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Research Article

Application of Six-Sigma Methodology in SSI: A Case Study

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Abstract

Six-sigma is a business-driven, multi-faceted approach to process improvement, reduced costs, and increased profit and this methodology application in SSI a big change in industrial field. The purpose of this paper is to find the implication of applying six-sigma methodology in SSI, taking a specific case of Hydraulic jack manufacturing industry. It helps to improve quality of product and cost saving. From the literature, this paper help to improve the six-sigma area of application in all types of organization, six-sigma application in Hydraulic jack manufacturing industry in SSI environment. Methodology adopted is DMAIC which is help to reduce the rejection rate of pump head of hydraulic jack set by removing error in process & method of operation. Statistical techniques Gauge R & R method, two sample test, Factorial method, control charts, Process capability analysis before & after application of six-sigma used. Six-sigma mainly implemented in large scale industries, but in this paper six-sigma methodology application in Hydraulic jack manufacturing unit a SSI to improve profit and control high rejection rate of pump head of hydraulic jack set. Application of six-sigma in SSI helps to improve Z-bench Sigma level from 2.21 sigma to5.64 sigma and cost saving of 0.01929 million/annum.

Keywords: *Six-sigma, SSI, DMAIC methodology, Manufacturing Industry.*

1. Introduction

Six-sigma is a business-driven, multi-faceted approach to process improvement, reduced cost & increasing profits. With a fundamental principal to improve customer satisfaction by reducing defects, its ultimate performance target is virtually defect-free processes and products (3.4 defective parts per million). Within this improvement framework, it is the responsibility of the improvement team to identify the process, the definition of defect, and the corresponding measurements. Six-sigma originated at Motorola in the early 1980s in response to a CEO driven challenge to achieve tenfold reduction in product failure level in five years, its application has been principally within large manufacturing companies and the question therefore remains how best to apply Six Sigma elsewhere, especially in small and medium scale enterprises. Technical detail, the primary goal of six sigma is to improve customer satisfaction, and thereby profitability, by reducing & eliminating defects. Although six-sigma has been implemented with success in many large corporations, there is still less documented evidence of its implementation in smaller organisations. Due to growing importance of supply chain management issues in global market environment, large firms are heavily dependent on small & medium scale Industries for the provision of high quality products and/or services at low costs. The increasing demand for high quality products and highly capable business processes by large organisations has left no choice on the Small scale & medium scale industries to consider the introduction of six-sigma business strategy. SSIs are the life-blood of modern economies. The importance of SSIs to the economy of the industrialised world as a whole cannot be over emphasised. It was proclaimed as a new approach to improving quality through statistical measurements and benchmarking. Despite the apparent popularity of Six Sigma, very little is known about the extent to which Six Sigma has actually been adopted by various firms in the India. The contribution of small scale industries (SSI) to the Indian economy cannot be ignored. SSI sector is strategically placed in the industrial population of the country and in the global economy as whole. The increasing demand for high quality products and highly capable business processes by large organizations has left no choice for the SSI except to consider the introduction of six sigma business strategy. To meet this new set of business needs, organizations need to deploy tools, which can enable them to remain competitive and grow in the increasing digital age (Burton 2004). Six-Sigma has been implemented with success in many large corporations and there are very few documented evidences of its implementation in smaller organizations. Each organization will have its own

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strengths and difficulties, some of which may only become apparent during the implementation of the Six Sigma improvement drive. One of the major advantages of Six Sigma as an improvement drive is the ability to introduce a common metric of customer-perceived quality, which should be applicable to any size and type of organization. As small companies are more agile, it is much easier to buy-in management support and commitment as opposed to large organizations. Moreover, small companies do not have the slack to free up top talented people to engage in training followed by execution of Six Sigma projects as they are crucial to the day-to-day operations and problem solving within the company. Linking compensation to Six Sigma implementation

2. Research Background

Jiju Antony and Maneesh Kumar, Christian N. Madu (2005) provide an analysis of six sigma implementation in UK manufacturing SMEs and highlights the strengths and weaknesses associated with SMEs

Darshak A. Desai(2006), attempt to introduce Six Sigma to small scale sectors. The paper discusses the real life case where Six Sigma has been successfully applied at one of the Indian small-scale units to improve one of the core processes.

Jiju Antony (2008) presents the viewponts from a number of leading practitioners and academics on the subject Can Six Sigma be effectively deployed in small and medium-sized enterprises (SMEs).

Prabhakar Kaushik and Dinesh Khanduja, Kapil Mittal, Pawan Jaglan (2008) apply Six Sigma methodology over the SMEs, the study could be a paradigm initiative towards high quality products and services at low cost for every SME. Application of Six Sigma project recommendation brought up the process sigma level to 5.46 from 1.40 by reduction in bush diameter variation in the process of bicycle chain bush manufacturing unit.

Pawan Jaglan, Parbhakar Kaushik , Dinesh Khanduja (2011) Six-sigma a road map for SMEs & contribution of small scale industries to the Indian economy cannot be ignored as this sector is strategically placed in the industrial population of the country and in the global economy as a whole.

Rajeshkumar U. Sambhe (2012) focus on a case of provoked mid-sized auto ancillary unit consisting of 350-400 employee and employed Six Sigma (SS) methodologies to elevate towards the dream of SS quality level. The methodology is executed on one of product assembly for trimming down defects level which are critical to customers and its implementation has had a significant financial hit on the bottom-line of the enterprise.

3. About the case study

The present study was carried out in Romac Hydro Industries, a SSI unit manufacturing hydraulic jack with separate pumping arrangement at Yamunanagar, Haryana (India).The main product of unit is Hydraulic jack from 50-200 Ton and its component are Hydraulic pump, Hose pipe, Pump head, Hydraulic jack ram & cylinder etc,as shown in figure1. Pump Head is a main component of hydraulic jack assembly because it helps to connect hydraulic pump to jack cylinder through hose pipe.

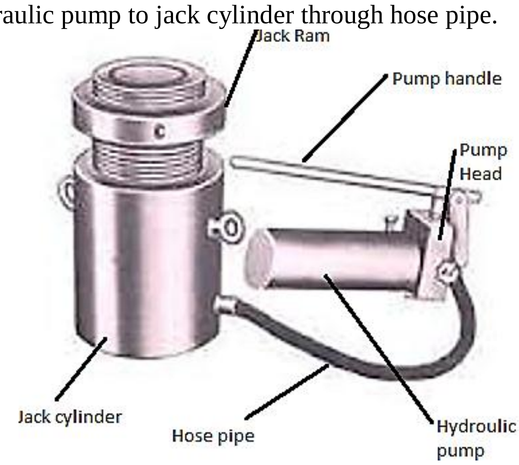

Fig.1. Hydraulic jack with separate pumping arrangement

Pump handles help to press fluid inside the hydraulic jack cylinder under pressure. In this arrangement pump handle press the plunger and plunger press the fluid in forward direction to lift the jack ram. The tolerance limit of plunger hole diameter is 11.98-12.02 mm. From the observation very high rejection rate in hydraulic jack due to variation in plunger hole diameter. So by six sigma methodology rejection rate of pump head due to plunger hole diameter variation reduced.

4. Application of six sigma DMAIC methodology

The DMAIC approach is designed to allow for flexibility and iterative-work, if necessary. As more is learned through the 5-step process, assumptions or hypotheses as to the root cause of the problem may be disproved, requiring the project team to revisit them and modify or to explore

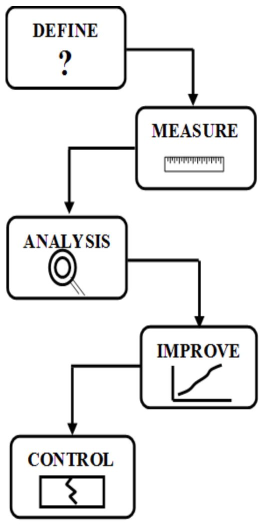

Fig.2 DMIAC Methodology adopted

alternative possibilities. The DMAIC methodology uses a process-step structure as shown in figure 2. Steps generally are sequential; however, some activities from various steps may occur concurrently or may be iterative. Deliverables for a given step must be completed prior to formal gate review approval. Step Reviews do occur sequentially. The DMAIC five steps are: Define, Measure, Analyze, Improve and Control (DMAIC) has been successfully implemented to achieve the existing sigma quality level from 2.21 to 5.64 as explained below.

4.1 Define

In this step we define the specific problem and also find the customer requirement. In this step we follow the process flow from raw material to the finish goods. It can easily understand by process flow map & High level process flow map shown in fig. 3& 4.

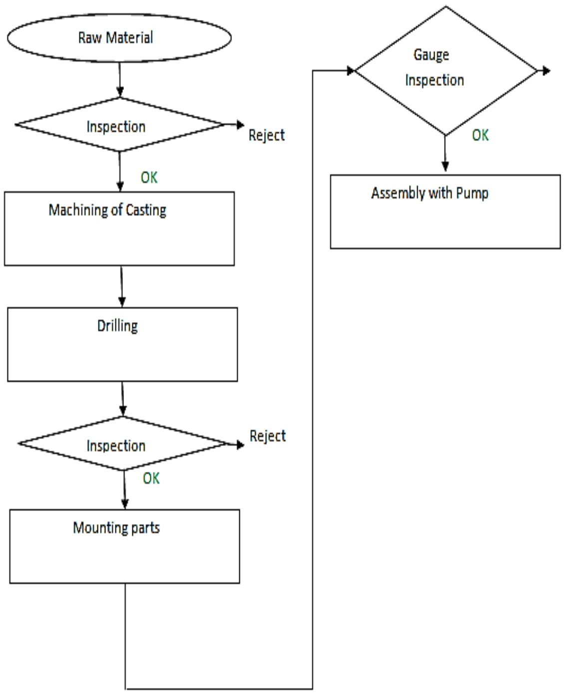

Fig.3 Process Map for Pump Head

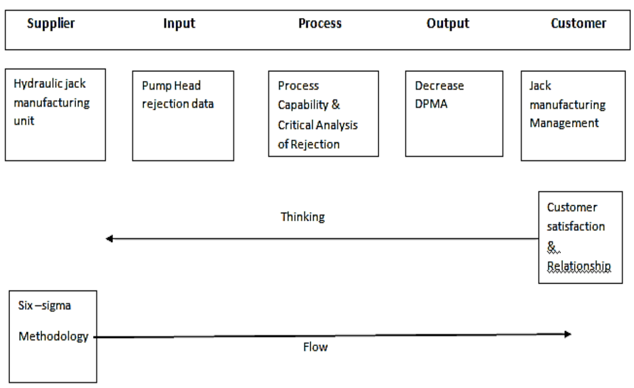

Fig.4 High level process flow map for Pump Head rejection

4.2 Measure

In this phase, a measurement system analysis is conducted which includes the Gauge repeatability and reproducibility (Gauge R&R) studies. The purpose of this study is to ensure that the measurement system is statistically sound. Gauge R&R studies determine how much of the observe process variation is due to measurement system variation. Two persons are needed to perform this experiment, which in this case were the operator on line and the investigator. The sample size was 10 and two readings were taken on each sample, thereby making a total of 40 readings. The gauge used for this experiment was a vernier-caliper. From the results of using Mini-Tab Gauge R&R study, repeatability and reproducibility comes out to be 22.55 % and 0.00 % and put the percentage study variation to be 22.55 %, which is <30 %, indicating that vernier-caliper was correct.

4.3 Analysis

According to Kapur and Feng (2005), the analyze phase examine the data collected in order to generate a prioritized list of source of variation. Many statistical tools are used to carry out the analysis which is explained as follows.

4.3.1 Process Capability analysis

Capability analysis is a set of calculations used to assess whether a system is statistically able to meet a set of specifications or requirements. To complete the calculations, a set of data is required, usually generated by a control chart; however, data can be collected specifically for this purpose & used mini-tab software to draw process capability graph shown in fig. 5.

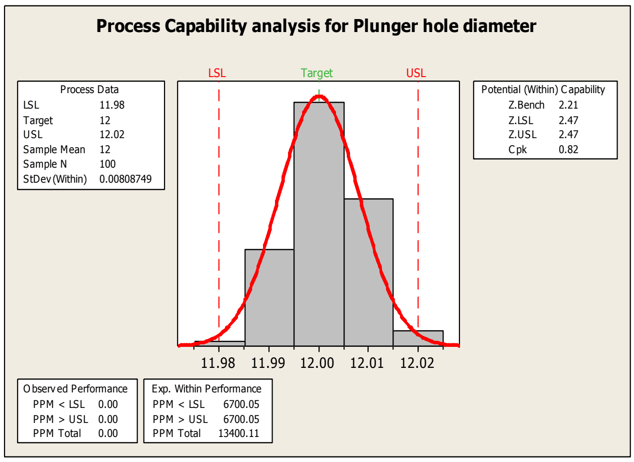

Fig.5 process capability graph

Z – Bench sigma value of process was found to be 2.21 and existing DPMO level of the process comes out to be 13400.11, which is remarkably high and this shows that there are lot of opportunities for improvement in the process.

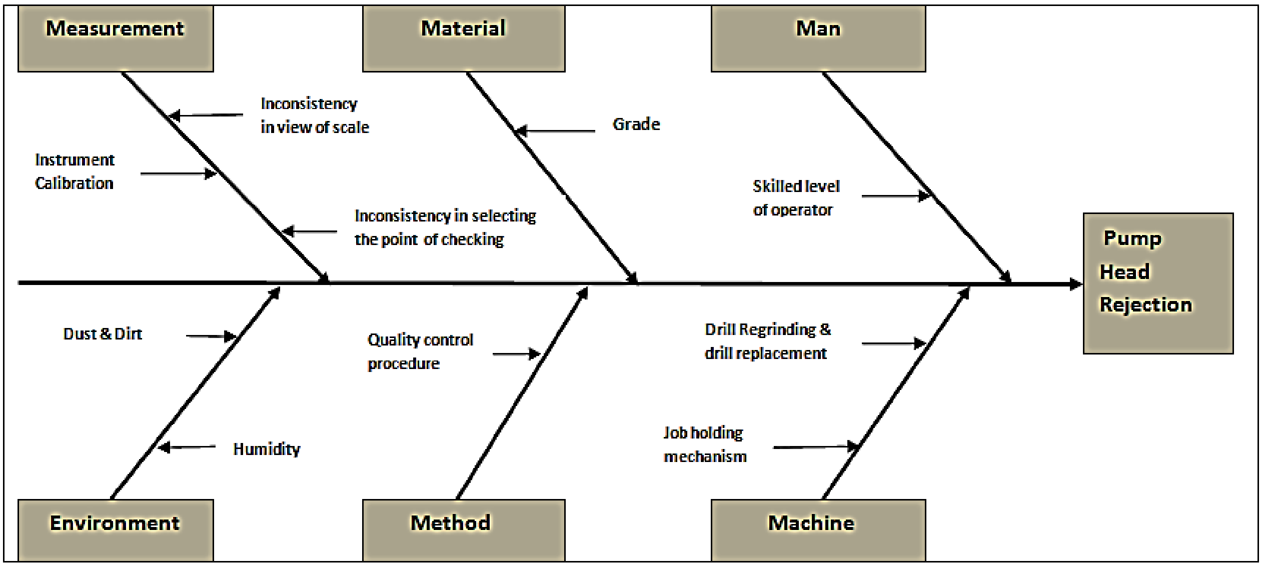

Fig.6 Cause & Effect Diagram

4.3.2 Cause & Effect Diagram

Using process capability analysis, the DPMO level and sigma level of the bush diameter rejection was known. Now it was the time to find out the causes of bush rejection. Using expert experience and critical analysis of actual process, a cause & effect diagram (as shown in Figure 6) was drawn to find out the causes of more bush rejections.

4.3.3 Two sample T- test

In two samples T-test four factors were taking for study from cause & effect diagram.

1) Two sample t-test for skilled & unskilled operator
First two samples t-test for skilled & unskilled operator by taking a sample size of 50 pieces for each unskilled & skilled operator & used mini-tab for P- value.

Two-Sample T-Test: Unskilled Operator 1, Skilled Operator 2

Two-sample T for Unskilled Operator 1 vs. Skilled Operator 2

	N	St Dev	SE Mean
Unskilled Operator1	50	12.0008	0.001
Skilled Operator 2	50	12.001	0.0011

Difference = mu (Unskilled Operator 1) - mu (Skilled Operator 2)
Estimate for difference: -0.00020
95% CI for difference: (-0.00315, 0.00275)
T-Test of difference = 0 (vs. not =): T-Value = -0.13 **P-Value = 0.893** DF = 97

Since the p-value for unskilled & skilled operator comes out to be >0.05 therefore this cannot be a factor for Hydraulic jack pump head rejection.

2) Two sample t-test for Regrinding of Drill
Second two samples T-test for Regrinding of Drill (after 15h and 25 h) by taking a sample size of 50 pieces and again find the P- value for this test.

Two-Sample T-Test: Drill Regrinding After 15h, After 25h

Two-sample T for after 15h vs. After 25

	N	Mean	St Dev	SE Mean
After 15th	50	11.9998	0.00622	0.00088
After 25	50	12.0044	0.0116	0.0016

Difference = mu (After 15h) - mu (After 25)
Estimate for difference: -0.00460
95% CI for difference: (-0.00832, -0.00088)
T-Test of difference = 0 (vs. not =): T-Value = -2.47 **P-Value = 0.016** DF = 74

Since the p-value for Drill Regrinding comes out to be <0.05 therefore this might be a factor for Hydraulic jack Pump head rejection.

3) Two sample t-test for Drill Replacement
Third two samples T-test for Drill Replacement (after 35 days and 45 days) by taking a sample size of 50 pieces and again finds the P- value for this test.

Two-Sample T-Test: 35 Days, 45 Days

Two-sample T for 35 Days vs. 45 Days

	N	Mean	St Dev	SE Mean
25 Days	50	12.002	0.00571	0.00081
45 Days	50	12.0016	0.0065	0.00092

Difference = mu (35 Days) - mu (45 Days)
Estimate for difference: 0.00040
95% CI for difference: (-0.00203, 0.00283)
T-Test of difference = 0 (vs. not =): T-Value = 0.33 **P-Value = 0.745** DF = 96

Since the p-value for drill replacement comes out to be >0.05 therefore this cannot be a factor for Hydraulic jack pump head rejection.

4) Two sample t-test for New & old job holding mechanism

Fourth two samples T-test for New & old job holding mechanism by taking a sample size of 50 pieces and again finds the P- value for this test.

Two-Sample T-Test: NEW, OLD Job Holding Mechanism

Two-sample T for NEW vs. OLD job holding mechanism

	N	Mean	St Dev	SE Mean
NEW	50	12.0002	0.00622	0.00088
OLD	50	12.0048	0.0109	0.0015

Difference = mu (NEW) - mu (OLD)
Estimate for difference: -0.00460
95% CI for difference: (-0.00814, -0.00106)
T-Test of difference = 0 (vs. not =): T-Value = -2.59 **P-Value = 0.012** DF = 77

Since the p-value for New & Old job holding mechanism comes out to be <0.05 therefore this might be a factor for Hydraulic jack Pump head rejection.

4.4 Improvement

In improve phase, design of experiment conducted for optimum results. From T-test we find two main factors from all which effect the process

- Drill regrinding
- Job holding mechanism

These experiments were conducted to optimize the value of the parameters drill regrinding and Job holding mechanism. A 2*2 experiment was designed, i.e. an experiment with two factors each levels. Table 1 & 2 shows the significant important factors for Plunger hole diameter variation.

Table.1 Significant Important Factor for Plunger hole diameter variation

Important Factor	Low Level	High Level
Drill Regrinding	25h	15h
Job Holding Mechanism	Old	New

Minitab was used to plot the main effects plot and interaction plot between the important factors shown in fig. 7 & 8 (Drill Regrinding and Job-holding mechanism).

Table.2 Readings of significant factors at various levels

S.No	Drill Regrinding	Job holing Mechanism	Plunger hole diameter(mm)
1	25th	Old	12.02
2	15th	Old	12.01
3	15th	New	12
4	25th	New	12

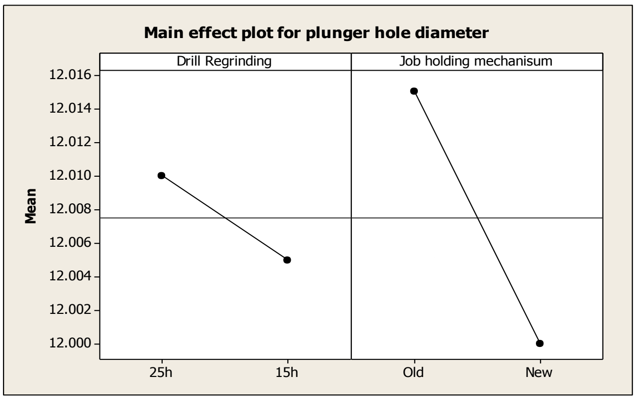

Fig.7 The main effect plot suggests that drill regrinding is a minor factor and Job -holding mechanism is a major factor.

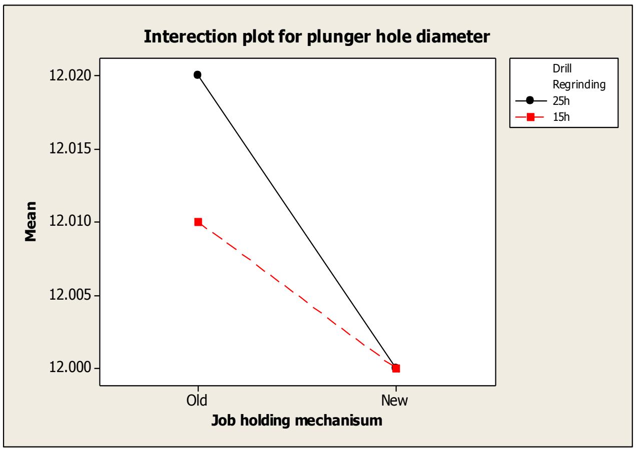

Fig.8 Plots

Interactions plot shows that the lines are not parallel to each other so there are interactions present between the factors. The change in the response mean from the low to the high level of drill regrinding depends on the level of Job -holding mechanism.

4.5 Control

In control phase, draw the X bar-R control chart to check the variation in the process after improvement & it shows the process within range near the target. In this process took 100 samples from after improvement in the operation for Drawing X bar-R control chart shown in fig.9.

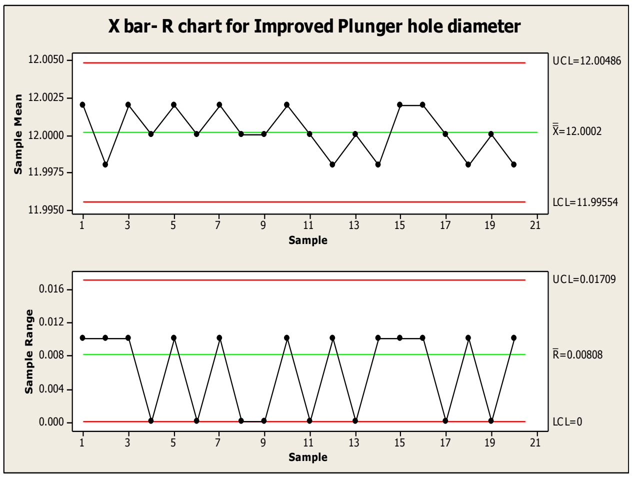

Fig.9 X bar-R control chart

4.6 Improved Result

Improved result in form of process capability analysis graph is shown in figure10. With the proper management of recourses & application of six-sigma in SSI help to improve sigma level up to 5.64 and total rejection level reduced to 0.01of production in PPM.

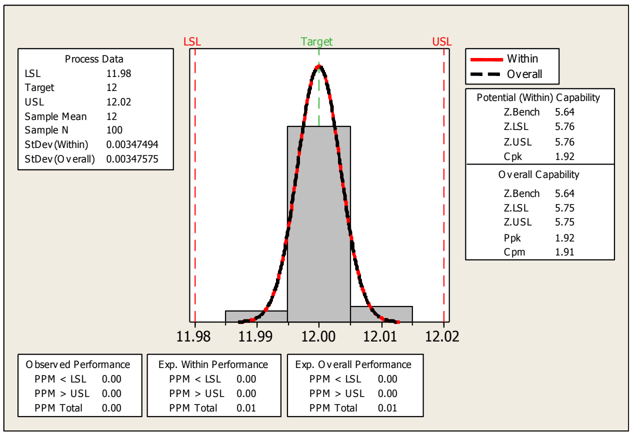

Fig.10 Process capability analysis for Improved Plunger hole diameter

Conclusion

Six-Sigma for SSI is a very important sector to grow over the last two to three years. Very few studies have been reported about the successful applications of Six Sigma in SSI. In the small companies is much easier to buy-in management support and commitment, as opposed to large organizations. The education and training component is much harder for smaller companies. Moreover, small companies do not have the slack to free up top talented people to engage in training followed by execution of Six Sigma projects as they are crucial to the day-to-day operations and problem solving within the company. It's an important field of research to grow our country economy.

This paper justify the successfully application of six-sigma in Hydraulics jack set manufacturing industry a small scale industry improve the sigma level from 2.21σ to 5.64σ and it help in the cost saving of Rs. 0.01929 million/annum.

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