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Study on Application of Six Sigma in Shoe Manufacturing Industry

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Abstract
Footwear industries are mostly set up in developing countries considering labour rate, availability of raw materials and environmental restrictions as industry uses lot of chemicals in producing final product. It is one of the industries in India that contribute a lot to the economic growth, exports, and imports and provides employment to the backward community with 30% share of women employment. The production system comprises of different operations such as cutting, skiving, assembly, sewing,lasting, finishing, inspection and packing.
For any manufacturing or service industry, quality and customer satisfaction is the priority. To achieve quality product, process parameters or variables that influence the output of each process need to be consistently controlled and requires skilled manpower, quality raw material, machines, tools proper environment conditions and proper inspection. Therefore, to attain customer satisfaction, product needs to be economical in cost, delivered in time and meet customer expectations. This paper deals with the DERBY shoe industry that registered with low process cycle efficiency due to high lead time and rejection at the rate of 26,435 per million opportunities, which means the industry is in the range of three sigma level which is not average industry level (Four sigma). With the implementation six sigma DMAIC methodology, the rejection rate is expected to come down to 3365 per million opportunities through which the industry can achieve four sigma, which is acceptable.
Keywords: *Six Sigma, DMAIC, Quality, Customer, lead time, Industry standard.*

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I. INTRODUCTION

Footwear industry is a labour oriented industry where a large number of workers are deployed in the production line. Among the resources like capital, materials, machines, energy, land, product information, technology etc., man power is very important and should be controlled in most appropriate manner. To attain the required quality and maximum productivity, proper operation sequencing and line balancing is indispensable because in a properly balanced line, machine and manpower utilisation would be much more and rate of production would be more.

1.1 Stages involved in shoe manufacturing

Manufacturing of footwear involves movement of raw materials to different stages such as Cutting, Fitting and Assembly, Sewing in Closing Department, Lasting in Lasting Department, Bottom Department where soles are produced and Finishing in Finishing Department.

Cutting: It is the first step in the making of a pair of shoes. In the cutting stage, different parts of shoe upper such as toe, vamp, quarter and counter are chopped off from the raw material (Leather) in the required size and shape through either manual tools such as knife or cutting machines using die cutter.

Skiving: The purpose of the operation is to skive edges of the parts which are to be joined to maintain the uniform structure at the joint for good appearance i.e., to avoid overlapping of the parts. It is performed before assembly stage.

Fitting and Assembly:Here, shoe parts are bonded using adhesive for proper stitching of these parts in sewing stage. Proper care should be taken such that there should not be misplacement of parts which would result in rework or rejection. Proper attention is required in this stage.

Sewing: It is one of the highly skilled operations performed in stitching department. This operation is done because application of glue at the joint during assembly stage may not give guarantee to sustain high strain during lasting operation. For safety, long life and to resist those stress and strain, stitching operation is performed. Sewing operation can also be performed in the toe lasting, side and seat lasting process etc… depending on the type of construction.

Last: Last is the pattern or replica of the final shoe to be produced. It is obtained in different shapes and sizes depending on the design, style etc., It is available in wood, metal, plastic and so on.
Lasting: It is the process where the upper retains the desired shape of the last shoe. This operation can be done manually or machine lasting. In machine lasting, the last with insole at the bottom is placed on the insole rest of the lasting machine. Shoe upper is then placed over the last. Then after setting the parameters (pressure, dwelling time etc.,) of machine, lasting is done in two phases. In the first phase, pincers hold and pull the upper margin where upper sits over the last. In the second phase, adhesive is applied to the insole margin by injectors and toe band holds the shoe upper at the time of pincers leaving the upper margin during the wiping process, where wipers wipe the upper margin to the insole to obtain the shape of top part of the shoe. The above process is common for both lasting stages Toe-lasting, Side and Seat lasting Stage.
Post-lasting: In this stage, after lasting the shoe upper, it is sent to heat setting where the shoe is subjected to high temperature air in order to relieve the stresses and strains in the shoe upper and softening of upper to the last. It is followed by sole attaching using adhesive followed by sole pressing and then Heel attaching to the rear part of the shoe resulting in the completion of the shoe.
Finishing: This is the final stage in the production. In this stage, the following sequence of operations have been performed to enhance the inherent characteristics of the product and also to upgrade the quality and aesthetic appearance of the product. The operations such as Dry cleaning, Wet cleaning, Edge cleaning, Base coat application, Polishing, Top coat application, Inspection, Packing.

1.2 Literature Review

Shetty (1963) pointed out that the technological base in the Industry was extremely primitive and a unit was rarely interested to adopt technological modifications in the process. Usha (1985) based on Tamil Nadu leather tanning Industry in the year 1978-1979. The study is based on the structure of workforce, Mechanisation and the prospect of the traditional skilled and unskilled workforce in the industry. Her major findings were that the leather tanning industries in Tamil Nadu account 90% to the Muslim community and rest belongs to Hindu community. As regards the mechanisation of Industry, most of the tanning and manufacturing industries preferring the labour-intensive technique. Qureshi (1990) discussed some issues faced by leather making artisans of Mewat region in the district of Gurgaon, Haryana. And also the leather quality defects, long lead time, lack of modernised techniques, less profitability, marketing at low prices letting the leather workers face some difficulty in the system.

Sahasranaman (1993) pointed out some basic problems of the leather industry. According to his study, he pointed out that the dominance of traditional production system, confinement of production to a particular community, absence of modernisation of technology were the basic problems of the Industry. Chandramouli's (1992) on "Leather and social development" focused on some characteristics of leather Industry. The author states that production of leather and leather products involves various socio-economic activities. The economic activities were largely in the form of generation of income, creation of employment etc., on the other hand, social activities from the leather industry involves social equity, better health, education etc., Bhavani (2010) highlights the issue of quality employment generation by the SSIs and negates the short term attitude of increasing the volume of employment generation compromising with quality. The author argues that employment generation by the SSIs may be high in quantitative term but very low in quality. Technological up-gradation would enable the small firms to create quality employment improving, duration and skill.

1.3 SIX SIGMA

Six-Sigma can be defined as one of the methods that aim to reduce the variation in operations or process or final product to meet the customer satisfaction. In other words, it is the process in which only less than 3.4 products are rejected out of 1 million parts which means 99.99996% of the products are accepted. Six-Sigma is highly disciplined and well-structured statistical approach for process improvement.
DMAIC and DMADV are the two methodologies commonly approached in process improvement.
DMAIC stands for Define phase, Measure phase, Analyse phase, Improve phase and Control phase. It is used to improve the existing process
DMADV stands for Define phase, Measure phase, Analyse phase, Design phase and Verify phase. It is used to design the new product or replacing new process when improving of existing process is not done.
Methodology:
In this work, DMAIC Approach is followed to identify the causes of the down time thereby finding out the possible solutions to minimise down time resulting in improved lead time, process cycle efficiency, reducing rework by maintaining quality.

1.4 CASE STUDY: SIX SIGMA APPLICATION IN SHOE MANUFACTURING

DMAIC Approach:

Define phase:

It is the first phase of the methodology. This phase begins with project charter where details such as Problem statement, project scope and boundary, voice of the customers etc., are taken into considerations. It acts as a foundation for the remaining phases. Inthis work, the industry is facing high lead time due to down time at different stages of production resulting in low process cycle efficiency ultimately dis-satisfaction among workers and end customers.

Table 1: Project charter in the define phase

Project title	Six sigma concept in Derby shoe manufacturing for quality improvements
Background and reasons for selecting the project	Footwear manufacturing process involve in potential sources of errors and problems which may lead to product complaints and rejection and high lead time
Project goal	To reduce downtime, defects and improve quality in footwear manufacturing using six sigma concept
Value of the customer	Quality of the product
Project Boundary	Focusing on complete shoe manufacturing process
Team members	Production manager, experienced shop-floor operator
Expected financial benefits	Considerable cost saving due to defects elimination
Expected customer benefits	Receiving the products with desired quality

Measure phase:

In this phase, we measure the different process using measuring tools and refine the problem statement and other outputs of the define stage. Creating a baseline metrics indicates how the process is performing before improvements begin. It also provides comparison between the current and improved process to know how much improvement done.

Measure phase of the DMAIC methodology consists of establishing reliable metrics to help monitoring progress towards the goal, which in the current study consist of recording down-time of different stages of the production system and number of quality defects in the Derby shoe manufacturing process. After defining the number of quality defects, defects per million parts and sigma level of the manufacturing system is calculated.

Table 2: Defects summary (Before six sigma improvement)

Name of the stage	No. of defects per 10,000 parts	No. of defects per million parts	Percentage (%)
Cutting	18.70	1870	7.07
Sewing	32.30	3230	12.21
Pre-lasting	56.10	5610	21.22
Post-lasting	76.50	7650	28.93
Finishing	80.75	8075	30.54
Total	264.35	26435	100

Analyse phase:

During analyse phase, teams develop hypothesis about causal relationship between cause and effect that narrow causation to vital few. This phase deals with identifying the variation in the processes. Tools such as Pareto chart, cause and effect relationship (fishbone diagram), control chart, Histogram etc… can be used. In this study, various effects and their root causes at different stages such as cutting stage, sewing stage, lasting stage and finishing stage are taken into consideration.

Table 3: Down time and Cycle time of manufacturing system*

Steps	Causes for down time	Down time (D/T) sec	Average Down time	Cycle time (C/T) sec	% Down time (D/T) sec
	Needle thread breakage	316			
		312	316		9.09
		320			
	Bobbin or looped thread breakage	38			
		41	41		1.18
		45			
Sewing	Skipped stitches	75		2880	
		71	75		2.15
		79			
	Seam pucker	67			
		60	62		1.78
		59			
	Variable stitch density	134			
		142	137		3.94
		136			

Finishing	Inefficient ironing	456	447	2880	12.86
		446			
		441			
	Improper polishing	142	146		4.20
		150			
		145			
	Inefficient spraying	132	138		3.97
		145			
		136			
	Bumps or hollows	86	91		2.62
		92			
		95			
Pre – lasting	Improper setting during toe lasting	1022	1036	4680	29.82
		1050			
		1035			
	Improper setting during seat lasting	60	59		1.69
		55			
		63			
	Inappropriate scouring	201	209		6.01
		215			
		210			
	Side lasting problems due to feather edge stitching	51	57		1.06
		58			
		63			
Post - lasting	Inefficient heat setting	767	759	2880	21.84
		759			
		751			
	Inappropriate sole press	68	68		1.95
		75			
		65			
	Improper chilling	66	66		1.89
		60			
		72			
	Improper sole attaching	215	214		6.16
		208			
		220			

**The above data in the table is secondary data collected from the journals, internet*

Table 4: Causes of the down time, their percentage & cumulative percentage

Causes of delay times	Down time (D/T)	Percentage of down time	Cumulative of percentages
Toe lasting problems	1036	26.4218312	26.4218312
Inefficient heat setting	759	19.3573068	45.779137
Inefficient ironing	447	11.400153	57.1792
Needle thread breakage	316	8.059168	65.238459
Improper sole attaching	214	5.4577	70.696250
Inappropriate scouring	209	5.3302	76.02652
Improper polishing	146	3.7235	79.7500
Inefficient spraying	138	3.5195	83.26957
Variable stitch density	137	3.49400	86.763580
Bumps or hollows	91	2.3208	89.0844
Skipped stitches	75	1.91277	90.99719
Inappropriate sole press	68	1.7342	92.73144
Insufficient chilling	66	1.6832	94.41469
Seam pucker	62	1.58122	95.995919
Seat lasting problems	59	1.504718	97.5006375
Side lasting problems	57	1.453710	98.954348
Bobbin thread breakage	41	1.0456	100

From the above table, major sources of the delay time are Toe lasting problems, Inefficient heat setting, Inefficient Ironing, Needle thread breakage, Improper sole attaching which contribute about 70% of the down time in the manufacturing. These causes need to be eliminated to some extent.

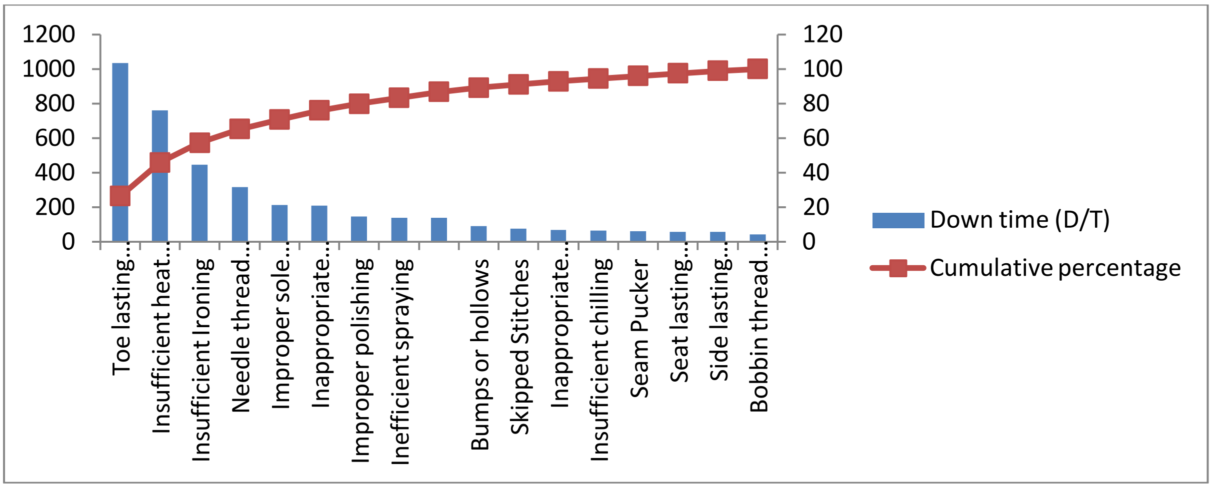


Figure 1: Pareto chart based on the causes of the down time

Cause and effect diagrams or fishbone diagrams or Ishikawa diagrams

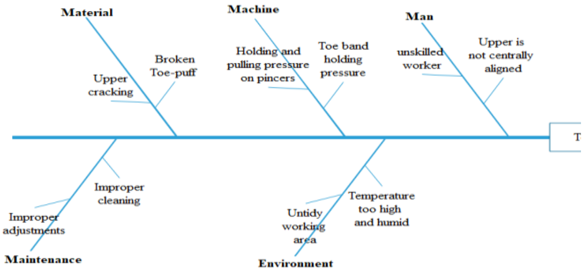


Figure 2: Cause and effect diagram for toe lasting

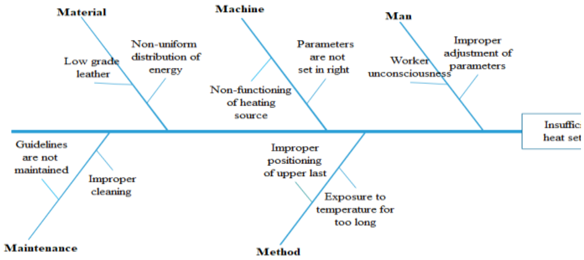


Figure 3: Cause and Effect diagram for insufficient heat setting

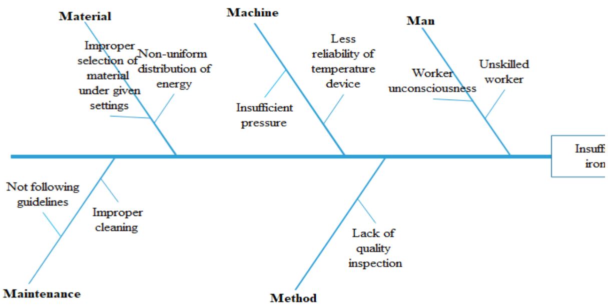


Figure 4: Cause and Effect diagram for insufficient ironing

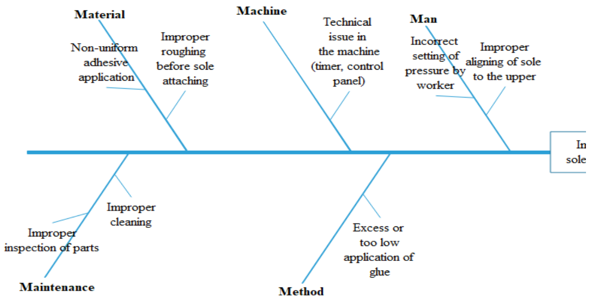


Figure 5: Cause and Effect diagram for Improper sole attaching

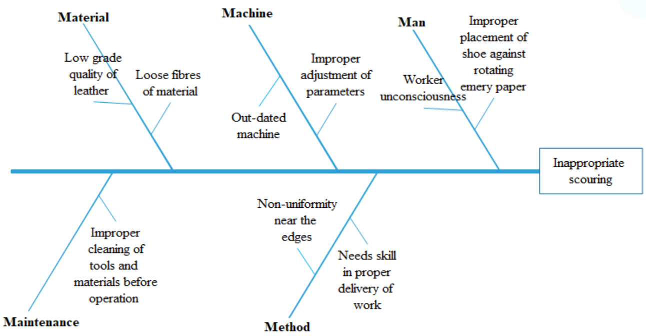


Figure 6: Cause and effect diagram for inappropriate scouring

Improve phase:

In this phase, we find out the solutions for identified root causes by either proper analysis, following proper measures, work instructions given by experts in such a way that impact of causes on the system should be reduced. Sometimes more than one solution will be existing and it is difficult to choose the one that fits the best. In such case, implementing one change and verify that change before moving into another one.

It is important to note that the teams brainstorm the possible solutions for the root causes identified in the analyse phase and rank those solutions according to costs, how effective the solution would be, and how likely the solution could be implemented.

Table 5: Problem statements with root causes and possible solutions

Problem statement	Root causes	Possible solution
Toe lasting problems	• Improper adjustment of the wipers, pincers • Improper pressing of the Teflon band over the vamp area • Improper upper activation	• Pre-setting the proper positioning and speed movement if pincers, wipers • Ensure wiper size matches the bottom last so that it attach upper to the insole uniformly • Ensure that Teflon band has same size as that of vamp area of the upper • Proper setting of activation
Insufficient heat setting	• Improper display of temperature reading • Non-uniform distribution of heat throughout the surface • Material characteristics	• Due to long period of machine serving, components in the machine deteriorate gradually. Periodic maintenance is compulsory. Check the conditions of machine components before the operation to ensure proper results. • It is best solution to subject the energy on the area where it is required. So that, energy saving is more and also uniformly subjected without damaging the material • Depending on the type of material, temperature should be fixed
Insufficient ironing	• Insufficient pressure or too excessive pressure • Wrong positioning and poor bonding	• Ensure proper application of pressure after reinforcement of material on the upper • During reinforcement on the upper, adhesive is needed. Ensure thin coat of adhesive on the surface for perfect bonding • Ensure proper aligning of toe-puff. It is necessary to have knowledge on when and how to perform the operation
Inappropriate sole attaching	• Non-uniform application of pressure after sole attachment • Improper roughing or polish	• After reactivation of adhesive on the surfaces of the upper and sole, bonding between sole and upper is made by uniform pressing with the help of hand or punch type press. • Before application of adhesive, ensure proper roughing on the surface of the sole.
Improper scouring	• Low grade of leather • Too much or low pressure on the surfaces	• Based on the leather quality, pressure on the surface should be adjusted during scouring because too much pressure on the surface cause damage and too little pressure won't do the operation effectively.

Control phase:

The last phase of DMAIC is control. This phase involves controlling the future state process by ensuring that any deviations from the target are corrected before they results in defects. This can be done by implementing tools such as statistical process control, visual workplaces and continuously monitoring the process.Teams build monitors that let them ensure the process continue to work successfully after changes are implemented.

II. RESULT AND DISCUSSION

By proper utilisation of resources such as material, machines, equipment, tools, proper control of process & work flow, proper infrastructure, working conditions, the lead time can be reduced, quality can be improved and defects can be reduced. Also other factor to be considered is parameters such as Temperature, Activation time, pressure etc., plays an important role in controlling the quality, defect rate. After implementing such methodology we can observe the changes from the initial conditions and improvement in quality.

Regression analysis

Regression analysis is a set of statistical process for estimating the relationship between a dependent variable and one or more independent variables. The most common form of regression analysis is linear regression, in which one finds the line that closely fits the according to a specific mathematical criteria.

Table 6: Down-time and Defects per million before improvement

Operation	Down time(X)	Defects per million(Y)
Cutting	180	1870
Sewing	126	3230
Finishing	206	8075
Pre lasting	340	5610
Post lasting	277	7650

Correlation coefficient (r) = $n \sum XY - (\sum X)(\sum Y) / \{(n \sum X^2 - (\sum X)^2)(n \sum Y^2 - (\sum Y)^2)\}^{½}$
By substituting the values from the above table, we get correlation coefficient (r) =0.51111
Positive regression coefficient indicates X and Y are directly proportional i.e., if X increases, Y also increases

Table 7: Cycle time and Defects per million parts before improvement

Operation	Cycle time(X)	Defects per million(Y)
Cutting	4680	1870
Sewing	2880	3230
Finishing	2880	8075
Pre lasting	4680	5610
Post lasting	2880	7650

By substituting the value of the above table in the above table in the formula, we get correlation coefficient (r) =-0.5211
Negative regression coefficient indicates that X and Y are inversely proportional i.e., X increases, Y decreases.

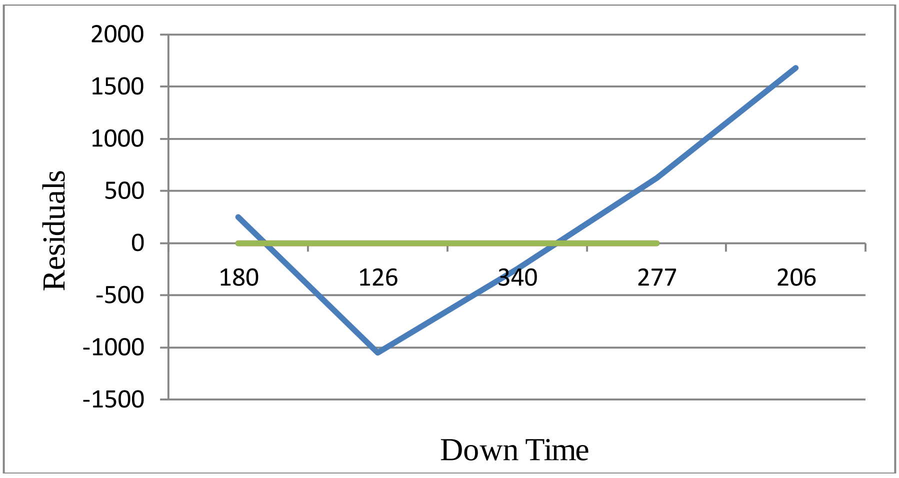
Table 8: Intercepts and coefficients of regression analysis

	Coefficients
Intercept	7484.91895872911
X variable 1	26.4646485504254
X variable 2	-2.27045461150421

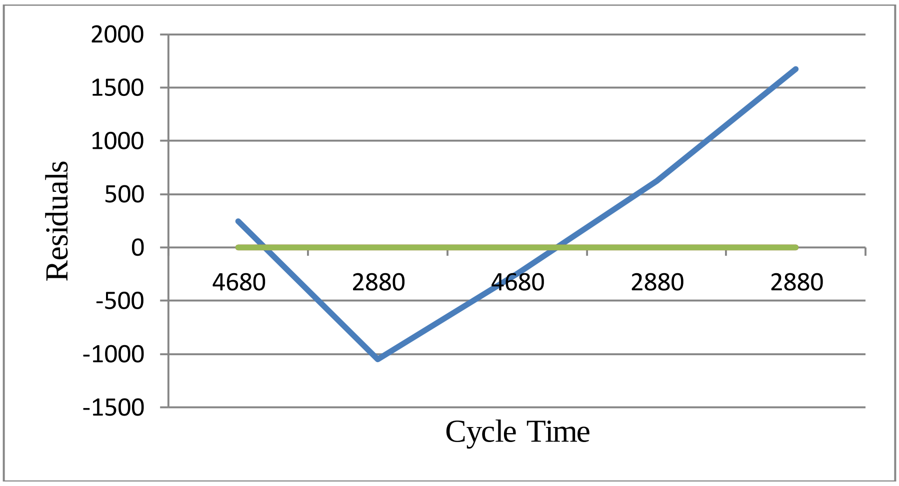
The regression equation is Y = a + b×X1 + c×X2
Y= 7484.919 + 26.46×X1 -2.27×X2 where X1 is Down time and X2 is Cycle time.
Residual analysis: Residual analysis is used to assess the appropriateness of a linear regression model by defining residuals and examining the residual plot graphs. Residual refers to the difference between observed values vs. predicted value.
Every data point has one residual. A residual plot is a graph in which residuals are on the vertical axis and the independent variables is on the horizontal axis. If the dots are randomly dispersed around the horizontal axis then linear regression is appropriate for the data; otherwise choose a non-linear model.

Table 9: Residual output

Observation	Predicted Y	Residuals	Standard Residuals
1	1622.8281	247.17	0.2348
2	4280.5553	-1050.553	-0.9980
3	5857.171	-247.1718	-0.2348
4	8276.717	626.7173	-0.5953
5	6297.727	1677.272	1.5934



Graph 1: Graph between down time & residuals



Graph 2: Graph between cycle time and residuals

By using the regression equation, Y =7484.919 + 26.46×X1 – 2.27×X2 the expected defects per million for decrease in down time and increase in cycle time are given in below table

Table 10: Defects per million after improvement

Operation	Down time(X1)	Cycle time(X2)	Defects per million(Y)
Cutting	100	5000	1219
Sewing	96	5000	1325
Finishing	150	5000	104
Pre lasting	200	5500	292
Post lasting	130	5000	425

Table 11: Comparison between Improvement of defect rate and sigma value (expected) after six sigma implementation

Quality levels(DPMO)		Sigma value	
Before the improvement	Expected	Before the improvement	Expected
26,435	3365	3.4	4.2

III. CONCLUSION

The parameters like Temperature, Activation time, Pressure, Adhesive usage etc., need to properly adjusted during the pre-start of the operation else small errors in the beginning leads to rejection of the product in the final stage. Proper maintenance at each department leads to identification of any faults, ultimately reduction in breakdown of the machines. In terms of six sigma level, the concept literally refers to reaching a sigma level of producing less than 3.4 defects. The number of defects can further be reduced by implementing the DMAIC analysis more number of times.

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