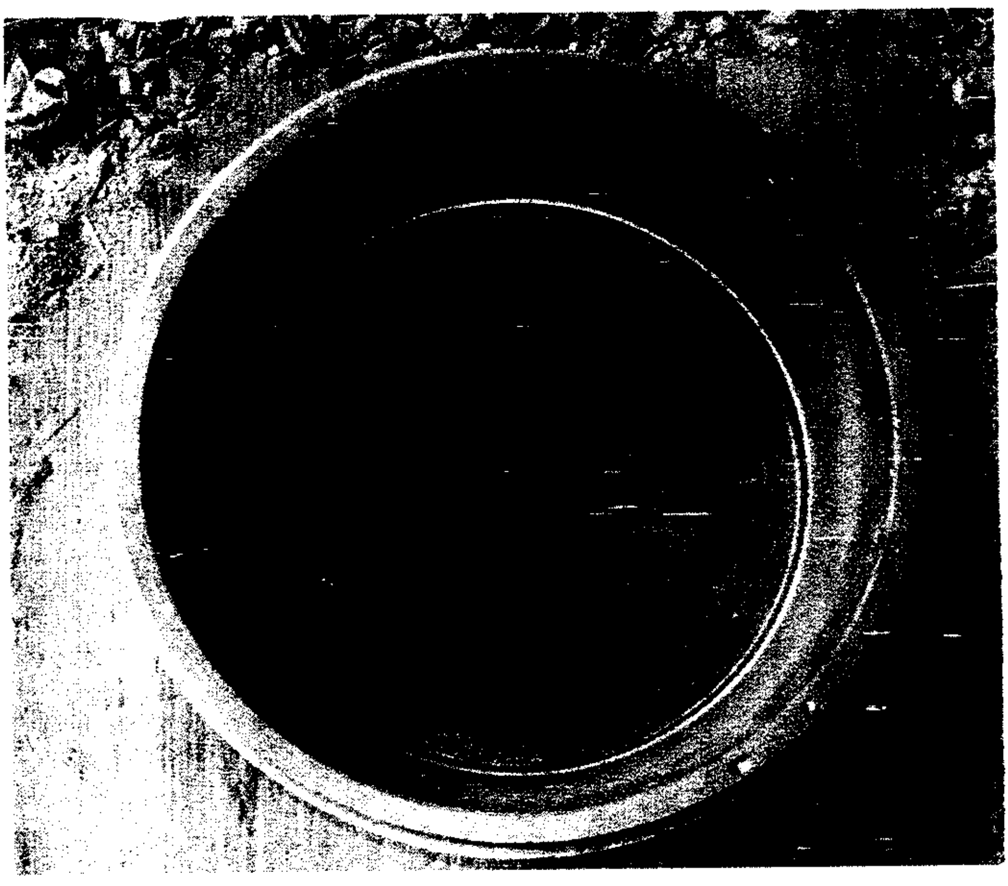


FIGURE 2.3 FRONT VIEW OF 608 BRAKE DRUM



OF 608 BRAKE DRUM

CHAPTER 3

ADOPTING STATISTICAL APPROACH

3.1. IMPORTANCE OF STATISTICAL APPROACH

3.1.1 Methods of arriving at a solution to the problem:

There are two main approaches to solving problems. They are,

1. Theoretical approach
2. Statistical Problem solving approach

THE THEORETICAL APPROACH:

The approach also known as the deductive methods is employed to solve the problems by using relevant physical, chemical, economical (or) other scientific theories (or) by analog with similar past occurrences.

THE STATISTICAL PROBLEM SOLVING APPROACH:

This approach could be described as inductive. In this approach we trace the causes of the phenomenon by repeatedly asking "why"? And identify the root causes of the problem from the facts.

3.1.2 The Problem Solving Process:

The conventional method of solving problems is based on trial and error. It consists of examining problems in the light of experience intuition, nerve (or) random inspiration, planning and implementing countermeasures based on the inferences, and starting over again if things do not go well. This approach, however does not work with matters in which we lack experience and fail to solve the problem if our intuition is off the mark.

The statistical approach to tackling problems can be split into three main stages and the differences between this and the conventional approach lie in stage 2 in the statistical approach, which is that, we do not rely merely in experience and random inspiration, but analyze the process based on factual data and accurately identify the factors adversely affecting the results.

3.1.3 The Seven Step Formula:

(Solving Process the Statistical Way)

Step 1.	:	Selection of topic
Step 2.	:	Understanding situation and setting targets.
Step 3.	:	Planning of activities
Step 4.	:	Analyzing causes
Step 5.	:	Consider action and implement action of counter measures.
Step 6.	:	Checking of result
Step 7.	:	Standardize and establishment of control.

3.1.4 Benefits of Statistical Problem Solving Approach:

(1) It enables problems to be solved more rationally, scientifically, efficiently and effectively than any other method.

(2) It lightens every person's problem - formulating and problem - solving difficulties and enables every body to play an important role in the workplace.

(3) It enables people to acquire the statistical view point through solving problems.

(4) It enables people to become competent in applying the statistical tools and allows them to master the scientific approach.

(5) It gives tangible benefits, mainly in terms of quality, but also in terms of cost delivery safety, morale, sales and so on.

(6) It improves work practices and raises management standards.

(7) It boosts the leadership and management abilities of workplace leaders.

(8) It promotes the personal growth of individual workplace members.

(9) It improves workplace communication and moral and greats cheerful, effective workplaces.

(10) It stimulates QC circle and quality term activities.

3.2. APPLICATION OF STATISTICAL APPROACH

3.2.1 Identifying the Facts:

In statistical approach we try as far as possible to make our various judgments based on the facts, not on guesswork. Our slogan is "speak with facts". If we are going to take the correct action it is essential to have a constant accurate grasp of the facts. When we go out and collect data. New facts come to light, and it often becomes clear that our vague guesses based on experience were way off the mark. Checking the facts enables us to devise effective countermeasures leading to good results. It is important to be constantly in command of the facts and to accept them for what they are.

Management by fact means not making decisions based on experience and intuition alone but acting in accordance with the facts.

3.2.2 Process of Application:

In order to make our decisions and actions on the facts we have to first quantify the situation in the form of data and convert our subjective judgments into important facts to follow the procedure described below.

Step 1: closely observe the actual location and actual objects.

Hint: Target the 4M (men, material, methods, machine)

Step 2: Decide on characteristics to be investigated.

Hint: select from among quality, cost, and quantifiable characteristics.

Step 3: Clarify the objectives of collecting the data.

Hint: for analysis? for adjustment?, for control?, for inspection?

Step 4: Collect accurate data

Hint: use check sheets, answer the 5W&1H

(What? where? when? why? who? how?)

Step 5: Carefully analyze the data using Q-7 tools.

Hint: seven QC tools, statistical method.

Step 6: Consider the results and produce accurate information.

Hint: proper transformation of info to next stage.

3.3. SELECTION OF Q-7 TOOLS

3.3.1 The list of Q-7 Tools:

The seven QC tools used for statistical approach of problem solving are as follows,

(1) Cause and effect diagrams.

(2) Pareto diagram

(3) Graphs

(4) Check sheets

(5) Histograms

(6) Scatter diagrams

(7) Control charts

3.3.2 Selection Of Q-7 Tools To Be Used In This Study:

The following quality control tools are used in this study.

1. Check Sheets
2. Pareto Charts
3. Cause and effect diagram

The specific reason for selecting the above Q.7 tools is shown in the table 3.1. The cause and effect diagram and Pareto diagram are giving the effective results in quality and the control charts are giving the effective result in process control.

Based on the effectiveness of Q-7 tools for a particular application and in comparison with requirement in this project, the above mentioned Q-7 tools have been selected. The table showing the effectiveness of Q-7 tools with respect to the application is given below,

Table 3.1 SELECTION OF Q7 TOOLS

Name & Application	New Product Development	Quality Improvement	Process Control	Administration	Sales management	Safety Management
Cause & Effect Diagram	✗	✓	✗	✓	✓	✓
Pareto Diagram	✗	✓	✗	✓	✓	✓
Graphs & Charts	✗	✗	✗	✓	✓	✓
Check Sheets	✗	✗	✓	✓	✓	✓
Control Charts	✗	✗	✓	-	-	✗
Histogram	✗	✓	✓	✓	✓	✓
Scatter Diagram	✗	✓	✗	✗	✗	✗

✓	*Most Suitable*	✗	*Applicable*

CHAPTER 4

PROCESS ANALYSIS

. In this chapter the various parameters influencing the process and factors that affects quality of product causing rejection of components have been identified and evaluated so as to correlate with the data on defects, in order to facilitate elimination of the causes by appropriate recommendations. The various stages of process have been thoroughly investigated. The inference obtained is as follows.

4.1. ANALYSIS ON SAND PREPARATION

Sand, the principle moulding material in foundry shop, has to be prepared with care so as to ensure that it possesses the important characteristics like refractory nature to withstand high temperature, chemical resistivity, and high degree of permeability to allow gases to escape.

4.1.1. Analysis of Sand Composition:

The principle ingredients of moulding sand are silica sand grains, clay (for bonding), moisture, Coal Dust, Bentonite, and Lustron. The data on ingredients of molding sand collected from moulding shop is as follows:

Table 4.1 SAND INGREDIENTS COMPOSITION

S.NO	INGREDIENT	WEIGHT(kg)	PERCENTAGE%
(1)	Return sand	450	82.5
(2)	New sand	60	13.5
(3)	Coal Dust	16	1.8
(4)	Bentonite	2	2.2
(5)	Lustron	2	2

4.1.2. Process of Preparation:

The knock out of the mould is done on the vibrator piate and holes are provided to collect the moulding sand. Then the return sand is passed through a conveyor over a magnetic separator. This device consists of a drum which is magnetized half a side. When return sand comes in contact with the magnetized side, the magnetic impurities contained in the sand are attracted and while it comes to the opposite side it gets demagnetized and hence the magnetic particles fall down on a collector drum. Then the sand will be poured over a reciprocating plate to extract dust which will be absorbed through a vacuum blower. The sand is then passed through the sand sieve to filter out the clay lumps and other tiny metal pieces that had escaped the magnetic separator. The sand sieve is a polygon shaped drum to a length of 6 m provided with a mesh for filtering. Then it is passed through a cooler (water spray type) and finally it is poured into the bunker through a conveyor.

A dust collector along with a blower is provided wherever the sand is passed on from one stage to the next. The sand from the bunker is brought through the conveyor to the mixer. The opening of the bunker is closed by the conveyor with by means of a small amount of clearance. The movement of the conveyor is properly controlled so as to deliver the required amount of sand to the mixer.

In mixer the required proportion of new sand and other additives are added manually and mixed well. The well mixed sand will be ready to use and it is transferred to corresponding jolting machine through a centralized conveyor which includes bucket elevator , horizontal conveyor system and fish mouth hopper. The fish mouth hopper is used to pour sand over the moulding box and is operated by a lever and link mechanism

4.1.3. Testing Of Sand:

The prepared green sand is tested periodically before using it for moulding. The testing of sand is done at regular intervals. The following tests are carried out.

The testing equipments are listed in table 4.2 and the testing results are given in table 4.3 respectively.

Table 4.2 TESTING EQUIPMENTS

S.NO	NAMES OF TESTING	NAME OF TESTER
(1)	Testing of moisture content	Infra-red moisture teller
(2)	Compatibility test	Compatibility tester
(3)	GCS test	Universal testing machine
(4)	GSS test	Universal testing machine
(5)	Permeability test	Permeability air flow meter.
(6)	Grain size(AFS number)	Sieve shaker.
(7)	Active clay content	Methylene blue test.
(8)	DCS test	DCS testing

Data collected on the results of testing of sand specimen of block dimension 2" x 2" x dia.2" (149.4gms) at sand temperature of 47 °C (Muller) and 35 °C (moulding) are as follows:

Table 4.3 TESTING RESULTS

S.NO	TESTING PARAMETER	TESTING VALUE
(1)	Moisture content	3.3%
(2)	Compatibility	43
(3)	Green compression strength	1.25 kg/cm^2
(4)	Green shear strength	350 gm/cm^2
(5)	Permeability	Permeability number 163

4.2. ANALYSIS ON MOULDING

4.2.1. Data on Moulding Equipments:

The data collected from the moulding department is given in table 4.4,

FIGURE 4.1 PATTERN OF 10TG BRAKE DRUM

FIGURE 4.2 PATTERN OF 608 BRAKE DRUM

Table 4.4 MOULDING EQUIPMENTS

S.NO	NAME OF EQUIPMENT	EQUIPMENT IN USE
(1)	Type of pattern	Single piece pattern
(2)	Pattern material	Aluminium
(3)	Moulding type	Green sand mould
(4)	Moulding method	Machine moulding
(5)	Flasks Used	One cope and one drag box (Prepared on separate m/c)
(6)	Reinforcements	4 M.S.nails
(8)	Transportation of moulds	Machine transportation

4.2.2. Moulding Process:

The moulding sand prepared in the sand muller is transferred to the moulding box through a centralized conveyor on the roof. The moulding machines are arranged in-line and hopper is provided over every machine with electro-mechanical controlled opening & closing provisions. Two machines are placed opposite to each other to prepare cope and drag simultaneously. These boxes are later transferred to the box rail and matched together and clamped.

The moulding process carried out in the simultaneous jolting and squeeze type moulding machine is described below.

First of all the pattern plate will be placed on the table of jolting and squeezing machine. Then the fish mouth of the hopper is opened and sand is poured over the pattern jolting action is started to consolidate the sand on the face of the pattern and thus initial sand packing is achieved. Then consecutively the squeezing action is made to impart the desired density in the upper portion of the mould.

Following this again some sand is poured over the mould surface and then simultaneous jolting and squeezing is made to finish the mould at required degree of mould quality which includes mould hardness, bonding of mould, etc.,

This process is carried out simultaneously for cope and drag boxes and then finished drag box is first transferred to assembling rail through the trolley. Then the finished cope box is held in over head box lifter. Then the formation of pouring mouth is done. After this it is cleaned with compressed air and is placed over the drag box and aligned properly and finally the boxes are clamped together. The prepared moulding boxes are passed on to the melting section by means of trolley on rails.

4.3. ANALYSIS ON MELTING AND POURING

4.3.1 Data on Melting Equipments:

The following are the data collected from melting and pouring department,

1. Furnace Type	:	Electric Induction Furnace
2. Capacity of Furnace	:	1 ton
3. Power Requirement	:	550 kW
4. Induction Frequency	:	60 Hz (Medium)
5. Melting Time	:	1 hr to 1.15 hrs
6. Tapping Temperature	:	1475 °C to 1500 °C
7. Pouring Temperature	:	1400 °C to 1425 °C
8. Pouring Type	:	Hand Shank
9. Pouring Equipment Used	:	Ladles
10. Pouring Time	:	8.5 min (completion of last mould)
11. Transportation	:	Through overhead pulleys
12. Charge Mix	:	

Table 4.5 CHARGE MIX

S.No	Ingredients	Percentage %
1.	**Pig Iron**	**32.82**
2.	**Steel Scrap**	**18.34**
3.	**Borings**	**26.67**
4.	**Returns**	**22.17**
5.	**Coke**	**3 to 4 kg**

13. Metal composition :

Table 4.6 METAL COMPOSITION

S.No	Element	Percentage %
1.	**Carbon**	**3.3**
2.	**Silicon**	**1.82**
3.	**Manganese**	**0.83**
4.	**Chromium**	**.18**
5.	**Sulphur**	**0.15 max.**
6.	**Phosphorous**	**0.2 max.**
7.	**Copper**	**0.25**

4.3.2. Melting and Pouring Process:

The medium frequency 450 kw furnace has normal melting rate and high frequency 1000 kw has high rate of melting and it is of dual track type i.e., the electrical supply is connected to two furnace which are ten meters apart but however only one furnace could be supplied with power . The advantage of this set up is that when melting is carried out in one furnace loading is done in another. This helps to reduce time in loading the charge mix. During finishing stage of melting the metal sample will be tested in spectrometer for checking up the composition. If it deviates from standard, then additional amounts of deficit components would be added. The metal is tapped out of furnace in ladles and transported to the moulding box rails (at a distance of about 100 – 150 mts) and poured through sprue at a timing of about 14 seconds per moulding box. After pouring the mould it is allowed to settle and it gets cooled.

4.4 RESULT OF ANALYSIS

The process of casting the brake drums is thoroughly analyzed. This analysis would be helpful in finding out the reason for rejections and in planning to overcome it. The data collected on various process stages will be compared with the rejection data and root cause of the defects will be identified.

CHAPTER 5

DATA COLLECTION

The rejection data of the components are systematically collected using check sheets, one of the Quality Control Tools. The following tables (Table 5.1 to Table 5.4) illustrate the rejection data.

5.1 DATA OF 10TG BRAKE DRUMS:

The following tables (Table 5.1 and Table 5.2) give the consolidated rejection data from various departments on 10TG Brake Drums for the months of January and February. The final table (Table 5.3) gives the average rejection percentage for both the months

Table 5.1 CHECK SHEET - 1

Product Name: 10TG Brake Drum		Weight: 60 kg (product) : 72 kg (Incl Runner & Riser)	
Product Code: S - 1869122			
Period : January 2007		Lot Size : 2940 pcs/month	
S.No	Rejection	Count	Total
1.	Blow holes	///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///	63
2.	Shift	///// ///// ///// ///// ///// ///// /////	30
3.	Rough Surface	///// ///// ///// ///// ///// ///// ///// /	28
4.	Sand Drop	///// ///// ///// ///// ///// ///// /////	24
5.	Scabbing	///// ///// ///// /////	10
6.	Shrinkage	///// ////	9
7.	Cold Shut	///// ///// ///// //	17
8.	Damages	/////	5

Table 5.2 CHECK SHEET - 2

Product Name: 10TG Brake Drum		Weight: 60 kg (product) : 72 kg (Incl Runner & Riser)	
Product Code: S - 1869122			
Period : February 2007		Lot Size : 2940 pcs/month	
S.No	**Rejection**	**Count**	**Total**
1.	Blow holes	///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///	78
2.	Shift	///// ///// ///// ///// ///// ///// ///// /	36
3.	Rough Surface	///// ///// ///// ///// ///// ///// /////	35
4.	Sand Drop	///// ///// ///// ///// ///// ///// ///// ///	38
5.	Scabbing	///// ///// /////	15
6.	Shrinkage	///// ///// /	11
7.	Cold Shut	///// ///// ////	14
8.	Damages	///// ///	8

Table 5.3 Rejection Table for 10TG Brake Drum

S.No	Rejection Type	No. of units Rejected	Percentage
1.	Blow Holes	70.5	33.49
2.	Shift	33	15.68
3.	Rough Surface	31.5	14.96
4.	Sand Drop	31	14.73
5.	Scabbing	12.5	5.94
6.	Shrinkage	10	4.75
7.	Cold Shut	15.5	7.36
8.	Damages	6.5	3.09
	Overall Rejection Percentage	7.16 %	

5.1 DATA OF 608 BRAKE DRUMS:

The following tables (Table 5.4 and Table 5.5) give the consolidated rejection data from various departments on 608 Brake Drums for the months of January and February.

Table 5.4 CHECK SHEET - 3

Product Name: 608 Brake Drum		Weight: 54 kg (product) : 64.82 kg (Incl Runner & Riser)	
Product Code: S - 1860822			
Period : January 2007		Lot Size : 3181 pcs/month	
S.No	Rejection	Count	Total
1.	Blow holes	///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// /////	60
2.	Shift	///// ///// ///// ///// ///// ///// //	32
3.	Rough Surface	///// ///// ///// ///// ///// ///// /	31
4.	Sand Drop	///// ///// ///// ///// ///// /////	30
5.	Scabbing	///// ///// ///// ///// //	42
6.	Shrinkage	///// //	7
7.	Cold Shut	/////	5
8.	Damages	////	4

Table 5.5 CHECK SHEET - 4

Product Name: 608 Brake Drum	Weight: 54 kg (product) : 64.82 kg (Incl Runner & Riser)
Product Code: S - 1860822	
Period : February 2007	Lot Size : 3181 pcs/month

S.No	Rejection	Count	Total
1.	Blow holes	///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///// ///	83
2.	Shift	///// ///// ///// ///// ///// ///// ///// ///// ////	44
3.	Rough Surface	///// ///// ///// ///// ///// ///// ///	33
4.	Sand Drop	///// ///// ///// ///// ///// ///// ///// ///	38
5.	Scabbing	///// ///// ///// ////	19
6.	Shrinkage	///// ///// ///	13
7.	Cold Shut	///// /	6
8.	Damages	///// ////	9

Table 5.6 Rejection Table for 608 Brake Drum

S.No	Rejection Type	No. of units Rejected	Percentage
1.	Blow Holes	69.00	30.94
2.	Shift	34.00	15.25
3.	Rough Surface	33.00	14.80
4.	Sand Drop	34.00	15.25
5.	Scabbing	28.50	12.78
6.	Shrinkage	9.00	4.04
7.	Cold Shut	9.50	4.26
8.	Damages	6.00	2.69
Overall Rejection Percentage		7.59 %	

CHAPTER 6

ANALYSIS ON DATA

6.1 DESCRIPTION OF PARETO CHART

Pareto chart, one of Q-7 tools, can be used for effectively analyzing the defects and those defects which cause about 70% -80% of total rejection can be identified. The rejection data collected previously is plotted in a Pareto chart and analyzed to obtain the major sources of rejection of castings.

The following five steps are followed in drawing the Pareto chart.

(1) Determine the method of classifying the data:
by problem, by cause, by nonconformity, and so forth.

(2) Decide if cost (best), frequency, or both are to be used to rank the characteristics.

(3) Collect data for an appropriate time interval or use historical data.

(4) Summarize the data and rank order categories from largest to smallest

(5) Construct the diagram and find the vital few.

The Pareto chart for 10 TG Brake Drum and 608 Brake Drum are given below in fig.6.1 and 6.2 respectively.

6.2 RESULT OF PARETO ANALYSIS

Based on the analysis of rejection data of 10TG and 608 Brake Drums made with the help of Pareto charts, the following defects are identified to be contributing to major part of the rejections. The defects are as follows,

a. Blow Holes
b. Shift
c. Rough Surface
d. Sand Drop
e. Scabbing
f. Shrinkage
g. Cold Shut

As these defects are found to be major defects in 10TG and 608 Brake Drums, further process will be carried out in view of these seven defects.

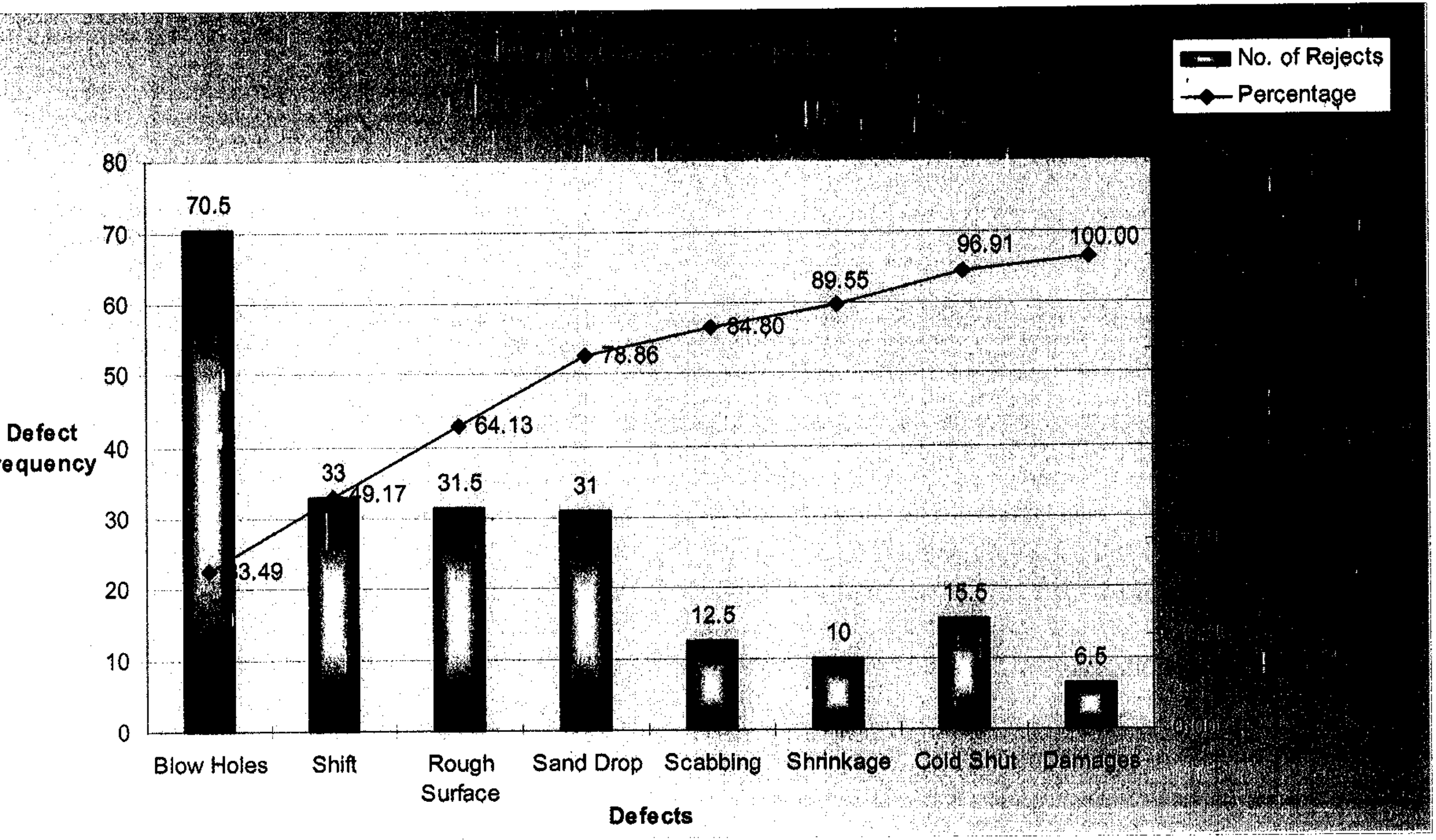


FIGURE 6.1 PARETO ANALYSIS ON 10TG DRUMS

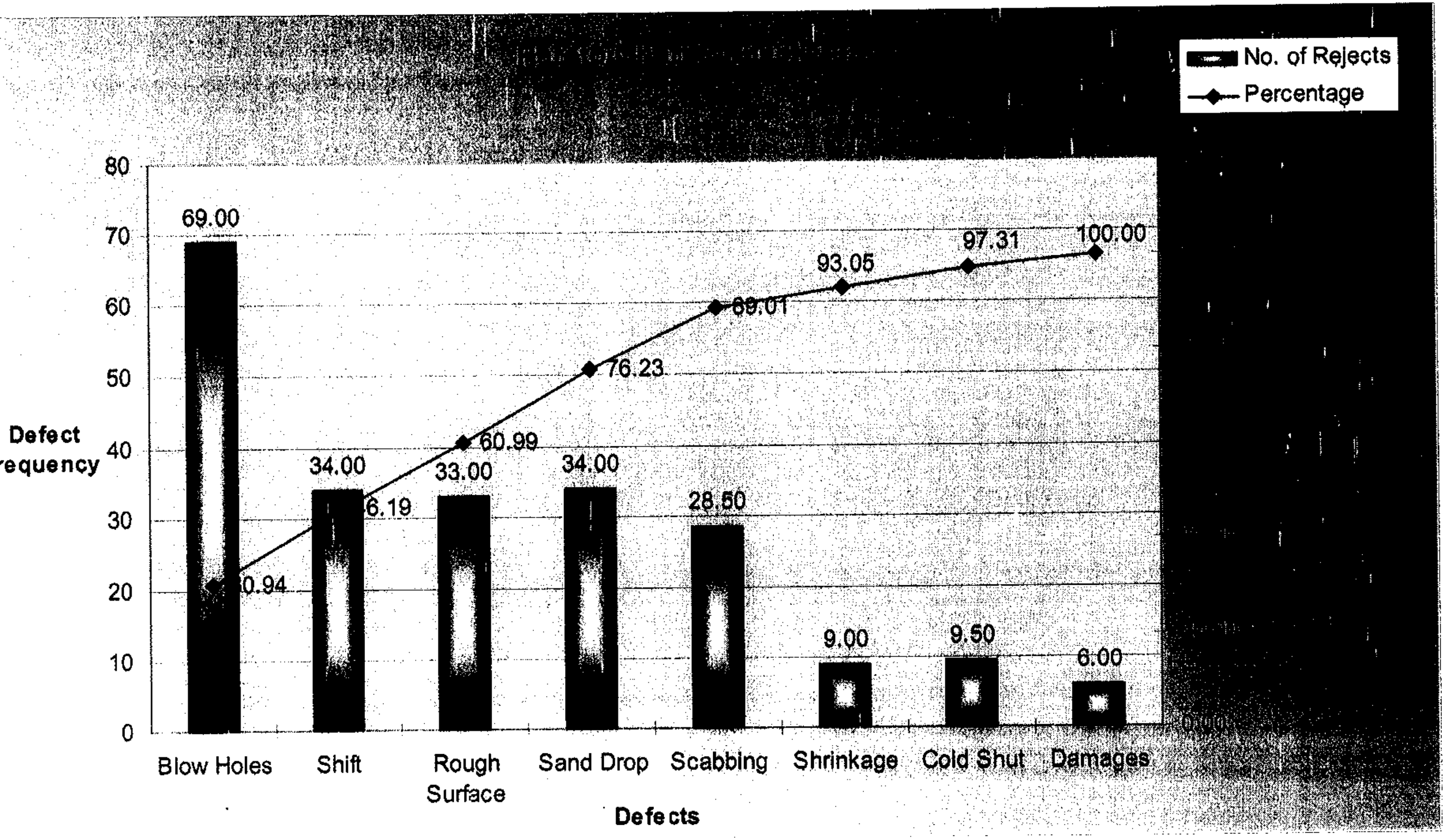


FIGURE 6.2 PARETO ANALYSIS ON 608 DRUMS

CHAPTER 7

POTENTIAL CAUSES AND REMEDIES BY TRADITIONAL APPROACH

7.1. POTENTIAL CAUSES

7.1.1 Potential Causes for Blow Holes:

The various potential causes identified based on process analysis and cause and effect diagram are listed below,

(1) Insufficient permeability of moulding/core sand.

(2) Presence of dead clay forming clay balls and also not mixing with sand.

(3) Gas accumulation at parting line due to too close cavities.

(4) Too low pouring temperature causing quick cooling of certain portion.

(5) Repouring of metal from ladle to furnace.

(6) Flask wall too close to mould surface.

(7) Gating system causing turbulence.

(8) Inadequate riser height.

(9) Slow pouring of metal or interrupted pouring.

(10) Late pouring of metal causing mould and core absorbing moisture.

(11) Unclean metal (painted scrap) entering into mould.

(12) High pouring time.

(13) Excessive clay binder in sand.

(14) Too high return sand with lot of dead clay.

(15) Too much moisture on core sand.

(16) Under baked cores.

(17) Inadequate venting on core.

(18) Use of wet core without proper drying.

(19) Mould wash too heavy to dry.

(20) Hard spot caused by improper ramming due to misplacement of flask.

(21) Venting through parting line.

(22) No preheating of Ladle

7.1.2 Potential Causes for Shifts:

The various potential causes identified based on process analysis and cause and effect diagram are listed below.

(1) Mismatch of different sections of a casting at the parting line.

(2) Misalignment of flasks.

(3) Improper alignment of pattern.

(4) Improper alignment of die parts

(5) Incorrect mounting of patterns on pattern plates.

(6) Mismatch of moulding boxes.

(7) Improper locating pins

(8) Misalignments of core halves during assembly

(9) Undersized or oversized coreprints.

(10) Incorrectly sized chaplets

(11) Improper use of prints and chaplets

(12) Improper dimensions of the flasks.

7.1.3 Potential Causes Rough Surface:

The various potential causes identified based on process analysis and cause and effect diagram are as follows,

(1) Isolated heavy section or light section requiring careful handling.

(2) Tie bars or reinforcing ribs not properly used.

(3) Lack of adequate fillets.

(4) Break up notches not provided.

(5) Worn out match plate causing parting line fins.

(6) Gating system promoting stresses.

(7) Too heavy risering.

(8) Poor collapsibility of core.

(9) Not using pre-measured quantity and standard measures for core sand mixing causing poor collapsibility.

(10) More hot strength on sand.

(11) High dry compression strength.

(12) Low green sand deformation.

(13) Hard ramming causing hard mould.

(14) Improper inoculation.

(15) Excessive carbide stabilizer.

(16) Red hot knock out.

(17) Casting failing to destroy binder property due to insufficient pouring temperature.

(18) Too heavy grinding causing crack.

(19) Improper design of shake out grid.

(20) Too much amplitude of vibration in shake out machine.

(21) More accumulation of casting at shot blasting section.

7.1.4 Potential Causes for Sand Drop:

The various potential causes identified based on process analysis and cause and effect diagram are listed below,

(1) Insufficient permeability of moulding/core sand.

(2) Core print not properly mounted onto the mould cavity.

(3) Insufficient core print to support the cores leading to sand drop.

(4) Weak, loose, springy flasks and bars.

(5) Rough handling of moulding boxes.

(6) Strong backing sand with weak facing sand or vice versa.

(7) Dropping of mould box or some weights over flask.

(8) Insufficient draft / back draft on pattern.

(9) Worn-out / damaged pattern and core boxes.

(10) Lack of crushing strips and sand collector.

(11) Worn-out match plate bushing.

(12) Excessive core wash or wet core.

(13) Insufficient dry strength of core.

(14) Worn-out pins and bushings.

(15) Improper reinforcement of moulding boxes.

(16) Improper blowing of moulds.

(17) Uneven levels of bottom of moulding box.

(18) Wet sand adhering to the inside wall of the moulding box.

(19) Low green compression strength of sand due to insufficient active clay.

(20) The nose of ladle touching the sprue.

(21) Resting of pouring ladles on moulding flask.

7.1.5 Potential Causes for Scabbing:

The various potential causes identified based on process analysis and cause and effect diagram are as follows,

(1) Insufficient fillets on gates and section changes.

(2) Bars improperly placed preventing uniform ramming.

(3) Rigging into small flask so that the vertical pattern wall is too close to flask reinforcement bar.

(4) Metal flow causing impingement on mould cavity.

(5) Gating causing localized overheating.

(6) Gating causing interrupted flow.

(7) Improper gating causing interrupted metal flow.

(8) Excessive pouring temperature.

(9) Interrupted pouring of metal.

(10) Too quick poring causing metal impinging on sand surface.

(11) High moisture content causing erosion of sand due to weakness.

(12) Insufficient hot strength.

(13) Excessive carbonaceous material causing boiling.

(14) Improper conditioning of sand.

(15) Dead clay at sand surface causing erosion.

(16) Excessive moisture on skin of core.

(17) Inadequate penetration of core wash.

(18) Insufficient hot strength on sand.

(19) Excessive sticking of sand on mould surface.

(20) Core blow causing scabbing on adjacent mould surface.

7.1.6 Potential Causes for Shrinkage:

The various potential causes identified based on process analysis and cause and effect diagram are listed below,

(1) Change in gating and pouring sprue section too abrupt.

(2) Isolated heavy sections unable to be fed.

(3) Area of feeding is insufficient at isolated sections.

(4) Gates and risers not promoting progressive solidification.

(5) Insufficient number of gating or risering.

(6) Risers too small-no feeding aids.

(7) Thin sections blocking feed path due to worn out section.

(8) Insufficient jolting capacity.

(9) Insufficient box size.

(10) Feed metal requirement not met due to improper gating arrangement.

(11) Pouring passage too long.

(12) Improper ratio of riser neck to casting section.

(13) Over inoculation.

(14) Too low phosphorus content.

(15) Pouring metal either too cold or too hot.

(16) Improper clamping of flasks.

(17) Mould or core having too high rigidity not allowing contraction.

(18) Cope flasks too shallow.

(19) Mould wall movement-no rigidity.

(20) Use of ineffective chills causing rapid cooling.

7.1.6 Potential Causes for Cold Shut:

The various potential causes identified based on process analysis and cause and effect diagram are listed below,

(1) Thin sections.

(2) Improper wall thickness.

(3) Improper gating system.

(4) Damaged patterns

(5) Slow pouring

(6) Intermittent pouring

(7) Poor fluidity of metal, due to low pouring temperature

(8) Improper alloy composition

(9) Insufficient metal

(10) Improper employment of chill spots.

7.2 CAUSE AND EFFECT DIAGRAM

Based on the above given potential causes, a statistical approach is followed by structuring the potential causes in the form of Cause and Effect Diagram, one of the Q-7 tools for making the evaluation of causes more effective. The Cause and Effect Diagram for various defects are given in figures 7.1-7.6

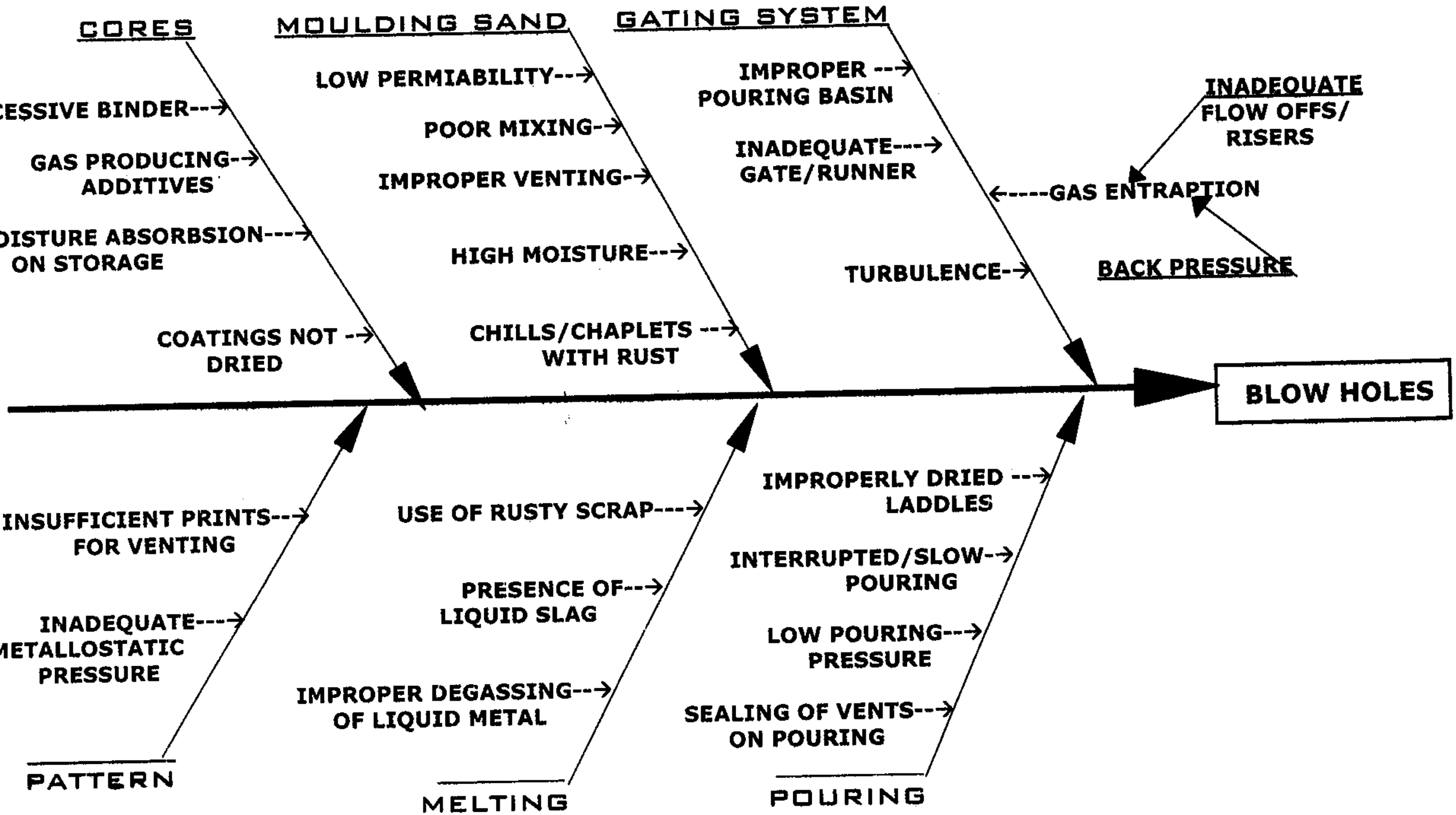


FIGURE 7.1 CAUSE AND EFFECT DIAGRAM FOR BLOW HOLES

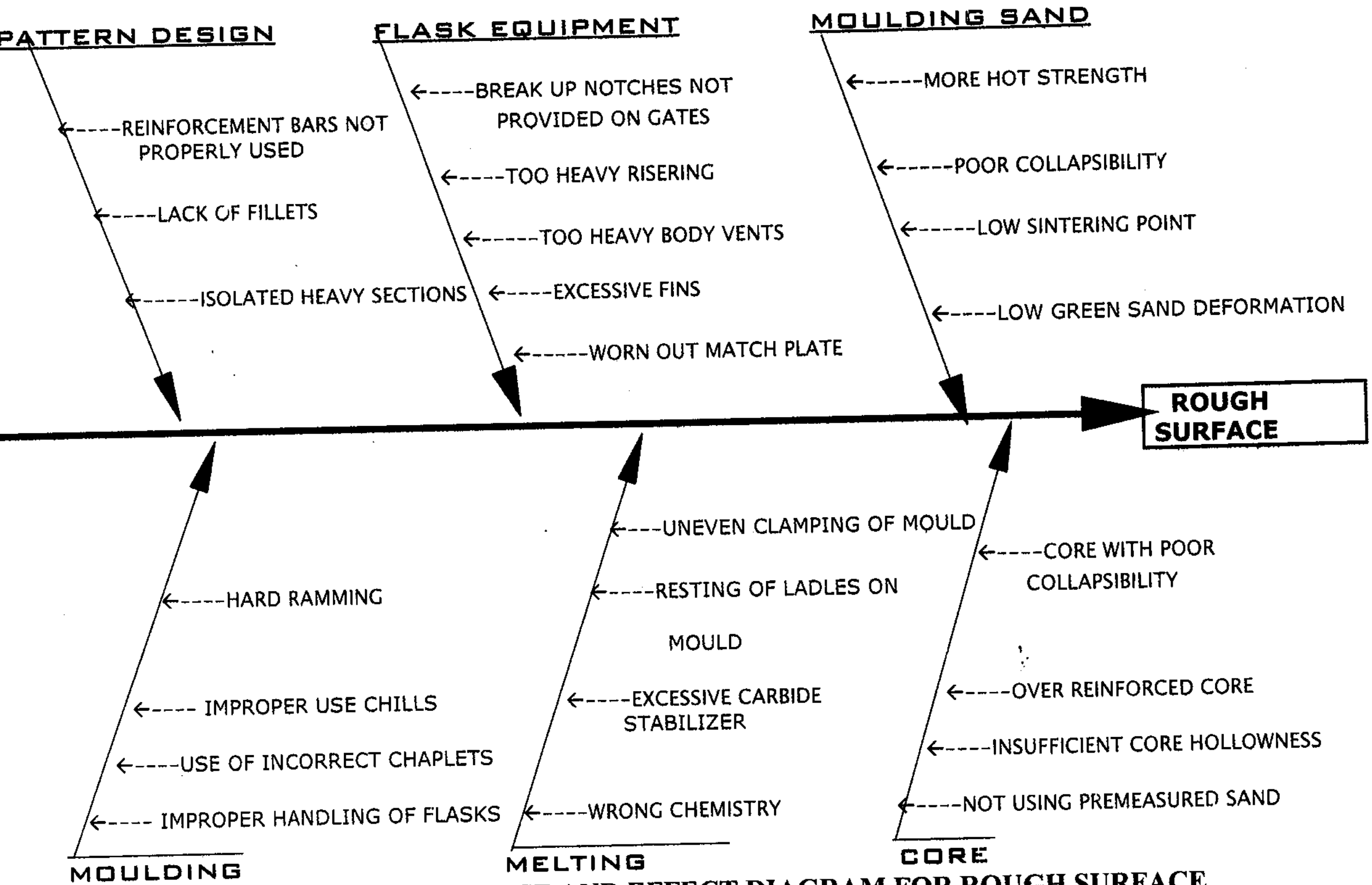


FIGURE 7.2 CAUSE AND EFFECT DIAGRAM FOR ROUGH SURFACE

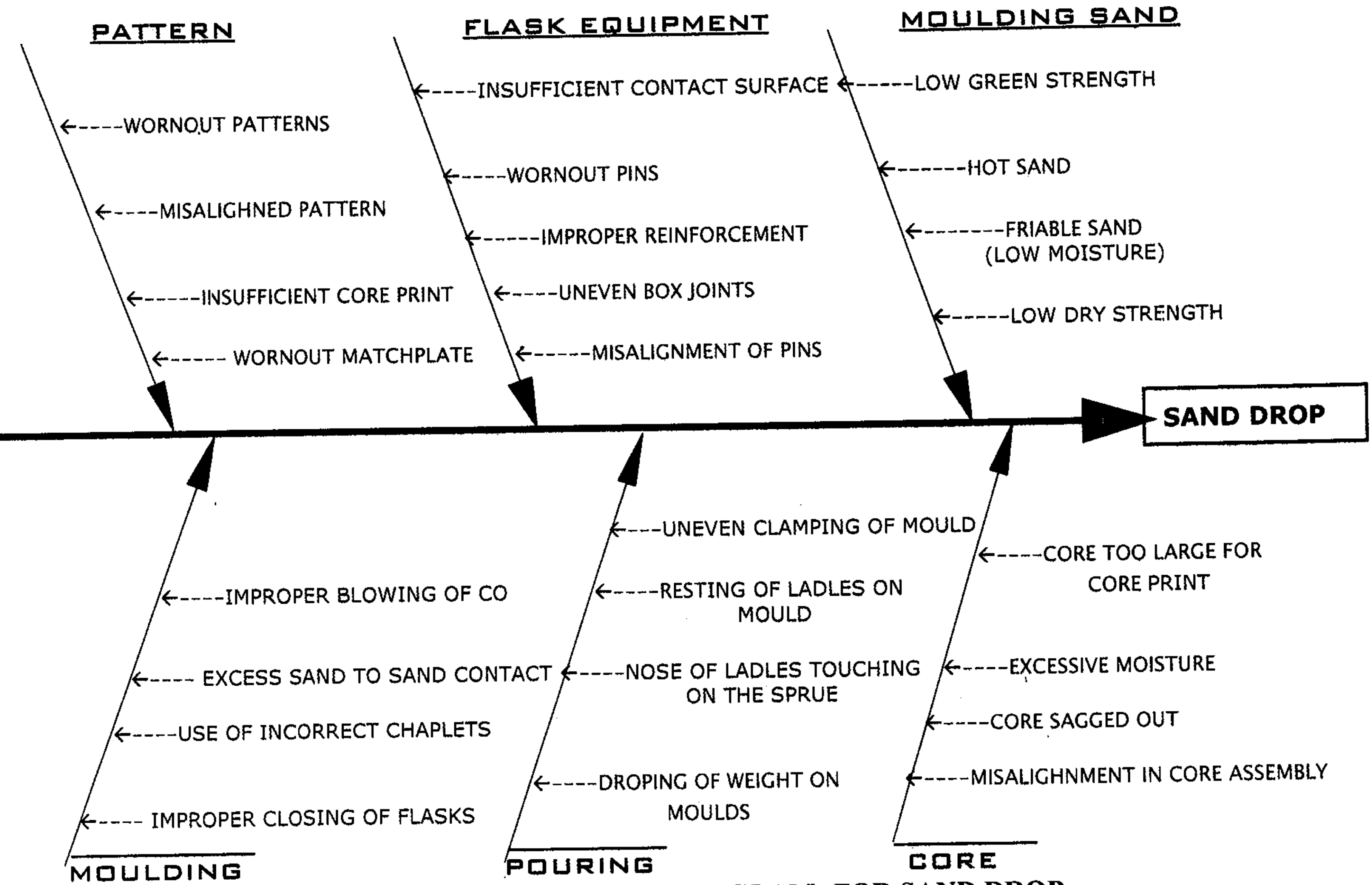


FIGURE 7.3 CAUSE AND EFFECT DIAGRAM FOR SAND DROP

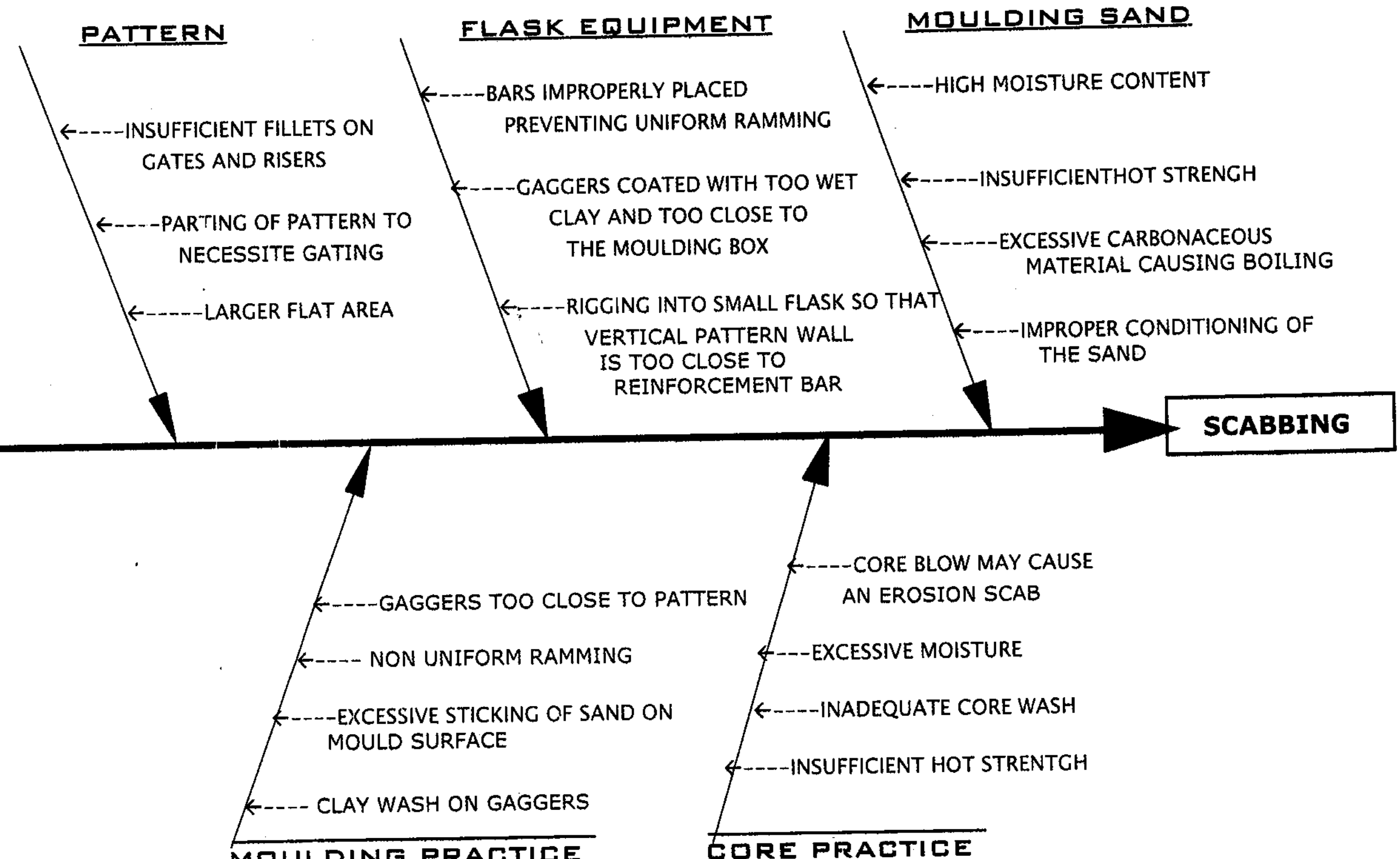


FIGURE 7.4 CAUSE AND EFFECT DIAGRAM FOR SCABBING

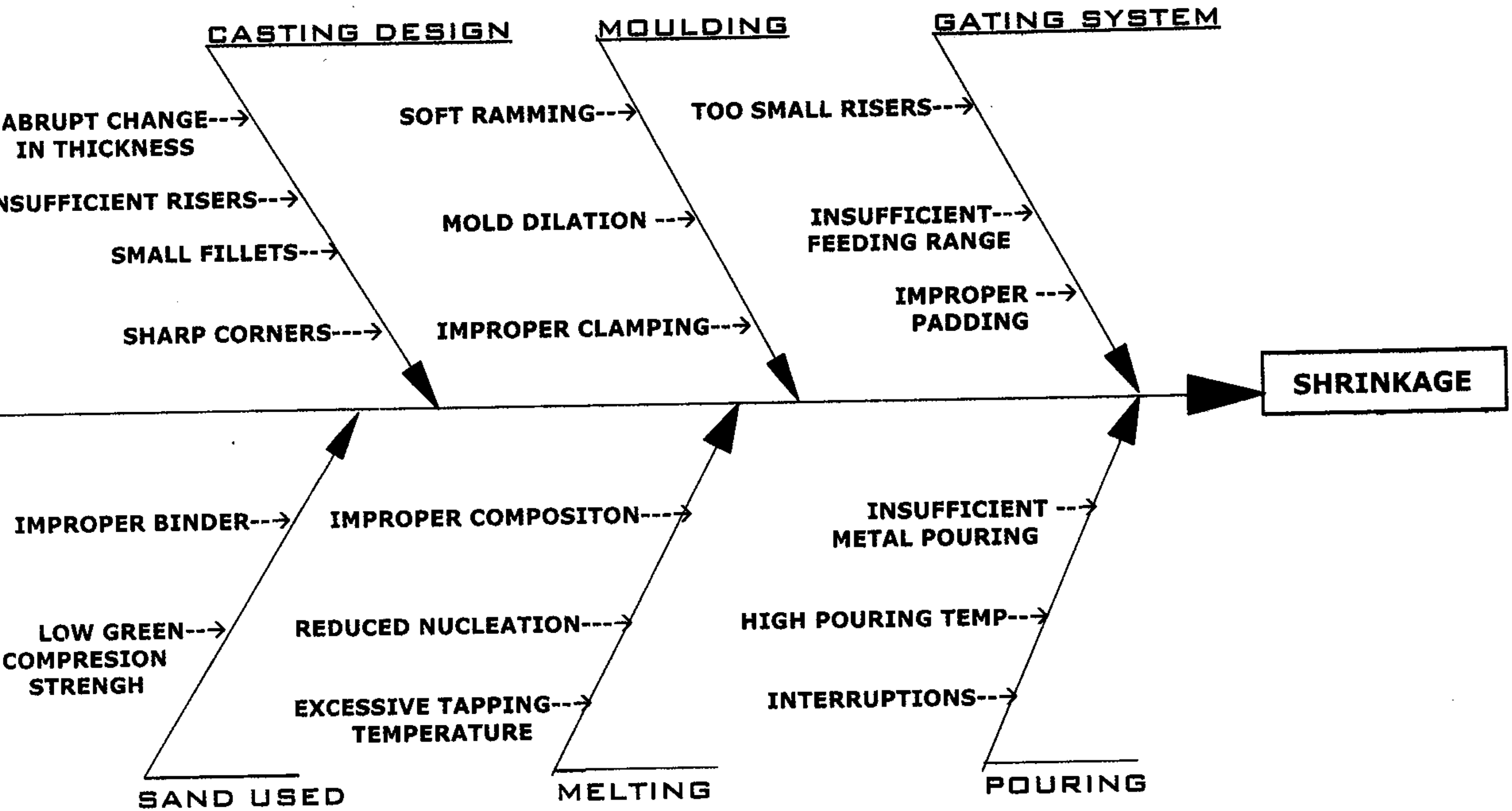


FIGURE 7.5 CAUSES AND EFFECT DIAGRAM FOR SHRINKAGE

CHAPTER 8

REMEDIAL MEASURES BY LOGICAL APPROACH

8.1. LOGICAL APPROACH

In traditional approaches after inspecting the component visually defect would be identified and theoretically the cause would be predicted. Where as in logical approach, the repetition of occurrence of defects and location of defect occurrence will be taken into account and accordingly causes would be decided and corrective action will be properly implemented so as eliminate the occurrence of defect entirely. This methodology would be more effective than the traditional trial and error method.

The Logical approach to defect diagnosis before any effective action can be taken in the foundry, it is imperative that the defect under consideration is accurately diagnosed .Effort should therefore, be directed in diagnosing a defect accurately, since after this has been done, the correct course of action is generally clear. The actual form or Shape of the hole is an important characteristic when diagnosing a defect. When considering blow-hole & shrinkage type defects collectively, they may be clearly divided into three main groups

(1) Smaller spherical holes

(2) Larger rounded holes

(3) Irregular hole.

8.1.1 Spherical Holes:

Let us consider now the possible ways in which spherical holes may be disposed through a casting. There are three main location of this class of hole, firstly on the top surface revealed during machining, they are some times revealed lodging underneath a core; secondly, on casting faces adjacent to moulds, again revealed on machining and thirdly those on cored faces sometimes seen prior to machining.

When the holes appear a top surface only, and are clear and bright, it is almost certain that they are due to low pouring temperature, and possibly high sulphur or manganese, or a combination of both. Metallographic examination will indicate gross manganese sulphide segregations, as well as associated iron-manganese silicate slag. The basic problem is one of low pouring temperature together with the dirty ladles, lack of skimming or the use of poor refractory materials. This type of defect often occurs in only several casting in particular batch, often the last few poured from one ladle, having the lowest temperature.

Higher metal temperature is necessary for the established and if both, or one of them is high, a reduction should take place. Where low metal temperature is unavoidable, for example in the production of very heavy castings, it is advisable to lower the manganese content and so reduce the tendency of the defect to occur. Clean ladles should be used, together with good skimming practice.

If the small spherical holes occur on all faces of the casting s adjacent to the mound and are slightly smaller than the previous type and have very shiny surfaces, they are most likely to be caused by contamination of the metal with aluminium. Metallographic examination will indicate continuous, graphite lining to the cavities. The presence of small quantities of aluminium in an iron even as little as 0.005% increases its tendency to pick up hydrogen from water vapour and during solidification of the casting, the hydrogen is rejected in the form of small holes .Sources of aluminium must be sought and one of the most common is from the scrap. Inoculants containing silicon normally have aluminium present, and should therefore be used sparingly. The moisture content of the sand must also be controlled, since if this is high the greater is the tendency for the defect to occur. It may be found that only those castings most remote from the down gate are affected and if so, this is a strong indication, and means of shortening the runner system should be investigated.

The third possible position for small spherical holes is adjacent to cores. These often are revealed after knockout and they tend to be more elongated than those holes due to aluminium contamination, and in some cases may even in some cases may even be slightly irregular. When holes of this type are seen, the type of binder used should be investigated. If a resin binder containing nitrogen is used, this is most likely the cause of the defect.

8.1.2 Rounded Holes:

Rounded holes result either from shrinkage of the metal, or from gas evolved from the mould, cores or inserts, these holes are normally larger than those previously discussed.

The surface sinks, which often have an excluded bead of metal inside them, and sometimes have small rounded holes underneath. In addition, small depressions may often occur at hot spots and when on sectioning, generally reveal an associated subsurface hole. Both types of defect generally occur in the heavy sections of castings. These defects are due to shrinkage and the major factors affecting their formation are:

a. The rigidity of the mould
b. High pouring temperature
c. High levels of inoculation

If the mould is insufficiently rammed it will yield under Ferro static and solidification pressures and give rise to a swollen casting or one which is larger than pattern dimensions. Normally the greater the amount of over sizing, the greater is the volume of shrinkage. When therefore this defect is experienced, castings should first be examined, either visually or dimensionally, to assess whether any swelling has taken place. Casting weight is also an indication of casting swelling. If swelling has taken place, then attention should be given to improving the compaction of a mould and may be the cores.

Pouring temperature is a known factor in contributing to these defects and therefore the question of lowering the pouring temperature should be considered. Occasionally, very low carbon contents can be responsible for both defects and if more rigid moulds and cores, together with lower pouring temperature fail to overcome the problem, the carbon content should be investigated. Inoculation increases the tendency for such defects to occur and should preferably be limited to a maximum of 0.3% by weight of metal treated. We come now to rounded holes which are generally in the body of the casting, although they do in certain cases come through to the surface. If the hole is adjacent to the mould face, and has a very thin shell of metal surrounding it, it is most probably due to a blow from the mould. Direct blows from moulds are rare, and normally only occur when excessively wet sand is used, or a mould coating is not being correctly dried.

It is, however, possible in very thin sections where one side of the section is mould and the other core, to confuse a blow from the mould or core. However, this may often be confirmed by examining castings prior to fettling. If a blow from the core is suspected, all core prints should be examined, since it is possible that metal may be entering the prints and thus blocking the vents.

Blow from cores in heavy sections are often associated with the core the sectioning may reveal a series of holes obviously traveling from the core. The question of improving the venting system of the core should be considered and an inspection procedure of all core vents should be established. The cores should be correctly baked and excessive binder contents should be avoided.

Cavities associated with the inserts such as denseners and chaplets are almost certainly due to rust, dirt or condensation. All inserts should be inspected prior to assembly in the mould, since any products of corrosion will most certainly result in some form of blow-hole. Chaplets should be coated with high purity tin or copper and denseners should be shot blasted prior to use. Continued use produces an oxide film and it is preferable to discard the denseners after they have been used four or five times.

8.1.3 Irregular Holes:

There are two distinct types of irregular holes. In several cases and in heavy sections, this type may occur as large voids and have a dendrite or fir tree like surface, This type of defect generally occurs in the heavier sections of castings or at hot spots, such as adjacent to in-gates and feeders, or changes in section. Should the defect have the above characteristics, it is most certainly internal shrinkage, and the major factors affecting its formation are;

1. Lack of mould rigidity
2. High pouring temperatures
3. High degree of inoculation
4. The phosphorous content of the iron

As mentioned previously, when considering top surface shrinkage defects, variations in casting weight or dimension will quickly indicate whether variations in mould or core rigidity are occurring. If so, efforts should be directed to produce castings of greater dimensional accuracy to improve soundness.

High pouring temperatures also give greater casting dimensions a greater tendency for unsoundness, and this factor should be controlled. Inoculants, whilst having certain metallurgical advantages can, if carried out excessively, promote this type of defect. Therefore, if inoculation is being carried out, the amount used should be checked and if possible reduced.

Rarely the chemical composition of an iron has a significant effect on the formation of internal shrinkage but phosphorous is the only element, which does affect the extent to which it occurs. The question of phosphorous should be considered as a likely cause, since fluctuations in the element can give rise to sporadic out breaks of internal shrinkage. Irons having phosphorus contents above 0.10% are prone to this defect, particularly in heavy sections, and where high degrees of soundness are necessary, such as in hydraulic values, levels of below 0.055 are desirable. If therefore attention to the above factors dose not alleviates the problem, the question of phosphorus should be considered.

The second type of irregular holes as shown in the lower illustration, occur as discrete fissures rather than areas of interconnected porosity. There are two forms – the more widely dispersed and more isolated, generally larger fissures.

The more widely dispersed fissures are often associated with cupola melted, low carbon equivalent irons produced from high steel scrap charges, and are due to high nitrogen content in the metal. During the past few years there has been a tendency to use more steel in cupola charges and the incidence of this defect has become more prevalent.

Should this type of defect be experienced and the cupola charge containing in order of, or above 50% steel, then it is highly probable that the defect is caused by high nitrogen content in metal.

In electrically melted irons this defect can result from the use of low grade, high nitrogen in the iron. Titanium can neutralize the effect of the nitrogen and additions of up to 0.03% either as ferrotitanium, titanium metal. Or incorporation of a titanium bearing pig iron in the charge should overcome the problem.

Metallographic examination will most likely indicate the graphite flakes in a compacted form, this being an important diagnostic indicator.

Fissure defects in the more isolated form are generally attributed to the evolution of hydrogen during solidification, they may therefore occur in irons produced from low steel scrap charges. It is often difficult to differentiate clearly between the two. If metallographic examination reveals the presence of a continuous graphite film with evidence of also compacted graphite flakes.

If the defect is suspected to be due to hydrogen, the aluminium content must be reduced, since this will promote hydrogen pick-up and all sources of water vapour, particularly in the furnace and ladle refractoriness, must be eliminated.

This defect often occurs in castings poured from the first few taps when the hydrogen content of the metal is higher than in subsequent taps.

It must also be appreciated that such defects can be the result of high nitrogen bearing resin systems and consideration should always be given to this possibility.

8.2. ROOT CAUSE EVALUATION

Though there are number of potential causes identified and remedial measures have been suggested, implementing the remedial suggestions on trial and error /traditional approach is rather difficult and will be ineffective. Hence a logical approach/ methodology have been adopted to find the root cause which considerably contributes to rejections. In this methodology , the root cause has been found by elimination of non critical causes is done through a brain storming session conducted by experts from various departments. In particular for the defects blow holes and shrinkage the key points of logical approaches given in the previous chapter has been followed to identify the critical causes. The causes are made non-critical by validation of the causes and by evaluation of feasibility of implementing the remedial measures. Sometimes voting system may also be adopted for concluding a cause as non-critical. After eliminating the non-critical causes, out of the remaining critical causes one would be evaluated as root cause for remedial measure will found and implemented.

The root evaluation is done only for the three defects out of the seven selected defects. The two defects of rough surface and sand drop were neglected because most of the causes involved in those two defects are related to labour which cannot be taken as critical cause and its other causes are also involved in the rest of three defects; so finding remedial measures for those three defects' causes could reduce the rejections due to rough surface and sand drop. However causes related with the carelessness of labour can be avoided only to a certain extend. The three defects to which root cause evaluation has been done are as follows,

(a) Blow Holes

(b) Shrinkage

(c) Mould Scabbing

Table 8. 1 ROOT CAUSE EVALUATION FOR THE DEFECT BLOW HOLES

S.NO	CAUSES	VALIDATION	EFFECT
(1)	Insufficient permeability of moulding/core sand	Too much of clay content causing low permeability	Critical
(2)	Presence of dead clay forming clay balls and also not mixing with sand	Low proportion of new sand	Critical (root cause)
(4)	Gating system causing turbulence	Proper runner system has to be provided	Non Critical
(5)	Too low pouring temperature causing quick cooling of certain portion	Checked with pyrometer	Non-critical
(6)	Excessive clay binder in sand.	Proportion to be changed	Critical
(7)	Venting through parting line.	Venting to be improved	Critical (root cause)
(8)	Hard spot caused by improper ramming due to misplacement of flask.	Labour dependent	Non-critical

(9)	Inadequate riser height.	Sleeve has been introduced	Non-critical
(10)	Flask wall too close to mould surface	Sufficient flask size provided	Non-critical
(11)	Ladles Damp	To be Preheated before tapping	Critical (root Cause)
(12)	Repouring of metal into the furnace	Repouring to be avoided by proper tapping volume	Critical (root Cause)
(13)	Slow pouring of metal or interrupted pouring	Labour dependent	Non-critical

Table 8.2 ROOT CAUSE EVALUATION FOR THE DEFECT SCABBING

S.NO	CAUSES	VALIDATION	EFFECT
(1)	Insufficient fillets and section changes.	Customer related	Non-critical
(2)	Rigging into small flask so that the vertical pattern wall is too close to flask reinforcement bar.	No feasible remedy	Non-critical
(3)	Unidirectional metal flow from causing impingement on mould cavity	Metal flow to be distributed	Critical
(4)	Improper gating causing interrupted metal flow.	Runners may be increased	Non-Critical
(5)	Excessive pouring temperature	Incorrect cause	Non-critical
(6)	Wrong proportion of binder and coal dust	Proportion has to be changed	Critical (root cause)
(7)	Too quick poring causing metal impinging on sand surface	Labour dependent	Non-critical

(8)	High moisture content causing erosion of sand due to weakness	Too much binder	Critical
(9)	Dead clay at sand surface causing erosion during pouring	Too high return sand and too much clay content	Critical
(10)	Excessive moisture on skin of core	Delayed pouring or uncured core	Non-critical
(11)	Excessive carbonaceous material causing boiling.	Composition checked	Non-critical
(12)	Insufficient hot strength	Additive ratio to be checked	Non-critical
(13)	Non uniform ramming	Incorrect since machine moulding	Non-critical

Table 8.3 ROOT CAUSE EVALUATION FOR THE DEFECT SHRINKAGE

S.NO	CAUSES	VALIDATION	EFFECT
(1)	Change in section too abrupt.	Customer related process. Cant be modified	Non-critical
(2)	Area of feeding is insufficient at isolated sections.	Remedy not feasible	Non-critical
(3)	Gates and risers not promoting progressive solidification.	Existent system found ineffective	Non-Critical
(4)	Insufficient number of gating or risering	Single side pouring not sufficient	Non-Critical
(5)	Insufficient jolting capacity.	Moulding machine with adequate capacity has been used.	Non-critical
(6)	Feed metal requirement not met due to improper gating arrangement.	Ineffective feeding system	Non-Critical
(7)	Improper ratio of riser neck to casting section.	Section modulus verified to be correct	Non-critical

(8)	Risers not providing feeding aids.	Sleeves are to be introduced	Non-Critical
(9)	Over inoculation	Calibrated cups for inoculants addition in use	Non-critical
(10)	Too low phosphorus content.	Percentage checked using spectrometer	Non-critical
(11)	Pouring metal either too cold or too hot.	Pouring temperature checked using pyrometer	Non-critical
(12)	Improper clamping of flasks	No feasible remedy since dependent on labour	Non-critical
(13)	Mould or core having too high rigidity not allowing contraction.	Composition verified	Non-critical
(14)	Cope flasks too shallow	Trailed to be sufficient	Non-critical
(15)	CO slag reaction	Manganese and Sulphur content checked before tapping.	Non-critical

8.3. FINALISED CAUSES AND REMEDIAL SUGGESTIONS

As a result of Root Cause Evaluation, certain causes have been short listed for which remedies can be implemented. The finalized causes that are found to be contributing to the major part rejections are as follows,

8.3.1 Venting System Related Critical Causes:

The critical causes related to venting system are as follows,

a) Insufficient number of vent holes.
b) Vent holes made at the metal area.
c) Metal filling up the vent holes and gas unable to pass out through them.
d) Vent rods not maintained properly.
e) Insufficient vent hole diameter.

These causes serve as the critical cause for the defect blow holes. The venting system in existence is found to be not that effective and hence is causing a lot of defects. Since blow holes have been found to occupy a major part of the defects, major changes have been required in this and hence have to be modified. As regard, a new system has been proposed with the modifications.

8.3.2 Sand Related Critical Causes:

The critical causes related to moulding sand are as follows,

a) Wrong proportion of binder and additives
b) High moisture content causing erosion of sand due to weakness
c) Dead clay at sand surface causing erosion during pouring
d) Insufficient permeability of moulding/core sand
e) Presence of dead clay forming clay balls and also not mixing with sand
f) Excessive clay binder in sand.

These critical causes are found to be contributing to the sand related defects like blow holes, sand drop, scabbing. From the Root Cause

Evaluation it is clear that the existing proportion of sand is not proper and binder proportion has to be modified.

8.3.3 Pouring Related Critical Causes:

The critical causes related to pouring of the molten material are as follows,

a) Repouring of metal back into the furnace
b) Damp ladles which need preheating equipments
c) Ladles not properly wetted with the molten metal.

These critical causes are found to be contributing to the increased percentage of blow holes as well as cold shuts. Also Repouring results in variations in the metal properties itself. Damp ladles results in cooling of the metal at the lower surfaces quickly, reducing the pouring time available still further

8.3.4 Aligning Related Critical Causes:

The critical causes related to the misalignment and mismatches are as follows,

a) Misalignment of the molding flasks.
b) Mismatch of cope and drag
c) Improper aligning pin dimensions
d) Worn out locating pins
e) Non replacement of old pins

These critical causes are found to be contributing to the increased percentage of shifts and mismatches. Since shifts are major defects, the castings cannot be repaired and have to be scrapped, contributing a large extent to the percentage defect also.

CHAPTER 9

IMPLEMENTATION OF REMEDIAL MEASURES

The remedial suggestions have been analyzed by the quality control department and representatives from each department. Then after a series of evaluation the following remedies are found to be effective and are implemented. The implementation of remedies for eliminating critical causes are as follows,

9.1 IMPROVISED VENTING SYSTEM

The existing venting system has been found to be insufficient and also the vent holes are found to be done on the molten metal.

Three additional vent holes are being recommended on each half of the central diameter to enable proper release of the gases from the mould. In the existent system the insufficient vent holes are found to result in entrapment of the gases. Also the vent holes being provided on the metalled area of the mould, results in additional metal having to be poured. Also the metal obstructs the gas flow. The venting rods, which have been found to be of improper dimensions and worn out, have been recommended to be replaced.

9.2 MODIFIED SAND PROPORTIONS

The inadequacy of coal dust serves as a cause for defect 'scabbing' and presence of high dead clay content also serves as causes for certain defects and hence the proportion of new sand has to be increased . Also the Lustron proportion needs to be increased. The presence of more dead clay on return sand indicates that clay content is more and excessive binder also causes some defects like blow holes. The actual and modified sand proportions are given in table 9.1 and 9.2.

Table 9.1 THE ACTUAL SAND PROPORTION

S.NO	INGREDIENT	WEIGHT(kg)	PERCENTAGE%
(1)	Return sand	450	85
(2)	New sand	60	11.3
(3)	Bentonite	16	3
(4)	Bentocol	2	0.35
(5)	Lustron	2	0.35

After a series of evaluation meeting in the production department, the cost factor has been analyzed and finally through a set of trails the following sand proportion has found to be effective in controlling sand related defects. The modified sand proportion contains reduction in the use of return sand when compared to actual sand used and an addition of another sand addititive "Coal Dust ".

Coal Dust: It is commonly used for protecting mould surfaces against the action of molten metal and improving surface finish in the castings. When the molten metal is in contact with mould surfaces containing coal dust, a gas envelope is formed which resists the fusion of sand to metal. Use of coal also increases both green and dry strength, reduces expansion, tendency to scabbing and metal penetration.

Table 9.2 THE MODIFIED SAND PROPORTION

S.NO	INGREDIENT	WEIGHT(kg)	PERCENTAGE%
(1)	Return sand	400	76.8
(2)	New sand	98	18.82
(3)	Bentonite	15	2.88
(4)	Bentocol	3	0.56
(5)	Lustron	3	0.56
(6)	Coal Dust	2	0.37

9.3 IMPLEMENTATION OF PRE-HEATING:

Since ladle preheating is a requisite in high temperature castings, and has to be done properly, it has been recommended. But instead of employing separate equipment for preheating, after discussions with the production and quality control departments, a simple low cost procedure was recommended.

This procedure involves, preheating the ladle by heating it with a burner for about two hours. Then the ladle is taken to the actual induction furnace. Here the molten metal is poured into the ladle and poured back into the furnace twice. This accomplishes two tasks namely, preheating the ladle to about 1500°C and also wetting the damp ladle with the molten metal, such as to prevent cold metals from previous runs stinking to it. Also it was made to understand that repouring the molten metal back into the ladle after completing a set of moulds will result in variations of metal properties. Though this may not be a major defective cause, it will lead to reduction in productivity and will have to be avoided.

9.4 REPLACED LOCATING PINS:

The locating pins were found to be worn out and faulty, having varying dimensions, causing mismatch of the Mould flasks and thus causing the Shifts. These were brought to the attention of the Quality control department, and were repaired or replaced, as the need required. Also the labors were made to understand the proper handling of the locating pins.

9.5 RESULTS OF IMPLEMENTATION

After the successful implementation of remedial measures, the process has been keenly observed and further casting rejections have been analyzed through rejection data analysis on data collected at the end of March 2007 and the following results have been arrived.

Table 9.3 REJECTION DATA OF 10TG BRAKE DRUM

S.NO	DEFECTS	REJECTION QUANTITY	REJECTION PERCENTAGE%
(1)	Blow Holes	38	1.29
(2)	Shift	16	0.54
(3)	Rough Surface	20	0.68
(4)	Sand drop	15	0.51
(5)	Scabbing	8	2.27
(6)	Shrinkage	8	0.27
(7)	Cold Shut	16	0.54
(8)	Damages (handling)	4	0.13
TOTAL PRODUCTION QUANTITY : 2940			
MONTH OF DATA COLLECTION: MARCH 07			
PRODUCT WEIGHT : 60 KG			
OVERALL REJECTION : 4.23 %			
REDUCED REJECTION PERCENTAGE : 2.93%			

Table 9.4 REJECTION DATA OF 608 BRAKE DRUM

S.NO	DEFECTS	REJECTION QUANTITY	REJECTION PERCENTAGE%
(1)	Blow Holes	35	1.10
(2)	Shift	13	0.4
(3)	Rough Surface	18	0.56
(4)	Sand drop	16	0.50
(5)	Scabbing	13	0.40
(6)	Shrinkage	9	0.28
(7)	Cold Shut	10	0.44
(8)	Damages (handling)	3	0.09
TOTAL PRODUCTION QUANTITY : 3181			
MONTH OF DATA COLLECTION: MARCH 07			
PRODUCT WEIGHT : 54 kg			
OVERALL REJECTION : 3.98 %			
REDUCED REJECTION PERCENTAGE : 3.61%			

CHAPTER 10

CONCLUSION

10.1 CONCLUSION OF THE PROJECT

The remedial measures have been successfully implemented and rejection percentages are found to be considerably reduced. The reduction of rejections has been clearly shown in the following histograms.

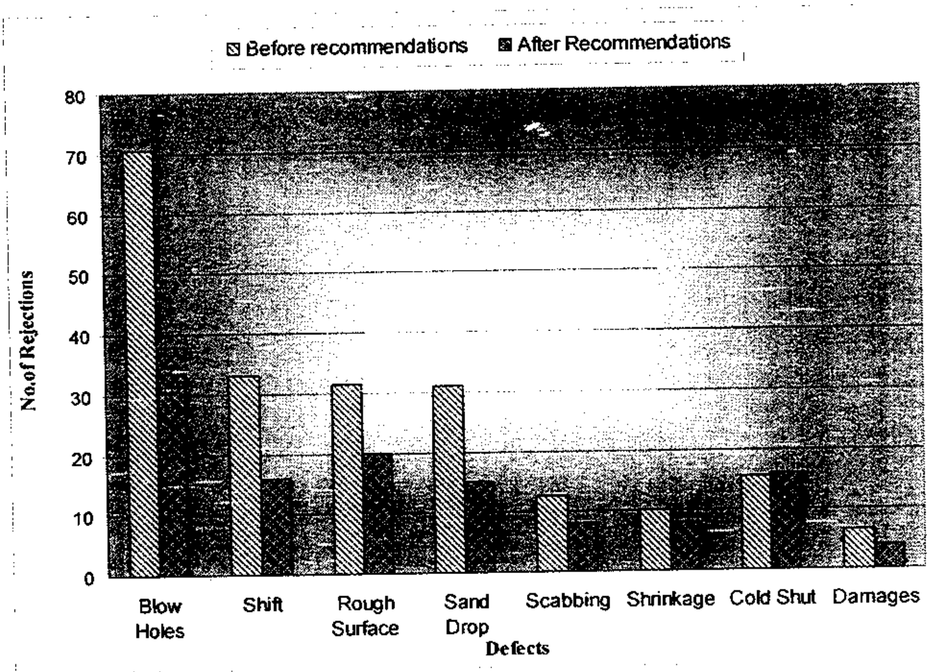


FIGURE 10.1 RESULT ON 10 TG BRAKE DRUM

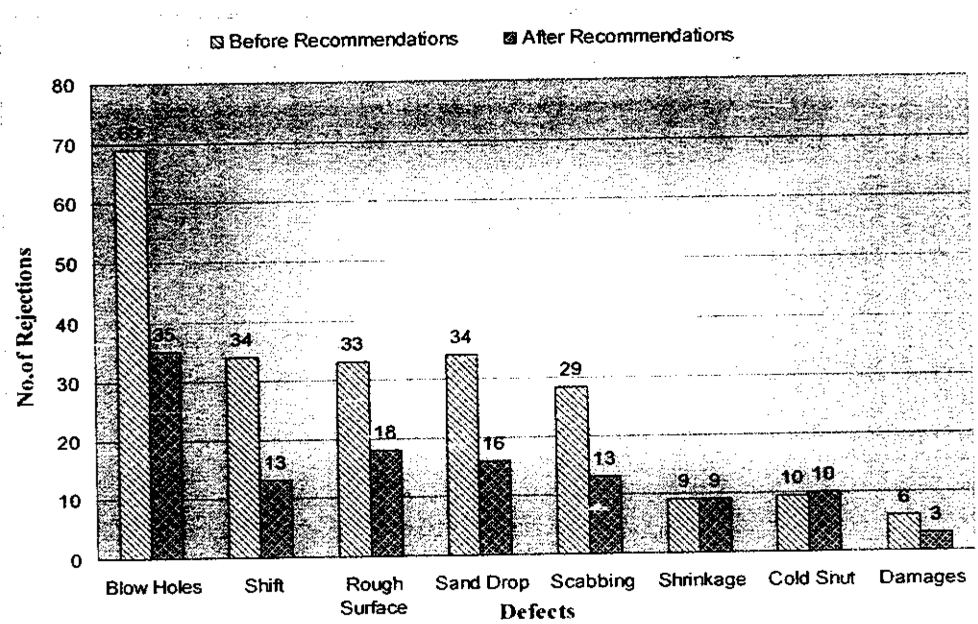


FIGURE 10.2 RESULT ON 608 BRAKE DRUM

The histogram obviously reveals the reduction in the percentage of rejections of the component 10TG Brake Drum from the previous value of 7.16 %

particular the identification of major defects through statistical approach and root cause evaluation through logical approach were found to be more effective and accurate which contributed to the reduction in rejections.

Thus as we have mentioned earlier the non-traditional technique of adopting statistical and logical approaches is proved to be an effective tool for productivity improvement. Through this project it has been suggested that replacement of traditional approaches with non-traditional techniques should be concentrated by each casting industry for their productivity improvement. We assure that adopting the non traditional approach and statistical methodology followed in this project will yield good results.

10.2 LIMITATIONS OF THE PROJECT

The major limitation in adopting these kinds of approaches is the requirement of QC personnel with thorough process knowledge and awareness about statistical and logical approaches.

Another main disadvantage is that the implementation of remedial measures is not that easier in a rejection sensitive process industry. Implementation is possible only if the remedies are strongly believed to be worthwhile. One more limitation is that, most of the foundries are labour dependent and to a maximum extend it could be semi-automated and hence the critical causes related to the labour carelessness or due to unskilled labour are not possible to be rectified and remedial measures found to be ineffective in spite of using the non-traditional techniques.

10.3 FUTURE WORK

In order to overcome the limitations mentioned above, automating foundries will eliminate manual errors. Also appointing QC personnel for adopting non-traditional strategies has to be done in foundries where it is not in practice.

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