

# Root Cause Analysis for Volume Flow Rejections of CB18-16 Pump from Functional Testing Station by Shainin Approach

Abhishek S Madival<sup>1</sup>, Ankush Tapare<sup>2</sup>, Dr. Gowri Shankar MC<sup>3</sup>

P.G. Student, Department of Mechanical and Manufacturing Engineering, MIT, Manipal, Karnataka, India<sup>1</sup>

Assistant Manager, BOSCH, Bidadi, Bangalore, Karnataka, India<sup>2</sup>

Associate Professor, Department of Mechanical and Manufacturing Engineering, MIT, Manipal, Karnataka, India<sup>3</sup>

**ABSTRACT:** The major challenge in a manufacturing industry is controlling the quality and production of a product. There are different types of problem-solving techniques used in a manufacturing firm. To achieve quick solution to complex problem simple shainin method is considered as most effective technique. The following study was conducted in BOSCH diesel systems which manufactures diesel fuel injection pumps for automobile applications. This study focuses on identifying the root cause for the rejections occurring in a functional testing station. The root cause analysis was conducted by performing experiments as per shainin approach and the results were updated in the process to reduce the rejections. By the study, shainin technique was found to be the simplest and quickest technique which can be used for resolving complex problems.

**KEYWORDS:** Diesel fuel injection pump, Shainin method, Component search, Root cause analysis.

## I. INTRODUCTION

A diesel fuel injection pump is a frequently used essential component on an automobile or other internal combustion engine device. An injection pump is the device which pumps the fuel into cylinders of an engine at high pressure. Pressurising the fuel helps to atomise the fuel and reduces the emissions from the engine. Traditionally, the injection pumps are driven indirectly from crankshaft by gears chains or toothed belts that also drives the camshaft. It rotates at half crankshaft speed in a conventional 4 stroke diesel engine. Its timing is such that the fuel is injected only slightly before top dead centre of that cylinder's compression stroke. In non-gravity feed designs, fuel must be pumped from the fuel tank to the engine and delivered under low pressure to the carburettor or under high pressure to the fuel injection system. Often, carburetted engines use low pressure mechanical pumps that are mounted outside the fuel tank, whereas fuel injected engines often use electric fuel pumps that are mounted inside the fuel tank Some fuel injected engines have two fuel pumps, one low pressure/high volume supply pump in the tank and one high pressure/low volume pump on or near the engine.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

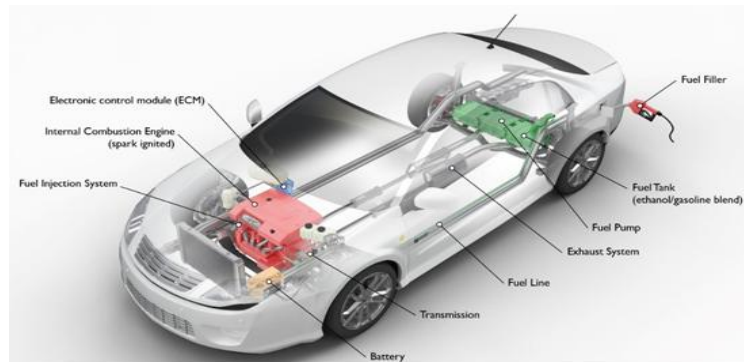


Fig.1. Fuel injection in automobile

### III. PROBLEM DEFINITION

Fuel injection pump consists of different machining and assembly operations where in the child parts of the product get assembled. After subassembly operations the pump will be tested at functional test bench. There were increased rejections of the pump from different test benches. There were different types of rejections occurring at different test points one of the major rejections was volume flow rejections. Volume flow rejections were occurring due to less volume being supplied from the pump. The main aim of the investigation was to reduce the volume flow rejections by root cause analysis using shainin method.

### III. LITERATURE REVIEW

[1] A.K. Verma (2004) et al, in their paper titled, “SHAININ Method: Edge Over Other DOE Technique”, discussed about shainin method. In this paper, three case studies have been discussed to show that how screening test of Shainin method can be applied on the Taguchi’s orthogonal array to assess the adequacy of the experiment. By the study it was found that the Shainin variable search method can be effectively used to find and fix the few important factors as well as its levels by conducting minimum number of experiments in the screening test.

[2] Nagaraja Reddy (2014) et al, in their paper titled, Quality Improvement during Camshaft Keyway Tightening Using Shainin Approach, discussed about the implementation of shainin approach in solving complex problems in manufacturing. The study focuses on resolving rejection of a camshaft. The objective of the work was to identify and eliminate the root cause which is causing camshaft keyway tightening during the assembly process. By the analysis Shainin technique was found to be simple and strong statistical tool to handle problems during manufacturing of components. Changing the cutter size for milling 3mm and 4 mm keyway had resulted in 0% rejection of camshafts due to keyway tight.

[3] Bhaskara (2014) et al, in their paper titled, “Root cause analysis of control rod friction problem in DFIP using shainin approach”, discussed about different factors of shainin approach like RedX, Component search. The study used shainin approach to resolve the rejections occurring during control rod’s dynamic friction check point at functional audit. By the study it was found that the governor cover main spring length variation was found to be causing control rod friction problem. Design optimization in spring length was needed avoid the malfunction event and reduce the rejection rate of FIP at idling condition check point during calibration. The study also concludes that the shainin was found to be simple and efficient statistical tool which can give clue about the most unsuspected design variation.

[4] Abhaysinh (2014) et al, in their paper titled, “Process optimization by using shainin six sigma tools and techniques – a case study in manufacturing industry”, studied optimization of tappet setting defects of water-cooled engine at in

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

process verification through Shainin design of experiment (DOE) and six sigma methodology. Root causes of engine rejection were identified by using shainin system and improvements were identified. Six sigma tools were used to optimize tappet setting defect.

[5] T. Kiatcharoenpol (2017) et al, in their paper titled, Implementation of Shainin's DOE: A Case of Plastic Injection Moulding Process, discussed about Shainin variable Search DOE. In this work, Shainin method was used to study the factors effecting displacement of plastic workpiece in injection moulding process. By the study it was found that Packing time (E), Cooling time (G) and interaction of EG were significant factors. This research also conducted a comparative analysis of Shainin method and Fractional factorial design based on case study of injection moulding process. It was found that the number of trials of Shainin method was 22 times less than fractional factorial design (reduce 65.63 %). The researchers propose Variables Search Method with Shainin was useful in reduce the number of trials.

[6] NitheshNaik (2019) et al, in their paper titled, "Failure analysis of governor in diesel engine using Shainin System™", conducted failure analysis of the governor of the diesel engine by using the shainin system. The component search and better versus current techniques of the SS are used. The step-by-step procedure identified the leading cause of the problem to be associated with the governor springs.

## IV. METHODOLOGY

Increasing reliability in manufacturing a product depends on effectively resolving the problems that arise during functioning of the product. Defect in any part of a component results in failure of the entire product causing a serious problem. In this regard Loss Causation Mode and RCA methods such as Fishbone diagram, Shainin, Why-Why analysis, Failure tree analysis etc. have been very effectively used in the industries. The Shainin- method starts with an assumption that there is one single root cause for the problem - or that this root cause has the largest contribution to the problem. The goal is to find that root cause and understand it. The subsequent solution then can be analysed by the root cause. Shainin system could be effectively used for solving the problems with the theory that there is a dominant cause for variation in the process output that defines the problem. In Shainin RedX is the property or parameter which will be dominating the problem and GreenY is the effect (defect, event) of RedX [7].

## V. APPROCH AND EXPERIMENTATION

The problem-solving methodology Shainin technique follows the order of Focus-Approach-Converge-Test-Understand-Apply-Leverage, which has been discussed in detail in the following sections.

- Focus: Rejections from functional testing station was resulting in loss of productivity. Volume flow rejection was one of the types of rejections from test bench. Initially rejection details from the functional test bench for 3 months were consolidated. It was observed that 1.796% of pumps get rejected in functional testing station for volume flow rejection. The rejected pumps must be reworked and again should pass through test bench.

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

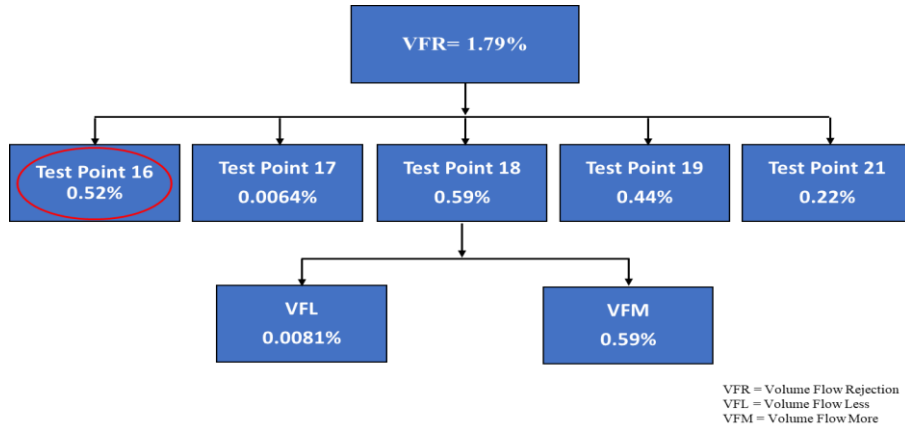


Figure.2. Test Point wise Rejection Tree

Volume flow rejection is observed when the volume of fuel from the HPA is not delivered according to the defined specification. The volume of fuel going out will be measured and displayed in the system monitor any deviation in the volume will be detected by the test program and automatically the testing will be stopped. In test bench at test point 16, 17, 18, 19, 21 volume flows will get measured.

There are two types of volume flow rejections, less (VFL) and more (VFM) volume of fuel being supplied from HPA. 1.2% of pumps fail due to volume flow less (VFL) rejections. Based on the data collected it was found that TP16 had the higher rejections compared to other test point where volume flow is measured.

CB 18 pump has different variety based on the customer requirement. The collected rejection data was consolidated based on the different variety of CB18 pump which were tested in the test bench. By the consolidation of data rejection tree for the variety of CB18 pump was developed and 043 type CB18 pump had a higher rejection rate of 61.39% as shown in the Figure.3.

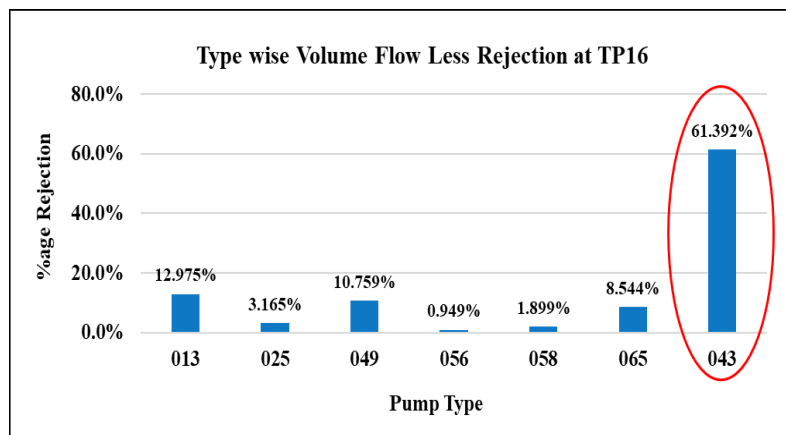


Figure.3. Type wise Volume Flow Rejections at TP16

The focus of the study was to identify and eliminate the root cause (RedX) which was causing the rejections at TP16 due to less volume being supplied from HPA for 043 type of pump.

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

- Approach: The effective utilization of the statistical tool and quickness of the root cause identification relies on the selection of samples with two extreme characteristics, that is WOW (worst of worst) and BOB (best of best). The rejection can be because of any one defective part or might be the combination of two or more parts. The defined GreenY is volume flow less rejections, it is difficult to analyse or use a technique to identify the RedX, since the pump has different sub parts and each part undergoes different operations. Hence, each part must be observed to identify the RedX. This problem could be efficiently handled primarily by doing validation of each sub assembled part by using component search of shainin method. The selection of BOB and WOW were considered based on the histogram graph as shown in Figure.4.

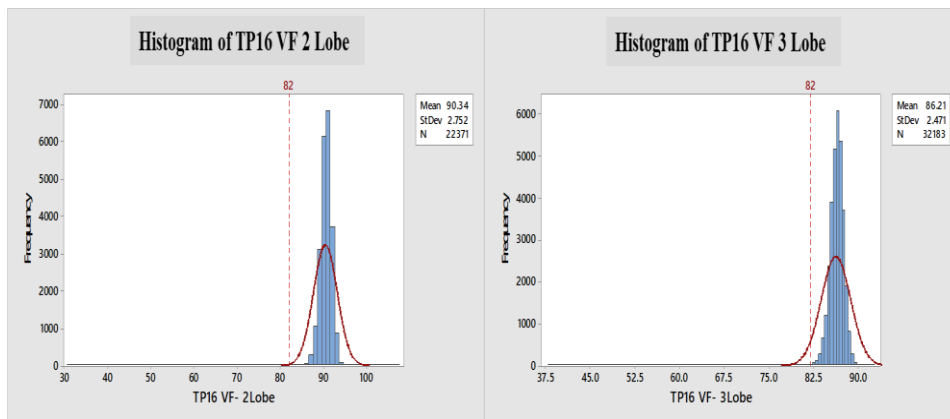


Figure.4. Histogram Charts of Volume Flow at TP16

- Converge: Converging towards RedX causing the GreenY has been achieved by Component search technique. The solution tree in the Figure.5 defines the different parts in the pump assembly which could be reason (RedX) for rejection. This solution tree guides in a right path to find and eliminate the root cause in a short duration.

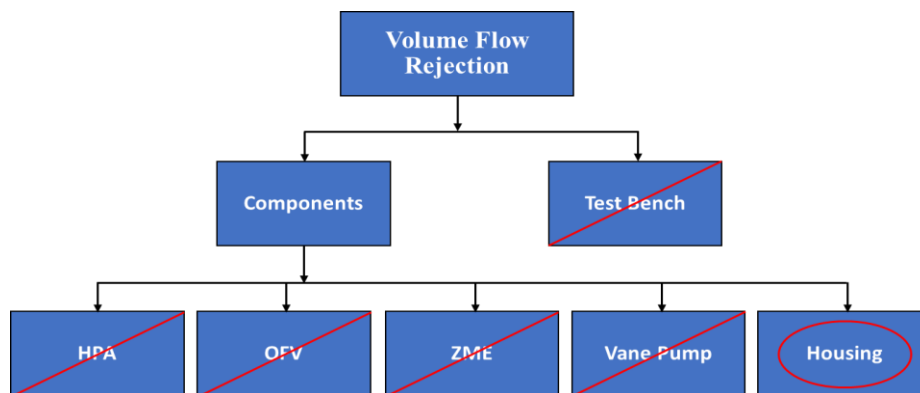


Figure.5. Component Search Trial Components

In order to confirm the process feasibility, at stage zero level of component search the test benches were studied. There were total 5 different individual test benches in the shop floor. In order to understand the contribution of each test bench a bench study was conducted. The rejection data of each test bench for TP16 was considered. By the data it was

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

found that all the test benches had almost equal rejections so, the probability of benches aiding any effect on rejection was eliminated.

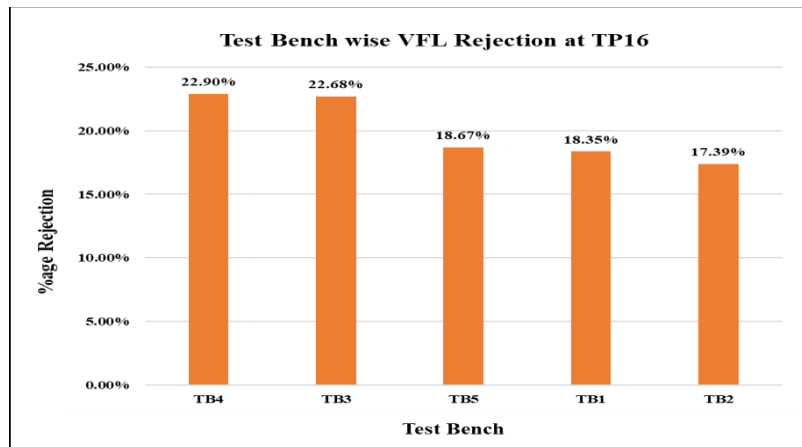


Figure.6. Test Bench Wise VFL Rejection Details

To understand the effect of each component on VFL rejection paired comparison was conducted. At each trial, components were interchanged between BOB and WOW and tested in functional testing station. The difference between the volume flow of BOB and WOW were studied. The details of the trials conducted are shown in Figure.7 Total 4 pairs of BOB and WOW samples were tested by using component search trials. By paired comparison study housing was found to be aiding to the rejection. It was further necessary to understand the defect in pump housing which was resulting in VFL rejections.

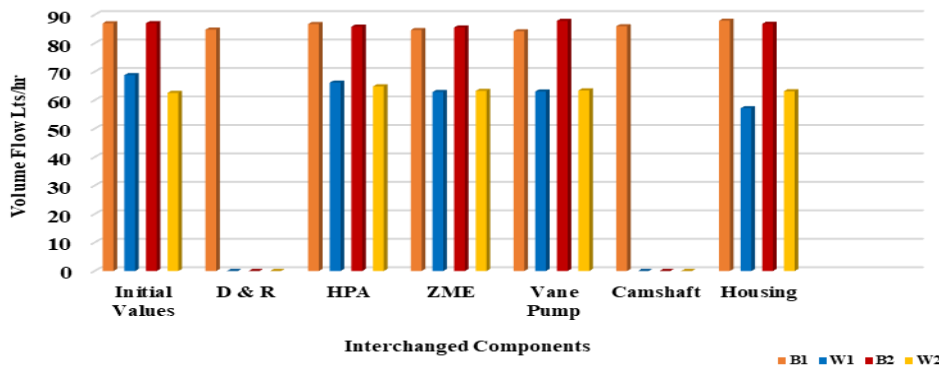


Figure.7. Component Search Trial Values 1

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

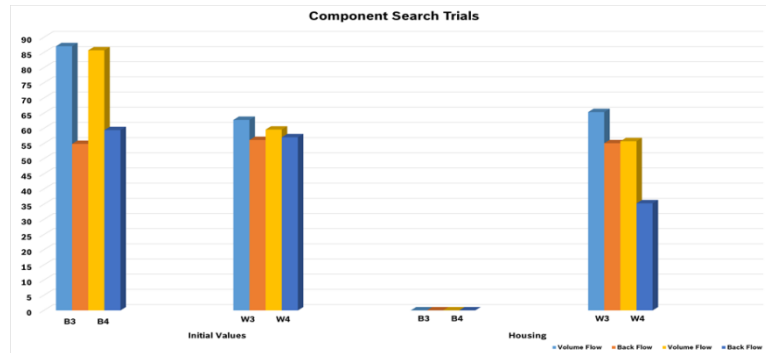


Figure.8. Component Search Trial Values 2

- Test: By the component search trials, the pump housing was found as the culprit for the VFL rejections at TP16. Further to understand the defect in housing different parameters or specifications of pump housing effecting the volume flow were noted. All the specifications were measured and were compared with BOB samples. There was not much contrast found by the comparison. One bore specification (depth of bore) inside the pump from which the excess fuel moves out to OFV was unable get measured since the measuring probe was unable reach the specified bore. By using endoscope equipment, the bore was inspected visually. Both BOB and WOW samples were visually checked by endoscope, variation in the bore depth was clearly visible. The pictures of the bores are shown in the Figure.9.



Orifice pressing depth in BOB



Orifice pressing depth in WOW

Figure.9. Endoscope image of BOB and WOW

One paired sample was cut sectional so that the probe can reach the bore and measure the specified bore. The measured bore depth of BOB sample was 4.15 mm and WOW sample was 11.36mm clearly indicating wide contrast. More than 10 samples which had failed in TP16 as volume rejection were checked using endoscope and all of them had similar defect.



## VI. RESULTS AND DISCUSSIONS

- Understand:** By the investigation it was confirmed that the variation in the depth of specified bore was due to an orifice which gets fitted inside the bore. orifice position was considered as RedX. It was necessary to understand the occurrence of the defect in order to eliminate the issue. When the defined design parameters for orifice pressing was checked, specified position of the orifice inside the bore after pressing was defined to be 18.5 mm from the ball pressed surface, any variation in the orifice position will lead excess fuel flow from HPA to OFV and vane pump thus lacking the fuel quantity inside HPA chamber. The excess fuel from the HPA will pass to OFV and a small amount of fuel will also go to vane pump. Figure.10 shows the flow of excess fuel from HPA, the intersection of these three bores is called as zero-degree point (ZDT). Finally orifice position was considered as RedX.

By the observation from the orifice pressing station, it was found that there was an issue with ball pressing pneumatic system. Whenever there was any interruption in the pneumatic pressure while feeding the orifice an error message would pop up in the system control monitor. When the operator refreshes the system, the orifice pressing operation was skipped and directly ball pressing operation was being carried by default. Since the deviation of position of orifice inside the bore was minimal and operators unaware of the issue these defective pump housings were passed through visual checking.

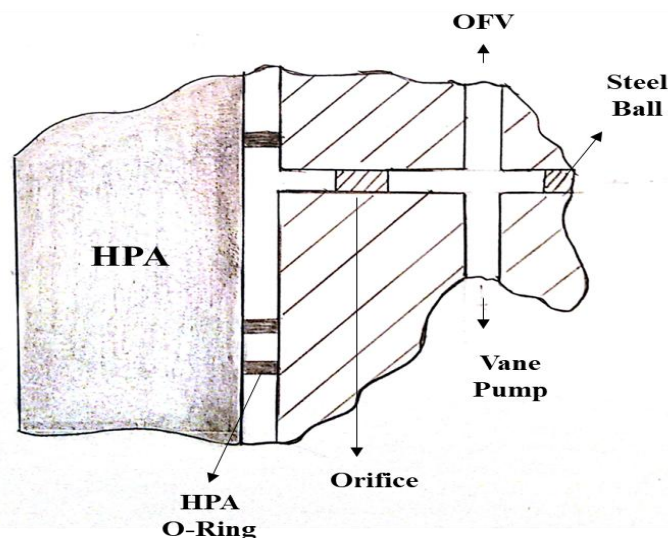


Figure.10. Schematic Representation of Excess Fuel Flow from HPA

- Apply:** It was evident that due to a pneumatic error in the system the orifice was getting mispositioned inside the bore. The pneumatic circuit was then updated to avoid this defect. Whenever the pneumatic error would pop up in display, even after refreshing the system the system was configured to carry the process from the beginning steps i.e. starting from orifice pressing thus the chance of orifice missing pressing operation was completely eliminated.



# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

## VII. CONCLUSION

By using the shainin method of problem solving the reason for the rejection was found to be defective pump housing. Further when the housing block was studied the ball pressing station operation was found faulty. The position of the orifice which gets pressed in ball pressing station was observed to be out of design specification. Due to a pneumatic error, while feeding the orifice to the bore, pressing operation was being not performed and ball pressing operation was skipped. The program was then updated and designed to avoid the skipping of orifice pressing operation. Shainin method was found effective and helped to resolve the issue quickly.

## REFERENCES

- [1] A.K. Verma, A. Srividya, "SHAININ Method: Edge Over Other DOE Techniques", International Engineering Management Conference, Reliability Engineering Group, Indian Institute of Technology, Bombay, 2004.
- [2] Mohamed GamalAboelmaged, Six Sigma quality: a structured review and implications for future research, International Journal of Quality & Reliability Management, Vol. 27 No 3, 2010.
- [3] Nagaraja Reddy, Dr.Varadaraja, "Quality Improvement during Camshaft Keyway Tightening Using Shainin Approach", International Journal of Scientific and Research Publications, Volume 4, Issue 7, July 2014.
- [4] Bhaskara P, Raghuvver Prasad, "Root cause analysis of control rod friction problem in DFIP using shainin® approach", International Journal of Mechanical Engineering and Technology (IJMET), Volume 5, 2014.
- [5] Abhaysinh K. Desai, L. M. Jugulkar, "Process optimization by using shainin six sigma tools and techniques – a case study in manufacturing industry", International Journal of Mechanical and Production Engineering, Volume 2, 2014.
- [6] PriyaanshParsad and D. R. Prajapati, Reduction of rejection of an automobile part using six sigma approach, Proceedings of National Conference on Advancements and Futuristic Trends in Mechanical Engineering, Department of Mechanical Engineering, PEC University of Technology, Chandigarh, India, Oct 2014.
- [7] Nagarjun.S, Dr.H.N. Divaka, Quality Improvement of Pumping Element used in Diesel Fuel Injection Pump, International Journal of Scientific and Research Publications, Volume 4, Issue 7, July 2014.
- [8] Pranay S. Parmar, Dr.Tushar N. Desai, Reduction of rework cost in manufacturing industry using statistical process control techniques: a case study, Industrial engineering journal, Vol. X & Issue No. 6, June 2017.
- [9] T. Kiatcharoenpol, T. Vichiraprasert, "Implementation of Shainin's DOE: A Case of Plastic Injection Moulding Process", Proceedings of IEEE, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand, 2017.
- [10] NitheshNaik, SuhasKowshik, "Failure analysis of governor in diesel engine using Shainin System™", Engineering Failure Analysis, Manipal Institute of Technology, 2019.