A Comparative Analysis of Taguchi Methodology and Shainin System DoE in the Optimization of Injection Molding Process Parameters

Rajendra Khavekar1, Dr. Hari Vasudevan2, Bhavik Modi3
1Training & Placement Officer, D. J. Sanghvi College of Engineering, Mumbai, India
2Principal, D. J. Sanghvi College of Engineering, Mumbai, India
3PG Student Department of Mechanical Engineering, D. J. Sanghvi College of Engineering, Mumbai, India
Email:khrajendra@rediffmail.com, principal@djsce.ac.in, mba27mba@gmail.com

Abstract: Two well-known Design of Experiments (DoE) methodologies, such as Taguchi Methods (TM) and Shainin Systems (SS) are compared and analyzed in this study through their implementation in a plastic injection molding unit. Experiments were performed at a perfume bottle cap manufacturing company (made by acrylic material) using TM and SS to find out the root cause of defects and to optimize the process parameters for minimum rejection. Experiments obtained the rejection rate to be 8.57% from 40% (approx.) during trial runs, which is quite low, representing successful implementation of these DoE methods. The comparison showed that both methodologies gave same set of variables as critical for defect reduction, but with change in their significance order. Also, Taguchi methods require more number of experiments and consume more time compared to the Shainin System. Shainin system is less complicated and is easy to implement, whereas Taguchi methods is statistically more reliable for optimization of process parameters. Finally, experimentations implied that DoE methods are strong and reliable in implementation, as organizations attempt to improve the quality through optimization.

Keywords: ANOVA, Design of Experiments, Shainin Systems, Taguchi Methods

1. INTRODUCTION
Competing and surviving in a highly fluctuating and turbulent industrial environment and at the same time ensuring a good level of customer satisfaction are the dominant challenges faced by manufacturing firms today. DoE is a versatile statistical tool and methodology used in the optimization of product characteristics or process parameters, which helps to achieve higher productivity and better efficiency. It also helps to improve the overall effectiveness of engineers and the manufacturing organization. The overall improvement obtained through the implementation of DoE technique highly depends upon the selection of appropriate methodology, which is suitable to solving the problem in-hand. A successful execution of the DoE technique is also dependent upon the adaptability of a methodology to the specified manufacturing organization. This study compares and analyses the two DoE techniques, such as Taguchi Methodology (TM) and Shainin Systems (SS), when implemented in a Plastic Injection Molding industry for optimization of process parameters to reduce the defect of shrinkage in the acrylic material.

Injection molding process produces polymer products with high rate of production and at a lower cost. Also, it can produce the complex geometry parts with sufficiently high accuracy, good finishing and better quality. It provides for the benefit of reprocessing of material, which helps in reducing scrap and achieves higher material utilization. But on the other side, inappropriate selection of process parameter generates various and high amount of defects like shrinkage, warpage, voids, short shot, sink, etc. It increases the rejection rate and decreases the first pass yield, which leads to lower...
effectiveness and reduced efficiency. This can be solved by some trial and error methods or by using well-established and structured experimentation techniques. A DoE methodology identifies the relation between input and output parameters and thus controls the output of the process. The experiments were conducted using seven parameters at two levels to obtain best set of parameters for minimum shrinkage. Process parameters considered are Injection Temperature, Injection Pressure, Packing Pressure, Injection Speed, Packing Time, Injection Time and Cooling Time.

2. Literature Review

Jeroen De Mast (2004) compared three quality improvement strategies, with the purpose of providing an aid to practitioners for assessment of strategy and to select a better motivated choice among them. He concluded that Shainin System focuses on identification of root cause of the problem and other two, namely Taguchi Methodology and Six Sigma program exploit statistical modeling techniques. A. J. Thomas and J. Antony (2005) in their study compared the operational effectiveness of two DoE techniques to provide a new perspective and to stimulate the use and the development of these statistical methods in industry. They found that Taguchi Method is complicated, costly and less flexible compared to the Shainin System, but it provides a robust process along with critical factors affecting and enhancing the product/process quality. Barıs Aksu and Kasım Baynal (2010) also compared the Shainin System with Taguchi Methods and concluded that TM requires more time, more number of experiments and high cost compared to SS and is more complicated as well. Bhaskara P. et. al (2014) employed a smooth implementation of progressive search principle based SS for solving the quality issues in a Diesel System Plant, following the discipline of FACTUAL approach of SS, where FACTUAL represents sequential steps to find, eliminate and prevent the root cause of rejection i.e. Focus – Approach – Converge – Test – Understand – Apply – Leverage. Logothetis, N (1990) first outlined the approach of DoE by Dr. Genichi Taguchi in view of the need for improvement in quality and reduction in variation from target. Objective, background and Parameter & Tolerance design stages of Taguchi’s methods with their general nomenclature have been explained. Later, the perspective on another DoE method - Shainin’s approach – for quality improvement and control in general were provided, making both the methodologies as widely used DoE tools in manufacturing industries.

3. Problem Definition

Proper selection of optimization techniques according to the problem in-hand helps in achieving higher improvement and better quality. To solve the difficulty in selecting optimization techniques, two DoE techniques are evaluated for defect reduction in a Plastic Injection Molding industry.25,000pcs. of perfume bottle cap were to be manufactured from acrylic material in the plastic injection molding unit. The defects like shrinkage, porosity, distortion and flow marks were observed during the processing of trial runs, with shrinkage to be highest defectives followed by porosity. Discussion with experts clarified that distortion is the effect of shrinkage, whereas flow marks were expected to disappear during regular running, and also the defect percentage of these two were not a serious issue. Brainstorming session and its outcome, the fishbone diagram suggested increase in the air-vents and preheating of material which could help to overcome porosity. After conducting corrective actions based on the brainstorming session and fishbone diagram, the defect of porosity was greatly reduced. Further, shrinkage reduction was essential to improve the process efficiency, for which identification of optimal combination of process parameter along with significant parameter influencing the output (quality) was required.

4. Methodology and Experimentation

Experiments were conducted for optimization of process parameter and the best set of input parameters, considering seven factors with two levels each, which gives minimum shrinkage. Taguchi methodology was used with L_{12} Orthogonal array for designing the experimental study and
then signal to noise ratio is used for analysis of the results obtained, and Variable Search was used from Shainin Systems.

i. **Defining the Objective of the experiment:** The experiments were performed to identify the optimum factor settings to achieve the minimum percentage defective for shrinkage in plastic injection moulding process.

ii. **Selection of quality Characteristics or Response for the Experiment:** The response selected for experiments was percent defective to identify optimum set of combination, considering the problem in-hand as amount of shrinkage was not of concern over the aesthetic look of the product.

\[
\% \text{Defectives} = \frac{\text{No.of defectives parts manufactured}}{\text{Total no.of parts manufactured}}
\]

iii. **Identification of control factors and factor levels:** After conducting the brainstorming session with concerned personnel, following factors were selected for further experimental study and investigation, as given below in Table I.

iv. **Selection of Orthogonal Array design:** For seven factors with two levels of each, L\(_{12}\) OA was selected. Design of experimental Runs is as follows:

v. **Conducting the Experimental Run:** For each experimental run, 35 injection molding shots were observed, producing 70 parts.

vi. **Statistical analyses and results:** From The response value obtained using L\(_{12}\) OA, following steps were followed for result interpretation and analysis.

**Signal To Noise ratio for smaller the better:** Signal to noise ratio for smaller the better is determined as

\[
-\text{SN}_i = -10 \log_{10} \text{mean of sum of squares of measured data} = -10 \log_{10} \frac{\sum_{i=1}^{n} y_{ui}^2}{n}
\]

Where, \(y\) = Response; \(u\) = trial number; \(n\) = number of trials taken for experiment; \(i\) = experiment number. The following Table II gives Results (percent defectives) and Signal to noise ratio along with OA design.

### Table I: Control factors

| Factors            | Description   | High Level | Low Level |
|--------------------|---------------|------------|-----------|
| Injection Temperature | A             | 200        | 185       |
| Injection Pressure     | B             | 140        | 120       |
| Packing Pressure       | C             | 110        | 100       |
| Injection Speed        | D             | 90         | 80        |
| Packing Time           | E             | 2          | 1         |
| Injection Time         | F             | 7          | 6         |
| Cooling Time           | G             | 20         | 15        |

### Table II: Experimental result

| Sr. No | A   | B   | C   | D   | E   | F   | G   | R1   | R2   | SNR   |
|--------|-----|-----|-----|-----|-----|-----|-----|------|------|-------|
| 1      | 185 | 120 | 100 | 80  | 1   | 6   | 15  | 31.43| 28.57| -29.55|     |
| 2      | 185 | 120 | 100 | 80  | 1   | 7   | 20  | 25.71| 28.57| -28.68|     |
| 3      | 185 | 120 | 110 | 90  | 2   | 6   | 15  | 30.00| 34.29| -30.16|     |
| 4      | 185 | 140 | 100 | 90  | 2   | 6   | 20  | 21.43| 18.57| -26.04|     |
| 5      | 185 | 140 | 110 | 80  | 2   | 7   | 15  | 28.57| 27.14| -28.90|     |
| 6      | 185 | 140 | 110 | 90  | 1   | 7   | 20  | 20.00| 18.57| -25.71|     |
| 7      | 200 | 120 | 110 | 90  | 1   | 6   | 20  | 21.43| 22.86| -26.90|     |
| 8      | 200 | 120 | 110 | 80  | 2   | 7   | 20  | 21.43| 17.14| -25.75|     |
| 9      | 200 | 120 | 100 | 90  | 2   | 7   | 15  | 25.71| 28.57| -28.68|     |
| 10     | 200 | 140 | 110 | 80  | 1   | 6   | 15  | 21.43| 22.86| -26.90|     |
| 11     | 200 | 140 | 100 | 90  | 1   | 7   | 15  | 18.57| 17.14| -25.04|     |
| 12     | 200 | 140 | 100 | 80  | 2   | 6   | 20  | 14.29| 15.71| -23.53|     |
The following Table III gives summarized form of previous detailed table with separation of effect of each factor and its level. It is implied from the table that Injection pressure is the most significant factor, followed by cooling time and packing time to be least significant factor for minimizing the defect rate.

**Analysis of Variance:**

Analysis Of Variance (ANOVA) was used to determine the significant factors affecting the response of the process and contribution of each factor causing the variation in the process output. Higher F-Value of a parameter indicates that variation in this process parameter affects the process performance greatly. The results of ANOVA are presented in a Table IV, displaying the values of sum of squared deviation, mean of square, F-Value and P-Value. P-Value less than 0.05 indicate that the factor is significant at 95% confidence level.

The ANOVA table IV indicates that Injection Temperature, Injection Pressure and Cooling Time are significant factors for variation in process output. It also indicates packing time and Injection time as least significant for the variation in the process.

**vii. Confirmatory run and Validation:** Optimum Settings obtained from the Taguchi Analysis using Main Effect Plots for S/N Ratio: Smaller-the-Better are given below in Table V and plotted in fig. 1.

| Level | A     | B     | C     | D     | E     | F     | G     |
|-------|-------|-------|-------|-------|-------|-------|-------|
| 1     | -28.18| -28.29| -26.92| -27.22| -27.13| -27.18| -28.21|
| 2     | -26.14| -26.02| -27.39| -27.09| -27.18| -27.13| -26.11|

| Rank  | 3     | 1     | 4     | 5     | 7     | 6     | 2     |

### Table IV: Analysis of Variance for SN ratios (Through MiniTab17)

| Source | DF | Seq SS | Adj SS | Adj MS | F – Value | p (%) | P-Value |
|--------|----|--------|--------|--------|-----------|-------|---------|
| I T    | 1  | 12.436 | 12.436 | 12.436 | 13.68     | 27.33 | 0.021   |
| I P    | 1  | 15.441 | 15.441 | 15.441 | 16.98     | 33.93 | 0.015   |
| P P    | 1  | 0.659  | 0.659  | 0.659  | 0.73      | 1.45  | 0.442   |
| P S    | 1  | 0.051  | 0.051  | 0.051  | 0.06      | 0.934 | 0.824   |
| I T    | 1  | 0.006  | 0.006  | 0.006  | 0.01      | 0.0001| 0.939   |
| I T    | 1  | 0.009  | 0.009  | 0.009  | 0.01      | 0.0001| 0.926   |
| C T    | 1  | 13.260 | 13.260 | 13.260 | 14.58     | 32.63 | 0.019   |
| Residual Error | 4  | 3.637  | 3.637  | 0.9093 |
| Total  | 11 | 45.501 |        |        |

![Normal Probability Plot](Image1)

![Main Effect Plot for SN ratios](Image2)

**Figure 1:** Normal probability and main effect plot.
Table V: Taguchi Analysis

| A   | B    | C    | D   | E   | F   | G   |
|-----|------|------|-----|-----|-----|-----|
| 200 | 140  | 100  | 80  | 1   | 7   | 20  |

**Variable Search Results:**

**Stage I: Ball Park:**
During the ball-park stage of variable search, six experiments were conducted. Three runs are conducted with all factors having high level and three with low level. Results of the same are produced in the following table.

1. **Defining the Green Y. i.e. Response or Output of the experiments:** Output of the system is % defectives, same as in Taguchi Methodology.

2. **Selection of the variables and Best and Marginal Levels of each factor or variable in the experiments:** Selected factors and their order according to the importance are shown along with their best and marginal level in the following Table VI.

3. **Early and quick evaluation of trends:** To identify the trends of the process initially, three pair of experiments are conducted with all factors with their best levels and marginal levels and are given in Table VII.

4. **Replication and tests of significance:** Test of significance is conducted based on upper control limits and lower control limits.

LCL and UCL for further experiments:

LCL: 23.427 – 36.573,  UCL: 10.567 – 23.713

**Stage II: Separation of important and unimportant factors:** Following Table VIII gives the results obtained during the running of a pair of tests with marginal level of highly suspected variable and rest all variables at Best level and vice versa. Similar sequence is followed for rest of 6 suspected variables. Also, it gives the result for capping run if needed and performed.

**Stage III: Capping Run:**
It is the validation of the second stage, initially two factors, Injection Temperature and Injection Pressure are found to be important. But during 1st capping run (5th and 6th experiments), it was found that these factors are important, but with other factors, since complete reversal was not observed. Finally, after 15th and 16th experiments, Cooling Time was also resulted as an important factor and then the capping run there after (with three factors) was found to be successful with complete reversal of output. Outcome of the capping run is, three significant factors (Injection temperature, Injection Pressure and Cooling Time), Red X, Pink X, Pale Pink X - affecting the response of the experiments significantly.

**Stage IV: Factorial Analysis:**
It is full factorial experimentation, where no experiments need to be conducted. Results obtained in

Table VI: Parameters for Shainin System for variable search

| Factor Code | Factor Description | Factor Level |
|-------------|--------------------|--------------|
|             |                    | Best | Marginal |
| A           | Injection Temperature | 200  | 185      |
| B           | Injection Pressure  | 140  | 120      |
| C           | Packing Pressure    | 100  | 110      |
| D           | Injection Speed     | 80   | 90       |
| E           | Packing Time        | 1    | 2        |
| F           | Injection Time      | 7    | 6        |
| G           | Cooling Time        | 20   | 15       |
Table VII: Result of Shainin System

| Stage | All Best Levels | All Marginal Levels |
|-------|-----------------|---------------------|
|       | No. of defective | % defective | No. of defective | % defectives |
| Initial Reading | 12 | 17.14 | 23 | 32.857 |
| 1<sup>st</sup> Replication | 14 | 20 | 21 | 30 |
| 2<sup>nd</sup> Replication | 11 | 15.714 | 20 | 28.571 |

the previous three stages are used to quantify the main and interaction effect of significant factors. This stage is applicable after suspected sources of variation have filtered out to 2 - 4 variables from 5 - 20 variables. Full factorial table for three significant factors – Injection Temperature, Injection Pressure and Cooling Time – is as given in Table IX.

Following Table X gives the separate effect of each factor and each level in the summarized form. From this table X, it is clearly identified that the Cooling Time is the most significant factor i.e. Red X for high rate of defectives, followed by Injection Temperature – Pink X – and Injection Pressure – Pale Pink X.

Confirmatory runs were followed to validate the optimum setting obtained. The result for the same is as given in Table XI. Taguchi Method indicates that out of 7 important factors considered - Injection Pressure, Cooling Time and Injection Temperature- are most effective and important factors. Confirmatory run validates the result and optimum settings given by Taguchi methodology and Shainin Systems reduces the Defect rate and hence the Rejection.

Table VIII: Result of Shainin System for separation of factors

| Test | Combination | No. of Defectives | Results | Conclusion |
|------|-------------|-------------------|---------|------------|
| 1    | A<sub>M</sub> R<sub>B</sub> | 18 | 25.71 | A is Important |
| 2    | A<sub>B</sub> R<sub>M</sub> | 26 | 37.14 | A is Important |
| 3    | B<sub>M</sub> R<sub>B</sub> | 17 | 24.28 | B is Important |
| 4    | B<sub>B</sub> R<sub>M</sub> | 27 | 38.57 | B is Important |
| 5    | A<sub>M</sub> B<sub>M</sub> R<sub>B</sub> | 18 | 25.71 | A and B are important with another factor* |
| 6    | A<sub>B</sub> B<sub>B</sub> R<sub>M</sub> | 16 | 22.85 | A and B are important with another factor* |
| 7    | C<sub>M</sub> R<sub>B</sub> | 10 | 14.28 | C is unimportant |
| 8    | C<sub>B</sub> R<sub>M</sub> | 23 | 32.85 | C is unimportant |
| 9    | D<sub>M</sub> R<sub>B</sub> | 9 | 12.85 | D is unimportant |
| 10   | D<sub>B</sub> R<sub>M</sub> | 24 | 34.28 | D is unimportant |
| 11   | E<sub>M</sub> R<sub>B</sub> | 8 | 11.42 | E is unimportant |
| 12   | E<sub>B</sub> R<sub>M</sub> | 24 | 34.28 | E is unimportant |
| 13   | F<sub>M</sub> R<sub>B</sub> | 9 | 12.85 | F is unimportant |
| 14   | F<sub>B</sub> R<sub>M</sub> | 23 | 32.85 | F is unimportant |
| 15   | G<sub>M</sub> R<sub>B</sub> | 18 | 25.71 | G is important |
| 16   | G<sub>B</sub> R<sub>M</sub> | 25 | 35.71 | G is unimportant |
| 17   | A<sub>M</sub> B<sub>M</sub> G<sub>M</sub> R<sub>B</sub> | 25 | 35.71 | Capping Run is successful |
| 18   | A<sub>B</sub> B<sub>G</sub> G<sub>B</sub> R<sub>M</sub> | 7 | 10.00 | |

* Experiment 5 and 6 shows that I T and I P are important factors, but they do not show the complete reversal of the response and hence some other factor must be important. In general, as the results of 5 and 6 are outside the control limits, Capping Run is successful. # Best cooling time (CT) results are unimportant with marginal set of lower control limits, but is important and significant as it shows results out of control for upper control limits.
Table IX: Result of the full factorial analysis

| Sr. No. | I T | I P | C T | Response |
|---------|-----|-----|-----|----------|
| 1       | 1   | 1   | 1   | 14.28    |
| 2       | 1   | 1   | 2   | 30.71    |
| 3       | 1   | 2   | 1   | 38.57    |
| 4       | 1   | 2   | 2   | 25.71    |
| 5       | 2   | 1   | 1   | 37.14    |
| 6       | 2   | 1   | 2   | 24.28    |
| 7       | 2   | 2   | 1   | 24.28    |
| 8       | 2   | 2   | 2   | 32.67    |

5. COMPARISON AND CONCLUSION

From the experiments conducted, it is concluded that:

1. Both the DoE techniques have given almost the same results, the only difference lying with their order of importance as given below in table XII.

2. Injection pressure is the most significant factor influencing the % defectives according to Taguchi methodology, whereas Cooling Time is the most significant factor according to Shainin System.

3. Experiments obtained the rejection rate of 8.57% from 40% (appx.) during trial runs, which is quiet low, representing successful implementation of DoE methods.

4. Taguchi methods require more number of experiments and consume more time as compared to Shainin System.

5. Shainin System is less complicated and easy to implement, but Taguchi methods is more accurate and reliable statistically for optimization of process parameters.

6. Shainin System has individual techniques at each phase of the experiment applicable as required for each individual goal. It gives a comprehensive DoE technique, ranging from clue generating to freezing and monitoring the gains achieved in day to day production, whereas, Taguchi methodology seems to be little weak in this phase.

7. Taguchi method has a statistically sound and reliable base for process and product performance optimization, through the Orthogonal Array.

Table X: Ranking of factors

| Level | I T   | I P   | C T   |
|-------|------|------|------|
| 1     | 31.915 | 31.2 | 33.165 |
| 2     | 24.995 | 25.71 | 23.75   |
| Delta | 6.92  | 5.49 | 9.42   |
| Rank  | 2     | 3    | 1      |

Table XI: Result of confirmatory test

| Set No. | No. of Pieces Produced | No. of Defectives Observed | % Rejection |
|---------|------------------------|----------------------------|------------|
| 1       | 70                     | 6                          | 8.57       |
| 2       | 70                     | 6                          | 8.57       |
| 3       | 70                     | 5                          | 7.14       |
| 4       | 70                     | 6                          | 8.57       |
| 5       | 70                     | 7                          | 10.00      |
| Total   | 350                    | 30                         | 8.57       |

Table XII: Result of both methods

| No. | Taguchi Methodology  | Shainin System    |
|-----|----------------------|-------------------|
| 1   | Injection Pressure   | Cooling Time      |
| 2   | Cooling Time         | Injection Temperature |
| 3   | Injection Temperature| Injection Pressure |
Hence, for optimization of the process and quality level along with reduced % defective and variation in the process, it is essential to control all the three factors reasonably. The comparison between both DoE techniques is summarized as follows in Table XIII.

| Comparison criterion | Taguchi Methodology | Shainin System |
|----------------------|---------------------|----------------|
| No. of experiments   | High (24 experiments, L_{12} OA replicated twice) | Low (21 experiments) |
| Statistical Reliability | High | Moderate |
| Improvement Pattern | Focuses on Robust Design, to bring the process mean on target and to control the variation. | Focuses on finding the root cause of variation and optimum tolerance for significant factor. |
| Time taken | High | Low |
| Complexity | High (MINITAB reduces complicated analysis) | Low |

6. REFERENCES

[1] A J Thomas and J Antony “A comparative analysis of the Taguchi and Shainin DoE techniques in an aerospace environment” International journal of productivity and performance management, 2005, Vol. 54 No. 8, 658 – 678
[2] Aksu, B. and Baynal, K., “Shainin and Taguchi Methods and their comparison on an application” International symposium on Computing in Science and Engineering, 2010.
[3] Antony J, “ Spotting the key variables using Shainin’s Variable search technique”, Journal of logistic and Information management, Vol. 12 No. 4, 325 – 331, 1999
[4] Bhaskara P, Raghuveer Prasad, K M Subbaiah, and G L Shekar, “Root cause analysis of control rod friction problem in DFIP using Shainin Approach” International Journal Of Mechanical Engineering And Technology (IJMET), Volume 5, Issue 9, September (2014), pp. 200-205, ISSN 0976 – 6340
[5] Harshal P Kale, Dr. Umesh V Hambire, “ Optimization of Injection Molding Process parameter for reducing shrinkage by using high density Polyethylene (HDPE) material”, International Journal of Science and Research (IJSR), Vol. 04, Issue 05, 722 – 725, May 2015
[6] Jeroen De Mast, “A methodological comparison of three strategies for quality improvement” International journal of Quality and Reliability Management, Vol. 21, No. 2, 2004, 198-213
[7] Keki R. Bhote, Adi K. Bhote “World Class Quality – Using design of experiments to make it happen” American management association, 2000 ISBN 0 – 8144 – 0427 – 8
[8] Mirigul Altan “Reducing Shrinkage in Injection Molding via the Taguchi, ANOVA and Neural Network Methods” Materials and Design 31 (2010) p. 599-604
[9] Mohd. Muktar Alam, Deepak Kumar “Reducing Shrinkage in Plastic Injection Moulding using Taguchi Method in Tata Magic Head Light” International Journal of Science and Research (IJSR), India
[10] N. Logothetis, “A Perspective on Shainin’s Approach to Experimental Design for Quality Improvement” Quality and Reliability Engineering International.vol. 6. 195-202 (1990)
[11] Nagaraja Reddy K M, Dr. Y S Varadarajan, and Raghuvpeer Prasad “Quality Improvement during Camshaft Keyway Tightening using Shainin Approach” International Journal of Scientific and Research Publications, Volume 4, Issue 7, July 2014 ISSN 2250-3153
[12] Ng Chin Fei, Nik Mizamzul Mehat, and Shahrul Kamaruddin, “Practical Applications of Taguchi Method for Optimization of Processing Parameters for Plastic Injection Moulding: A Retrospective Review”, ISRN Industrial Engineering Volume 2013

[13] Thomas A J and Antony J, : “Applying Shainin’s Variable search methodology in aerospace application”, Journal of assembly automation, Volume 24, Number 2, pp. 184–191, 2004

Prof. Rajendra Khvekar is the Training and Placement officer at D. J. Sanghvi College of Engineering, Mumbai. He has a Master Degree from NIFFT, Hatia, Ranchi. Presently he is pursuing his doctorate degree from the University of Mumbai. His areas of specialization are in Foundry Technology, Forming Technology, Design of Experiments, Materials Technology and Shainin Systems.

Dr. Hari Vasudevan is the Principal of Dwarkadas J. Sanghvi College of Engineering, Mumbai. He has a Doctorate Degree from IIT Bombay, Master’s Degree as well as a Post Graduate Diploma from VJTI, Mumbai and graduate degree from GIT, Karnatak University. He is also a certified ERP Consultant from S.P. Jain Institute of Management & Research, Mumbai under the University Synergy Programme of BaaN Institute, Netherlands. His areas of specialization are in Manufacturing Engineering, Manufacturing Strategy, Market Orientation of Manufacturing Firms and World Class Manufacturing Systems.

Bhavik Modi was born in August of 1988 in Mumbai, India. He received his B.E. in Mechanical Engineering from Walchand Institute of Technology, Solapur University, India in 2011. He is currently a post graduate student at D. J. Sanghvi College of Engineering, Mumbai University, India. He is interested in improving manufacturing systems and its efficiency, optimization of products/processes performance and Design of Experiments.