To Implement "Lean Six Sigma" Concept in Automobile Manufacturing – A Case Study

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1. Abstract

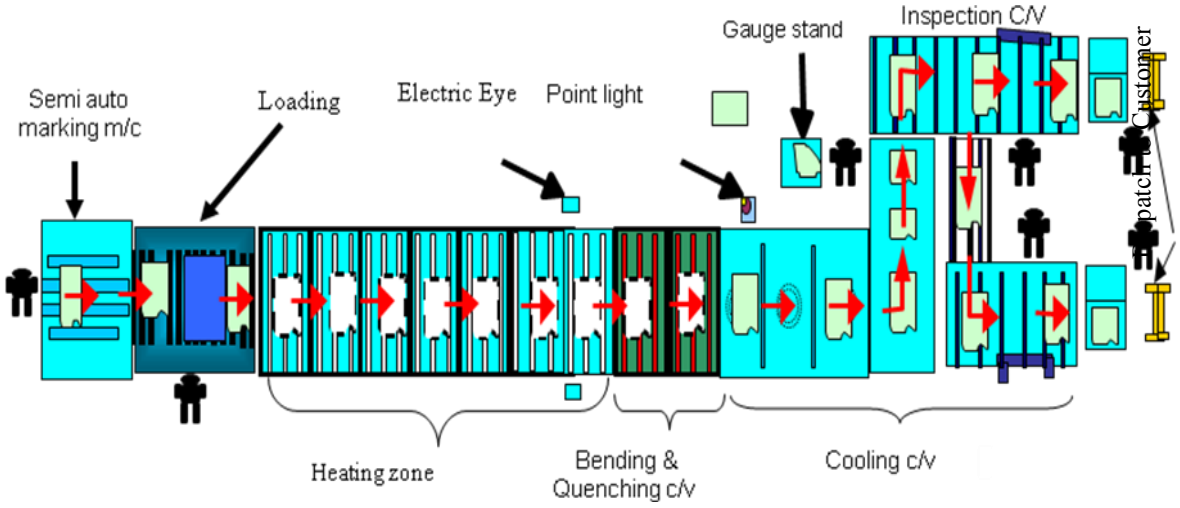
With the ever increasing demand of the customer in a highly competitive environment quality perfection is a desirable objective. The purpose of this paper is to bring the focus on problem solving techniques using Lean Six Sigma methodology and to change the mind set of peoples within the organization that root cause cannot be established just by thinking and engineering guesses. Six Sigma methodologies help to pin root causes using simple data collection and analysis technique. This case study will explain the application of various graphical and statistical tools of problem solving in real life like Pareto, Box Plot, Main effect plot, Interval plot and Binary logistic regression. The study was conducted at M/S Asahi India Glass an auto glass manufacturer a Tier 1 supplier of Maruti Suzuki India Limited (Largest Car Manufacturer of India). The major pain area was high rejection in Tempering process i.e. 62158 PPM against the target of 45000 PPM in FY 2013-14. With the scoping tools like tree diagram and Pareto, Product Backlite glass of Swift Dzire (MPG-BCK) was found the major contributor and characteristics identified for analysis were Curvature NG, Blast Head Breakage, and Roller Imprint. This rejection was being reported since inception. As a result by this case study after analysis and countermeasures the overall rejection reduced by 40%.

1.1 Keywords

Automotive Industry Case study on Quality improvement, Manufacturing Process–Tempered Glass, Customer Satisfaction, Major management Pain Area and Application of Various Statistical tools.

2. Introduction

In today's competitive market when customer has countless options, Quality at lowest cost has become the emblem of any organization. From pin to aeroplane, everything demands the maximum Quality at the minimum price. In early 90's, it was the producer who was deciding the prices but today the trend has taken a 180˚ turn. Now it's the customer who is aggressively deciding the pricing policies. Seeing such a competitive situation, it is the need of the hour to optimally utilize the resources. Same is the state of affairs with automobile companies around the world. "Providing best quality at the least cost" is the working principle which can only be achieved by reducing the rejection and reworks within the process. The case study depicted in this Lean Six Sigma project that was completed at one of the Tier-1 supplier Asahi India Glass (Tempered Back door Glass).Case study was conducted by one of the MACE counselor and Asahi India team under the championship of Dr. K.Kumar (Ex Director-MSIL). VT Furnace (I-94) was the newly installed furnace and the unique feature is that it produces side door as well as back door glass on the same furnace.

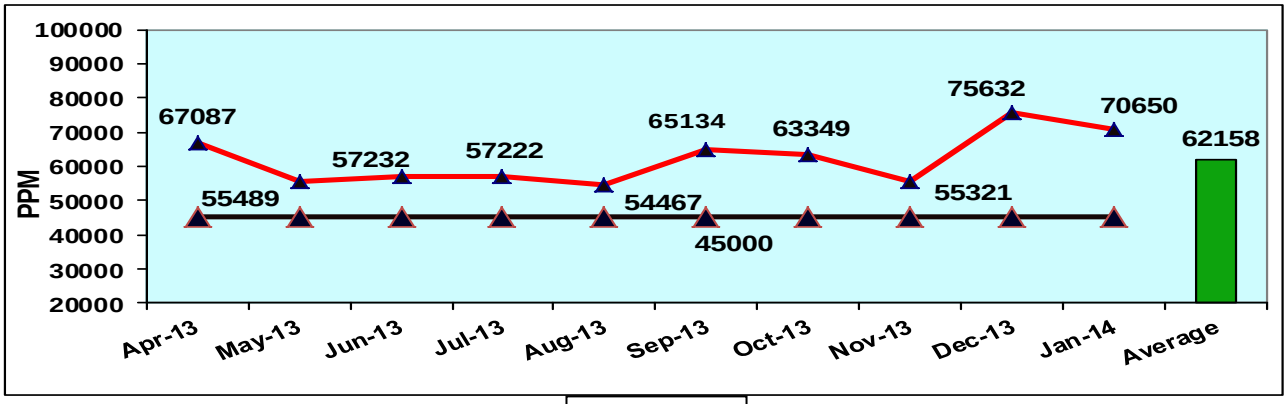


VT Furnace (I-94)

2.1 Project Overview

2.1.1 Problem Statement

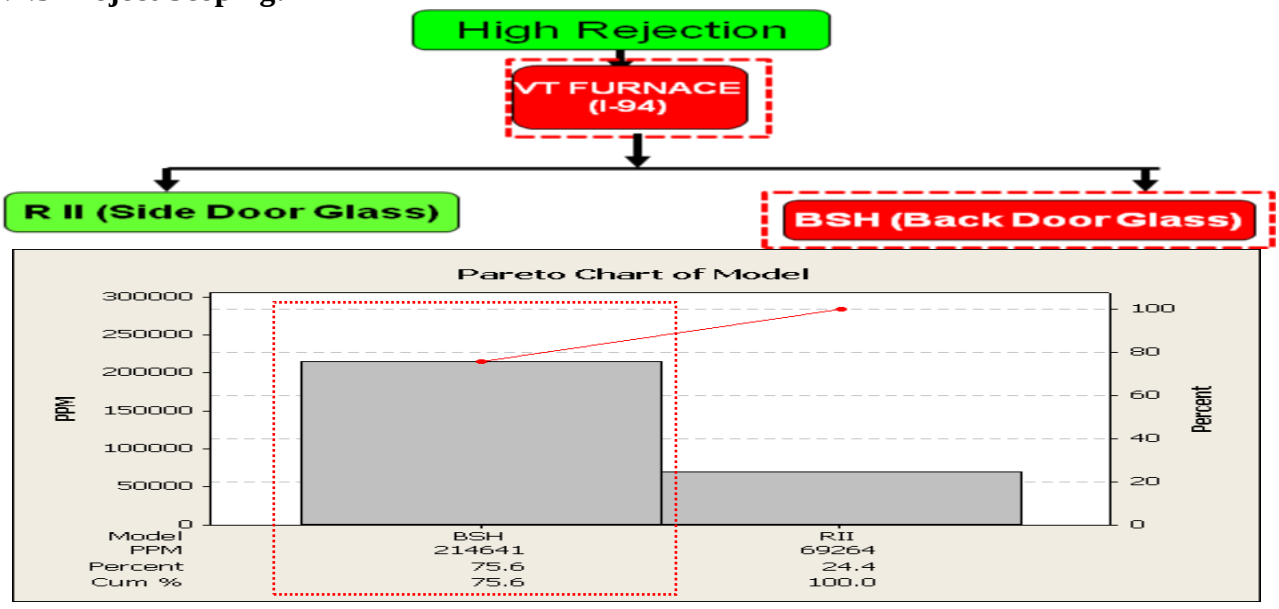
High rejection at tempering process VT Furnace (I-94) was from inception. Total internal Rejection, at tempering process on VT Furnace (I-94), is 62158 PPM from Apr`13 to Jan`14 during the Year 2013, against target of 45000 PPM.



2.1.2 Product Detail

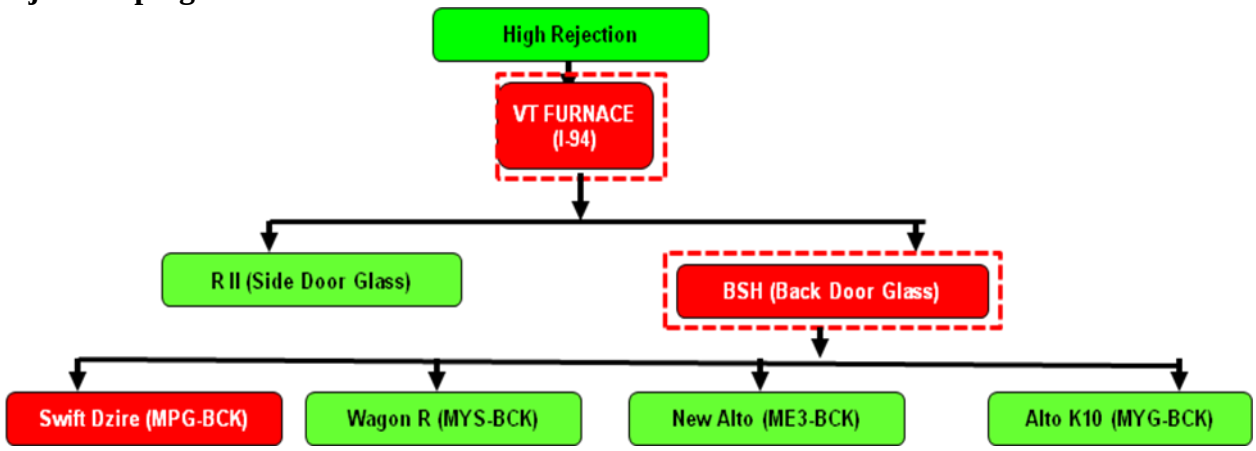
Tempered Glass: Tempered glass is toughened glass used in automotive. Glass is heated from 670 to 720 degree Celsius and toughened with quench air pressure 1600 to 1900mm of aqua after bending to the desired radius.

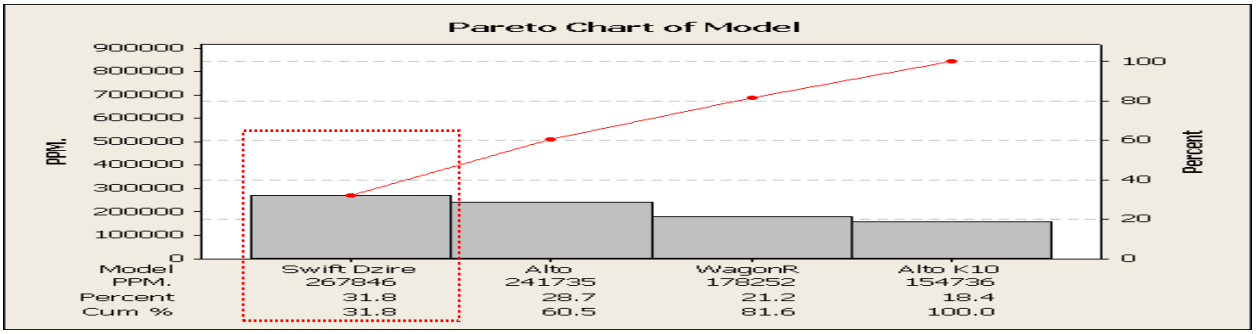
2.1.3 **Project Scoping:**



Inference: Rejection in BSH contributes 75% so we select BSH for further analysis.

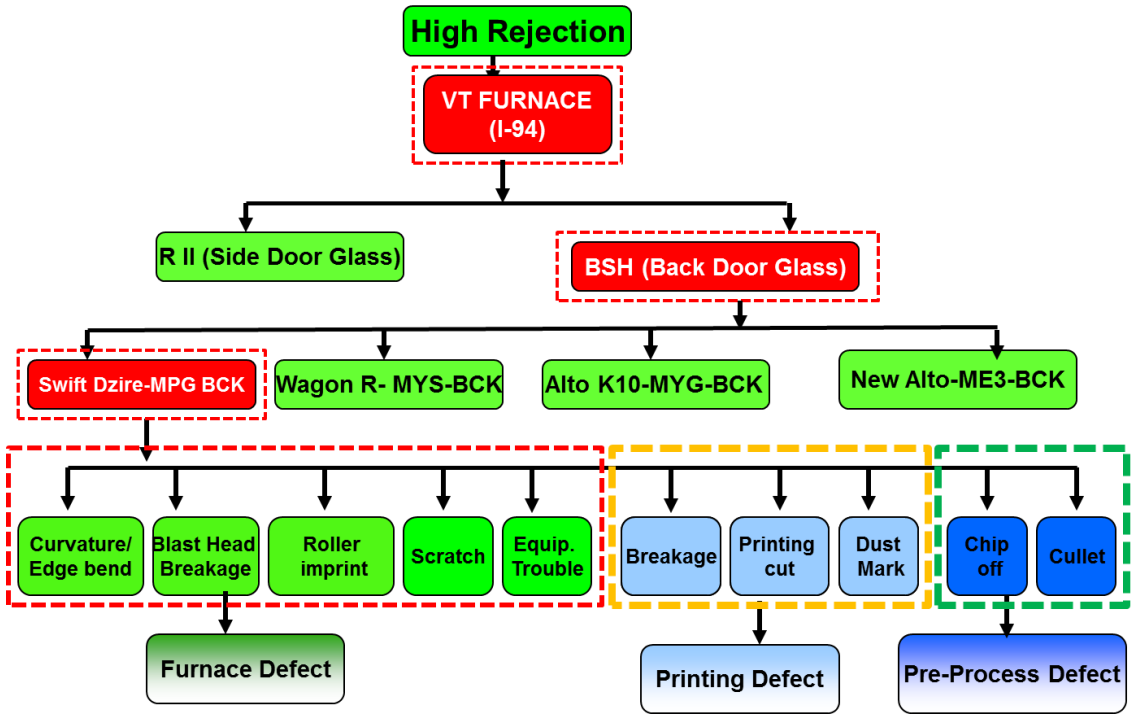
Project Scoping:



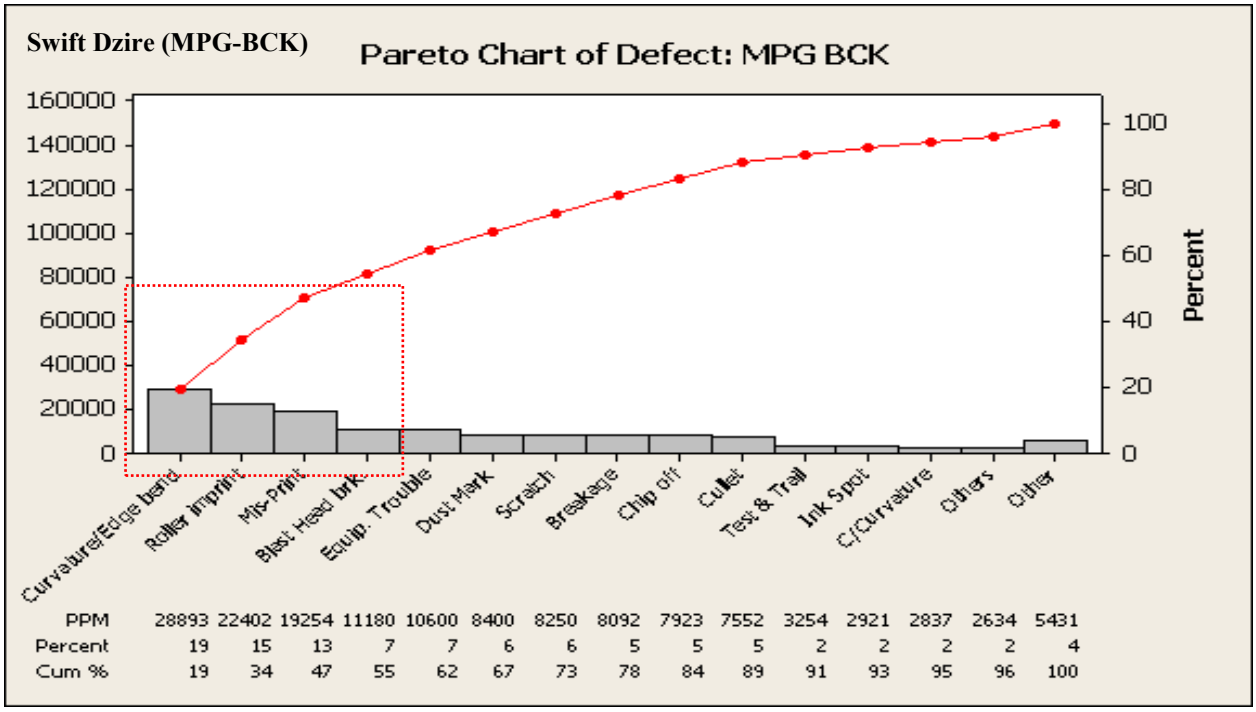


Inference: Swift Dzire (MPG-BCK) contributes the most rejection so we selected this model of glass and it was expected that similar countermeasures will apply to other model will also reduce the rejection.

Final Scoping:



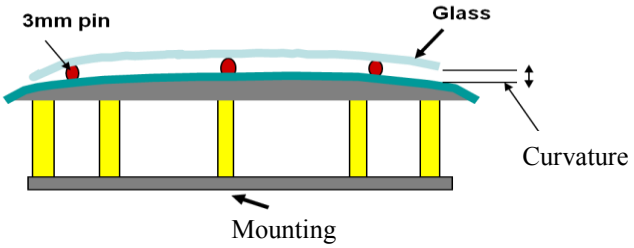
Inference: Found the scope from satellite level (Tempering model) to Project level (Particular Defects).

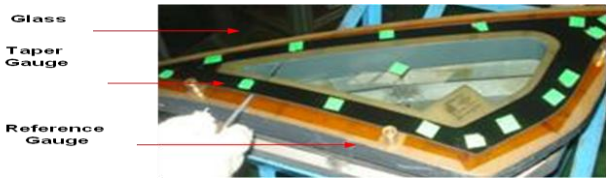


Inference: Curvature, Blast Head Breakage and Roller imprint are top three defects which contributes 41% of total rejection. So further we will show defect details and target setting.

2.1.4 Problem Definition

Curvature NG: Curvature is gap between glass and gauge. It is measured with the help of taper scale its reading should be in the range of (3±1.5)mm.

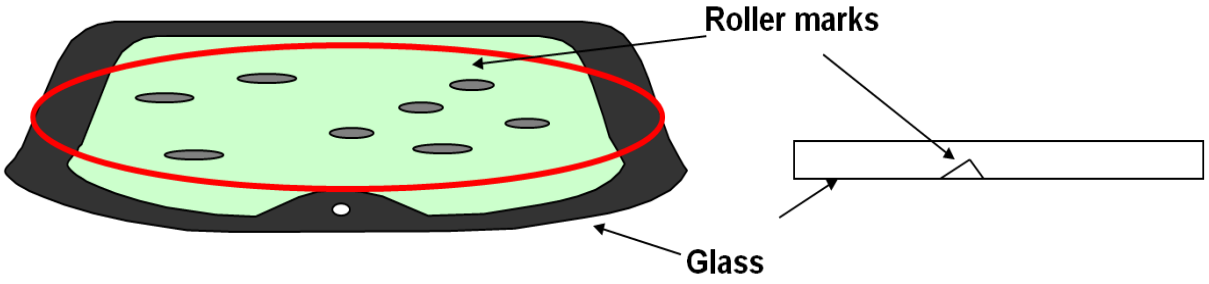




Blast Head Breakage: Glass when breaks into smaller particles during quenching of the glass during high quench pressure after bending process is called Blast head breakage.

Glass broken into finer particles during quenching

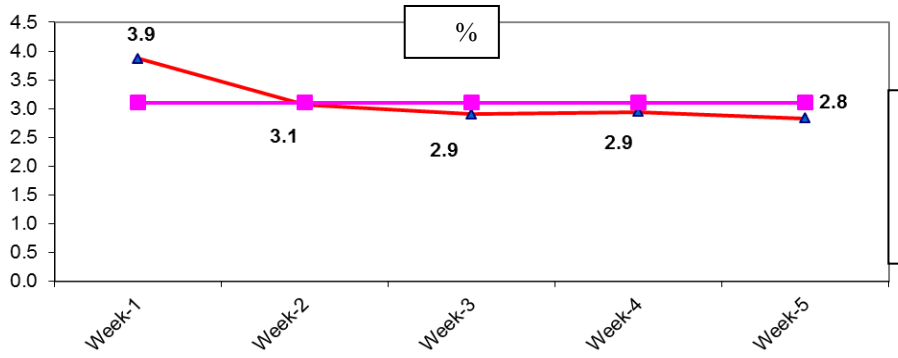
Roller Imprint: Deposition of foreign particles on the glass surface transmitted from rollers to glass is called roller imprint.



2.1.5 Target Setting

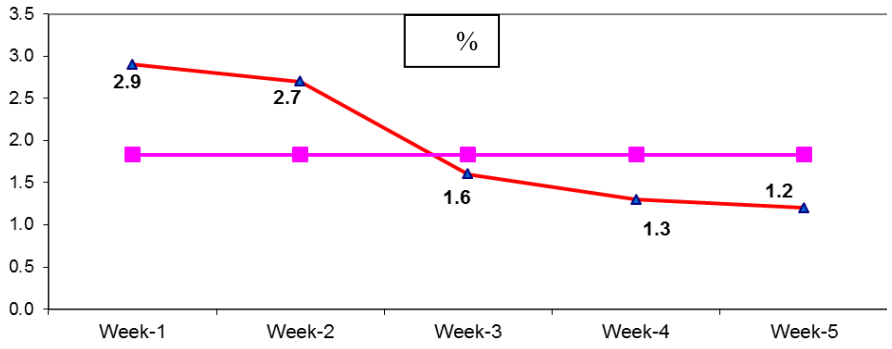
For setting the target we collected the 5 weeks data under the observation of one of the team member and target was set based on the 5 weeks authentic data as per the guidelines.

Week wise Rejection Trend: Curvature NG



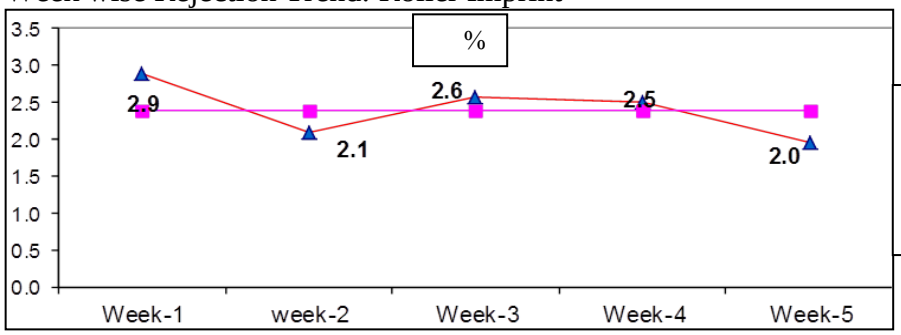
Based on the management guidelines target was set aggressively based on average current PPM level.
Target = 1.44%

Week wise Rejection Trend: Blast Head Breakage



Based on the management guidelines target was set aggressively based on average current PPM level.
Target = 0.6%

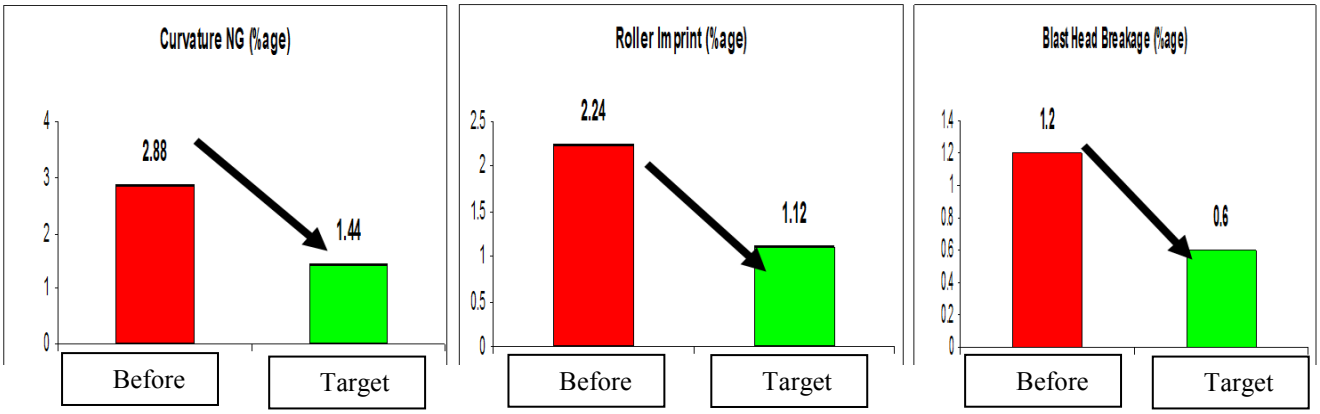
Week wise Rejection Trend: Roller Imprint



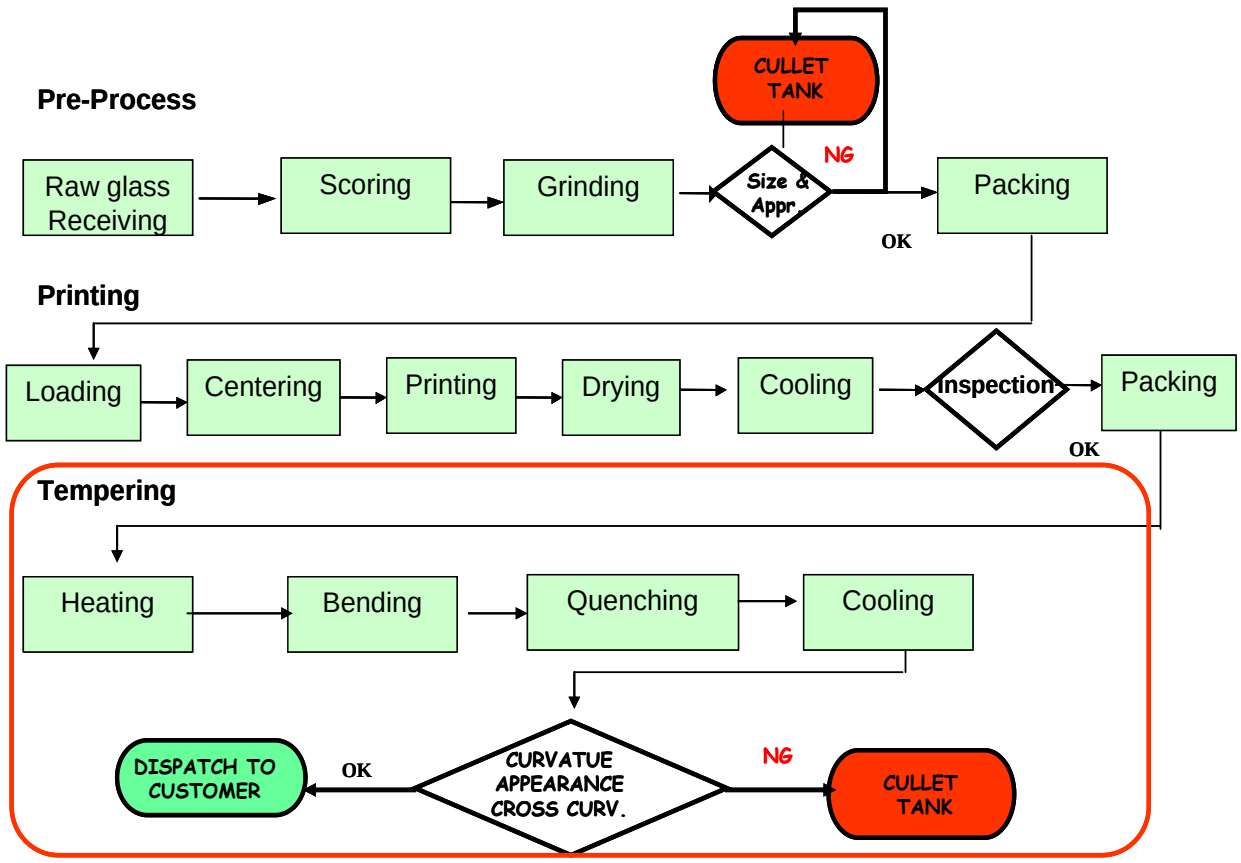
Based on the management guidelines target was set aggressively based on average current PPM level.
Target = 1.12%

Objective Statement:

To reduce the in house curvature NG defect from 2.88% to 1.44%, Blast Head Breakage defect from 1.2% to 0.6%, Roller Imprint defect from 2.24% to 1.12% in Swift Dzire (MPG-BCK) by 31st Oct`14.

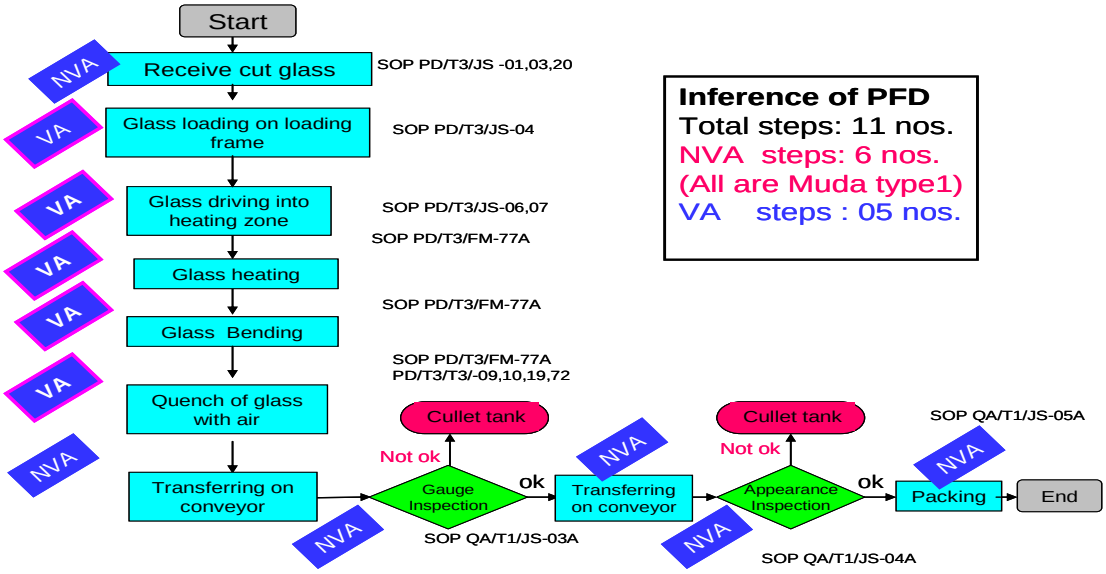


3.1 Process Flow Diagram:



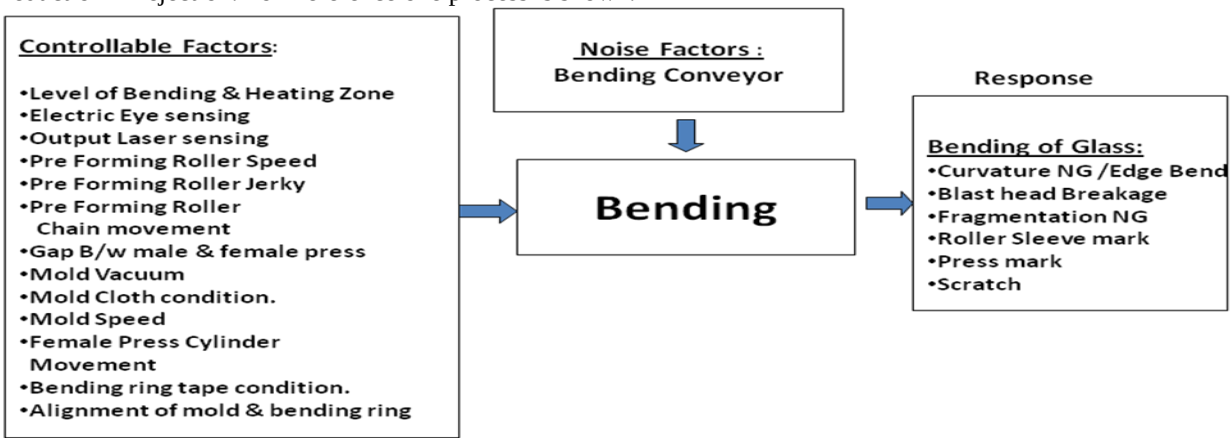
Inference: Find out the focused area, from the process flow diagram, and then go for detailed process map of this focused area.

Detailed Process Flow of Focused Area:



3.2.1 Input Output Sheet:

Input-Output Sheet is a systematic expansion tool which is used for detailed study of process like Input Parameters, specifications, Output features & specifications. It is supported with Capability analysis and measurement system analysis. On the basis of CFT inputs I-O Sheet and Cause & Effect diagram was prepared and it was found that total 63 Input factors may be causing Curvature NG, Blast Head Breakage, and Roller Imprint problems. 7 Nos. Quick Win Opportunities were identified after process verification. Kaizens were implemented to counter all the quick wins and there was significant reduction in rejection. For Reference one process is shown.



One process sample is shown below:

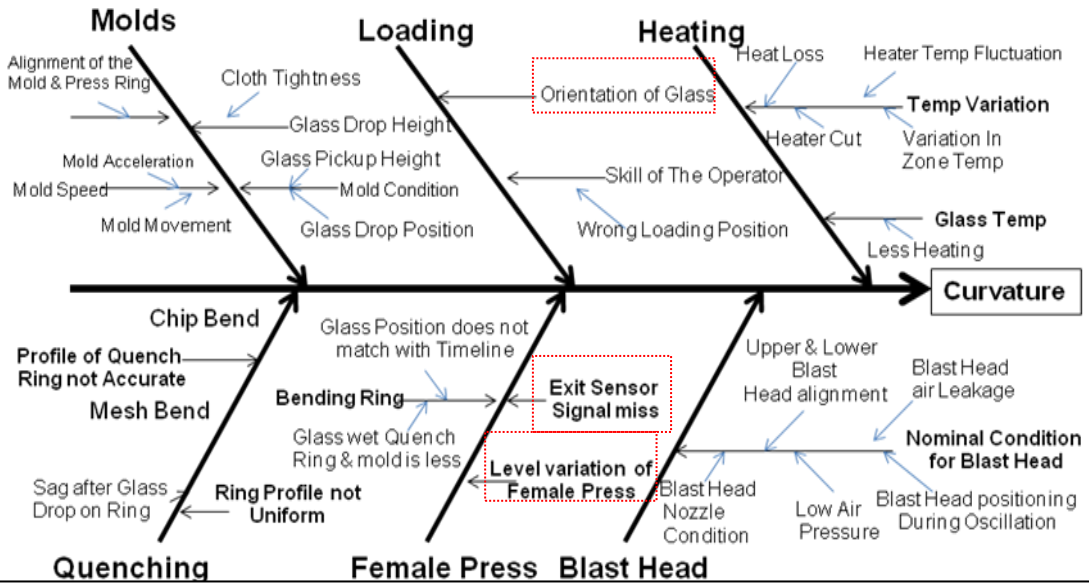
	Process Ouputs/Features					Process Inputs(s)				
Process Step	Output	Feature (Y)	Specification	MSA	Capability	Input(X)	C/N	Feature	Specification	Test(s) / Analysis
Bending	Desired Curvature & Cross Curvature	No Curvature NG	Chain Should Rotate Smoothly	Y	FTY=90%	Roller Speed	C	High/low	As Per Model Specific	OK
		No Fragmentation NG	As per Std Operating Cond. PD/T3/FM-31	N		Gap	C	Less	0.5 to 1.0 mm	Check
		No Reflection	Alignment of Mold and Bending Ring	N		Vaccum	C	Pressure more/Less	As Per Model Specific	OK
		No Mark on Glass		N		Female Press	C	Time slow	As Per Model Specific	OK
		No Breakage		N		Rubber Nozzle	C	Nozzle Proper	Nozzle Dmage	OK

FTY= Total OK Glass / Total Receiving C=Controllable factor and N= Non Controllable factor.

3.2.2 Identification of improvement scope in Basic condition:

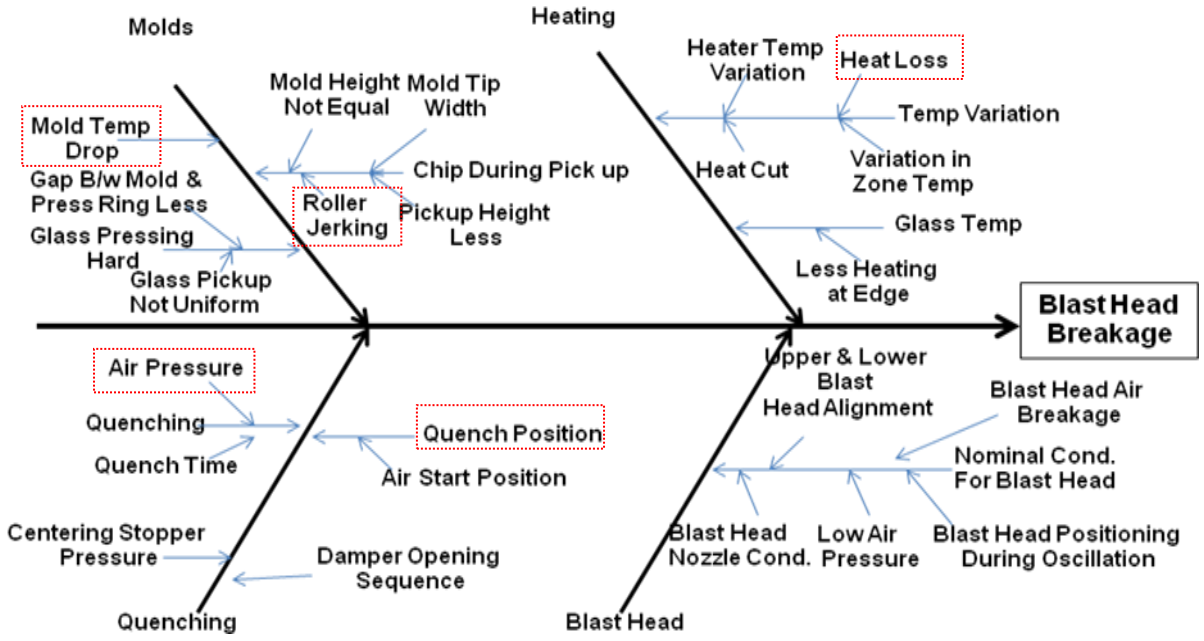
S. No.	Quick Win Opportunity	Action to be taken	Cause of Defect	Current Status
1.	Fork Lift Speed More	Education and Training provide to the all Fork lift driver	Print Cut	Continuous
2.	Dust on Loading Rubber Roller	Covering done from the top side for preventing dust & foreign particle.	Roller Imprint	Completed
3.	5 WIP Pallet found in which Glass not cover properly from the side.	Packing to be improved by fixing tape on both side and job standard made for packing of glass.	Roller Imprint & Light Printing	Completed
4.	Print cut on the glass due to packing loose in Pallet.	Education and Training to be provide to all Printing Group for Handling & Packing of Printed glass and job standard made.	Print Cut	Completed
5.	Quench Ring Chip teeth bend.	Quench Ring chip teeth to be corrected and point add in Next model tooling check sheet	B/H B/age	Completed
6.	Pre-forming roller sleeve found dirty.	Sleeve to be replaced & check point to be add in Next model tooling tooling check sheet	Roller Imprint	Completed.
7.	2nd Zone Roller Seal damage	Damage 2nd Zone Roller Seal to be replaced.	Roller Imprint	Completed
8.	Leakage found in air duct cloth in BSH blast head	Duct cloth to be replaced & Thickness of Duct cloth to be increase.	B/H B/age	Completed.

3.3.1 Cause and Effect Diagram: Curvature NG



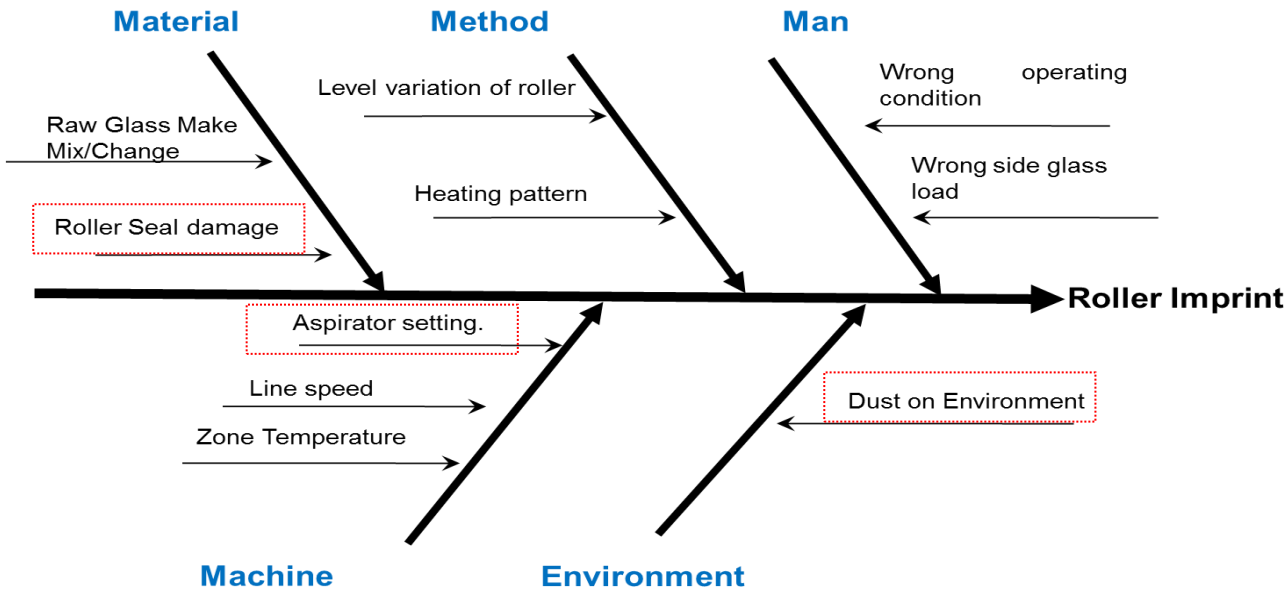
Inference: Cause and Effect diagram is being made to find out the any left out factors other than Input Output sheets. The other factors found out to be three for Curvature NG which were not found are being highlighted.

3.3.2 Cause Effect Diagram: Blast Head Breakage



Inference: Cause and Effect diagram is being made to find out the any left out factors other than Input Output sheets. The other factors found out to be Five for Blast Head Breakage which were not found are being highlighted.

3.3.3 Cause Effect Diagram: Roller Imprint



Inference: Cause and Effect diagram is being made to find out the any left out factors other than Input Output sheets. The other factors found out to be three for Roller Imprint which were not found are being highlighted.

3.4 Cause and Effect Matrix:

Cause & Effect Matrix is used for filtering the input factors based on their relationship with output. A severity no. is assigned to output on a scale of 1-10 and ranking is assigned to each Input factor based on relationship with Output. A input criterion is 0 for none, 1 for weak, 3 for moderate and 9 for strong relationship with Output. Rating is calculated for each factor which is the result of multiplication of Input ranking and Output severity. A cutoff rating no. limit is decided by the team and factors having the value more than or equal to cutoff no. are considered for analysis. A cutoff no. limit for rating was decided 91. And 28 factors were filtered among 63 input factors which were having rating greater than or equal to 91. For Reference sample portion is shown:

			1	2	3	
			Curvature	Blast Head Breakage	Roller Imprint/Distortion	
		Customer Priority	9	10	9	
	Process Step	Process Input (X)				Total
1	Receiving of Pre-Process Glass	Pallet Cond	0	1	9	91
2	Receiving of Pre-Process Glass	Process Card	1	5	9	140
3	Loading	Stopper Setting	9	9	0	171
4	Loading	Orientation	0	9	0	90
5	Loading	Glass Position	9	9	0	171
6	Loading	Operator	5	5	1	104
7	Heating	Glass Temp-Low	5	9	0	135
8	Heating	Glass Temp- High	0	5	9	131
9	Heating	Heater cut	5	9	0	135
10	Heating	Heater-Temp Fluctuation	5	5	9	176

Inference: After more funneling by C& E matrix 28 factors remains for analysis.

- **Ranking co relation:-**

  0=none ,1 = week ,5= moderate ,9 = strong
- **Inference:-**
- Total no. of inputs found 28 for all three Characteristics (Curvature, Blast Head Breakage & Roller imprint)

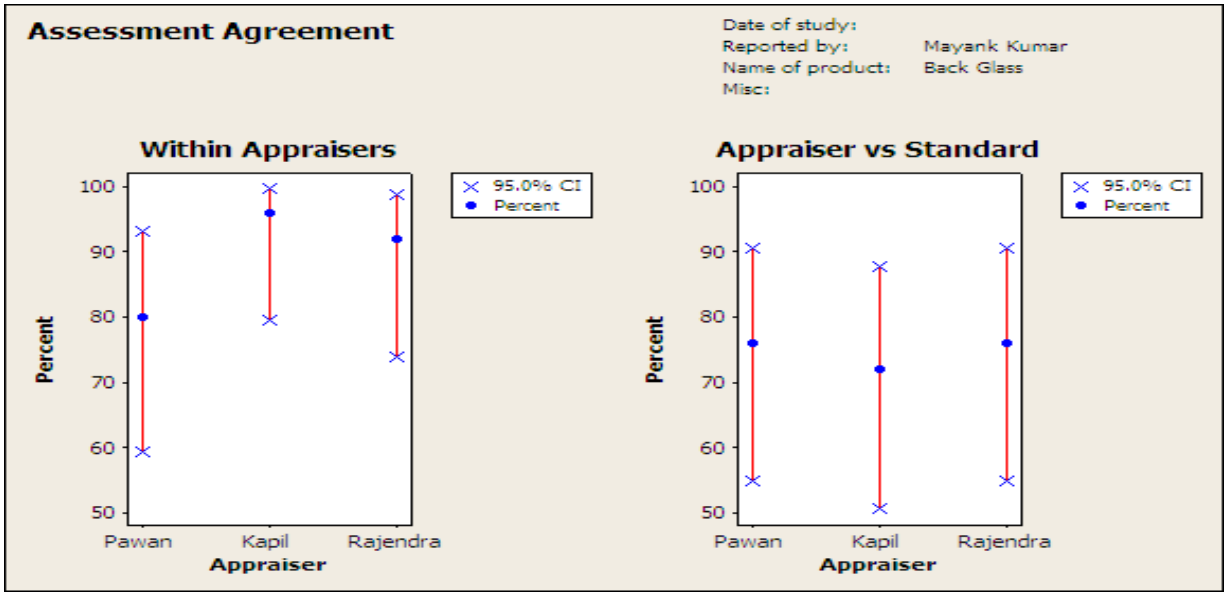
3.5 Second Level Elimination by PFMEA:

A potential cause is that which is having higher degree of relationship with output and higher frequency of occurrence which is established through PFMEA. This is a secondary filtering tool which is used to identify the factors having high occurrence and Risk Priority Number. A cut off value of RPN and Occurrence is decided by team.
PFMEA was made by CFT and cut off value of RPN was decided 140 or more. Following 8 input factors were filtered among 28 factors.

1. Main line speed	2. BSH speed	3. Zone Temp 1	4. Zone Temp 2
5. Zone Temp 3	6. Zone Temp4	7.Quench pressure	8. Female press position

The Overall Conclusion drawn from Measure phase was that Graphical and Statistical study required for 8 input factors having higher degree of relationship with Output established through C&E Matrix and Higher Occurrence & RPN Level established through PFMEA.

3.6 MSA for Attributes:



Inference: 1. Measurement system is acceptable.

2. No significant difference between and within Inspector`s decision and appraiser with standard was found. (Assessment agreement is more than 70%).

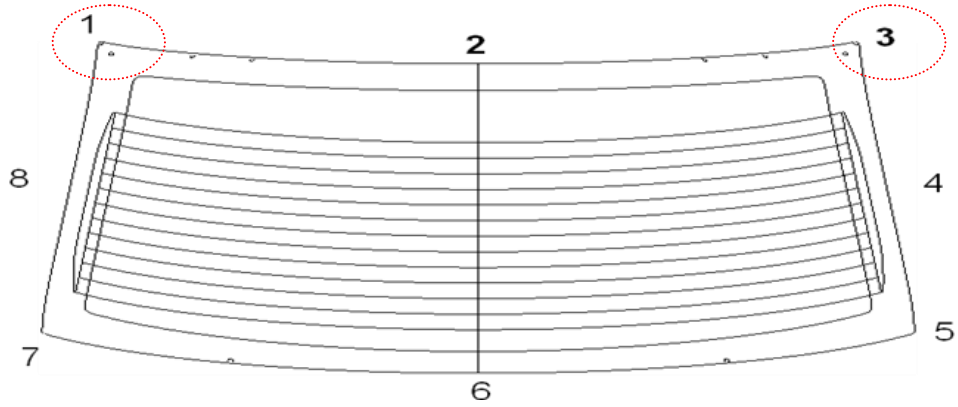
Within Appraisers

```
Assessment Agreement
Appraiser  # Inspected  # Matched  Percent      95% CI
Pawan              25         20    80.00  (59.30, 93.17)
Kapil              25         24    96.00  (79.65, 99.90)
Rajendra           25         23    92.00  (73.97, 99.02)
# Matched: Appraiser agrees with him/herself across trials.
```

Each Appraiser vs Standard

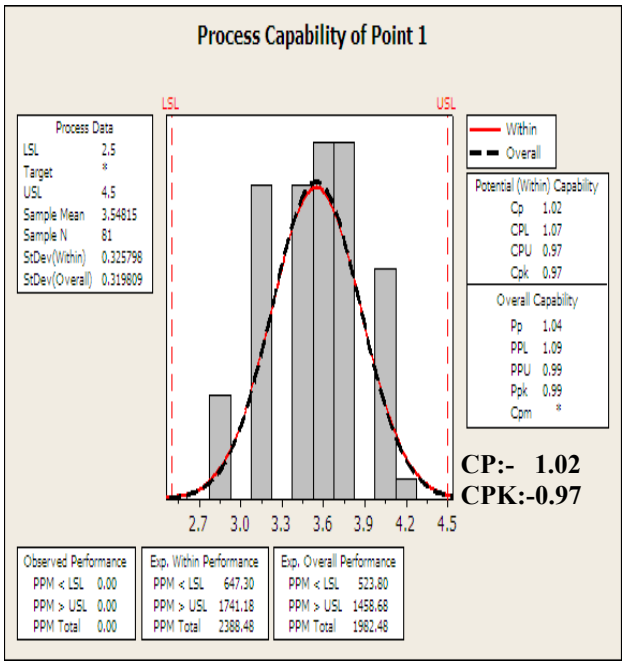
```
Assessment Agreement
Appraiser  # Inspected  # Matched  Percent      95% CI
Pawan              25         19    76.00  (54.87, 90.64)
Kapil              25         18    72.00  (50.61, 87.93)
Rajendra           25         19    76.00  (54.87, 90.64)
# Matched: Appraiser's assessment across trials agrees with the known standard.
```

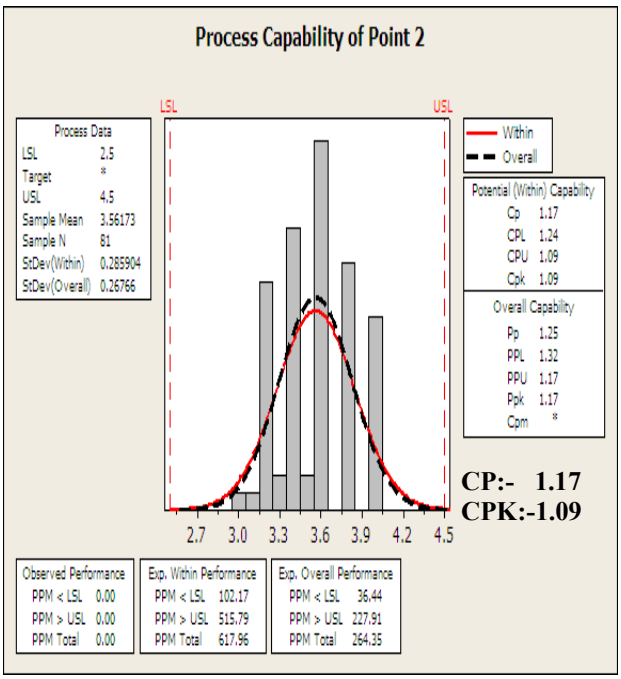
3.7 Capability Analysis for Curvature:

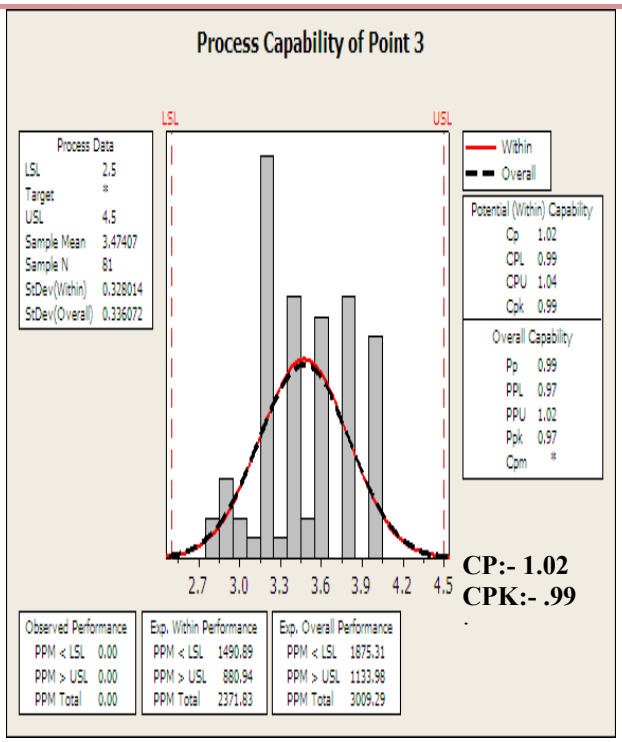


Point	1	2	3	4	5	6	7	8
CP	1.02	1.17	1.02	1.36	1.52	1.52	1.53	1.37
CPK	0.97	1.09	0.99	1.32	1.48	1.47	1.49	1.21

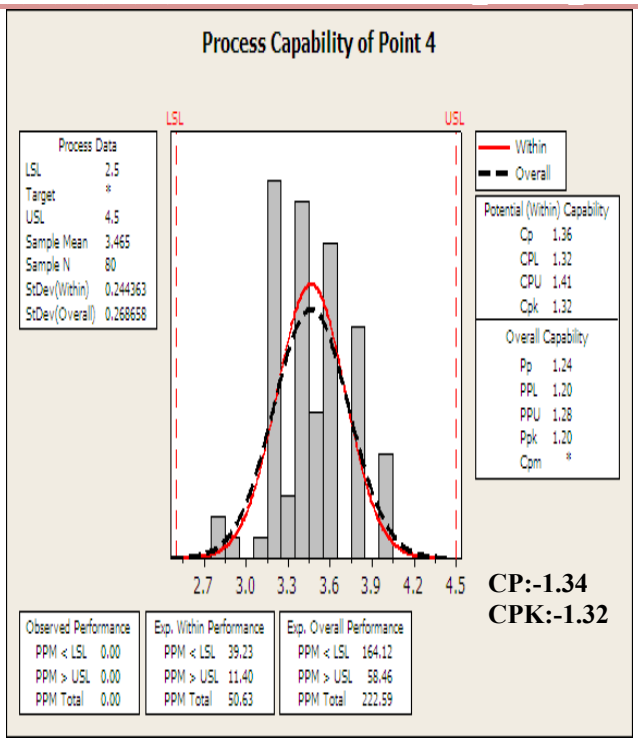
Inference: CPk is found to be less than 1.33 for point 1 and 3 out of Eight point taken for capability analysis. So further improvement is required in process to make process more capable.



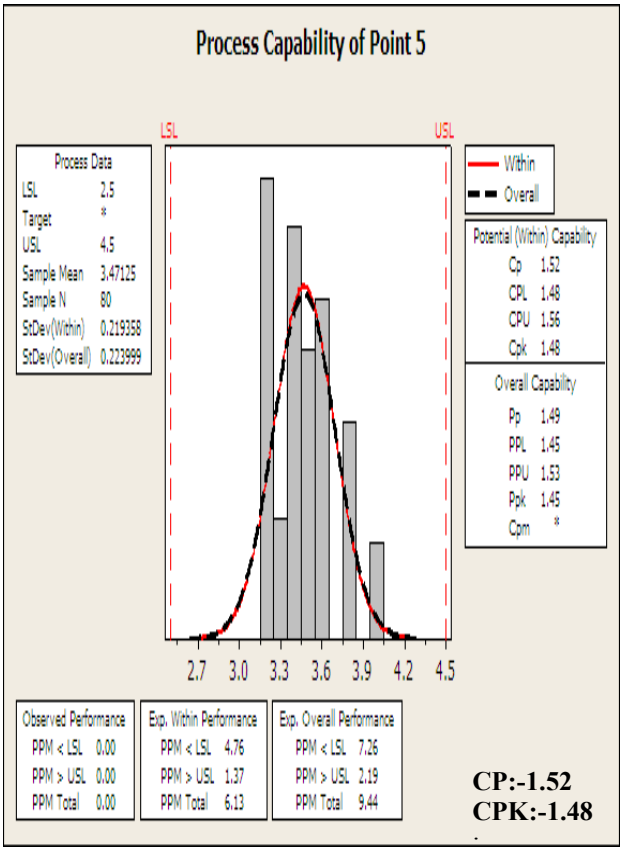




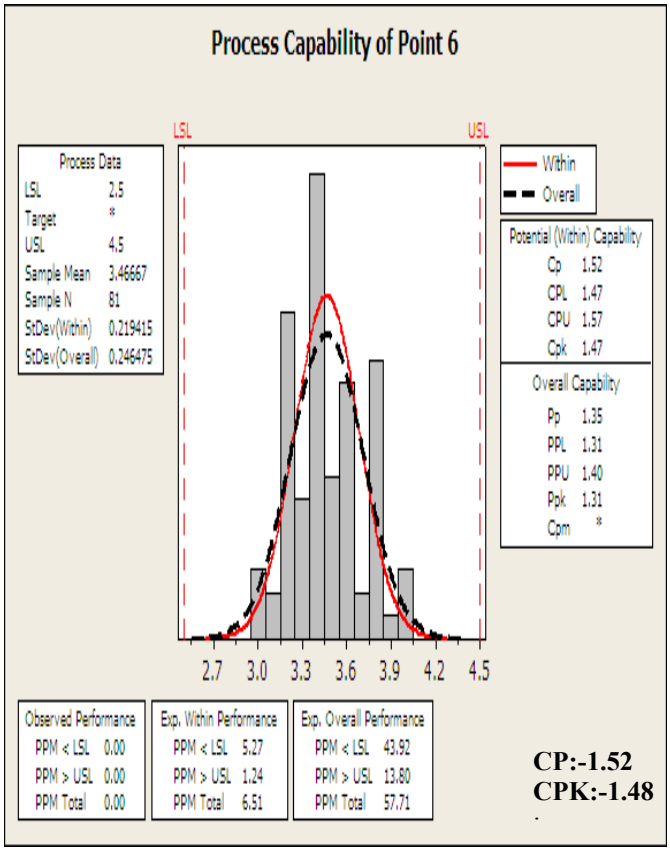
CP:- 1.02
CPK:- .99



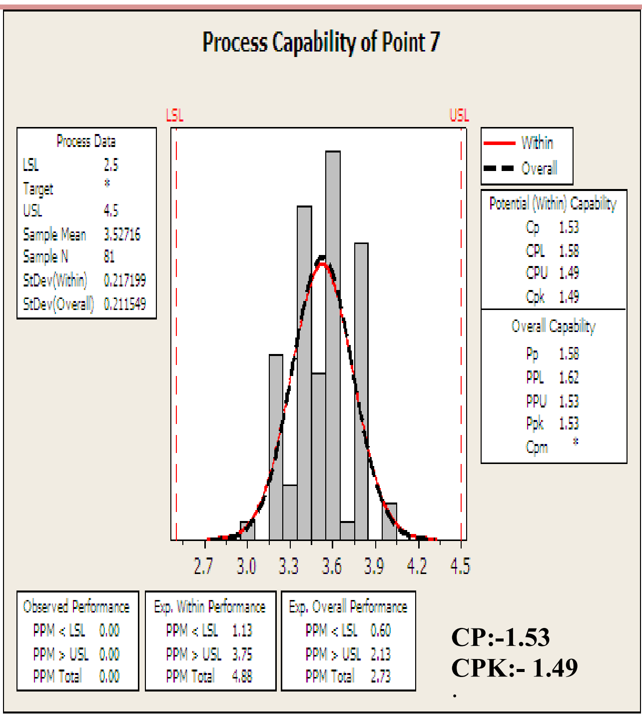
CP:-1.34
CPK:-1.32

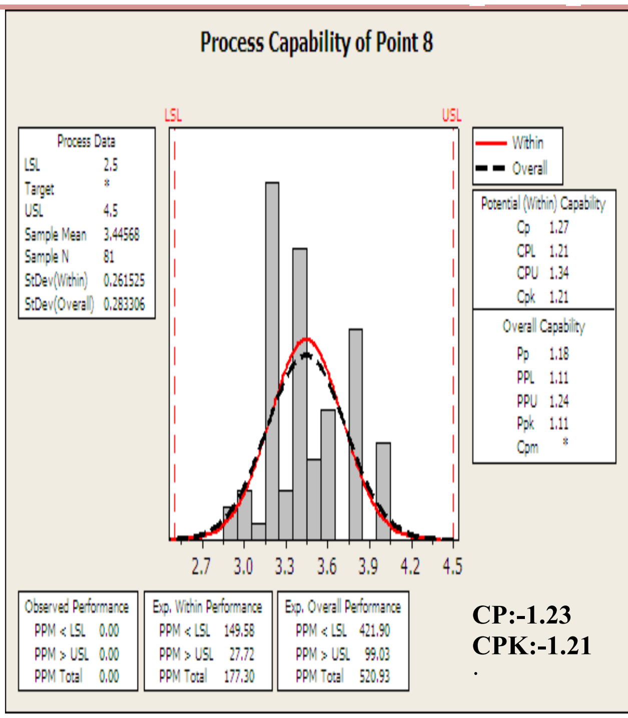


CP:-1.52
CPK:-1.48



CP:-1.52
CPK:-1.48





4.1 Graphical Analysis:

Data Collection Plan:

1. **Sample size = 5 continuous Glass after every 30 minutes.**
2. **1380 Glass Data collected.**

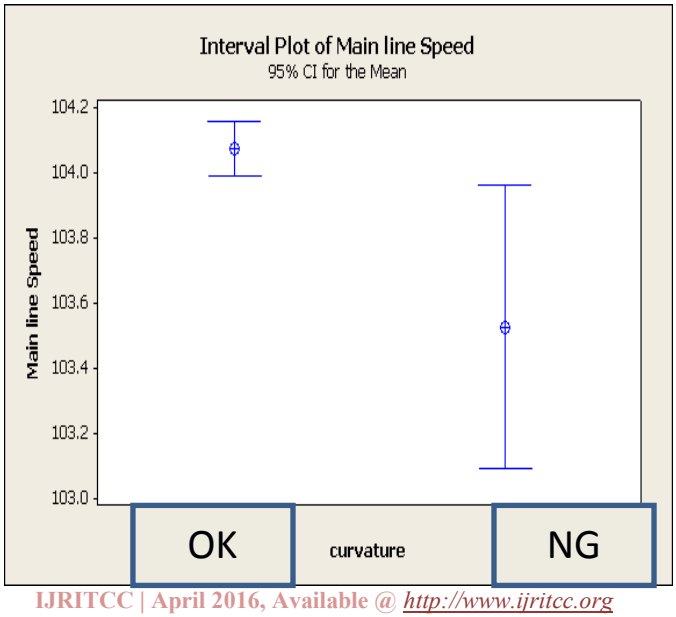
Sample part is attached. Please find the appendix

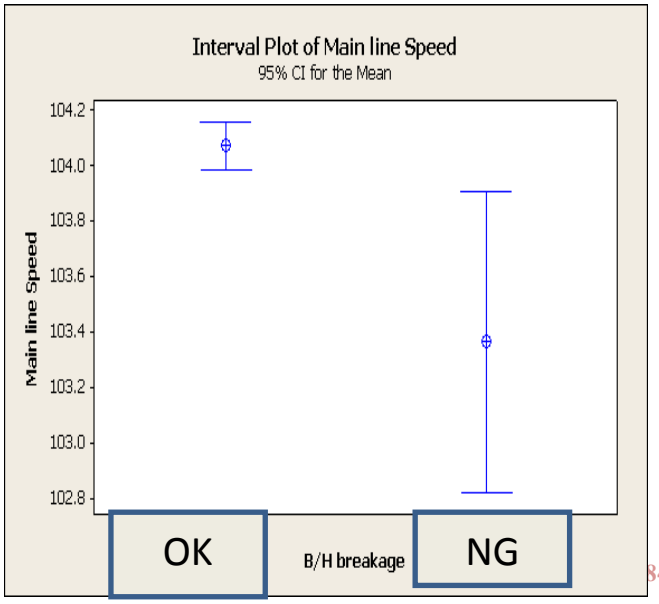
Date	Shift	Operator	Time	Main line Speed	BSH speed	Temp act. Zone 1 Upper	Temp act. Zone 1 Lower	Temp act. Zone 2 Upper	Temp act .Zone 2 lower	Temp act. Zone3 upper	Temp act. Zone 3 lower	Temp act. Zone 4 upper	temp act. Zone 4 lower
17/01/14	iind	tara chand	2:00pm	105	600	680	675	690	685	710	705	725	715
17/01/14	iind	tara chand	2:00pm	105	600	680	675	690	685	710	705	725	715
17/01/14	iind	tara chand	2:00pm	105	600	680	675	690	685	710	705	725	715
17/01/14	iind	tara chand	2:00pm	105	600	680	675	690	685	710	705	725	715
17/01/14	iind	tara chand	2:00pm	105	600	680	675	690	685	710	705	725	715
17/01/14	iind	tara chand	2:30pm	105	600	681	675	691	686	712	706	738	718
17/01/14	iind	tara chand	2:30pm	105	600	681	675	691	686	712	706	738	718
17/01/14	iind	tara chand	2:30pm	105	600	681	675	691	686	712	706	738	718
17/01/14	iind	tara chand	2:30pm	105	600	681	675	691	686	712	706	738	718
17/01/14	iind	tara chand	2:30pm	105	600	681	675	691	686	712	706	738	718
17/01/14	iind	tara chand	4:30pm	109	600	679	674	685	680	712	700	725	713
17/01/14	iind	tara chand	4:30pm	109	600	679	674	685	680	712	700	725	713
17/01/14	iind	tara chand	4:30pm	109	600	679	674	685	680	712	700	725	713
17/01/14	iind	tara chand	4:30pm	109	600	679	674	685	680	712	700	725	713
17/01/14	iind	tara chand	4:30pm	109	600	679	674	685	680	712	700	725	713
17/01/14	iind	tara chand	5:00pm	109	600	680	675	685	680	711	701	725	713
17/01/14	iind	tara chand	5:00pm	109	600	680	675	685	680	711	701	725	713
17/01/14	iind	tara chand	5:00pm	109	600	680	675	685	680	711	701	725	713
17/01/14	iind	tara chand	5:00pm	109	600	680	675	685	680	711	701	725	713
17/01/14	iind	tara chand	5:00pm	109	600	680	675	685	680	711	701	725	713
17/01/14	iind	tara chand	5:30pm	109	600	682	676	687	679	712	700	737	712

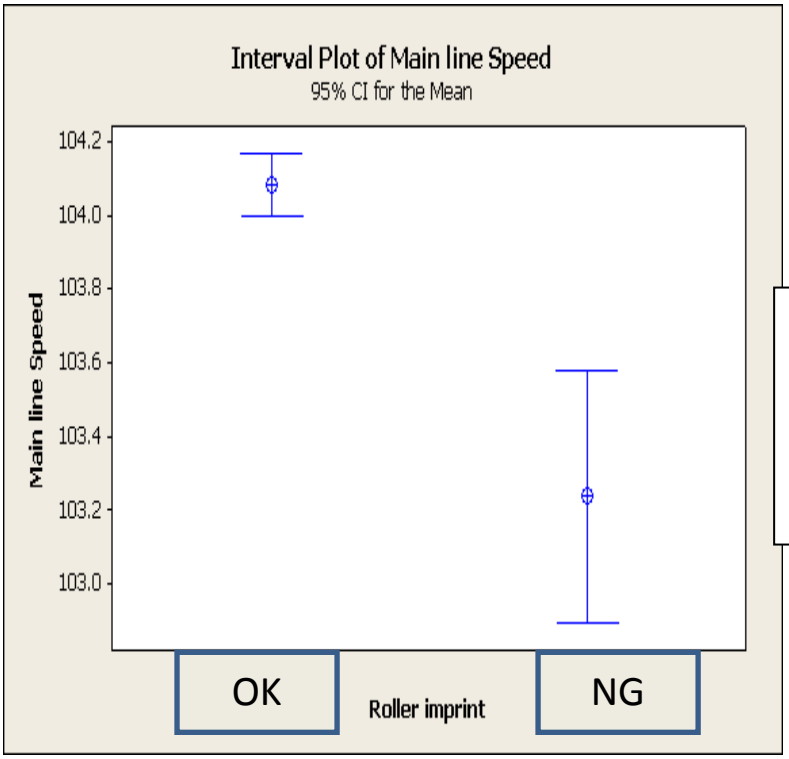
Various Graphical tools are used for analysis between discrete & Continuous Xs (Input factors) Vs Discrete & Continuous Y (Output). A list of graphical tools used for studying the relationship between Xs and Y is shown in table below. C denotes Continuous and D denote Discrete factors.

PLAN FOR GRAPHICAL ANALYSIS						
S.No.	Factors-Xs	Input Type	Y1 (Curvature)	Y2 (B/H B/age)	Y3 (Roller Imprint)	Tool to be Used
1.	Main Line speed	C	D	D	D	Interval Plot, Main Effect Plot
2	BSH Speed (Pre-forming roller speed)	C	D	D	D	Interval Plot, Main Effect Plot
3	Heater Temp(Z-1,2,3,4) Lower & Upper	C	D	D	D	Interval Plot, Main Effect Plot
4	Quench Pr. Upper & Lower	C	D	D	D	Interval Plot, Main Effect Plot
5	Quench Position Upper & Lower	C	D	D	D	Interval Plot, Main Effect Plot
6	Female Press Position	C	D	D	D	Interval Plot, Main Effect Plot
7	Aspirator Setting	C	D	D	D	Interval Plot, Main Effect Plot

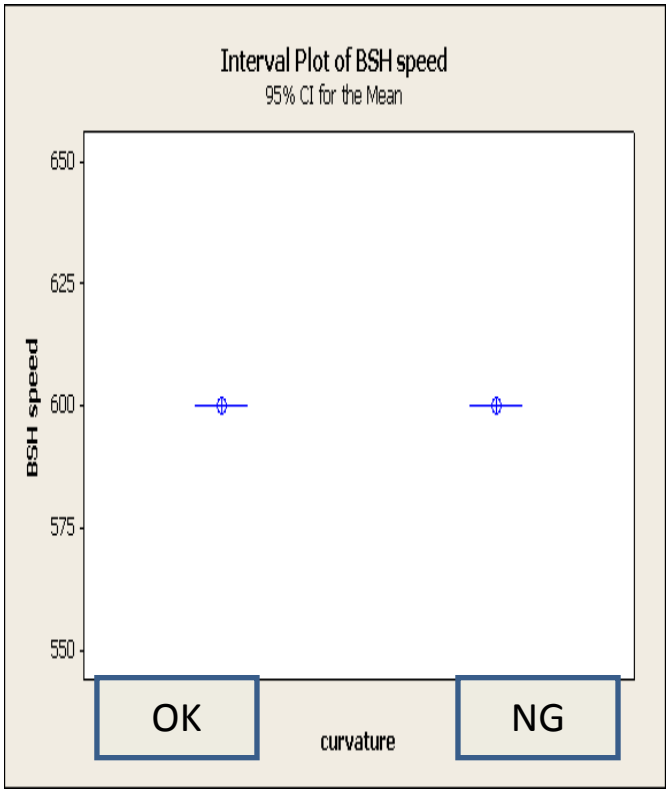
A graphical analysis was done as per Table above to see the relationship between different Input factors and Output. Analysis of Curvature NG, Blast Head Breakage, and Roller Imprint for all the significant factors is shown using Interval plots below.

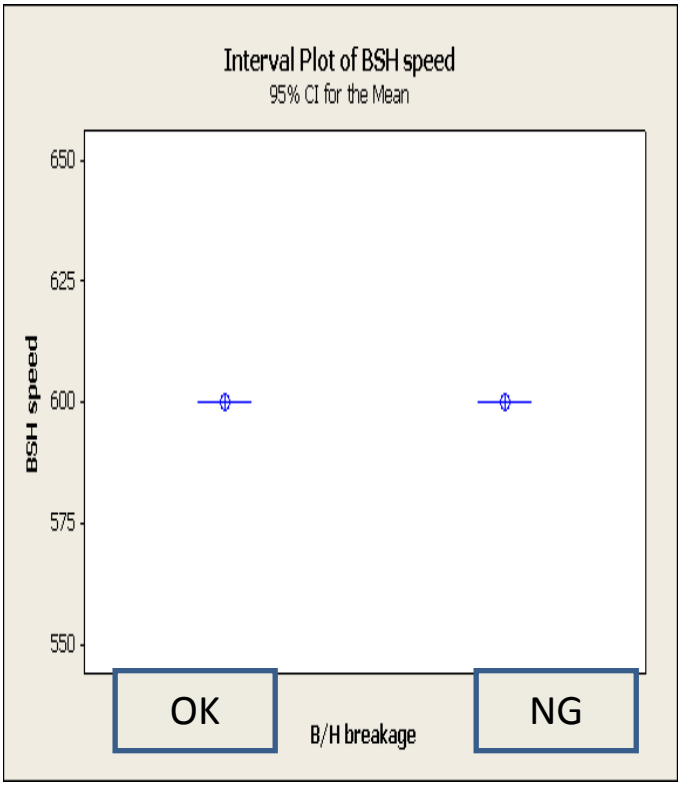




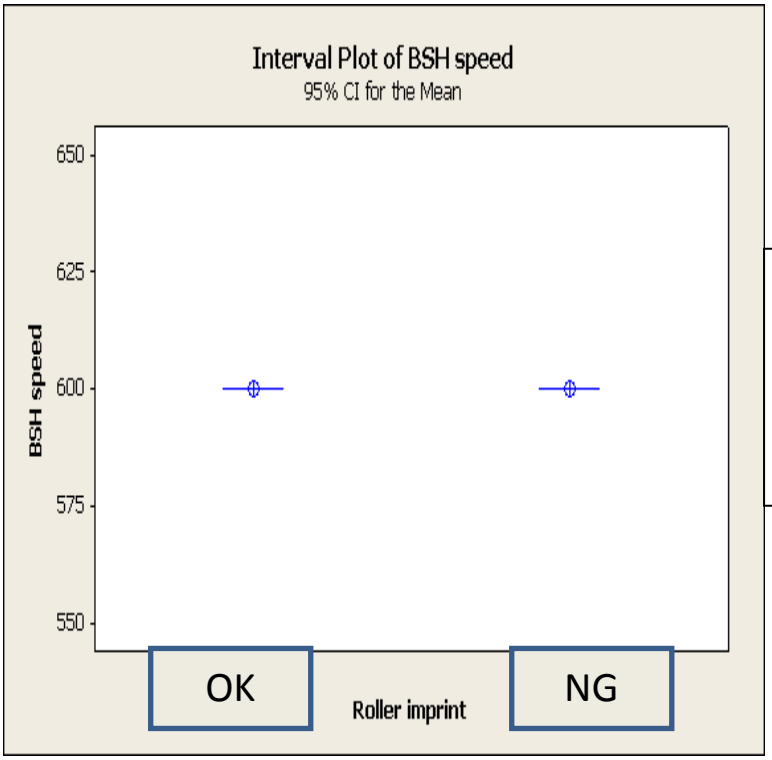


Inference: - Main Line speed found significant for Curvature NG, Blast Head Breakage and Roller imprint which can be further verified by Statistical Analysis. (Main Line speed is speed during loading of glass on conveyor).Unit is mm/s

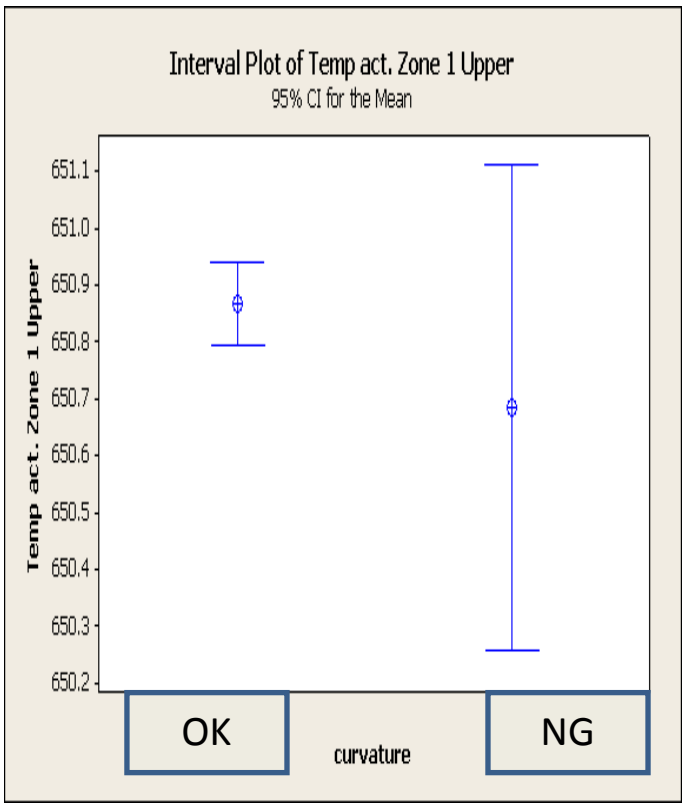


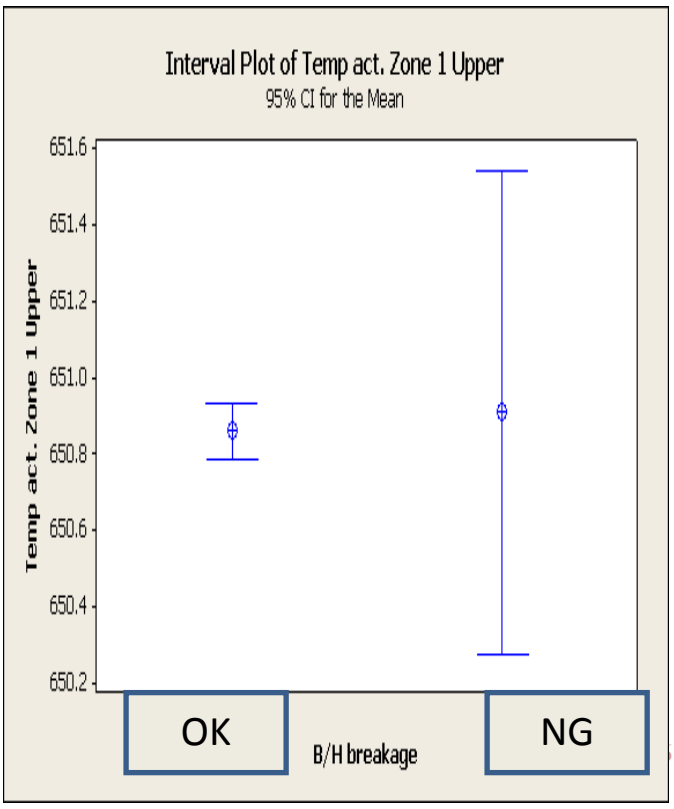


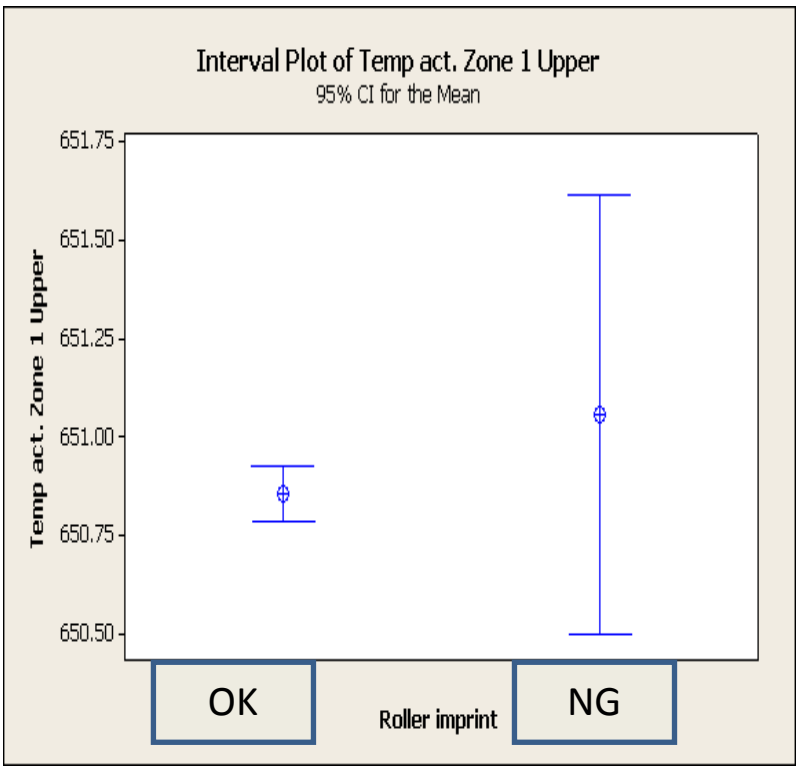
s



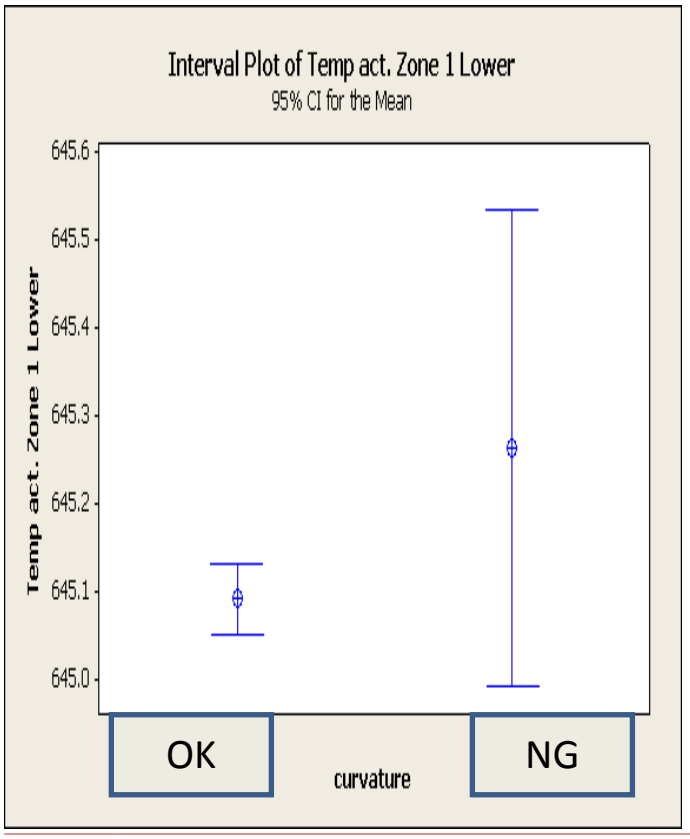
Inference: - BSH speed found insignificant for Curvature NG, Blast Head Breakage and Roller imprint which can be further verified by Statistical Analysis. (BSH speed is speed during loading of glass on conveyor).Unit is mm/s

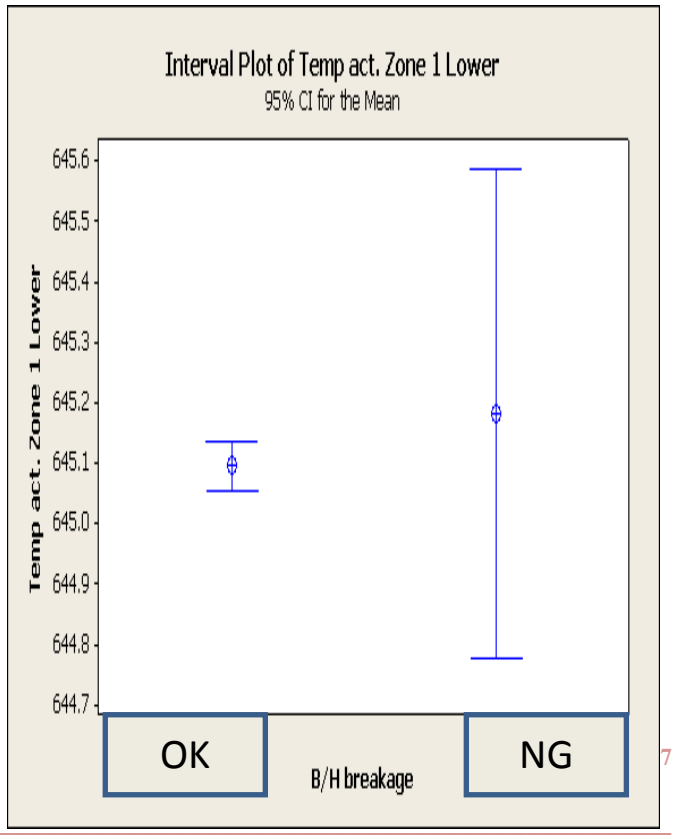


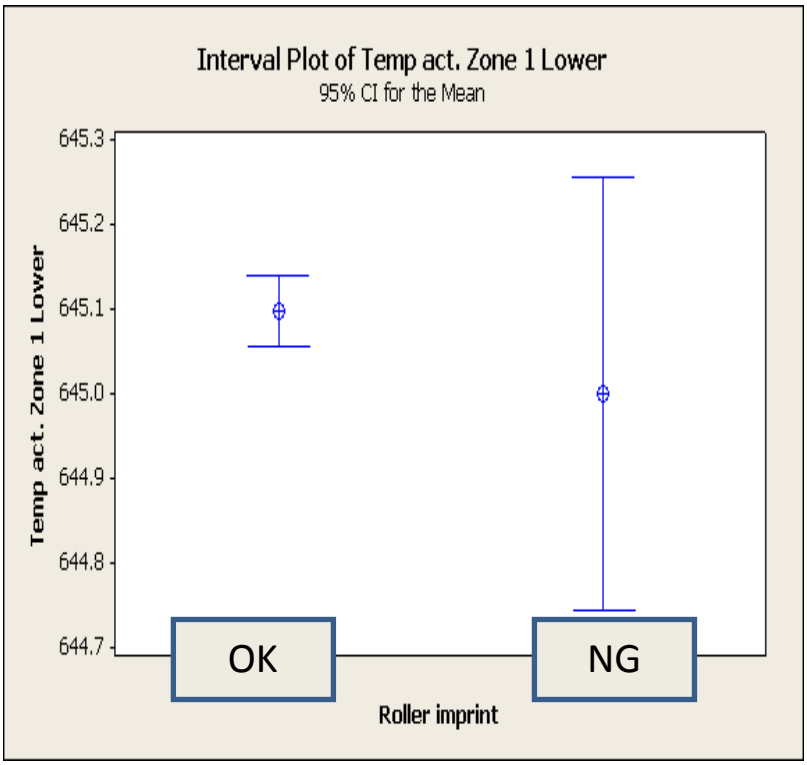




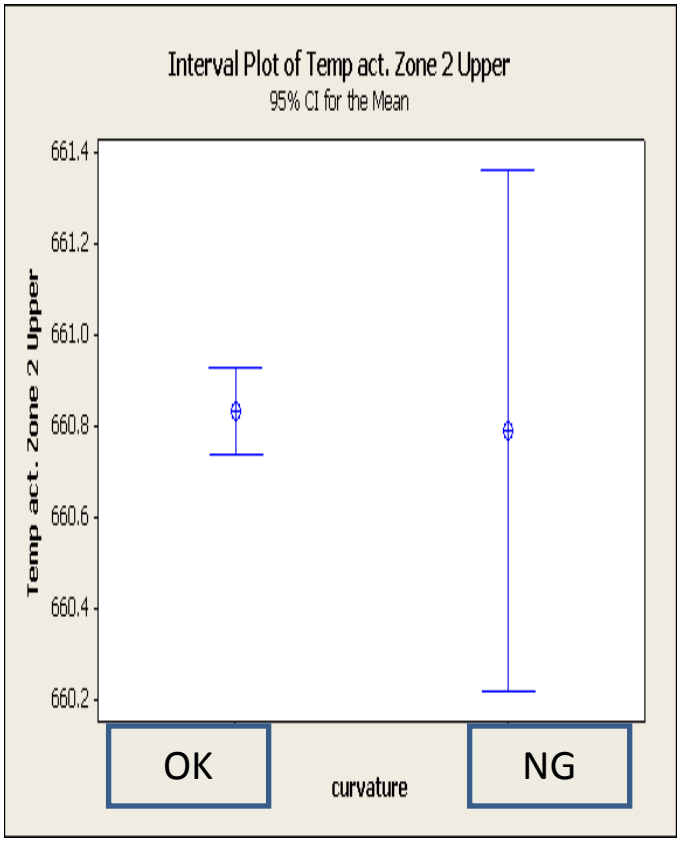
Inference: - Zone-1 Temp Upper found significant for Curvature NG Breakage & Roller Imprint which can be further verified by Statistical Analysis. Unit is Degree Celsius.

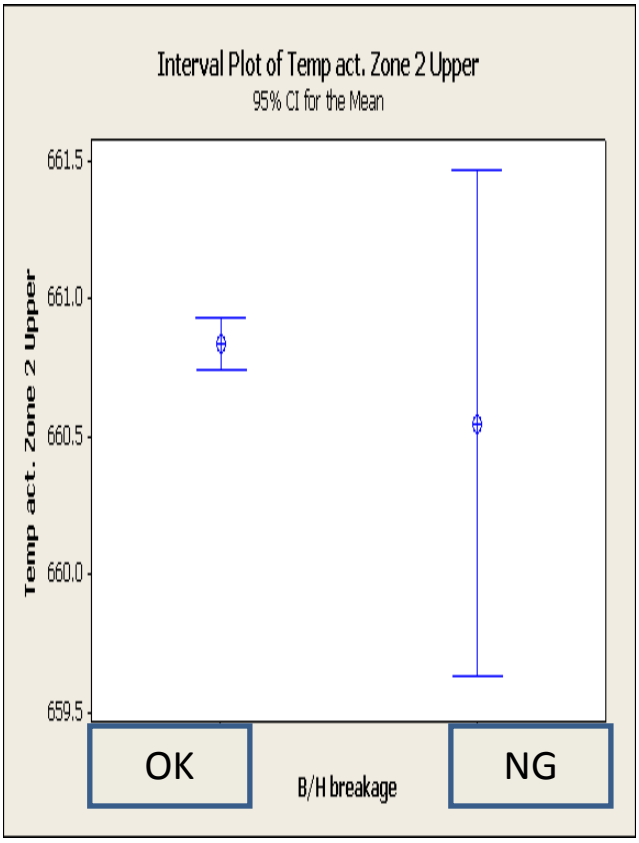




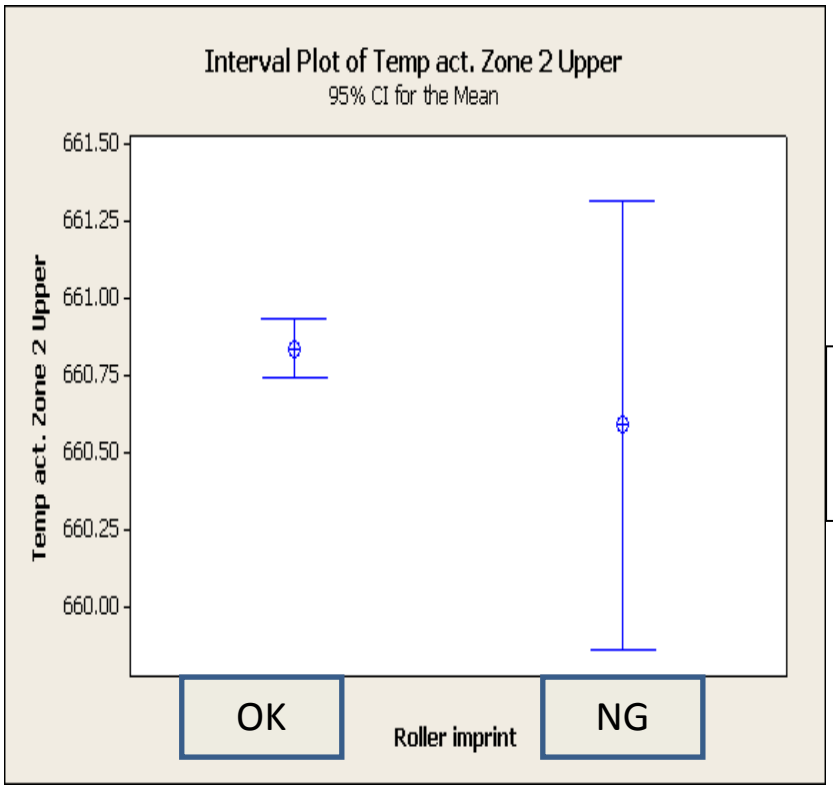


Inference: - Zone-1 Temp Lower found significant for Curvature NG Breakage & Roller Imprint which can be further verified by Statistical Analysis. Unit is Degree Celsius.

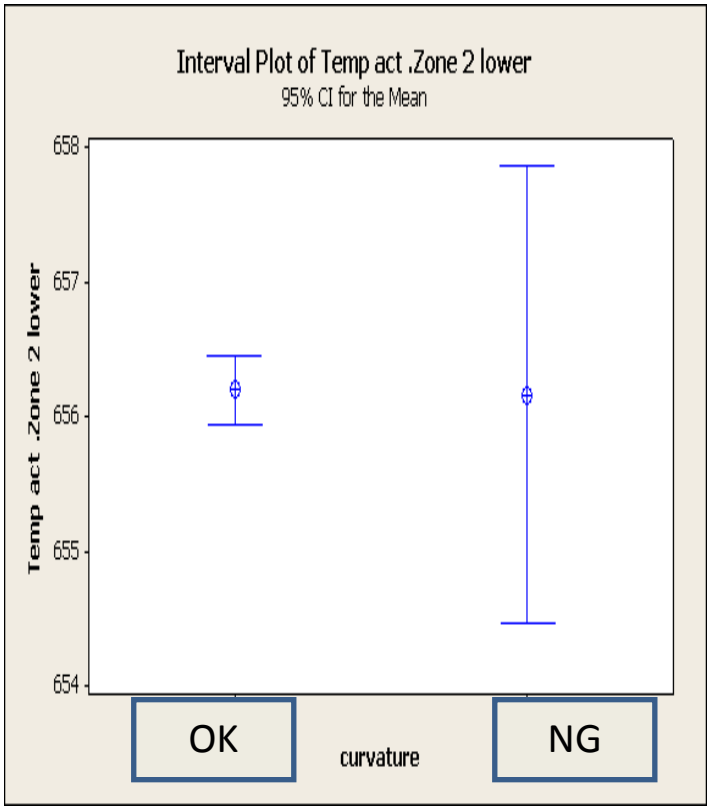


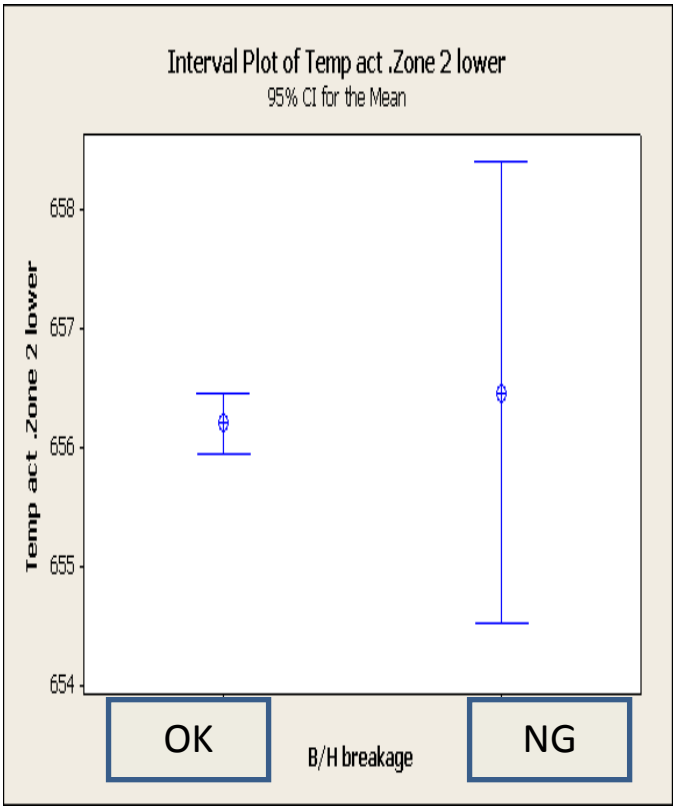


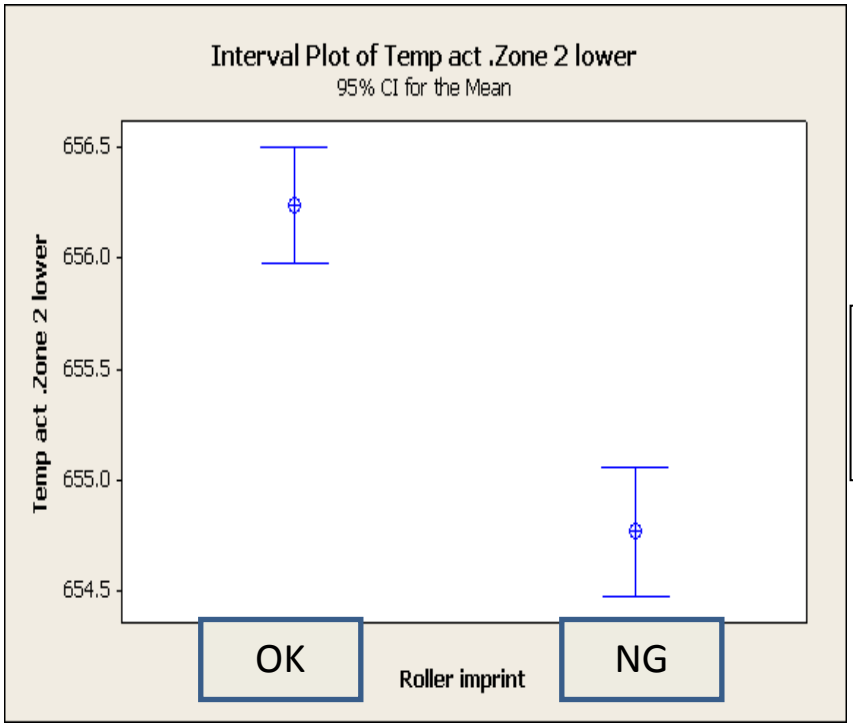
 ISSN: 2321-8169
370 - 408



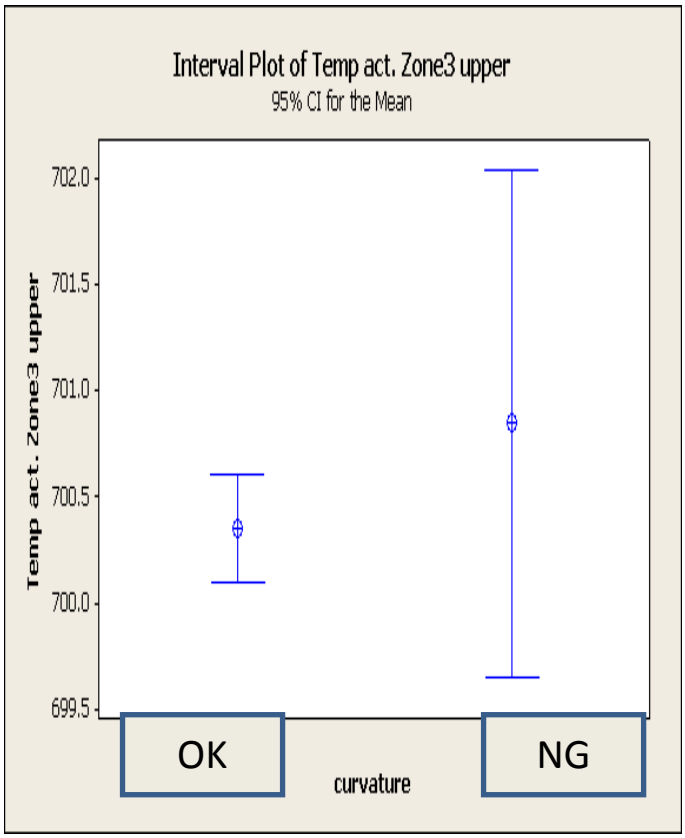
Inference: - Zone-2 Temp Upper found insignificant for Curvature NG, breakage & Roller Imprint which can be further verified by Statistical Analysis. Unit is Degree Celsius.

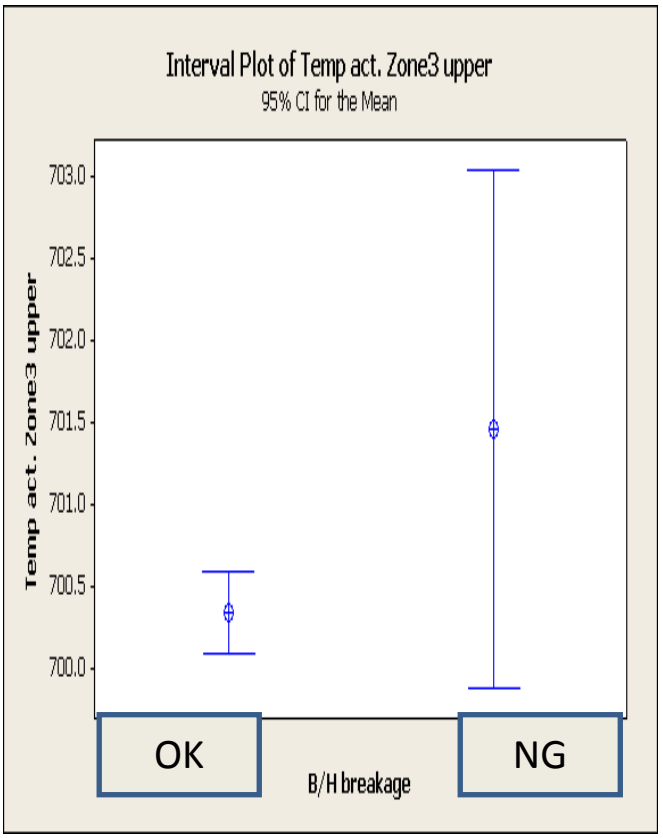




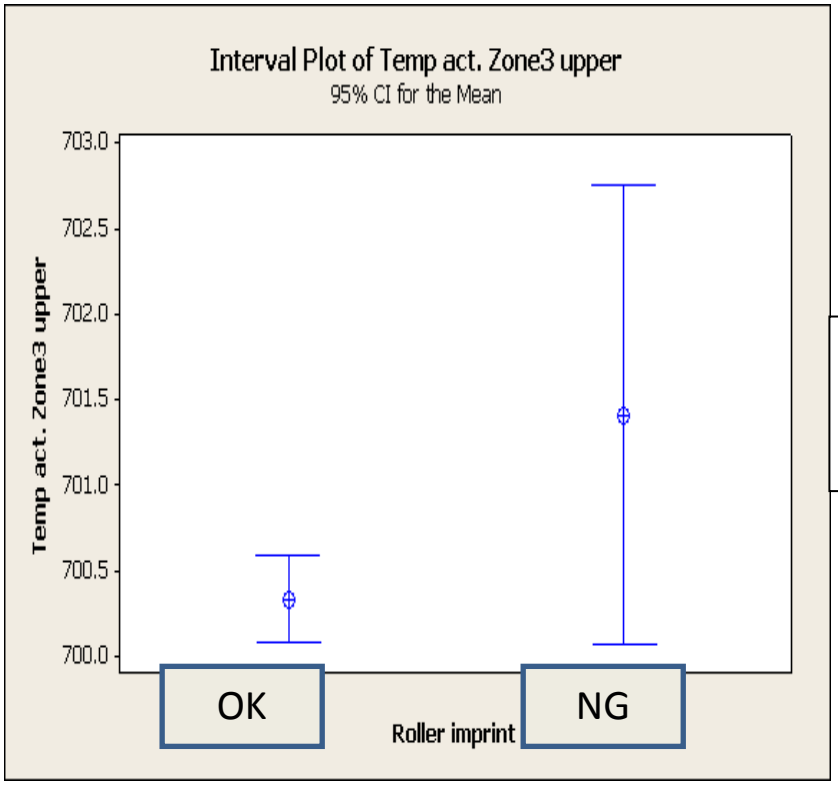


Inference: - Zone-2 Temp Lower found significant for Curvature NG & Roller Imprint which can be further verified by Statistical Analysis. Unit is Degree Celsius.

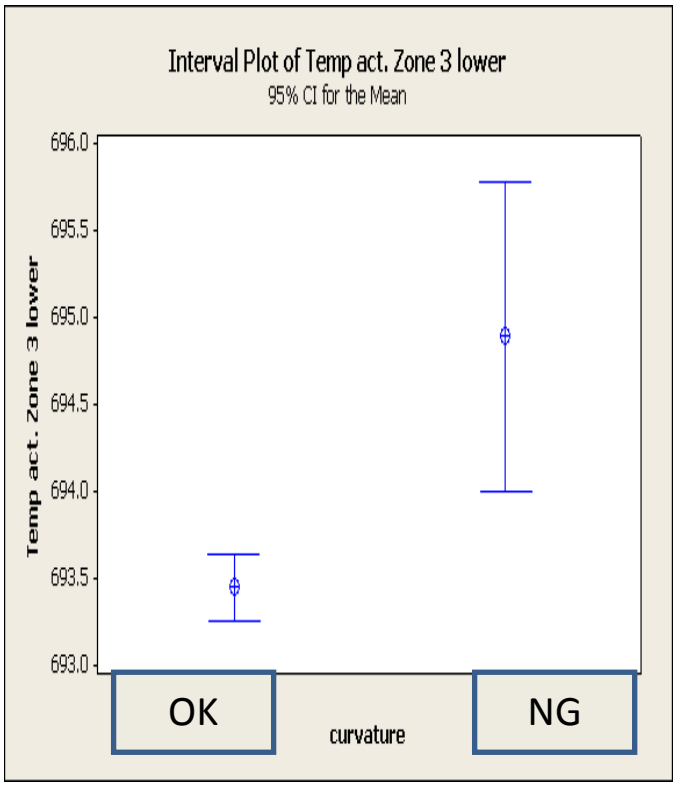


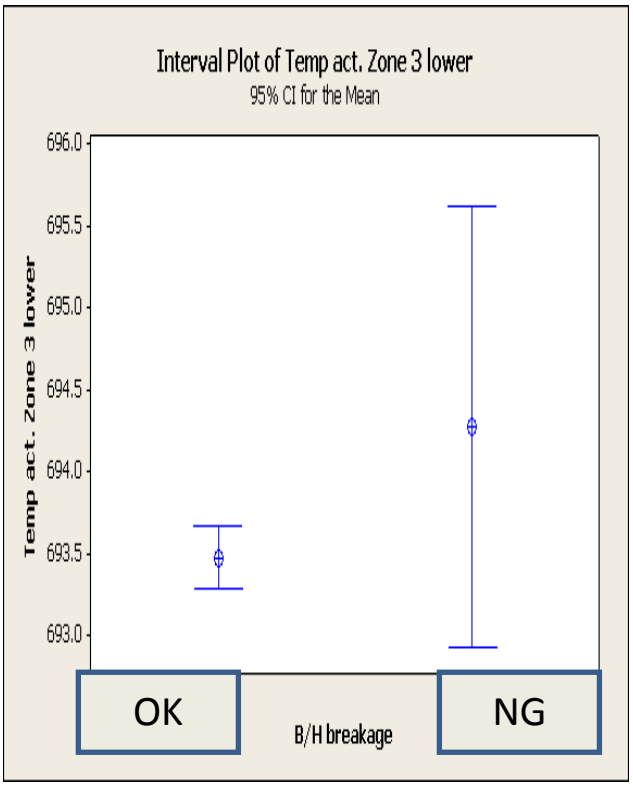


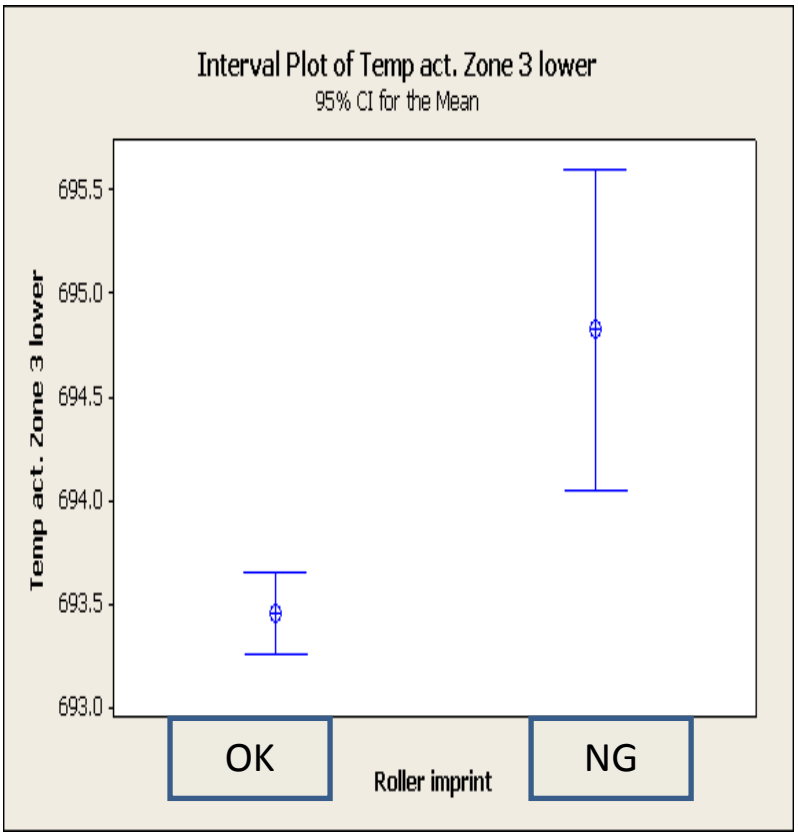
 ISSN: 2321-8169
370 - 408



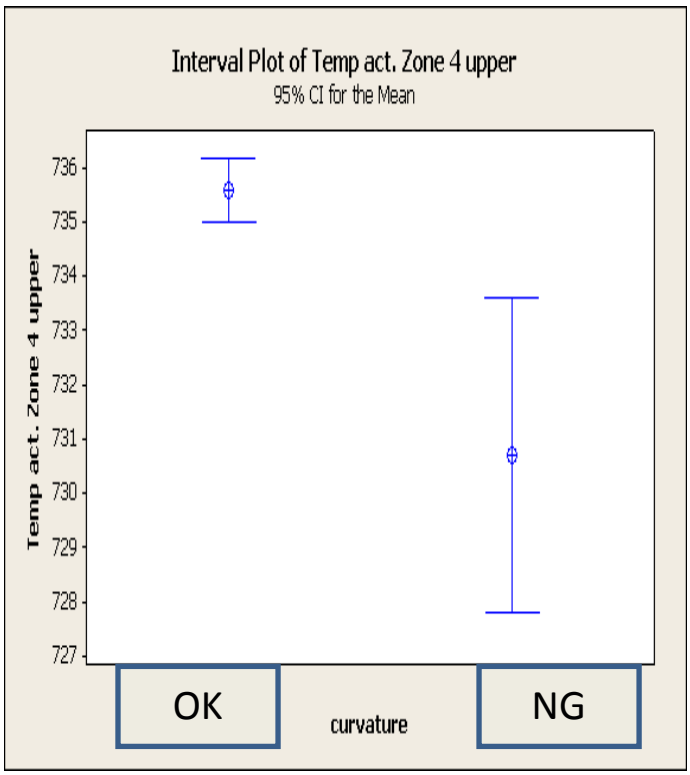
Inference: - Zone-3 Temp Upper found insignificant for Curvature NG , Breakage & Roller Imprint which can be further verified by Statistical Analysis. Unit is Degree Celsius.

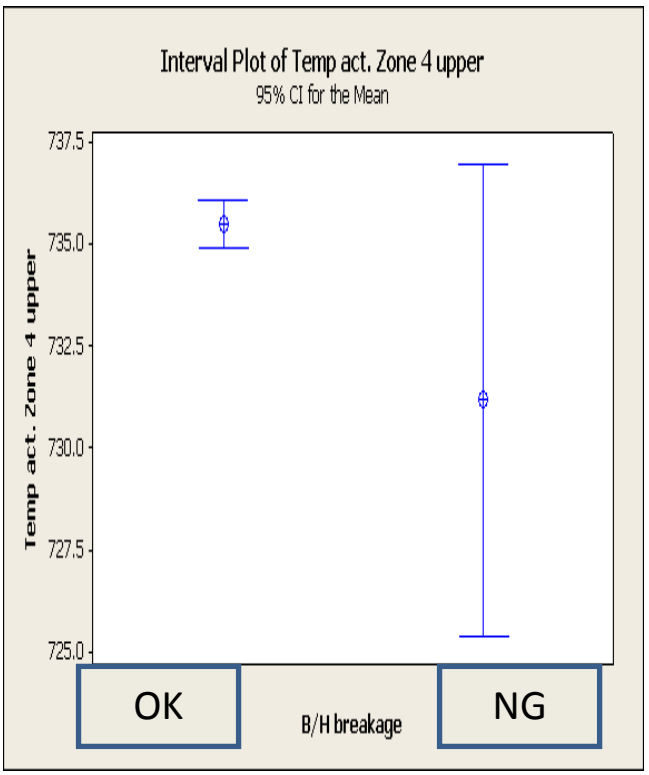


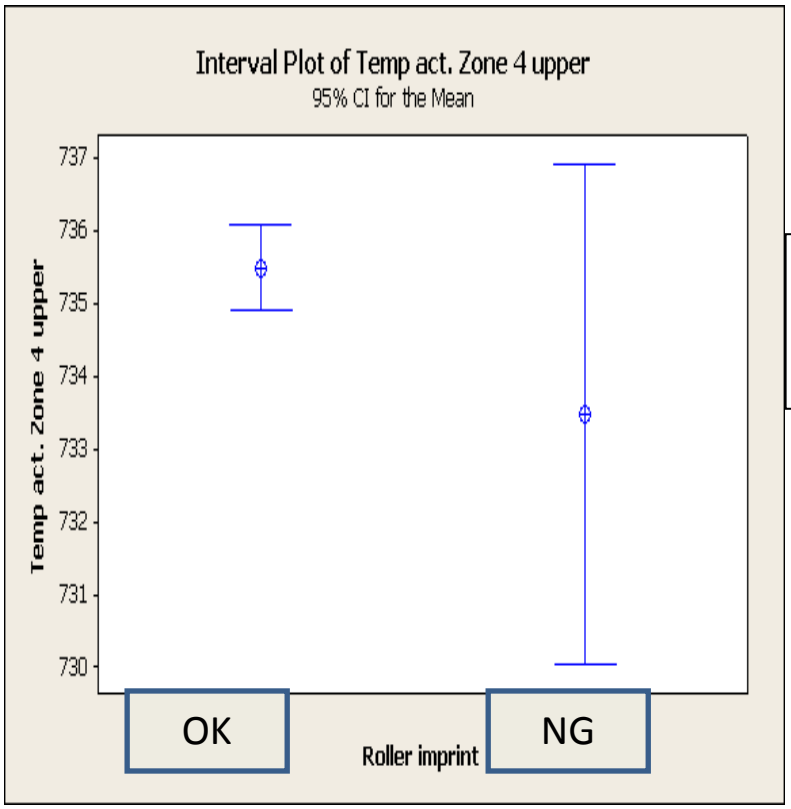




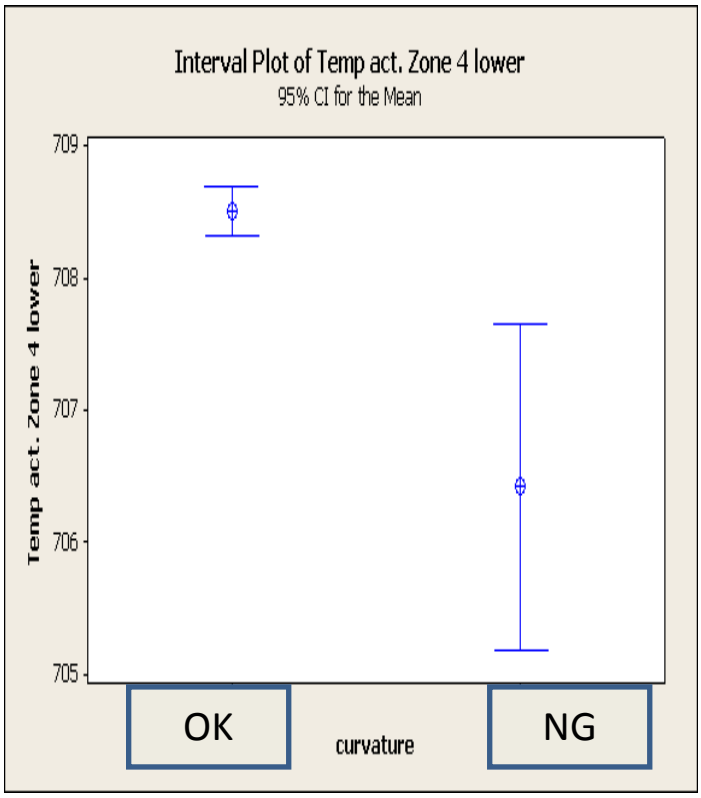
Inference: - Zone-3 Temp Lower found significant for Curvature NG & Roller Imprint which can be further verified by Statistical Analysis. Unit is Degree Celsius.

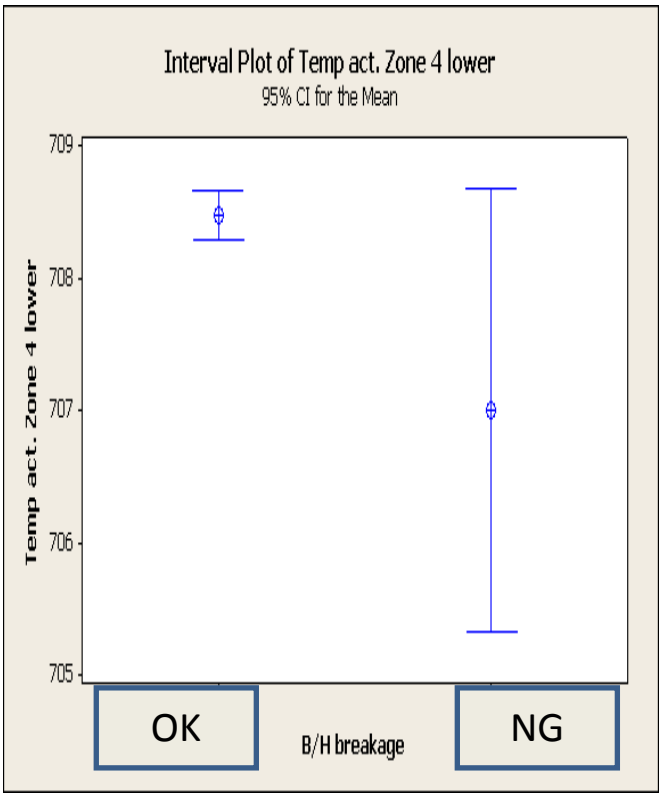


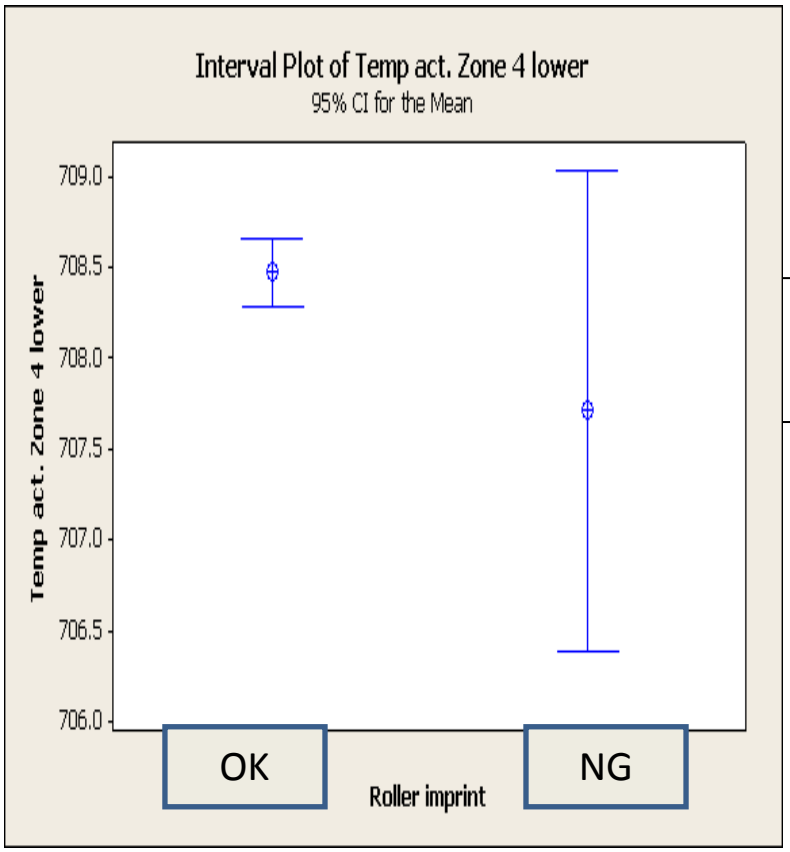




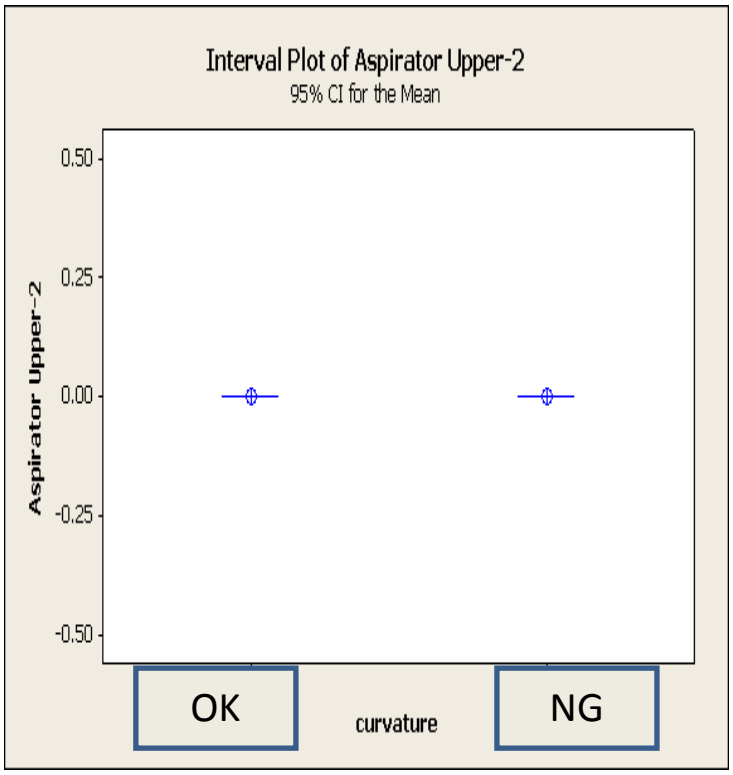
Inference: - Zone-4 Temp Upper found significant for Curvature NG which can be further verified by Statistical Analysis. Unit is Degree Celsius.

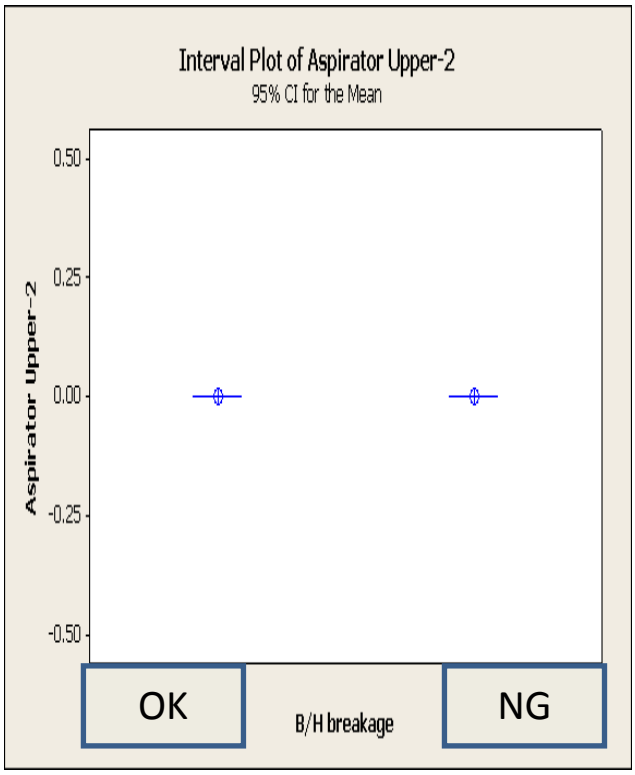


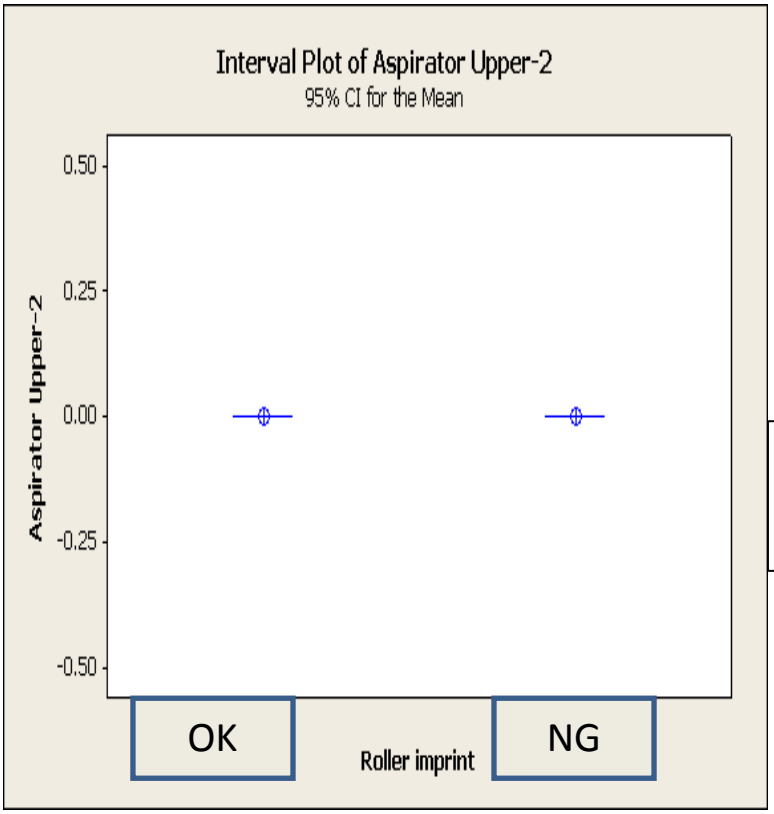




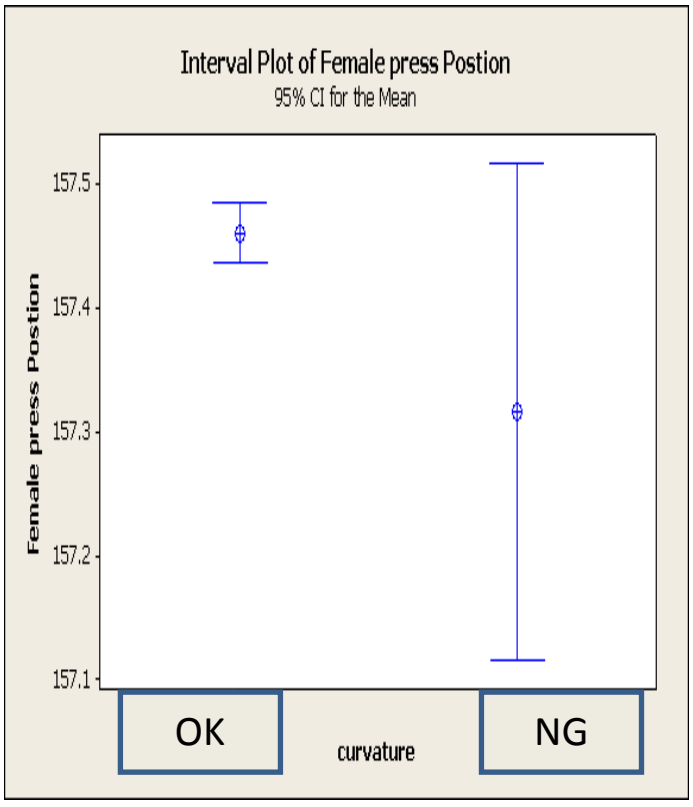
Inference: - Zone-4 Temp Lower found significant for Curvature NG which can be further verified by Statistical Analysis. Unit is Degree Celsius.

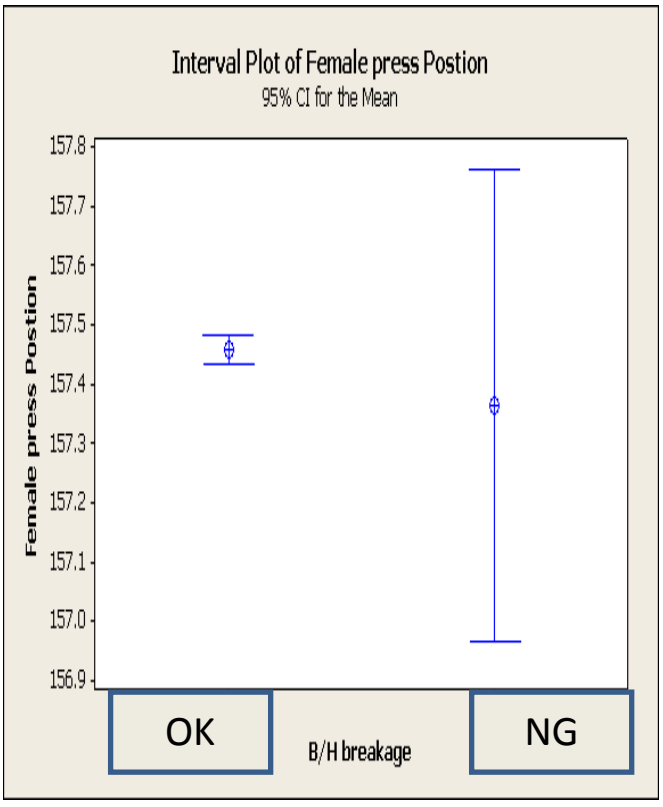


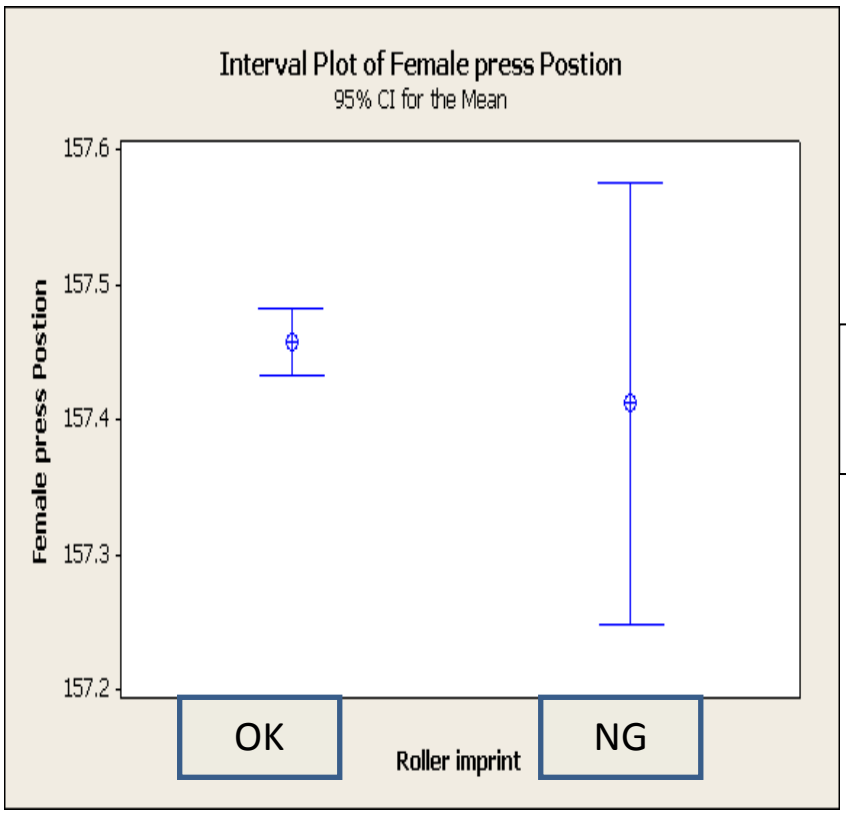




Inference: Aspirator Upper is found to be non significant for Curvature NG, Blast Head Breakage, Roller Imprint.







Inference: Female Press Postion is found to be non significant for Curvature NG, Blast Head Breakage, Roller Imprint.

Conclusion: Graphical Analysis

S. No.	Factors	Curvature NG	BH Breakage	R. Imprint
1	Main Line Speed	Significant	Significant	Significant
2	BSH Speed	Insignificant	Insignificant	Insignificant
3	Zon-1 upper	Insignificant	Insignificant	Insignificant
4	Zone-1 lower	Insignificant	Insignificant	Insignificant
5	Zon-2 upper	Insignificant	Insignificant	Insignificant
6	Zone-2 lower	Insignificant	Insignificant	Significant
7	Zon-3 upper	Insignificant	Insignificant	Insignificant
8	Zone-3 lower	Significant	Insignificant	Significant
9	Zon-4 upper	Significant	Insignificant	Insignificant
10	Zone-4 lower	Significant	Insignificant	Insignificant
12	Female Press Position	Insignificant	Insignificant	Insignificant

4.2 Statistical Analysis

With the help of Graphical analysis we get the feeling that which input factors may be significant but based on graphical analysis only we can not conclude that which input factors are significant. With the help of statistical analysis we can conclude that which parameters are significantly affecting the Output. Binary Logistics regression is used as the output is Discrete (NG/OK) and input is Continuous. An example of Binary Logistic Regression for Curvature NG with Main Line Speed is shown below.

Binary Logistic Regression: curvature versus Main line Speed

Method

Link function Logit
Rows used 680

Inference: Main Line speed is found to be significant for Curvature NG as P value is equal to .05

Response Information

Variable	Value	Count
curvature	1	19 (Event)
	0	661
	Total	680

Deviance Table

Source	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	1	4.949	4.9494	4.95	0.026
Main line Speed	1	4.949	4.9494	4.95	0.026
Error	678	168.466	0.2485		
Total	679	173.415			

Binary Logistic Regression: Roller imprint versus Main line Speed

Method

Link function Logit
Rows used 680

Inference: Main Line speed is found to be significant for Roller Imprint as P value is equal to .05

Response Information

Variable	Value	Count
Roller Imprint	1	17 (Event)
	0	663
	Total	680

Deviance Table

Source	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	1	11.72	11.7163	11.72	0.001
Main line Speed	1	11.72	11.7163	11.72	0.001
Error	678	147.28	0.2172		
Total	679	158.99			

Binary Logistic Regression: curvature versus Temp act. Zone 3 lower

Method

Link function Logit
Rows used 680

Inference: Zone 3Loower is found to be significant for Curvature NG as P value is less than .05

Response Information

Variable	Value	Count
curvature	1	19 (Event)
	0	661
	Total	680

Deviance Table

Source	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	1	7.123	7.1232	7.12	0.008
Temp act. Zone 3 lower	1	7.123	7.1232	7.12	0.008
Error	678	166.292	0.2453		
Total	679	173.415			

Binary Logistic Regression: Roller imprint versus Temp act. Zone 3 lower

Method

Link function Logit
Rows used 680

Inference: Zone 3Loower is found to be significant for Roller Imprint as P value is less than .05

Response Information

Variable	Value	Count
Roller imprint	1	17 (Event)
	0	663
	Total	680

Deviance Table

Source	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	1	5.647	5.6472	5.65	0.017
Temp act. Zone 3 lower	1	5.647	5.6472	5.65	0.017
Error	678	153.346	0.2262		
Total	679	158.993			

Binary Logistic Regression: curvature versus Temp act. Zone 4 upper

Method

Link function Logit
Rows used 680

Inference: Zone 4Upper is found to be significant for Curvature NG as P value is less than .05

Response Information

Variable	Value	Count
curvature	1	19 (Event)
	0	661
	Total	680

Deviance Table

Source	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	1	6.134	6.1340	6.13	0.013
Temp act. Zone 4 upper	1	6.134	6.1340	6.13	0.013
Error	678	167.281	0.2467		
Total	679	173.415			

Binary Logistic Regression: curvature versus Temp act. Zone 4 lower

Method

Link function Logit
Rows used 680

Inference: Zone 4 Lower is found to be significant for Curvature NG as P value is less than .05

Response Information

Variable	Value	Count
curvature	1	19 (Event)
	0	661
	Total	680

Deviance Table

Source	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	1	11.83	11.8302	11.83	0.001
Temp act. Zone 4 lower	1	11.83	11.8302	11.83	0.001
Error	678	161.58	0.2383		
Total	679	173.41			

Similarly all the critical Xs were checked for relationship with Curvature NG, Blast Head Breakage, and Roller Imprint and the results are tabulated below.

Conclusion: Statistical Analysis

- Main Line speed
- Zone Temp 2 Lower
- Zone Temp 3 Lower
- Zone Temp4 Upper
- Zone Temp4 Lower

5 Design of Experiments

In DOE the significant factors found after statistical analysis are kept at different levels, then process is run at that setting as per design and Output Record are resulted in DOE sheet.

DOE planning sheet

Team Leader:- Mayank Kumar

Product:- Swift Dzire (MPG-BCK) Glass
Process:- VT Furnace (I-94) Tempering process

Problem Statement:- Curvature NG, Blast Head Breakage & Roller Imprint in Swift Dzire (MPG-BCK) Glass

Response 1:- Curvature NG Type:- Continuous Unit Of measure:- %

Response 2:- Blast Head Breakage Type:- Continuous Unit Of measure:- %

Response 3:- Roller Imprint Type:- Continuous Unit of measure:- %

5.1 DOE Factors and Levels:

DOE FACTORS					
Levels	Main Line Speed mm/s	Zone Temp-2 Lower C	Zone Temp-3 Lower C	Zone Temp-4 Upper C	Zone Temp-4 Lower C
	(A)	(B)	(C)	(D)	()
Low(-1)	103	655	680	705	710
High(+1)	107	665	690	715	720

DOE Data Collection:

No. of Factors :- 5
Total Run :- 16
Block :- 2
Resolution:- V
Design:- ½ Fraction

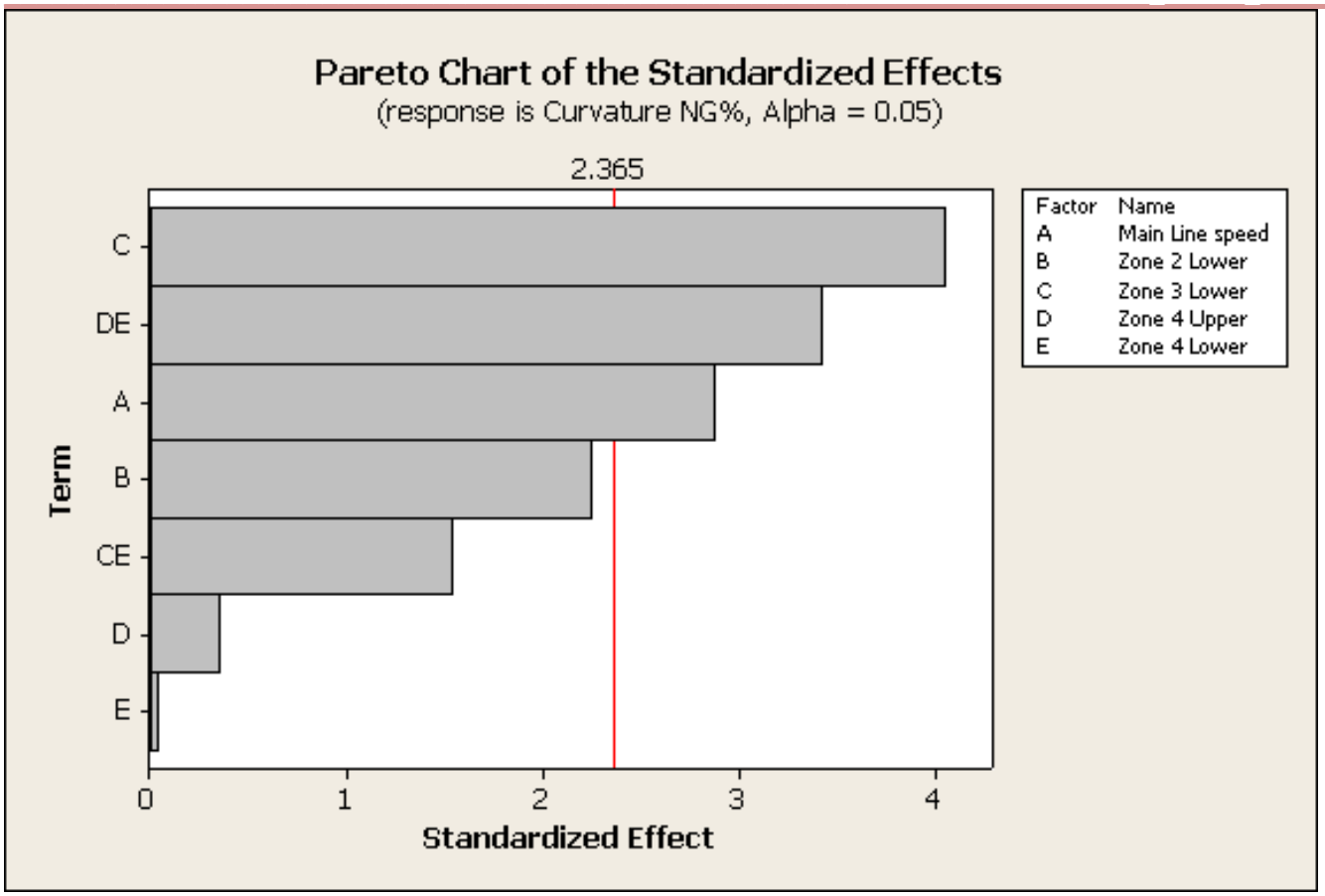
StdOrder	Blocks	Main Line speed	Zone 2 Lower	Zone 3 Lower	Zone 4 Upper	Zone 4 Lower	Curvature NG%	B/H Breakage%	R. Imprint%
1	1	107	655	680	705	710	0.5	0.25	0
2	1	103	665	680	705	710	0.25	0	0.5
3	1	107	655	690	705	720	2.5	0	0
4	1	103	665	690	705	720	1.25	0	1.25
5	1	107	655	680	715	720	1.25	0	0.5
6	1	103	665	680	715	720	0.5	0	0
7	1	107	655	690	715	710	2.25	0	0
8	1	103	665	690	715	710	1.25	0	1
9	2	103	655	680	705	720	0.2	0	0.2
10	2	107	665	680	705	720	0.2	0.2	0
11	2	103	655	690	705	710	0.6	0	0.4
12	2	107	665	690	705	710	0.6	0	0.4
13	2	103	655	680	715	710	0	0	1.2
14	2	107	665	680	715	710	0.4	0	1
15	2	103	655	690	715	720	0	0	1.4
16	2	107	665	690	715	720	0	0.6	0.4

Factorial designs allow for the simultaneous study of the effects that several factors may have on a process. When performing an experiment, varying the levels of the factors simultaneously rather than one at a time is efficient in terms of time and cost, and also allows for the study of interactions between the factors. Interactions are the driving force in many processes. Without the use of factorial experiments, important interactions may remain undetected.

Therefore, for 4 factors at 2 level each, factorial design was created and experiment was conducted taking 500 Glass on each Run for total 16 runs.

5.1.1 Analysis of Variance for Curvature NG:

 ISSN: 2321-8169
370 - 408

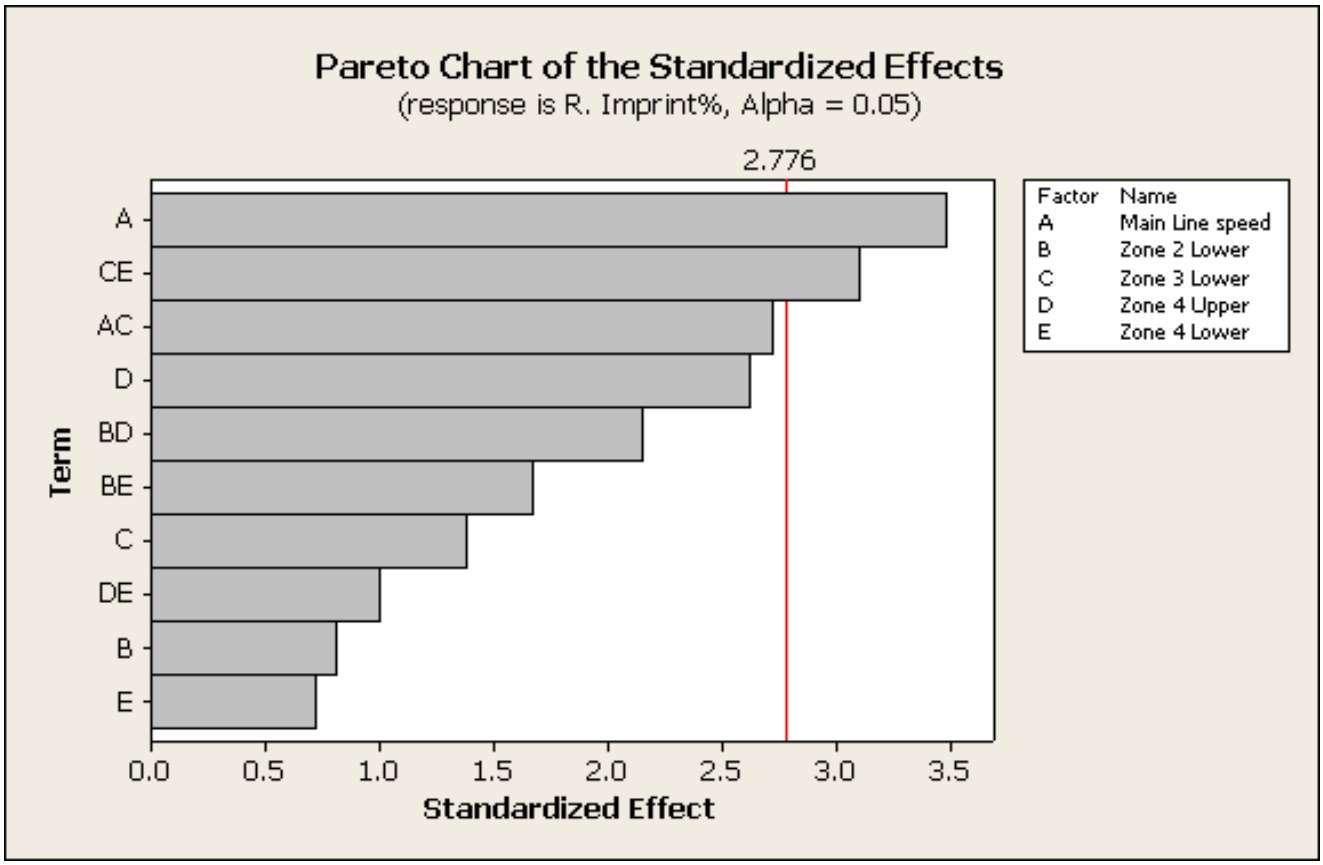


Analysis of Variance for Curvature NG% (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	1	3.75391	3.75391	3.75391	37.08	0.000
Main Effects	5	3.01078	3.01078	0.60216	5.95	0.018
Main Line speed	**1**	**0.83266**	**0.83266**	**0.83266**	**8.23**	**0.024**
Zone 2 Lower	1	0.50766	0.50766	0.50766	5.01	0.060
Zone 3 Lower	**1**	**1.65766**	**1.65766**	**1.65766**	**16.38**	**0.005**
Zone 4 Upper	1	0.01266	0.01266	0.01266	0.13	0.734
Zone 4 Lower	1	0.00016	0.00016	0.00016	0.00	0.970
2-Way Interactions	2	1.42031	1.42031	0.71016	7.02	0.021
Zone 3 Lower*Zone 4 Lower	1	0.23766	0.23766	0.23766	2.35	0.169
Zone 4 Upper*Zone 4 Lower	**1**	**1.18266**	**1.18266**	**1.18266**	**11.68**	**0.011**
Residual Error	7	0.70859	0.70859	0.10123		
Total	15	8.89359				

Curvature NG = 0.7344+0.2281*Main line speed+0.3219*Zone-3 Lower -0.2719*Zone-4 Upper*Zone-4 Lower

5.1.2 Analysis of Variance for Blast Head Breakage:

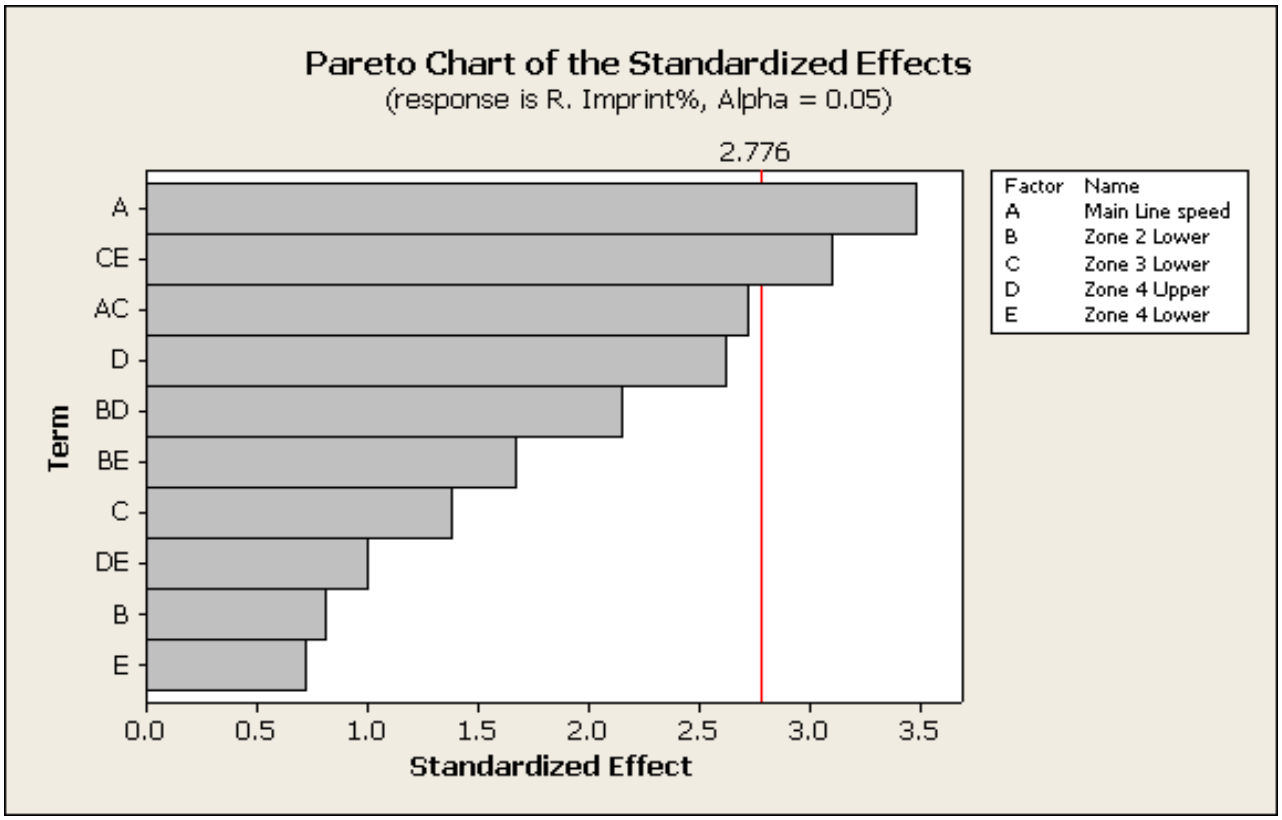


Analysis of Variance for B/H Breakage% (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	1	0.018906	0.018906	0.018906	2.61	0.205
Main Effects	5	0.109531	0.109531	0.021906	3.03	0.196
Main Line speed	**1**	**0.068906**	**0.068906**	**0.068906**	**9.52**	**0.054**
Zone 2 Lower	1	0.018906	0.018906	0.018906	2.61	0.205
Zone 3 Lower	1	0.001406	0.001406	0.001406	0.19	0.689
Zone 4 Upper	1	0.001406	0.001406	0.001406	0.19	0.689
Zone 4 Lower	1	0.018906	0.018906	0.018906	2.61	0.205
2-Way Interactions	6	0.243438	0.243438	0.040573	5.60	0.093
Zone 2 Lower*Zone 3 Lower	1	0.026406	0.026406	0.026406	3.65	0.152
Zone 2 Lower*Zone 4 Upper	1	0.026406	0.026406	0.026406	3.65	0.152
Zone 2 Lower*Zone 4 Lower	**1**	**0.068906**	**0.068906**	**0.068906**	**9.52**	**0.054**
Zone 3 Lower*Zone 4 Upper	**1**	**0.068906**	**0.068906**	**0.068906**	**9.52**	**0.054**
Zone 3 Lower*Zone 4 Lower	1	0.026406	0.026406	0.026406	3.65	0.152
Zone 4 Upper*Zone 4 Lower	1	0.026406	0.026406	0.026406	3.65	0.152
Residual Error	3	0.021719	0.021719	0.007240		
Total	15	0.393594				

B/H Breakage = 0.0656+0.0656*Main line Speed+0.0656*Zone-2 lower*Zone-4 Lower +0.0656*Zone-3 Lower*Zone-4 lower

5.1.3 Analysis of Variance for Roller Imprint:

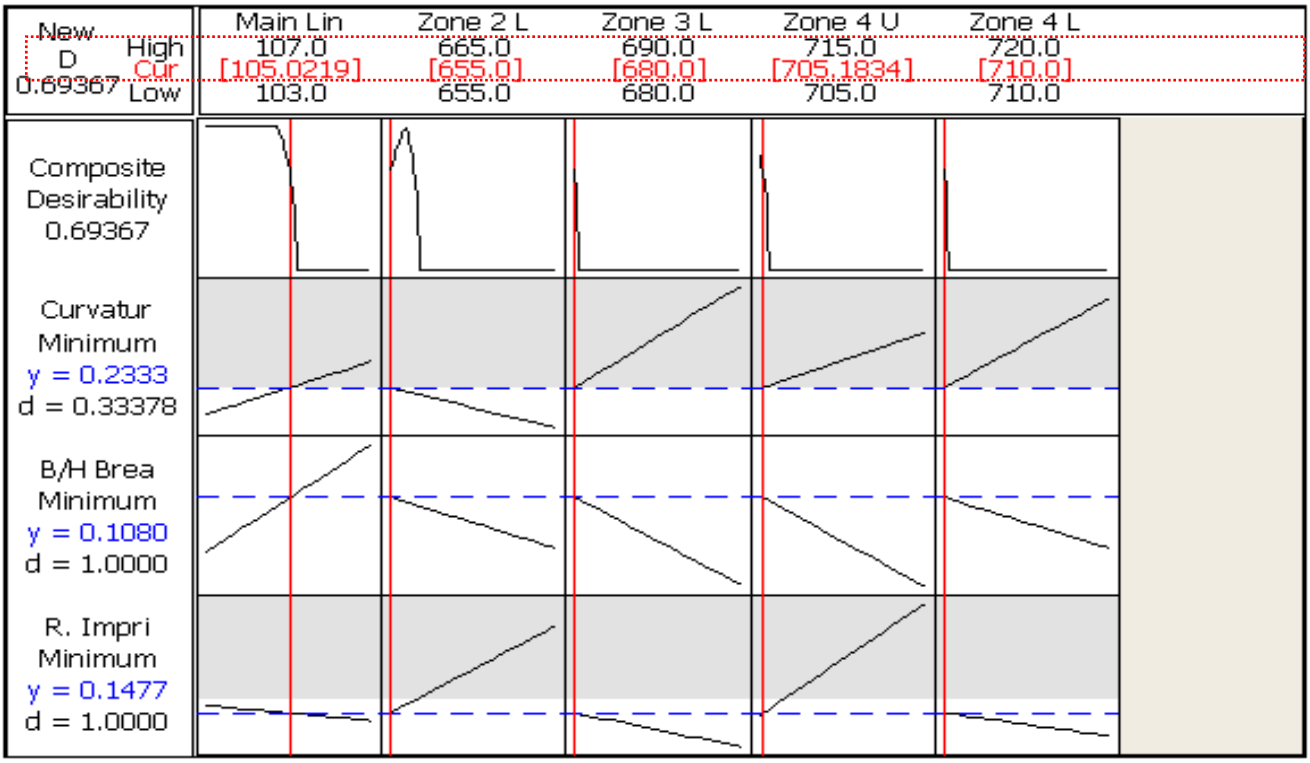


Analysis of Variance for R. Imprint% (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	1	0.19141	0.19141	0.19141	2.78	0.171
Main Effects	5	1.51703	1.51703	0.30341	4.40	0.088
Main Line speed	**1**	**0.83266**	**0.83266**	**0.83266**	**12.08**	**0.025**
Zone 2 Lower	1	0.04516	0.04516	0.04516	0.66	0.464
Zone 3 Lower	1	0.13141	0.13141	0.13141	1.91	0.239
Zone 4 Upper	1	0.47266	0.47266	0.47266	6.86	0.059
Zone 4 Lower	1	0.03516	0.03516	0.03516	0.51	0.515
2-Way Interactions	5	1.74453	1.74453	0.34891	5.06	0.071
Main Line speed*Zone 3 Lower	1	0.50766	0.50766	0.50766	7.37	0.053
Zone 2 Lower*Zone 4 Upper	1	0.31641	0.31641	0.31641	4.59	0.099
Zone 2 Lower*Zone 4 Lower	1	0.19141	0.19141	0.19141	2.78	0.171
Zone 3 Lower*Zone 4 Lower	**1**	**0.66016**	**0.66016**	**0.66016**	**9.58**	**0.036**
Zone 4 Upper*Zone 4 Lower	1	0.06891	0.06891	0.06891	1.00	0.374
Residual Error	4	0.27563	0.27563	0.06891		
Total	15	3.72859				

Roller Imprint = 0.5161-0.2281*Main line speed-0.1781*Main line speed*Zone-3 Lower

Response Optimiser: DOE



After analyzing the experimental data total three factors and their interactions were found significant among four input factors. Using the Minitab optimization of the process was done and a Model **Y = f(Xs)** was establish for all three Outputs Curvature NG, Blast Head Breakage, and Roller Imprint individually as well as for total rejection. The DOE optimized revised settings are 105 mm.sec for Main Line Speed, 655˚C for Zone Temp 2 Lower, 680˚C for Zone Temp 3Lower, and 705˚C for Zone Temp 4 Upper & 710 for Zone Temp Lower.

5.2 Confirmatory Test

A confirmatory run was taken by setting the optimized parameters.

S.No.	Date	Total Production	OK	Total Defect	Curvature	B/H Breakage	R/Imprint	E/Trouble	Other Defect (Chips,MisPrint, Scratch,Dust mark,Cullet)	Process Yield
1	6/4/2014	1143	1072	71	8	2	6	0	55	93.79%
2	8/4/2014	3394	3198	196	11	4	8	0	175	94.23%
3	16 & 17/04/14	4820	4522	298	12	5	13	0	271	93.82%
4	22/04/14	5376	5079	297	12	7	33	30	215	94.48%
5	30/04/14	2847	2697	150	7	5	17	8	113	94.73%
6	5/5/2014	2085	1970	115	1	6	8	0	100	94.48%
7	8/5/2014	5309	4950	359	6	6	9	0	257	94.90%
Total		24974	23709	1265	57	35	94	38	1046	94.53%
%age				5.27	0.23	0.14	0.38	0.16	4.19	
PPM				50653	2282	1401	3764	1603	41884	

6.1 Standardization

a) Process parameters Zone 2, Zone3, Zone4 Temperature and Main Line Speed revised and standardized with other Parameters.

Process Parameter					
	Z-2 (L) °C	Z-3 (L) °C	Z-4 (U) °C	Z-4 (L) °C	Line Speed
Before	685±10°C	700±10°C	710±10°C	715±10°C	110±5 mm/sec
After	655±5°C	680±5°C	705±5°C	710±5°C	102±3 mm/sec

b) Training to all concern for the revision made in standard operating conditions regarding changes which has taken place in parameters.

6.2 Control

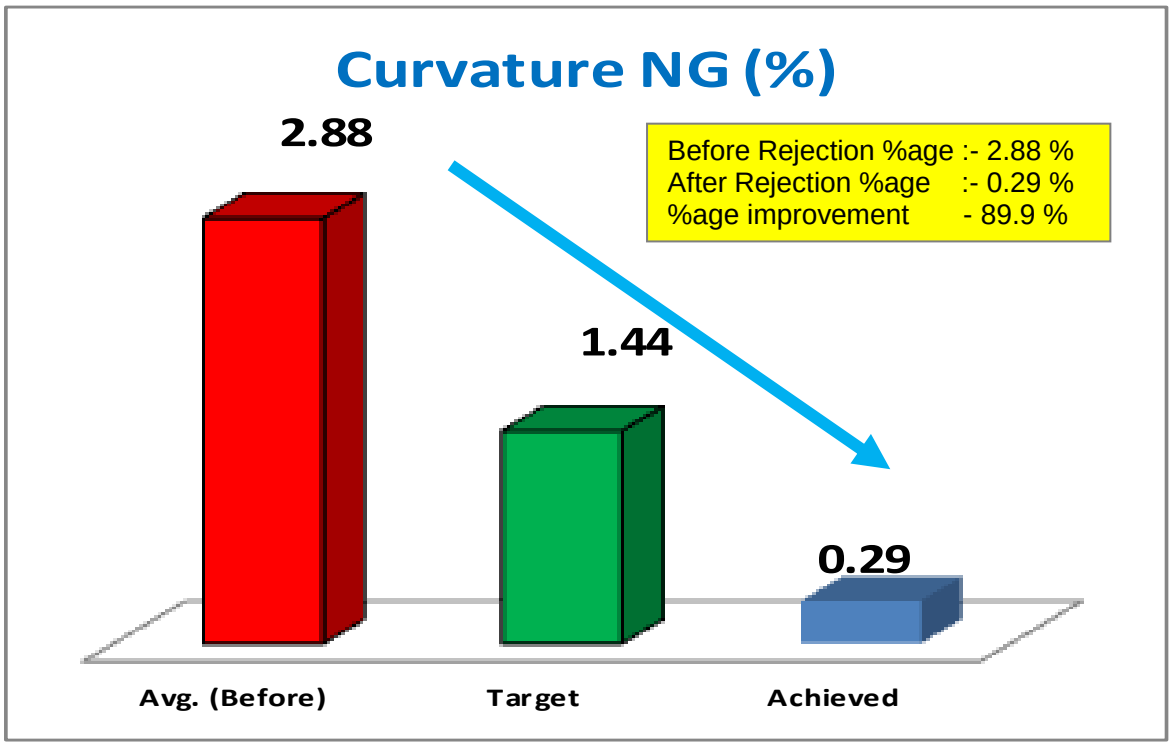
Further we require to control the Main Line speed, Zone Temperatures (heating condition) Quench pressure to control the Curvature NG, Blast Head Breakage and Roller Imprint in Swift Dzire (MPG-BCK).

Recommended actions:-

- Updated Process Condition.
- Control Methods
  - Updated FMEA :- FMEA updated & reduced RPN no calculated on basis of severity occurrence and detection value
  - Check sheet: - Check sheet for controlling the press gap and monitoring the process parameters implemented.
  - Formal Control Plan on basis of FMEA activities decided & revised the control plan according to the activity & desired frequency
  - Poka Yoke: - Press gap standardized to improve the drop style of the glass.

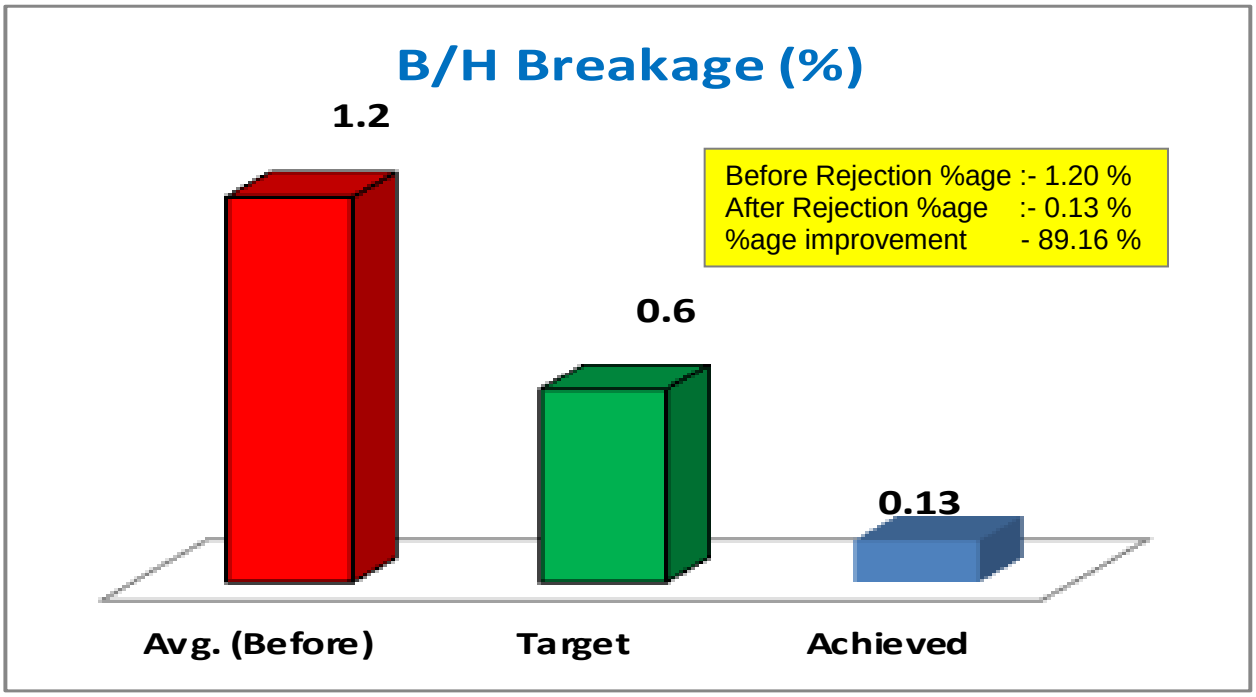
6.3 Results

6.3.1 Curvature NG : Target Vs. Achievement

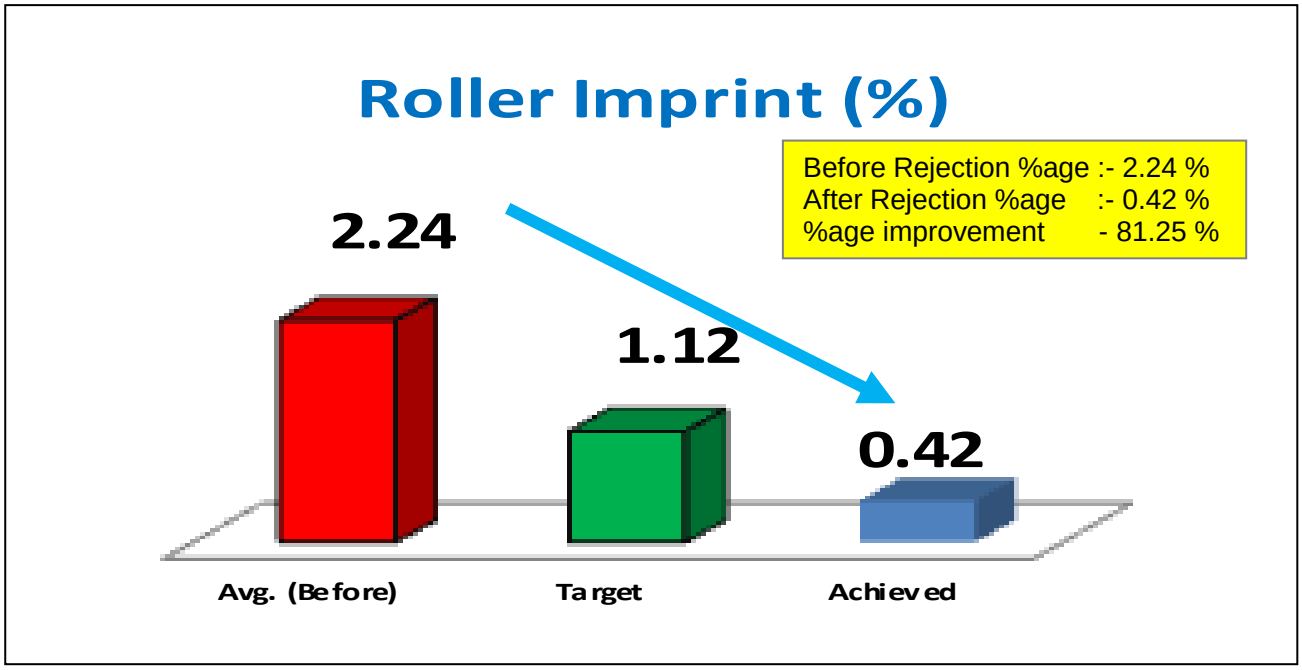


 ISSN: 2321-8169
370 - 408

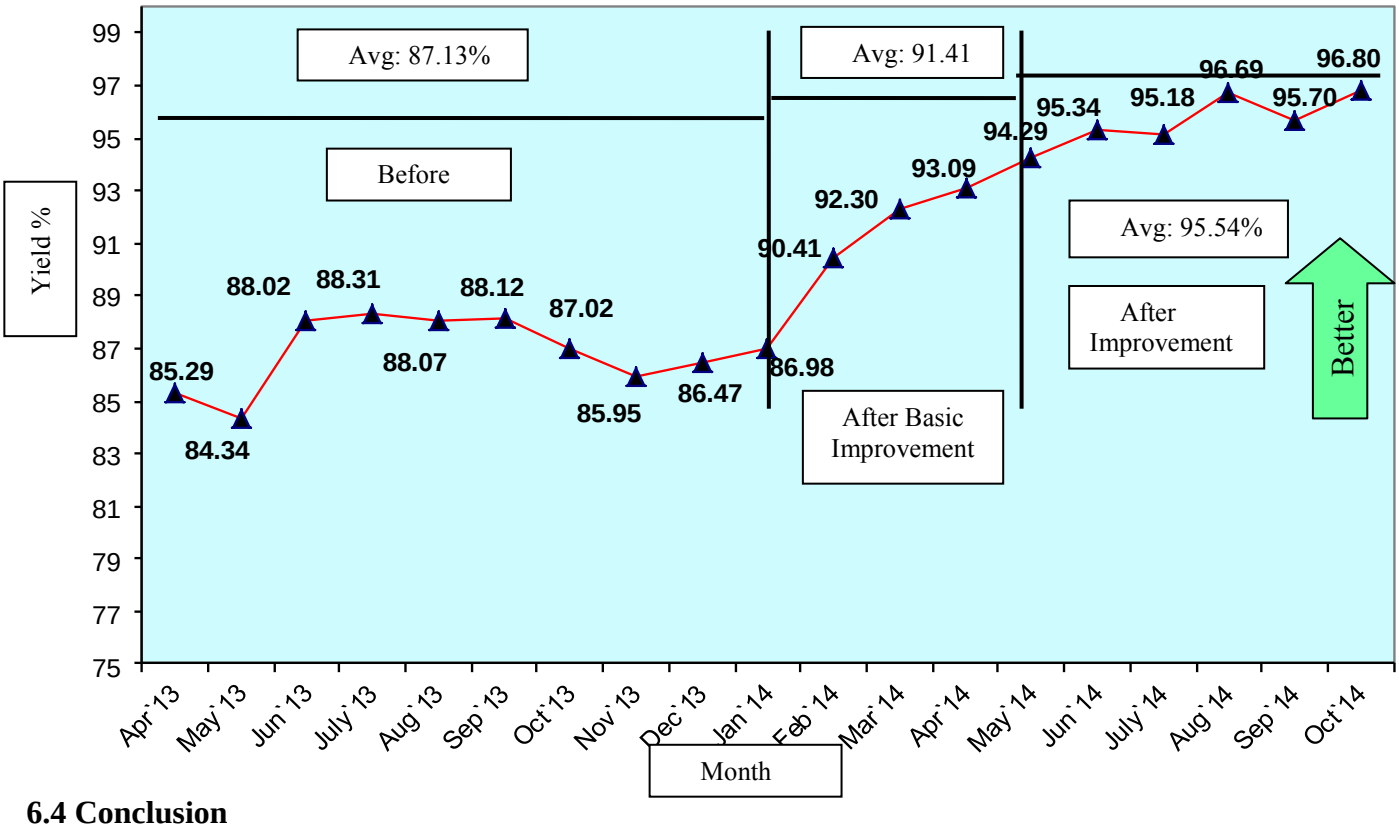
6.3.2 **Blast Head Breakage Trend: Target Vs. Achievement**



6.3.3 **Roller Imprint Trend:**



6.3.4 **Swift Dzire (MPG-BCK) Trend Overall:**



6.4 Conclusion

6.4.1 Gains from the study

- Curvature NG of Swift Dzire (MPG-BCK) reduced from 2.88% to 0.29%.
- Blast Head Breakage of Swift Dzire (MPG-BCK) reduced from 1.20% to 0.13%.
- Roller Imprint of Swift Dzire (MPG-BCK) reduced from 2.24% to 0.42% .
- Yield of Swift Dzire (MPG-BCK) increased from 87.13% to 95.54%.
- Overall PPM of Swift Dzire (MPG-BCK) reduced from 6.21% to 4.5% PPM.

6.4.2 Scope of horizontal deployment

Horizontal deployment to be done in following products of Maruti Suzuki India Limited vehicles.

1. Wagon R (MYS-BCK)
2. New Alto (ME3-BCK)
3. Alto K10 (MYG-BCK)

The Case study presented is related to Application of Statistical techniques to resolve Quality problem in automotive industry. This study covers the study of process capability, yield and high impact problems like Curvature NG, Blast Head Breakage & Roller Imprint using various statistical tools. It can be concluded from the study that chronic problems can be resolved using statistical techniques. Understanding of the problem and data collection is very important parts for successfully resolving the chronic Issues. Hence Yield can be improved by resolving the quality problems.

References:

1. Levin Rubin, “Statistics for Managers” (2008), Pearson Prentice Hall, Seventh Edition
2. Journal – Indian Institution of Industrial Engineering
3. AIAG Manual, Failure Mode Effect Analysis” (2008), Fourth Edition