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Process Improvement of Liquid Filling Machine using Six Sigma Methodology

Sukrut Deshmukh[1], Swapnil Chavan[2]

[1,2] Undergraduate Scholar, Pune, Maharashtra, India,

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Abstract - *This paper deals with improvement in overall process of the liquid filling machine. The primary objective of this paper is to study and evaluate the process of liquid filling machine and obtain an efficient way by improving the sigma level. The current approach focuses in increasing the performance of the machine to ensure the required quality of the process. The six sigma methodology using DMAIC (Define – Measure – Analyze – Improve – Control) is applied in real conditions to the case. The study presents the work conducted before the load cell feedback and after the load cell feedback is given. The increase in accuracy of readings and improved standard deviation represents the process variability in both the cases. By using the DMAIC cycle, it has been possible to improve productivity by reducing the defect rate. The research work has been carried out in a packaging manufacturing company to show how to improve its productivity and quality by using six sigma methodology. This paper explores the relationship between process improvement and process modelling.*

Keywords: **Six Sigma, DMAIC, Process Improvement, Liquid Filling Machine, Productivity, Quality, Defect Reduction.**

1. INTRODUCTION

Manufacturing firms globally are constantly on the lookout for newer ways to improve the process constantly so that defects can be reduced. With the concept of six sigma, there is a lot of emphasis on the manufacturing firms to improve the process continuously and provide customers with quality products at competitive prices. Six sigma is a process improvement methodology that focuses on utilizing rigorous data analysis to minimize variation in those processes. It is a customer focused continuous improvement strategy that minimizes defects and variation towards an achievement of 3.4 defects per one million opportunities in product design, production, and administrative process. Six Sigma is a strategy of continuous improvement of the organization to find and eliminate the causes of errors, defects and delays in business organization processes, and focusing on higher net income. Six Sigma is based mainly on understanding the customer needs and expectations, disciplined use of facts and statistics analysis, and responsible approach to establishing, managing and improving the manufacturing processes.

2. METHODOLOGY

Phase 1: DEFINE -

During the Define phase, the team discussed data availability and validity, and developed the following project description:

"Process Redesign to reduce the defects and increase the efficiency of Liquid Filling Machine".

In past years, the liquid filling machine had a low level performance in the volumetric requirement of the required product. The expected quantity of packaging is 100grams. Historical data shows that 25% overall readings are unacceptable as Q1 = 99.25grams.

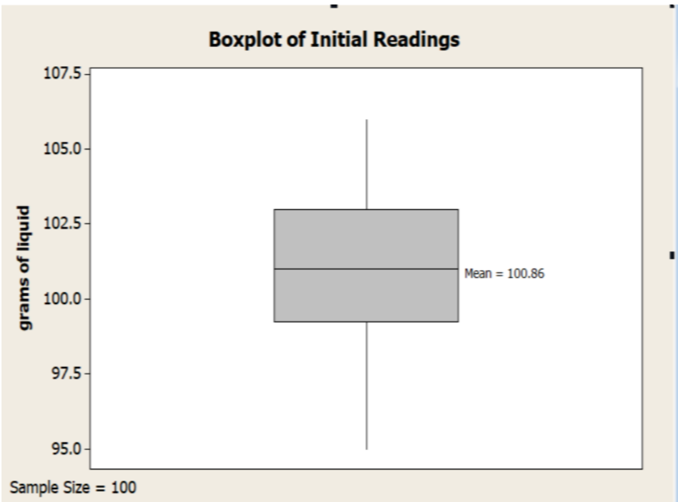

Fig 1 – Box diagram of the failure rate.

The first step was to identify the problem through the selection of the critical customer characteristics and the response variable. The critical characteristic, in this case, was the volumetric measurement over the combination of volumetric & weightmetric measurements.

Phase 2: MEASUREMENT -

This phase is to certify the validity of the data through the evaluation of the measurement system. Measuring baseline performance is major output of this phase used for the evaluation of accuracy and advisability of the system. The goal of this phase is to estimate how the system of measuring contributes to the total variance of watched parameter. The trials of liquid filling machine were taken with the previous setup by the Operator. The sample size considering to be 100, the readings were noted as shown in table 1. The minimum value obtained while experimenting is 95grams while the maximum obtained is 105grams. But the acceptable range specified by the customer is 100 ± 1 grams. The statistical analysis shows that the total accuracy obtained by the previous setup is 11grams (i.e. ± 5.5 grams) with the standard deviation of 2.734.

Table 1 – Data Measured by Operator (Sample Size – 100)

Readings range	Frequency	Percentage	Remarks
(min.) 95-98	16	16%	NOT Accepted
99-101	43	43%	Accepted Range
102-105 (max.)	41	41%	NOT Accepted

Observations: Total % Unaccepted – 57% (net)

Total % Accepted – 43%

The baseline performance metric as calculated:

Units Inspected = 100

Defects observed = 57

DPU = 57/100 = 0.57

Using Minitab, the results obtained are: DPMO = 434474.6

Hence, Sigma Level = 1.66

Table 2 – Statistical Analysis of Old setup

Sample Size	100
Min.	95
Max.	106
Total accuracy	11
Accuracy	±5.5
Average	100.86
Standard Deviation	2.734072332

Phase 3: ANALYSIS –

This phase describes the potential causes identified which have the maximum impact on the low process yield and helps to examine the processes that affect the CTQs and decide which X's are the vital few that must be controlled to result in the desired improvement in the Y's. Ultimately, this leaded to generate ideas for improvement. It is very important to analyze the process as lack of proper analysis may lead to the process to a wrong way which will deviate from the main function of improvement.

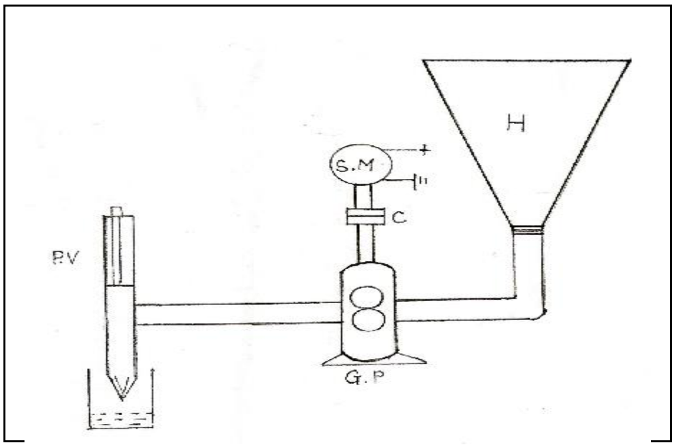

Fig 2 – Schematic Diagram of Liquid Filling Machine (Old Setup)

Nomenclature – H = Hopper
S.M = Servo Motor
G.P = Gear Pump
C = Love Joy Coupling
P.V = Puppet Valve

The old setup procedure as shown in fig 2 is explained below.

At first, liquid is poured into the hopper. Then the liquid is gravitationally fed to the helical gear pump which imparts kinetic energy to the liquid. The helical gear pump is driven by servo motor. The Servo motor specifications are – 3ϕ AC Servo motor with rated output of 1.5 kW and constant torque of 7.16 Nm @ 2000 rpm. The gear pump specifications are – capacity of 25 LPM with max. pressure of 10 kg/cm^2. The gear pump is then coupled to the servo motor through the love joy coupling. Further, the liquid is filled in the container with the help of puppet valve. The puppet valve is operated pneumatically that makes way for liquid to pass. The cylinder of the puppet valve is operated by solenoid coiling. The signal received to the solenoid coil is through PLC. The histogram of readings obtained from old setup for sample size of 100 is shown below (Fig 3).

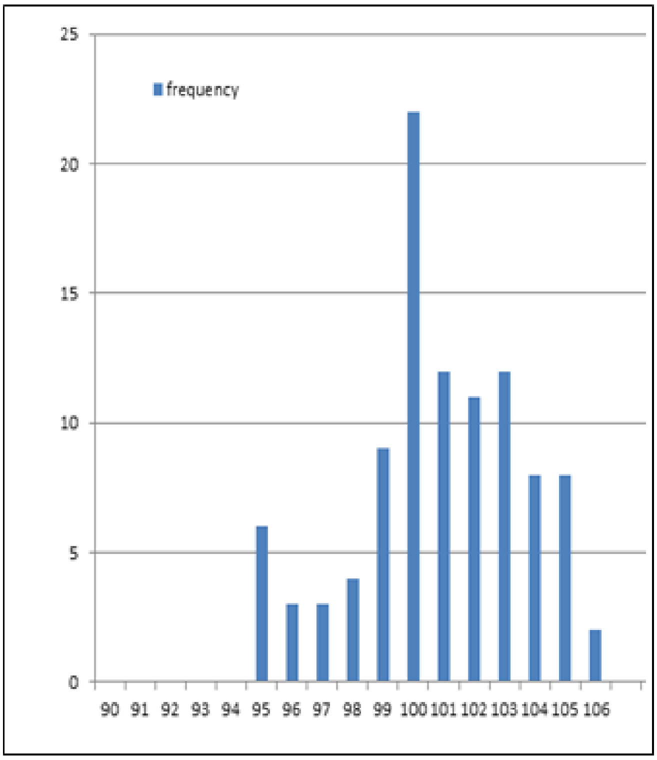

Fig 3 – Histogram of readings of previous setup.

As per customers repeated feedback, there was a need to increase the efficiency and accuracy of the machine as the product cost was too high. The statistical data obtained can be referred from table 2. The critical characteristic, in this case, was only dependent on the volumetric measurement

Phase 4: IMPROVE –

In the Improve phase, there is implementation of targeted process improvements. Once it was identified the factors that significantly affect the response variable being analyzed, the next step was to identify possible solutions, implement them and verify that the improvement is similar to the expected by the experimental designs. According to the

results obtained, corrective measures were applied for the improvement of the significant variables.

The latest improved and updated setup procedure is as shown in fig 4 is explained below.

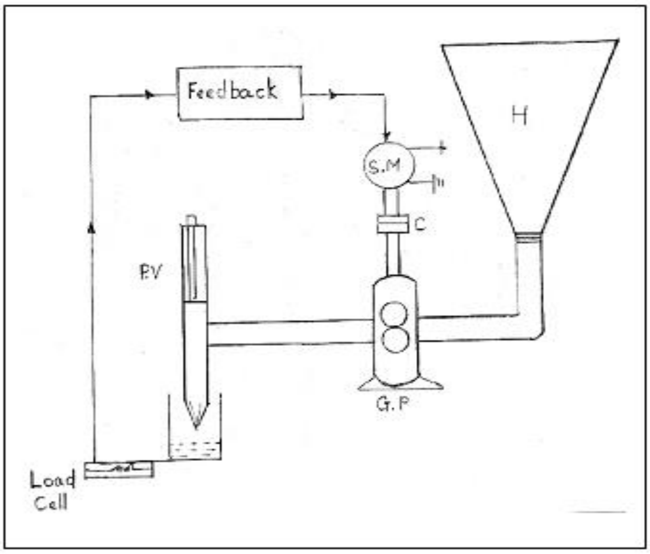

Fig 4 – Schematic Diagram of Liquid Filling Machine (Improved Latest Setup)

Nomenclature – H = Hopper
S.M = Servo Motor
G.P = Gear Pump
C = Love Joy Coupling
P.V = Puppet Valve

As seen in above diagram, from pouring of the liquid in the hopper till filling it in the container, procedure is same as explained in previous section. There was no change in the core setup of the machine. However, the new improvement involves addition of weightmetric response along with volumetric. In weightmetric, load cell is attached to the platform of the container. This accurately measures the bulk and dribble cycle and provides feedback to the servo motor which in result controls the flow rate of the liquid.

Table 3 – Statistical Analysis of Improved Setup

Sample Size	100
Min.	99
Max.	103
Total accuracy	4
Accuracy	±2.0
Average	100.72
Standard Deviation	0.943665751

Table 4 – Data Measured by Operator

Readings range	Frequency	Percentage	Remarks
98 & below	0.0	0%	N.A.

99-101	78	78%	Accepted Range
102-103 (max.)	22	22%	NOT Accepted

Observations: Total % Accepted – 78% (net)

Total % Unaccepted – 22%

The baseline performance metric as calculated:

Units Inspected = 100

Defects observed = 22

DPU = 22/100 = 0.22

Using Minitab, the results obtained are: DPMO = 197481.2

Hence, Sigma Level = 2.35

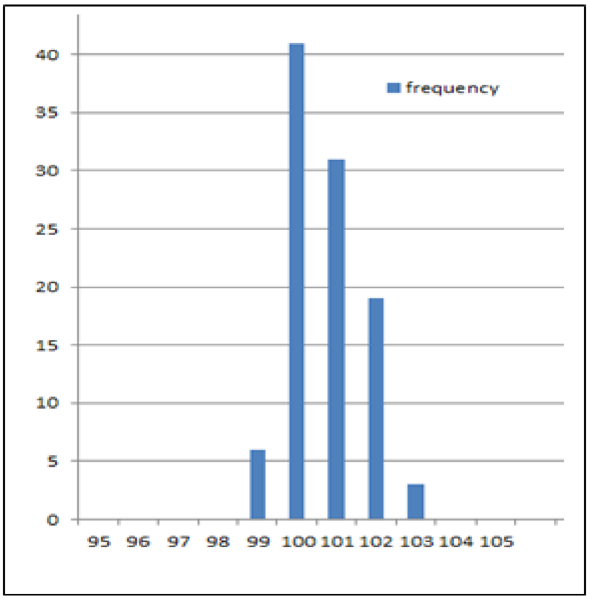

Fig 5 – Histogram of new readings of improved setup

After the implementation of the new setup, there were positive feedbacks from the customers mentioning decrease in defects and increase in efficiency and accuracy of the machine. As calculated, there has been significant improvement in the sigma level of the new setup. Also, as the accepted % increased from 43% to 78%, the production process is optimized eliminating variation in grams.

Phase 5: CONTROL –

In order to achieve a stable and efficient process, the modification in the setup of the Liquid filling machine was made. The introduction of load cell feedback and flow meter were essential to significantly control the liquid flow while packaging of product. It was also necessary to place these devices at accurate positions that will facilitate the process control and achieve the required output. Based on the results generated, a modification in working plan of the Liquid filling machine was revised and deployed, which resulted in the reduction of defects and avoided wastage of fluid. Due to recurring customer problems and fluid control mechanism and in order to assure the efficiency of the process, it was considered necessary to improve the process of the Liquid filling machine. Table 5 shows the comparison before and after the implementation of the process. As observed, there is significant amount of improvement in the values of sigma level.

Table 5 – Comparative before and after Implementation of Six Sigma Level

	% Defect	Six Sigma	DPMO
Base Line	57%	1.66	434474.6
Evaluation	22%	2.35	194781.2

3. CONCLUSION

The implementation of this project has been considered as successful because the critical factor for the process was found and controlled. Therefore, the control plan was updated and new operating conditions for the production process yielded higher efficiency with improved customer satisfaction. The improved Liquid filling machine proved to be cost efficient as the process improvement resulted in eliminating variation and managing the production process with less-defect. This paper attempted to produce such a model which related factors of quality and its impact on the process improvement parameters. The base line of the project was 1.66 sigma level and the gain of 0.69 sigma level (i.e. 2.35) that represents improvement of 61.4% in the overall output. The potential benefits observed were – fewer defects resulted in decrease in the number of products to be scrapped which also means that the raw materials, energy, and resulting waste associated with the scrap are eliminated. Also, the maintenance preventive program was modified to achieve the goal stated at the beginning of the project. It is important to mention that the organization management was very supportive and encouraging with the project team. Finally, Six Sigma implementation can be helpful in minimizing the variations and improving the process – capability of the manufacturing processes.

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