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Blow-hole Defect Analysis of Cylinder Block- A Case Study

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Abstract
In this researchpaper the Blow-hole defect analysis of MH1-VST 4-Cylinder Block is presented as a case study. The said component is a 4 cylinder block and it is fitted on front end of the tractor. As the MHI-VST 4-Cylinder block is the central component of tractor or any vehicle. It plays important role in lubrication as well as temperature control & stability of the engine & it has to be of the highest quality so there is no room for shortcuts. In this paper Pre & Post analysis of part is done by using quality control (QC) tool such as pareto chart, Cause effect diagram & DMAIC approach is followed & Proper actions are taken to reduce the defect & rejection rate at factory end. The work is done under two phases in the first phase identifying drastic effect of blow hole in production & in the second phase sorting out the issues by using various QC tools & expert opinion.

Keywords: Blow hole, Pareto chart, Cause and effect diagram quality control tool.

1.0 Introduction

Castings are used in order to manufacture complex shapes. The castings are bound to have one or more defect. The presence of defects may subject casting to rejection. The defect causes stress concentration. More time and money would be saved if it ever becomes possible to produce to hundred percent good casting. We can minimize defects by taking precautionary measures in the casting processes.

The same is the case in MHI-VST 4-Cylinder block there are numbers of defects in this casting. Four defects are identified such as blow hole, core crack, sand drop and shrinkage has maximum effect on the rejection percentage. The defects were identified by past production lots & reports provided by the quality department.

The MHI-VST 4-Cylinder block is the central component. It has to be highest possible quality so that it can perform its vital role in the operation of cylinder heads, timing case, sump & flywheel. MHI-VST 4-Cylinder block are specially designed to withstand a variety of temperatures & loads to maintain the stability & lubrication of each individual engine. Each block has a number of oil galleries to transfer oil throughout the engine, thereby maintaining the lubrication of all critical components. The block also contains the water galleries needed to provide cooling to the engine to maintain its optimum operating temperature. MHI-VST 4-Cylinder block unit includes a cylinder walls, coolant passages & cylinder sleeves.

B. Chokkalingam& S.S. Mohamed Nazirudeen, Here the authors studied the analysis of Casting defect through defect diagnostic Study Approach [1] & Dr. B.Ravi has give the detailed information of casting simulation and Optimization its benefits, bottlenecks and best practices [2] which gives us some importance of simulation in casting also it provides valuable information of methodical study which helps to design method for our study. Also in our study for difeerent casting defects we require remedies and this information we got from the paper of Rajesh Rajkolhe in his paper Defect Causes And Remedies in casting process : A Review listed different types of casting defects and also helps to provide correct guideline to quality control department to find casting defects and will help them to analyze defects which are not desired[3] also Sunil Chaudhari, Hemant Thakkar in their paper Review On analysis of foundry defects for quality improvement of sand casting the research work made by several researchers and an attempt to get technical solution for minimizing various casting defects and to improve the entire process of casting manufacturing[4] and also Darshan A. Bhatt, Hardik R Mehta in their paper reducing rejection rate by applying varying parameter on crankcase. They conducted series of experiments by applying varying parameters like pressure, temperature, holding time etc [5]

1.1 Blowholes in Sand Casting

There are different types of defects produced in sand casting. A high proportion of casting defects are caused due to evolution of gases. One of the major casting defects caused due to gases is holes (gas holes). Gas holes are pinholes and blowholes. This designation belongs to size of the hole and not its origin. Blowhole is very prevalent cause of casting scrap. Figure 1 shows schematic of blowholes, showing blowholes near core, surface blowholes and casting with blowholes.[7]

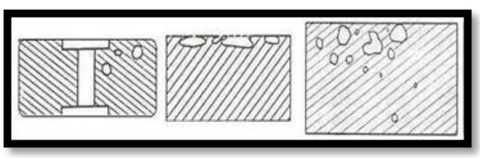

Figure.1 Schematic of Blow Holes [7]

The blowholes are smooth walled cavities, essentially spherical, often not contacting the external casting surface. The largest cavities are often isolated. In specific cases, the casting surface can be strewn with blowholes. The interior walls of blowholes can be shiny, more or less oxidized or in case of cast iron can be covered with a thin layer of graphite. Figure 2 shows some slag blowholes having smooth surface and slag accumulated on smooth surface. [7]

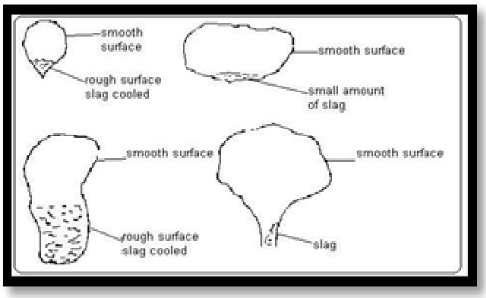

Figure 2 Slag Blowholes [7]

The blowholes are usually revealed by machining or by heavy shot blasting. The defect may take the form of well defined bubble shaped cavities beneath the surface of the casting. These forms of holes may arise from entrapment of more than one sort of gas during the course of mold filling and solidification. It is important to know the origin of and reactions producing these gases, so that correct diagnosis and cure can be affected.

1.2 Types of Blow-holes

When the hot metal is poured inside the sand mold, sand and sand contents gets heated and large amount of gases are produced inside the casting. The main gas producing processes in the mold are:

a) Rejection of dissolved gases from the metal
b) Entrapment of core and mold gases evolved under pressure
c) Reaction of carbon in the metal with oxygen or oxides.

1.3 Blowholes due to high gas content of the metal:

They are also called as endogenous gas holes or blowholes. These holes are caused due to excessive gas content in the metal bath and rejection of dissolved gases during solidification. The gases involved in this defect are hydrogen and nitrogen. Both are soluble in liquid cast iron and relatively insoluble in solid iron. As casting solidifies the insoluble gas is rejected and produces holes between growing crystals. Blowholes from carbon monoxide may increase on size by diffusion of hydrogen or less often nitrogen.

1.4 Carbon oxygen reaction holes

The gas holes in this group may appear in variety of forms, but the gas responsible is carbon monoxide, produced by the reaction of oxygen containing substances with the carbon present in the cast iron. Manganese sulfide in the oxide rich liquid slag allows the reaction to take place at lower temperatures and facilitates the entrapment of gas in solidifying metal.

1.5 Blowholes from mold or core gases

They are also called as exogenous gas holes. These holes are caused due to excessive moisture in molds or cores, core binders which liberate large amount of gas, excessive amount of additives containing hydrocarbons and blacking and washes which tend to liberate too much gas.

If the gas which is evolved from molds and cores cannot freely escape, it may get trapped in the liquid metal. The bubbles formed remain in the casting during solidification. The gases producing these holes consist mainly of steam, coal gas and hydrocarbon gases from decomposition of organic core binders.

1.6 Mechanical entrapment of gas

They are also called as exogenous gas holes or blowholes. These holes are caused due to insufficient evacuation of air and gas from mold cavity and insufficient mold or core permeability. The blowhole formation is also affected by the parameters like pouring temperature, rate of pouring, slag inclusion, moisture and clay content of mold and sand, type of binder and type of additives used etc.

1.7 Blowholes from Green Sand Molds

The principal sources of gas from green sand molds are moisture and seacoal, from which it is liberated quite rapidly on heating. The escape of this gas during mold filling takes place via two routes, the pores of the molding sand and special vent holes provided by the Molder. The holes in the majority of cases are large and have smooth walls. There is optimum moisture content for sand depending upon the proportion of fines and the type of clay used and if this is exceeded then blowholes may be produced. It is up to 4 percent for sands containing fireclay and bentonite. The permeability of the naturally bonded sand is usually low and the effect of moisture is to reduce this even further, at the same time increasing the gas producing potential of the mixture. It is more dangerous than the use of lower permeability base sand at lower moisture content. The addition of sea coal will also reduce the permeability of molding sand and increase the quantity of gas produced. Further, sand having high sea coal content requires more moisture to bring it to a workable condition. A study on behavior of gases in case of a plane wall in dry mold indicates a rapid buildup in pressure at the mold metal interface. Slow pouring leads to a low pressure after filling the mold, consequently gas which enters the metal before the mold is full aided in escaping by metal movement.[6]

2.0 Methodology for Blow hole analysis:

i. First the collection of all rejection data from the company is done regarding the MH1-VST 4-Cylinder block.
ii. Analysis of data & study of all the defects occurring in MHI-VST 4 cylinder block casting. There are different defects such as blow hole, sand drop, core crack, shrinkage, damages etc. occurring in casting.
iii. By using quality tool Pareto chart we have found that blow hole is significant defect compare to all other \
iv. With the help of another QC tool cause & effect diagram it is determined all the possible causes responsible for MHI-VST 4 cylinder block casting with effect to blow hole.

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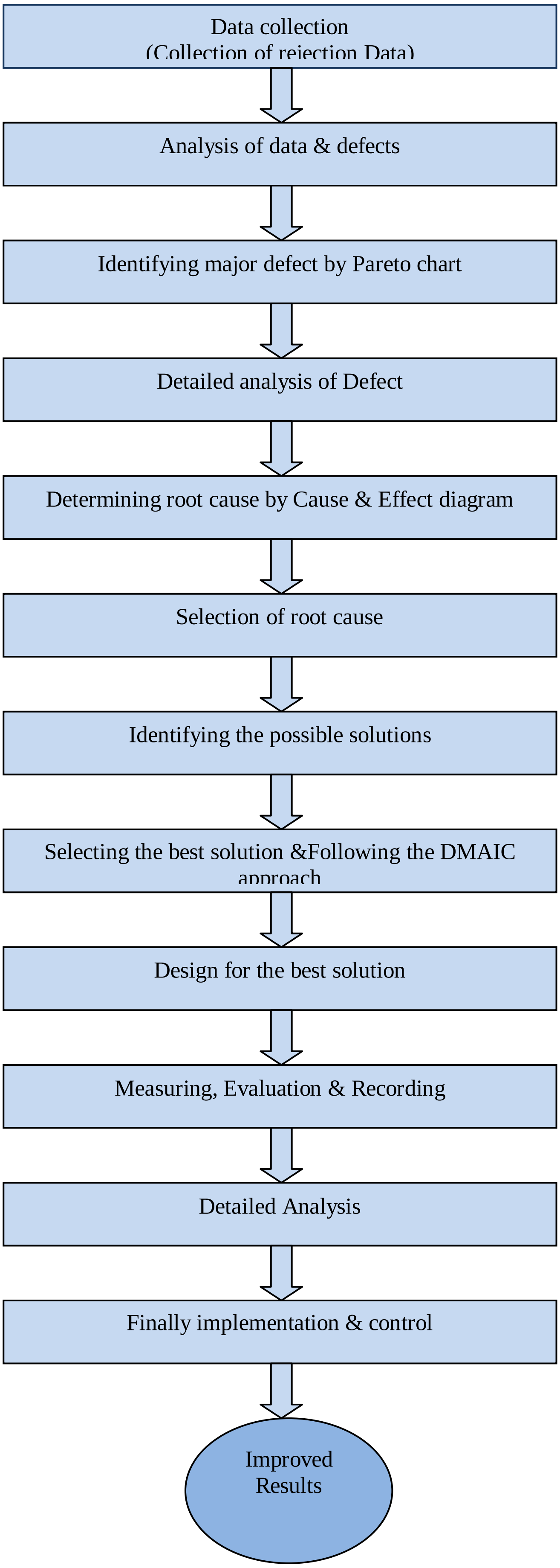

Figure.3 Methodology

v. We have determined the root cause such as improper moulding sand properties, core setting, foreign material in moulding sand of MHI-VST 4 cylinder block casting.

vi. After this the solution is identified for blow hole defect of MHI-VST 4 cylinder block such as design of proper gating system, proper core setting and controlling sand properties.

vii. After this best solution is selected to eliminate blow hole defect of MHI-VST 4 cylinder block. The solution includes core setting and proper mould box closing.

viii. After this the solution is implemented and carried out pilot test.

ix. The defects are minimized.

3.0 Pareto Diagram

Pareto diagram is a tool that arranges items in the order of the magnitude of their contribution. It identifies a few items exerting maximum influence. Pareto diagram is used in quality improvement for

1. Prioritizing projects for improvement
2. Prioritizing setting up of corrective action teams to solve problems
3. Identifying products on which most complaints are received
4. Identifying the nature of complaints occurring most often
5. Identifying most frequent causes for rejections or for other similar purposes. [6]

From data, quantities of defects Pareto chart is prepared.

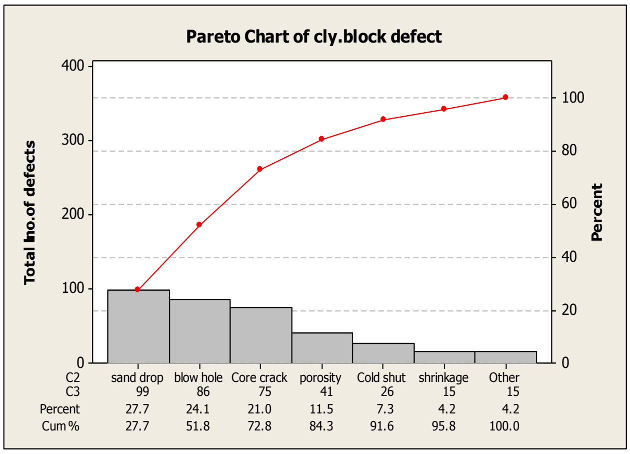

Figure.4 Pareto chart

It is observed that the effect of Blow hole & Sand drop is very significant compare to other defects so the detail analysis of Blow hole is decided to be made & necessary actions to be taken in order to reduce the rejection.

Firstly the sources of blow hole defect is been selected to analyse & different types of blow hole occurring is been studied in detail for correct analysis. Depending upon the analysis & data a systematic methodical approach is been devised for controlling the defect.

Cause- effect diagram is one of the approaches to enumerate the possible causes. When all possible causes are known to us, the operating conditions are verified and applied to determine the potential cause item by item. As the primary factors are identified, they are further examined to find the specific problems that cause the defects. After the particular cause has been identified, remedies are suggested to eliminate defects.

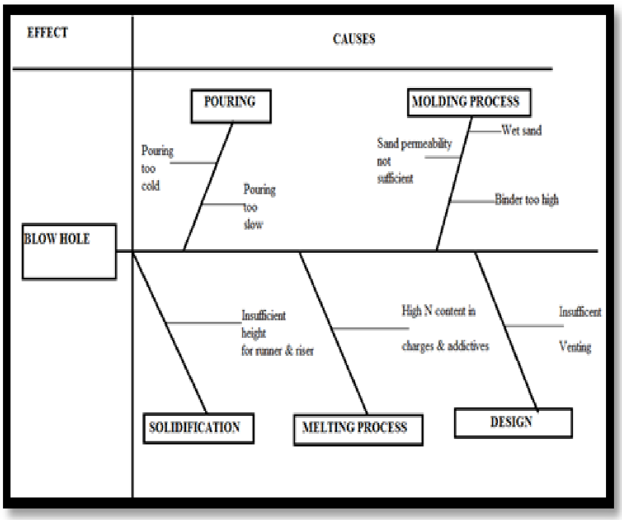

Figure.5 Cause & Effect Diagram

This diagram is useful in representing the relation between the effect & possible causes that influence it. Also it is useful when we want to find out the solution to particular problem that could have number of causes for it & when we are interested in finding out the root cause.

3.1 Description

Various factors responsible for occurring Blow hole such as Pouring, Molding process, Solidification, Melting process, Design.

a) Design- This is one of major cause for occurring blow hole. If the design of pattern is incorrect then it leads to Blow hole. There are various factors responsible of creating wrong pattern. Also if the design of gating, runner. Riser system is wrong then it leads to blow hole. In MHI VST 4- Cylinder block pattern there is insufficient venting due to this escape of gas is not possible which leads to blow hole.

b) Molding process- Various Sand parameters such as permeability, compatibility, grain size and shape, percentage of binder is high or low then it leads to blow hole. In MHIVST 4-cylinder block sand permeability is low due to this trapped gas is unable to escape during pouring and so wet sand leads to blow hole.

c) Melting process- During melting of metal if the content of nitrogen & CO gas is excess then it leads to blow hole. Also if the Proportion of addictives & charges are incorrect then leads to blow hole.

d) Pouring- During the pouring of molten metal in MHI VST 4-cylinder block there is chances of trapping of air due to pressure. Due to this air gets trapped also there is no chance to escape the trapped air. So pouring should be done in proper manner.

e) Solidification-If there is insufficient height for runner and riser then it leads to blow hole. The molten metal gets chance to solidify early which cannot fill the cavity of MHI VST 4-cylinder block casting which leads to blow hole.

4.0 Action Taken

4.1 Blow Hole Due To Trapped Air

Figure.6 Blow Hole on Face of Component

As shown in above figure 5 the blow hole is occurred on the face of MHI-VST 4-Cylinder block casting. While removing of sand from mould some amount of air is trapped inside the mould which is unable to escape back. Due to this Blowhole defect occurs on the face.

4.1.1 Action taken:-

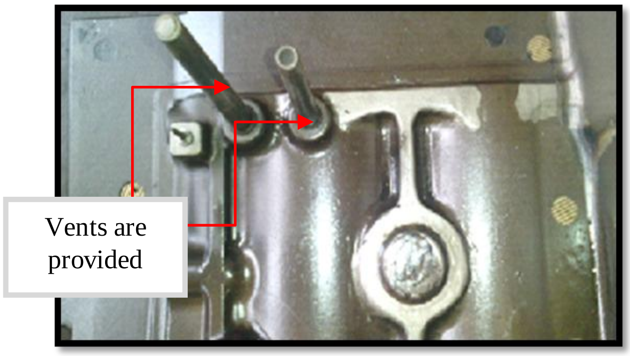

Figure.7 Vent on face

As shown in figure 7 Vents are provided where the blow hole occurs so that the trapped air can escape which cannot result into blow hole. The diameter of vent is around 10mm to 12mm. So that trapped air can be easily escape.

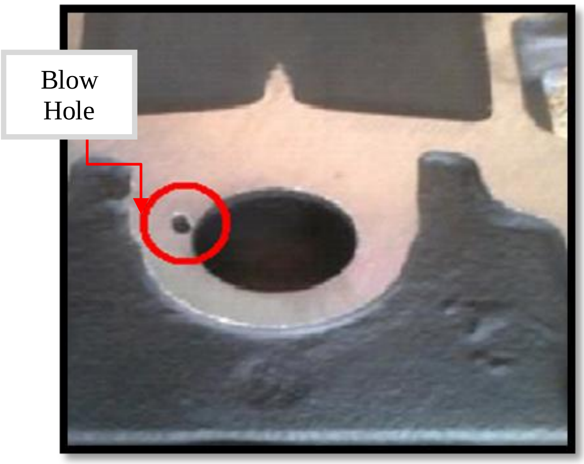

Figure.8 Blow Hole Due To Core

4.2 Blow Hole Due To Core

As shown in figure 8 Blow hole occurs when the core is wet during pouring of metal combination of hot water and cold water takes place which results into water vapour.

4.2.1 Action Taken

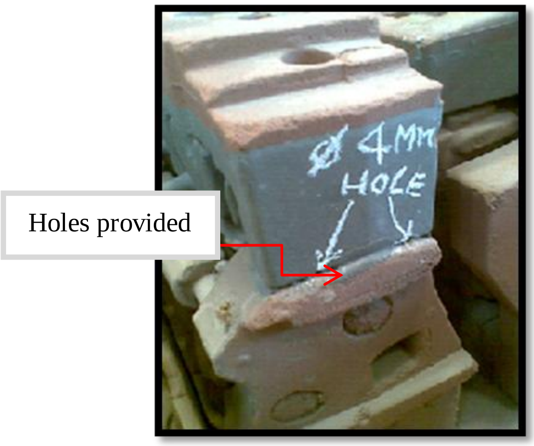

Figure.9 Holes Provided

As shown in figure 9 the blow hole is eliminated by drilling two holes on the core of diameter 4mm

4.3 Blow Hole on Head Face

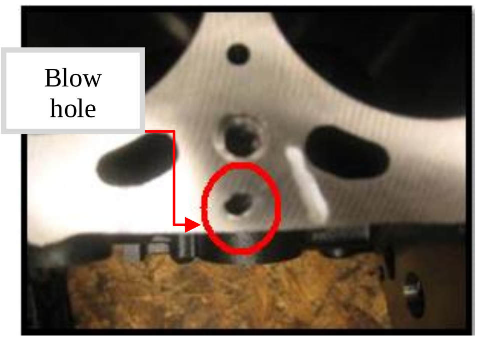

Figure.10 Blow Hole on Head Face

As shown in figure 10 the blow hole occurs on head face of cylinder. The blow hole occurred due to the air which is trapped during cleaning. As the blow hole size is large we cannot provide vent.

4.3.1 Action Taken

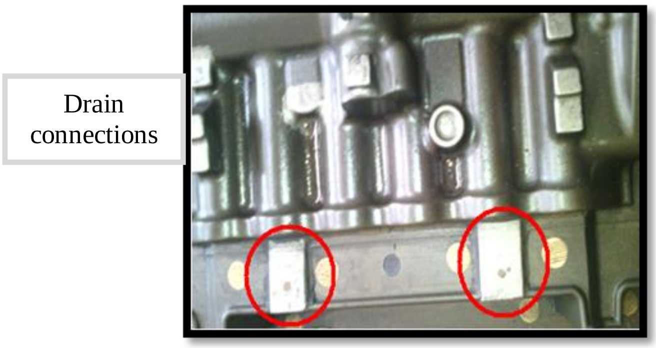

Figure.11 Drain Connection Provided

As shown in figure 11 the size of blow hole is large so we cannot use vent to escape the gas so we provided the two drain connections to escape the trapped air so that blow hole cannot be occur.

5.0 Result analysis

Table.1 Rejection analysis of blow hole (Before)

Month	Production Quantity	Casting Rejected	Rejection (%)
April	964	286	29.61
May	628	323	51.43
June	574	209	36.41
July	456	144	31.58
August	858	353	41.4

The rejection analysis before the analysis was shown in above table 1 from April to August. This data is provided by the quality department of company & this is comprises of total rejection.

Table.2 Result analysis of blow hole (After)

Month	Production qty	Casting Rejected	Rejection (%)
September	300	35	11.67
October	320	30	9.38
November	300	25	8.34
December	350	27	7.71
January	300	15	5.00
February	320	9	2.82

The rejection analysis after the actions been taken is shown in above table 2 from September to February. Maximum amount of blow hole is reduced with the techniques as discussed above. The rejection rate is drastically come down.

6.0 Conclusion

The main objective of the work was to reduce the overall rejection percentage of MH1-VST 4-Cylinder Block which was brought down 28 % to 30% . This is mainly because of significantly reducing the larger effect of blow hole in production. Also there is increase in the yield by 12 % which was firstly less than 68 % to 72 %. The profitability of foundry was also increased directly by overcoming the rejection rate & production runs become smooth for further production.

7.0 Acknowledgement

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