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How to improve the yield of a cutting process

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Abstract

Purpose: To improve the yield of cutting process automobile glass manufacturing process. There is more rejection in cutting process as compared to the budgeted target. So, we have to improve the process through Six Sigma approach. In this approach we perform different experiments related to the process to reduce the defects which are very frequently comes in the process.

Design/Methodology/Approach:

- What is the current state of defect rejection in CNC cutting process?
- Determine the root causes behind the defects.
- Calculate the Measurement system analysis and agreement of operators with the measurement instruments.
- Determine the source of variability in cutting and grinding process.

Findings: The automobile glass is tempered on the furnace at the temperature range of 750 to780 °C to toughen the glass. For this purpose, it is first cut into desired shape from the raw glass and then grinds on the periphery. In cutting and grinding process various defects is generated from the process and they needs to be controlled to improve the process yield. So, our major pain area is the pre-process defects which occurred during the cutting and grinding process. Pre – process has 2.3% defects which are selected for the project.

Keywords: Six Sigma, Quality, Yield, Cause and effect diagram.

1. Problem definition

To improve the yield of cutting process automobile glass manufacturing process. There is more rejection in cutting process as compared to the budgeted target. So, we have to improve the process through Six Sigma approach. In this approach we perform different experiments related to the process to reduce the defects which are very frequently comes in the process.

2. Objectives

- What is the current state of defect rejection in CNC cutting process?
- Determine the root causes behind the defects.
- Calculate the Measurement system analysis and agreement of operators with the measurement instruments.
- Determine the source of variability in cutting and grinding process.

3. Selection of the problem

The automobile glass is tempered on the furnace at the temperature range of 750 to780 °C to toughen the glass. For this purpose, it is first cut into desired shape from the raw glass and then grinds on the periphery. In cutting and grinding process various defects is generated from the process and they needs to be controlled to improve the process yield. So, our major pain area is the pre-process defects which occurred during the cutting and grinding process. Pre – process has 2.3% defects which are selected for the project.

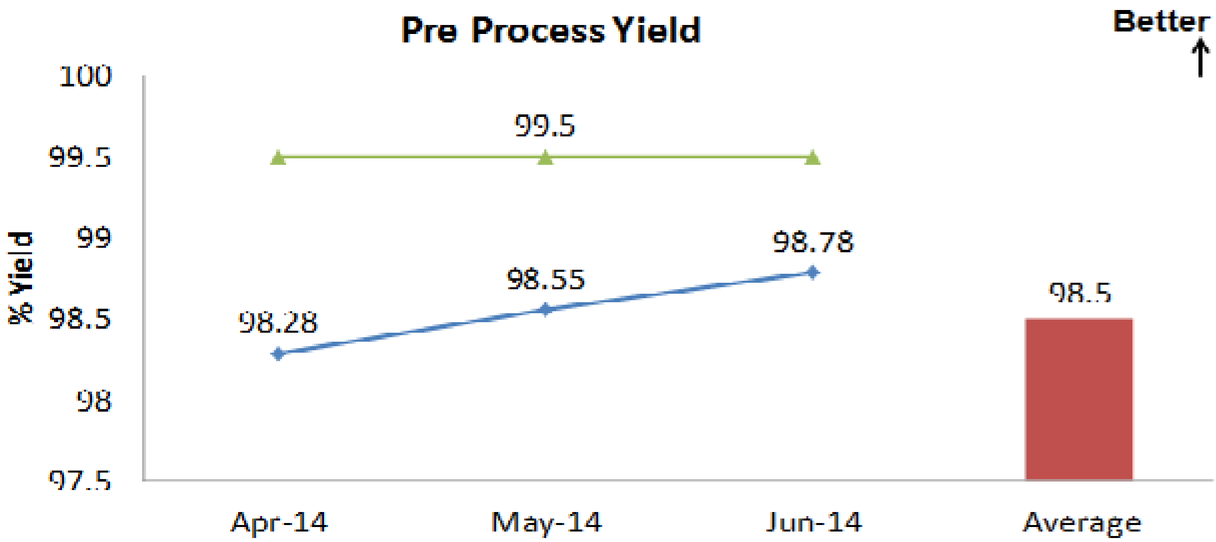

Figure 3.1 Run chart for rejection PPM (Apr 14 to Jun 14)

From the trend chart shown above we conclude that percentage rejection in the pre-process yield is 98.5 as compared to the target of 99.5%. Then we find the area where the problem exists in the process. This can be targeted by the scoping tree. We find that our main problem area is pre – process. In pre-process there are two major defects in cutting and grinding process. These are selected for the further study.

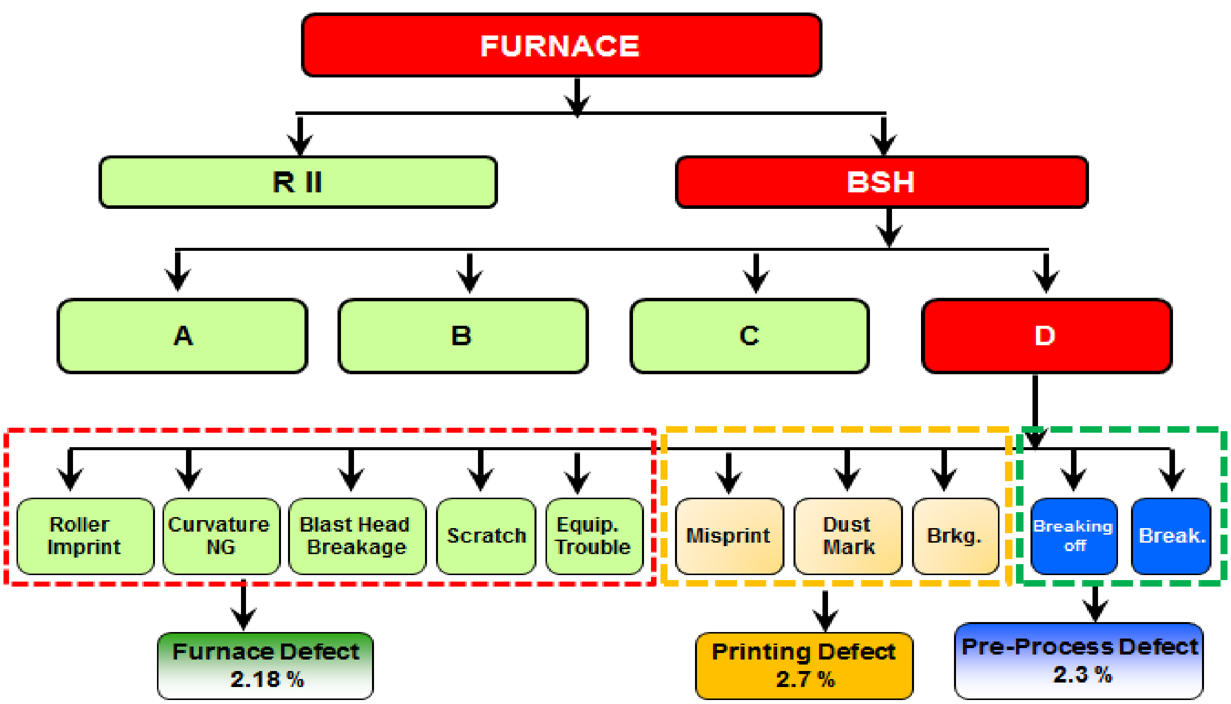

Figure 3.2 Scoping tree for the problem selection

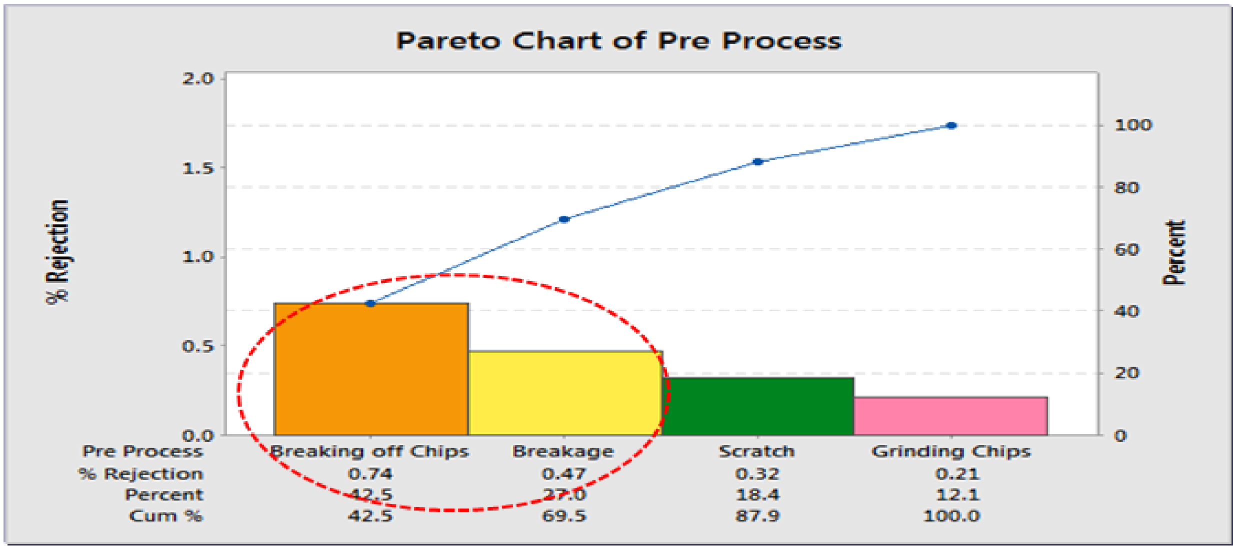

Figure 3.3 Pareto chart for rejection in Short-filling process (june 13 to march 14)

4. Product detail

Tempered Glass: Tempered glass is toughened glass used in automotive. Glass is heated from 680~720°C and toughened with Quench air pressure 1700~2100mm of Aqua after bending to the desired radius.

After selecting the problem area, we collect the data for the last four month and plot there trend chart. From there, we found that the problem is consistent outside the criteria having more rejection.

5. Target setting

The average process yield for the cutting process is 98.5% as compared to the budgeted yield of 99% and for printing process average yield is 98.5% as compared to the budgeted yield of 99.5%.

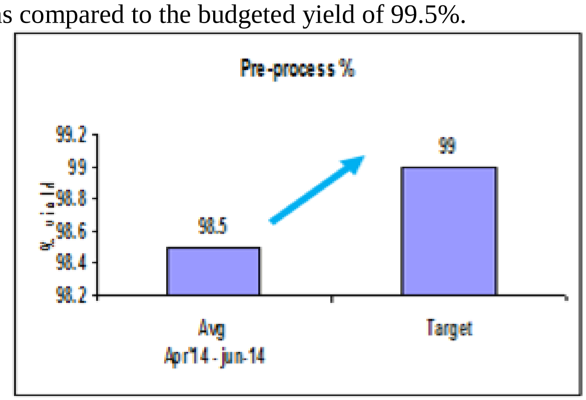

Figure 3.4Target setting.

6. Process flow diagram

Symbols are used to define certain types of steps in a flowchart: rectangles formost steps and diamonds for decisions. See the next screen for a list of flowchart symbols.

A cutting process flowchart is shown below. Each symbol on the map can have additional information added to it such as inputs and outputs. To see an example of the inputs and outputs of a step in the process flowchart, roll over the step indicated in the image below.

7. Creating process flow diagram

1. Define (identify) the process.
2. Brainstorm the activities involved in the process.
3. Arrange the activities in proper sequence.
4. Determine inputs and outputs.
5. Identify time lags and non-value added steps.
6. Once the sequence is agreed upon, draw arrows to show the flow.

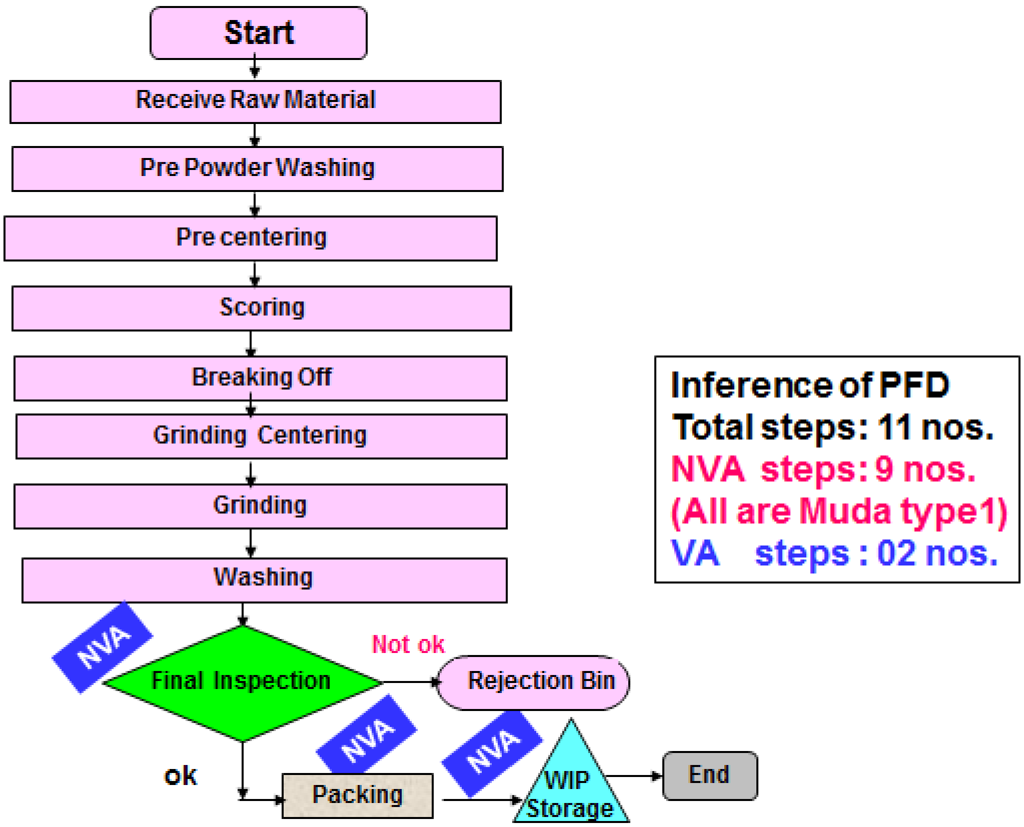

Figure 3.5 Process flow diagram

The above figure shows the process flow diagram for the process. We see that there are total eleven steps in the process in which nine steps are non-value added. There is only two value added steps which added actual value to the product. They are scoring and grinding.

We check the input/ output sheet for each step. From there we conclude that there are eight steps which have the 100% output and on the three steps there is yield loss.

8. Input – Output sheet

Inputs (Xs) are causes (independent variables) that contribute to specific outputs (Ys) or effects (dependent variables). Not only are inputs and outputs important to sequential processes in an operation, they are also important to consider from a supplier-to-customer perspective.

- Do I know the external customer requirements for this process?
- Do I know the internal customer requirements if they, in fact, exist?

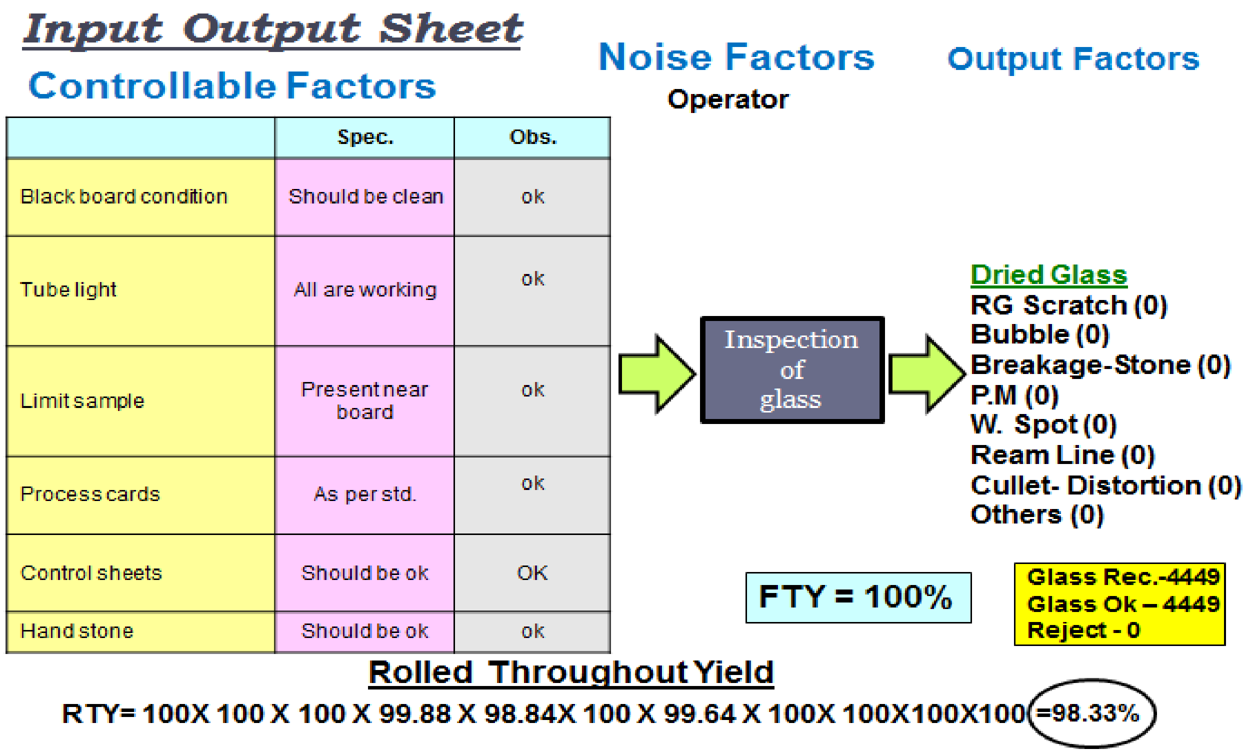

Table 3.1 Input/output sheet.

Inference of input output sheet

1) Total numbers of factors = 64
2) Controllable factors = 58
3) Non controllable factor = 6
4) Cause and effect diagram for breaking off chips
5) Cause and effect diagram for grinding chips.

9. Cause and effect diagram for Breaking off Chips

The cause and effect diagram is also called the Ishikawa diagram after its developer, Kaoru Ishikawa. He first used it in 1943 to explain to engineers how various factors could be sorted and related. It is also referred to as a fishbone diagram because it visually resembles the skeleton of a fish. Today, the cause and effect diagram, sometimes abbreviated as the C-Ediagram, endures as one of the most widely used quality tools.

"The root of all quality improvement lies in understanding processes. Many existing tools assist managers, engineers, and others in this work. You need not always look for the newest tool, software, or management theory to construct a sound foundation on which to build improvements".

Causal factors are generally related to influences from (sometimes referred toas the 7 Ms):

- People or workers (Man)
- Equipment (Machine)
- Methods
- Materials
- Environment (Mother Nature)
- Data and information systems (Measurements)
- Management

9.1 Constructing Cause and Effect diagram

- Agree on a problem statement (effect). Write it at the center right of an easel or whiteboard. Draw a box around it and draw a horizontal arrow running to it.
- Brainstorm the major categories of causes of the problem. If there is difficulty here, use generic headings: Methods, Machines, Man, Materials, Measurement, Mother Nature, and Management. Write the categories of causes as branches from the main arrow.
- Brainstorm all the possible causes of the problem. Ask "Why does this happen?" As each idea is given, write it as a branch from the appropriate category. Causes can be written in several places if they relate to several categories.
- Ask again, "Why does this happen?" about each cause. Write sub-causes branching off the causes. Continue to ask "why?" and generate deeper levels of causes. Layers of branches indicate causal relationships.
- When the group runs out of ideas, focus attention to places on the fishbone where there are fewer ideas.

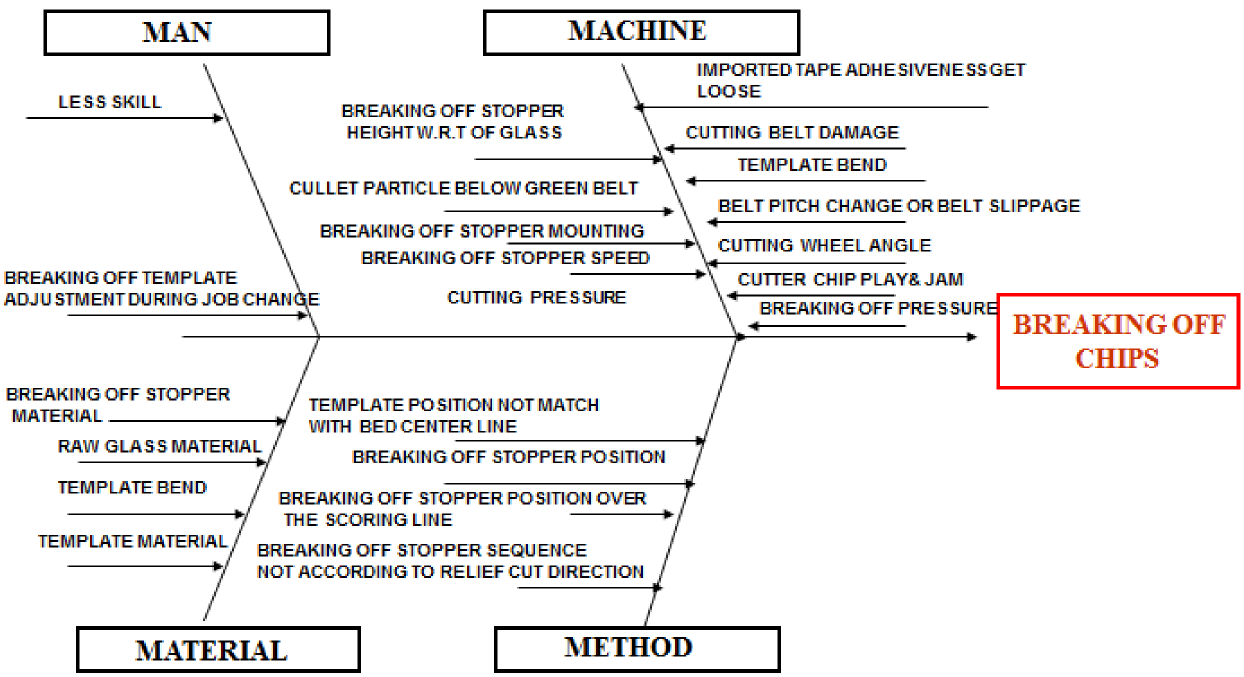

Figure 3.6 Cause and Effect diagram.

10. Trial for reducing breaking off chips

Trial with cutting pressure

Trial 1:

With Increased cutting pressure (2150 Pcs).

	Before	After
Cutting pressure	1.8 – 2.0	2.2
Breaking off Chips Rejection	0.012	$\frac{7}{1636} = 0.0043$

Test and CI for One Proportion

Test of p = 0.012 vs p ≠ 0.012

Sample	X	N	Sample p	95% CI	Exact P-Value
1	7	1636	0.004279	(0.001722, 0.008796)	0.001

Increased cutting pressure reduces the breaking off chips problem.

Figure 3.7Trial for cutting pressure.

From the above experiment we see that, we perform an experiment with increased cutting pressure. The value of cutting pressure is increased from 1.8 to 2.2 kgf. Minitab helps us to calculate the proportion for the experiment. We conduct the one proportion test to check the validity of the experiment. From the output, we find that the increased cutting pressure reduces the breaking off chips problem. The breaking off trend after the experiment is shown in the figure below.

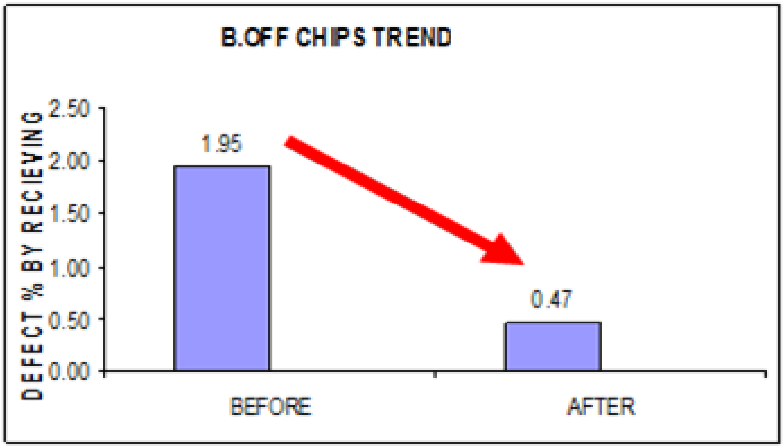

Figure 3.7Process improvements after increasing the cutting pressure.

11. Design of Experiments

Design of experiments (DOE) are used to craft well-designed efforts to identify which process changes yield the best possible results for sustained improvement. Whereas most experiments address only one factor at a time, the design and analysis of experiments methodology focuses on multiple factors at one time. DOE provides the data that illustrates the significance to the output of input variables acting alone or interacting with one another.

Design of experiments (DOE) is a "branch of applied statistics dealing with planning, conducting, analyzing and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters."

Design and analysis of experiments provides these advantages over other, more traditional methods:

- Evaluating multiple factors at the same time can reduce the time needed for experimentation.
- Some well-designed experiments do not require the use of sophisticated statistical methods to understand the results at a basic level. However, computer software can be used to yield very precise results as needed.
- The costs vary depending on the experiment, but the financial benefits realized from these experiments can be substantial.

To optimize the correlation of Cutting pressure, Breaking off pressure and Height of Breaking off stoppers w.r.t Table. (6400 pcs)
The number of breaking off chips recorded after the experiment and to be compared with current level of breaking off chips.

	Low	High
Cutting Pressure	2.0 kgf	2.2 kgf
Breaking off Pressure	2 kgf	3 kgf
Stopper Height wrt Table	20 cm	25 cm

Table 3.2 Parameters for the process input

Block	Cutting Pressure	Break Off Pressure	Stopper Height wrt Table	% Breaking off Chips
1	2	3	25	1.5
1	2	2	20	1.75
1	2.2	3	20	2.25
1	2.2	2	25	0.75
2	2	2	25	0.5
2	2	3	20	1.5
2	2.2	3	25	1.25
2	2.2	2	20	1
3	2	3	20	0.25
3	2.2	2	20	0
3	2	2	25	0
3	2.2	3	25	0.25
4	2.2	3	20	0.75
4	2	3	25	0.75
4	2.2	2	25	0.25
4	2	2	20	1

Table 3.3 Treatment level for experiment.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	5.96484	0.85212	12.83	0.001
Blocks	3	4.41797	1.47266	22.18	0.000
Linear	3	1.35547	0.45182	6.80	0.014
Cutting Pressure	1	0.03516	0.03516	0.53	0.488
Breaking off Pressure	1	0.66016	0.66016	9.94	0.014
Stopper Height wrt Table	1	0.66016	0.66016	9.94	0.014
2-Way Interactions	1	0.19141	0.19141	2.88	0.128
Cutting Pressure*Breaking off Pressure	1	0.19141	0.19141	2.88	0.128
Error	8	0.53125	0.06641		
Total	15	6.49609			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.257694	91.82%	84.67%	67.29%

Figure 3.9 Minitab output window.

Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		0.8594	0.0644	13.34	0.000	
Blocks						
1		0.703	0.112	6.30	0.000	1.50
2		-0.734	0.112	-6.58	0.000	1.50
3		-0.172	0.112	-1.54	0.162	1.50
Cutting Pressure	-0.0937	-0.0469	0.0644	-0.73	0.488	1.00
Breaking off Pressure	0.4063	0.2031	0.0644	3.15	0.014	1.00
Stopper Height wrt Table	-0.4063	-0.2031	0.0644	-3.15	0.014	1.00
Cutting Pressure*Breaking off Pressure	0.2188	0.1094	0.0644	1.70	0.128	1.00

Regression Equation in Uncoded Units

% Breaking off chips = 14.14 - 5.94 Cutting Pressure - 4.19 Breaking off Pressure
- 0.0813 Stopper Height wrt Table
+ 2.19 Cutting Pressure*Breaking off Pressure

Figure 3.10 Minitab output window (continued).

The output from the Minitab's session window shows that the breaking off pressure and the stopper height with respect to table are the significant factors for breaking off chips. We set these factors with the Minitab software at the values where breaking off problem is optimized by the use of response optimizer as shown in figure below.

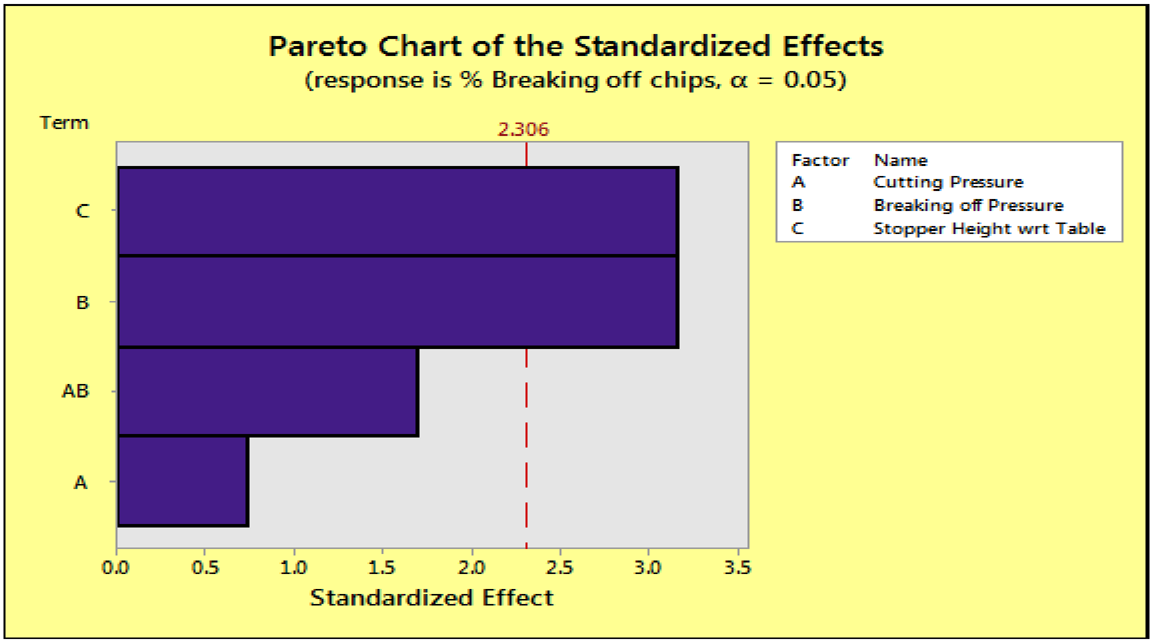

Figure 3.11 Pareto chart for standardized effects.

Pareto chart in the above figure shows that the term B and C are contributing the defects. These are optimized and the run the process at the customized setting we obtain good results.

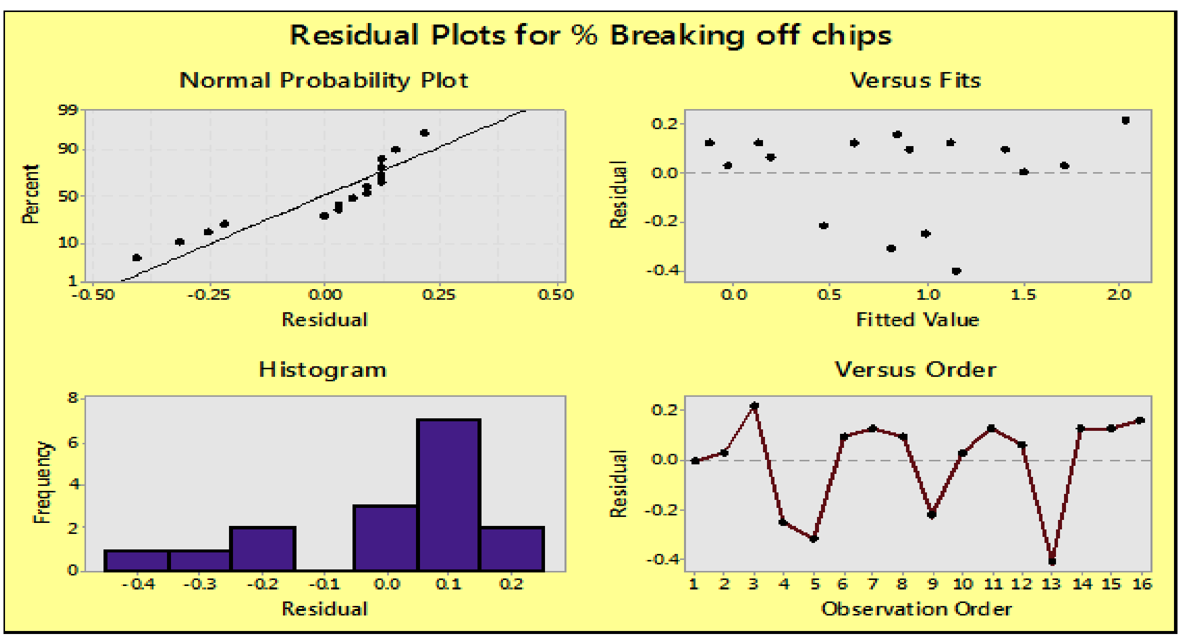

Figure 3.12 Residual plots for breaking off chips.

From the above figure we conclude that the probability plot for the breaking off chips is normal and there is no order of residuals. Histogram also looks normal and there is no pattern for fits.

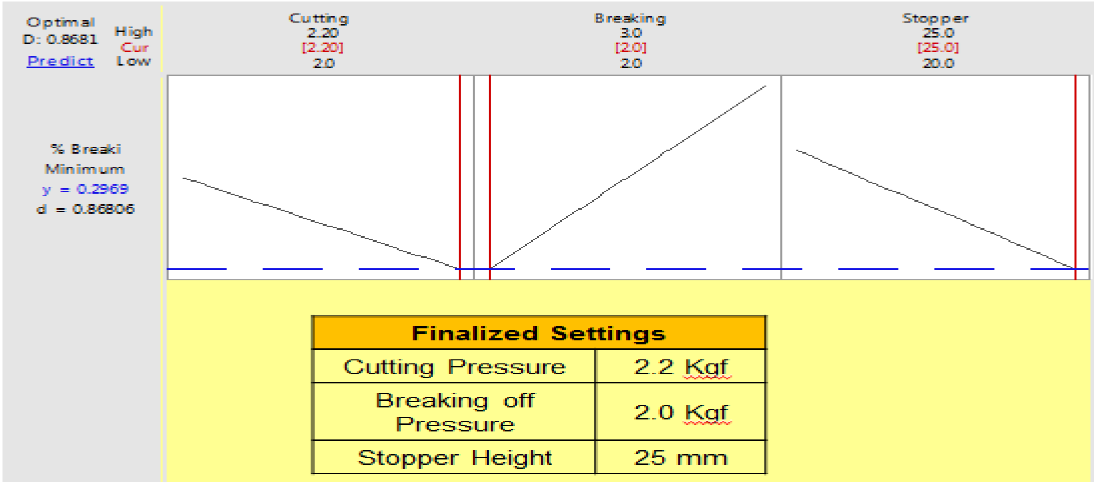

Figure 3.13 Response optimizer output for breaking off chips.

The optimized result for the breaking off chips is shown in the figure.
The figure given below shows the improvement in the process after implement the results and the process parameters.

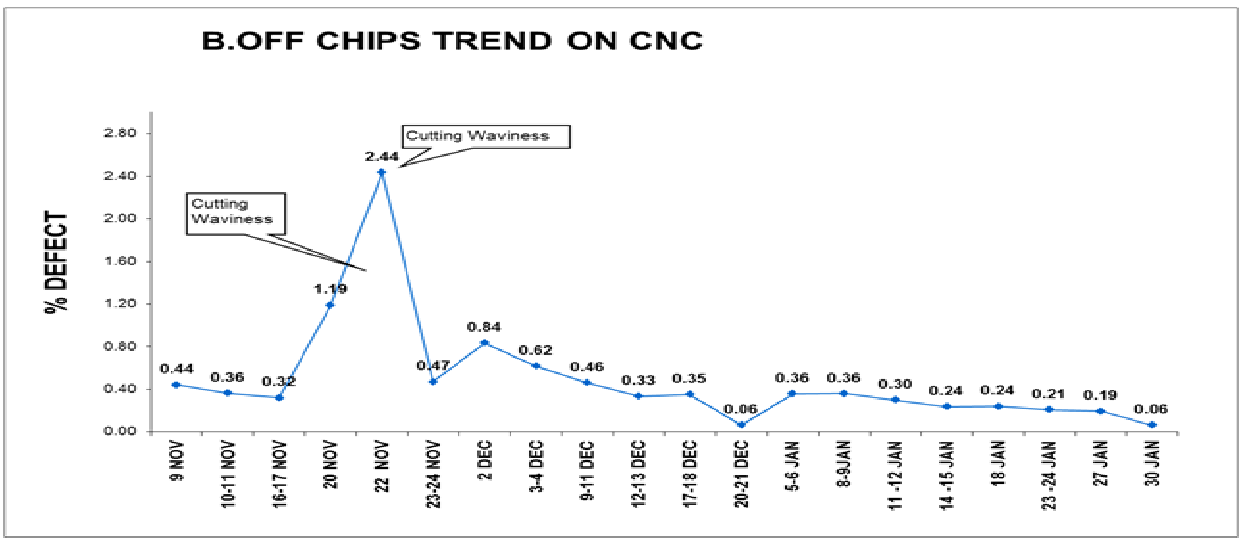

Figure 3.14 Breaking off trend after improvement in the process.

12. Cause and effect diagram for grinding chips

Cause and effect diagram for the grinding chips are shown below. The factors which contributed the grinding chips are shown as per the category, i.e., man, machine material, and method.

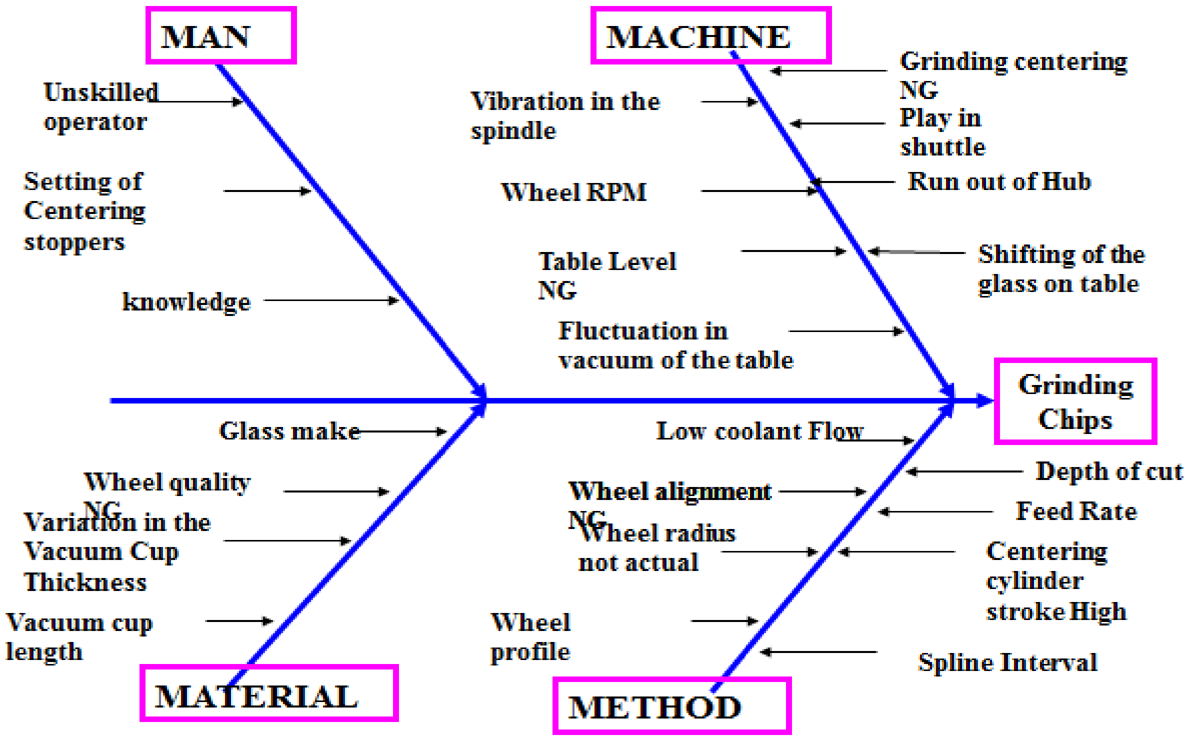

Figure 3.15 Cause and effect diagram for the grinding chips problem.

13. Trial for grinding chips

A trial was done to reduce the grinding chips problem with the leveling of the grinding table. Initially, the trial done the table for the grinding process was not leveled as per the standard. Then, during the maintenance of the machine the grinding table leveled and the process again started. Hence, reduce the grinding chips problem.

Trial 2:

With levelling the grinding table (2150 Pcs).

Historical Proportion = 0.6%

Sample received = 4680

Sample rejection = 12

Test and CI for One Proportion

```
Test of p = 0.006 vs p < 0.006

                                                    Exact
Sample   X     N   Sample p  95% Upper Bound      P-Value
1       12  4680   0.002564         0.004151        0.001
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Hence grinding chips have been significantly reduced by levelling the grinding table.

Figure 3.16 Trial for leveling the grinding table.

Grinding chips trend after leveling of the grinding table

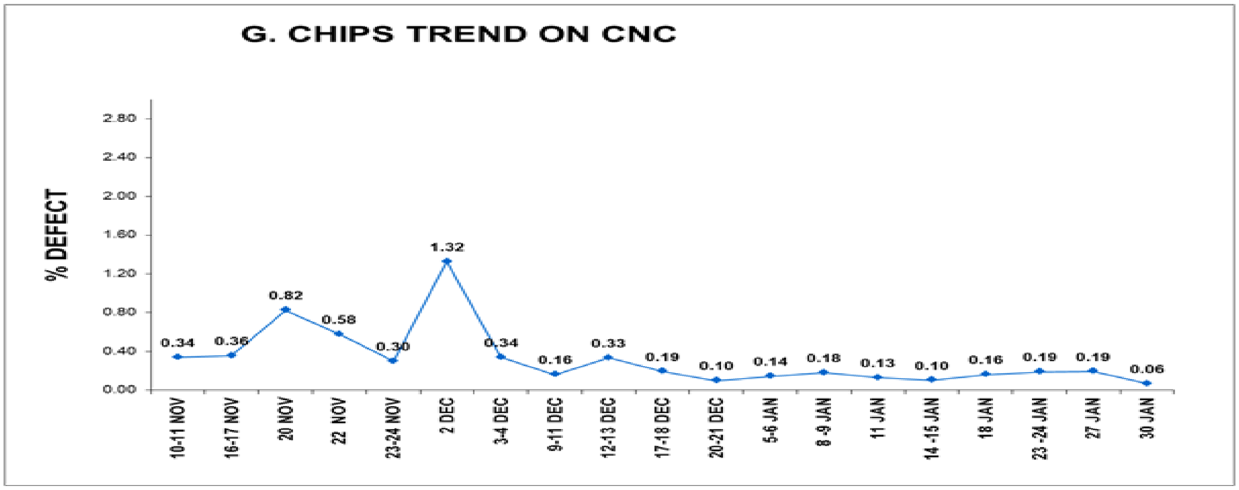

Figure 3.17 Trend after improvement in the grinding chips.

Results

The main focus in this project was to improve the process yield which was against the budgeted target. As a result, a set of improvements were recommended that would increase the yield by a total of 0.5%. This improvement gives several benefits for the target company and those benefits will now be explained more deeply.

The reason why companies keep buffer stocks of finished products is to answer to customer demand fluctuations. In addition to buffer stocks, there are only two ways to buffer against demand spikes. One is to give a long delivery lead time to the customer, thus buffering with time. The second is to have excess capacity for the demand spikes, thus buffering with capacity. If the demand would always be known far to the future and no uncertainties would occur in the manufacturing process, then there would be no need to keep stock of finished goods. This however does not happen in the real world.

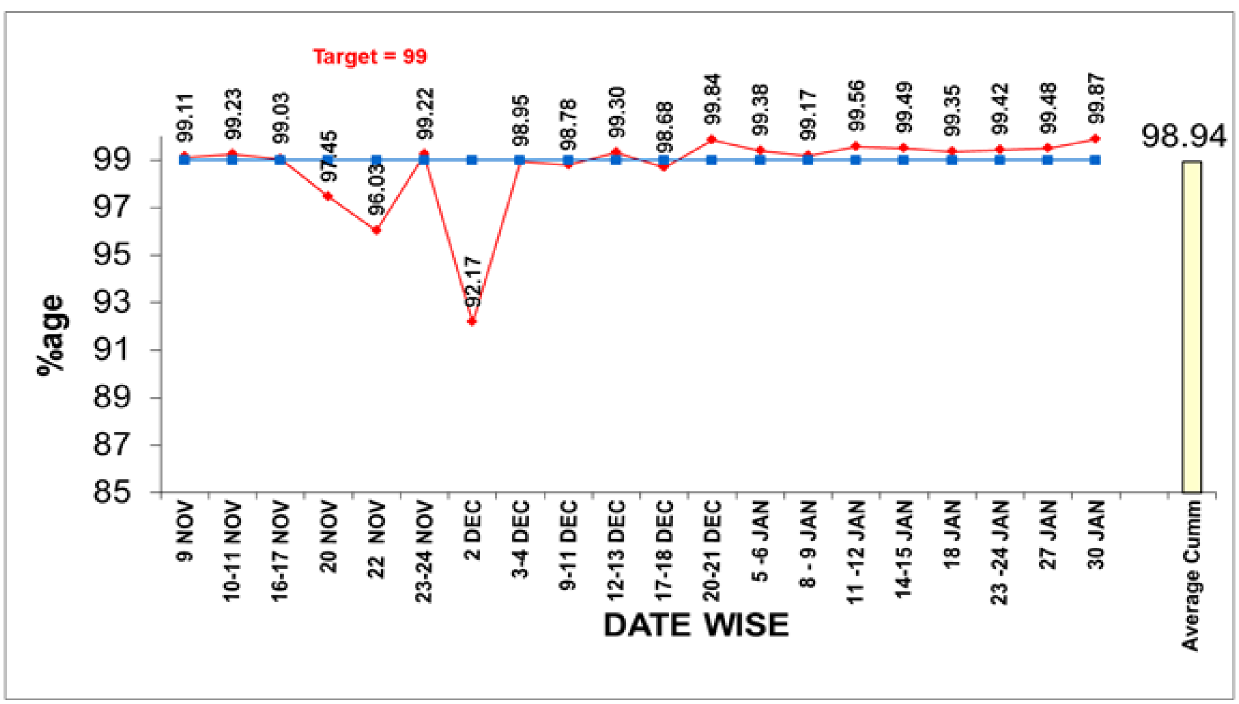

Figure 4.1 Trend chart after the improvement of the process.

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