IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 2 Ver. I (Mar. - Apr. 2016), PP 87-94
www.iosrjournals.org

Quality Improvement For Dimensional Variations In Automotive Casting Using Quality Control Tools

Abhijeet B. Vante[1], G. R. Naik[2]
[1](P.G. Student, Department of Production Engineering, KIT's College of Engineering, Kolhapur, India)
[2](Associate Professor, Department of Production Engineering, KIT's College of Engineering, Kolhapur, India)

Abstract: *Casting defects reduces the total output of castings. It is essential to understand the causes behind these defects. This paper discusses the research carried out in the foundry to control the increased rejection. The component under study is 3 cylinder metric block. The dimensional variations in casting wall thickness are analyzed as major defect contributing in rejection. Quality control tools such as Pareto analysis, cause and effect diagram, why-why analysis, are used for analysis of casting defects. Remedies to minimize the rejection are suggested and implemented. Various chaplets are tried and tested as remedies. The previously used 3 disc round chaplet is replaced by rectangular v-make chaplet. This change contributed in reduction in rejection as well as cost of poor quality. Rejection due to water jacket wall less is reduced from 7% to 2.13%. Reduced rejection indicates better control resulting in quality improvement of 3 cylinder metric block.*
Keywords: *Casting Defects, Pareto Analysis, Cause and Effect Diagram, Quality Improvement, Quality Control Tools, Process Mapping.*

I. INTRODUCTION

Quality plays an important role in building reputation of the company in the market. But nowadays just maintaining an optimum level of quality is not sufficient. If a company wants to take competitive edge over rivals then it should rise to quality improvement. Quality improvement can be achieved through better control.[1]

The target area of this particular research is foundry industry. Quality is a very important keyword when there is lot of similar industries clustered in the same region. Quality is hampered mainly due to castings defects, which are unwanted irregularities in the specifications or dimensions of the casting.[2] In this research a 3 cylinder metric block is taken under study. Rejection analysis is carried out to find major defect contributing in casting rejection. And remedies will be suggested to achieve the aimed quality.[3]

A standard quality management methodology is designed to achieve quality improvement through better control. So methodology here will be consisting of quality control tools. Scope of the research will be limited to finding root cause and remedies of the major defect which is contributing the most in rejection percentage.[4]

II. LITERATURE SURVEY

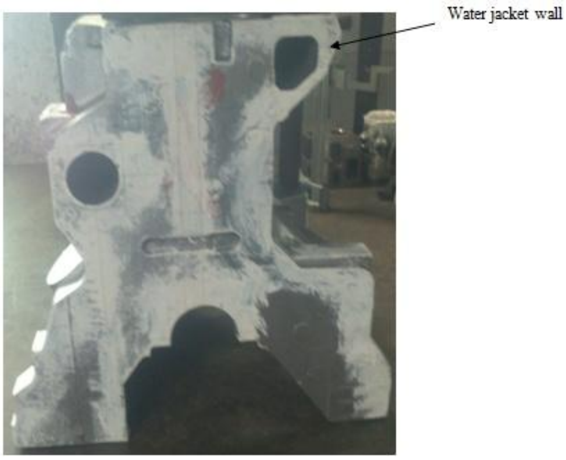
Kaskhedikar et al (2013) discussed various quality control tools consisting 7 quality control tools, kaizen, 5s and six sigma. They explained how quality improvement can be achieved through better control.[5] Joshi et al (2014) carried out rejection control in the foundry by using quality control tools, such as Pareto chart and cause and effect diagram.[3] B.R.Jadhav et al (2013) used 7 quality control tools to carry out rejection control of an automotive component.[2] Bhaskar Sinha (2007) used a tool named GeomCalliper for measurement of an optimal wall thickness.[6]

Karve et al discussed a method for determining dimensional capability guidelines for use by casting customers which incorporates sample casting inspection uncertainty.[7] K. Gawdzinska (2011) studied the use of quality control tools such as Pareto analysis and cause and effect diagram for differentiating major defects and finding their root causes.[8] Kinagi et al (2014) worked on foundry rejection analysis. They've given a proper methodology consisting of quality control tools such as Pareto analysis, doe etc. Defects are minimized to achieve development in quality.[4]

Various defects such as sand drop, blow hole, mismatch and oversize are discussed in the literature survey. Authors used traditional quality control tools along with simulation for casting rejection control.[9] study for achieving dimensional accuracy using quality control tools is not reported. This is considered as research gap. Also, the modern techniques such as, ANN, x-ray inspection, DoE, simulation for casting rejection analysis are reported.[10]

III. PROBLEM STATEMENT

The foundry under study is facing the problem of dimensional variations at casting wall thickness for the component 3 cylinder metric blocks. Company is facing loss of significant revenue due to cost of poor quality. Investigation and analysis of problems leading to defect and increased rejection are needed. A methodology for achieving consistent quality in the production of the component 3 cylinder metric blocks needs to be developed.



Three cylinder metric block showing water jacket wall

Dimensions of casting are measured during inspection. A section of rejected casting shows that dimensions of it are deviating from the specifications. The dimensional variation is at water jacket wall thickness. The measured and specified dimension is given below in Table 1.

Sr. No.	Measured Dimension	Specified Dimension
1.	4.70mm	7-9mm

Table 1 Dimensional Variation at Casting Wall Thickness

IV. PROCESS MAPPING OF CURRENT MANUFACTURING SETUP

A process map is a graphical representation of a process flow that identifies the steps in the process, the input and output variables of a process and the opportunities for improvements. Every process map must be the result of teamwork because it is impossible that just one person could have all the knowledge about the process and hence the importance of the chartering of the team, especially a cross-functional team.

In the process mapping of casting following steps are used-

4.1 Identification of the process

The component under research is a 3 cylinder metric block. It is manufactured by casting process in the foundry. There are various production lines in the company foundry. This component is manufactured on ARPA 900 production line. Casting process consists of steps such as sand preparation, mold making, pattern making, core making, melting, pouring, shakeout, and inspection. All these steps are represented in the form of process flow diagram below in Fig.1

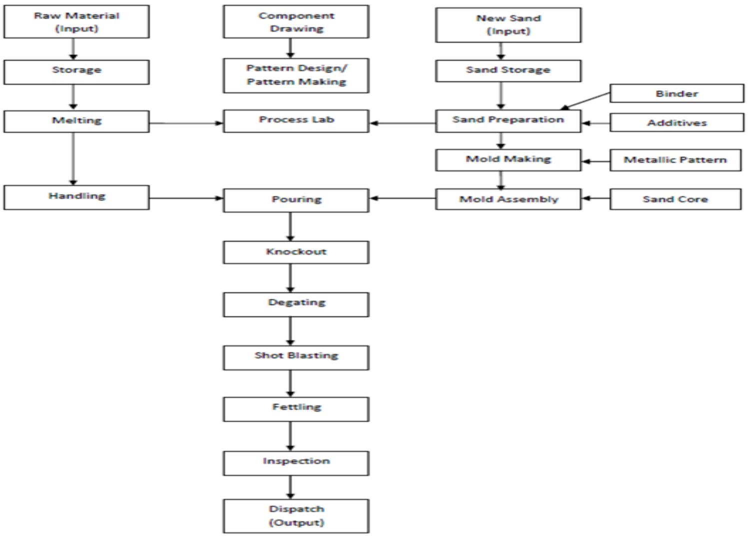


Figure 1 Process flow diagram

4.2 Mapping the total process

Fig.2 represents ARPA 900 production line and instruments for performing various steps in the casting process.

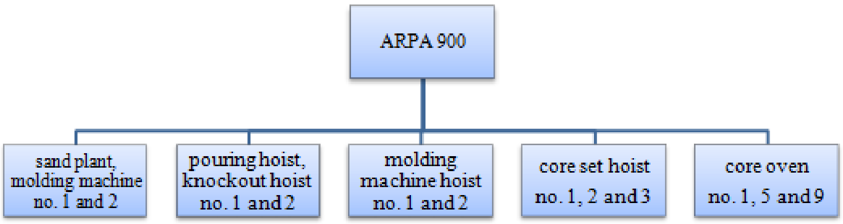


Figure 2 The ARPA 900 production line

Table 2 gives the operation details for various casting operation in brief.

SR. NO.	PROCESSES	PROPERTIES
1.	**Pattern making**	i.Pattern material= metal ii.Pattern life= 1,00,000 impressions iii.Cost of pattern (including tooling) =25 Lakhs. iv.Allowance= 4mm
2.	**Molding**	i.Machine used for moulding= Jolt Squeeze ii.Additives= Betonite powder, Furnace oil, Coal dust powder iii.Tests performed on sand= Compactibility, Permeability, Strength
3.	**Core making**	i.Core making process= cold box, shell core making ii.Total no. of cores= 6 iii.Types of cores used= side cores, barrel cores, water jacket core
4.	**Assembly**	i.Machines used= core transfer fixture ii.Chaplets used= round chaplets
5.	**Melting and pouring**	i.Pouring temp= 1380-1410^{0}c ii.Time taken for single pouring= 30 sec. iii.Pouring by 1 laddle= 7 fillings
6.	**Fettling**	i.Processes used= shot blasting, chipping, grinding ii.Machines used= cutters, grinders, shot blasting machines, hammers iii.Paint colour= green
7.	**Inspection**	i.Specifications to be measured= wall thickness, swelling, assembly shift ii.Instruments used= wall gauge, box shift gauge

Table 2 Mapping of sub-processes of casting

4.3 Identify and eliminate wastes

By observing and analyzing the current manufacturing setup we have found some irregularities in core making. The problem is represented below in Table 3.

Problem Spotted	**Problem Impact**	**Origin**	**Department**
Twisting And Cracking Of Water Jacket Core	Water Jacket Wall Less	Water Jacket Shell Core	Core Making

Table 3 Identification of problem

The cracked and twisted water jacket cores are represented in Fig. 3

Figure 3 Cracked and twisted water jacket core

Possible causes of the above mentioned problem-
1. Molten metal pressure and temperature
2. Chaplets of imperfect size and improper position
3. Gases and venting
4. Core strength
5. Core sand properties

4.4 Implement the New Process

Trials method is carried out to find the solution of the of the dimensional variations in water jacket area of 3 cylinder metric block which is described in this paper. The useful solutions and outcomes of the trials are integrated in this process. The changes that are made in the process after trials are-
1. Increase in pouring temperatures.
2. Use of rectangular chaplets.

V. PARETO ANALYSIS FOR DEFECT CATEGORIZATION

Table 4 gives the cumulative Pareto analysis for the 3 cylinder metric block. Pareto analysis which is also known as 80:20 principle is implemented in rejection analysis to find out which 20% defects have the 80%damage or impact.

Casting Defects	% Rejection	Cumulative Count	Cumulative %
Wall Less	7	7	68.82989184
Broken Core	1.5	8.5	83.57915438
Blow Hole	1	9.5	93.41199607
Other Defects	0.67	10.17	100

Table 4 Rejection percentage of wall less

From the analysis it is clear that dimensional variation at water jacket wall i.e. wall less has the maximum share in increased rejection. Since scope of our research is limited to the major defect reduction and analysis so, focus of the paper will be on minimizing rejection due to wall less. Fig. 4 shows the graphical representation of the above tabulated data. Rejection percentage is presented on y axis.

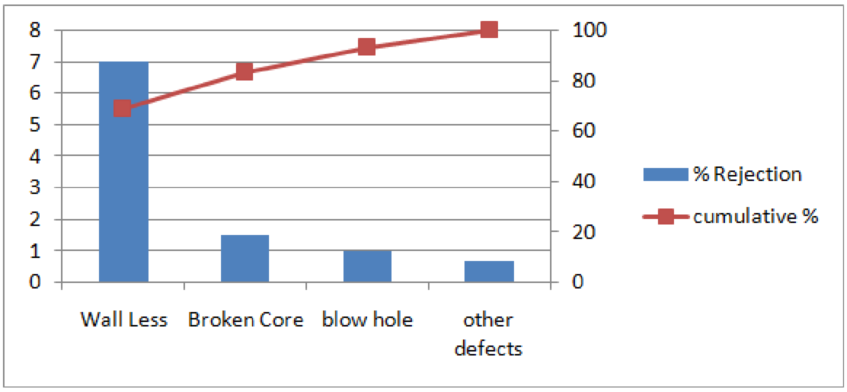


Figure 4 Pareto analysis for defect categorization

VI. USE OF QUALITY CONTROL TOOLS FOR ANALYSIS

6.1 Cause and effect diagram

Cause and effect diagram, as the name indicates is the relationship between the causes of the defect and the resulting effect caused by it. It is represented in diagrammatic form in a branch like structure. Fig.5 shows the cause and effect diagram for dimensional variation at water jacket wall. Causes are divided into 5 categories such as- man, machine, tooling, method and material.

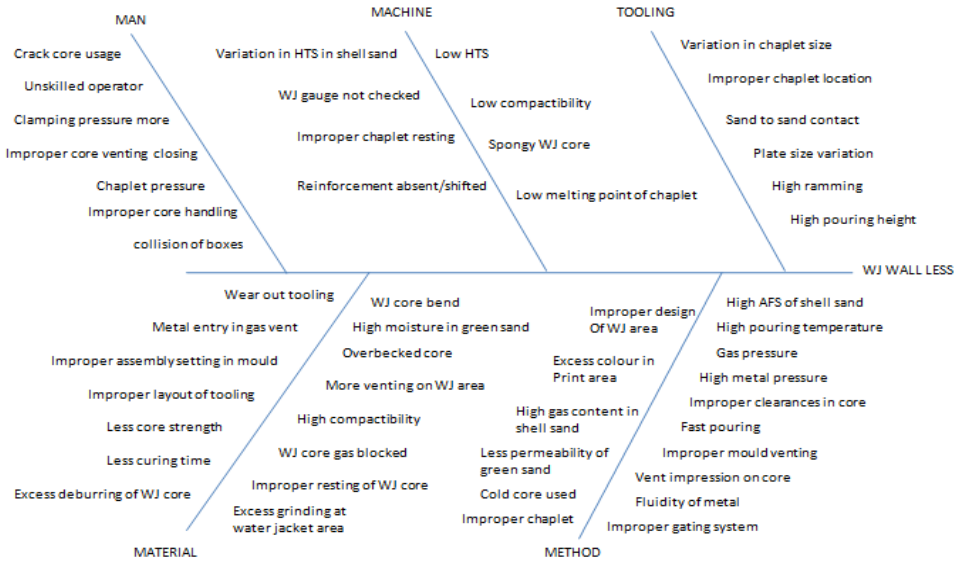


Figure 5 Cause and effect diagram for water jacket wall less

6.2 Why-Why analysis

There are several reasons contributing to the water jacket wall less. But the reason which needs the permanent change in tooling is use of various chaplets. Water jacket core is getting twisted and broke during process. Fig.6 represents the stepwise process that gives the reason by using why-why analysis.

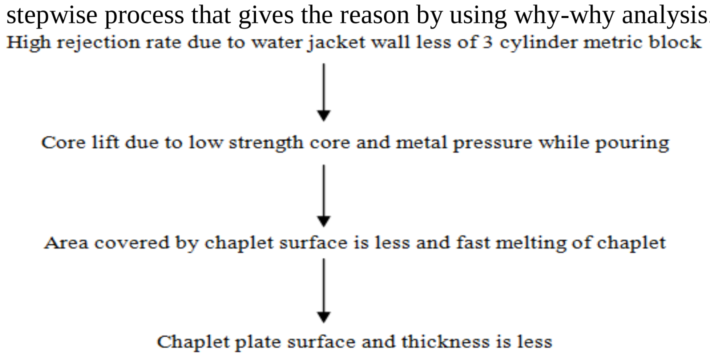


Figure 6 Why-Why analysis for water jacket wall less

VII. CORRECTIVE ACTIONS AND PREVENTIVE MEASURES FOR MAJOR DEFECTS

7.1 Trials for implementation of possible set of solutions

Foundry carry out trials to test the effectiveness of suggested changes.[11] If these changes are successful then these changes are continued and implemented in the casting process. Trial lots are of variable sizes. There are total 8 trials carried out in the month of august '15. From these trials, 2 trials showed successful changes that can be continued. The trials and action taken are described below in Table 5.

Trial No.	Date	Action taken	Continuity	Trial lot size
1.	07-08-15	-3 disc chaplet used on water jacket (2 nos.)		20
2.	09-08-15	-3 disc chaplet is used on water jacket (1 nos.)		22
3.	10-08-15	-rectangular chaplet used at rear end(1 nos.) -3 disc chaplet used at rear end (1 nos.)		2 21
4.	14-08-15	-1st box temp= 1415-1418^{0}c -last box temp=1390^{0}c	continued	14
5.	16-08-15	-rectangular tin coated chaplet 5 hole -perforated rectangular chaplet -100% pouring time monitored		7 7 5
6.	17-08-15	-plane square chaplet -plane square with 5 hole -square perforated chaplet -1 side square and 1 side round chaplet		17 14 14 20
7.	18-08-15	-rectangular tin coated chaplet 5 hole		167
8.	23-08-15	-Rectangular chaplet with 5 perforation(50*25*10)	continued	35

Table 5 Trials on 3 cylinder metric block

7.2 Pouring Temperature

From the 2 successful trials, major changes include increase in pouring temperature. 1st box temperature and last box temperatures are increased in order to increase the fluidity of the molten metal. This ensures optimum pressure and proper mold filling. Table 6 shows the changes made in pouring temperatures.

Pouring Temperatures(In ^{0}c)			
1st Box Temperature		Last Box Temperature	
Before	After	Before	After
1410	1418	1380	1390

Table 6 Pouring temperatures for 3 cylinder metric block

Fig. 7 shows the graphical representation of the above tabulated data. Temperatures are presented on y axis.

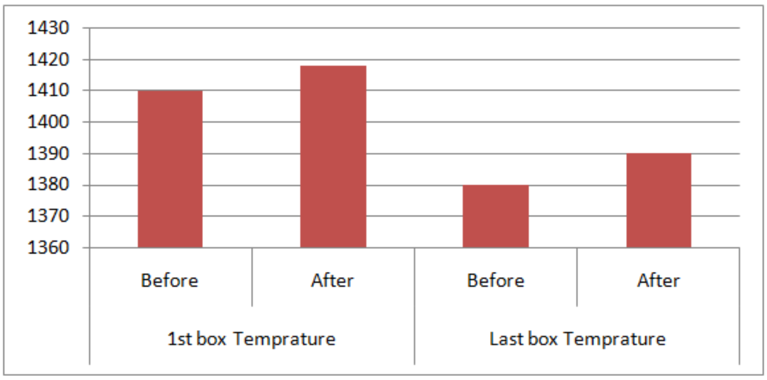


Figure 7 Changes in pouring temperatures

7.3 Chaplet on WJ core

Water jacket core was facing the problem of twisting and breaking. This is resulted into dimensional variation at water jacket wall thickness. This problem is rectified by using rectangular chaplet on water jacket core. Rectangular chaplet ensures the required surface area. It successfully bears the pressure of molten metal. Fig. 8 shows the corrected action.

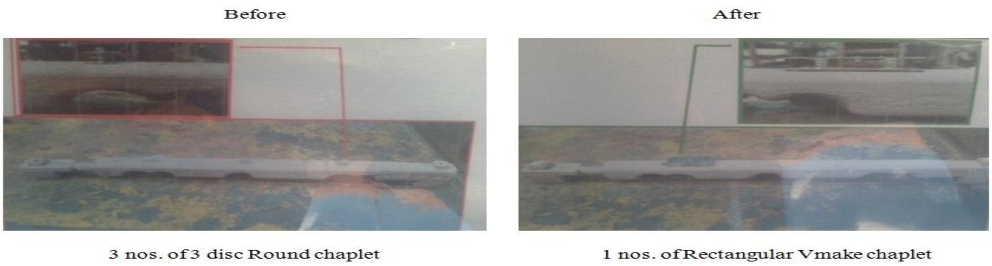


Figure 8 Changes in surface area of chaplet used

7.4 Corrective action and preventive measures

In the research various causes found contributing in rejection percentage. Some of the parameters behind these causes are modified and some changes are made permanently. These changes are successfully integrated in the process. Table 7 gives the changed parameters and their specifications.

Sr. No.	Parameter	Nature Of Parameter	
		Before	After
1.	Pouring Temperatures	1st Box Temperature=1410^{0}c Last Box Temperature=1380^{0}c	1st Box Temperature=1418^{0}c Last Box Temperature=1390^{0}c
2.	W.J. Chaplet	3 Nos. of 3 Disc Round Chaplet	1 Nos. of Rectangular Chaplet

Table 7 Corrective action and preventive measures for wall less

VIII. RESULTS AND DISCUSSION

8.1 Reduction in rejection percentage

The corrective actions and preventive measures are implemented and integrated in the casting process of 3 cylinder metric block. In the Table 8 reduced rejection percentage due to water jacket wall less is represented. And it is reduced significantly showing improvement in quality.

3 Cylinder Metric Block WJ WALL LESS Rejection %	
Before	After
7	2.13

Table 8 Reduction in rejection percentage due to WJ wall less

Fig. 9 shows the graphical representation of the above tabulated data. Rejection percentage is presented on y axis.

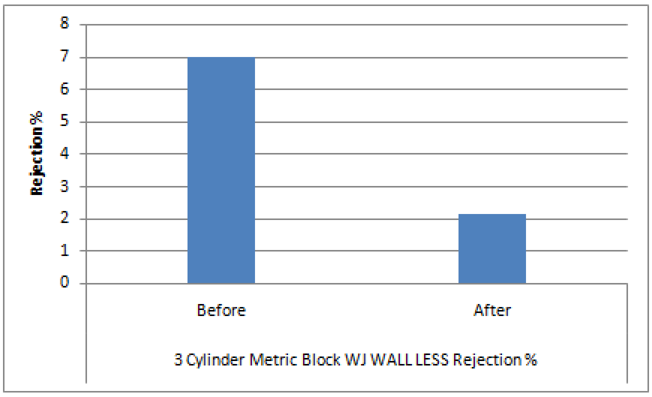


Figure 9 Rejection percentage of 3 cylinder metric block

8.2 Cost of poor quality

Table 9 indicates the significant reduction in cost of poor quality. Even though the orders are varying, still the difference between costs of poor quality is almost 50% less than the cost of poor quality before implementation of the corrective actions.

	Castings Poured	Castings Rejected Due To Wall Less	Cost Of A Casting In INR	Cost Of Poor Quality In INR
Before (Jan'15)	1317	92	8000	7,36,000
After (Sept'15)	1910	41	8000	3,28,000

Table 9 Cost of poor quality before and after analysis

IX. CONCLUSION

Dimensional variations in casting wall thickness are identified as major defect in casting rejection. Quality control tools are used to identify the major defects and their possible causes. Trials are carried out on casting lot to identify the possible remedies. Pouring temperatures and chaplet size are optimized to lower the rejection percentage. Rejection percentage for dimensional variation at water jacket is decreased from 7 to 2.13. Increase in pouring temperature of molten metal and use of rectangular chaplet at water jacket core area results in significant reduction in casting reduction. Increased accuracy in dimensions according to standard specification indicates improvement in quality.

REFERENCE

Journal Papers

[1] Chaudhari S., Thakkar H., "Review on analysis of foundry defects for quality improvement of sand casting", *Int. journal of engg. research and applications*, *Vol.4, Issue 3*, 2014, 615-618.
[2] Jadhav B.R., Jadhav S.J., "Investigation and analysis of cold shut casting defect and defect reduction by using 7 quality control tools", *Int. Journal of advanced engg. And research studies*, 2013, 28-30.
[3] Joshi A., Jugulkar L.M., "Investigation and analysis of metal casting defects and defects reduction by using quality control tools", *Int. journal of mechanical and production engg. Vol.2, Issue 4*, 2014, 87-92.
[4] Kinagi P., Mench R.G., "A development of quality in casting by minimizing defects", *Int. journal of recent research in civil and mechanical engg., Vol.1, Issue 1*, 31-36.
[5] Kaskhedikar K., Katore H.V., "improvement of quality and productivity in casting industries", *Mechanica confab, Vol. 2, No.3*, 2013.
[6] Sinha B., "Efficient wall thickness analysis methods for optimal design of casting parts", *Engineering design*, 2007.
[7] Karve A.A, Chandra M.J., Voigt R.C., "Determining dimensional capabilities from short-run sample casting inspection", *AFS Transactions*, 2002, 699-703.
[8] Gawdzinska K., "Application of the pareto chart and ishikawa diagram for the identification of major defects in metal composite casting", *Archives of foundry engineering, Vol. 11, Issue 2*, 2011, 23-28.
[9] Mane V.V., Sata A., Khire M.Y., "New approach to casting defects classification and analysis supported by simulation".
[10] Bose B.V., Anilkumar K.N., "Reducing rejection rate of casting using simulation model", *Int. journal of innovative research in science engg. and tech., Vol.2, Sp. Issue 1*, 2013.
[11] Shivappa D.N., Rohit, Bhattacharya A., "Analysis of casting defects and identification of remedial measures- A diagnostic review", *Int. journal of engg. inventions, Vol. 1, Issue 6*, 2012, 01-05.

BIOGRAPHY

Mr. Abhijeet B. Vante, PG Student, B.E (Mech. Engg.) M.E. (Mech.-Prod) (Pursuing), KIT's College of Engineering, Kolhapur. The topic of Dissertation- 'Quality Improvement For Dimensional Variations In 3 Cylinder Metric Block Using Quality Control Tools'.
Publications-2

Mr. Girish R. Naik, Associate Professor, (Dept Of Prod Engg.) KIT's College Of Engineering, Kolhapur. M.E. (Mech-Prod.), B.E. (Indl. Prod.), D.C.P, D.B.M, Phd (Pursuing), Academic Experience 26 Years, Publications – 60.