An Optimization Of Process Parameters: To Minimize The Casting Defects Of Mild Steel Product In Green Sand Casting Process By Using Orthogonal Array And Taguchi Method

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Abstract- *The main purpose of this paper is to reduce the casting defects by analyzing and detecting with the use of non-destructive testing methods. In most of the industries as we all are aware about the normal casting defects which are generated during the pouring of the metal. The main casting defects those are found in foundry are generally sand particle inclusions, gas bubbles, pinholes, cold shuts and other surface defects. The output of this paper is to reduce the selected process parameter like moisture content, green sand strength, sand particle dimension and hardness of mould, which affects the casting defects in the foundry. The improvement in the casting defects is found to be 42.99%.*

Keywords- Chaplets, Core print, Cores, Die casting, Foundry, Green molding sand & Casting defects.

I. INTRODUCTION

As described earlier, several different methods are available to shape metals into useful products. Casting is one of the oldest process for making some articles, which basically involves pouring molten metal into a mould cavity. During solidification, the metal takes the shape of the mould cavity. Casting first was used around 4000 B.C. to make ornaments, arrowheads, and various other objects. A Wide variety of products can be cast, and the process is capable of producing intricate shapes in one piece, including those with internal cavities, such as engine blocks. The casting processes developed over the years are shown in Fig. 1.

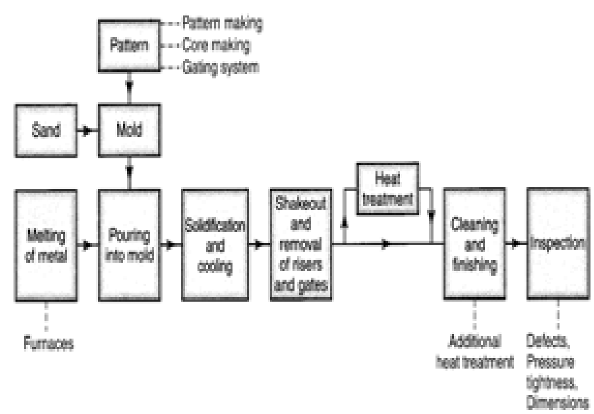


FIG.1. Outline of production steps in a typical sand-casting operation

II. GREEN SAND CASTING OPERATION

After the mould has been shaped and the cores have been placed in position, the two halves (cope and drag) are closed, clamped, and weighted down to prevent the separation of the mould sections under the pressure exerted when the molten metal is poured into the mould cavity. A complete sequence of operations in sand casting is shown in Fig. 2. After solidification, the casting is shaken out of its mould, and the sand and oxide layers adhering to the casting are removed by vibration (using a shaker) or by sand blasting. Castings also are cleaned by blasting with steel shot or grit (shot blasting). The risers and gates are cut off by oxy-fuel -gas cutting, sawing, shearing, or abrasive wheels; or they are trimmed in dies. Gates and risers on steel castings also may be removed with air carbon-arc cutting or torches. Castings may be cleaned further by electrochemical means or by pickling with chemicals to remove surface oxides.

The casting subsequently may be heat treated to improve certain properties required for its intended use; heat-treatment is particularly important for steel castings. Finishing operations may involve machining, straightening, or forging with dies (sizing) to obtain final dimensions. Inspection is an important final step and is carried out to ensure that the casting meets all design and quality-control requirements.

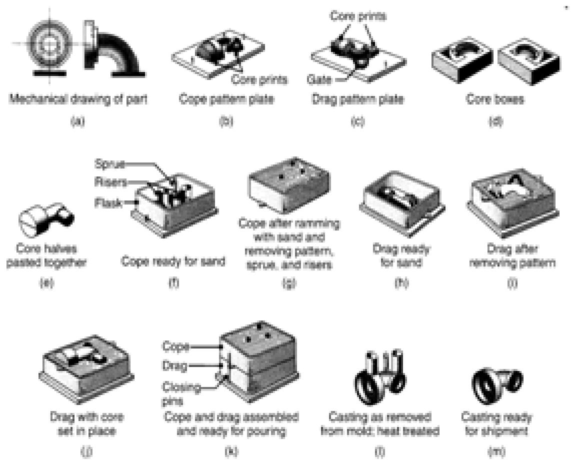


Fig.2. Schematic illustration of the sequence of operations for sand casting.

III.TYPES OF SAND MOULD

Sand moulds (Fig.3) are characterized by the types of sand that comprise them and by the methods used to produce them. There are three basic types of sand moulds: green-sand, cold-box, and no-bake moulds. The most common mould material is green molding sand, which is a mixture of sand, clay, and water. The term “green” refers to the fact that the sand in the mould is moist or damp while the metal is being poured into it. Green-sand molding is the least expensive method of making moulds, and the sand is recycled easily for subsequent reuse. In the skin-dried method, the mould surfaces are dried, either by storing the mould in air or by drying it with torches. Because of their higher strength, these moulds generally are used for large castings.

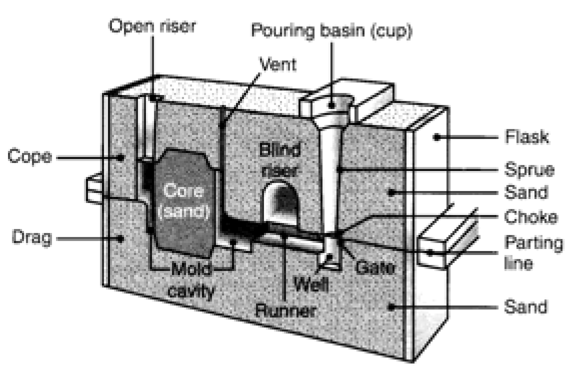


Fig.3. Schematic illustration of a sand mould, showing various features.

Sand moulds can be oven dried (baked) prior to pouring the molten metal; they are then stronger and impart better dimensional accuracy and surface finish to the casting. However, this method has the drawbacks that (a) distortion of the mould is greater, (b) the castings are more susceptible to hot tearing because of the lower collapsibility of the mould, and (c) the production rate is lower because of the considerable drying time required.

The major features of moulds in sand casting are as follows:

1. The flask, which supports the mould itself. Two-piece moulds consist of a cope on top and a drag on the bottom; the seam between them is the parting line. When more than two pieces are used in a sand mould, the additional parts are called cheeks.
2. A pouring basin or pouring cup, into which the molten metal is poured.
3. A sprue , through which the molten metal flows downward.
4. The runner system, which has channels that carry the molten metal from the sprue to the mould cavity. Gates are the inlets into the mould cavity.
5. Risers, which supply additional molten metal to the casting as it shrinks during solidification. Two types of risers-a blind riser and an open riser-are shown in Fig. .3.
6. Cores, which are inserts made from sand. They are placed in the mould to form hollow regions or otherwise define the interior surface of the casting. Cores also are used on the outside of the casting to form features such as lettering on the surface or deep external pockets.

MATERIAL OF CASTED WORKPIECE

Mild steel or low carbon steel is mostly used alloy steels for making most of the industrial products.The main components involved in mild steels are as follows: Carbo,Silicon,Manganese,Sulphur,Phosphorus,Nickle,Chromium,Molebdenum,Tungsten and Vanadium as alloying elements.

CASTING DEFECT

Casting is a very versatile process and capable of being used in mass production. The size of components is varied from very large to very small, with intricate designs. Out of the several steps involved in the casting process, molding and melting processes are the most important stages. Improper control at these stages results in defective castings, which reduces the productivity of a foundry industry. Any irregularity in the molding process or carelessness by employ causes defects in castings which may sometime be tolerated, sometime eliminated with proper molding practice or repaired using method such as welding and metallization. The following are the defects which are likely to occur in sand castings in industry –

- Blow hole

- Fin
- Cold shut
- Sand drop and
- Rough surface.

1. BLOW HOLES

Clean, smooth walled rounded holes of varying size from pin heads to full section thickness, often exposed during machining.

Causes:

- Low pouring tempera-ture.
- Excessive turbulence during pouring.

Fig.1 Blow Holes

Remedies:

- Use correct pouring temperature -and check with pyrometer.
- Modify gating to reduce turbulence, use sivex filter.
- A thin projection of metal – not a part of cast .

2. FIN

Usually occur at the parting of mould or core sections.

Causes:
- Incorrect assembly of cores and moulds.
- Improper clamping.
- Improper sealing.

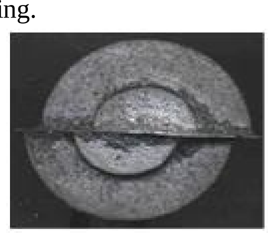


Fig.2 Fins

Remedies:
- Reduces by proper clamping of cores and mould.

3. COLD SHUT

Castings not fully form having lines or seam of discontinuity or holes with rounded edges through casting walls.

Fig.3 Cold Shut

Causes:
- Incomplete fusion where two streams of metal meats.
- Metal freezes before mould is filled.
- Die too cold.

Remedies:
- Increase pouring temperature.
- Increase die temperature or improve venting.
- Increase permeability of sand.

4. SAND DROP

Sand drop is also called as sand crush. The sand mould drops part of sand blocks, so they will cause the similar shaped sand holes or incomplete .

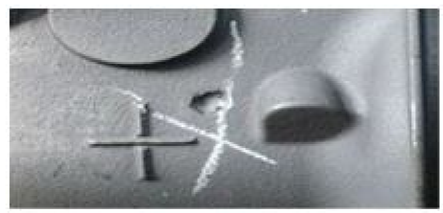


Fig.4 Sand Drop

Causes:
- Low green strength .
- Low mould hardness .

Remedies:
- Increase mould hardness .

5. ROUGH SURFACE

Roughness must be assessed relative to the grain size of the casting selected. Under certain circumstances a work piece cast in coarse sand with fully uniform surface must be assessed as being smooth, although it is rougher than a "rough area" on a work piece cast in fine grained sand.

Causes:
- Sand mixture not proper
- High water content
- Abrupt mould
- Very High pouring temperature

Fig.5 Rough Surface

Remedies:

- Use finer sand
- Reduce water content
- Increase compaction pressure
- Reduce casting temperature

IV.METHODOLOGY

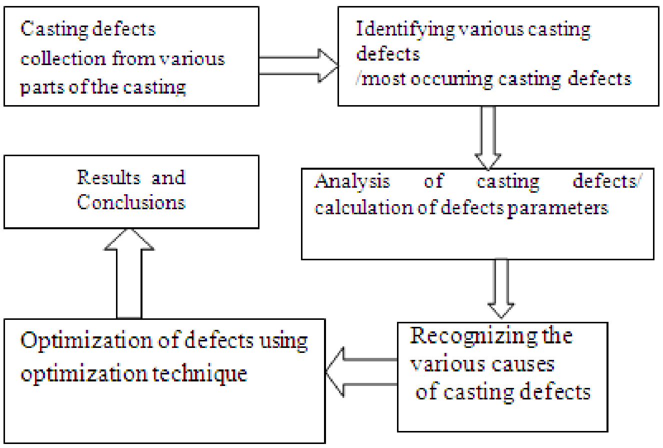


Fig. 6 METHODOLOGY

V. OPTIMIZATION OF PROCESS PARAMETERS TO REDUC THE CASTING DEFECTS

The purpose of this paper is to fulfill the criteria of optimization under which the casting defects reduced. There are some proper steps by which the defect will be optimized are falls under this categories:

1. To make a list of parameter involved which are mostly responsible for the causes of defects.
2. Casting defects is mainly considered as the most important factor in rejection of casting , as the casting is related as internal casting defects(sand drops, pinholes and blow holes) as well as external casting defects(surface cracks ,hot tears and fins).
3. Based on the experimental conditions, collect the data related with green sand casting process which is collected by orthogonal array and parameter level.
4. Now optimize the all individual parameter at the optimized level by the optimization techniques.
5. Verify the optimum settings result in the predicted reduction in the casting defects.
6. The main causes of rejection in castings are due to improper pattern, improper gating system, improper control of sand parameters, improper molten metal composition. The process parameters of the sand casting can be listed as follows:
   - Sand moisture Content (%)
   - Green sand Strength (g/cm2)
   - Sand Particle dimension (AFS)
   - Hardness of Mould (Nu)

For each parameter during a process a range is decided between the different levels which optimize the parameter to a certain level and is acceptable in the foundry of an organization for the purpose showing the reduction in casting defects. The parameters, along with their ranges and different levels are given in the following Table-(a).

Table-(a).

S.No.	Parameters	Range	Level -1	Level -2	Level -3
1.	Sand moisture Content (%)	3-4.8	3.6	4.2	4.8
2.	Green sand Strength (g/cm^2)	1300-1500	1350	1400	1450
3.	Sand Particle dimension (AFS)	50-56	52	54	56
4.	Hardness of Mould (Nu)	45-75	55	65	75

VI. MEASUREMENT OF QUALITY CHARACTERISTICS BY TAGUCHI METHOD

Casting defects was selected as a quality characteristic to be measured. The most common defects occurring in the foundry were monitored and recorded. The smaller the better number of casting defect implies better process performance. Here the objective function to be maximized is: Smaller is better **Max $\eta = -10 \times \log10\ [\mathrm{sum}\ (\delta^{2i}/n)]$.**

Maximizing 'η' leads to minimization of quality loss due to defects. Where S/N ratio is used for measuring sensitivity to noise factors, n is number of experiments orthogonal array and δ be the i-th value measured.

(A) Formation of Orthogonal Array L9

Formation of an orthogonal array depends upon the number of control factors and interaction of interest. It also depends upon number of levels for the control factors of interest. Therefore with one control factor moisture percentage of two levels and other control factors sand particle size, green compression strength (GCS), mould hardness number and orthogonal array is selected with 9 experimental runs and four columns. Taguchi has provided in the assignment of factors and interaction to arrays. The assigned L9 orthogonal array is shown in Table 2 and the experimental orthogonal array having their levels are assigned to columns is shown in Table 3.

Table -2 ORTHOGONAL ARRAY L9

Trail No.	W	X	Y	Z
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	1	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

(B)Experimental Orthogonal Array L9:

Table -3 EXPERIMENTAL ORTHOGONAL ARRAY L9

Trial No.	W Sand moisture Content (%)	X Green sand Strength (g/cm^2)	Y Sand Particle dimensi -on (AFS)	Z Hardness of Mould (Nu)
1	3.6	1350	52	55
2	3.6	1400	54	65
3	3.6	1450	56	75
4	4.2	1350	52	75
5	4.2	1400	56	55
6	4.2	1450	52	65
7	4.8	1350	56	65
8	4.8	1400	52	75
9	4.8	1450	54	55

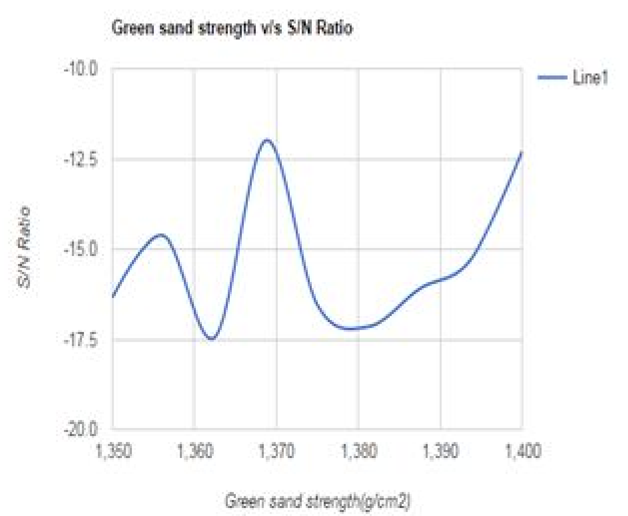
VII. RESULTS OF EXPERIMENT & S/N RATIO

The result of this experiments is obtained by conducting thrice for the same set of parameters using a single-repetition randomization technique .The casting defects that occur in each trial conditions were found and recorded. The average of the casting defects was also determined for each trial condition as shown in Table 4. The casting defects are "smaller the better" type of quality characteristics. Smaller the better S/N ratios were computed for each of the 18 trials and the values are given in Table 4:

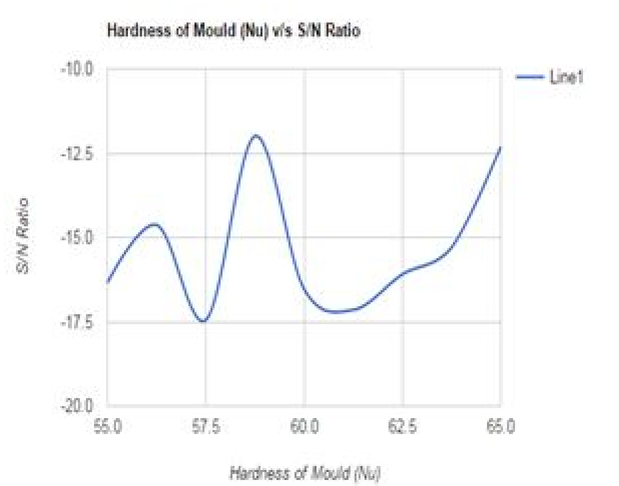
Table 4: Casting Defects Value and Signal to Noise (S/N) Ratio against Trial Number

Trial No.	% Defects in Experiments (δ) 1	2	3	Total	Avera-ge	S/N Ratio
1	6.5	5.8	7.3	19.6	6.533	-16.3407
2	5.6	4.8	5.73	16.13	5.377	-14.6355
3	7.78	6.3	8.14	22.22	7.407	-17.4423
4	4.3	3.9	3.71	11.91	3.970	-11.9924
5	6.84	5.33	7.74	19.91	6.637	-16.5354
6	7.66	7.24	6.67	21.57	7.190	-17.1483
7	7.32	4.82	6.73	18.87	6.290	-16.0962
8	3.71	7.7	5.32	16.73	5.577	-15.2873
9	4.7	4.3	3.22	12.22	4.073	-12.3001

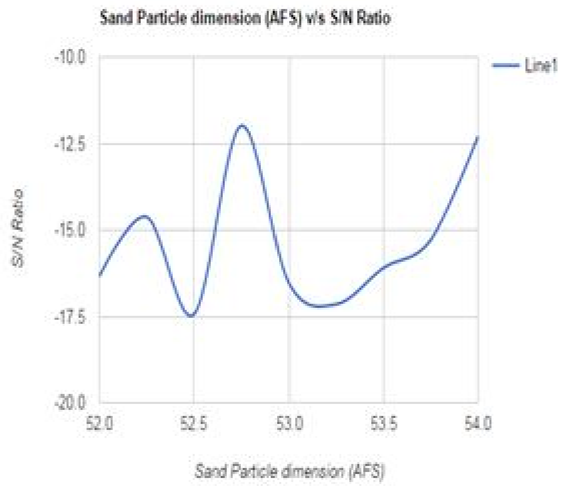
Following four types of graphs are represented from the subject point of view as shown in Fig.7:



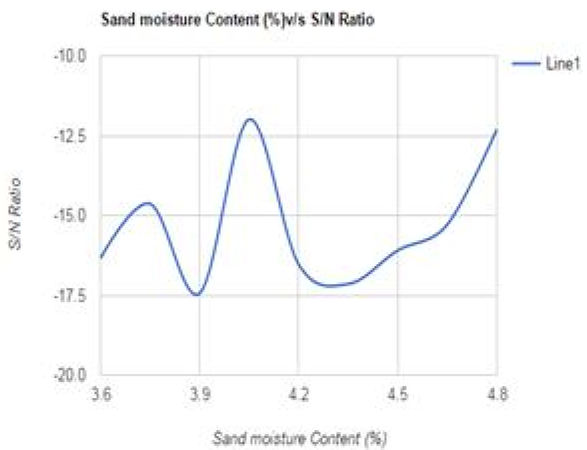
(a)



(b)



(c)



(d)

Fig.7- (S/N) Ratio v/s different Mould properties referring fig (a),(b),(c) and (d).

VIII. CONCLUSION

The optimum conditions for the parameter computed for the mould are given below as-

Moisture (%) – level 2 – 4.2
Green Strength (g/cm2) – level 1 – 1350
Sand Particle Size (AFS) – level 1 – 52
Mould Hardness (Nu) – level 3 – 75

The improvement expected in minimizing the variation is 42.99% which means reduction of casting defects from the present of 22.22% to 11.91% of the total casting product in the foundry. This also reflect that by using Taguchi method the factor levels when optimized will result in reduction of casting defects and increase the yield percentage of the accepted casting without any additional investment. A usage of quality tools like pareto chart is useful for finding the major defects in the daily operations of foundry. Quality of casting can be improved by aesthetic look, dimensional accuracy, better understanding of noise factor and interaction between variables, quality cost system based on individual product, scrap reduction, reworking of casting and process control.

IX. FUTURE SCOPE

The present method adopted to solve the optimization problem of Casting process is simple enough and is flexible in selection of objective functions for such manufacturing processes. During the solution of the problem, it has been found that the results obtained by the Taguchi method towards the exact solutions. This approach may be coupled to other optimization algorithms to get multistage multi-criterion optimization by Taguchi approach. Then this method will be able to show its importance in real life complex manufacturing problem solution.

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