PRODUCTIVITY IMPROVEMENT BY REDUCTION OF REJECTIONS IN GRID CASTING USING SIX SIGMA METHODOLOGY

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Abstract: *The core and the heart of the battery industry is Grid. This paper discusses about the quality and productivity improvement by reducing the rejections in Grid casting section in one of the Battery manufacturing Multinational companies. The quality improvement would be attained by sigma methodology's DMAIC approach. It depicts reducing rejections in Grids from grid casting machine. Data collection and Pareto analysis indicated the high rejections are due to flashes and wire miss. The root causes are found out by six sigma using Variable search tool and validated by Better Vs Current Tool. By the results of DMAIC, Modifications are carried out in grid casting methodology and the process parameters optimized. This resulted in reducing the rejections from 9.5 % to 2.1 % and average improvement of grid caster's productivity. To confirm whether Six Sigma implementation would be simplified, this paper highlights usage of Shainin DOE instead of Taguchi DOE.*

Keywords: *Six Sigma, DMAIC, Pareto Analysis, Shainin DOE, Variable Search, Better Vs Current Tool.*

1 INTRODUCTION

In recent past, academicians, practitioners and organizational researchers have recognized that the Six-Sigma has a powerful potential to affect an organization's ability to compete within an increasingly global and dynamic market place. The purpose of six sigma is to make customer happier and increase the profit of an organisation by reducing variation. A six sigma process is one in which 99.99966% of all opportunities to produce some feature of a part are statistically expected to be free of defects (3.4 defective features per million opportunities).six sigma is achieved by DMAIC and DMADV methodology. If we want to improve already existing process, we will use DMAIC. If we want to create new product or design new business process, then we use DMADV methodology.

1.1 Six Sigma's Methodology-'DMAIC'

Six sigma's DMAIC methodology, helps in identification and elimination of the root cause of the problem there by improving the quality of the product by better utilisation of resource. The DMAIC involves five phases i.e., Define, Measure, Analyse, Improve and Control. Fig 1 shows the phases in six sigma

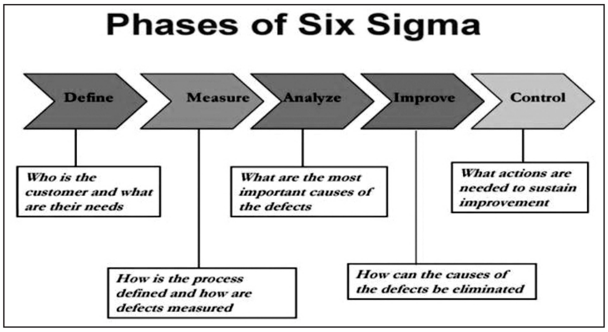


Fig 1. DMAIC Approach

2 EXPERIMENTAL WORK

2.1 Define Phase

Define phase involves: a) identifying and understanding the problem and its impact on the business b) Customer's voice i.e., identifying their needs and project expectations C) Setting up the project goals

2.1.1 Process flow to show various phases in grid preperation

Grid Casting Section: Here the Grids for the Battery are produced from Grid Casting machine. The CPM (casts per minute) varies from machine to machine.

The Fig 2 illustrates the sequential process flow of grid casting. It includes each step required for lead bar transform into grid. Whereas the Lead bar is the input of the process and after completing each step it converts into grid.

The output from the Grid casting machine are grids and is a combination of good and bad Grids.

The bad grids include rejections due to flashes, wire miss, cross cut, improper lead filling etc.,

2.1.2 Problem Statement: Less production is observed due to more rejections in 5AH positive model grids in machine 10 because of Flashes and Wire miss

Machine wise Rejections and Analysis:

From the Pareto analysis as shown in Fig 3, it is found that the major rejections are found in 5AH positive model grids. This model runs in 10th machine. Hence it is considered for the work.

Software Used: MINITAB 15

Tool Used: Pareto Analysis

Analysis of Historical Data

First Level of Stratification:

From the Past 3 months live experimental data analysis, we found that M10 Machine is Having More Rejections as 5AH +Ve grids are from M10.

Second Level of Stratification from the Past Data:

Fig 4 shows that Flashes and wire miss are the major defects in 5AH positive model grids

From past six months historical data analysis it was found that flashes and Wire misses are having 76.5% contribution in Overall rejections of the Grid casting section.

As the model, machine and type of defects are confirmed, the reason for defects are to be found from concentration chart

2.1.3 Concentration Chart

The defect concentration chart (also problem concentration diagram) is a tool that is useful in analyzing the causes of the product or part defects.

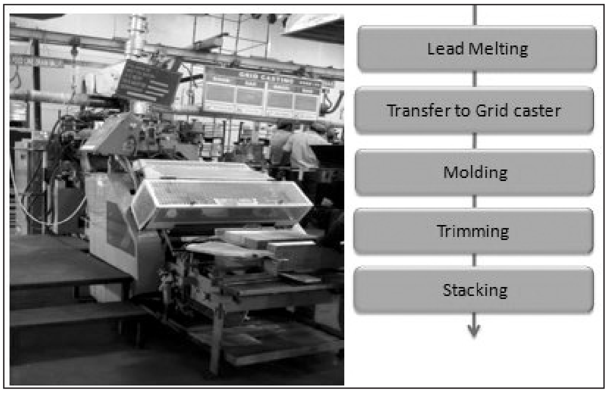


Fig 2. Grid Casting Machine

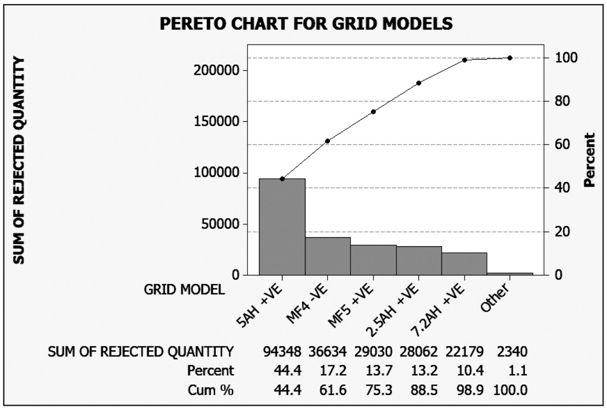


Fig 3. Pareto Analysis for Grid Model

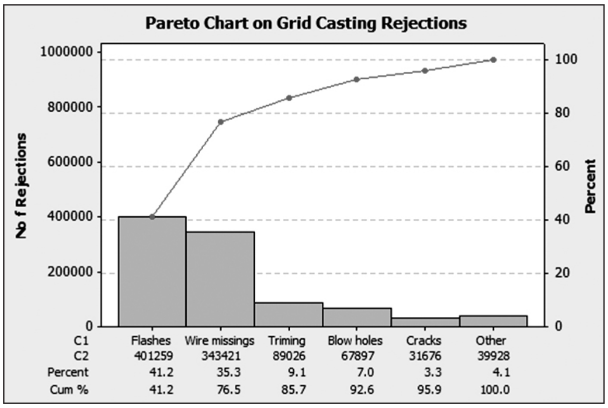


Fig 4. Pareto Analysis for Defect Types

Table 1: Percentage of Zone Wise Rejections for 33 Samples

Rejections	Zone 1	Zone 2	Zone 3
Flashes	42	33	26
Wire miss	57	27	22

Table 2: Process Parameter Audit

Process Parameter	Standard	Observed
Ladle Right	485±25	495
Ladle Left	485±25	496
Lower mould heat Moving	140±25	148
Lower mould heat stationary	140±25	200
Mould gate cooling stationary	150±25	178
Bottom cool moving	140±25	188
Bottom cool stationary	140±25	197
Lug cool stationary	140±25	525
feed line	485±25	525
C.C.S Water Temperature	55-75	58

Table 3: Machine and Tool Audit

Machine/Tool Condition	Standard	Observed
Temperature of the mould	-	Ok
Grid mould k.o pins	Visually	Ok
Mould cylinder	Visually	Ok

Rule: 80% of the problem is need to concentrate in any location

Collected 33 samples – (Standard for any Product, Process)

Identified the locations and found out from Table 1 that the flashes and wire miss are not constrained to any single zone of the Grid. They spread throughout the grid.

Table 4: Grid Thickness and Weight Audit

Inspection Condition	Standard	Observed	Conclusion
Grid Thickness	3.5+/-0.2	3.48	OK
Grid Weight	405+/-20	412	OK
Visual Inspection	Appearance	OK	OK

From concentration chart it is clear that the problem is nowhere concentrated at single location and need to go for identifying the suspected source of variation.

GOAL: To reduce the rejections from 9.5% to 1.5% (80% by six sigma)

2.2 Measure and Analysis Phase

Measuring involves calculating the process capability by running process audit, tool and machine audit, Input material Audit

Analysis involves determining root causes of variation or suspected source of variations.

Selected Machine: Machine -10

Model: 5AH Positive

2.2.1 Process Parameter Audit

Table 2 shows the process parameter audit findings

From the process parameter audit, it was found that some readings related to Ladle and cooling system are out of specification limits

2.2.2 Machine and Tool Audit

Table 3 shows that there is no problem involved in machine all the pins, mould back cylinder were checked and is in order

2.2.3 Grid Thickness and Weight Audit

The Table 4 shows that the grid thickness and weight are with in specification limits

After running the audits it was found that the rejections have fallen from 9.5% to 7.3%. Fig 5 shows the reduced rejections

From the audits, all the parameters are with in specification limits except for CCS and ladle temperatures in most of the trails. Hence suspecting the design parameters i.e., CCS temperature and Ladle temperature. Between these two only one will be having major contribution.

To confirm whether the SSV's (suspected source of variations) we got is correct or not, the following analysis is done

By above settings shown in Table 5, three trail runs were run for each setting separately and analysis was done for + and – settings and found that D/d(D is difference of medians and d is average of ranges) ratio is greater than 3 as shown in Table 6. Generally for a process to be in control, the D/d ratio should lie between 1.25 to 3.But here D/d ratio is greater than 3, which shows that the process is out of control and these two parameters i.e., ccs and ladle temperatures are causing problem is confirmed.

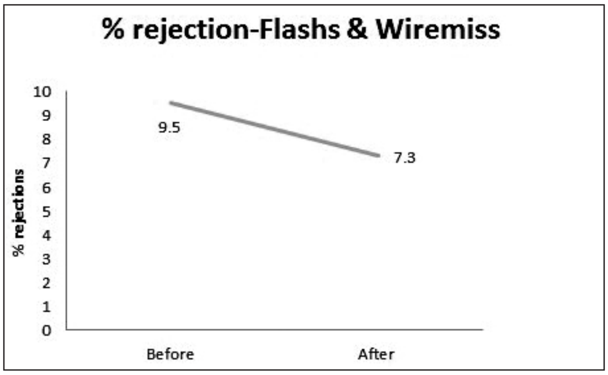


Fig 5. Reduction in Rejections

Table 5: + and – Settings of CCS and Ladle Temperatures

Parameter	Setting	+ setting
CCS temperature	55	60
Ladle temperature	485	495

Hence as explained above, it is confirmed that our suspected source of variations (SSV's) are correct and they are the cause for rejections

2.2.4 Identifying the Optimized Parameter

Tool Used: Variable search (Variable Search is a Tool from Shainin DOE)

To know whether the CCS temperature or the Ladle temperature is having major impact on the grid's flash and wire miss rejections variable search shainin DOE is used

According to that we have to find RED X (major contribution for defects) by swapping the + & - settings readings as shown in Table 7. Here the CCS temperature settings are swapped and trails are run

By the settings as shown in Table 7, trails were run and percentage of rejections noted in table 8. In table 8, first, second and third run are trails by

Table 6: D/d Ratio for Current Settings

	-setting	+setting
Trail1	4.7	1.8
Trail2	5.3	2.1
Trail3	5.1	2.4
Median	5.1	2.1
Range	0.6	0.6
D(medians difference)	3	
d(average of ranges)	0.6	
D/d ratio	4.9	

Table 7: Swapped + and – settings of CCS Temperature

Parameter	-Setting	+ setting
CCS temperature	60	55
Ladle temperature	485	495

Table 8: Trail Runs by Swapping CCS Temperature

	-setting	+setting	Average	UDL(+)	LDL(+)	UDL(-)	LDL(-)
First Run	4.7	1.8	3.6	3.0	1.2	6.0	4.2
Second Run	5.3	2.1	3.6	3.0	1.2	6.0	4.2
Third Run	5.1	2.4	3.6	3.0	1.2	6.0	4.2
CCS Temperature	2.3	5.9	3.6	3.0	1.2	6.0	4.2

settings in Table 5(actual settings).ccs temperature denotes trails by Table 7

Table 8 shows trails and percentage rejections by swapping CCS temperature

The formulae to calculate UDL and LDL values are

UDL(+) =MEDIAN (+) +1.45*d

LDL(+) =MEDIAN (+) -1.45*d

UDL(-) =MEDIAN (-) +1.45*d

LDL(-) =MEDIAN (-) -1.45*d

The graph is plotted for percentage rejections in table 8 as shown in Fig 6

The Fig 6 shows that all the readings are with in deviation limits except for the reading for which we have swapped the ccs temperature according to Shainin Red X concept i.e., A(+)R(-).

Hence from the above Fig 6 it is found that CCS temperature is contributing for major rejections and it is confirmed the major root cause of the problem

So we have to find the new specifications for ccs temperature to reduce rejections

2.2.5 Finding the New Specifications For CCS Temperature

The – and + settings readings from table 8 are noted in Table 9

By factorial table analysis,

Table 9 shows + and – settings readings and their medians

Make a simple mathematical equation based on the contribution of significant parameters and arrive at the optimal setting

Contribution of

A= Difference of A(-) to A(+) = -3

C= Average of medians= 3.65

For one variable, we know that Y= mx+C

Here y is the response and C is the deviation

0=c-1/2 Ax contribution of A

0=3.65+(-1.5A)

1.5A=3.65

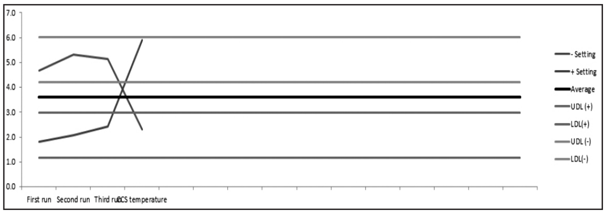


Fig 6. Graph for Percentage Rejections Table 8

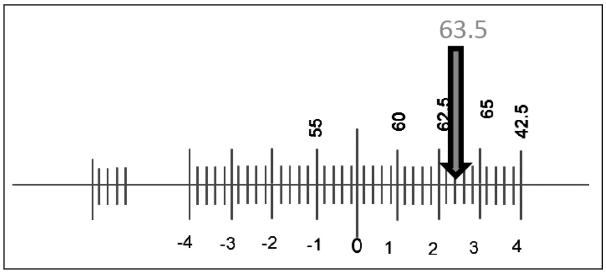
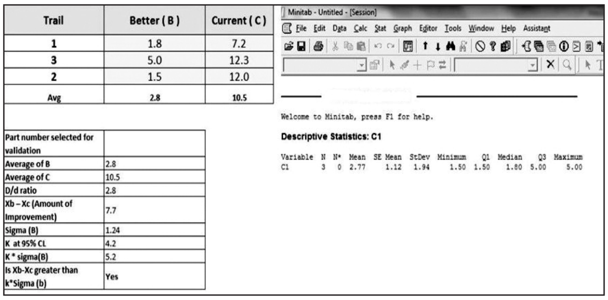


Fig 7. Decoding of CCS Temperature



Trail	Better (B)	Current (C)
1	1.8	7.2
3	5.0	12.3
2	1.5	12.0
Avg	2.8	10.5

Part number selected for validation	
Average of B	2.8
Average of C	10.5
D/d ratio	2.8
Xb – Xc (Amount of Improvement)	7.7
Sigma (B)	1.24
K at 95% CL	4.2
K * sigma(B)	5.2
Is Xb-Xc greater than k*Sigma (b)	Yes

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Descriptive Statistics: C1

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
C1	3	0	2.77	1.12	1.94	1.50	1.50	1.80	5.00	5.00

Fig 8. B Vs C analysis by Mini Tab

Table 9: Factorial Table

Setting	Response	Median
-ve	5.9,4.7,5.3,5.1	5.2
+ve	2.3,1.8,2.1,2.4	2.2

Table 10: D/d Ratio for New Settings

	-setting	+setting
Trail1	7.2	1.8
Trail2	12.3	5.0
Trail3	12.0	1.5
Median	12	2.8
Range	5.1	3.5
D(medians difference)	9.2	
d(average of ranges)	4.3	
D/d ratio	2.1	

A=2.4

Now we got the new specification as 2.4

Table 11: Variation Analysis

Variation Analysis						
Plant					Time from	15:30
Section	Grid casting				Time to	17:13
M/C No			Temp.	Set point		
			CCS	63		
			Ladle	495		

Time	CCS Temp.	Ladle Temp.	Production	Flashes	Wire miss	Remarks
15:35	63	495	10	_	_	
15:37	59	493	20	_	_	
15:39	58	496	20	_	_	
15:41	59	493	20	_	_	
15:43	60	498	20	_	_	
15:45	60	495	20	_	_	
15:47	60	493	20	_	_	
15:49	62	493	20	_	_	
15:51	62	493	20	_	_	
15:53	62	495	20	_	_	
15:55	63	497				
15:57	63	496	53	_	7	Shinkage- 17nos.
15:59	63	495				
16:01	64	496	20	_	_	
16:03	64	497	20	_	_	
16:05	65	497	20	_	_	
16:07	65	492	20	_	_	
16:09	65	493	16	_	4	
16:11	65	497	25	10	7	water OFF16:12to16:30
16:13	65	494				Shinkage-8nos.
16:35	61	496	12	8	_	
16:37	62	498	20	_	_	
16:39	62	491	20	_	_	
16:41	63	495	20	_	_	
16:43	63	492	20	_	_	
16:45	63	491	20	_	_	
16:47	63	494	20	_	_	
16:49	64	496	20	_	_	
16:51	64	499	15	1	4	
16:53	65	495	20	_	_	
16:55	65	492	20	_	_	
16:57	65	493	20	_	_	
16:59	65	494	15	_	5	
17:01	66	493	19	_	1	
17:03	66	492	20	_	_	
17:05	66	494	19	_	1	
17:07	66	491	20	_	_	
17:09	66	496	18	_	2	
17:11	66	495	15	_	5	
17:13	66	496	20	_	_	
17:15					_	
Min	58	491	10			
Max	66	499	53			
Avg	63	495	20			
	8	8	43			
Spec	58	490				
	66	500				

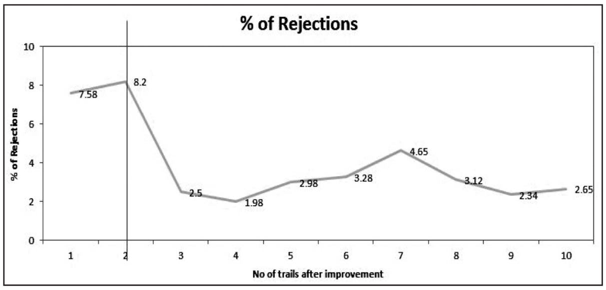

Fig 9. Overall Reduction in Rejections

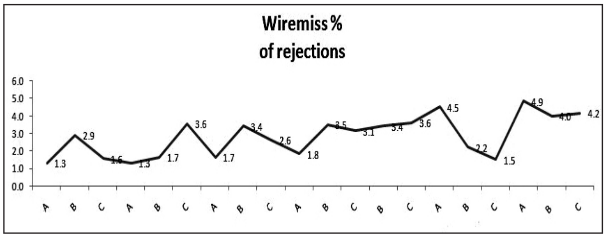

Fig 10. Reduction in Wire miss %

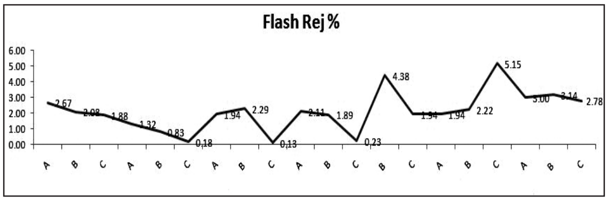

Fig 11. Reduction in Flashes %

By decoding it, we get the decoded temperature as 63.5 as shown in Fig 7

Based on the above decoding, the new specification of CCS temperature is found as

63 +/- 5 degrees

2.2.6 Better Vs Current Analysis

After finding the new specification, three trails were run by old and new specifications and analyzed in mini tab as follows

Fig 8 shows the Better vs Current analysis in mini tab. Better denotes percentage of rejections by new specification, current denotes percentage of rejections by old specification. From Fig 8 it is evident that

X_b-X_c(amount of improvement) is greater than k*sigma value which is the sign of improvement in rejections according to B vs C analysis

2.3 Improvements

After finding the new specifications for CCS temperature, to confirm whether process is in control or not, again the D/d ratio is found as shown in Table 10 and found that D/d ratio is 2.1 which lies between 1.25 and 3 which confirms that now process is in control and improved.

Also some improvements are carried out in the machine such as,

- A solenoid valve indicator is provided for the easy monitoring of circulation of water in the pipes for operator to avoid variation in process
- An alarm is introduced at CCS for the awareness of operator when there is change in ccs temperature to avoid defects

2.4 Control

Trails were run by new specification and tabulated in Table 11 and found that flashes and wire miss were nullified

2.4.1 Trails Runs by New Specification

After implementation of Modifications in Equipment, Optimization of the Process Parameters & Change in Methodology of operations, the Rejections are reduced from 9.5 % to 2.1%

3. RESULTS AND DISCUSSION

Six Sigma is an effective way to find out where the greatest process needs are and which the softest points of the process are. Also, Six Sigma provides measurable indicators and adequate data for analytical analysis. Systematic application of Six Sigma DMAIC tools and methodology in any field, yields greater profitability.

3.1 Reduction in Rejections Trend

After finding the new specification, by setting it the trend of overall rejections was observed for days and plotted as shown below

The Fig. 9 shows the reduction in rejection trend of grids.

After finding new specifications by trail runs, wire miss and flash trend is shown in Fig. 10 and Fig. 11.

The above Figures shows the reduction in flashes and wire miss % at various shifts A, B, C.

3.1.1 Benefits

Tangible benefits:

- Projected annual savings before the start of the project is : 0.228 Million
- Actual savings realized now is: 0.222 Million

Intangible Benefits:

- Operator fatigue Reduction
- Reduction & Elimination of NVA activities
- Transportation of Rejected grids
- Movement of operator
- Extra Processing
- Time of Operator on Segregation of Rejected grids

4. CONCLUSION

- Operational Six Sigma methodology was selected to solve the rejection problem in grid casting process in one of the battery manufacturing company. On implementation, it provided a real time monitoring system by which the root causes were identified and eliminated, by proper analysis.
- Six Sigma via, DMAIC project shows that the performance of the company is increased to a better level as regards to: enhancement in customers' (both internal and external) satisfaction, adherence of delivery schedules, development of specific methods to redesign and reorganize a process with a view to reduce or eliminate errors, defects; development of more efficient, capable, reliable and consistent manufacturing process and more better overall process performance, creation of continuous improvement and "do it right the first time" mind set.
- Six Sigma provides business leaders and executives with the strategy, methods, tools and techniques to change their organizations. Six Sigma as a powerful business strategy has been well recognized as an imperative for achieving and sustaining operational (process) effectiveness, producing significant savings to the bottom line and thereby achieving organizational excellence. If implemented properly with total commitment and focus, Six Sigma can put industries at the forefront of the global competition.

REFERENCES

a) Journals

1. Bewoor, Anand K; Pawar, Marut S: Use of shainin tools for simplifying six sigma implementation in qms/iso certified environment – An indian sme case study, 'Journal of Engineering Research and Studies', vol. 1, no. 2, Oct - Dec, 2010, 177-194.
2. Kabir, Md. Enamul; Boby, S M Mahbubul Islam; Lutfi, Mostafa: Productivity Improvement by using Six-Sigma, 'International Journal of Engineering and Technology', vol. 3 no. 12, December, 2013.
3. Valles, Adan; Sanchez, Jaime; Noriega, Salvador; Nuñez, Berenice Gómez: Implementation of Six Sigma in a Manufacturing Process A Case Study, 'International journal of industrial engineering', vol. 16, no. 3, 2009, 171-181.
4. Pugnaa, Adrian; Negrea, Romeo; Miclea, Serban: Using Six Sigma Methodology to Improve the Assembly Process in an Automotive Company, 'Procedia - Social and Behavioral Sciences', vol. 221, 2016, 308 - 316,
5. Srinivasan, K; Muthu, S; Prasad, NK; Satheesh, G: Reduction of paint line defects in shock absorber through Six Sigma DMAIC phases, 'Procedia Engineering', vol. 97, 2014, 1755 - 1764 ,
6. Ledolter, J; Swersey: Dorian Shainin's Variables Search Procedure: A Critical Assessment, 'Journal of Quality Technology', vol. 29, no. 3, 1997, 237-247.

b) Books

1. Montgomery DC: Hand book of Design and Analysis of Experiments, 5th Edition, John Wiley and Sons, New York, 2001.
2. Gitlow, Howard S: A guide to lean six sigma Management, 2nd edition, 2009.
3. Pyzdek, Thomas: The Six sigma Handbook: (A complete guide for six sigma Green belts and Black belt's), 4th edition, 2014 ◘

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The topics on various aspects of manufacturing technology can be discussed in term of concepts, state of the art, research, standards, implementations, running experiments, applications, and industrial case studies.

Authors from both research and industry contributions are invited to submit complete unpublished papers, which are not under review in any other conference or journal.

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