Impact of Advanced Manufacturing Technology tool in Manufacturing Industry of Northern India-Reflective Practices

*Satnam Singh Kailey, **Talwinder Singh Bedi

*Business Development Manager, Guru Teg Bahadur Foundry, Punjab, India.
**Associate Professor, RIMT University, Mandi Gobindgarh, Punjab, India.

Abstract
Nowadays, every industry is focusing on high quality product for meeting customer demand. In competitive world, manufacturers are looking for high quality product for enhanced competitiveness. The survey followed by case studied has been performed to assess the effectiveness of questionnaire prepared from literature survey. This study has been carried out in the manufacturing industry of Northern India in order to reduce the rejections of the critical product under study using AMTs tool viz. SPC (Statistical Process Control) and analyzing different success factors, and benefits of AMTs using questionnaire survey. Z-test shows how AMT tool is helpful in improving the quality of the product and gain different benefits. Ranking of the different success factors is done by fuzzy AHP method. A thorough study of existing process revealed that the organization is facing the problem of rejection in Arm Chain Tensioner due to wearing of locating plate in the company under study. Results indicate reduction of rejection rate from 5% to .51% which leads to the net savings of rupees 45090.
Key words: AMTs, Manufacturing Industry and Rejection Rate.

1. Introduction

1.1 Introduction to AMTs

Advanced manufacturing technology (AMT) possesses significant charactertics to improve manufacturing operation in manufacturing scenario. It includes different strategies like computer numerical controlled, statistical process control. Robotics and computer aided design/ manufacturing etc. (Rao, 2007). It includes different strategies including structural changes and new technologies like just in time and total quality management. It also contains application of computer aided process planning (Young and Selto, 1991). AMTs include hard and soft technologies to improve the efficiency and effectiveness of manufacturing operations. It is claimed that AMT is an approach of setting goals and objectives for all round development. It also includes process control tools including SPC and quality control tools Mize (1987). The authors claimed that AMTs implementation framework includes manufacturing strategy in decision area. AMTs are helpful in design and manufacturing activities. It involves quality and maintenance activities (Hofmann and Orr , 2005).

1.2 Introduction to SPC

SPC is AMT tool that deals with reducing rejections, control of quality and targeted at continuous improvement of manufacturing operations. The variations in production operations can be easily measured using statistical technique. The variability and control of process quality can be measured by using SPC. Manufacturing companies are implementing advanced techniques like SPC to enhance the manufacturing operations by system simplification. Process variability can be measured using advanced manufacturing technology like SPC. Management of production system including SPC helps to identify and remove variability in the processes caused by chance causes variability and process causes variability. Process quality can be controlled by implementing SPC in a systematic manner (Cheng and Dawson, 1998). Effective utilization of material, machines and men is the part of operations and production management. SPC is the function of variability removal using simple to complex manufacturing system processes in industrial operations. The understanding of reasons for process and chance variability is must in implementing advanced technique like SPC (Rungtusanatham, 2001). It includes measurement of production and performance variability of machines and processes for enhanced competitiveness.

1.3 Introduction to Proposed Research

SPC is a process of measuring variability and monitoring the performances of a process in systematic manner leading towards managing in-process quality. Variation in manufacturing and assemble processes can be measured using SPC. SPC is capable of showing consistency for the long period of time due to its accuracy and removing rework and scrap. SPC shows consistency when the causes of variability are clear and root cause analysis is easily done. It aims at prevention of defects, delivery time, method attitude and material. Therefore Industries is applying SPC tools to enhance the performance of manufacturing operations. This study is an attempt to access the performance of SPC tool in an Industry of Northern India manufacturing sheet metal components.

The rest of the article is as follows: section 2 contains literature review, section 3 includes research methodology and design, section 4 contains introduction to the industry and setting of case study, section 5 contains results and discussion, section 6 contains economic analysis and section 7 contains conclusions and limitations of the study.

2. Literature Review

The authors studied performance parameters including productivity and quality improvement as a part of production design process. Production system performance is measured using SPC. Quality characteristics have been measured using sampling inspection and offline inspection. The error of 2.54 has been found, out of which 68% having error above 1%. The maximum error in the system is 0.1%. Production rates enhancement improves the quality information which leads towards control system responsiveness. In such situations, increase in machine efficiency and rejection reduction is possible *(Colledani and Tolio 2009)*. The authors implemented SPC to evaluate production system performance. The error in measurement is 2.84%. The error in the total system is 0.25%. Quality improvement is achieved by controlling the control system. Quality information is obtained by measuring control characteristics (quality characteristics). Further results indicated 2% reduction in quality rejection by implementing SPC tools in the systematic manner *(Joelianto and Kadursman, 2010)*. The authors applied SPC tools to improve treated water. The chlorine in residual form, aluminum in tanks is under consideration having been measured using SPC tools. Control limits as been determined using R chart. Turbidity has been measured in view of analyzing, checking and improving the quality characteristics. The coefficients including Cpk has been improved from 1.5 to 2, and Cp fro 1.2 to 1.8 *(Fauad and Mukkattash, 2010)*. The authors improved cap of quality from 1.025 to 1.25 in company manufacturing soap. Data was measured using R and X bar chart. Process measured was out of control. Various causes have been analyzed using cause and effect diagram. Reduction in rejections of 4% has been obtained by using process control tools. The process capability has been increased from .165 to .75. The charts helped to predict the root cause of the problem *(Mahesh and Prabhuswamy, 2010)*. The author reduced effects in foot step assembly, fender of radiator, and foot board assembly. 400 observations have been taken to measure quality characteristics and measure the variable characteristics. Root cause of the problem was measure using Ishikawa diagram. After implementing process control tools, rejection percentage has been reduced from 5.1% to 2% and process analysis has been performed which leads towards 0.928 improvement in process capability

(Prajapati, 2011). The author performed a case study of oil pump manufactured by automobile using SPC. R chart and X bar chart has been prepared using analysis of 2500 observations from grinder. First 1000 observations were seems to be ok as the values of Cpk and Cp are 0.28 and 0.49 but the remaining 1500 were out of control having Cpk and Cp values 1.75 and 1.85 respectively *(Dhinakaran et al., 2012)* The authors implemented SPC in tile manufacturing company manufacturing tiles. Defects in the tiles have been measured using R chart and six parameters were taken into consideration for analysis of the product. Process control tools were implemented to look into the machines and the process. Other technique of quality was applied in relation to X bar chart to reevaluate the process and quality was significantly improved *(Mostafaeipour et al., 2012)*. The author applied SPC tools in seals manufacturing industry. Ishikawa diagram was drawn to identify imperfections in the product manufactured. The drivers of improvement were measured using process control tools and measures are suggested based the study. 400 observations are taken and control charts were drawn for the underlying problem. Results indicated 0.0953 reductions in total rejections and from 9.1% to 5% *(Prajapati, 2012)*. They utilized SPC tools to control procedure of exhausting operation. Variable controls were utilized to capture procedure focusing and machine capacity. Procedure capability was measured using control charts for variables. Nonconforming quantity for particular period of time was checked using control charts. The value of Cpk has been improved from 0.97 to 1.12. Expansion process has been controlled. Changes in expansion process have been measured. Imperfections graph was drawn and main drivers are measured. Variability of the time in whole was also measured *(Raiyanshi and Belokar,* 2012). The author demonstrated the application of SPC in infusion molding. Infusion process was out of control while observing 300 parts. Capacity and information methodology was not stable. Temporary procedure was the root cause of the problem (quality related aspects). Disposal of wellspring was used to standardize the procedure and time of plasticizing. Variability of process parameters has biggest effect on methodology. Stability of the process is controlled by 25% and assembling process is controlled by process control tools. *Kanu (2013)*. The author explained the application of SPC in Lucas Indian Service for controlling, visualization of the process by selecting the sample randomly. The improvements were imposed using process control tools. The decision making technique has been applied to assess human effectiveness and getting results from the SPC charts. Further, advantages of implementing SPC and application have been ascertained to measure effectiveness *(Parkash et al., 2013)*. The authors studied the application of SPC in company manufacturing pipes. Defective rates were on the higher side. Lot wise

rejection of the product was there. Variability of the process was there and measured using SPC tools including P chart, C chart and R chart. The effects have been removed by controlling the expanding pressure in the machine. Circularity of the process as also been controlled by using process control tools *(Banker et al., 2014)*.

3. Research Methodology, Framework and Research Design

3.1 Research Methodology and Design

For this study, firstly questionnaire survey has been performed and then case study has been done to discuss practical application of the study. The measurement of different success factors has been done four point scale (4=To a great extent, 3=Reasonable well, 2=To some extent, 1=Not at all important) and benefits on (4=Extremely High Gain, 3=High Gain, 2= Reasonable Gain, 1=Nominal Gain) as shown Appendix. The questionnaire is tested for its accuracy and completeness by two experienced managers from multinational companies of northern India. Fuzzy AHP and z test helped to synthesized questionnaire with case study. The data base of the industry has been collected from directorate and confederation of Indian industry. Sample size for the survey is 45. The respondent to the survey includes managing directors, partners, managers, heads, senior engineers and engineers. The methodology for the proposed research is shown in figure 1.

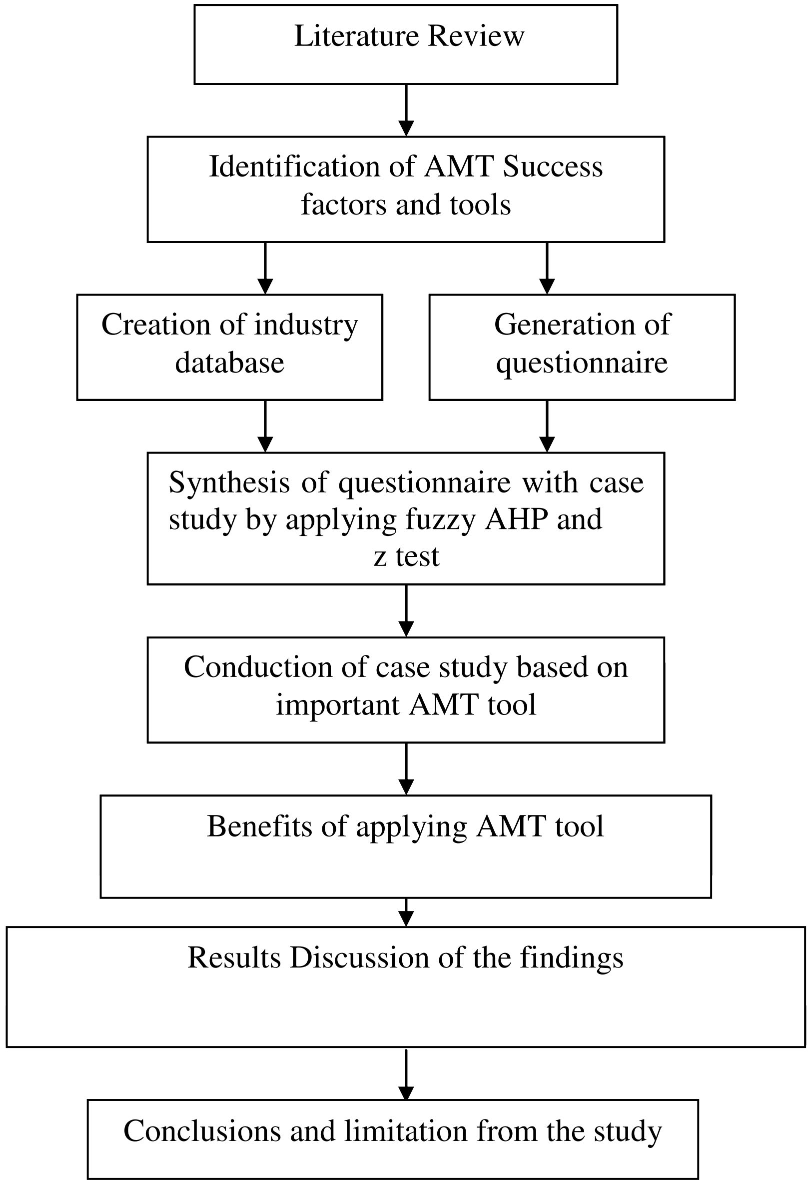

Figure 1: Research Methodology

Initially, Questionnaire has been prepared from literature review and database of Indian manufacturing industry has been created from confederation of Indian industry and Indian industrial directory. Framework has been prepared by applying multi criteria decision making approach from which three important issues are taken to conduct case study in manufacturing industry of northern India based on convenience sampling followed by snowball sampling.

3.2 Framework

3.2.1 Fuzzy AHP

The values in the scale of relative importance are crisp numeric values like 1,3,5,7,9 etc. in fuzzy these crisp numeric values are converted into fuzzy number. Table 1 shows fuzzy value and fuzzy values.

Table 1. Fuzzy values assigned to the different crisp variables

Number & Fuzzy value	**Reciprocal Number & Fuzzy value**
1=1,1,1	1/2=1/3,1/2,1
2=1,2,3	1/3=1/4,1/3,1/2
3=2,3,4	1/4=1/5,1/4,1/3
4=3,4,5	1/5=1/6,1/5,1/4
5=4,5,6	1/6=1/7,1/6,1/5
6=5,6,7	1/7=1/8,1/7,1/6
7=6,7,8	1/8=1/9,1/8,1/7
8=7,8,9	1/9=1/9,1/9,1/9
9=9,9,9	

Table 2: Pair-wise Decision Matrix

AHP Decision Matrix with Fuzzy Numbers							
AMT Criteria	AMTI	TM	TBA	ETI	OF	IPA	EPA
AMT Issues	1,1,1	1/2,1/3,1/4	3,4,5	1/3,1/4,1/5	2,3,4	3,4,5	5,6,7
Top Management	4,3,2	1,1,1	4,5,6	2,3,4	2,3,4	4,5,6	4,5,6
Team Based Activities	1/5,¼,1/3	1/6, 1/5,¼	1,1,1	1/2,1/3,1/4	1,1,1	2,3,4	3,4,5
Education, Trainings & Incentives	5, 4,3	1/4, 1/3,½	4,3,2	1,1,1	2,3,4	2,3,4	3,4,5
Organizational Factors	¼,1/3,½	1/4, 1/3,½	1,1,1	1/4, 1/3,1/2	1,1,1	2,3,4	3,4,5
Internal Planning Activities	1/5, 1/3,¼	1/6, 1/5,¼	1/4,1/3,1/2	1/4, 1/3,1/2	1/4, 1/3, 1/2	1,1,1	2,3,4
External Planning Activities	1/7,1/6,1/5	1/6, 1/5,¼	1/5,1/3,1/4	1/5, 1/3,1/4	1/5, 1/3,1/4	1/4,1/3, 1/2	1,1,1

Table 3: Geometric means of fuzzy comparison values

AMT Criteria	**Geometric means**		
AMT Issues	1.39	1.51	1.61
Top Management	2.44	2.97	3.34
Team Based Activities	0.72	0.79	0.88
Education, Trainings & Incentives	1.63	1.74	1.79
Organizational Factors	0.53	0.65	0.85
Internal Planning Activities	0.32	0.42	0.59
External Planning Activities	0.24	0.28	0.35

Table 4: Averaged and normalized relative weights of criteria

AMT Criteria	**Weights**		
	Average	**Normalized**	**Ranking**
AMT Issues	0.18	0.18	**3**
Top Management	0.36	0.35	**1**
Team Based Activities	0.10	0.10	**4**
Education, Trainings & Incentives	0.21	0.20	**2**
Organizational Factors	0.08	0.08	**5**
Internal Planning Activities	0.06	0.05	**6**
External Planning Activities	0.04	0.04	**7**

In this research, Fuzzy - AHP methodology has been applied to provide rank to the performance indicators. The result of Fuzzy – AHP method showed that top management has scored 0.35 in terms of relative closeness and placed at rank 1 after that education, training and incentives placed at rank 2 and AMT Issues factor come at number 3. The output showed that external planning activities are least important in present work and placed at 7^{th}rank depends upon the value of normalized weights.

3.2.2 z-test to the benefits of AMTs

In order to assess the benefits, z test has been applied to the questionnaire. The measurement of each scale is done on four point scale. Important benefits in terms of quality have been found out. The values of z stat have been calculated using Microsoft Excel 2007 version. Table 5 shows values of z stat.

Table 5 z-test

Benefit in terms of quality	**Mean**	**Standard Deviation**	**z-stat**
Reduced customer complaints and reducing rejection	3.0167	0.9437	11.802*
Effective utilization of quality tools	2.875	0.8596	6.0534*
Reduced Scrap and rework	2.25	0.7697	3.558*
Reducing operator mistakes	2.6583	0.7503	9.6117*
Reduction in percentage defectives	2.775	0.7386	11.494*
Improving work life quality	2.45	0.7543	6.5356*
Z critical (0.05) = 1.96 Z critical (0.01) = 2.58		*Significant at 5% level	

Results indicate that reducing customer complaints and rejections and effective utilization of QC tools shows highest mean among all benefits and all are significant at 5% interval. SPC tool is implemented to capture and synthesized the research survey with practical application in the case company under study.

Rejections reduction is closely related to SPC (statistical process control) tools. Effective utilization of QC tools (second rank) is elaborated in the case study.

4. Introduction to the Industry and case study settings

XYZ company was established in 1985 under prompt leadership. The characteristics include corporate culture and sound business practices done in the company. Core strength of the company includes dedication, knowledge and values for every people. Manufacturing of different product is the main capability of the company. Dedication and Enthusiasm is the cause of major concern to meet level of competences. XYZ company is adopting AMTs including SPC using management principles. New Swan Enterprises a manufacturing arm chain tensioner for Honda motorcycle and scooter pvt. Ltd. The industry faces problem of high rejection rate of Arm Chain Tensioner. The production of Arm Chain Tensioneris approximately 100640 pieces per month. November 2023 data show that rejection rate is increased up to 5%. The cost almost above doubles due to rejection. To handle the problem Statistical Process Control has been proposed to be implemented on this product. So, the main focus of present research work is to implement a most important tool for analysis a problem than improving the quality of Arm Chain Tensioner. New swan enterprises manufacturing near about 200 separate component, but some of them are critical component on the basis of their part rejection cost. For focusing the most critical component out of these, November 2023 data was taken for the analysis that is show in Table 6.

Table 6. Rejection cost of Arm Chain Tensioner for November 2023

Component name	Total component	No of defective component	Cost per component	Total cost	% age
Arm chain	100640	5032	10	50320	5%

5 Results and Discussion

5.1 Top Management Support (TMS)

Top management positively influences the synergy between technology and organizational structure. Organizational structure is greatly affected by implementation of AMT success factors in systematic manner to achieve different including productivity, quality, cost and safety. In the present study, projects done in the case company are greatly influenced by top management support in terms of money investment in the small incremental improvement or continuous improvement. TM has been considered as important in implementing AMT activities in the firm is from constant support from top management support. Quality improvement projects are enhanced using continuous support from top management.

5.2 Education, Training and Incentives

Full knowledge of AMT implementation procedure is needed to implement AMT success factor in a systematic manner. Training has been imparted to every employees regarding implementation of AMT tools. Quality related aspects of product are the cause of major concern in the company under study. Incentive scheme like best KAIZEN done by the employees has been started. Training imparted improves the technical skills of the employees; spreads good knowledge about implementing all tools of AMTs. Incentive scheme encourages employees to involve in improvement activities to capture the needs of the company.

5.3 Identification of the problem (rejections and cost of rejection)

XYZ company manufactures near about 200 different component, but some of them were critical component on the basis of their past rejection costs. For focusing the most critical component out of these, November 2023 data was taken for the analysis i.e. the month as shown below table 7.

Table 7. Component wise rejection cost in November 2023

S.NO	Product Name	Total quantity production	No. of defective product	Cost per product	Total cost	%age
1	Arm chain	100640	5032	10	50320	98.13%
2	Bracket	8674	23	13	299	.39%
3	Spring Clamps	5109	15	6	90	.17%
4	Brake Rod	3897	21	8	168	.32%
5	Filter	830	2	100	200	.39%
6	Seat Catch	513	1	200	200	.39%
Total					51277	

After constructing the table, it was found that Arm Chain Tensioner was contributing 98.13%of the total rejection and remaining all components 1.87% were very low as compeer to Arm Chain Tensioner cost. So this was the only component that should be concentrated and it was very important to analyze the cause's rejection.

5.4 Identification of the defect

After the identification of critical component the next step was to identify the defects occurred in Arm Chain Tensioner component. In Arm Chain Tensioner defectives pieces due to it dimension were 4964 out of 5032, due to Bur were 47 out of 5032 and due to other defects were 21 out of 5032. On the basis of November 2023 month data following defects were found:

Table 8. Raw Data Based on Month of November 2023

S.no	Defects	Frequency	%age rejection
1	Dimension 9.90-.1	4964	98.64%
2	Bur	47	.93%
3	Other defects	21	.41%

Figure 2. Picture of Arm Chain Tensioner

5.5 Identification of critical quality characteristics

Critical quality characteristic is the quality feature which must be controlled to avoid rejection. After the selection of component the next step was to find out the critical characteristics on the basis of %age contribution of particular quality characteristics for the rejection of the component. Pareto analysis was done to find out the critical quality characteristic. The pareto analysis of defect is shown in Figure 3.

Table 9. Arm Chain Tensioner data for Pareto analysis

Rank	Defects	%age count (Rejection)	Cumulative
1	Dimension 9.90-.1	98.64%	98.64%
2	Due to burr	.93%	99.57%
3	Other defects	.41%	100%

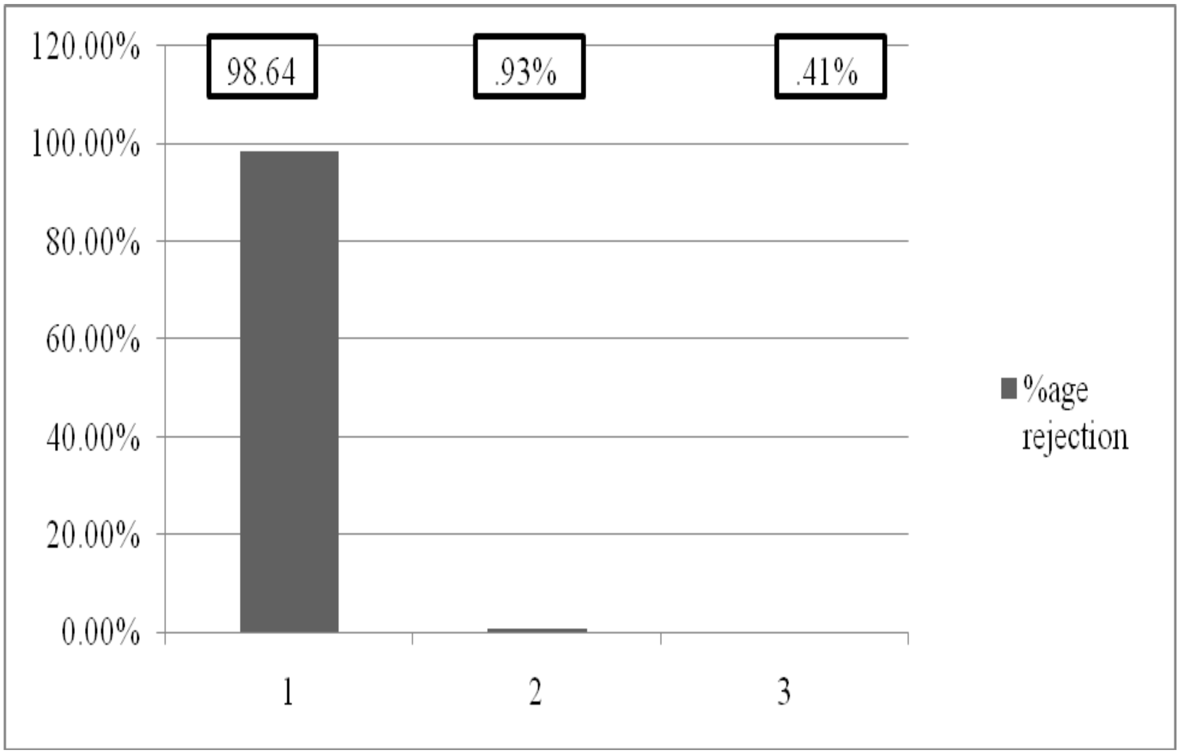

Figure 3. Pareto analysis of defect

After thorough analyzing the Pareto Chart it was found that defect due to variation of dimension 9.90-.1mm had more frequency, so that was the main contributing for rejection. That defect was the main concentration of study, so by reducing that defect quality of the component could be improved.

5.6 Data collection before improvement

Data from the ongoing process was collected. The sample size taken as 5 and the frequency of sample was half an hour. After finding the critical characteristic next step was to select the appropriate control chart. The outcome was X bar and R chart are suitable for critical characteristic due to following reason:

- The outcome of the critical parameter was quantitative value.

- More than 9 subgroup size taken.

Data was measured with a help of Vernier Caliper, so the check sheet for dimension 9.94 -.1mm is shown in Table 10 as follows:

Table 10. Check sheet for X bar and R chart

Sub Group	sample					SUM	X BAR	RANGE (R)
1	9.93	9.94	9.91	9.92	9.89	49.59	9.918	0.05
2	9.93	9.94	9.92	9.93	9.95	49.67	9.934	0.03
3	9.93	9.94	9.93	9.92	9.94	49.66	9.932	0.02
4	9.91	9.91	9.91	9.94	9.94	49.61	9.922	0.03
5	9.91	9.94	9.92	9.92	9.95	49.64	9.928	0.04
6	9.93	9.94	9.89	9.94	9.94	49.64	9.928	0.05
7	9.93	9.94	9.92	9.94	9.93	49.66	9.932	0.02
8	9.94	9.93	9.91	9.95	9.92	49.65	9.93	0.04
9	9.91	9.89	9.91	9.94	9.94	49.59	9.918	0.05
10	9.93	9.94	9.89	9.91	9.93	49.6	9.92	0.05
11	9.93	9.94	9.92	9.92	9.92	49.63	9.926	0.02
12	9.93	9.94	9.92	9.94	9.91	49.64	9.928	0.03
13	9.93	9.94	9.93	9.93	9.93	49.66	9.932	0.01
14	9.92	9.89	9.91	9.95	9.94	49.61	9.922	0.06
15	9.94	9.94	9.92	9.94	9.91	49.65	9.93	0.03
16	9.92	9.94	9.92	9.94	9.93	49.65	9.93	0.02
17	9.92	9.94	9.92	9.94	9.94	49.66	9.932	0.02
18	9.89	9.91	9.91	9.94	9.94	49.59	9.918	0.05
19	9.93	9.94	10.02	9.94	9.92	49.75	9.95	0.05
20	9.92	9.92	9.92	9.92	9.93	49.61	9.922	0.01
21	9.93	9.94	9.92	9.91	9.91	49.61	9.922	0.03
22	9.95	9.94	9.92	9.92	9.94	49.67	9.934	0.03
23	9.93	9.94	9.92	9.94	9.93	49.66	9.932	0.02
24	9.91	9.91	9.91	9.91	9.94	49.58	9.916	0.03
25	9.89	9.93	9.94	9.91	9.95	49.62	9.924	0.06
Total							248.18	0.85

Calculation for control limit

Average ($\bar{\bar{x}}$) = Total of bar / 25 = 248.18 /25 = 9.9272

Range $(\bar{R})$ =Total of R / 25 = .85 / 25 = 0.034

For X bar chart :

Upper control limit (UCL)

$\bar{\bar{x}} + A_2 \bar{R}$ =9.9272 + 0.577*0.034 = 9.94682

Lower control limit (LCL)

$\bar{\bar{X}} - A_2 \bar{R}$ =9.9272 - 0.577*0.034 = 9.90758

For R chart :

Upper control limit (UCL)

$D_4 \bar{R}$ = 2.114*0.034 = 0.07188

Lower control limit (LCL)

$D_3 \bar{R}$ =0 * 0.0304 = 0

The X bar and R Chart for the problem is shown in Figure 4 and Figure 5.

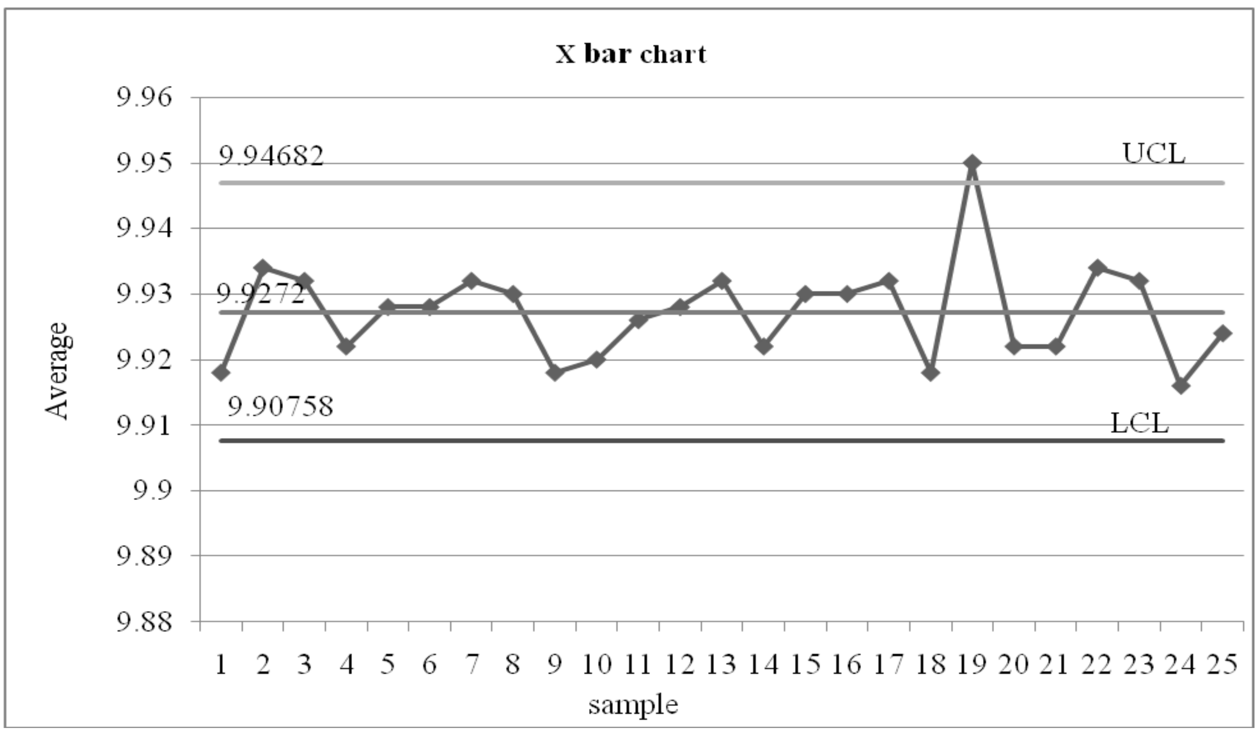

Figure 4. X bar chart

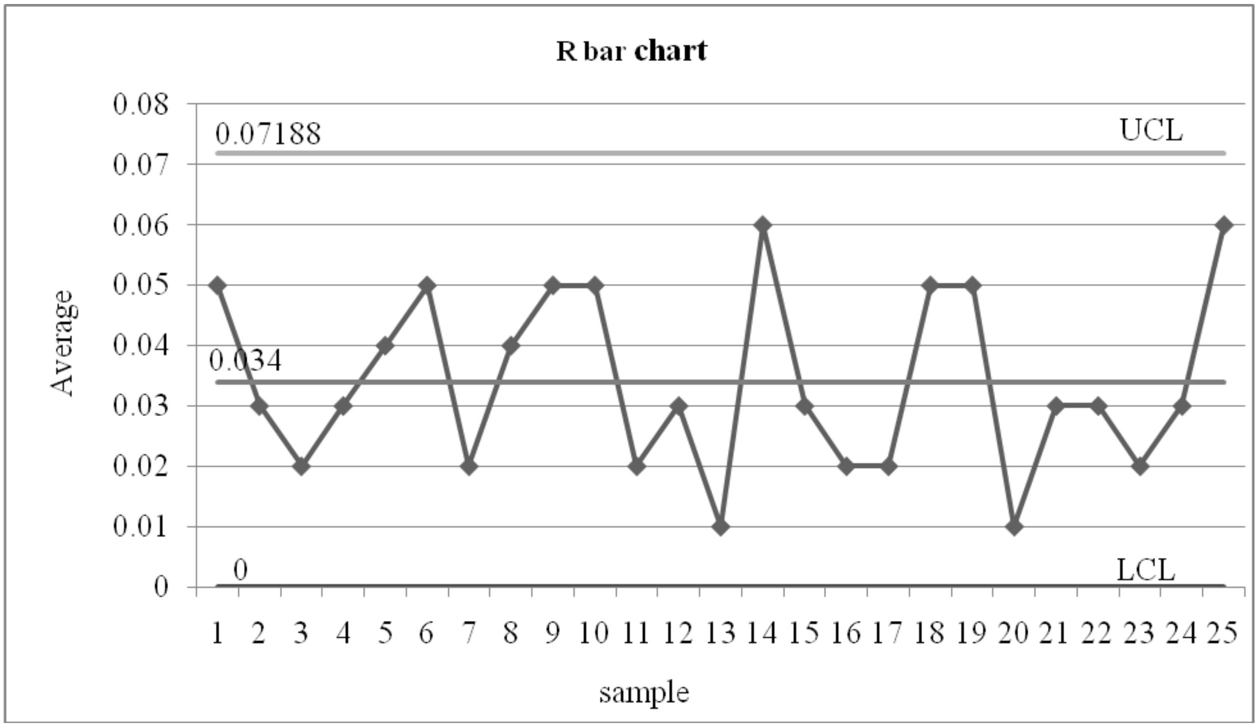

Figure 5. R chart

5.7 Interpretation of control chart

After calculation and plotting a graph from above calculation chart for range was drawn and it was found that all the points were within the limits. After analysis the X bar chart it was found that point 19 was above the UCL. Which means the process was not smooth. So, the process was out of control.

Root Cause analysis

The root cause of the problem in terms of 4M's is analyzed using Ishikawa Diagram as shown in Figure 6.

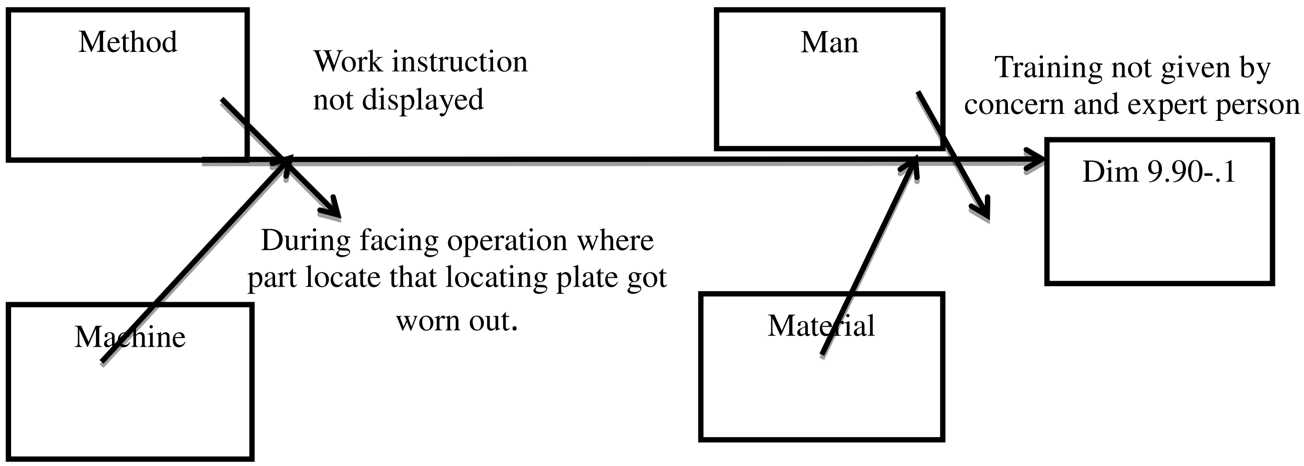

Figure 6. Ishikawa cause effect diagram for rejection of Arm Chain Tensioner

Method

- Work instruction not displayed.
- Frequency of locating plate change after 50000 pcs.

Machine

- During facing operation where part locate that locating plate got worn out.

Man

- Training not given to concern person.
- Not clean the locating plate.

Improvements done in the existing process

- For the improvement of the process, change the method of inserting pieces in it.
- Work instruction display.
- Brush the locating plate.
- Change the material of the plate (more hard).
- Change frequency of locating plate after every 10000 pieces.

5.8 Data collection after improvements

After improving the root cause of the problem in the rejection of product, again reading are taken at facing operation on check sheet. Data was measured with a help of Vernier Caliper, so the check sheet for dimension 9.94 -.1mm is shown in Table 11 as follows:

Table 11. Check sheet after improvement for X bar and R chart

Sub Group	sample					SUM	X BAR	RANGE (R)
1	9.85	9.86	9.85	9.88	9.89	49.33	9.866	0.04
2	9.85	9.85	9.88	9.86	9.87	49.31	9.862	0.03
3	9.91	9.87	9.88	9.86	9.86	49.38	9.876	0.05
4	9.85	9.88	9.87	9.84	9.85	49.29	9.858	0.04
5	9.88	9.84	9.89	9.86	9.88	49.35	9.87	0.05
6	9.88	9.85	9.84	9.88	9.89	49.34	9.868	0.05
7	9.86	9.85	9.83	9.84	9.9	49.28	9.856	0.07
8	9.85	9.88	9.89	9.87	9.88	49.37	9.874	0.04
9	9.85	9.91	9.84	9.86	9.89	49.35	9.87	0.07
10	9.88	9.87	9.86	9.83	9.86	49.3	9.86	0.05
11	9.84	9.89	9.84	9.87	9.88	49.32	9.864	0.05
12	9.84	9.86	9.84	9.88	9.86	49.28	9.856	0.04
13	9.91	9.84	9.87	9.86	9.88	49.36	9.872	0.07
14	9.84	9.85	9.86	9.88	9.85	49.28	9.856	0.04
15	9.84	9.85	9.85	9.84	9.89	49.27	9.854	0.05
16	9.88	9.87	9.89	9.89	9.84	49.37	9.874	0.05
17	9.85	9.88	9.85	9.86	9.87	49.31	9.862	0.03
18	9.84	9.85	9.89	9.86	9.9	49.34	9.868	0.06
19	9.85	9.86	9.87	9.87	9.84	49.29	9.858	0.03
20	9.85	9.88	9.87	9.86	9.85	49.31	9.862	0.03
21	9.84	9.85	9.88	9.86	9.85	49.28	9.856	0.04
22	9.87	9.85	9.87	9.88	9.86	49.33	9.866	0.03
23	9.87	9.86	9.92	9.85	9.87	49.37	9.874	0.07
24	9.85	9.89	9.9	9.86	9.86	49.36	9.872	0.05
25	9.86	9.85	9.87	9.92	9.86	49.36	9.872	0.07
Total							246.62	1.2

5.9 Calculation for control limit

After taking reading again calculate Average ($\bar{\bar{x}}$) and Range ($\bar{R}$) and then calculate lower control limit (LCL) and upper control limit (UCL).

Average ($\bar{\bar{x}}$) $= \bar{\bar{x}}/25 = 246.626/25 = 9.86504$

Range ($\bar{R}$) $= R/25 = 1.2/25 = 0.048$

For X bar chart:

Upper control limit (UCL)

$\bar{\bar{x}} + A_2 \bar{R} = 9.86504 + 0.577 * 0.048 = 9.89274$

Lower control limit (LCL)

$\bar{\bar{x}} - A_2 \bar{R} = 9.8516 - 0.577 * 0.0552 = 9.83734$

For R chart :

Upper control limit (UCL)

$D_4 \bar{R} = 2.114 * 0.048 = 0.10147$

Lower control limit (LCL)

$D_3 \bar{R} = 0 * 0.0552 = 0$

After calculations a graphs are plotted between lower control limit (LCL) and upper control limit (UCL) in R chart and X bar chart as shown in Figure 7. and Figure 8.

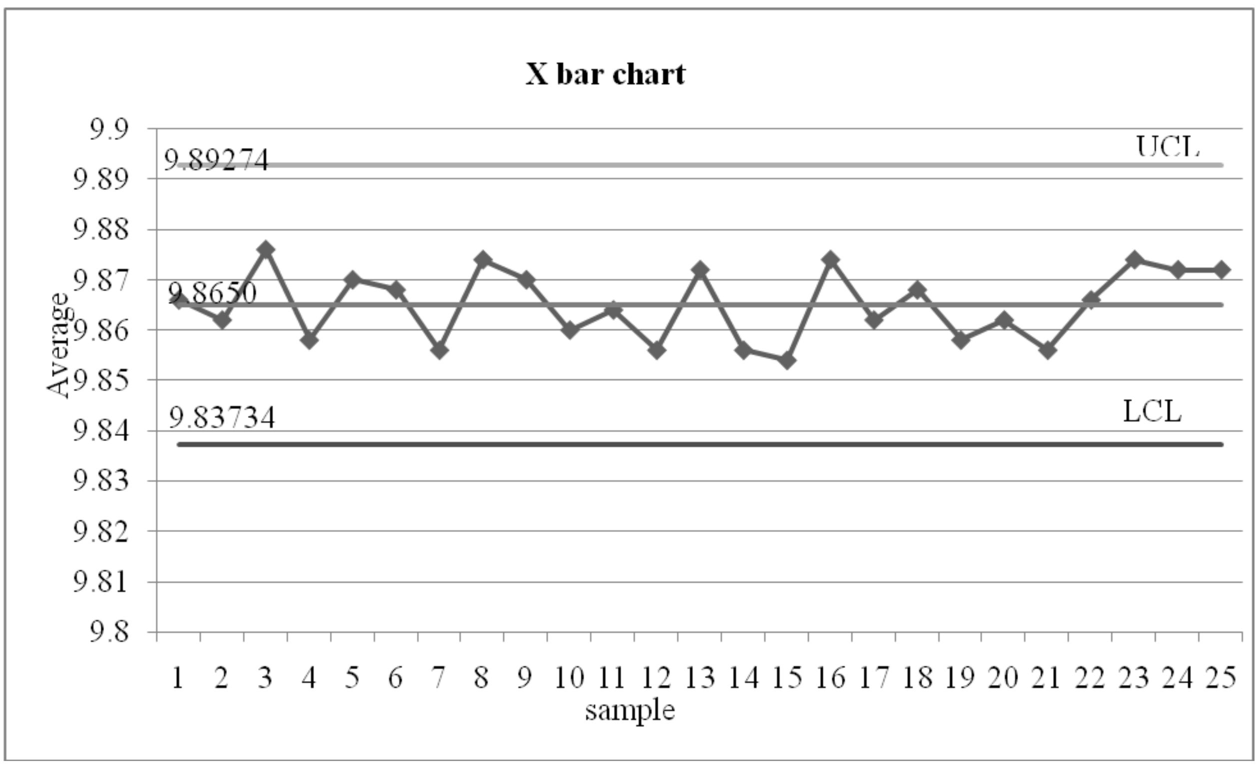

Figure 7. X bar chart

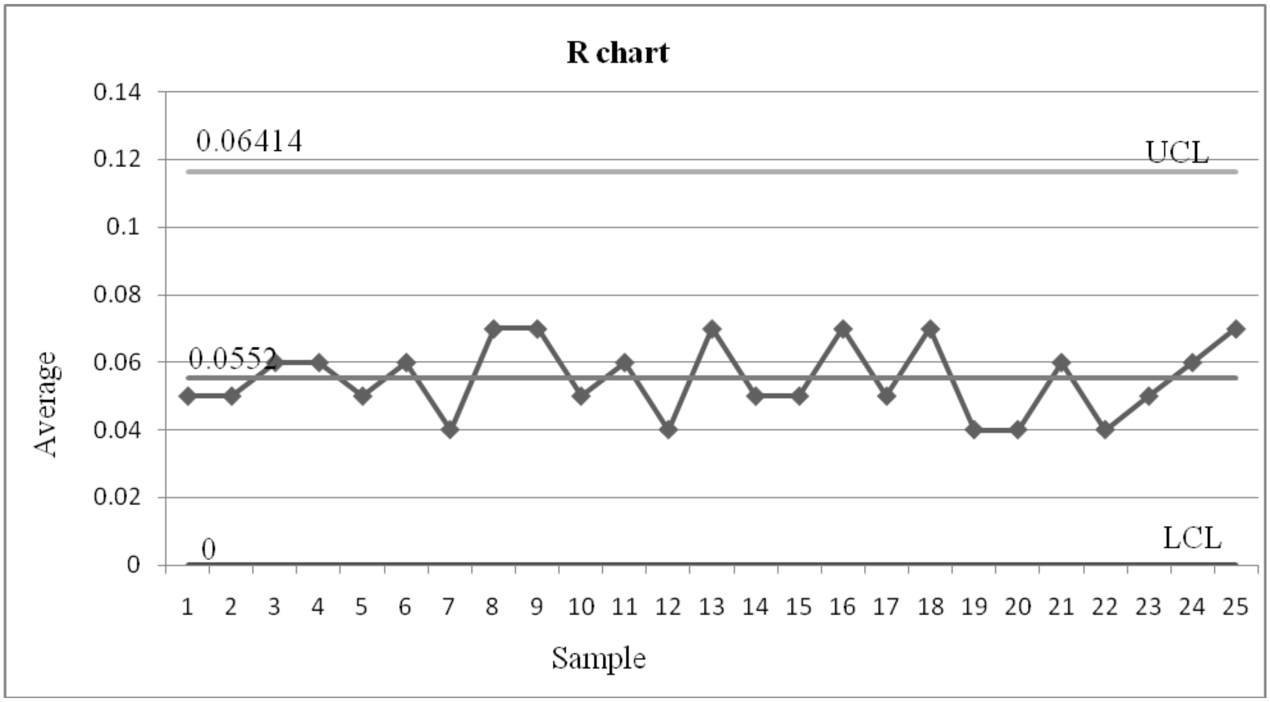

Figure 8. R chart

5.10 Interpretation of control chart

After plot a graph between lower control limit (LCL) and upper control limit (UCL) in R chart and X bar chart. It was found that all the point in X bar and R chart were within limits. So in facing operation dimension 9.90-.1 was with in control limits.

6. Economic analysis

It shows in R chart all points were within limits range of the process was in control and in X bar chart all points were within limits so process was in control. So after implementing statistical process control the process was in control. Rejection of Arm Chain Tensioner in Dec 2023 was .51%.

- In November 2023 rejection of Arm Chain Tensioner was 5%. So 5032 pieces were rejecting and total cost of rejection for Arm Chain Tensioner was Rs50320.
- In December 2023 rejection of Arm Chain Tensioner was .51%. So523 pieces were rejecting and total cost of rejection for Arm Chain Tensioner was Rs5230.

Table 12. Rejection cost of arm chain for Dec2023

S. No	Product name	Total quantity production	No of defective component	Cost per component	Total cost rejection
1	Arm chain	100765	523	10	5230

Rejection of Arm Chain Tensioner in November 2023 = 5032 pieces
Cost per component = Rs10
5032 *10 = Rs50320
Rejection of Arm Chain Tensioner in December 2023 = 523 pieces
Cost per component = Rs10
523 * 10 = Rs5230
Rejection reduced in December 2023 = 5032 – 523 = 4509
Saving in December 2023 = 4509 *Rs10
Net Saving = Rupees 45090

7. Conclusions and Limitations

The present study demonstrate the application of AMT tools viz. top management support, training, education and incentives, and SPC tool viz. X bar and R chart for its justification towards performance improvement by achieving different benefits in terms of reducing rejection and customer complaints. With the implementing of statistical process control viz. tool control chart, facing process become stable and rejection of Arm Chain Tensioner as been reduced from .51% from 5%. The control procedure of current manufacturing system processes has been studied before analyzing charts and appropriate preventive and corrective action have been taken to ascertain the benefits occurred. The procedure also includes correct interpretation of control charts and economic analysis. The rejection loss has been reduced by 89.60%. Economic analysis show that after implementing SPC, loss due to rejection of Arm Chain Tensioner become Rs5230 from Rs50320, reduced by 89.60% and net saving of INR 45090 have been achieved. SPC tools significantly aimed at improving the process cost associated with manufacturing operations. The selection of manufacturing Industry is based on convenience sampling technique. Defective part per million for the critical product can also be detected. The study can be extended to reduced rejection of bur defect in Arm Chain Tensioner.

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