

## Statistical Process Control (SPC) Application in a Manufacturing Firm to Improve Cost Effectiveness: Case study

I.Madhanhire<sup>1</sup>, C Mbohwa<sup>2</sup>

<sup>1</sup>Department of Quality and Operations Management, University of Johannesburg, Johannesburg, South Africa  
Mechanical Engineering Department, University of Zimbabwe, Harare, Zimbabwe

<sup>2</sup>School of Engineering Management, University of Johannesburg, Johannesburg, South Africa  
e-mail: imdanhire@eng.uz.ac.zw

**Abstract** -This study investigated the use of the statistical process control (SPC) as a tool in a manufacturing firm to improve quality and cost effectiveness. With emphasis on early detection and prevention of the problems, SPC was shown to have a distinct advantage over other quality methods such as inspection of final products. There was need to check gauges and machines, and determine need for some maintenance or overhaul work to be carried out as faulty machines could not produce expected quality products. There was need for operators to be trained, new documents to be produced and actions for the future to be agreed on. There was a need for reviewing the operations and monitoring key equipment for re-tooling or adjustment to achieve required levels of plant performance.

**Keywords** – cost effectiveness, SPC, inspection, quality, performance, monitoring

### I. INTRODUCTION

The key to being competitive lies in the ability to exceed customers' needs and expectations; as well as providing, in the manner required by the customer, a quality product at low cost, on time, every time. In this era of strains on resources and rising costs of manufacturing, it becomes increasingly apparent that decisions must be made based on facts, not just opinions [1, 2]. Consequently, data must be gathered and analyzed. This is where statistical process control (SPC) tools come in to help in the decision-making and determining if the process is operating at an acceptable level [3].

The major challenge the companies in Zimbabwe face is associated with competitiveness as manufacturing organization fail to compete in region and globally. In this regard, there is need for these entities to work on improving product quality and cutting cost as they manufacture their products. Thus this study is intended to spell out the concept of SPC for the benefit of those intending to use it their processes [4].

### II. LITERATURE REVIEW

#### A. SPC overview

Statistical Process Control (SPC) is the application of statistical methods to monitoring and control of a process to ensure that it operates at its full potential to produce a conforming product. Under SPC, a process is monitored so that it behaves predictably to produce as much conforming product as possible with least possible waste [5, 6]. Key tools in SPC are control charts, continuous improvement and design experiments. Variations in the process that may affect the quality of the product can be detected and corrected, thus reducing waste as well as the likelihood that problems will be passed on to the customer. [7].When a process is considered out of control, an alarm is raised, so that engineers look for assignable causes of variation and try to eliminate them. It is more effective to take a proactive approach to prevent the occurrence of out of control situations allowing the process to be adjusted in a preventive way so that fewer non-conforming items will be produced [8,9].

#### B. SPC implementations

In SPC application, it is important to understand and identify key product characteristics which are critical to customers or key process variation. The key steps for implementing SPC are as shown in Fig 1 below [10].

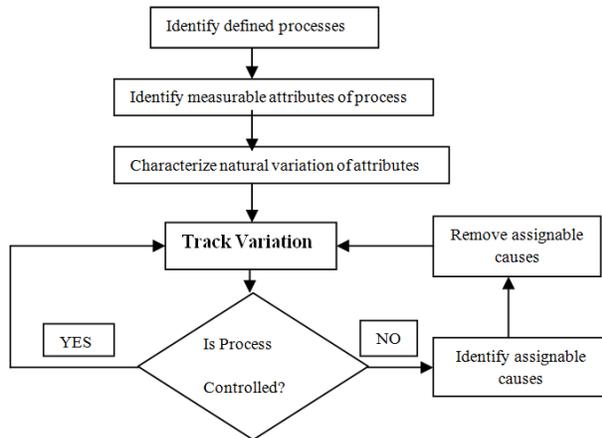


Fig.1 Steps in SPC implementation (Source GOLD PRACTICE)

The Pareto’s 80/20 rule is used to identify the vital few processes, which control manufacture, and then build the planning around these key processes and products for quality control activities.

C.SPC tools

In practice, reports of SPC in manufacturing tend to concentrate on a few processes such as formal inspections, testing, maintenance and personal improvement processes. Control charts are the most common tools for determining whether a process is under statistical control [9].

TABLE I  
SEVEN SPC QUALITY TOOLS (Source GOLD PRACTICE)

Tool	Application / Use
Check Sheet	To count occurrences of problems
Histogram	To identify central tendencies and any skewing to one side or the other
Pareto Chart	To identify the 20% of the modules which yield 80% of the issues
Cause and Effect Diagram	To identify assignable causes
Scatter Diagram	For identifying correlation and suggesting causation
Control Chart	For identifying processes that re out of control
Graph	For visually displaying data e.g in a pie chart

The combination of an Upper Control Limit (UCL) and a Lower Control Limit (LCL) specify, on control charts, the variability due to natural causes [11].

Also Table 1 shows some of tools used in SPC, as away to explore the natural variability of processes. Some are used as techniques for eliminating assignable causes. Analysis of defects is the most common for eliminating assignable causes. Also analysis-related techniques such as Pareto analysis and brainstorming are applied. SPC requires defined processes and a discipline of following them. It requires a climate in which personnel are not punished when problems are detected [5].

III. METHODOLGY

Data collection entailed use of observation, company documents and structured experiments. The objective was to assess the level of effectiveness to which SPC tools were used on the manufacturing processes involved, implementation challenges encountered as well as establishing gaps which could provide ready opportunities for improving. The main two processes were the aerosol can manufacturing and crown production lines. In the latter, digital dial height gauge was used to get the physical height parameter of the random sample.

#### IV. CASE STUDY

##### A. Background

The SPC study was carried at Metpack which is an organization based in Harare. It is mainly involved with the manufacturing of metal packing in form of open top food cans, motor oil cans, aerosol cans, paint and chemical cans, shoe and floor polish tins, roof seals and bottle crowns. Containers are supplied both as plain and decorated. Metpack routinely collects an array of data from its manufacturing processes. It is the analysis of this data, which provides the invaluable insight into the behavior of these processes. SPC techniques are then used to highlight areas that would require further investigation to be undertaken. Thus the variations are identified in targeted processes for rectification and continuous quality improvement across the organisation.

##### B. Aerosol can manufacturing process

The firm manufactures three-piece aerosol cans which are mainly used for non-food applications, such as cosmetics, boy care products, insecticides and lubricants. In essence, the principles of two or three piece can manufacture apply, whilst the ends differ and are fitted as a unit. All three-piece aerosol cans are made from steel and the coating varies according to the intended contains.

As aerosol cans are pressurized systems, the containers should be capable of withstanding the internal pressures generated during filling, subsequent transport, warehousing and consumer usage. Thus some legislation governs the manufacture of empty can and subsequent filling.

##### C. Crown manufacturing lines process

Crowns are traditional bottle tops that are removed with a bottle opener. The sealing insert covers the beverage contact surface of the crown. It is either a liner made from plastic (polyethylene or an ethylene, vinyl acetate copolymer) or a compound made from a plastisol (PVC), which is expanded into foam to enable it to seal the bottle.

A few drops of molten plastic are dropped into upturned crown and pressed to form the beverage contact internal surface. With a plastisol, the crown is spun to spread the plastisol. There is no intended direct contact between the coating of the crown and the contents of the bottle.

In the crown production making process given in Figure 2, the variability of crown height on the Callahan press is closely monitored for conforming standard deviations with acceptable levels.

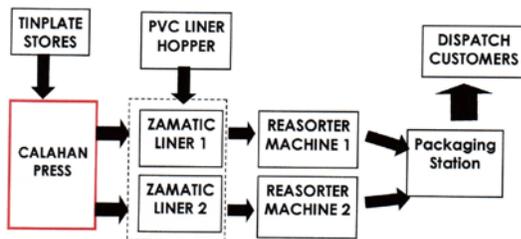


Fig. 2 Crown production flow process

Serial processes normally contribute to an additive effect of non conformance and high process capability indices  $C_{pk}$  and there is need to assure an acceptable end of line  $C_{pk}$ . If unacceptable number of non-conforming product reaches the factory floor, and cost increases due to scrap and rework. SPC techniques are used to maintain low non-conformance rate.

From the product specification drawing in Figure 3, crown height was established as one of the critical parameters which are correlated to product fit and function.

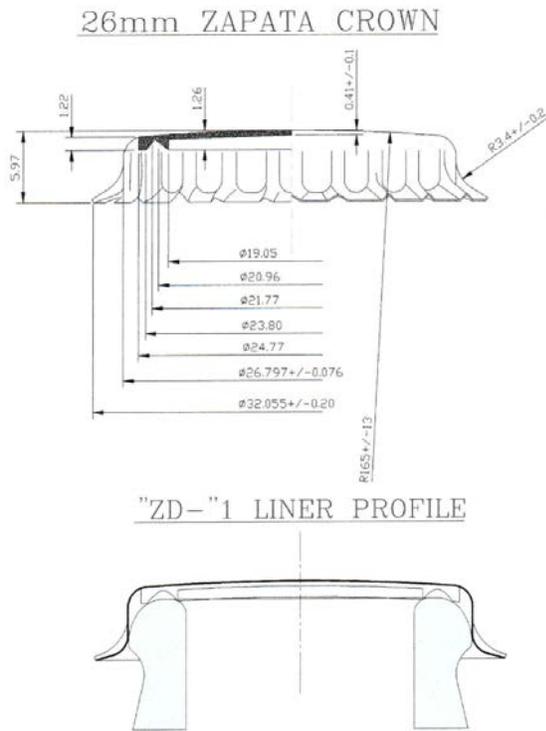


Fig. 3 Crown specifications

## V. RESULTS AND DISCUSSION

### A. Aerosol cans process

An analysis of defects on the aerosol line was done to assess the spoilage level based on the information from internal complaints on specific problems observed. Pareto analysis was generated from these as given by Table II below. Print defects were found to be contributing more than 80% of the complaints such as color variation, print of center and water marks.

TABLE II  
INTERNAL COMPLAINTS – FIRST QUARTER 2014

Print Defects	Number of Complaints	Cumulative Complaints	Cumulative Percentage
Color variation	19	19	41.3%
Print off-centre	12	31	67.4%
Water marks	6	37	80.4%
Missing pass	4	41	89.1%
Lacquer contamination	3	44	95.6%
No varnish	2	46	100%

After an evaluation of the internal complaints that contributed to high spoilage on the aerosol line, an evaluation of the frequency of occurrence of defects for the period between September 2012 to September 2013 was also carried out to find most common causes. The following were found to be contributing about 80% of the defects: split weld, split flanges, weld spatter, blistered side seam, burning hole on seam, decoration /lacquer scratches, damaged cylinders, and body squareness / alignment

The main sources of spoilage were identified first on the can and then welder as most defects are linked to this machine.

Another critical parameter investigated was the double seam shown in Fig 4, as many of its dimensions are critical to minimize potential microbiological ingress (can integrity). A number of finished cans failed to pass the pressure

test done on them.

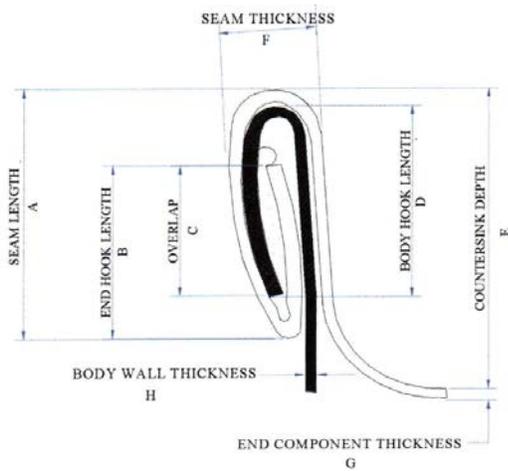


Fig. 4 Double seam

*B. Bottle crown production (before machine adjustments): Height*

Data analysis was carried out on spreadsheets to get overall machine data, and overall frequency distribution histogram in Fig. 5, Fig. 6 and Fig.7.

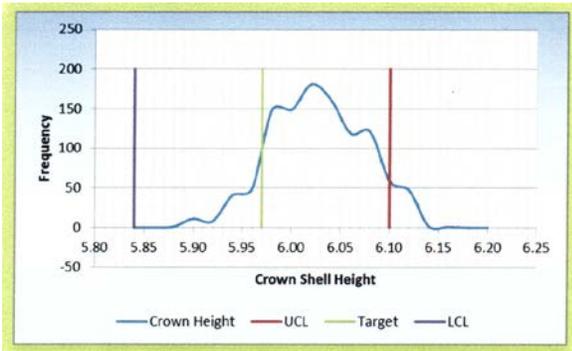


Fig. 5 Overall machine histogram(initial height results)

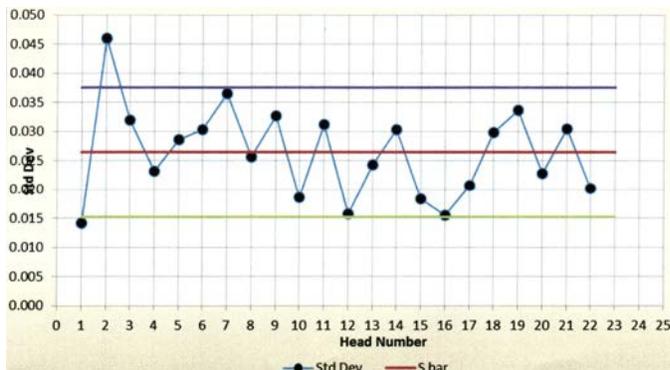


Fig. 6 Standard deviation control chart (initial results)

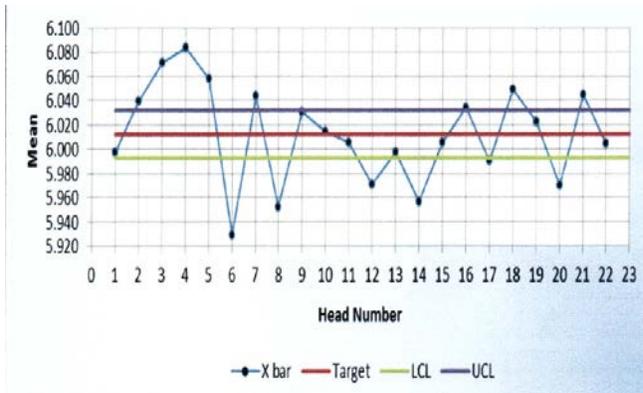


Fig. 7 X bar control chart (initial results)

*C. Bottle crown production (final machine data): Height*

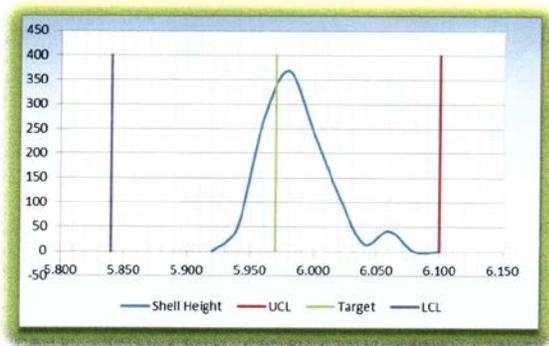


Fig. 8 Overall machine histogram (final height results)

After the machine adjustments identified above were implemented, a new set of results was obtained and these results were compared to the initial set of results. The estimates of component variance on Callahan press required to be reduced in line with Fig 8 above.

*D. Bottle crown production (before machine adjustments): Diameter*

Crown diameter is also another critical parameter that was used in machine adjustment. It was measured on the same samples used for crown heights. The actual measured diameter values for the initial sample (before machine adjustment) and the final sample (after machine adjustment) have given rise to the Fig 9 and Figure 10 respectively given below.

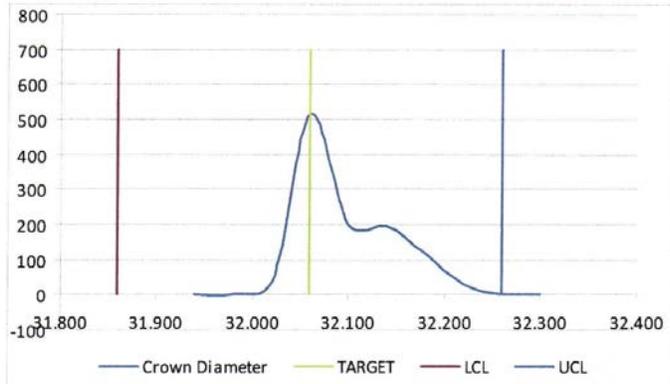


Fig. 9 Overall machine histogram (initial diameter results)

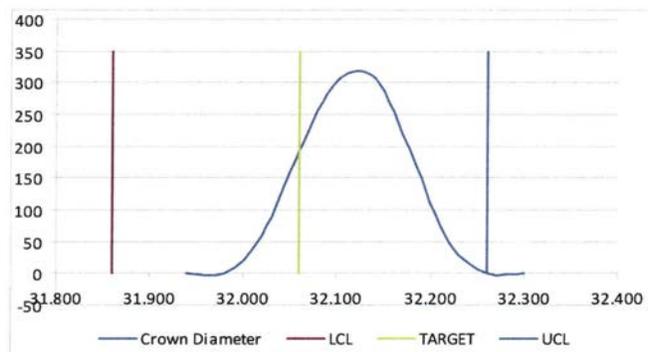


Fig10 Overall machine histogram (final diameter results)

The overall machine histogram indicated that even though the machine adjustment improved the distribution on the crown diameter values, it also introduced a positive skew in the overall diameter distribution but all values remained within specification. Clearly the adjustment sort of ‘disturbed’ the diameter values with increases in machine mean and overall machine standard deviation.

#### E. SPC appreciation

Operators produced  $\bar{x}$ -control charts to guide them on required machine setting. The fact that these were produced and filed suggested that the operators did not know the reason why they were producing the charts. Thus SPC could improve the performance as the action part was a missing link at the case study company. Misapplication of SPC programs and methods were apparent as charts were not interpreted correctly.

#### VI.RECOMMENDATIONS

In the aerosol can production line, most welding defects were recorded, thus there was need to do trial runs with some shift in the standard machine settings. As the defects could be attributed to deviations in old setting and new settings would require to be put in place to correct this adverse result linked to machine’s age and normal wear and tear. The combined effect of these two could have caused the shift in original standard settings.

The aerosol can integrity to pass pressure tests, the aspects like percentages of overlap and butting have to be increased by adjusting the parameters such as seam length, end hook length and the seam thickness shown in the Figure 5 double seam configuration.

On crown height, the initial analysis showed some variability and in each case action should be progressively taken to eliminate the cause of variation by reducing spread in Fig 6, reducing the variation around the mean in Fig 7 and ensuring that the crown heights are within the Lower Control Level (LCL) and Upper Control Level (UCL) in Fig 8. Fig 8 showed that some extensive machine setting had to be done on the Callahan Press to ensure the crown heights are within LCL and UCL to conform to the standard of 5.97mm given in Fig 3.

On crown diameter, the exercise of determining the two critical process characteristics – machine setting (from process mean) and machine variability(from process standard deviation), was recommended and has to be repeated at least once a year.

## VII. CONCLUSION

SPC provides surveillance and feedback for keeping processes in control and signals when a problem within the manufacturing process has occurred. Based on the observed exercise at the case study company, initial results were corrected progressively as good final results were generated by choosing critical parameters to correct through machine adjustment. The control limits of a process would give information on what a process could do when it is operating properly. These limits would be set by the quality of the machinery and the skills of the operator for cost effectiveness of the plant production.

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