Analysis of Pores Size and Distribution Effects On the Total Dimensional Specification of Pinion Gear, Head Stock And Drive Disc of Manganese Steel (46MNSi4) Casts using Control Chart And Ishikawa Diagram (Case at Akaki-Basic Metals Industry – Ethiopia)

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Abstract

Pores are formed on casts in different sizes and forms. Porosity, cavity and blow holes are grouped as pores are the main challenges in steel castings at one of the foundry Industry in Ethiopia. This research was carried out mainly on pores defect analysis of manganese steel (46MnSi4) castings.

The casts affected by pores of various types were 4784kg of pinion gear, 900kg of drive disc and 4538 kg of headstock. Due to porosity on the surface of castings and other similar pores in the sub surface of castings secondary work of these components were carried out. Due to large amount of metal removal by secondary work, the casts lost their dimensional specifications and qualitythus rejected.

To carry out this research mixed (exploratory and experimental) research method with quantitative and qualitative approaches was used. Instruments used for data collection were physical observations, photographic analysis and experimental analysis. Data was gathered from both primary and secondary sources. The result of the experiment was analyzed using control charts and Ishikawa (cause and effect) diagram. Based on the analysis results, the root causes of porosity were identified. Mold preparation problems, molding material property, pouring temperature and time, poor gating system design, inappropriate material composition and improper utilization of reclaimed sand were the main causes for porosity.

Experimental analysis revealed that the maximum pore depths on the drive disc, pinion gear and headstock components were 24mm, 23mm and 24mm respectively. The sizes of pores were very large and many in number, distributed in wide areas of caststhat consequently need removal of excess metal from the surface for finishing.However, excess removal of metal cased the casts to be below the required specification.

Because of low quality the casts were rejected. Rework was done and the cost for rework was high (USD34482.1025). Controlling the parameters of casting avoiding the factors may improve the quality of castings.

Key words: *Casting, Porosity, Dimension of casts, Defects, quality of casts*

I. INTRODUCTION

Metal founding is one of the oldest of all industries, which dated back to the down of civilization. Authors [1],[3] and [6] stated that even in pre-historic times, as far back as 5000BC metal objects in the form of knives, coins, arrows and household articles were in use. Around 500 BC the era of religious upheavalsstarted, and metals began to be used for statues of gods and goddesses. Bronze Age was considered as development era of casting and bronze is still the most popular cast able metal. Casting new is the key for world economy and almost all metals cast using different technology. Economic development of most developed countries is based on casting.

The advancement of economy and civilization of the world today is directly or indirectly based on

manufacturing mainly of goods and products including textiles, metals, plastics, ceramics etc.
Casting is one branch of metal manufacturing, which 80%the world metallic products have been producing.
According to [8] manufacturing is an activity that has been existed with humankind from the beginning, and which has been presented throughout recorded history. As per [4], manufacturing or production can be defined in two ways, as technological and economical. Economical and technological development a country is relayed on manufacturing mainly on casting.
Researchers [4] and [17]Mikell P. Groover and describe casting as a production of shaped articles by pouring molten metal intomolds and allowing it to solidify and cool either in the mold and or in air depending up on the required structure and property as well as type of metal that was cast. Casting as other manufacturing products can be affected by various problems.The problems associated with casting include low mechanical property, porosity related defects like blow hole, pinhole surface porosity etc. These problems reduce the quality of casts.
The formation of defects in castings can be attributed to many factors, includingdesign problem, process problem and material characteristicsas well as equipment employed. This complexity makes the defect analysis more of an art-based on experience than an in-depth scientific analysis. Among the defects of castings porosity is the main and difficult one.
Porosity is one of the regular problems whichhasserious impact on the quality of castings which consequently worsen the mechanical properties of a product.Author [11] described porosity as the most common problem to consumers that should be controlled through better understanding of its nature and source so that quality products can be achieved. According to [18] porosity in castings is due to bubbles or gases and due to a decrease in the solubility of gases during solidification, gases dissolved in a molten alloy are rejected from the solid to the liquid, resulting in an increase in the gas concentration in the remaining liquid. As a result, the last liquid to solidify may contain relatively high dissolved gas content that exceed the limit of solubility in the particular metal.
Dissolved gases in the molten steel may emerge from various sources, but charge materials containing high amounts of nitrogen, oxygen, hydrogen and decomposing organic mold binders during pouring are the most common sources.
As it is known in practice shrinkage and shrinkage porosity are other casting defects. From the work of [15], volume contraction during solidification creates shrinkage in castings. Some of the factors contributing to shrinkage are the density differences of liquid and solid steel, the viscosity of the liquid, the solidification range, the solidification rate, and the permeability of the mushy zone. Shrinkage porosity thus can be formed while shrinkage of molten metal takes place.
According to [19], based on the formation mechanism porosity in castings may be classed as macro-porosity, which is large in size and or micro-porosity, which is small in size. Macro-can be corrected easily than the micro porosity which is complex in its nature. Macro porosity is formed in sub surface or in deep part of the cast. Such porosity may be blow hole.
Pore (porosity) related defects in shape casting are major cause of casting rejections and rework in industry.
Author [27] considered that porosity may be from hydrogen or while shrinkage takes place. Thus hydrogen porosity and shrinkage porosity can be the causes for rejection of cast products.
According [20],most of the problems experienced in producing sound metal casting arise because of lack of control of dissolved gas or reaction of gas with molten metal in the casting during the period of solidification. Gases are absorbed in molten metal from different sources like wet furnace charge (effect of previous melting cycle), electrolytic source alloying additions containing hydrogen resulting from the reducing conditions employed in melting,lubricants on the scrap metal, fluxes slag making additions.
Furnace atmosphere may contain water vapor, CO, CO_2 and SO_2as products of fuelcombustion and the normal atmospheric gases such as nitrogen and oxygen. Gas absorption from furnace atmosphere may be facilitated by conditions peculiar to a melting furnace:-
a)Molten metal absorb gases while passing through air during tapping from the furnace in to the ladles or when being transported from ladle to mold;
b)Molten metal may also absorb gases from the mold if the mold material contains excess moisture or volatile hydrocarbons.
Another researcher [21] explained that gas is absorbed both in molten metal and in solid metal but as a general rule the amount of gas absorbed in molten surpasses by far the amount of residual gas that may reasonably be present inthe solid metal. Such being the case, bubbles that are the most serious problem out of the defectsoccurring in castings are generated on the occasion of the solidification of the metal.
Member companies of the Japan Steel Castings and Forgings Association carried out a survey on the causes exerting influence on the gas defect and high temperature crack. Concentration of different gases in the metal and other factors may be the causes of pore formation.
Hydrogen, nitrogen and oxygen are diatomic gases, which are causes of pores including blow holes, porosity and pin holes. Hydrogen and nitrogen contained in the molten steel lead to the formation of

blow holes.Pin holes occurring in steel castings, are followed by oxygen content in the molten steel.

Generally porosity in castings is formed due to many reasons and affects quality of castings.

The products from the foundry factory Akaki Basic Metals Industry are the main input materials for the rest of the workshops in the industry.Researchers[31] discussed castings may be damaged and rejected due to different defects including shrinkage ,porosity ,sand sintering and other related factors. The causes may be material composition, improper design of gating system, uncontrollable and non standard parameters and may beunskilled operators. Porosity is one of the main steel casting problems,which occur during solidification of castingassociated with incomplete gas evolution from the cast and the mold. The main problems in the foundry factory of the case industry, especially in steel castings of the industry includeare mainlyformation of defects,cost expend for reworks, high rejections, high production cost, loss of customers and limitedmarket competition. Blow holes, sand inclusion, sand burning, cracks, hot tears, surface cracks, pin holes and shrinkage cavity are the major defects appear in cast iron and steel castings of the industry.

For the purpose of avoiding pores and cavities, large amount of material is removed from the surface of the steel castings using secondary work (machining and grinding operation).Secondary work cases under size of the cast as a result of which rejects become high. Thus the objective of this research is porosity effects analysis on the dimension of cast pinion gear, drive disc and head stock components of Manganese steel using control chart and Ishikawa diagram.

II. MATERIALS AND METHODS

A. Materials

Pinion gear, Drive disc and Head stoke components were cast from manganese steel of low carbon content displayed in Table 1. Composition analysis was made using spectrometer. In addition different materials including washed and dried silica sand, no-back binder, which composed of resin, catalyst and additives, paint that was applied on the pattern for easy removal of the pattern from the mold, wood for making pattern and water to test the clay content of the silica sand were used.

Table I. Materials used in casting

Part	Material	Composition				
		C	Mn	S	P	Si
Pinion gear	Manganese steel(46MnSi4)	0.25-0.35%	0.6-0.8%	Max0.05%	Max0.05%	Max0.6%
Drive disc	Manganese steel(46MnSi4)	0.42-0.5%	0.9-1.2%	Max0.4%	Max0.04%	0.7-0.9%
Head stock	Manganese steel(46MnSi4)	0.25-0.35%	0.6-0.8%	Max0.05%	Max0.05%	Max0.06%

B. Method

Mixed method that include experimental, and exploratory method withboth quantitative and qualitative approaches were used to carry out this research.

. Data gathered fromboth primary and secondary sources,physical observation at the industry, experimental analysis using ferrous metal spectroscopy, measurements of the selected defective casts using Vernier caliper.Photographs with the help of digital camera were used to obtain information for analyzingdefects.

Equipmentinclude:- sieve analyzer, clay content tester, medium frequency induction furnace, fettling and finishing equipment, wooden rammer, Pyrometer, wooden pattern were used for experimental work.

Sample data provides adequate information about the study object. According to [24], [25] and [26] in the context of sampling, an element is an object (or group of objects) for which data or information is gathered. A sampling unit is an individual element or a collection of non-overlapping elements from the population. A sample frame is a list of all sampling units. A cluster sampling method was used.

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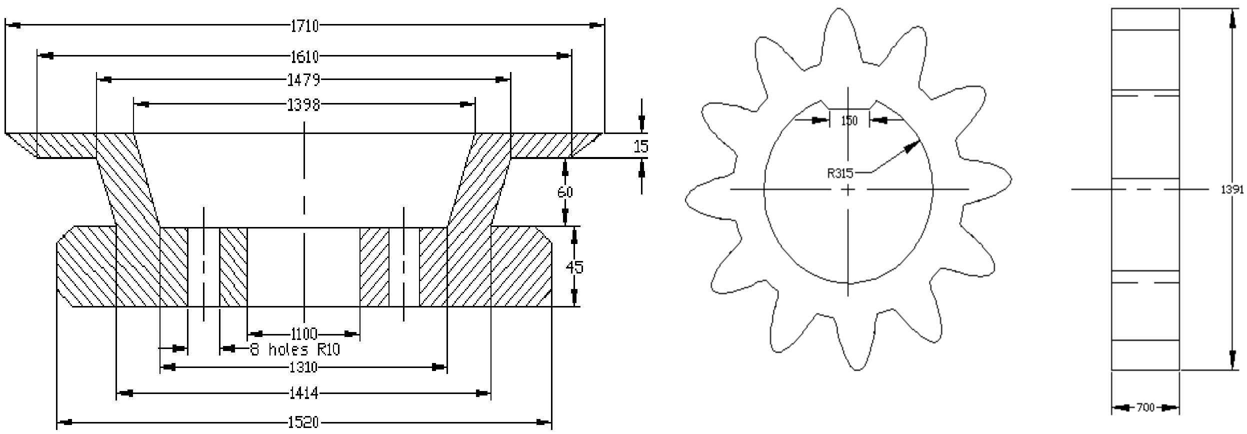
The case metal industry suffers by quality related problems of cast products. Some of the defective casts of the industry include large gears, head stock, trash plates, scraper plates, flanges, rollers, wheels, pulleys, sleeve liners, pinion gears, and sprocket gears of steel. Among these defective castings the pinion gear, drive disc and head stock castings of manganese steel were chosen for this research. Sample is displayed in fig.1.



Sectional front view of the drive disc

Schematic diagram of the pinion gear

Fig.1Sample component schematics

III. DATA COLLECTION AND EXPERIMENTAL ANALYSIS

A. Data analysis

To carry out this research data were collected using interview, physical observation, photograph as well as experiments. The casts in foundry and machine shops were observed and the workers of this industry particularly the foundry workers were interviewed randomly.

As observed, casting method used to produce the pinion gear, drive disc and head stoke was sand casting. For mold making dry silica sand reclaimed and furnished with fresh sand that was bonded with furan resin (no bake system of mold making) was used. Manual ramming used to make the mold. Pouring was made from the top for the pinion gear, side for the drive disc and head stoke casts through the riser. Induction furnaces of medium frequency were used for melting and pouring was carried out using the old tea pot ladles. The riser used to cast all the three casts was cylindrical in shape with similar dimensions located in a vertical position. Grinding and machining operations were performed for fettling process of castings. After grinding and machining, visual examination and measurement of the pores using Vernier caliper of 0.01mm accuracy were carried out. 100 randomly selected pores were selected.Depths and diameter of the pores were measured using Vernier caliper. In addition,to obtain more information about the number and dimensions of pores,photographs with the help of digital camera were made.

Analysis of the data collectedwas analyzed as below.

From observation it was understood thatcasts were produced from the mentioned manganese alloy steel. Composition analysis was made using TRECN portable solid spectrometer of 4mm minimum sample thickness handling type, which is available at the case industry and is specifically used for ferrous metals.

The main reasons for the selection of such Manganese steel for casting purpose at ABMI include: The material gives a wide range of flexibility when processing,probability of defect formation is lowcomparing to the other steel types.Lower defects may be observed in case of high content of carbon in manganese steel.

From the observation it was found that the three casts mentioned above were cast with the same method that is sand casting with cylindrical riser and vertical gating system. Porosity of different sizes was observed on the three casts.

From the interview of foundry workers it was understood that, the pinion gear and drive disc may face wear since they are subjected to rotational motion of alternative load and continuous friction. On the other hand the head stoke is subjected to high compressive stress. The purpose of the head stoke is to carry very large and huge rollers, gears and other heavy components in horizontal position. Generally all the three casts lack their strength and reduce their quality due to many factors including porosity formation. Secondary work was used to fettle or finish the casts to the required dimensional specification. However the casts lose their specific dimensional standard and caused rejection of these huge casts. In this regard financial lose damages the economy of the industry and consequently the country.

B. Experimental data

Experiments were carried out in the factory in casting and finishing area. The mold material used in the foundry shop was silica sand. The case Metals Industry uses dry sand (no bake molding system) for mold making. Silica sand (SiO_2) obtained in the local area has the following specifications: Color: white - light brown,Fusion point: (1427 - 1760)^{0}C,Grain Fineness Number: (25 - 180), Clay content: (0 - 1.5) %,Silica content - (94 - 99)%has been used in this industry .

In the case factory when sand is prepared permeability of the sand was not tested. The sand system was comprised of new sand and mechanically reclaimed sand. While making the pattern for the mentioned casts only the machining and draft allowances were considered. Shrinkage allowance was not considered. Shrinkage porosity was also observed in the cast and lead to rejection of casts.

The sand mold was made with resin binder.

On the preparation of chemicals metal to sand ratio used was 1:5 and for the molding 1.2% resin for100kg of sand, and 0.6% catalyst were used. Some amount of new sand was mixed with large amount of used sand.

Induction furnaces of medium frequency capacity 3300 kg were used for melting the metal during the production process of the pinion gear drive disc and head stock components.

Since very high temperature was involved in the melting of steels the furnace, Al_2O_3 powder was used to line thefurnace.

Deoxidizing agent was added to remove the oxygen dissolved in the liquid steel. This also ended the removal of carbon by oxidation in to carbon monoxide bubbles. The common deoxidizers used were ferromanganese, ferrosilicon and silicon manganese. The ladle used was preheated with low temperature (200^{0}c). The steel was deoxidized further in the ladle just before pouring. Ladle deoxidation was done with ferrosilicon and ferromanganese as well as aluminum.

Pouring was done at a temperature of 1650^{0}C using tea pot ladle. Solidification time was not measured and done by trial and error. Gating system and riser parameters were analyzed based on the sizes of the three produced casts. The gating system used in the case industry was top type and lacks accuracy as it was made without proper design parameters, which may be the cause for porosity formation. The flow of metal was turbulence form thatthere was very high aspiration or sucking of the gasses that cause formation of bubbles and porosity related defects.

On the process of feeding there was under filling of the mold cavity thus the casts were undersized and more porosity was observed at the top parts of the casts. Pouring was done traditionally; erosion of the mold due to weak mold strength that resulted from inappropriate hand ramming was observed.

C. Analysis of pore sizes effect of on the dimension of the casts

Analysis of pore size effects on casts dimensionalspecification was carried out. Pores formed on the casts ware photographed and their dimensions were measured. The photographs results are displayed in (figs.2-4).Pores were observed on almost all the surfaces of the casts. The depth and width of pores vary in size from cast to cast and from area to area. Secondary work (grinding and machining) was carried out.The result showed that the pores affect the cast strongly that it has not been removed after secondary work.

The required dimension (the thickness, length and width of casts) was not as in the designed size (specification). The obtained dimensions were much less than the required cast specification. The pores were identified as blow holes, porosities and cavities.The surface porosities were removed easily using secondary works but the blow holes and cavities of irregular shapes remained on the finishedcast surface.

More over sand was stamped on some cavities and blow holes made the task more complicated that consequently became additional reason for rejecting of the cast.

As it has been seen from the photographs, the selected components contained different defects. Fig.2(a) shows the top surface of the defective drive disc cast after machining and grinding. In fig.2 (b), (c), (d) and (e) it is easily identified that both the top and bottom portions of the drive disc were highly damaged by porosity. Not only the top and bottom portions, but also the internal walls of the drive disc were affected by porosity (fig.2 (f) and (g)). The headstock was affected by blowholes (fig.3 (c) and (d)). The visual inspection of the pinion gear showed that in addition to the pores t, formation of slag inclusions (fig.5 (c), poor surface finish on the face (d) and rough casting surface on the teethas well as crack on the surface of the gear , sand sintering and formation of shrinkage cavity were observed .

The pores which are observed in the pinion gear, drive disc and headstockcastsarerandomlydistributed and orientated .Most of the pores in these castings are spherical and oval in shape that it was possible to measure the diameter of each pore.

(a) Top surface of the defective drive disc
(b) Top surface of the drive disc after first hand grinding
(c) Voids on the top surface
(d) Top surface after final grinding
(e) Bottom surface of the drive disc
(f) Internal wall of the drive disc after first hand grinding
(g) Defective internal wall

Fig.2. Defective drive disc component

(a) Slag inclusion on the side of plate 7and(b) Porosity on the surface of plate 4 (c) Blow holes on plate 5 and (d) Blow holes on plate 9

Fig. 3. Defective headstock component

(a) Blow holes on internal surface (b) Repaired shrinkage cavity (c) Slag inclusions and blow hole (d) Rough surface finish

Fig.4. Defective pinion gear component

According to[6],[13],[14] and[30]defect sources may be input materials, technology and skilledman power problems. Surface defects may be improved by various methods including mechanical works. Many of the problems that occur in finished products have their origin. Removing internal defects formed during casting can be very costly, since they are usually difficult to detect, and are often not found until late processing stages or even at service time. Some defects are caused by simple mistakes, but these are specific to the individual casting process.

As mentioned above,after secondary work was performed measurement of the pore depth and diameters was taken using vernier caliper. About 100 points, on the major damage was measured in 5 days (20 measurements per day) and the results are displayed in table 2 below.

The measurements were taken to qualitatively analyze the effect of pores on the cast quality and to determine the root causes of defects.

Table II : Various Sizes Of Pores Collected By Measurement (All Dimensions In Mm)

Sample	1^{st}day		2^{nd}day		3^{rd}day		4^{th}day		5^{th}day	
	Depth	Diameter	Depth	Diameter	Depth	Diameter	Depth	Diameter	Depth	Diameter
1	23	9	17	7	9.5	8	15	9.5	12	6
2	15	7	17	10	12	10.5	22	6	12	8
3	12	7.5	15.5	12	7	7	12.5	7	9	6
4	16	10	10	10	7	5	5	8	19	6
5	11.5	7.5	8	12	6	6.5	5	7	21	8.5
6	15	8	13	10	14.5	8	7.5	5	24	9
7	7	8	7	6.5	7	6	15	8.5	12	9
8	22	7.5	10	8	11	8	18	10	13	7
9	8	6.5	21	9	8.5	6.5	9	6	16	5.5
10	18	9	9	7	12	7	21	6	15	10
11	15.5	8	9.5	7.5	15	6.5	14	7	13	8.5
12	8	8.5	14.5	7	10	5.5	13	9	14	10
13	16	8	7	5	10	6	12	4.5	13	9
14	8	8	6	7	13	7	13	5	6	5.5
15	8	7	15.5	9	9	8	21	8.5	11	7.5
16	4	5.5	17	10	4	5	22	8	13.5	9
17	24	9	19	10	8	8.5	14.5	6	17	9.5
18	13.5	11	12.5	7.5	9	4	8	11	16	9
19	17	8	7	5	10	8	11	9	22	5.5
20	11	6	11	7	17	6	10	7.5	20	9

As seen in table (II) in the measurement values obtained, the maximum depth and diameter of the pores are 24mm and 12mm respectively. The diameters and depth of pores are all greater than 1mm which is out of the acceptable standard in casting technology. These largest values were obtained from the top surface of the drive disc having a plate thickness of 40mm. Reduction of 24mm metal from the 40mm thickness derived the drive disc to be rejected as the remaining 16mm is out of the stipulated standard. The maximum bubble diameter and depth (for steel casting) at a temperature of 1500^0C from 200 mm thick metalis 18.1mm and 17.3mm respectively, which can beconsidered as a temperature depth proportion. But 12mmdiameter pore that is maximum was obtained from the portion of thedrive disc with the required thickness of 40mm. Comparing the temperature and depth proportions of the standard value and measurements done at the industry, one can easily understand that the porosity level atthe industry was very severe. The pore depths and diameters are graphically represented in Figs. 6 and 7 respectively.

Depth of pores (fig.5) was considered as the key problems that affect the quality of casting. Hence the figures represent data collected in different days. High variation is observed indatacollected on the first and fifth days, in which all most all depths of pores above 20mm. Data collected in the rest days are in between 5mm and 20mm.These all pores were seen after final secondary work of the cast.

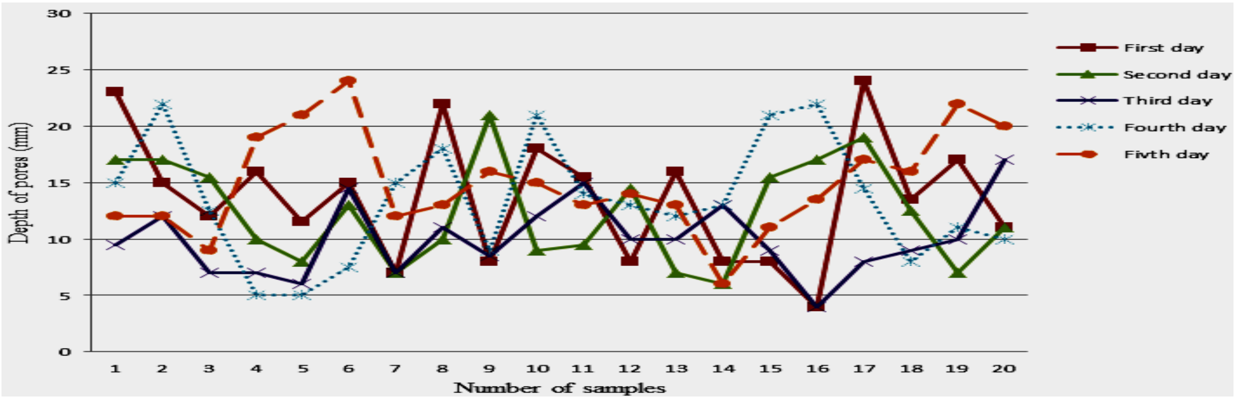


Fig.5 Depth of pores (mm)

Thus the product in one way can be damaged while exposed to the service as the pores become stress risers and in another way the casts were under size and cannot fit to the required service.

As seen in fig.6, the diameter of pores varies in castings. Especially the data collected in the second day showed maximum pore diameter was above, 10mm. As mentioned above if the diameter of the porosity in any cast is more than 2mm and number of pores on the cast surface is not more than 5 in a particular cast, the cast is considered to be under size and below the required standard that can be rejected. Therefore, it is possible to conclude that increased pore size on casts both in diameter and depthscan highly affect the final quality of cast. More over reworking is impossible as the pores are distributed in large area. In this case the financial lose is high for the industry.

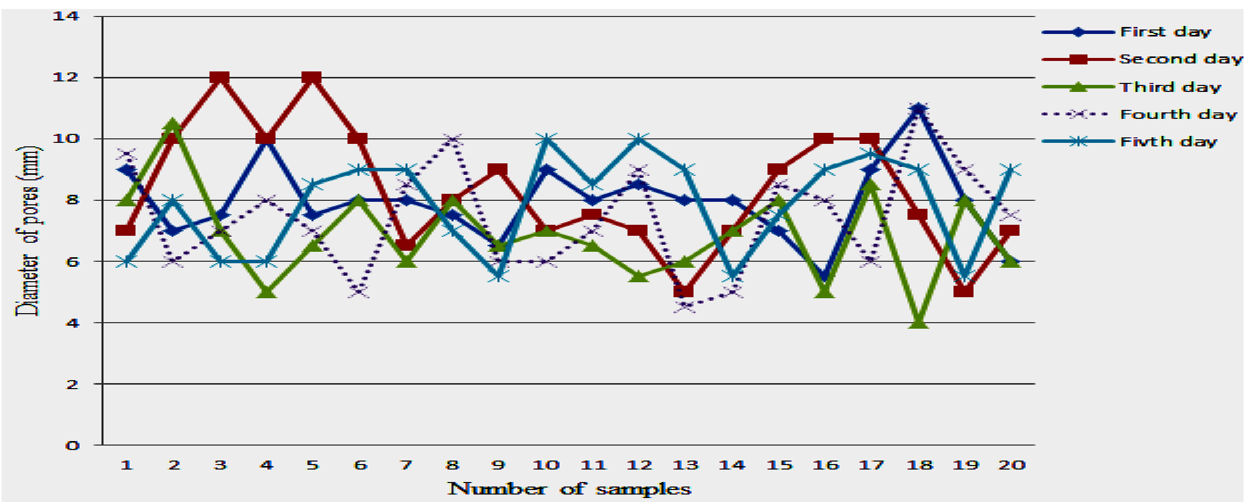


Fig.6. Diameter of pores (mm)

IV. RESULT AND DISCUSSION

Data displayed inTable 2 were obtained from the measurements takenfrom the casts. Based on their seriousness nonconformities or defects were classified in four classes as very serious, serious, major and minor. According to ANSI and ASQC the weights given for very serious, serious, major and minor nonconformities are 100, 50, 10 and 1 respectively. Quantitative analysis was conducted to determine the nonconformities. The average number of nonconformities per unit for each category, upper control limits (UCL) and lower control limits (LCL) in the U-chart were calculated using the known statistical quality control models. The values of UCL, LCL and CL were calculated using the formulae:

$$UCL = \overline{U} + 3\bar{\sigma} (1)$$

$$LCL = \overline{U} - 3\bar{\sigma} (2)$$

$$CL = w1u1 + w2u2 \ldots\ldots + \ldots wnun \ (3)$$

Where $w_1, w_2 \ldots w_n$-weight average of each category

$\bar{\sigma}$-standard deviation of u

The results obtained based on the calculations of the U-chart for nonconformities in pore depths and diameters, which are plotted in figs.7 and 8 demonstrate the level of porosity defects on the selected component. From the figs. it is possible to underline that the process is in control, however form the real practical work the defects are too much and are above the required level .Hence there is a mismatch between the calculated value and the real condition. Taking the method of calculation as an error, it is important to improve the quality more by improving the process parameters and by identifying the root cause of the defects.

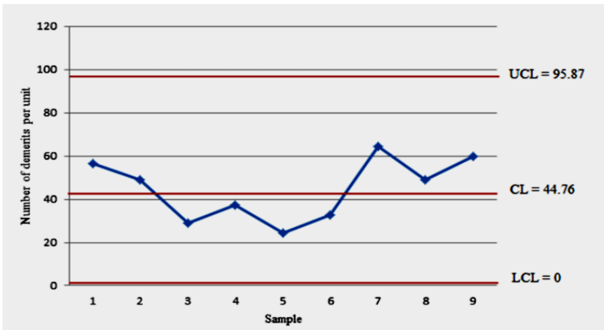


Fig. 7U- chart for nonconformities in pore depths

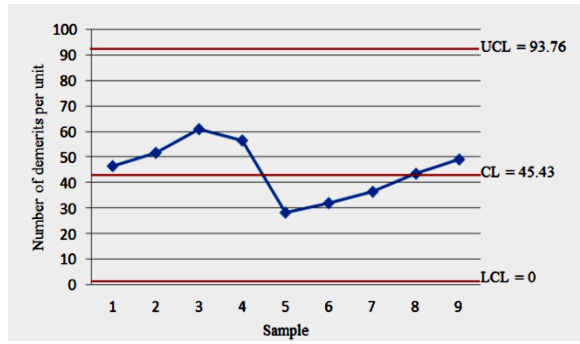


Fig. 8U- chart for nonconformities in pore diameters

Since the control chart method was not confirmed the problem clearly, it was necessary to find the actual reasons or root causes of formation of pores. For this purpose the Ishikawa (fish bone) diagram was used (fig.10). Surface porosities, blow holes, sand inclusion, sand burning, pin holes and shrinkage cavity were the major defects appeared in different casts of the case Metals Industry.

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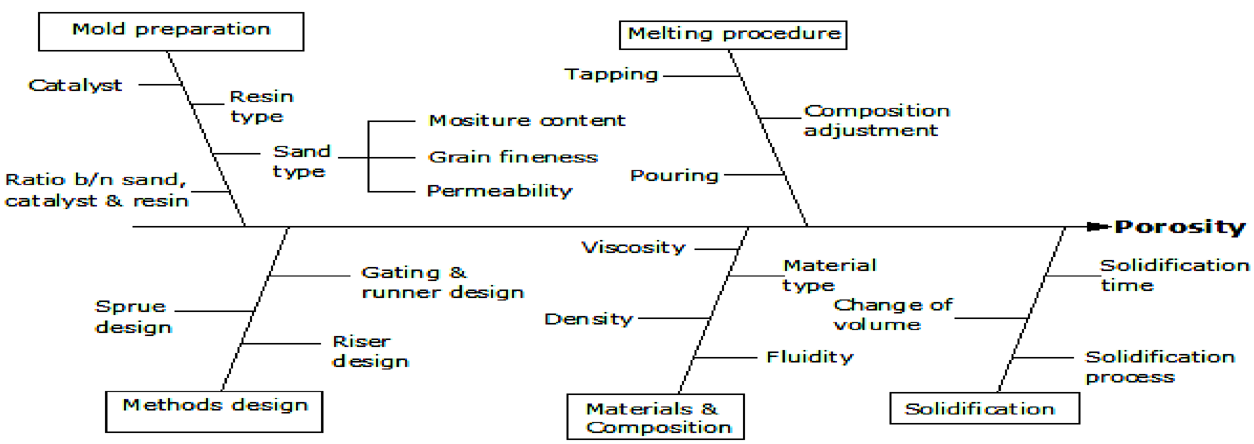

Fig.9Cause and effect diagram of porosity

As seen in fig.9 the key causes of the defects(pores) that occurred on of pinion gear, drive disc and head stock components, which caused the dimension reduction were mold preparation that include catalyst and resin ratio, sand type and the ratio of sand to resin, catalyst content, method of gating system design, melting procedure that expresses in terms of tapping method, pouring time and mechanism, composition adjustments, materials and physical properties that include density, viscosity, fluidity and solidification that can be explained by solidification process, volume change and solidification time. The hydrodynamic force was greater than1.62[29] lead to the formation of blow hole and porosity in ferrous metals.

The gas that could not bubble out during solidification process, were serious causes of porosity and blow holes formation. The height of pouring and time of pouring were not properly adjusted.Especially pouring height varied with the wide range and lead to high heading pressure that again influenced on the flow characteristics of the liquid metal.

Turbulence flow facilitated liquid metal and mold material reaction. Flow of liquid metal is characterized in to three main forms stream flow, fragmental flow and drop type flow[29].As author [13]explained, flaw may make the normal function or appearance of the product to be in poor condition and may lead to the possibility of salvage or, to rejection as well as replacement. Flow characteristics are depending up on viscosity, flow rate, time of pouring, and height of flow, surface tension and density of the liquid metal [30]. Regarding the condition of the pinion gear, drive disc and headstock castings the melting temperature was high, the viscosity reduced as a result velocityof flow increased and flow rate also increased.The height of pouring was above 200mm (as per observation).thus the pressure head was high. The conditions lead to turbulent flow of the steel.

Obviously in this case the flow character was stream type as the feeding head having large diameter was used as a pouring cup, this may be the reason for high hydrodynamic force that break the bottom of the mold wall and detach the sand due to its impingent effect.

The solidification time for steel was not controlled in a proper way and thus the high temperature liquid metal remained in the mold for long time became cause of formation of bubbles due to dissolved gas remnants and hence created favorable condition for the formation ofpores. At the same time the pouring mechanism was manual anddone using tea pot ladle, thus the uncontrolled filling of the mold led to turbulence flow.

In addition to the above problems there was no controlfor pouring time. Pouring was done traditionally by old ladles. Use of proper furnace types fordifferent steel materials, provision of temperature controlling devices for melting and pouring practices, proper gating system design, coating proper refractory materials may improve thecondition of porosity and other defects on steel castings of various categories.

Solidification time and solidification mechanisms were not considered as critical factors and these factors led the casts to develop porosity and aligned defect.Skilled man power,equipment,gating system design,materials problems, methods of casting used aswell as metal pouring problems in theindustry were also additional influential factors for pores formation on castings.

It is obvious that on sand casting, the casts need secondary works to achieve the required size and surface finish. The mentioned components in this paper were exposed to grinding and machining. While machining and grinding certain materials were removed. In the case industry, to obtain the required size and surface finish, after casting casts have been treated by grinding and machining, however mostly the required dimensional specifications have not been not achieved and the case casts too fail to full fill the required standard. The dimensions became under sized. It was because of high porosity and internal blow holes, which were observed after secondary work, where the dimensions of pores reached 23mm in depth on thepinion gear, 16mm diameter on lower portion of drive disc and 24mm deep. Because of these the products were rejected.

To rework the rejected casts, which the gross weight of pinion gear, drive disc and headstock together was 18, 586kg (8698kg+1637kg + 8251kg), a total of ET Birr 965498.87 (USD34482.1025) per heat was required. The amount is huge and correction must be done on the process and parameters.

V. CONCLUSION

Porosity, cavity, blow holes are one of the main defects formed in steel castings, which requires clear understanding of its causes. Developing the remedial method by analyzing the defect is very important. Physical observation, photographic analysis, cause and effect analysis, measurement of depth and diameter of pores of the selected cast manganese steel components confirmed that the pinion gear, drive disc and the headstock components were under dimensional specifications due to porosity and other similar defects. In adequate mixing of sand, pouring, problem, protection of gas from entrapment, skill of the foundry men, furnaces and metals themselves were considered as causes of pore formation. Maximum pore depth was 24mm; diameter was 12mm from 40mm thick cast. This dimension of pore made the cast to be rejected. The amount of large variation in dimension on casts was because of excess removal of materials by machining and grinding. Hence the product was out of the required dimensional specification and quality.

The amount of finance required to rework of rejected casts was huge (USD34482.1025) per heat that the factory and at large the country lose huge economy.

It is advisable to control the process so that pores may minimize and quality of cast be improved.

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