Quality Control Engineering in Foundries

DR. THOGULUVA RAGHAVAN VIJAYARAM
PhD Profesor
School of Mechanical and Building Sciences
VIT University, Chennai

Introduction to Foundry Quality Control

Quality is defined as the fitness for use or purpose at the most economical level. The two important concepts of quality are : Firstly, the finished product must meet the established specifications, and secondly, customer's satisfaction is derived from quality products and services. Both of these can be attained by integrating quality development, quality maintenance and quality improvement of the product. These aspects of a product can be achieved through a sound quality control system. The various meanings of quality are the fitness for purpose, conformance to requirements, grade, and degree of preference, degree of excellence and measure of fulfillment of promises. The product should have certain abilities to perform satisfactorily. The various factors governing are suitability, safe and fool proof workability, durability, affordability, maintainability, aesthetic look, satisfaction to customers, economical and versatility. The factors controlling the quality of design are the type of customers is the market. Profit consideration, environmental conditions and special requirements of the products. The quality circles help in improvement of the product quality and productivity. It implies the development of skills, capabilities, confidence and creativity of the people through cumulative process of education, training, work experience and participation.

The objectives of QC are to improve the industries income by making the product more acceptable to the customers by providing long life, greater usefulness, versatility aesthetic aspects, maintainability etc, to reduce company's cost through reduction of the losses due to defects (ie) achieve long scrap, less rework, less sorting, fewer customer return etc, to achieve interchangeability of manufacture in large scale production, to produce optimum quality at the minimum price, to make inspection prompt to ensure QC at proper stages to ensure production of non-defective products, judging the conformity of the process to be established standards and taking suitable action when there are deviation to improve the quality and productivity by process control, experimentation and customers feedback and developing quality consciousness in the concern.

The QC concept has 3 major attributes. They are (1) QC is a form of participative management, (2) QC is a human resource development technique and (3) QC is a problem solving technique. The basic organizational structure of Quality Circle is described as follows: AQ Circle should have an appropriate organizational structure for its effective and efficient performance. The organizational structure of QC may vary from industry to industry, but it is useful to have a basic frame work as a model. The various steps in the Quality Circle Operation are (1) the problem identification, (2) problem selection, (3) problem analysis (4) generating alternative solutions, (5) selecting the most appropriative solution, (6) preparing the plan of action (7) presenting the solution to the management and (8) implementation of the solution.

Inspection of the Quality Control Inspection programmer is such that it gives the accurate measure of the efficiency of the whole system and ensures to reduce and sort out the defective products from the lot during processing. Feedback from both the interval inspection and the customers, are obtained regarding quality for taking corrective action. The emergence of the mass production lead to the development and sophistication in the inspection techniques. Emphasis was still an the finished products. In the modern era, quality is considered as an emergent property. The concepts like Total Quality Control, TQC, Quality Assurance, Company Wide Quality and Creativity (CWQC) and zero defect Quality Control are developed inspection oriented approach by identifying the problems before they occur and solving them. The Quality Assurance Engineering plays a vital role in the Quality Control aspect. The total quality of Assurance is equal = (Quality of Design + Quality of manufacturing conforming to design + Quality of performance). The quality rating of the outgoing product is explained by the monthly sample size. Inspection methods are followed in term of the measurement, go – and no – go checking, functional test, visual inspection, 100% inspection and sampling inspection. The degree of inspection is given by ABC Standard. It is classified as Normal Inspection, Reduced Inspection and Tightened Inspection. To check and assess the quality, the following tests should be performed. They are the destructive test, non-destructive test and process inspection tests.

Statistical Quality Control In Foundries

A quality system performs inspection, testing and analysis to ensure that the quality of the products produced is as per the laid down quality standard. It is called as ' Statistical Quality control' when statistical techniques are employed to control, improve and maintain the quality or to solve quality problems. Basic statistical principles were employed to develop sophisticated techniques of QC. It led to the introduction of 'sampling tables' and controls charts. It was used to control the quality of the products during the manufacturing stages.

Statistical analysis was used as a feedback to bring the appropriate changes in process and also for controlling the process. SQC is based on the statistical theory with control charts and sampling plans forming the opening wedges for the use of statistics in industry other techniques such as correlation, analysis of variance and the design of experiments found their way into the industrial laboratories and research departments.

In recent years, the SQC is applied in focus of the following basis (1) response surface analysis useful in chemical industries, (2) Reliability engineering (life testing), and (3) A whole new dimension of the quality problem. SQC is mainly based on the mathematical concepts of statistics. It consists of 3 general activities. (1) Systematic collection and graphic recording of accurate data (2) Analysis the data (3) Practical Engineering or management Action, to the information obtained indicates, the significant deviation from the specified limits. Modern techniques of statistical Quality Control acceptance sampling have an important part to play in the improvement of Quality, enhancement of productivity, creation of Consumer confidence and development of industrial economy of a country.

Experimental

The grey cast iron foundry chosen for this research work is basically a semi captive foundry with total molten metal production of approximately 240 tons per month. In this foundry, the total castings produced from this is 156 tons per month. The total rejections is approximately 18% and the average yield is 60.8%. Three hundred different types of castings are produced by them. Among these, the components which highly prone to defects are taken for study. The existing quality control can be improved only by adopting new methods. So, a lot of experimental methods are tried and it is implemented time by time. It is difficult to find a direct correlation between the foundry variable and the occurrence or a defect in a particular casting. Each defect is studied individually to find the critical factors. Analysis of each defect in a systematic manner for a particular casting has almost clearly indicated the reasons for the occurrence of the particular defect from its appearance. By considering the above factors, the components which are taken for the experimental analysis are given below with reference to the major defects that is occurring in the corresponding components.

COMPONENT NAME	MAJOR DEFECTS
1. 3 MTC Body	Cold Shuts, Sand Drop, High Hardness, Improper Surface Finish.
2. 2 ½ SB26 CSGI	Slag Inclusion, Blows and Cold Shut
3. 2E Bed	Shrinkage
4. M6 Bowl	Blows, Cold Shuts.
5. 7.5 MTC B Cover	Slag Inclusions, Sand Drop
6. 5 MTC B Cover	Cold Shuts, Sanddrop
7. 3 MTC BKT	Cold Shuts, Sanddrop and Poor Finish.
8. 5 MTC BKT	Cold Shuts, Sanddrop and Poor Finish
9. 3DC7 IMP	Shrinkage and Blows
10. 2 F Bed	Cold Shuts, Blows
11. 2HS 10 IMP	Blows
12. 2 ½ 5 MHT8CV	Slag Inclusions and Blows
13. 4HC26 CSGI	Slag Inclusions
14. 2 ½ 5MH99 CVIMP	Blows
15. 23MHT8 CV CSG	Cold Shuts, Sanddrop
16. An additional experimental work is done in 120 tone bailing press bearing bracket castings to study the surface finish.	
17. In Addition to this Experimental Work is Done to Frame A Sand Control Chart	

The previous rejection reports available in the foundry are studied It is clear that the rejections due to the defects in the corresponding components are high and so these are only taken for experimental studies.

Results and Discussion

The results are discussed on the basis of the major contributing factors for the occurrence of each defect and also to find out the exact reason for each defect and the significance of the defect.

Coldshuts, Sanddrop and Slag inclusions Problems in 3 Mtc Body

The gating system was modified and implemented. Experimental trials were conducted in the production run. In the first trial, castings were made with the existing gating system. Out of 30 castings made 2 of them were rejected due to coldshuts. With new gating system there were no rejection due to coldshuts. In the second trail, the old gating and the new gating system were implemented simultaneously and the results were studied. In the old gating system, out of 57 castings inspected, 4 castings were rejected. Among them, 2 of them were rejected due to coldshuts and 2 of them were rejected due to other defects. But in the new gating system, out of 57 castings, 10 castings were rejected due to the mould breakage while pouring. In the third trial 64 moulds were poured in old and new gating system. In the old gating system out of 64 castings, 115 of them were rejected due to coldshut. But in the newly designed gate, 64 castings were inspected and 4 of them were rejected due to colshut only. But 37 castings were broken due to improper ramming. The sand properties were controlled to limited values and it was kept within the satisfactory levels. So the mould breakage was mainly due to the improper ramming between the runner bar and the inner circumference of the body. So, the rejections were mainly due to the improper ramming between them and not due to the newly designed gating system. The mould hardness was also checked at different locations. It ranges from 65 to 70. because of the modified gating system, the pouring time has reduced from 15 seconds to 11.4 seconds. The average temperature observed during pouring in the trial after modifying the gating system ranged from 1340^{o}C to 1360^{o}C which was quite satisfactory. But there was temperature drop while holding the metal and also during traveling from the holding place to the pouring section. The total distance traveled by the metal was 13.5 meters nearly. Hence in this newly designed gating system, a runner bar extension was provided to trap the slag inclusions and no rejection was observed due to the slag treatments. Because of this change in the gating system coldshut defects were reduced.

The study on the pouring temperature was done. Some more trials were made of find out the temperature drop during traveling of the metal from the melting section to the moulding section. In the first tap, the temperature was 1290^{o}C initially. After holding 3 minutes, the temperature was dropped to 1270^{o}C. So nearly 20^{o}C was dropped. In the second tap, the temperature was 1350^{o}C. after holding 3 minutes, the temperature was dropped to 1310^{o}C. So, nearly 40^{o}C was dropped. In the third tap, the temperature was 1300^{o}C initially. After holding 3 minutes, the temperature was dropped from 1300^{o}C to 1260^{o}C. So, nearly 40^{o}C was dropped. Totally 100^{o}C was lost because of the long distance traveling of the metal from the melting section to the pouring section, which has resulted coldsuhts in the 3MTC body. After this, the temperature was increased to above 1300^{o}C and then the moulds were poured. During the pouring of the metal into the moulds, the pouring practice was also checked and it was found that the slag inclusions were raised only due to the improper skimming practice. So, during pouring, good skimming practice was performed to trap the slag inclusions.

The jolting time was found out first to observed whether uniform ramming was performed or not. Initially the jolting time was 15 to 18 seconds and the mould hardness was 68 to 75. This may cause sanddrop in the 3MTC body. So, finally jolting time was increased to 20 seconds and the mould hardness was increased to 85. By controlling these variables, 15 moulds were poured and no rejections were observed due to coldshuts, slag inclusions or sanddrop in 3MTC body.

High Hardness Problem in 3MTC Body

The percentage of moisture varies from 4.75% to 5.3% and this was not a very high one. So, of moisture was within the recommended range. Hence no problem was observed due to moisture content. Next, the metal composition was analyzed and it also lies within the recommended range. The carbon% varies from 3.2% to 3.58%, which was a satisfactory one. The silicon % also varies from 1.96% to 2.72% and the Mn 5 also varies from 0.595% to 0.77%. It was found that in thin sections (fine) of the 3MTC body, no problem was observed due to high hardness. The hardness value was 167 BHN and the fractured portion showed a grey surface.

Micrograph was also taken for this sample and it showed a highly merchantable structure of type A graphite flakes of uniform distribution. Sample were also collected from the thick sections in the inside bore of the 3MTC body and hardness were measured and it ranged from 207 BHN to 302 BHN. From the microstructure study, it was observed that there were more rosette groupings of type B flakes in thick sections. So, it was due to the high phosphorus content which was present in the molten metal.

Slag Inclusions in 2 ½ Sb 26 CGSI

The gating system was observed and it was found to be a satisfactory one. It has also a runner bar extension to trap the slag inclusions. So, the defect were mainly due to the improper skimming practice. Finally, good skimming was performed by using strainer cores and 5 moulds were poured. No rejections were observed due to slag inclusions.

Shrinkage in 2E Bed

The gating system was studied and it was found to be a satisfactory one. The chemical composition (C and Si%) was found to be satisfactory one. In the first trial, cast iron chills were used and the castings were rejected normally. In the second trial, the gating system was modified and it was implemented in the production run. But, the castings were rejected normally. finally, in the third trial, the casting design it self was modified at the critical hard spot region and it was implemented in the production run. No rejections were observed due to shrinkage.

Blows and Coldshut Problems in M62 Bowl

First, the core hardness was checked and it was found to be in the recommended range from 35 to 40. The pouring temperature was found to be 1320°C, which was not a very high one. Initially, the number of vents were only 4. But it was increased to 10. The initial moisture % was 6.4. By proper control it was reduced to 5%. By controlling all these factors, 15 moulds were made and metal was poured into the moulds. No rejections were observed due to blows or coldshuts in M62 bowl.

Slag Inclusions In 7.5 MTC B Cover

The newly designed gating system with the increase in the reservoir pool height was implemented in the production run. The initial reservoir pool height was 16mm. But it was increased to 34mm. Strainer cores were also used with this. 15 moulds were made and poured with the newly designed gating system and no rejections were observed due to slag inclusions.

Box Shift, Sanddrop and Coldshut Problem in 5 MTC B Cover

It was found that the box shift problem was mainly due to non alignment of round and flat fins on the top and the bottom mould boxes. By checking and controlling this, out of 25 moulds inspected 5 moulds were eliminated during pouring. The properties of sand were found out. It was found to be a satisfactory one. For coldshut problem, the temperature was distance was also adjusted from 16 meters to 12 meters. By controlling all these variables 20 moulds were made and the metal was poured into the moulds. No rejections were observed due to box shift, sanddrop and coldshut.

Coldshuts and Sanddrop Peblems in 3 MTC BKT

The pouring temperature was observed and it was found to be in the range 1280°C. the jolting time and the mould hardness was found to be in the range 17 to 19 seconds and 75 to 90. The observed value of mould hardness was found to be a satisfactory one. But the temperature was found to be very low for pouring. So, the temperature was increased from 12080°C to 1340°C. So, by controlling all these variables, the moulds are made and poured. 13 moulds were and poured. No rejections were observed due to the coldshut or sanddorp.

Coldshut Problem in 5 MTC BKT

The pouring temperature was observed and it was found to be in the range 1280°C to 1290°C. Finally the pouring temperature was increased from 1280°C to 1340°C and 13 moulds were made and poured. No rejections were observed due to clodshut.

Shrikage Problem in 3 DC7 IMP

The rejected castings were taken and chemical composition was analysed. It was found that the Carbon %, silicon, Mn% and P% ranges from 3.4378 to 3.2032, 2.53 to 2.60, 0.65 to 0.68 and 0.29 to 0.30%. This was found to be a satisfactory range. A good casting sample was also taken and it was also chemically analyzed. The C%, Si %, Mn% and P% ranges within the recommended limits. So, it was not due to this. The gating system was studied and it was found to be a satisfactory one. Finally, the pouring temperature was observed for each tap. In the first tap, the temperature was 1310°C and moulds were poured. Rejections were observed due to shrinkage. In the second tap, the temperature was 1300°C and moulds were poured. Rejections were observed due to shrinkage. In the second tap, the temperature was 1300°C moulds were poured and rejections ere observed due to shrinkage. In the third tap, the temperature was 1275°C, and moulds were poured. No rejections were observed due to shrinkage. In the fourth tap, the temperature was 1300°C and the moulds were poured. Rejections were observed due to shrinkage. So, the moulds were poured in the third tap temperature range of 1275 °C nearly. 14 moulds ere poured at this temperature and no rejections were observed due to shrinkage.

Coldshut Problem in 2F BED

The temperature range initially was found to be in the range 1290°C to 1310°C. Finally, the temperature was increased from 1310°C to 1340°C and 15 moulds were made and poured. No rejections were observed due to cold shuts.

Blows Problem in 2 HS10 IMP

Initially, the jolting time was high and moulds hardness value ranges from 85 to 90. Initially, the numbers of vent holes are only 3. The initial% of moisture present in the sand was found to be 6.2. Finally the mould hardness was reduced to 70.

The number of the vents in the moulds ere increased from 3 to 12. The moisture % also reduced from 602% to 5.2% and the moulds are made by controlling all the properties. 20 moulds were made and poured. No rejections were observed due to blows.

Blows and Slag Inclusions in 2 ½ 5MHT8 CVCSG

Pouring temperature as observed and it was found to be in the range 1310°C to 1330°C, which was not a very high one. The study of the gating system showed that it has a runner bar extension to trap the slag or dross impurities. The strainer cores were used properly. The initial moisture % was 7.2. Finally, it was reduced to 5.2% and by controlling all these factors, 20 moulds were made and poured. No rejection were observed due to blows or slag inclusions.

Slag Inclusions Problem in 4HC 26 CSGI

It was found that the gating system and the use of strainer cores during pouring was found to be satisfactory. But, skimming was not performed properly. So, skimming practice was adopted correctly and 15 moulds were poured. No castings were rejected due to slag inclusions.

Blows in 2 ½ 5MHT9 CVIMP

Firstly, the core hardeners were checked and it was found to be in the range 38 to 42, which was a satisfactory one. The initial jolting time was high and the mould hardness was also high which ranges from 8 to10 seconds and 80 to 85.

The initial moisture % in the sand was 6%. Finally, the jolting time was decreased and hence the mould hardness was also decreased from 85 to 70. The moisture % was also reduced to 5% and moulds were made. 10 moulds were made and poured by controlling all these variables. No rejections were observed due to blows.

Cold in 3 MHT8 CVCSG

The initial pouring temperature was found to be in the range 1260°C to 1280°C. This was a very low pouring range. So, the temperature was increased from 1260 degree C to 1300 degree C and 15 moulds were poured. No rejections were observed due to cold- shuts.

Suface Finish Problem in 120 Tonne Baling Press Bearing Bracket

The result of the surface finish determination taken on the fiat surfaces of the 120 tone Baling press Bearing Bracket Castings are shown in the Table 4.36.

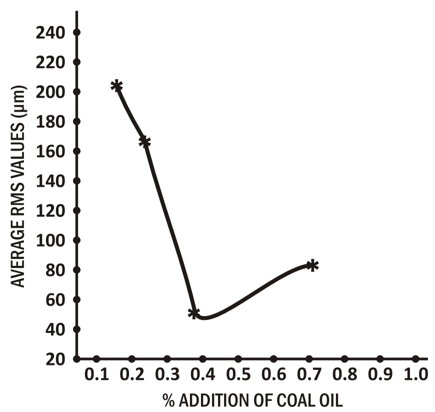
It was found that the lowest surfaces a roughness value is obtained with only 0.6% addition of coal oil to the moulding sand. From the graphs, it was found that the surface roughness

Table 4.36 : Obervations of Surface Roughess Values with Various % Addition of Coal Oil

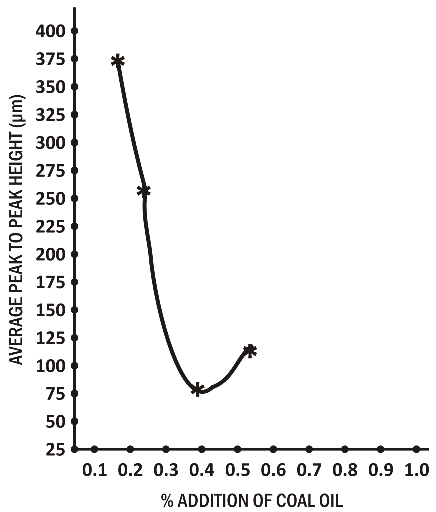
% Addition of Coal Oil	RMS Average Values	Average Peak to Peak Height	Average Absolute Height
0.3	199.5	370	174.38
0.4	161.6	252.5	144
0.6	39	78.13	42.4
0.8	62.29	117.5	53

The variations in the surface roughness values with increasing coal oil additions are shown in the graphs. 5.1, 5.2 and 5.3.

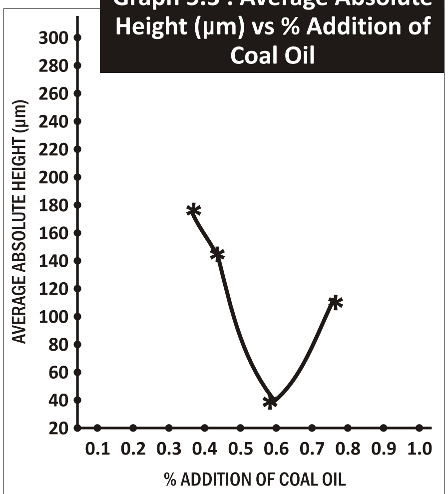
Graph 5.1 : RMS Values vs % Addition of Coal Oil



Graph 5.2 : Average Peak to Peak Height (µm) vs % Addition of Coil Oil



Graph 5.3 : Average Absolute Height (µm) vs % Addition of Coal Oil



values with 0.4% addition of coal oil are RMS average =161.6m, Average peak to peak height = 252.5m and Average absolute height = 144m. The values decreases to RMS average =39m, average peak to peak ht = 78.13m and average absolute height = 42.4m when 0.6% coal oil gives better surface finish than 0.4% addition of coal oil. From the Table-1 and Table-2, it was found that because of this adequate quality control of the components that were taken for study, the rejection rate has decreased from

13.65 to 10.76%. So nearly 2.89% rejection was reduced. From the table-1, the total castings produced from January to June on the weight basis was found to be 132807.5Kg and the rejected weight was 18126.7Kg. The % of rejection was found to be 13.65. The total castings produced from July to December was found to be 149639.1 Kg and the rejected weight was 16094 Kg. The % of rejected was found to be 10.76%.

Suggestions

It is found that most of the defects have been caused only due to limited manpower availability to look after the entire quality control operations of the foundry. As the production department personnel are more concerned about the quality than the quality, they will try to compromise the quality of the castings. Hence it is suggested that a separate quality, control department be functioned, in order to improve the overall quality of the castings. Further it is more important to have a perfect understanding between the production and the quality control department, for smooth functioning of the foundry. Although the cost incurred to employ additional staff is high it is negligible compared to the total profit that could be obtained by the by the resulting increase in the quality of the casting. Hence it is suggested that adequate staff be employed to ensure complete control of all the foundry variables. Number of trials conducted is less, which will not improve the overall result. So, control should be implemented on the regular production run and it should be periodically reviewed. To reduce the rejection percentage defects like coldshuts, shrinkage, blows, slag inclusions, high hardness and sanddrop should be avoided. The general parameters, which causes the above defects should be critically controlled. Then only it is possible to do further work to reduce rejections from 10% range to the minimum possible extent. Instead of concentrating the defect analysis study on so many casting, it is better so concentrate on selected few components like 3MTC body, 2E bearing bed, 3DC7 IMP, MTC B cover and extend the results to other components later. Studies on temperature, distance travelled by the metal, sand control, raw material control, skimming techniques should be carried out regularly and systematically to reduce the rejections. Further work on quality control at this foundry should be carried out only by adopting the recommendations, which will give fruitful results.

Acknowledgement

The author expresses his thanks and gratitude to the School of Mechanical and Building Sciences, SMBS, VIT University, Chennai Campus, Vandalur-Kelambakkam Road, Chennai 600127, India.

❍❍❍