# Root Cause Analysis of Secondary Dead Stroke Problem of TMC using Shainin Approach

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***Abstract:*-The two major challenges that industries are facing today are continuous improvement in productivity andquality of the product. Various quality tools were developed and used to meet those challenges. Some of the leading manufacturers in automobileequipment,has been successfully employing the efficient statistical tool 'Shainin®' for the root cause identification and for analysis and optimization of the quality related issues. Shainin® is popular being asimplest and effective tool to employ in solving the manufacturing related problems. The present paper deals with one ofthe quality issues resolved by using Shainin®methodology.**

***Keywords*: Shainin®Methodology, FACTUAL, Root Cause Analysis (RCA), RedX,GreenY.**

## I.INTRODUCTION

Statistical Process Control (SPC) is the application of statistical methods to monitoring and control of a process to ensure that it operates at its full potential to produce a conforming product. Under SPC, a process behaves predictably to produce as much conforming product as possible with least possible waste. Key tools in SPC are control charts, continuous improvement and design experiments. Variations in the process that may affect the quality of the product can be detected and corrected, thus reducing waste as well as the likelihood that problems will be passed on to the customer. With its emphasis on early detection and prevention of problems, SPC has a distinct advantage over other quality methods, such as inspection, that apply resources to detecting and correcting problems after they have occurred. When a process is considered out of control, an alarm is raised, so that engineers can look for assignable causes of variation and try to eliminate them. It is more effective to take a proactive approach to prevent the occurrence of out ofcontrol situations allowing the process to be adjusted in apreventive way so that fewer non-conforming items will beproduced.

Tandem Master Cylinder has become the most essential part of braking system for vehicles and equipment such as trucks, tractors, passenger vehicles, etc. The tolerance should be kept within the limits as it plays crucial role in safety. Nowadays, the quality of such product has become the dominant criteria to acquire the global market. The leading companies in quality production by deploying advanced quality measures in its manufacturing processes and thus, satisfying the customer. It has been possible through continuous improvement and proactive quality maintenance techniques like Shainin® System, various control charts, Six Sigma, etc., in the production processes. The quality of the product may be quantified in terms of money (INR), First Pass Yield (FPY), part per million (ppm), etc. There is a need to employ a simpler and efficient tool along with the traditional seven quality tools in order to achieve the Six-sigma quality in manufacturing industries. Since the customer complaint, line stop kind of issues are having crucial impact on productivity, cost control and customer satisfaction parameters.

### i. Tandem master cylinder

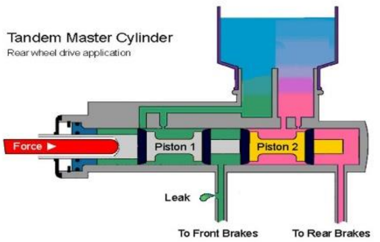


Fig. 1. Schematic of TMC

Fig. 2. TMC Body

At the assembly time on TMC line 8, the TMC body travels from Station-1 to Station-20 packing with Primary and secondary spring assembly, reservoir, grommet and pin assembly, filter, O-ring, reservoir cap assembly, and stickers, etc. The assembly line faces the issue of non-conformance of TMC due to secondary dead stroke reading going out of specified tolerance limit.

## II. LITERATURE REVIEW

The Stephen H. Stainer and R. Jock Mackay in their research paper "An Overview of the Shainin System for Quality Improvement" provides the Shainin system's step for problem solving. Here, the algorithm is defined for a single project and is designed to fit into a larger project selection and management process. The algorithm is divided into two parts, the diagnostic and the remedial journeys. In the diagnostic journey, the problem is defined, the measurement system is assessed, and the dominant cause of variation is identified and verified. In the remedial journey, the effect of the dominant cause is eliminated or reduced by changing then product design, the process, or the control plan. in the given figure, the purpose of first stage of the algorithm is to quantify the magnitude of the selected problem. For these, the output of the processes using an appropriate sampling scheme for a sufficiently long period is monitored. [1]

There is a use of baseline distribution to quantify the problem, to set a goal that has a potential to improve the process and to assess any propose remedy. The base line distribution is also used to check the dominant cause exhibit its full effect in each investigation. The idea of quantifying the nature problem is a part of all problem-solving approaches. The usual feature of Shainin system is the explicit link between the search for the dominant cause and the base line distribution. In the second stage of Shainin system, the algorithm involves the quantification and establishment an effective measurement system. In Shainin system without a good measurement system, it is difficult to learn about the processes, improvement in the process and thus measurement system itself may be the home to the dominant cause of the problem. In most of the problem, there is consideration of several measurement system. Now the goal for the third stage of the Shainin system algorithm is to generate clues about the dominant cause, this is one of the types of progressive search. At this stage, we are emphasizing the new key in the Shainin system which is “Talk to the Parts”.

Jan Kosinain his research paper "Shainin methodology: An Alternative or An Effective Complement to Six Sigma?" provided a brief overview of six Sigma and Shainin Red X methodology and propose the modification of Six Sigma methodology in order to achieve improve efficiency of DMAIC in the diagnostic journey using some of the approaches of Shainin Red x methodology.

This paper presents a proposal of DMAIC framework modification using selected tools and procedures of Shainin Red X methodology in the diagnostic phase. The contribution of this article is proposal of modified methodology which should improve the effectiveness of problem solving.

Quality improvement in manufacturing are in many cases focus on the reduction of process variation is a critical factor of process stability and therefore the cost effectiveness of the system of the process. There are two ways to reduce process variation:

1. to identify and control the root cause and
2. to decrease the sensitivity of the process how to the source of the variation.

Several strategies of quality improvement have been developed in order to define methodology for problem solving the most often used methodology for improvement activities is Six Sigma statistically. The target of Six Sigma is to centre the process mean to the target value and to reduce process variation. The role of Six Sigma is to improve quality using data analysis that leads to identification of the root cause and the consecutive implementation of corrective measures. [2]

Developing effective Red X problem solver by Richard D Shainin includes the strategy of Red X problem solving. Which is a skill that needs to be learn and develop. As with any skill, student must pass through four phases of competence before they are fully developed. Red X problem solving is a highly structured and discipline system for finding the hidden causes that are keeping systems from performing properly. It is particularly effective at revealing higher order interaction. Its foundation is built on two principles the red x principle and Y→X thinking.

The Red x principle deal with the natural phenomenon. It is understanding of the physical world that leads to a scientific evolution and a new ability to solve problems. Y→X thinking is a structure approach for revealing the Red X, when it is hidden. Properly applied it converge on the red x through a progressive search that eliminate the sub systems that can't be involved during driving the variation. Instead of asking ‘what's wrong', Y→X thinking asked what's different. [3]

Pavol Gejdos, in his article “Continuous Quality Improvement by Statistical Process Control” emphasizes on SPC and DMAIC model as a tool for continuous quality improvement. The advantage of this tool is that they can identify the factors which causes unnatural variability of a process that result of errors and poor quality. Tools like capability index, histogram, model DMAIC, control charts etc can reliably determine the anomalous variability in the process and thereby improve the quality. Through the DMAIC model, there is a systematic improvement in the quality. Histogram shows the normal distribution of the frequency monitored quality characteristics. The random causes which are permanent cause of the process influence all the process components. And definable causes occur as a consequence of specific circumstances. They induce in real process reflected in unnatural fluctuation in the data used for evaluating process variability. The above mention causes can successfully find by DMAIC model along with SPC tool which are used to improve the process quality.

SPC can be regard as a very effective tool in ensuring process stability and DMAIC as improvement model. The combinations of tool are very suitable for achieving the desired objectives and efficient manner can help to solve all task and problem of the process of quality improvement. [4]

Johannes Ledolter and Arthur Swersey in the paper, “Dorian Shainin's Variables Search Procedure: A Critical Assessment”, compares the Shainin technique’s variable search tool with a fractional factorial method. Shainin technique refers the most important factor as “Red X”. The second most important factor is called “Pink X” then the “Pale Pink X” and so on. The variable such technique based on the principle of the effects of the most important factors. It consists of several stages. In stage 1, one ranks the factor in the descending order of judgment of each factors ability to influence the output and assigns two level to each factor. The one is best level and other is worst level. The greater difference between the best and the worst level shows that there is a Red X. In stage 2, the swapping stage one switches the level of each factor. And in stage 3, the data from the first two stages are arranged in the form of a full factorial of the factors found relevant in Stage 2; factors that have been crossed out earlier are ignored in this analysis. [5]

In the paper called “An overview of theory and practice on process capability indices for quality assurance”, authorsChien-Wei Wu, W. L. Pearn and Samuel Kotz states that the process capability analysis is an important and well-defined tool in applications of statistical process control (SPC) to a continuous improvement of quality and productivity. The relationship between the actual process performance and the specification limits (or tolerance) may be quantified using suitable process capability indices. Process capability indices (PCIs), in particular Cp (process capability index), Cm (machine capability index), Cpk (process performance index), Cmk (machine performance index) and Cpmk (third generation capability index) are very useful to calculate numerically the measure of meeting of production sustainability to a particular level. It also helps to determine the process assessment, process consistency, process departures, process yield or loss and purchase decisions. The behaviour of process yield or loss can be determined in terms of non-conformities (parts per million).

A process may have symmetric or asymmetric tolerances. If the target value is set to be the mid-point of the specification interval, then the process is said to have a symmetric tolerance. There may be cases with asymmetric tolerances in manufacturing industries. From the customer's point of view, asymmetric tolerances indicate that deviations from the target that are less tolerable in one direction than the other. For calculating the capability index, sample data is collected and because of some inevitable sampling errors, certain degree of uncertainties are always introduced into capability assessments. Higher the value of Cp or Cm, better is the process or machine, and vice versa. Similarly, for higher value of Cpk or Cmk, output is within specified limit or the data of process or machine is well centred and vice versa. [6]

## III. APPROCH AND EXPERIMENTATION

Shainin RedX methodology was developed by Dorian Shainin from the 1950sto the 1990s. The main difference between Shainin's approach to problem solving and traditional problem-solving methodology is the convergent approach used to identify a root-cause, the so-called Effect to Cause (Y to X). To apply the convergent approach, it is absolutely necessary to understand the output Y. Knowledge of the product and related processes, symptoms of failure as well as the contrast between good and bad parts are key elements in understanding the output Y. The output Y must be a measurable technical parameter with a clear relation to the physics of the failure – this defines the output we want to improve– GreenY. The progressive and convergent strategy is a crucial component in identifying the potential root-causes (Xs) by deep investigation of the parts (so called "talking to the parts"), the elimination of suspects and the comparison of good and bad parts along with finding extremes and contrasts. The potential causes – RedX candidates are tested using efficient confirmation methods.

Progressive search works in conjunction with the assumption that there are only one or two dominants causes. If we can attribute most of the observed variation to one family, we can eliminate all varying inputs that act in other families from consideration as a possible home of the dominant cause. For example, suppose we find that variation part-to-part is much larger than variation time-to-time, then all varying inputs that change over the longer time frame, such as properties of batches of raw material, can be eliminated as dominant causes.

Another consequence of the assumption of a dominant cause is that we can gain a lot of information about this cause by comparing units with extreme values of the output. To our knowledge, this explicit use of ''leveraging'' is unique to compare the ''best of the best'' (BOB) and ''worst of the worst'' (WOW) units. The values of the dominant cause must be substantially different on these two groups of units and hence it will be identifiable. One advantage of leveraging is that we can eliminate families of causes using investigations with small samples of extreme units. Note, however, to find a small number of extreme units, we may need to measure the output on a large number of units. Also, the terminology can cause confusion. For outputs with two sided specifications, none of the extreme units is best of the best.

The problem-solving roadmap is called as FACTUAL:

1. Focus: Transformation of business case into technical project and project definition
2. Approach: GreenY identification and description, development of investigation strategy, measurement system verification
3. Converge: Converging on RedX, compare best and worst case, RedX candidate identification
4. Test: RedX confirmation, risk assessment
5. Understand: Understanding of GreenY to RedX relationship, translation of costumer requirement into limits, understanding interactions, establishment of appropriate tolerance limits
6. Apply: Implementation and verification of corrective action, updating plans, GreenY monitoring
7. Leverage: Lessons learned taken, calculation of benefits.

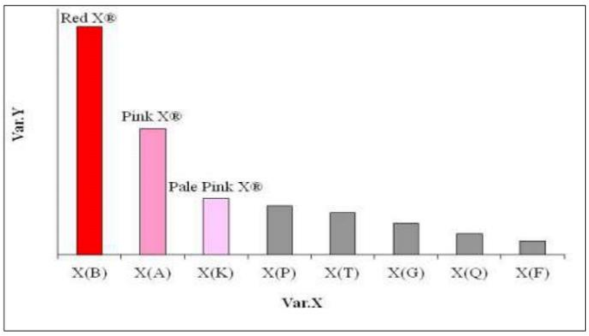


Fig. 3. Pareto chart

By the application of the Pareto principle we can define the contribution of theXs – process inputs – to the delta Y – increment of the output (Figure 1). FollowingShainin's philosophy there are no more than three root-causes playing asignificant role: the dominant cause of the variation is called RedX, the twoother main causes are called Pink X and Pale Pink X. RedX can be a singlevariable or an interaction between separate variables.

*A.Six Sigma*

Six Sigma, on the other hand, is a data driven methodology used to identify root causes for variations in a production processes in order to achieve organizational excellence. Six Sigma management strategies require process improvement through identifying problem, root causes, process redesign and reengineering and process management. Six Sigma follows a model known as DMAIC (Define, Measure, Analyse, Improve and Control). Therefore, six Sigma starts by analysing defects and lean initial focus is on customer, process flow and waste identifications (Sampson, 2004). However, using one of these tools has limitations. Since lean eliminates the use of six Sigma's DMAIC cycle as a management structure to define required process capabilities to be truly lean. On the other hand, six Sigma eliminates defects but does not address how to optimize the process flow. Hence, applying both six Sigma and lean tools sets results in far better improvements than it could be achieved with either one method alone.

Six Sigma is an organization-wide approach used to specify exactly how organization managers set up and achieve objectives. It demonstrates how breakthrough improvements tied to significant bottom-line results can be achieved. The Six Sigma methodology goes beyond the improvement process and tools because it requires an intelligent use of data, emphasis of statistical analysis and designed experiments. Six Sigma prescribes an improvement process known as DMAIC methodology:

1. Define: Improvement of project goals, goals based on customer needs and wants
2. Measure: Current process and establish metrics to monitor the path to achievement of goals
3. Analyze: Current process to understand problems and their causes
4. Improve: Process by identifying and piloting solutions to problems
5. Control: Improved process with standardization and ongoing monitoring

*B.Pareto Charts*

The Pareto (pah-ray-toe) chart is a very useful tool whenever one needs to separate the important from trivial A Pareto Chart is simply a frequency distribution (or Histogram) of attribute data arranged by category Montgomery. It is a special type of bar charts in which the categories of responses are listed on the X axis, the frequencies of responses (listed from largest to smallest frequency) are shown on the left side Y-axis, and the cumulative percentages of responses are shown on the right side of Y-axis. This diagram named after the Italian economist Alfredo Pareto. Dr. Joseph Juran recognized this concept as a universal that could be applied to many fields. He coined the phrases Vital Few and Useful Many in quality problems.

Pareto diagram is used to plot the relativefrequency of variable measure categories under study in a descending order using bar graph. Such ordering helps the decision maker to focus on those problems which needs greatest potential improvement. It helps in identifying the dominant factors among all factors which reduces the quality performance. Pareto, an Italian economist propounded that relatively few factors will account for large percentage of total cases like 80-20 rule.

*C.Histogram*

Histogram is a special bar chart for measurement data. Histograms is used to chart frequency of occurrences. In the histogram, the data is grouped into adjacent numerical categories. Minitab can organize the data into groups, and plot the histogram. The difference between bar chart and histogram is that the X-axis on a bar chart is a listing of categories; whereas the x-axis on a histogram is a measurement scale. In addition, there are no gaps between adjacent bars.

*D.Control Charts*

Variable control charts are used to study a process when characteristics is a measurement, for example, cycle time, processing time, waiting time, highest, area, temperature, cost or revenue. Measurement data provides more information than attribute data: consequently, variables charts are more sensitive in detecting special cause variation than are attribute charts. Variable charts are typically used in pairs. One chart study the variation in a process, and the other studies the process average.

## IV. RESULT AND DISCUSSION

Secondary Dead Stroke reading should be between Lower Control Limit (LCL) and Upper Control Limit (UCL) of 0.9 mm and 1.5 mm, respectively.

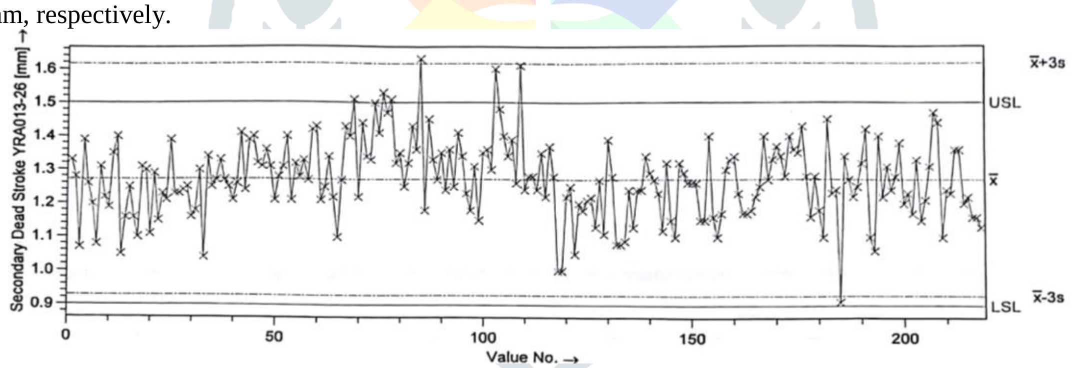


Fig. 4 Control chart of Secondary Dead Stroke reading of TMC model YRA013-26

Secondary Dead Stroke reading should be between Lower Control Limit (LCL) and Upper Control Limit (UCL) of 0.9 mm and 1.5 mm, respectively.

After collecting the multiple readings of Secondary Dead Stroke, the control charts and histogram are drawn. The minimum and maximum values of collected data are 0.91 mm and 1.63 mm, respectively with range value of 0.72 mm. Out of 218 components examined, 212 components are within the limit while 6 components cross the UCL.

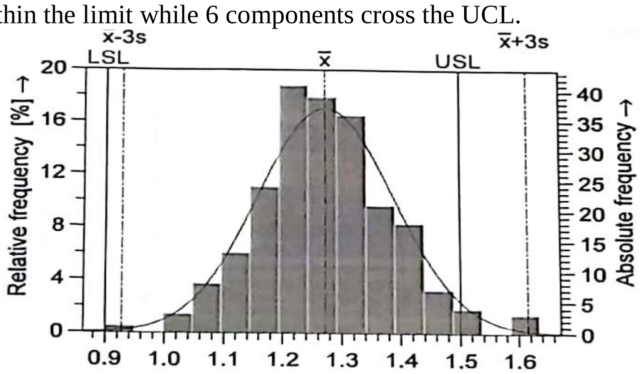


Fig. 5 Histogram and Frequency Distribution of Secondary Dead Stroke reading of TMC model YRA013-26

Mean value of collected data is 1.27 mm with Six-Sigma limits of 0.92 mm and 1.61 mm (Range= 1.68 mm). The probability that the reading taken is within control, greater than UCL and less than LCL is 97.6%, 2.34% and 0.06%, respectively. The difference between expected and calculated mean value of mean shows that the process deviates to upper side by 0.07 mm. The Machine Capability Index ($C_m$) is 0.87 and Machine Performance Index ($C_{mk}$) is 0.66. The requirements were not met. The results show that the process is not in control.

*A.Focus*

Since the focus of the project in the bussiness point of view is about 3% TMCs produced are rejected and sent to rework during dead stroke measurement, the primary and secondary springs have been compressed pneumatically to check their dynamic conditions. The additional cost of rework is the reason for taking up the project as priority. The project objective is to identify and eliminate the root cause which is causingrejection in secondary dead stroke.

*B.Approach*

The effective utilization of the statistical tool and quickness of the root cause identification relays on the selection of samples with two extreme characteristics (WOW and BOB). The type of problem that is tackled is apparently limited to variation problems. The generic form of problem is a certain quality charactersistic has a probability distribution which does not meet the demands. Here, the sample which gives value close to mean is BOB and which is towards either of the extremes is WOW.

*C.Converge*

Converging towards the Red X causing the Green Y has been achieved by carefully observing the assembly line.during analysys all the variables whch are going to affect the system are identified. After arranging them in a proper stage, the variables which highly affect the process among corresponding variables is highlighted and other variables gets eliminated during converge approach. By continuing this steps we reach to our RedX.

## V. CONCLUSION AND FUTURE SCOPE

Currently done analysis and further investigation will lead us to the root cause,i.e., Red X, which can possibly help us to achieve the Green Y, which is reduction in first time rejection percentage and hence the rework rate also. However, entire TMC assembly analyis, disciplined quality manufacturing of components, awareness about the quality management and robust measurement techniques are much essential to achieve and sustain the lower or zero rejection rates during the calibration of the same.

Shainin has found to be simple and efficient statistical tool, which can give clue about most unsuspected design variation also.

Further steps of Shainin Methodology, i.e., FACTUAL will lead us to find the Red X. The possible corrective actions that can be taken to improve the quality of product by reducing rejections are controlling the upper and lower control limits, changing the assembly parameters and time-to-time maintenance and calibration of machine.

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