"Mathematical Modeling and Analysis of Various Parameters Responsible for Gray Cast Iron Defects"

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Abstract - *A defect in castings does not just happen. Casting defects are unusually not by accidents, they occur because some step in manufacturing cycle does not get properly controlled and somewhere something goes wrong. They are caused by wrong practice in one or more of the basic operations involved in the casting process as in the equipment used, or by the design of the part. A defect may be the result of a single clearly defined cause or a combination of factors, in which case necessary preventive measures are more obscure. If not controlled the rejection may be up to 50% also. Hence close control and standardization of all aspects of manufacturing techniques offers the best control against the occurrence of defects in castings. Normally castings also contain certain imperfections and discontinuity which contribute to a normal quality variation. Such imperfections are considered as defects when they affect the appearance or the satisfactory sound functioning of the casting. Defective casting offers ever-present problems to the foundry industry. Defective casting account higher losses to sand casting industry. Hence a systematic study can overcome the defects.*

INTRODUCTION

Foundry industry suffers from poor quality and productivity due to the large number of process parameters, combined with lower penetration of manufacturing automation and shortage of skilled workers compared to other industries. Global buyers demand defect-free castings and strict delivery schedule, which foundries are finding it very difficult to meet.

Casting defects result in increased unit cost and lower morale of shop floor personnel. The defects need to be diagnosed correctly for appropriate remedial measures, otherwise new defects may be introduced. Unfortunately, this is not an easy task, since casting process involves complex interactions among various parameters and operations related to metal composition, methods design, molding, melting, pouring, shake-out, fettling and machining. For example, if shrinkage porosity is identified as gas porosity, and the pouring temperature is lowered to reduce the same, it may lead to another defect, namely cold shut.

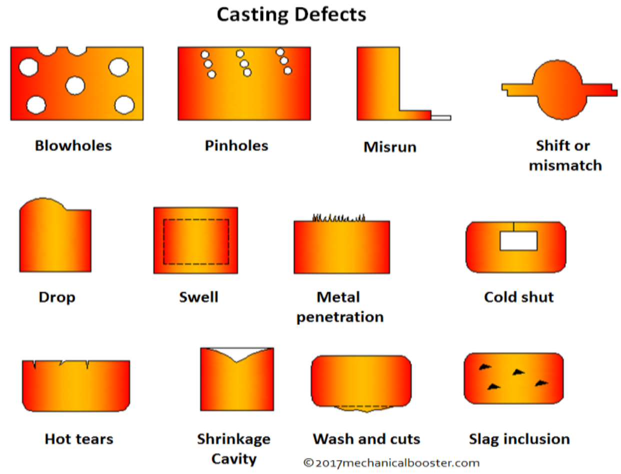
CASTING DEFECTS

Casting Defect is an unwanted irregularity that appears in the casting during metal casting process. There are various reasons or sources which are responsible for the defects in the cast metal. Some of the defects produced may be neglected or tolerated and some are not acceptable, it must be eliminated for better functioning of the parts.

Types of Defects

Casting defects can be categorized into 5 types:

a) ***Gas Porosity***: Blowholes, open holes, pinholes
b) ***Shrinkage defects***: shrinkage cavity
c) Cold material defects: Cut and washes, swell, drops, metal penetration, rat tail
d) Pouring metal defects: Cold shut, misrun, slag inclusion
e) Metallurgical defects: Hot tears, hot spot.



Types of Moulding Sand

The various types of moulding sand are

a) Green sand
b) Dry sand
c) Loam sand
d) Parting sand
e) Facing sand
f) Backing sand
g) System sand
h) Core sand

PROPERTIES OF MOULDING SAND IN CASTING

During casting of metals in the foundry shop we use sand for the preparation of mould. It is the moulding sand properties which improves the quality of the casting metal. If a sand of suitable property is chosen, than it greatly minimises the casting defects that may be produced during the mould preparation and casting.

Properties of Moulding Sand

A moulding sand should possess the following 6 properties

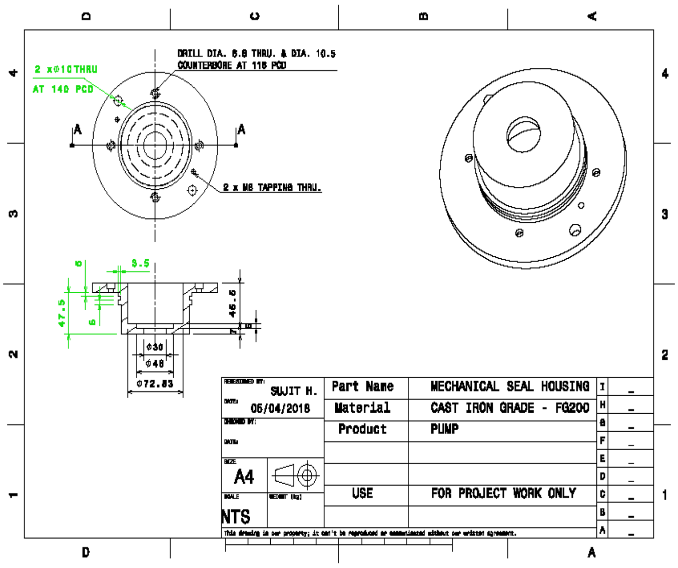
1. Porosity
2. Flowability
3. Collapsibility
4. Adhesiveness
5. Cohesiveness or strength
6. Refractoriness

OBJECTIVE

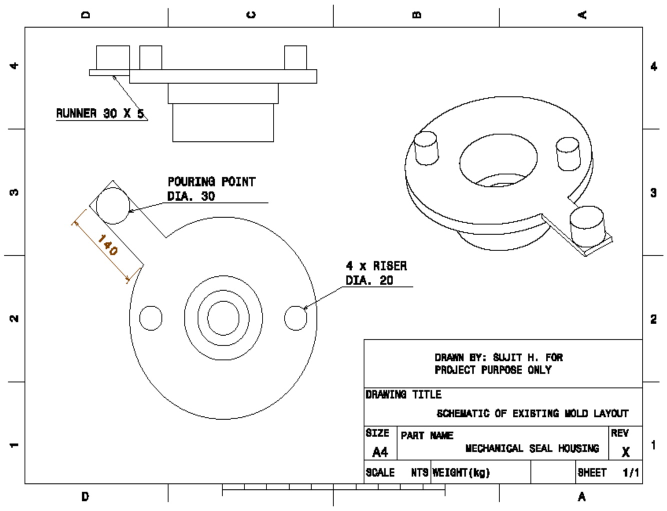
The following objectives are:

- To identify various causes of occurrence of defects and put them together.
- To develop a mathematical model of parameters responsible for casting defects.
- To identify corresponding remedies and put them together.
- To develop a knowledge base related to casting defects.

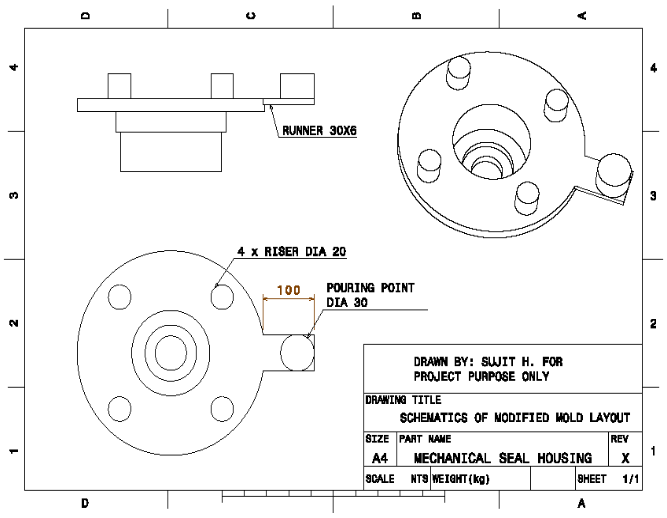
DESIGN AND MODELLING



a) Mechanical Seal Housing

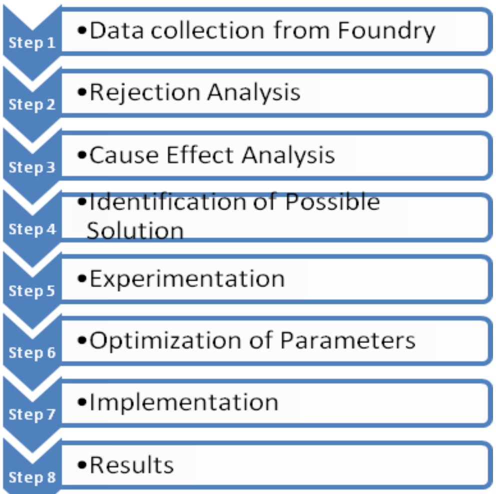


b) Existing Mould Layout



c) Modified Mould Layout

Analysis



Defect	Rejection Qty.	Percentage Rejection
BLOW HOLE	238	25.81
SAND DROP	217	23.54
COLD SHUT	71	7.70
SHIFT	45	4.88
MOULD BROKEN	38	4.12
SHRINKAGE	18	1.95
GROOVE DAMAGE	7	0.76
SCABBING	2	0.22
Total	636	68.98

Table1 : Major Casting Defects in Pump part in the Foundry

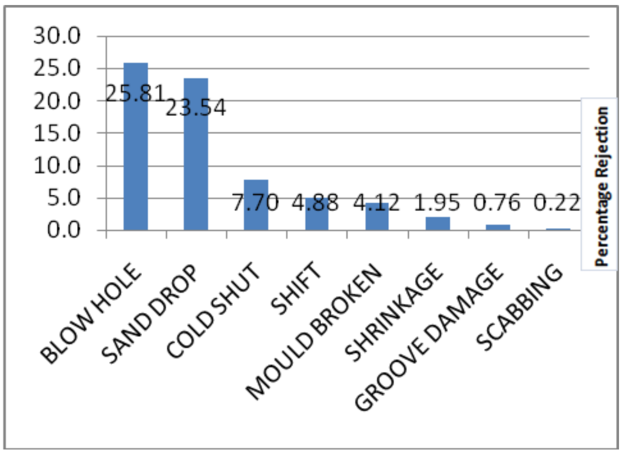


Chart (2): Pareto Analysis of Major Casting Defects in the Foundry

As seen from the rejection analysis out of 922 Castings, 68.98% castings were rejected due to above defects. It is seen that from 68.98% total rejection, 25.81 % castings are rejected only because of **Blow Hole defect** which was identified during machining and 74.19 % defects are because of Sand Drop, ColdShut, Core Shift, Mould Break Groove damage and Scabbing.

Pareto analysis works on 80/20 principle which states that 80% of rejection occurs only because of 20% defects. From the analysis of above Pareto chart, it is clear that **49.35 %** rejections are only because of two types of defects which are **Blow Holes and Sand Drop**. So by working on these defects we can increase the productivity and reduce overall defect.

Figure below shows a 3D graph plot of clay versus Mold hardness. It is clear from the figure that medium clay percentage and mold hardness provides a better quality of castings. With increase in clay percentage, the defects are also noted to be increasing

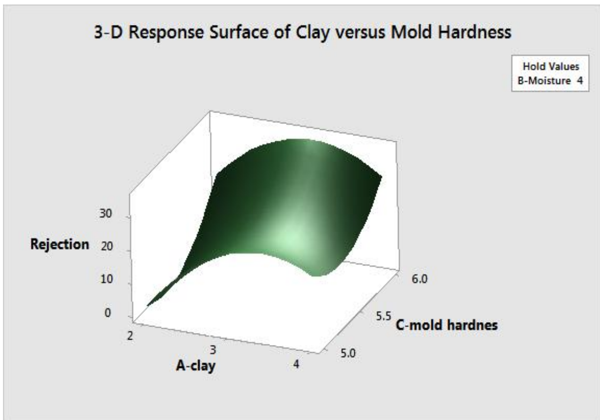


Figure (25): 3-D Response Surface Plot

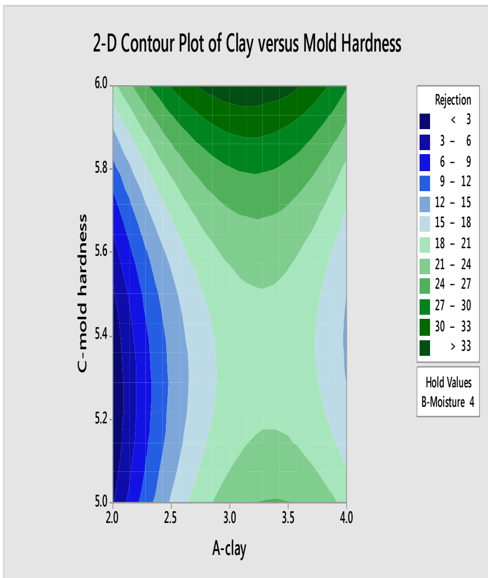


Figure (26) : 2-D Response Surface Plot

RESULT AND DISCUSSION

Numerical optimization

By numerical optimization, the target or the goal of the experiment can be set. Here the aim is to minimize the defective components in Mechanical Seal Housing castings. From Table below, it was noted that there were 5 possible solutions for minimizing the defect percentage close to zero.

Solutions	Clay %	Moisture %	Mold Hardness (Kg/cm2)	Defect %	Desirability
1	2	4	5.25	0.31	0.937
2	2	3.96	5.26	0.32	0.936
3	2	4	5.21	0.36	0.928
4	2	3.92	5.35	0.61	0.879
5	2	3.87	5.45	1.58	0.684

CONFIRMATION EXPERIMENTS

The main purpose of these confirmation experiments is to validate the setting obtained from Design expert software which is likely to achieve the defect free castings. A set of 10 confirmation experiments were conducted three times with the optimal settings producing 30 samples of pump adapter castings. On inspecting the samples for defects, all the 30 castings were found to be defect free.

Comparison of existing and experimented settings

Sr. No.	Factors	Existing Range	Experimental Range
1	Clay Percentage	1%	2%
2	Moisture Percentage	4%	3.87 - 4%
3	Mold Hardness	No measure	5.21 - 5.45 kg/cm2
% Approved castings		58.70%	100%

Hence, the parametric settings may be taken as optimal for producing large quantities of Mechanical Seal Housing castings with minimal or no defects. In general, the use of higher clay content and mold hardness with moderate moisture percentage led to better castings as shown in Table

CONCLUSION

In this work, parametric optimization for controlling casting defects in FG 200 Mechanical Seal Housing was attempted by design and of experiments (DOE). Relevant experiments were conducted in a foundry producing pump components. The major parameters that were responsible for producing casting defects in pump components were identified as proportions of clay, moisture and Mold hardness respectively. Each parameter was analyzed with three different levels. Further the contribution of the parameters was analyzed using ANOVA technique to find their effects. Interaction effects between the factors were also studied.

F-Test of the ANOVA revealed that the parameters of proportion of clay and Mold hardness were equally significant in the casting process. These parameters were noted to be more critical in producing quality cast components.

The optimized parametric setting was determined by Minitab software:

Clay – 2%

Moisture – 3.87 to 4 %

Mold Hardness – 5.21 to 5.45 kg/cm2 as a range of values for the input conditions that can be easily practiced by workmen in industries.

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