Defect Analysis for Sand Casting process (Case Study in foundry of Kombolcha Textile Share Company)

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Abstract - *This research aimed to identify the cause of casting defect and to suggest possible remedies in order to produce conforming casting product in the foundry of Kombolcha textile share company, Ethiopia. During casting defect analysis, the common casting defects blowholes, pinholes and shrinkage were identified. The major and minor process variables which were responsible for each casting defects were indicated using fishbone diagram. For analysis of possible causes, Experiments were conducted for moulding sand to determine clay content and grain fineness number (GFN). For defective part, composition analysis using spectrometer was also done. Analysis showed that high clay content (52.7%) of moulding sand, wrong gating system design, incorrect pattern design and unknown pouring temperature were responsible for the defects. Experiment was conducted for remedial actions using reclaimed sand with grain fineness number 40.19 and clay content of 1.5%, for correct gating system and pattern design for casting of brake casing of weaving machine. Good results were obtained with exception of difficulty in pattern removal during mould making due to coarseness of the sand. Finally, the possible remedies for the defects were suggested.*

Key Words: - Sand Casting, Casting Defects, defect analysis, fishbone diagram, and gating system.

1. INTRODUCTION

Metal casting is one of the primary manufacturing processes which uses to produce simple or complex products and is the only method uses to produce massive objects in one single piece by pouring molten metal into mould or die cavity, and allowing it to solidify into shape of the cavity[13].Metal casting process is a complex process with several sub-processes, such as patternmaking, mould and core making, melting and pouring, heat treatment and cleaning, finishing, which in turn have several process variables[7].To produce product within customers acceptance specification, proper control of varies process variable at each process stage within the required level is important to produce conforming casting product. Deviation of any process parameter will cause one or more casting defects on the product.

A few manufacturing industries are found in Ethiopia in which casting process is the one that uses to produce metallic parts. These parts use for internal customers who wants to substitute their broken spare parts. Since the process is supported by shop-floor trial and there is shortage of skilled workers, the casting products produced are not quality product to satisfy customers need. Solving this problem in these foundries is important to satisfy customers need.

Casting process in foundry of Kombolcha textile Share Company produces parts such as Armature disk, front flange, real flange, and pulley of different size, cast iron and Aluminum ingot of different size, machine frame and others by using Cast iron and Aluminum as a casting material. Since this foundry is supported by shop floor trial, parts produce in this foundry are most of the time defective products. Therefore, identify the cause of casting defect and suggesting possible remedies to quality enhancement is important for the company itself to increase its productivity with having fast spare part supply for maintenance service and also to satisfy its external customers.

2. Literature Review

B.chokkaligam and S.S.Mahammed Naziruden [3] applied defect diagnostic approach for casting defect analysis and optimized the process for quality improvement for one of the casting product automobile transfer case. They found that major defect was mould crush as shown by Pareto chart and root cause for this defect was mismatch of the cores as shown by fishbone diagram. They selected best solution, which is the production of a single core which reduced casting rejection to 4% from 21%. Rajesh Rajkahe and J.G.Khan [16] classified casting defects with respect to filling related, shape related, thermal and appearance and presented different types of defects under each category with their possible causes and remedies. This is very important for foundries for easy reference to take corrective action when nonconformances occur during production. Sunil Chaudhari and Hemant

Thakker [18] revised different researches which involved in casting defect analysis and their quality improvement. They summarized causes and remedies suggested by different researchers on major sand-casting defect, shrinkage cavities, moulding material defects, pouring metal and metallurgical defect. Aniruddha Joshi and L.M. Jugulkar [1] did casting defect analysis for foundry which produces automotive components like engine flange, cylinder head cover and bearing housing. They used the quality control tools such as check sheet to collect data, Pareto diagram to identify the major defects and cause and effect diagram to identify the cause of the defect.

3. Methodologies and Materials

Here, casting defect analysis was done by following steps set up in the casting defect analysis map as shown figure.1 below. During analysis necessary dates were collected from the foundry, experiments were conducted for moulding sand (such as sieve analysis, clay content test) and composition analysis for casting material.

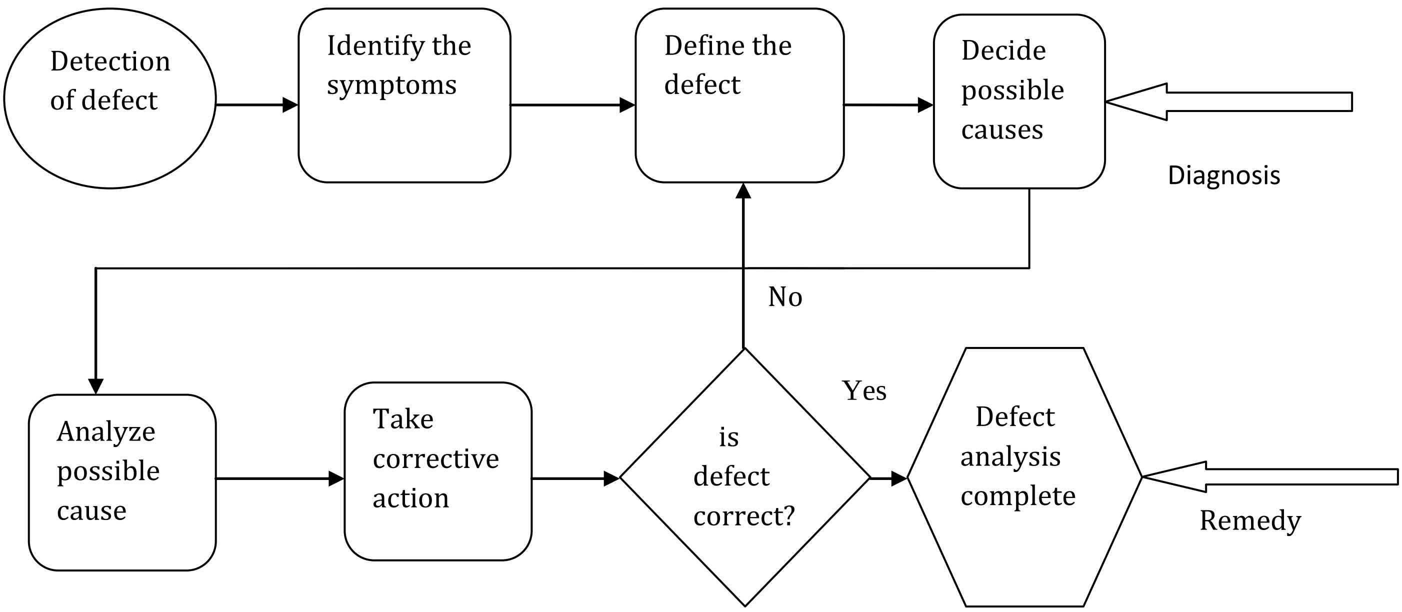


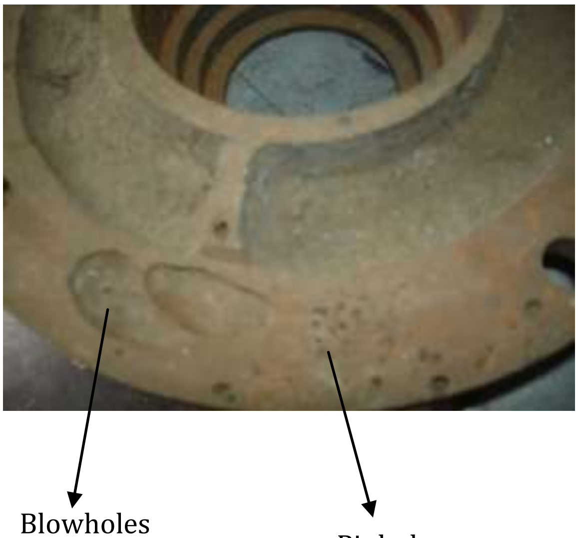
Figure.1 Defect analysis map [3]

3.1. Detection of the defect

Almost all product of casting in this foundry are defective products. From the evidence, only a few are acceptable casting product with certain tolerance, the majorities are rejected product. As shown in figure 2.

a) Shrinkage due to fast solidification at thin section

b) Shrinkage due to over melt



c) blowholes and pinholes

d) Shrinkage at the joint of section

Figure.2 a, b, c and d are examples of casting defects commonly occurred in the foundry

3.2. Identify the Symptoms and defining defects

From the symptoms, let's define the kind of defects.

Table 1. Symptoms commonly absorbed and related defect types

No.	**Symptoms Absorbed**	**Kind of casting defect**
1.	Numerous holes of small diameter (less than 2mm)	Pinholes
2.	Smooth and round holes (about 3mm in diameter)	Blowholes
3.	Large and rough void or depression, Holes at the joint section	Shrinkage cavity
4.	Embedment of sand on casting surface	Burn-on

3.4. Decide possible cause

Fish bone diagram is one of the methods for identifying causes of the defects. The diagram indicates all the possible major and minor causes which are responsible for the occurrence of the above listed defects where there is any deviation from their acceptance level. The following are the fishbone diagrams for those defects occurred in this foundry.

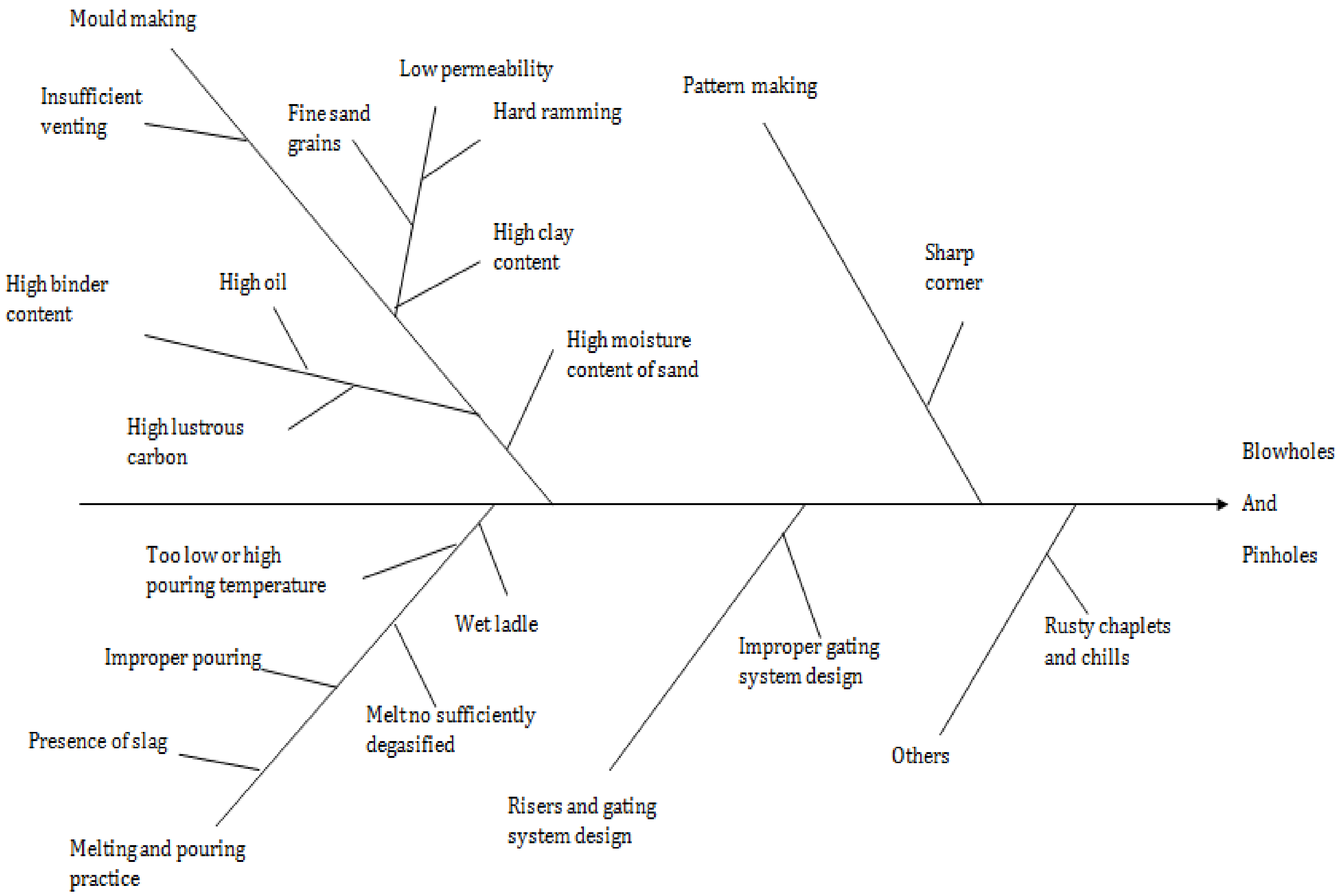


Figure 3. Cause and effect diagram for blowholes and pinholes

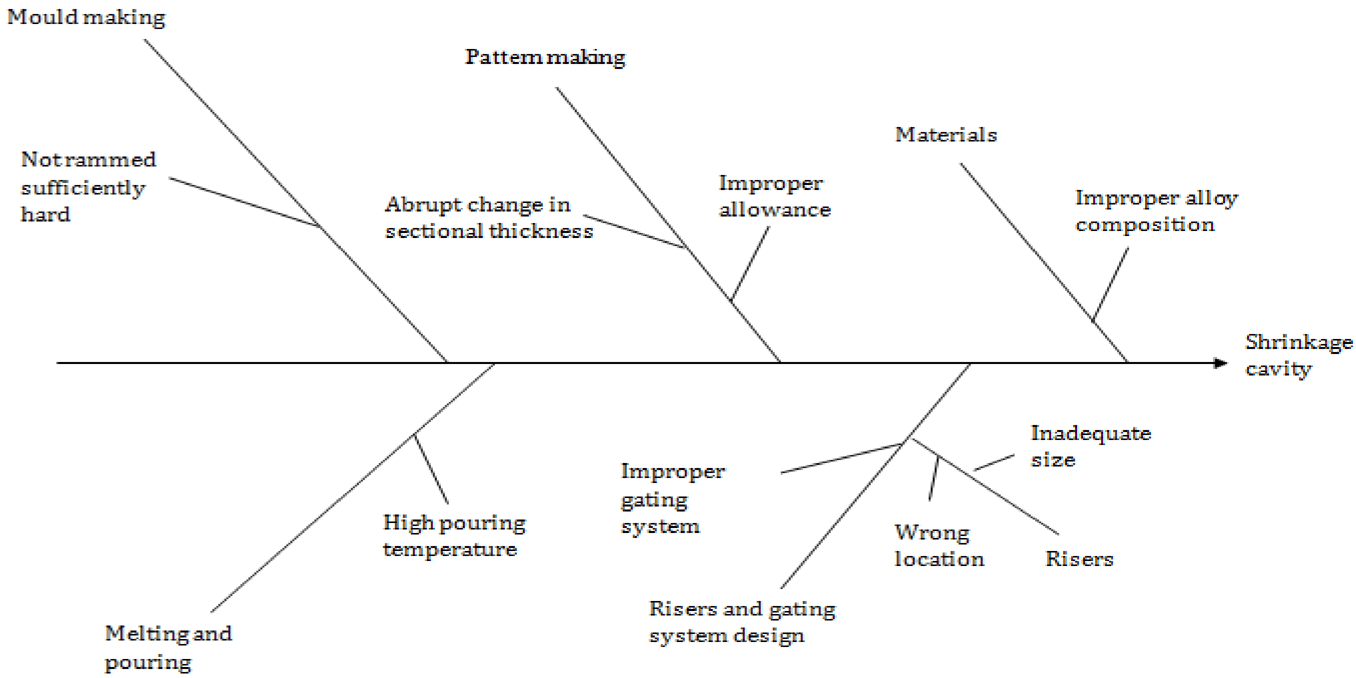


Figure 4. Cause and effect diagram for shrinkage cavity

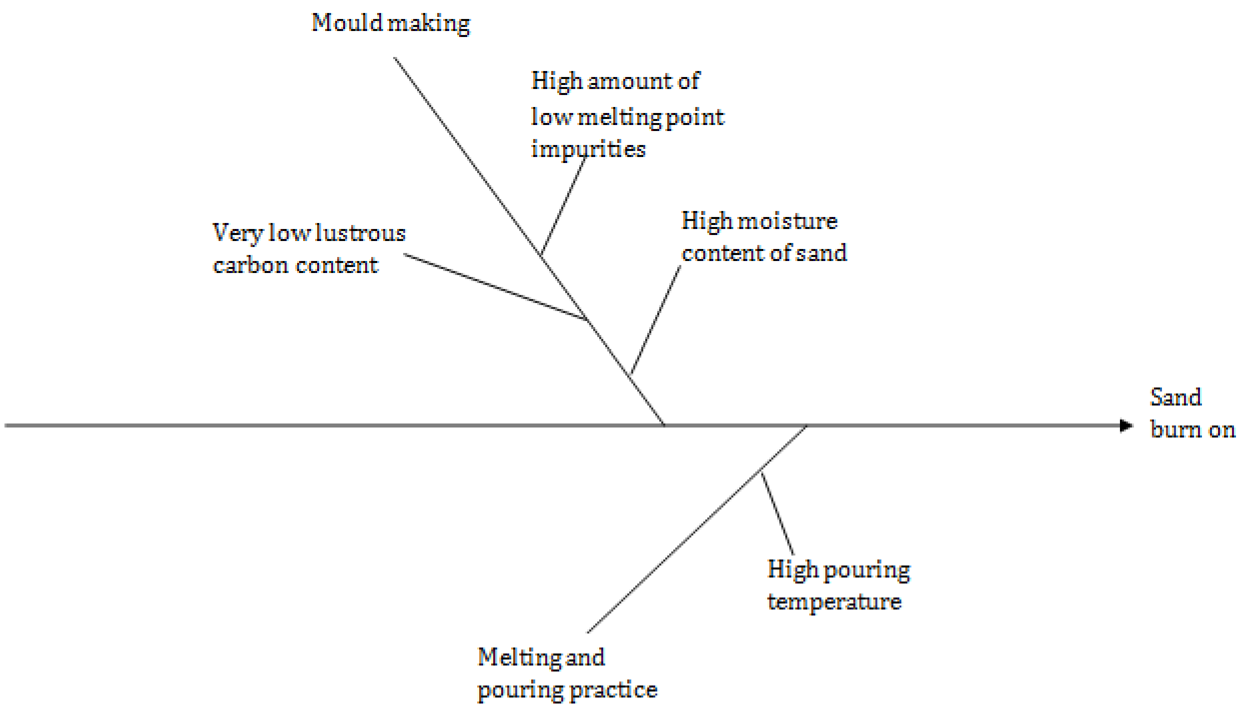


Figure 5. Cause and effect diagram for sand burn on

3.5. Analysis of possible cause

In order to identify from all sub-causes shown in fishbone diagram, which one is responsible for the defect indicated, detail examination of process parameters in this foundry is important. Therefore, to analyze possible causes of the defects, experimental test to some measurable variables and practical examinations of existing foundry work were done.

The following were Experimental tests

1. Clay content test
2. Grain fineness number test
3. Chemical Composition analysis for sample defective casted metal

Testing of clay content

The test was conducted in foundry laboratory of Federal Micro and small enterprise development agency, Ethiopia.

Laboratory equipment used: clay washer, oven drier and weighing scale.

Chemical used: 25c.c standard solution of (NaOH) sodium hydroxide

The clay content test was done for foundry sand (see figure 5, below) which use in this foundry.

100g of sand sample was taken and results the following;

$$\text{Clay content} = \begin{bmatrix} initial\ weight\ of \\ sand\ sample \end{bmatrix} - \begin{bmatrix} final\ weight\ of \\ sand\ sample \end{bmatrix}$$

$$=100g - 47.3g = 52.7g$$

In percentage, 52.7% of molding sand is clay and 47.3% of molding sand is silica grain. Based on clay content test, clay content of 52.7% is extremely contradictory to the recommended percentage of clay for different types of moulding sands which uses for mould making process. Based on their classification, maximum clay content is not more than 2% for high silica sand and up to 10% for natural moulding sand [13].

Figure.5 The moulding sand which use in this foundry

Figure.6 Photo during silica sand drying using oven drier after clay washing

Grain fineness number (GFN) test

This experiment was conducted next to clay content test for silica grains of 47.3g left after clay removal.

Laboratory equipment used: Sieve shaker, weighing scale**.**

Sieve analysis was done for 47.3g of silica sand grains. The test was carried out in power driven shaker consisting of number of sieves having varying and known number of meshes fitted one over the other. Shaking was for about 15-minutes. Finally, the weight of silica grain on each sieve was weighted and the following result was obtained. (experimental result is show in table 2 below)

Figure.8 Photo during shaking of sand in sieve shaker and weighing of each sieve with grains on it.

$$\text{Grain fineness number (GFN)} = \frac{\text{total product}}{\text{total sum of percentage weight retain in each sieve}}$$

$$= \frac{1673.3}{99.93} = 16.74$$

Grain fineness number (GFN) 16.74 determined by experiment is very small number, it indicates this sand is very coarse which has very small fineness number less than the average fineness number which varies for cast iron from 45-65 and light alloys(e.g.Aluminium) 70-100 [13].

Table 2. Measured and calculated sieve analysis data

Sieve No.	Diameter of Sieve hole	Weight of sieve	Weight of Retained sand sieve	Weight retained sand		Multiplying Factor	Product
				(g)	(%)		
6 mesh	3.35mm	482.52	488.89	6.37	13.46%	2	26.92
12 mesh	4.70mm	407.42	416.57	9.15	19.34%	6	116.04
20 mesh	850mm	370.84	389.30	18.46	39.02%	12	468.24
30 mesh	600 µm	349.17	355.29	6.12	12.95%	20	259
40 mesh	425 µm	339.26	342.01	2.75	5.82%	30	174.6
50 mesh	300 µm	331.06	332.54	1.48	3.14%	40	125.6
70 mesh	212 µm	307.73	308.84	1.11	2.34%	50	117
100 mesh	150 µm	306.12	306.91	0.79	1.68%	70	117.6
140 mesh	106 µm	306.14	306.71	0.57	1.21%	100	121
200 mesh	75 µm	300.34	300.71	0.37	0.79%	140	110.6
270mesh	5.3 µm	293.76	293.84	0.08	0.17%	200	34
Pan		276.56	276.563	0.003	0.01%	270	2.7
Total					**99.93**		**1673.3**

Chemical Composition analysis for sample defective product

The test was conducted in foundry laboratory of Akake basic metals industry, Ethiopia.

Laboratory equipment used: Spectrometer

Sample of defective cast iron part was taken and the following composition analysis was found.

Table.3 Composition of cast iron sample

C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Nb
3.67	2.00	0.482	0.183	0.164	0.074	<0.003	0.057	0.025	<0.009	0.092	<0.005

Ti	V	W	Pb	Sn	Mg	As	Zr	B	Fe
0.027	0.016	<0.040	<0.010	0.006	<0.002	0.016	<0.003	<0.001	93.1

Composition of metal determines the desired strength and metallurgical structure of the parts to casted. In case of ferrous casting, it is necessary to know the percentage of Carbon, Silicon, Sulphur, Manganese, and Phosphorous contents. To get the actual structure of cast iron, carbon in the range of 3.5-4%,silicon in the range of 1-3%,manganese in the range of 0.4-1%,phosphrous no to exceed 1% and Sulphur kept below 0.05%.[13]

The above spectroscopic analysis indicates that all the required elements are in correct composition range to produce parts from cast iron with actual structure and without shrinkage defect which result from unsuitable metal composition.

All major causes and sub-causes indicated on the fish-bone diagram were experimentally tested and practically absorbed. Causes which were responsible for those defects were identified and possible remedies were suggested as shown in the table below.

Table 1. Shows defect type, the major cause, tested sub-causes, observed sub-causes and possible remedies

No.	Defect type	Major causes	Tested sub-causes	Practically observed sub-causes	Possible remedies
1.	Blowholes and pinholes	Mould making	Clay content test (52.7%) (very low permeability which cause gas or air entrapment)	Insufficient venting	Use molding sand which have the following required properties (dry sand moulding) Fineness number between 45 – 65 for cast iron and alloys (e.g.Aluminium) 70-100. Clay content ≤ 2% Permeability 100- 150 Use venting at sharp corner
		Pattern making		Sharp corner of patterns (gas may accumulate at corner of mould cavity)	Avoid sharp corner during pattern making Correct pattern design procedure
		Risers and gating system design		Improper gating system design (which cause turbulence and aspiration of air)	Proper design of gating system
		Melting And pouring practice		Too low or high pouring temperature Improper pouring Melt no sufficiently degasified	Use temperature measuring instrument such as pyrometer Adjust pouring time
2.	Shrinkage cavity	Pattern making		Abrupt change in sectional thickness Improper allowance	Follow correct pattern design procedure
		Risers and gating system design		Risers • Inadequate size and wrong location • Improper gating system design	Design the correct size of the riser and determine feed ranged Calculate and determine gating system size and direction
		Melting and pouring practice		High pouring temperature	Control pouring temperature using temperature measuring instrument like pyrometer

3.	Sand burn on	Mould making		High moisture content of sand (this is due to high clay content)	Use sand with low cay content. Use of coal dust
		Melting and pouring practice		High pouring temperature	Control pouring temperature using temperature measuring instrument like pyrometer

Notice. Those major cause and sub-cause which were on correct design, composition and working procedure are not listed in the above table.

But for sand burn-on sub-causes such as amount of low melting impurities and lustrous carbon content were not tested due to absence of gas determinator. Here conclusion was done for moisture content with respect to clay content and unknown pouring temperature.

4. Casting experiment for remedial actions

Casting experiment was done for one of the common products, brake casing of the weaving machine, in foundry of kombolcha textile Share Company. The following remedial actions were done for this selected product.

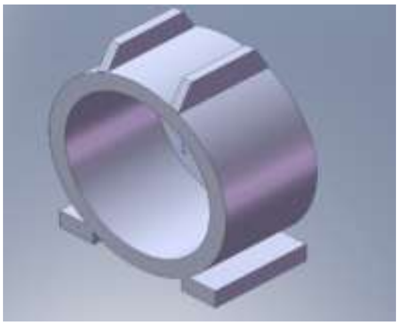


Figure 9. Isometric view of brake casing

4.1. Change of moulding sand

Reclaimed sand (used sand) with the following properties was brought from foundry of federal medium and small enterprise agency, Ethiopia.

Grain fineness number = 40.19

Clay content = 1.5%

Figure.10 Reclaimed moulding sand brought from foundry of Federal small and micro enterprise development agency, Ethiopia.

4.2. Pattern design

The pattern was designed and manufactured for selected product by following the correct pattern design procedure. It results the split pattern as shown below.

Type: split pattern **Material of pattern**: Aluminum

Allowance: Contraction allowance of 10.5mm/M and Machining allowance of 3mm were given for cast iron [13] .

a) Left part of split pattern b) Right part of the split pattern

Figure 11. Isometric view of split pattern

4.3. Design of gating system

To avoid turbulence and to have smooth metal flow, the gating system for the selected product was designed. Here design analysis for determination of pouring cup, sprue size, choke area, runner size, pouring time required, average filling time of the casting and effective metal head of the casting was done. At the end, appropriate gating system that is pressurized gating system with ratio 4:1 was selected and based on sprue design, taper sprue cutter was manufactured. The following figure is resulted dimensions of sprue, sprue well, and two gates for gating ratio 4:1.

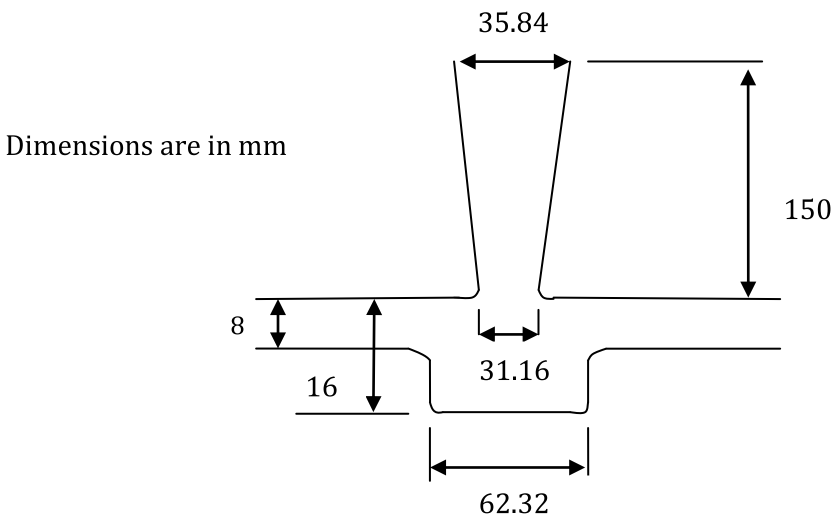


Figure 12. Dimension of Sprue, Sprue well and two gates in mm for gating ratio 4:1

Procedures for Experiment

Pattern was manufactured as shown figure (a) below based on designed dimension. Sprue cutters (figure.b below) was manufactured based on the dimension of sprue as shown in figure 12.Starting from pattern making up to finishing, the following are casting steps which was done.

a) Split Patterns

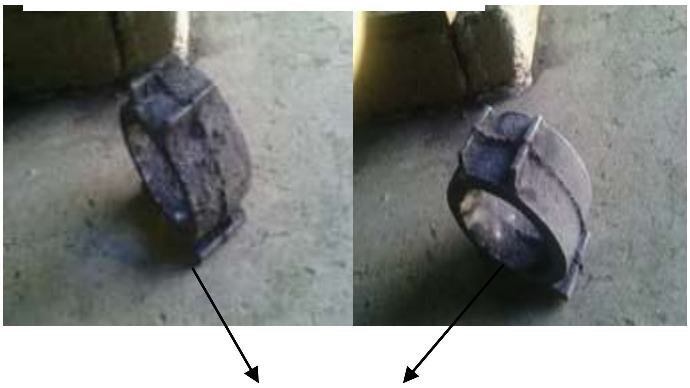
b) Sprue cutter for gating ratio 4:1

c) During mould making

e) Assembled mould ready for pouring

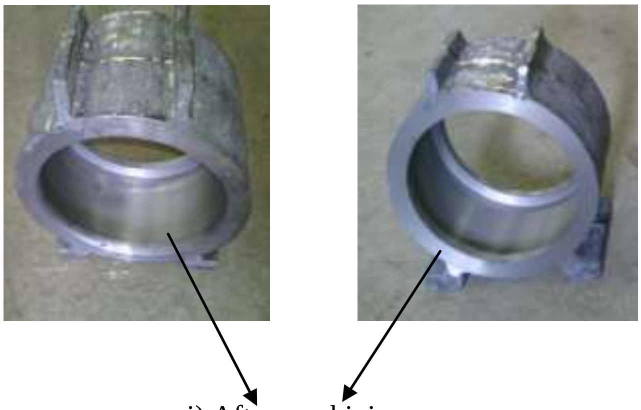
f) Melting process

g) Pouring process



h) After shake out

i) After sand removal by hand grinding



j) After machining

5.1. Results and discussion

Three experiments were conducted. Testing of moulding sand, clay content test (52.7%) and grain fineness number (GFN) (16.74) indicated that the sand in this foundry is not moulding sand. It cannot use for mould making process. It was main reason for the defects to occur. Therefore, it must be removed and substitute by other moulding sand.

During metal composition analysis of defective parts, alloys content was in the required range. Therefore, it was not responsible for the defects to occur.

Incorrect pattern design, wrong gating system design and uncontrolled melting process were absorbed which were the causes for defects. In order to minimize those problems, correct working procedure must be followed.

For remedial actions, experimental test was done using other moulding sand, correct pattern design and gating system design for brake casing of weaving machine. But the problem absorbed during the experiment were difficulty in mould making and rough casting surface due to coarseness of this reclaimed sand and sand burn on also absorbed.

6. Conclusions

From defect analysis, the defects in this foundry were gas porosity (blowholes and pinholes) and shrinkage porosity. The main reason for these defects was high clay content (52.7%) of the previous sand, unknown melting temperature, incorrect gating system and pattern design.

Experiment for remedial action resulted with conforming casting product for designed pressurized gating system (gating ratio 4:1). This is because the flow is streamlined and defect due to turbulence is avoided, the sand used for mould making has high permeability therefore no air or gas entrapment which causes blowholes or pinholes. The pattern and gating system design were controlled to avoid blowholes, pinholes and shrinkage.

For production of quality casting parts, this foundry must provide other moulding sand and control of other process parameters during pattern making, gating system design and pouring practice is important.

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