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IMPLEMENTATION OF STATISTICAL PROCESS CONTROL IN A SHEET METAL MANUFACTURING INDUSTRY

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Abstract - *This research has approached analysis and report on the Statistical Process Control (SPC) in a Sheet metal manufacturing Industry situated in sector - III, Pithampur, Madhya Pradesh (India). The objectives of this research are: To study the quality Management practices of a sheet metal manufacturing Industry, to develop the basic in-house process competence for laser cutting process i.e., by reducing the production of non-confirming products (rejections) by applying the statistical process control tools, Its effects on overall profit generation, to understand the issues and challenges of implementation of SPC and to analyze data and give some recommendations from the study of SPC. By using SPC tools specially the control chart.*

Key Words: Statistical Process Control, Laser cutting Process, Control charts, Manufacturing Industry, Ishikawa Fishbone Diagram, Variation, 4M

1. INTRODUCTION

Statistical Process Control (SPC) procedures can help you to record process manner. The most effective SPC tool is the control chart. SPC proposed and developed by Walter A. Shewhart in the early 1920s [1,2]. Statistical quality control refers to using statistical techniques for measuring and improving the quality of processes and includes SPC in addition to other techniques, such as sampling plans, experimental design, variation reduction, process capability analysis, and process improvement plans [1,2,11]. SPC is used to monitor the constancy of processes used to manufacture a product as designed. It aims to get and keep processes under statistical control.

1.1 introduction to LASER machine:

LASER (Light Amplification by Stimulated Emission of Radiation) process

The laser cutting process has been selected to the intended SPC implementation. Industrial sheet metal Computerized Numerical Control (CNC) Programmable Laser cutting machine is used. The laser cutter is very powerful tool and therefore can be very dangerous, if not handled with enough safety and care.

Description of Laser Cutter:

Product: AMADA - ALPHA

Technology: CO_2 Laser

Product handling: Sheet metal

Control type: CNC

Other characteristics: High-speed, table type

X travel: 1,270 mm, 2,520 mm (50 inch)

Y travel: 1,270 mm, 1,550 mm (50 inch)

Cutting speed: 114,000 mm/min (74.803 inch/sec)

Laser power: 3,500 Watt

CO2 lasers use an electromagnetically stimulated gas—typically, a mixture of carbon dioxide, nitrogen and sometimes hydrogen, xenon or helium—as their active laser medium.

The general idea of this CO2 laser system is that a beam is directed down to a part for cutting. The part sits on a computer-controlled platform which moves the piece around the stationary laser beam. Cutting is achieved by passing the beam through a focusing lens. A focused beam exits through the bottom of a cutting head nozzle. Gas, such as oxygen, is fed into the side of the chamber below the focusing lens. This gas exits the nozzle along with the beam and the laser beam/oxygen combination serves to vaporize the steel for cutting.

1.2 Literature Review (Related Articles):

Mostafaeipour A. in 2012 in thier paper 'SPC technique in ceramic tile manufacturing plant' suggested SPC for reducing the unwanted ceramic tile defects and wastages. They adopted pareto chart to group different causes for inappropriate effects and its category. Also, they adopted six-pack charts to offer six different packs in the format of one diagram. Finally, they recommended complementing the correct SPC frequently in the manufacturing plant to minimize ceramic tile waste.

Parmar P.S., Deshpande V.A. in 2014 in their paper 'Implementation of statistical process control Techniques in industry: A Review' assessed that Quality of the finished article was how traditionally achieved and what SPC can improve the process as a whole.

Abtew M.A., Hong Y., PU L. & Kropi S in 2017 in their paper 'Implementation of SPC in the sewing section of garment industry' found that the analysis before and after the implementation of SPC showed that the rejection percentage was reduced by 2.74%. Successful implementation of the result of their project can significantly improve process performance of other similar manufacturing units with appropriate modifications.

Atre V.V. in 2018 in their paper 'Process Capability Analysis in single and multiple batch manufacturing systems' determined that by reducing process variations a process can be controlled.

Madinhare I., Mbohwa C. in (2016), in their article 'Application of Statistical Process Control (SPC) in Manufacturing Industry in a Developing country' attempted to address the deficiency of literature of SPC implementation. With emphasis on early detection and prevention of the problems. Also, appreciated that many industries found SPC as beneficial tool as an overall quality advancement.

2. METHODOLOGY

For developing the basic in-house process competence, to reduce the non-confirming products and for quality improvement, here, we are using the control charts (an effective SPC tool). For which,

The general methodologies are as follows:

- In step one; the product and its Critical parameters needs to be selected.
- Step two is collection of relevant data. At least 15 data values of 4 samples should be collected and specification limits should be specified.
- In step three, a variance between product and process should be made.
- In step four, calculate the control limits for the $\bar{X}$ chart. And project them onto the chart.
- The step five is analyzing sources of variation involves defining what process factors affect the natural process spread (process variation) and the process centering. With this information, it may be possible to improve the process.
- Take relevant measures to improve the process performance.

2.1. Product selection:

Here, for laser cutting process and bending process the sample is a bracket with critical parameters; hole of diameter 11 mm (Laser cut) and radius 2xR3 (Bending process) is taken.

Table -1: Product Details

Material: IS2062 E250BR	Part name: Bracket
Operation: Hole by laser cut	Specifications: ϕ11±0.5
Instrument used: Digital Vernier caliper	Sheet thickness: 3
Type of laser used: co_2 laser at 650 watts	All dimensions are in 'mm'

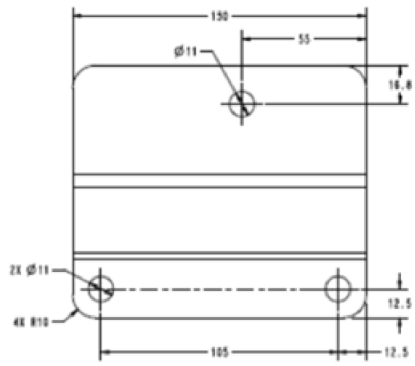

Fig.1. Bracket CAD drawing

Specifications:

Tolerance: ±0.5 mm

Upper specification limit (USL): 11.5 mm

Lower specification limit (LSL) : 10.5 mm

Lower specification limit (LSL) : 10.5 mm

Sample Size (n): 4

SUBGROUP (N)	SAMPLE SIZE (n)				MEAN ($\bar{X}$)	RANGE (R)
	1	2	3	4		
1	13.02	12.95	12.92	12.99	12.97	0.1
2	13.02	13.1	12.96	12.96	13.01	0.14
3	13.04	13.08	13.05	13.1	13.07	0.06
4	13.04	12.96	12.96	12.98	12.985	0.08
5	12.96	12.97	12.9	13.05	12.97	0.15
6	12.9	12.88	13	13.05	12.9575	0.17
7	12.97	12.96	12.96	12.99	12.97	0.03
8	13.04	13.02	13.05	12.97	13.02	0.08
9	13.05	13.1	12.98	12.96	13.0225	0.14
10	12.96	13	12.96	12.99	12.9775	0.04
11	12.9	13.05	12.98	12.88	12.9525	0.17
12	12.96	12.98	12.97	13.02	12.9825	0.06
13	13	12.96	12.99	12.9	12.9625	0.1
14	12.88	12.94	13.05	13	12.9675	0.17
15	12.96	12.96	13.04	12.98	12.985	0.08
				TOTAL	12.987	0.105

Table-2 Observation Table

2.2. Calculations:

Initial Calculations [15]:

For $\bar{X}$ CHART:

Grand average is

$$\bar{\bar{x}} = \frac{x1+x2+\cdots+xN}{N} = 12.98$$

Average of ranges $\bar{R}$

$$\bar{R} = \frac{R1+R2+\cdots+Rn}{n} = 0.10$$

$UCL_{\bar{X}} = \bar{\bar{x}} + A_2\bar{R}$

$= 12.98+0.73*0.10 = 13.05$

$LCL_{\bar{X}} = \bar{\bar{x}} - A_2\bar{R}$

$= 12.98-0.73*0.10 = 12.90$

A_2 is a constant whose value is 0.73 for given m/n=4

Upper control limit = 13.05

Center line (mean) =12.98

Lower Control limit = 12.90

Note: All specifications are in 'mm'.

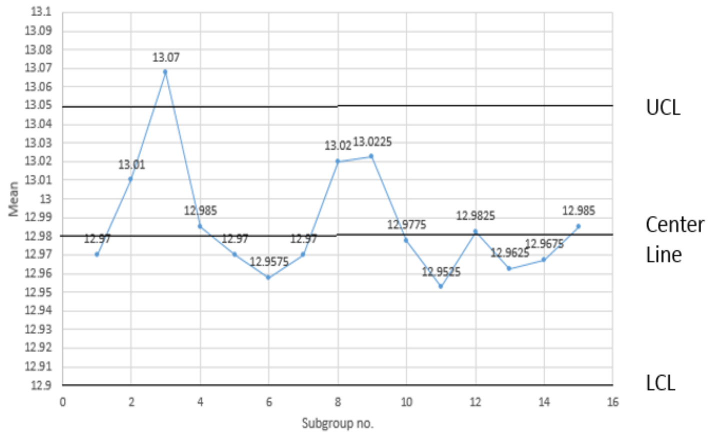

Chart -1: Initial $\bar{X}$ control chart

Interpretation of initial control chart:
Showing the Process is out of upper control limit.

- According to the chart variability the Special-cause variation is present
- Cause may or may not be intentional (power surges, computer crash, health of the operator etc.).
- Performed Audit on the variable batch timing.
- Root cause is power surge during one batch caused the process fluctuation.

2.3. Revaluation of $\bar{X}$ Chart:

Excluding the sample no. 3 which is out of control and again calculate the remaining for specification limits

Referring to the formulas from initial calculations:

Grand average

$$\bar{\bar{x}} = \frac{x1+x2+\cdots+xN}{N} = 12.981$$

Average of ranges

$$\bar{R} = \frac{R1+R2+\cdots+Rn}{n} = 0.108$$

Control limits:

$UCL_{\bar{X}} = \bar{\bar{x}} + A_2\bar{R}$

$=12.981+0.73*0.108=13.05$

$LCL_{\bar{X}} = \bar{\bar{x}} - A_2\bar{R}$

$= 12.981-0.73*0.108$

$=12.908$

Note: All specifications are in 'mm'.

Upper control limit = 13.05 mm

Center line (mean) =12.981 mm

Lower Control limit = 12.902 mm

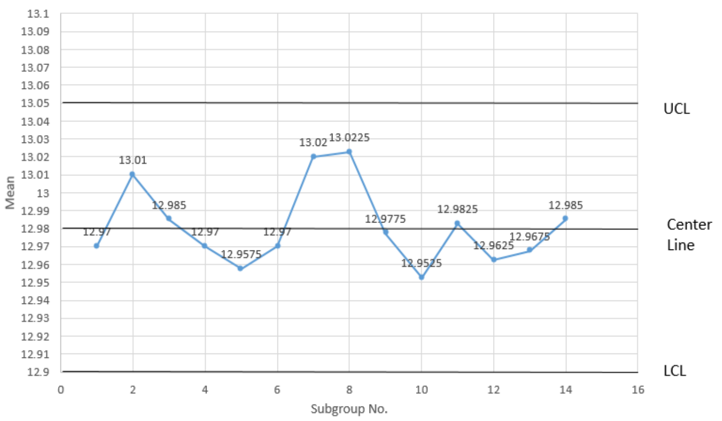

Chart -2: Final X̄ control chart

Analysis of revaluated x-bar chart:

The control chart for ranges is drawn and it is found that all points are within the upper & lower control limits. Then X chart is analyzed and it is found that no point goes out of control so the process is under control and stable.

- The process is under common-cause of variability which is Normal, random variation (man, machine setting, temp. dirt etc.)
- Finding the root cause shows the lack of proper and complete knowledge about laser machine which can be rectified or improved.

2.4. Identifying Variation and root cause:

When a process is stable and in control, it displays common cause variation, variation that is innate to the process. A process is in control, based on past experience it can be predicted how the process will vary (within limits) in the future. If the process is unstable, the process displays special cause variation, non-random variation from external factors. In initial control chart the trend is out if upper control limit which is 13.05 (in mm) shows that the process has the special cause of variation. After the analysis the special or assignable cause found to the 'power surge' and 'fluctuation' during one batch.

In final control chart which is after the removing of that certain batch (batch no. 3) which caused interruption in process in initial control chart and recalculating the data the process comes under control. The common trend along the center line in final control chart shows that the common causes of variation still exists which can be improve over time. The cause of trend in final control chart is operator's insufficient knowledge about the laser machine which results in common cause of variation. Hence the operator training is recommended.

2.5. Cause and Effect diagram:

To identify possible causes of problem the cause and Effect diagram also known as Ishikawa fishbone diagram is widely used. [10,11]

The four M's of process incompetence for Laser process are:

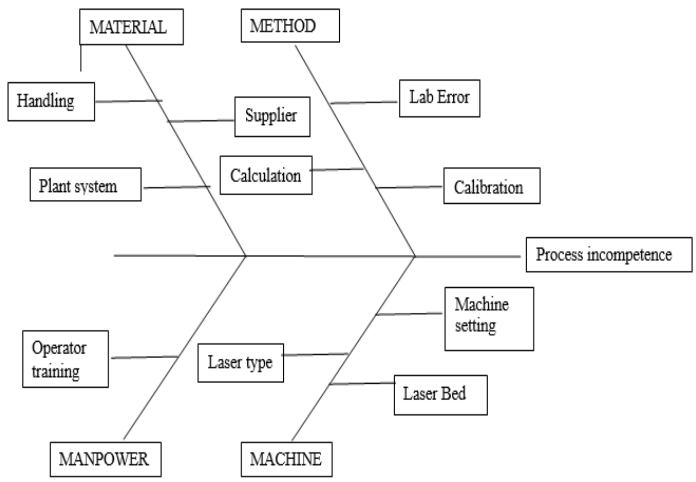

Fig.2. Fishbone diagram

To develop basic in-house competence, we have to work on reducing rejection in Laser cutting process it results in profit generation. Rather than dealing with scrap, work towards reducing scraps and generating required product in given time limit.

1. Material: The material management is the very important task for a company. Material managing is the basic necessity there should be following aspects of material to keep in mind:

a. Material Handling: The temperature and environment conditions can affect the material critically. So, the material should be placed at required environmental conditions.

b. Supplier: From quotation to deliver the material should be properly stated in order to avoid wrong selection. So, the company should maintain close contact to the supplier and required to select the right supplier for suitable material.

c. Plant system: To follow the material throughout the plant is a hassle, in order to avoid making things complicated the plant layout should be properly outlined for essential departments.

2. Method: The method or process defines the product. Absence of an improper method for the recognition of product is necessary. Following aspects of method are:

a. Lab error: Errors related to measurement and measurement devices come under Lab Error.

b. Calibration: The calibrations of devices are necessary for measurement. The NABL certified calibration of devices should be needed.

c. Calculation: the SPC method requires critical calculation of the data.

3. Manpower: From the Operator working on the Laser Cutting machine to the supervisor the knowledge of the machine and method comes first. Thus, there is principal requirement of the training of the operator.

4. Machine: For Laser cutting process the machine plays an important role. There are three aspects of machine in Laser cutting.

a. Machine Setting: The setup should be properly placed according to the layout near the material section so there is no need of moving material around.

b. Laser bed: The bed should be clear from debris. Previous cutting scrapes or chips should be properly removed from the bed and clean the bed section for coming material for proper cutting.

c. Laser Type: The proper selection of laser can cut out the material properly and the risk of abrasiveness and partly unclean cut is reduced or completely well cut.

3. CONCLUSIONS

- Overall, there is an awareness towards the quality management systems and procedures in the industry, however a lot needs to be done when it comes to the actual adherence to the quality principles.
- Since the specification's limits were exceeded by less than 2 batch. Then after applying SPC in same, and after excluding the previous non-conformities it can be concluded that the process is improved.
- On reducing rejections wastage of resources can be reduced. Hence overall profit by reducing scrapes is increased. Reduction of rejections results in overall profit generation. SPC is more constructive when it is integrated into in-general companywide quality advancement program.

3.1. Further Advancements:

The SPC is widely used process, for the process improvement, managing time and reducing scrapes together with six- sigma and TQM (Total quality management) and other quality control tools the wastage can be minimized to the lowest and hence the profits can be maximized further.

The SPC can be applied to the other processes for the same results.

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