An Over View of Casting Defects in Automatic High-Pressure Line

Raji Rajan[1], Afsal Shaheed[2], Pranav G Pradeep[2], V.R Pramod[3]
[1]*Associate Professor, Department of Mechanical Engineering SNIT, Adoor, Kerala- 691554, India*
[2]*UG students, Department of Mechanical Engineering SNIT, Adoor, Kerala- 691554, India*
[3]*Associate Professor, Department of Mechanical Engineering NSS College of Engineering, Palakkad, Kerala, India*

***Abstract*—The objective of the paper is to identify and know various casting process in automatic high-pressure line and to investigate various casting defects occurring in it. The detection of defect in HP-line has been done to reduce the product rejection.A brief description of automatic casting process is given in this paper and alsocasting defects those are repeatedly occurring are discussed along with their causes and remedies. A brain storming section has conducted to determine and identify the defects.Then the fishbone diagram is used to explore possible cause of defect. A control chart is used to detect variations in the processing and notifies if there is any departure from the specified tolerance limit. These control charts immediately tell the undesired variations and help in detecting the cause and its removal.**

***Keywords*—Casting-defect, Fishbone-diagram, Brainstorming, HP-line, P-chart, SPC, UCL, LCL**

I. INTRODUCTION

The automatic HP-line in casting industry PQR selected for the study is a fully automated plant consisting of several inter-related unit each performing assigned work until the product process is completed.The plant were manufactured, supplied and erected by M/s BMD West Germany. The line has 68 set of mould box in the system and has a capacity to produce 80 moulds per hour. The activities are controlled from a control room aided with computers. HP moulding has consistent and higher level of mould hardness and as a result of this mould wall movement is virtually eliminated giving a casting with reliable dimensions, closer tolerance and often even eliminating excess machining stock. Various techniques like brainstorming, cause and effect diagram and control charts are used in this paper. In order to find out the recurring defects and its causes a brainstorming session has been conducted.Creative thinking is necessary to find out the defects and its cause in automatic casting is specifically to producereplacement. The literature [1] exposed up new options for innovation and customization in training programs to improve creative thinking skills. The suggestions from brain storming technique is taken in to account. The fish-bone diagram shows the causes of the various defects. The P-chart is a characteristic chart for defective items. The centre line value represented by p (p bar) may be defined as the ratio between the total number of defective products observed in all samples combined and the total number of products inspected.

II. COMPANY PROFILE

Company ABC selected for the study was started with aim of manufacturing all type of ferrous casting under the same roof and was stepped 1981. Unit has an optimum capacity of 18000 tonnes per annum. The commercial production was started in 1986.The plant comprises of two distinct production lines, conventional moulding line and automated high pressuremoulding.The company can manufacture ferrous castings of all grade and sizes ranging from 5kg to 8000kg. Thehigh pressure moulding line is afully automated system in which smaller casting are manufactured in large quantity.

III. RESEARCH METHODOLOGY

Brain storming is a technique for stimulating a group of people to come out with their ideas on specific topic. A group of people meet and generate ideas. The session may be used to identify, analyse, and solve the problems. The defects found in brainstorming technique are related to sand properties, in gate system, air leakage, slag removal, human error, moisture, venting, clay level, pouring temperature. The suggestions made for the removal of these defects are sand properties should be according to specification .The sand process parameters should be decided experimentally depending on quality of sand[2].Then provide tangential ingate for quick flow of molten metal, minimise air leakage, avoid slag inclusion, avoid human error in cleaning, control moisture in sand, proper venting, clay should be maintained to a level of 12%, pouring temperature, should not be above specification, pattern must be clean for every three impulse, ramming carefully, avoid jerking of mould in movement, reduce high blow, pour the molten metal with correct temperature[3]. The cause-and–effect-diagram is a picture composed of lines and symbols designed to represent a meaningful relationship between an effect and its causes.The fishbone diagram is a tool for recognizing the core causes of quality problems [4].It was developed by Dr Kaoru Ishikawa in 1943 and it sometimes referred to as Ishikawa diagram or a fishbone diagram because of its shape.Generally. This diagram investigates either a ‘bad’ effect and to take action to correct the causes or a ‘good’ effect and to learn those causes that are responsible. For every effect, there are likely to be numerous causes. The “fishbone” takes an effect and traces its possible causes using the five factors of a process. People, methods, Materials, Equipment and Environment.It is possible to draw the skeleton of the fishbone by identifying all the possible sources of variation in the process. Any variation of the process that occurred concurrent with the defect is documented on this tool. Minor excursions from the process or many special process events are listed. There are many process variables, which can contribute to defects the fishbone diagram shown in Fig.1 can efficiently identify the significant sources of the variation and allow the proper corrective action to be initiated.

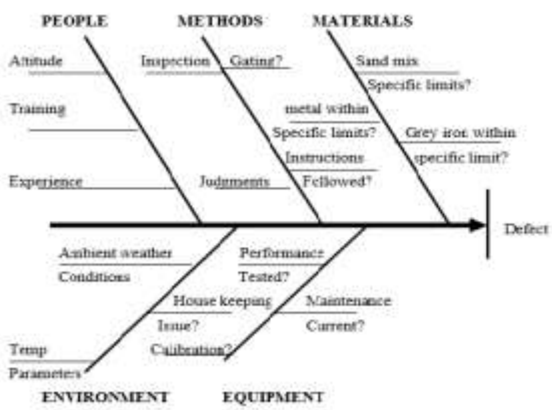


Fig. 1 Fish bone diagram 1

Once the cause-and-effect diagram is completed, it must be evaluated to determine the most likely cause. This activity is accomplished in a separate session. The procedure is to have each person vote on minor causes. Team member can vote on more than one cause. Those causes with the most votes are circled as in Fig. 2, and the four or five most likely causes of defect are determined.

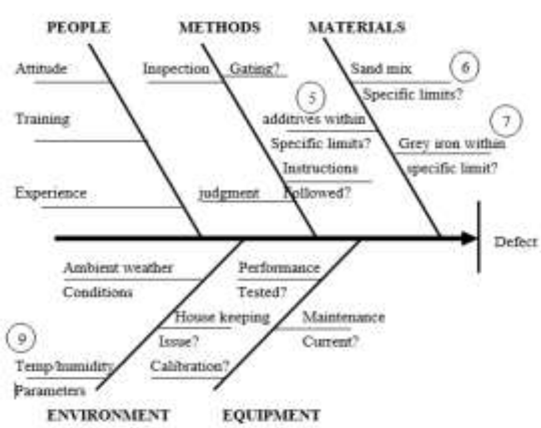


Fig. 2 Fish bone diagram 2

After obtaining the second fishbone diagram, the most votes is for the temperature parameters. Then comes the combination of grey iron, then sand mix and additives.

Control chart is the most effective statistical process control (SPC) tool, originally developed by Walter Shewhart in the early 1920s. Control charts are graphical representation based on statistical sampling theory, according to which an adequate sized random sample is drawn from each lot [5]. A control chart detects variations in the processing and warns if there is any departure from the specified tolerance limit. These control chartimmediately tell the undesired variations and help in detecting the cause and its removal. Control chart assists as a common language for conferring process performance [6]. The letterCindicate whether the process is in control or out of control at a particular point of time. It ensures level of quality, and hence also builds up the reputation of the organization due to customer’ssatisfaction. It detects unusual variations taking place in a process.It helps in reducing the rejection, as it warns in time, so that process can be rectified in time.

IV. Result And Discussion

After conducting the brainstorming technique obtained fish-bone diagram. With the help of p-chartgraphs were plotted to know whether the parameters are within the control limit. The fraction defective value is represented in a decimal as proportion of defectives out of one product, while percent defective is the fraction defective value expressed as percentage.The standard deviation for fraction defective denoted byσ p = $\sqrt{p(1-p)/n}$, where n is the sample size and p is the fraction defective. The two control limits, upper limit and lower limit are calculated by simply adding or subtracting 3σ values from centre line value. The trial limits are computed to determine whether a process is in statistical control or not.

So, UCL = $p + 3\sqrt{p(1-p)/n}$ and LCL= $p - 3\sqrt{p(1-p)/n}$. For plotting graph make abscissa for sample number and ordinate as percent defective. Then marked the various points as in the table as sample number vs. percent defective.

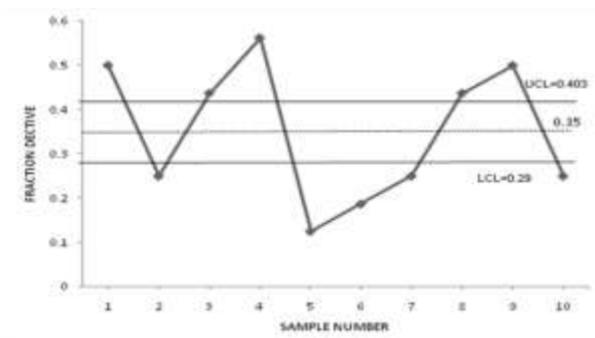
TABLEI

DATA FOR CALCULATING AND PLOTTING P-CHART 1

Day	No. of castings Inspected(a)	No. of defective castings(b)	Fraction defective (b)/(a)
Day 1	80	40	0.5000
Day2	80	20	0.2500
Day3	80	35	0.4375
Day4	80	45	0.5625
Day5	80	10	0.1250
Day6	80	15	0.1875

Day7	80	20	0.2500
Day8	80	35	0.4375
Day9	80	40	0.5000
Day10	80	20	0.2500
Total	800	280	

p is the ratio of total no. of defective castings found to the total number of castings inspected, n is the no.of castings inspected every Day, here n is 80.Thus, UCL= p +3√p (1-p)/n that is 0.403, similarly LCL is p - 3√p (1-p)/n that is 0.297



Graph 1- p chart 1

Hence the process is out of control an investigation to hunt for the cause become necessary. Inspection of castings aims at finding both surface and subsurface in casting. Inspection will ascertain the quality of castings and result in their acceptance or rejection. There will be visual, surface inspection for foundry defects, geometric checking for shape and dimension. Physical, metallurgical and chemical tests.Testing of mechanical properties (destructive and non-destructive) after inspection the defect found is blow hole.This is due to gases a produced inside the casting. The main gas producing processes in the mould are [7] [8] rejection of dissolved gases from the metal, reaction of carbon in the metal with oxygen or oxides

Smooth-walled cavities, essentially spherical, often not contacting the external casting surface (blowholes). The largest cavities are most often isolated; the smallest (pinholes) appear in groups of varying dimensions. The interior walls of blowholes and pinholes can be shiny, more or less oxidized or, in the case of cast iron, can be covered with a thin layer of graphite. The defect can appear in all regions of the casting.

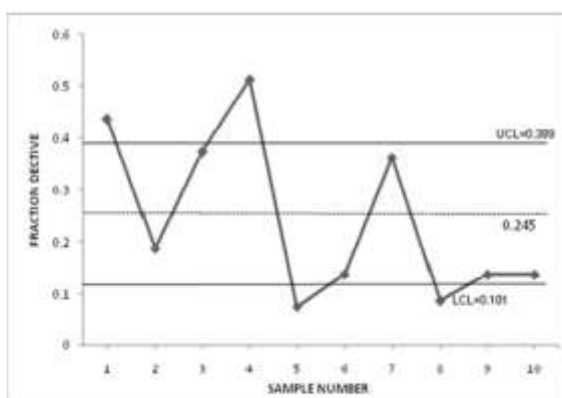
Blowholes and pinholes are produced because of gas entrapped in the metal during the course of solidification. Excessive gas content in metal bath (charge materials, melting method, atmosphere, etc.); Dissolved gases are released during solidification. In the case of steel and cast irons: formation of carbon-monoxide by the reaction of carbon and oxygen, presents as a gas or in oxide form. Carbon monoxide may increase in size by diffusion of hydrogen or, less often, nitrogen causing blow holes.Excessive moisture in moulds or cores. Core binders which liberate large amounts of gas, Excessive amounts of additives containing hydrocarbons, Insufficient evacuation of air and gas from the mould cavity, Insufficient mould and core permeability, Entrainment of air due to turbulence in the runner system.Some remedies for blow hole are to, make adequate provision for evacuation of air and gas from the mould cavity, increase permeability of mould and cores, avoid improper gating systems, assure adequate baking of dry sand moulds, control moisture levels in green sand moulding, reduce amounts of binders and additives used or change to other types, keepthe sprue filled and reduce pouring height, increase the static pressure by enlarging runner height, after rectifying the defects found again inspection on samples give this result as given in table.

TABLE 2

DATA FOR CALCULATING AND PLOTTING P-CART 2

Date	No. of castings Inspected(a)	Defective no. of Castings found(b)	Fraction defective(b)/(a)
Day 11	80	35	0.4375
Day 12	80	15	0.1875
Day13	80	30	0.375
Day14	80	41	0.5125
Day15	80	6	0.075
Day16	80	11	0.1375
Day17	80	29	0.3625
Day18	80	7	0.0875
Day19	80	11	0.137
Day20	80	11	0.137
Total	800	196	

p is the ratio of total no. of defective castings foundto the total no. of castings inspected and n is the no. of casting inspected every day therefore p=0.24.Thus, UCL= p + 3√p (1-p)/n= 0.389 similarly LCL= p - 3√p (1-p)/n= 0.101



Graph 2- p chart 2

Again the process is out of control an investigation to hunt for the cause become necessary. After inspection the defect found is misrun. This is a defect where a portion of the casting is missing, usually distant from the gate area. Edges are rounded and the adjacent surfaces are generally shiny.Possible causes of misrun is inadequate pouring temperature. The gating may be too small or improperly located with respect to the casting features. This can be due to improper venting.

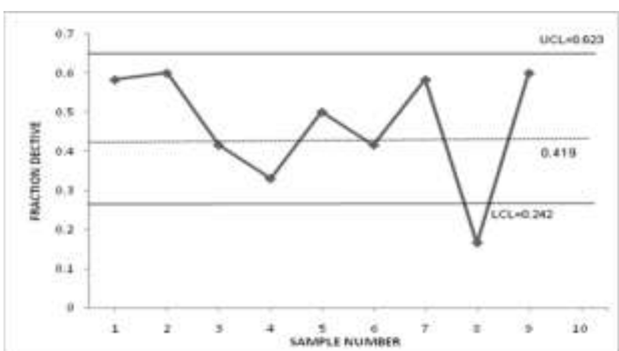
Corrective measures taken and checked another set of samples.

TABLE3

DATA FOR CALCULATING AND PLOTTING P-CART 3

Date	No. of castings Inspected(a)	Defective no. of Castings found(b)	Fraction defective(b)/(a)
Day 21	60	35	0.583
Day 22	60	15	0.600
Day 23	60	30	0.416
Day 24	60	41	0.330
Day 25	60	6	0.500
Day 26	60	11	0.416
Day 27	60	29	0.583
Day 28	60	7	0.166
Day 29	60	11	0.600
Day 30	60	11	0.00
Total	600	196	

P is the ratio of total no. of defective castings foundto Total no. of castings inspected thus p is 0.0433and n is 60 Thus UCL is p + 3√p (1-p)/n thus UCL is 0.6235 similarly LCL is p - 3√p (1-p)/n thus LCL is 0.2425



Graph 3- p chart 3

During inspection rejection of the casting is mainly due to pour short. The upper or extended areas of the casting are not filled. The edges adjacent to the missing section are slightly rounded; all other contours conform to the original pattern. The sprue, gates and pattern are filled to the same height on the casting.

Possible causes are insufficient quantity of metal poured. This can also to be due to an interruption of the pour, which does not allow the molten metal into the mould.

During visual inspection another defect found is cold shut. That is a linear discontinuity with rounded edges. The defect has a characteristic appearance and may vary in depth. In mildest case, it may consist merely of a shallow groove with rounded edges. A cold shut may occur on a wide surfaces of the casting, in thin sections that are difficult to fill or where two streams of metal coverage in the mould due to the sequence of filling.

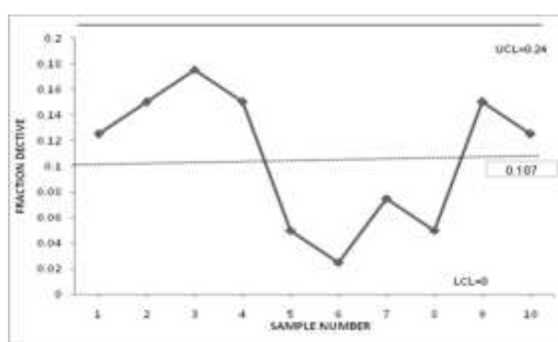
Again corrective measures adopted and check another set of samples.

TABLE 4

DATA FOR CALCULATING AND PLOTTING P-CART 4

DAY	No. of castings Inspected (a)	Defective no. of Castings found(b)	Fraction defective(b)/(a)
Day 31	40	5	0.125
Day 32	40	6	0.150
Day 33	40	7	0.175
Day 34	40	6	0.150
Day 35	40	2	0.050
Day 36	40	1	0.025
Day 37	40	3	0.075
Day 38	40	2	0.050
Day 39	40	6	0.150
Day40	40	5	0.125
Total	400	43	

p is the ratio of total no. of defective castings found **to** Total no. of castings inspected thus p is 0.108and n is 40 Then UCL is p + 3√p (1-p)/n thus UCL is 0.24 similarly LCL is p - 3√p (1-p)/n thus LCL is -0.04 sinceLCL is negative and thus has been taken as being with zero.



Graph 4- p chart 4

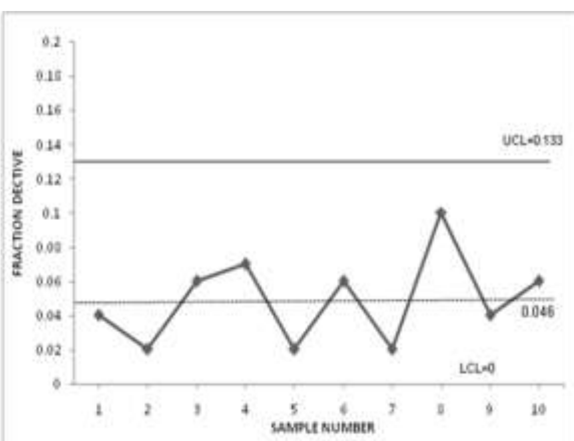
Now from the graph 4 it is found that the process is under control. After making sure that all the parameters are in specific limit again one set of samples are analysed to get feasible solution.

TABLE V

DATA FOR CALCULATING AND PLOTTING P-CART V

Date	No. of castings Inspected(a)	Defective no. of Castings found(b)	Fraction defective(b)/(a)
Day41	50	2	0.04
Day42	50	1	0.02
Day43	50	3	0.06
Day44	50	2	0.07
Day45	50	1	0.02
Day46	50	3	0.06
Day47	50	1	0.02
Day48	50	5	0.01
Day49	50	2	0.04
Day50	50	3	0.06
Total	500	23	

P is the ratio of total no. of defective castings foundto Total no. of castings inspected thus p is 0.046 and n is 50 Then UCL is p + 3√p (1-p)/n thus UCL is 0.133 similarly LCL is p - 3√p (1-p)/n thus LCL is -0.034 sinceLCL is negative and thus has been taken as being with zero



Graph 5- p chart 5

From the graph 5 it was found that the values are very near to the average value. So the solution is feasible.

From the Table VI it is clear that if the pouring temperature is below 1350 ^{0}C, the casting obtained is found to be defective. So temperature is one of the main factors to cause defect.

TABLEVI

POURING TEMPERATURE EFFECT ON CASTING

Temperature (^{0}C)	Cause of defect during casting		No. of rejected casting
1387 – 1377	-	-	Nil
1379 – 1350	High blow	Parting line leak	120
1380 – 1385	High blow	Parting line leak	125
1386 – 1360	High blow	-	34

V. RESULT AND FINDINGS

The cause of defects in automate high pressure line casting is found to be most probably occurred due to high pouring temperature when molten metal cools. Metal cools in the mould before solidification it contracts and unless more molten metal is available by feeding there may be insufficient metal completely to fill the mould cavity and so unsoundness is caused.With grey iron, however, there is also an expansion during solidification which tends to affect the earlier contraction of the liquid metal. The good casting properties of cast iron derive in large measure from this. However, solidification is also accompanied by a tendency for the casting to swell which promotes unsoundness. Defects arising from contraction of the liquid metal and casting expansion are generally known as 'Shrinkage' defects.Sinks, downs and pipes are 'shrinkage defects which are visible on the casting surface and the major factors affecting their formation areLack of mould rigidity, High pouring temperature. If mould is not rigid enough, it will yield to the pressure of the metal and the solidification expansion as a result, the casting will be larger than pattern dimensions. The metal to fill the enlarged mould cavity is down from the hottest areas of the casting giving rise to sinks, draws, and pipes in these areas if no more liquid metal is available to fill them.If pouring temperature is high, the molten metal contracts more. The casting expands more in the absence of feed metal. Sinks, drawn and pipe occur in the last areas to solidify.

VI. CONCLUSION

Fineness and permeability of sand mix are in conflict with each other and hence they must be balanced for optimum results. Correctly identify the defect symptoms prior to assigning the cause to the problems, false remedies not only fail to solve the problem, they can confuse the issues and make it more difficult to cure the defect. If defect occurs, measures must be adopted to eliminate its cause and repetition .Correct pouring temperature has important effect to obtain defect free Casting.

REFERENCES

[1]. Fahri Karakas, Mustafa Kavas, (2008) "Creative brainstorming and integrative thinking: skills for twenty-first century
[2]. Sunil Chaudhari and Hemant Thakkar "Review on Analysis of Foundry Defects for Quality Improvement of Sand Casting" International Journal of Engineering Research and Applications Vol. 4 Issue 3 (March 2014)
[3]. Dr D.N. Shivappa1, Mr. Rohit, Mr. Abhijit Bhattacharya "Analysis of Casting Defects and Identification of Remedial Measures – A Diagnostic Study" International Journal of Engineering Inventions Vol. 1, Issue 6 (October2012)
[4]. Swarbrick J. Encyclopedia of pharmaceutical technology. 3rded, Vol. 6. New York: Marcel Dekker, Inc.; 2007. p. 3503.
[5]. Shewhart WA. , Statistical Method from the Viewpoint of Quality Control, 1939 Washington, DC Graduate School of the Department. Of Agriculture
[6]. S., Juran JM (1999). Juran's Quality Handbook (5th Edition).
[7]. "Casting Atlas of Defects", American Foundryman Society, pp 81-97, 1973
[8]. W.D. Scott, R.W.Monroe, "Gas Generation at the Mold – Metal Interface", AFS Trasactions, V-86, pp 599 – 610, 1978