Application of 7 QC Tools to Investigate the Rejection of Lathe Beds – Case Study of a Machine Tool Manufacturing Company

Amit Sridhar, the quality control engineer was worried. After reading the inspection report about the quality of the lathe beds after they were heat treated, he was not sure of what needs to be done. Out of the 32 lathe beds that went through the process of flame hardening, six had to be rejected due to defects. Having already seen the heat treatment section, he decided to visit the foundry section from where the raw lathe beds had arrived. He called the foundry chief Mr. Murugan and asked him to call a meeting the next day morning. Murugan immediately guessed that the Vice-president of Operations, Mr. Tayub too would be attending the meeting and started thinking as to how to handle the crisis.

"Yes, it is a crisis" Amit was talking to the heat treatment section's head Mr. Sundar, and both of them decided to hold a brainstorming session to investigate the issue.

About the Company

SSG Industries (name changed to protect the identity of the company) is a pioneer in the field of manufacturing machine tools and is highly reputed for its quality products for more than 50 years. The company has an array of machine tools under its manufacturing facility located in the industrial town of Coimbatore. The products are known for strength and durability and both the small and large scale manufacturers used to buy the machine tools.

The case writer(s) R. Jagadeesh,Dean - Academics and Professor - Operations, may be reached at jagadeeshraj@sdmimd.ac.in

SSG Industries followed the practice of backward integration for all its products. The foundry and the forging units located on the outskirts of the town directly supplied the raw structures to the company. These raw forms later used to undergo all the machining, finishing and heat treatment processes, to become the finished products. SSG had the latest machining facilities and hence was able to achieve the final dimensions without any difficulty. Rarely there used to be any complaint from the assembly department, and the products would always get the stamp of acceptance from the customers.

The company over a period of time had moved to produce semi-automatic and fully automatic machine tools that were in good demand from the automobile industries. These machine tools had the capability of producing the auto components to the desired accuracy of dimensions, and surface finish. Hence the concern of the SSG Industries was always to ensure high degree of quality in their products so as to have zero rejections in the assembly section.

The Issue on Hand

Among the machine tools manufactured by SSG Industries, lathe constitutes the bulk of the sales for the company and hence the company had set up a dedicated production line to manufacture the lathes.

The lathe bed is the major and most important structural element in a lathe. Relative alignment of other mounted elements like head stock, tailstock, and carriage and tool post, and consequently the machining accuracy of parts produced on the lathe, depends on the quality of the bed. That is why the technique of manufacturing the beds requires special expertise and attention.

In several batches of lathe beds produced in the company, the lathe beds were found to have developed cracks and based on inspection such lathe beds were rejected. While the flame hardening process was first considered as the main reason, it was also found that the lathe beds got rejected due to the cracks that were induced in the

casting process. This was considered as the main problem or focus for the study and subsequently the entire process of heat treating the lathe beds was taken up for elaborate analysis.

The Meeting Enlightens!

As expected Mr. Tayub chaired the crucial quality assessment meeting with Amit and Murugan, seated on one side, and all the supervisory staff of the foundry division and Sundar from the heat treatment division, were present. They all agreed that the issue is critical and should not be allowed to go out of hand. Amit suggested that initially the rejection was very low and perhaps did not warrant any investigation. But as the number of rejections has increased, everyone felt that it is time to explore deeply and ascertain the causes behind the rejection. Murugan informed that special tools may be required. At this juncture, Tayub intervened.

"I suggest using the 7 QC tools to analyze the situation and also to find the solution".

Amit replied "we are already using the run charts to keep track of the rejections and also use the control charts, which are a part of the 7 QC tools and of course other tools have not yet been tried".

The meeting concluded with the decision that 7 QC tools would be appropriate as they are found to be quite helpful and can solve more than 90% of the quality problems, (Ishikawa, 1988). At the same time, Amit and Murugan decided to delve further into the application of 7 QC tools before they could start using the same to solve the rejection problem.

Quality Improvement is the Primary Goal

Quality improvement is a primary requirement in any production system that sends products or service as its outputs. Thus, it is a major goal in any manufacturing industry. Machine tool manufacturers spend a lot of efforts in maintaining and improving quality of their products

using a variety of tools and techniques. 7 QC Tools are considered quite powerful and helpful in solving quality problems and hence have occupied a prominent place in the field of quality management. These tools are almost commonly used across all types of industries because of the simplicity and ease with which these tools can be learned and applied to practical situations. The legendary quality guru Kaoru Ishikawa has stated that 95% of the quality problems can be solved by using "7 Q C Tools" and this should indicate the power of these tools in solving the problems. Incidentally, these tools are never missed in any quality management training conducted by companies and industries. This shows the importance attached to these quality control tools.

Seven Quality Tools – An overview

The Seven Quality Control Tools popularly called the 7 QC Tools, comprise graphical methods and help to transform the data into easily understandable diagrams or charts. This further helps to understand the situation or to analyze the problem easily and leads to developing solutions which aim towards quality improvement. Further, these charts and diagrams help to highlight the important aspects of a problem clearly so that the concerned persons can focus attention on them and start developing the solution.

The 7 QC Tools listed in alphabetical order are:

1. Cause and Effect Diagram
2. Check sheet
3. Control Chart
4. Flow Chart
5. Histogram
6. Pareto chart
7. Scatter Diagram

These 7 QC tools can together enable a quality problem to be analyzed and solved and also help to prevent a problem from recurring so that the quality problem is once for all solved. It is not the intention here to describe these tools in greater details as these tools are described in all quality related literature particularly textbooks and training manuals. It would not be exaggerating to say that almost all the quality control and management books include a description of the QC tools. Hence a detailed description can be found in many popular books, written by different authors, (Austrom & Lad, 1986), (Kume, 1987), (Chang, 1993), (Mears, 1994), (Wadsworth, Stephens, & Godfrey, 2001), (Evans & Lindsay, 2004), (Tague, 2005), (Defeo & Juran, 2010), and (Montgomery, 2012).

As stated in http://www.beyondlean.com/7-quality-tools.html, the 7 Quality Tools are problem solving tools which can:

- Help to identify and prioritize problems quickly and more effectively
- Assist the decision making process
- Provide simple but powerful tools for use in continuous improvement activity
- Provide a vehicle for communicating problems and resolutions throughout the business
- Provide a way of extracting information from the data collected.

To provide a continuity of reading a brief overview of all the seven tools is provided here.

Cause and Effect Diagram

The cause and effect diagram is also sometimes called as “fishbone diagram” or “Ishikawa diagram” after the Japanese quality expert late Dr. Kaoru Ishikawa. It is a useful method for listing and classifying the causes under different categories that lead to a problem or result or effect. The causes are classified according to their type or nature and represented in proper order.

The Diagram Consists of Two Sides

(1) Cause side – factors that influence the related effect or characteristic, and

(2) Effect side – represents a problem or an outcome in a given situation or a result.

The two sides are connected by a thick arrow called the trunk. The arrow head leads to the effect side while branches and sub-branches added to the trunk represent the causes responsible for that effect. The major branches added to the trunk represent the main categories of causes and the small and tiny branches represent the sub-category of causes. The branches can be expanded or new branches can be introduced depending on the number of causes.

Check Sheet

A check sheet is a list in the form of a diagram or table format, prepared in advance to record data and is useful for later analysis. It is also called as a tally sheet. There are five basic types of check sheets as given below:

a) Classification -To classify the items under different headings

b) Location - To indicate position of an item

c) Frequency - To indicate the presence or absence of an item, and also the number of occurrences of that item

d) Measurement scale - To provide a measurement scale divided into intervals to enable easy marking

e) Check list - To indicate the items or tasks to be performed to complete a task

Control Charts

A control chart is a line graph used to assess and validate the stability of a process. The graph consists of a horizontal center line and two parallel lines called upper control limit and lower control drawn on

either side of the center line. Data pertaining to a quality characteristic is collected over a period of time and the values are plotted as points on the graph in the chronological order. The points are connected by straight lines.

The spread and position of the points on the graph relative to the center line and the control limits indicate the state of control of the process. They also help in distinguishing the random causes from the assignable causes which need to be investigated further. When all the points are within the control limits, and these points do not exhibit any abnormal pattern, then the underlying process is said to be under statistical control. In such cases no action may be necessary and the process is allowed to continue. If the points fall outside the control limits or display any abnormal pattern, then the process is deemed to be out of control and under the influence of special causes. In such cases the process would be stopped and investigated for causes. Then the required corrective action is taken and the process is continued. The control charts used in industries are divided into two groups namely Control charts for variables, and Control charts for attributes.

Flow Chart

A flowchart is a graphical method of displaying a system's operation or sequence. A familiar type of flowchart is the computer program flowchart, which is used in programming. A flowchart consists of several standard symbols connected in a logical manner to depict the flow of operations or information or tasks in the desired sequence.

Histogram

A histogram is a frequency distribution diagram which displays the distribution of data in the form of a bar graph. It is constructed from the data collected in a frequency table which shows the data distributed across several class intervals and the frequency of occurrence under each class. The histogram drawn from the frequency table is composed of columns whose widths represent the class interval and the height represents the frequency. The histogram

provides a visual representation of the data distribution and gives a quick assessment on the spread and shape of the distribution.

Pareto Diagrams

A Pareto diagram, named after Vilfredo Pareto, an Italian economist, is a specialized bar graph that can be used to show the relative frequency of events such as defects, repairs, claims, failures, or any other entity, in the descending order. This helps to focus on the vital few and not to start with the trivial many, to improve the quality.

Scatter Diagram

A scatter diagram represents the relationship between two types of data or two variables. The two variables are plotted along the two conventional coordinate axes and the relationship between the variables will be evident by the scatter or spread of the points. Thus a scatter diagram helps to find the correlation between two variables.

Application of 7 QC Tools in Industries – A Literature Review

7 QC tools have been used across many types of industries particularly when the companies embark on a journey of total quality management or continuous improvement. The first step in the quality improvement drive usually starts from using the 7 QC tools, because these tools provide for data collection, analysis and improvement.

In a textile mill while implementing the ISO 9000 standards, the company used these basic quality tools to effectively improve the quality, (Sarkar, 1998). A manufacturing industry used these quality control tools to minimize the variation and to reduce the number of defects, (Escalante, 1999). The use of these tools in a plastics manufacturing company in Portugal (Dias & Saraiva, 2004) reaffirms the use in diverse industries. How these tools are helpful in a process industry can be understood by referring to a case study of a chemical industry, (Paliska, Pavletiæ, & Sokoviæ, 2008).

It is to be noted that the basic QC tools can be used from the beginning of the product development process to the last phase of production and delivery besides the continuous improvement process, (Sokoviæ, Jovanoviæ, Krivokapiæ, & Vujoviæ, 2009). A cable manufacturing company in Sweden used these tools to increase the electrical resistance in cables thereby saving the copper as the raw material, (Sabet Azad & Mokhlesi, 2009). The application of 7 QC tools in a milk producing cooperative enabled the organization in building a culture of continuous improvement, (Trehan & Kapoor, 2011). How these quality tools are used to study the production processes, find the root cause of the problems and to improve quality in a tire retreading industry indicates the application of these tools in lesser known industries, (Behnam & Alvelos, 2011). In the construction industry, for example, the basic quality tools have been used to improve the quality of the processes, save materials, and money, (Aichouni, 2012). It may be noted that, as a byproduct of the application of these quality tools, the thinking process of the people involved also improves and better analysis is possible, (Magar & Shinde, 2014).

Both Amit and Murugan were surprised to see the diverse application of the basic QC tools and got a clear picture of what needs to be done and how the improvement journey should proceed toward the desired results.

About the Manufacture of Lathe Bed

In the majority of cases the bed is made of high-grade cast iron having approximate tensile strength of 28 kgf / mm^2 and with a hardness of BHN 200. The bed is cast following the usual process of pattern making, molding, etc. The mechanite process is generally used to produce high quality castings. All these data is taken from an unpublished dissertation made available in the industry.

Next, the bed is shot or sand blasted and then fettled. Then follows the preliminary marking in which the reference surfaces are marked. The purpose is two folds: Firstly this helps to ascertain whether the shape and size of the casting conform to the design so that it can be

taken up for subsequent machining: secondly, the marking will help to set up the work piece and the machine faster.

The rough machining is normally done on a planing machines. In some cases where the batch quantity is very high, a Plano miller can also be used. A number of beds can be machined in one set-up depending on the capacity of the planer. Normally an allowance of 2 mm is left for finish machining. The rough machined bed is then subjected to artificial ageing. This is again followed by shot or sand blasting to remove the scales, which appear after ageing. The bed is then primed, that is, given a primary coating of paint.

The finish machining is then done on high accuracy planing machines. This is followed by marking and drilling the holes required for fixing headstock etc. Then the bed is heat treated by the usual process of flame or induction hardening which imparts a hardness of 40-45 HRC (Hardness measured on Rockwell C Scale). The finish painting is done after that. The final and most important operation of grinding the guide ways then follows. Figure 1 shows a typical lathe bed.

Considering the requirements of the machine tool to support and machine the metal parts, it is observed that the hardness of the lathe bed is “critical to quality” and it would be accepted or rejected based on hardness assessment. The dimensions and the surface finish are given lesser importance and the whole bed would be rejected if the hardness is not satisfactory. Accordingly, the final inspection involved testing the hardness of the lathe bed to ascertain if the hardness is within the acceptable value.

Figure 1 : Lathe bed

Problem Definition

The problem investigated in this case study is about the rejections of lathe beds, because of the defects that occurred after the heat treatment process using flame hardening, which was used to provide the required hardness.

Description of the Flame Hardening Process

The lathe bed being a heavy component remains stationary and is heat treated using a movable equipment which provides the heating using a gas torch. The flame coming out of the jet is traversed across the whole length to heat treat the surface of the bed. An overhead guide carries a traveling head which moves parallel to the surface of the bed and the length of travel is pre-set based on the length of the bed. The traveling head moves along a guide rail powered by an electric motor with a variable speed drive. A torch and a nozzle are fixed to the traveling head to provide a flame and a water jet respectively. Using oxy-acetylene gas the torch produces a flame and starts heating the top surface of the bed. The water jet following the torch provides rapid quenching and both move along the guide rail with the same speed. The intensity of the flame as well the water jet are predetermined based on prior experimental runs. A forward and return movement of the traveling head is considered as one cycle. The height at which the traveling head is fixed above the bed decides the gap between the flame tip and the surface of the plate. This height is also preset by the operator and no adjustments are supposed to be made during the process. Once the hardening process is completed the hardness is measured and recorded.

Criteria for Acceptance

The hardened bed is expected to possess a certain hardness as specified by the design department and any bed not having the hardness in that range is rejected. The flame hardening process which imparts a hardness of about 42 (Lower Specification Limit, LSL) to 48 (Upper Specification Limit, USL) HRC is considered satisfactory. A bed

with hardness higher than 48 HRC is rejected. HRC refers to the hardness value as measured along the Rockwell C scale. The Rockwell scale is a hardness scale based on indentation hardness of a material and the result is a dimensionless number noted as HRA, HRB, HRC, etc., where the last letter is the respective Rockwell scale, (https://en.wikipedia.org/wiki/Rockwell_scale).

Data Collection

In order to ascertain the quality of the lathe bed, the hardness data was collected on 32 beds that were hardened in a certain sequence and the reading of the hardness inspection are given in the Table 1. A run chart of hardness values is shown in Figure 2.

Table 1 :

Hardness values (in HRC) of 32 beds

No.	Hardness	No.	Hardness	No.	Hardness	No.	Hardness
1	44	9	45	17	45	25	45
2	50	10	51	18	45	26	47
3	49	11	48	19	47	27	48
4	44	12	45	20	51	28	48
5	47	13	45	21	44	29	43
6	44	14	42	22	50	30	45
7	49	15	45	23	48	31	45
8	45	16	43	24	47	32	43

Figure 2 : Run chart of hardness values

Preliminary Observations

The run chart indicates that six of the 32 lathe beds have excess hardness, four have the maximum permissible hardness, and one lathe bed has the minimum hardness. A histogram of the raw data is depicted in Figure 3. From the histogram the data doesn't appear to be closely following the normal distribution, and 26 out of 32 lathe beds have the hardness between the acceptable range of 42 to 48, and hence 6 lathe beds are rejected.

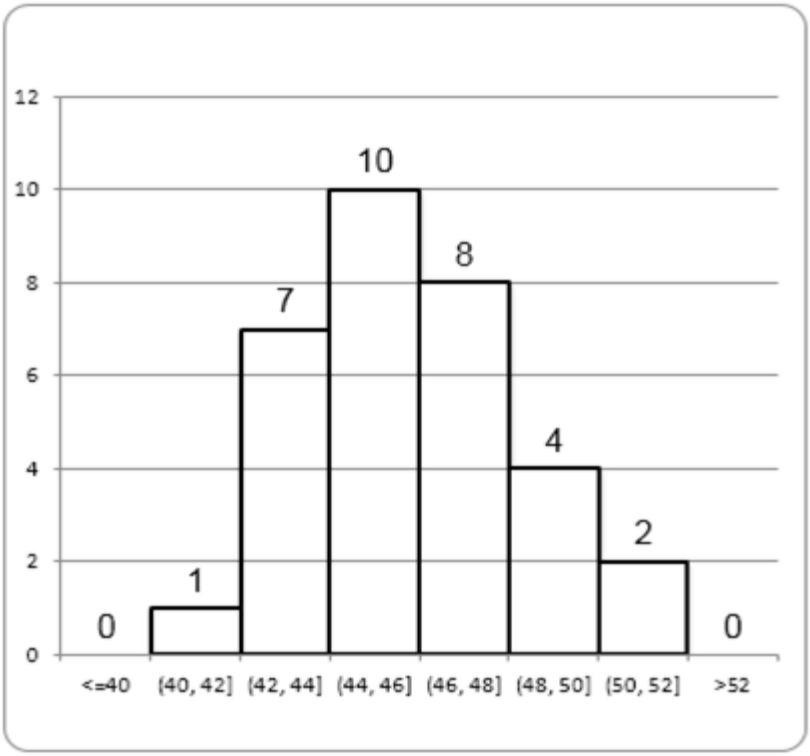

Figure 3 : Histogram showing the frequency distribution of hardness values

Main Causes of Defects in Hardness

Amit decided to ascertain the causes and based on his discussions with Murugan and the foundry department, realized that the defects

can occur due to two main reasons, namely, metallurgical errors, and errors in the flame hardening process. However, Mr. Sundar informed, the metallurgical errors were found to be having very little effect on the hardness values and hence it was decided to ignore the causes associated with that factor.

Exploring the Causes – Cause and Effect Diagram

Amit and Murugan arranged a brainstorming session and also conducted some trial runs of the flame hardening process and came out with the reasons behind dissatisfactory results in the hardness values. Based on the data they collected, a cause and effect diagram was constructed as shown in Figure 4.

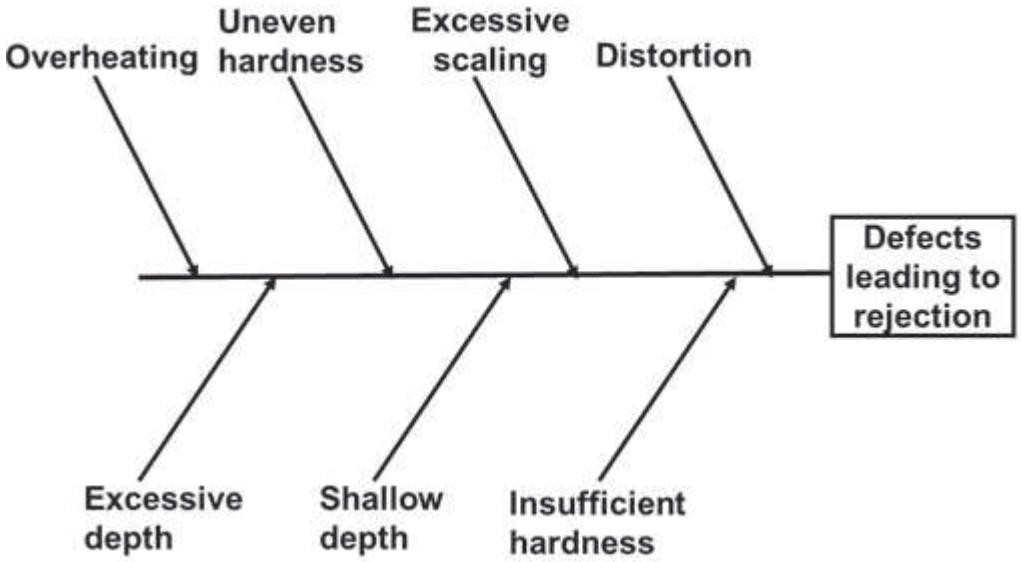

Figure 4 : Cause and effect diagram for the rejection of lathe beds

The seven main causes were further explored for the sub-causes and the Table 2 summarizes the causes for each main reason behind the hardness defects.

Table 2 :
Reasons for different defects in the lathe bed caused by flame hardening

Overheating: Heating cycle too long. Flame heads too close to work. Oversize flame nozzles. Excess oxygen in the flame. Excessive fuel gas pressure. Improper pattern of flame tip.	**Spotty or Uneven Hardness**: Non-uniform heating. Time interval between heating and quenching too short. Quenching medium not agitated enough. Water in quenching oil. Scale on work. Improper quenching medium. Surface decarburized.
Insufficient Hardness (below Minimum Required): Heating cycle, too short (under heating). Severity of quench, too low. Delay before quenching too long. Part not thoroughly quenched. Materials harden ability too low for quench. Surface decarburized.	**Distortion:** Shape of part or relation of portion to be hardened, to the rest of the section, not well adapted to flame hardening. Metallurgically unsuitable prior structure. Heating cycle too long. Non- uniform quenching. Non- uniform heating. Excessive rate of quench. Excessive materials harden ability.
Shallow Depth of Hardening: Low materials harden ability. Excessive rate of gas flow. Flame velocity too high. Short heating cycle too low. Severity of quench too low. Delay before quenching too long.	**Excessive Depth of Hardening**: Low flow rate of gas. Excess of fuel gas in flame. Flame velocity too low. **Excessive Scaling:** Heating cycle too long. Rates of gas flow, too low. Flame velocity too low. Delay before quenching too long. Improper arrangement of flame heads.

Investigation into the Causes and Process Quality

The next step in the investigation is to ascertain the process quality by plotting the control charts and to check whether the process is under statistical control. For this purpose Amit decided to use the x-bar and R charts, by dividing the 32 observations into 8 sub-groups

of 4 observations each. The control chart for averages and the control chart for the ranges are shown in Figure 5 and 6 respectively. It is clear from the charts that the process is under statistical control, as all the points are well within the three sigma limits. This means the process is under control but not able to control the defects being produced. This calls for the assessment of process capability and Amit and Murugan decided to explore the process capability analysis using the existing data.

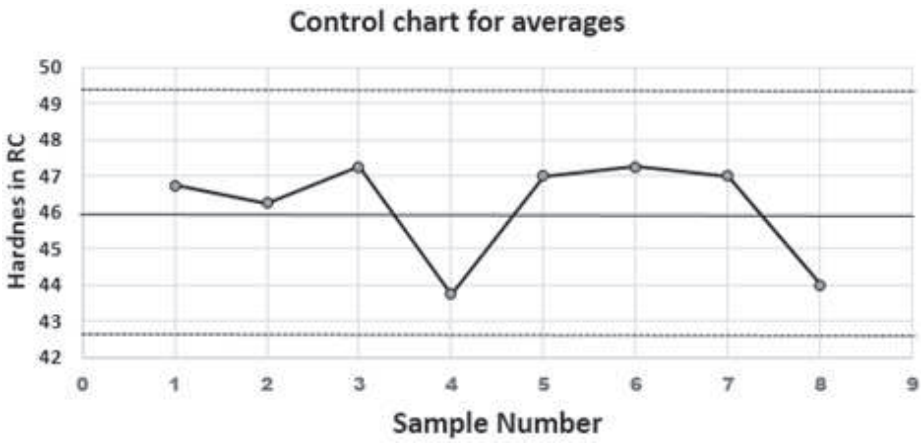

Figure 5 : The X-bar control chart

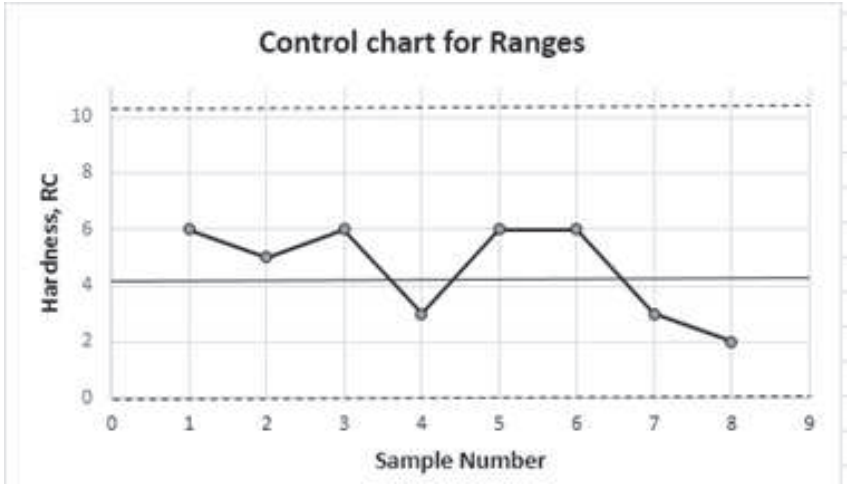

Figure 6 : The control chart for ranges – R chart

Process Capability Assessment

The number of observations available for analysis is 32 and hence Amit was wondering whether it is sufficient to conduct the analysis. Because, somewhere he had read that at least 50 observations would be required to analyze the process capability and draw better conclusion about the process. Murugan suggested they can also establish the sigma level of the process and find out how well the process is placed along the six sigma scale. This he felt would also impress Mr. Tayub as he would be able to comment on the process quality in the contemporary manner.

The process capability analysis results are shown in Table 3. Amit also collected data about the minimum acceptable values. The minimum expected value for Cp is 1.33 and any value less than 1.00 is considered as a very poor process. Further it was clear to Amit that the process is not properly centered. The sigma level of the process was fond to be 2.1 which renders the process as not acceptable.

Table 3 :
Process Capability Analysis Results

Process Capability Index	Notation	Estimated Value
Process Potential Index	Cp	0.40583
Scaled Distance Factor	K	0.38542
Process Performance Index	Cpk	0.24942
Taguchi Capability Index	Cpm	0.36740
DPMO (total rejects multiplied by a million)		272977.8271
Process Sigma Level		2.103831531

Review Meeting

Mr. Tayub along with Amit and Murugan carefully looked at the analysis report and started wondering. Is the heat treatment process poor and not capable of meeting the expectations? was the question in the mind of all the three present in the meeting. Finally, Murugan

suggested that they should now do something seriously to arrest the poor quality of the process. Obviously the questions was how to improve the quality such that the rejections would come down.

Amit intervened, "Sir, we cannot conduct actual experiments to test the capability of the process and I suggest we do something else to at least understand what needs to be done".

Tayub replied saying he has no objection for any such trials as the component involved is costly and hence any rejection will seriously pull down the profits.

Will the Simulated Test Help to Decide the Course of Action?

Amit was wondering as to should they move towards more detailed statistical analysis or they can go ahead with simple simulation model. More than the method, the real cause of concern was to reduce the number of rejections. Recalling the basics of quality control, Amit and Murugan decided to control the variation, but were not sure as to what should be the benchmark and what would be the corresponding improvement.

As a first step, the two decided to use the sigma scale to decide the first level improvement in standard deviation by reducing the variation. Accordingly using the goal seek function in Excel sheet, the first attainable target was set at 3 sigma level for the process and thus the standard deviation was found to be 1.23. Using this value Amit decided to run the simulation experiment and the results are shown in Table 4 for 20 samples of size 4. The values were simulated within the acceptable range of 42 to 48 RC with the average of 45 RC and a standard deviation of 1.23 RC. The simulated data had the process parameters as: process mean = 46.388, and process standard deviation = 1.311. The control charts when plotted did not show any out of control points and hence the process was considered as within control.

Table 4 :
Analysis of the Simulated Data

	Control Limits for X-bar Chart		Control Limits for R Chart
CL X-bar	46.388	CLR	2.700
UCL X-bar	48.354	UCLR	6.162
LCLX-bar	44.421	LCLR	0.000

CL = Center Line

UCL = Upper Control Limit

LCL = Lower Control Limit

In the next step, the process capability analysis was carried out and it was found that the process capability is inadequate based on the process capability indices. The rejects were estimated to be around 10%, that is, for every ten lathe beds produced, one bed would be out of specification limits.

Final or not Final Meeting

Amit and Murugan discussed the simulated results with Sundar, the heat treatment section chief and solicited his opinion. At that time Sundar told them that there are two critical variables within the flame hardening process that affect the hardness. The two variables happened to be the gap between the nozzle tip of the flame torch and the bed surface, and the speed of travel of the flame torch over the bed surface. While they were happy about the new discovery they realized that these two variables are not usually recorded because there used to be some manual interventions by the operators during the process. This means the variables were not set at the same level during the process of hardening as different beds used to be flame hardened, and thus the effect of these two variables on the hardness could not be ascertained, and Amit mentioned this to Murugan. So, our next step could be noting down the gap and the speed of travel for at least 10 lathes and then do a fresh analysis, the three concluded.

Next day, Amit, Murugan, and Sundar, waited for Tayub, and handed over a report containing all their findings.

Tayub asked "What do we do to reduce the defects. Any specific plan?"

Amit replied "We have succeeded in analyzing the situation, perhaps we have to continue for some more time, this method of manual adjustments to minimize the defects".

The others simply nodded their heads as they also could not conclude about the present situation.

References

Aichouni, M. (2012). On the use of the basic quality tools for the improvement of the construction industry: A case study of a ready mixed concrete production process. *Int. J. Civ. Environ. Eng*, *12*(5), 28–35.

Austrom, D. R., & Lad, L. J. (1986). Problem-Solving Networks: Towards a Synthesis of Innovative Approaches to Social Issues Management. *Academy of Management Best Papers Proceedings*, 311–315. http://doi.org/10.5465/AMBPP.1986.4980881

Behnam, B., & Alvelos, H. (2011). Exploring the Potential of Quality Tools in Tire Retreading Industry: a Case Study. *International Journal of Engineering Science and Technology*, *3*(6). Retrieved from http://www.researchgate.net/profile/Behnam_Bahmankhah/publication/228769281_Exploring_the_Potential_of_Quality_Tools_in_Tire_Retreading_Industry_a_Case_Study/links/0deec527a8d367672a000000.pdf

Chang, R. Y. (1993). *Continuous Improvement Tools Volume 1: A Practical Guide to Achieve Quality Results* (1 edition). Irvine, Calif: Practical Learning Press, a Division of Richard Chang Associates, Inc.

Defeo, J., & Juran, J. (2010). *Juran's Quality Handbook: The Complete Guide to Performance Excellence 6/e* (6 edition). New York: McGraw-Hill Education.

Dias, S., & Saraiva, P. M. (2004). Use Basic Quality Tools To Manage Your Processes'. *Quality Progress*, *37*(8), p47–53.

Escalante, E. J. (1999). Quality and productivity improvement: a study of variation and defects in manufacturing. *Quality Engineering*, *11*(3), 427–442.

Evans, J. E., & Lindsay, W., M. (2004). *The Management and Control of Quality* (6 edition). Mason, OH: South-Western College Pub.

Ishikawa, K. (1988). *What is Total Quality Control? the Japanese Way*. (D. J. Lu, Trans.) (1St Edition edition). Englewood Cliffs, N.J: Prentice Hall.

Kume, H. (1987). *Statistical Methods for Quality Improvement*. Tokyo: Productivity Press.

Magar, V. M., & Shinde, V. B. (2014). Application of 7 Quality Control (7 QC) Tools for Continuous Improvement of Manufacturing Processes. *International Journal of Engineering Research and General Science*, *2*(4), 364–371.

Mears, P. (1994). *Quality Improvement Tools & Techniques*. New York: McGraw-Hill Trade.

Montgomery, D. (2012). *Statistical Quality Control* (7 edition). Hoboken, NJ: Wiley.

Paliska, G., Pavletiæ, D., & Sokoviæ, M. (2008). Application of quality engineering tools in process industry. *International Journal Advanced Engineering,(ISSN 1846-5900)*, *2*(1), 79–86.

Sabet Azad, P., & Mokhlesi, R. (2009). Statistical Quality Control in Cable Industry Case Study: Copper Consumption Reduction in Nexans IKO Sweden. Retrieved from http://bada.hb.se/handle/2320/5497

Sarkar, A. (1998). Implementation of ISO 9000 in a textile mill. *Total Quality Management*, *9*(1), 123–131.

Sokoviæ, M., Jovanoviæ, J., Krivokapiæ, Z., & Vujoviæ, A. (2009). Basic quality tools in continuous improvement process. *Strojniški Vestnik-Journal of Mechanical Engineering*, *55*(5), 333–341.

Tague, N. R. (2005). *Quality Toolbox* (2 edition). Milwaukee, Wis: ASQ Quality Press.

Trehan, M., & Kapoor, V. (2011). TQM journey of an Indian milk-producing cooperative. *TQM Journal*, *23*(4), 423–434. http://doi.org/10.1108/17542731111139491

Wadsworth, H., Stephens, K., & Godfrey, B. (2001). *Modern Methods For Quality Control and Improvement* (2 edition). New York: Wiley.