PRODUCTIVITY IMPROVEMENT OF HIGH END CNC MACHINES BY DMAIC METHODOLOGY

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ABSTRACT

This research mainly emphasizes on productivity improvement with the application of DMAIC (Define, Measure, Analyze, Measure, Improve, Control) which is sub methodology of Six Sigma. It shows the application of Six Sigma in Auma India Pvt. Ltd. to reduce the cycle time and set-up times of High End CNC machines. At Auma, one of the most critical problem is that the existing production rate cannot meet the customer demands. This work was focused on improving the production rate of CNC machines without sacrificing on quality and to improve output and productivity of the whole machining station.

The main problem regarding the production rate lies in long cycle time in machining station. Cycle time determine downtime, capacity, product quality, and to some extent costs. The other problem is related to the long cycle time of various components. This project implements Six Sigma methodology-DMAIC proposes a set of solutions, such as set up sequence optimization, set up operation simplification, to reduce set up time without sacrificing quality. Productivity per month was improved from 71% to 75%. Future recommendations were also provided that would further increase productivity.

Keywords: *DMAIC, Cycle Time, Six Sigma.*

1. INTRODUCTION

The present paper describes the results of a research focused on Six Sigma implementation process, in Auma India which is a leading manufactures of electric actuators, actuator controls and valve gearboxes for the automation of industrial valves / gates / dampers. Customers are the life blood of any business; the organization should relentlessly look for new ways to consistently uphold the expectation of customers by accentuating on quality, manufacturing cost that leads to competitive enhancement and increase in market share. To overhaul this woe, project charter team espouses a statistical breakthrough tool called Six Sigma to analyze the variations in the processing stages for reducing the defect less than 3.4 defects per million opportunities (DPMO). [1] Proposed "Six Sigma is a measure of variation about the average in the manufacturing process or the service industry". [2] Portrayed that by using DMAIC procedure, the variance, waste and errors that beset an operation can be ingrained. [3] Brought the DMAIC approach to analyze the manufacturing lines of a brake lever at a Connecticut automotive component manufacturing company. [4] Proposed that integration of Six Sigma with Statistical quality systems results in effective proceeding to identify the most relevant improvement areas.

2. DMAIC Methodology

2.1 Define phase: The define phase, narrowly illustrate the case that had been taken which faces a hailstorm from customer end due to increase in low production rate. The project charter is an influential element of initializing, planning, executing, controlling and surviving the study. The purpose of the project charter is to instigate a Six Sigma project by defining its scope and project variables [5].

Table 1.Project charter

Problem statement: Productivity loss due to High cycle time.	Goals: To collect data of present situation for the selected products. - To provide a capacity matrix for components machined on machines based on monthly production quantity. - To analyse factors for long cycle time and set up time and identify root causes. - To propose appropriate solution, implement, validate and quantify the cost benefits.
Critical to Quality (CTQ): Start up Loss, Man resource.	Cost of poor quality: - Increased set up time resulting in loss of production. - Production losses due to non-value added activities.
Customers: In process quality, assembly, dispatch.	Consequences of not doing it now: -Financial impact / Opportunity cost. -Productivity Loss.
Target: Current productivity: 71% Expected Productivity: 76%	

SIPOC (Supplier, Input, Process, Output, Customer): SIPOC describes the transformation process of inputs form suppliers to output for customers & gives a high level understanding of the process, the process steps (sub processes) and their correlation to each other.

Table 2. SIPOC

Suppliers	**I**nputs	**P**rocess	**O**utput	**C**ustomers
Purchase	Castings , Cutting oil		Finished parts	Inspection and testing
HR	Operators		Rejected parts	Assembly
Company	Machine			Vendors
Tool crib	Tools and instruments	Machining		
Design	Drawings			
PPC	Work-order CNC			
Drawing	CNC part Program			

2.2. Measure Phase: The first step in analyzing any process for scope of improvement is to understand the current status of the process "where are we now". Only by understanding the current status of the process we can plan for improvements. Data collection is the first step for this.

Cycle Time: The following table shows the cycle time collected of various components on different machines using stop watch.

Table 3 Cycle Time collected for various components on DMG ECO 2 Machine

SI No.	**Components**	**Cycle Time (minutes)**	**Idle (Minutes)**	**REMARKS**
1	BEARING FLANGE SA6	4.4		
2	BEARING FLANGE SA12	4.4	2	Operator not present
3	WORM WHEEL SA25 Z=40 DIA 129.5	6.5	3	Operator not present
4	HOLLOW DRIVE SHAFT SA6 Z=29	5.4		
5	HOLLOW DRIVE SHAFT SA12 Z1=39 Z2=12	6.2		
6	CLUTCH RING SA25 Z=45	6.2	13	Operator helping other operator,
7	WORM WHEEL SA6 Z=42 DIA 78.8	5		
8	WORM WHEEL SA100 Z=40 DIA 167	11.5	2	Getting Insert from store
9	BEARING FLANGE SA25	11.5	2	Insert tightening, Operator not present
10	MOTOR FLANGE EX-AI71 (SA6EX)	11.6		
11	BEARING FLANGE	14.5		

Table 4 Cycle Time collected for various components on DMG ECO1 Machine.

SI No.	Component	1st Operation(Minutes)	Idle (Minutes)	Remarks	2nd Operation(Minutes)	Idle (Minutes)	Remarks	Total Cycle time (Minutes)
1	ADAPTER FLANGE SA25.	15.5			26	4	Talking	41.5
2	BEARING FLANGE GK25.1 SQ 340x81 FG	19.4			14.6			34
3	BEARING FLANGE GK30.1 SQ 370x88	22.1			20.2			44.4
4	BEARING FLANGE GK35.1 SQ 450x105	12.4			16.1			28.5
5	MOUNTING FLANGE A100 DIA 210x165	11.6	3	Replacing Insert,Talking	11.6			23.2
6	MOUNTING FLANGE A200 DIA 300x97	24.6			23.6			47.6
7	MOUNTING FLANGE A200-F25 DIA 300x98	23.3			17.3	1	Talking	41
8	MOUNTING FLANGE A400 DIA 350x160	47.2			49.4			96.6
9	MOUNTING FLANGE ABG25.1 DIA 390x56	20.1			15.3			35.5
10	MOUNTING FLANGE F16 GS125.2 245 SQx76	12.3	1	Talking	9.13	1	Talking	21.4
11	MOUNTING FLANGE GS160 F25 FG	9.6	5	Insert finding and replacing	17.6			27.2
12	MOUNTING FLANGE GS160 F30 FG	16			17.21	2	Talking	33.2
13	MOUNTING FLANGE GS200 F30	24.5	11	Late return from lunch, Searching Insert	17.6			42.3
14	MOUNTING FLANGE GS200 F35 FG	30.4			21.6			52.1
15	SA25 Bearing flange	26.2			63			89.2
16	MOUNTING FLANGE SA100AB DIA 289x110	20.4			17.1			37.5
17	MOUNTING FLANGE SA50 AB	17.3			12.3	2	Tightening Insert	29.6
18	BEARING FLANGE SA100 SQ 230x50	7.5	4	Operator talking,Chamfering keeping M/C idle.	12.6			20.1
19	BEARING FLANGE SA25 SQ 180x40 FG	12.4			11.5			24
20	CLUTCH RING SA100 Z=58	12.4			2.63			15
21	MOUNTING FLANGE	42.5			26.6			69.1

Table 5 Cycle Time collected for various components on DMG Beta Machine.

SI No.	Component Load Schedule	1st Operation (Minutes)	Idle (Minutes)	Remarks	2nd Operation (Minutes)	Idle (Minutes)	Remarks	Total Cycle time (minutes)
1	WORM GSD250 DIA 100 LENGTH 636 RH	14.2	5	Operator not present after M/Cing,Completing paper work,Tightening Insert	5.07			19.2
2	WORM GSD315 DIA 125 LENGTH 788 RH	11.2			12.2			23.4

3	WORM GS160 DIA 60 LH-1/00-1350	12.2			9			21.2
4	WORM GS200 DIA 75.6 RH-1/00-1350	10.3	4	Talking	11			21.3
5	WORM GS250 DIA 96 RH-1/00-1350	18.4	15	Waiting for components	9.1	2	Insert Tightening	27.5
6	WORM GS315 DIA 120 RH-1/00-1350	21.1			17.4			38.5
7	ADAPTOR SA50 DIA 140x33	6.5			10.3			16.8
8	MOTOR HOUSING A190 SQ 165 AI90	10.3						10.3
9	AI90 MOTOR HSG PDC	5.1	4	Talking	1.3			6.4
10	BEVEL WHEEL ABG30.1 Z=72 DIA 324x46	12.4			18.4			31.6
11	BEVEL WHEEL ABG35.2 Z=72 DIA 397x48	33.5			29.6			63.1
12	BEVEL WHEEL GK35.1(8:l)Z=72 DIA 397x147.4	26.3			47.6			74
13	SLEEVE ABG DIA 230x225	25.1			11.2			36.3
14	SLEEVE ABG25.1 DIA 200x211.5	22.6			11.6			34.2
15	ADAPTOR FLANGE GS400/SA DIA 415x132	14.5			8.4			23
16	MOTOR FLANGE MD112 SQ 200x99.5	14.2	2		14.6			29

2.3 Analysis phase

The measure phase transparently displayed that the performance level of the current process is unsatisfactory which need to be improved. The root cause that affects productivity should be identified and analyzed, so that process improvement can be done in respective areas. The cause and effect diagram in Fig. 1 was wielded to identify various factors.

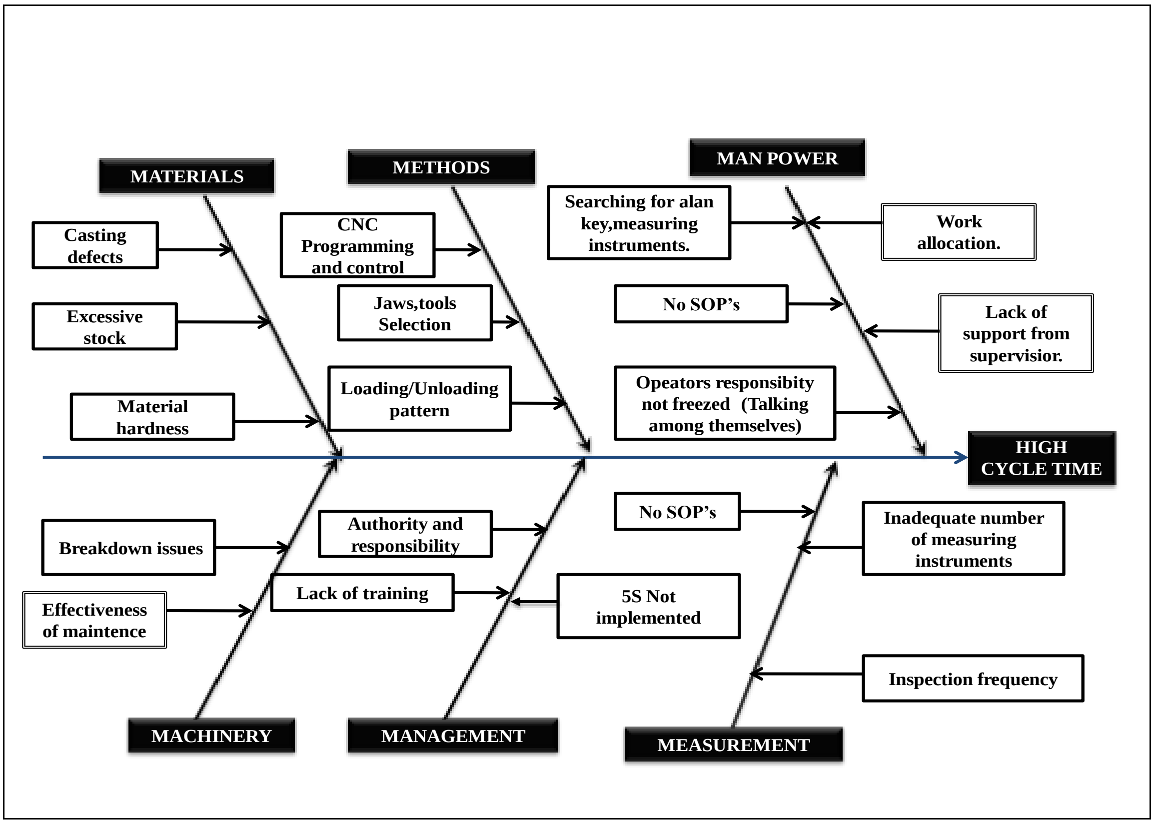
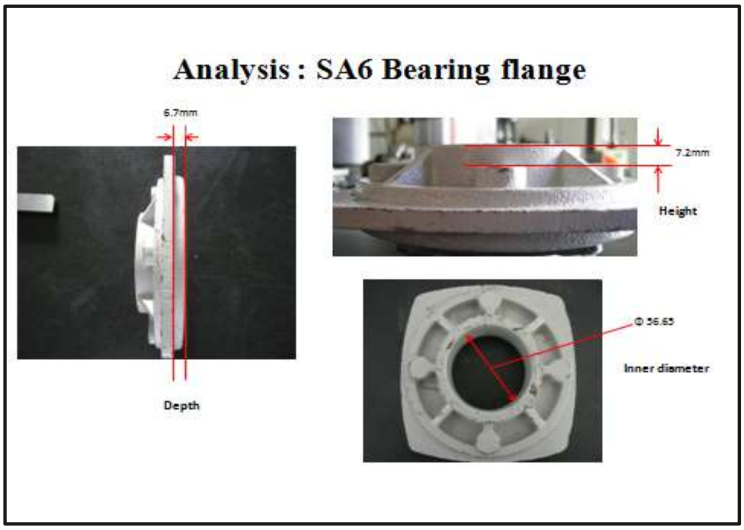


Figure1. Fish bone diagram for high cycle time

During analysis the following components were found with excessive stock materials which lead to high cycle time.

SA6 Bearing flange



The excess weight and material cost spent (per month) is shown below

Figure 2 SA6 Bearing flange

Table 6 Excess allowance table

Component	Specification	Dimension as per drawing	Dimension in present casting	Dimension to be provided as per EN ISO 8062/AG specification	Present excess machining allowance
SA6 Bearing flange	Depth	2	6.7	4	2.7
	Height	5	7.2	5.5	1.7
	Inner diameter	58	56.65	58	1.35

1. In case of depth, the allowance has to be changed to 4mm (i.e., 2mm+2mm allowance) instead of 6.7mm, reducing by 2.7mm.

Present weight in casting

$$= \left[\frac{[\pi(125^2 - 56.65^2)]}{4} \times 6.7 \times 1E - 9 \times 7800\right]$$

= **510g**

The weight required as per specification

$$= \left[\frac{[\pi(125^2 - 57^2)]}{4} \times 4 \times 1E - 9 \times 7800\right]$$

= **300g**

Thereby, weight reduction = 510-300 = **210g**

Cost reduction = 0.21x600x75 = **Rs. 9450/- per month**

2. In case of height, the allowance is changed to 5.5mm (i.e., 5mm+0.5mm allowance) instead of 7.2mm, reducing by 1.7mm.

Present weight in casting

$$= \left[\frac{[\pi(72^2 - 56.65^2)]}{4} \times 7.2 \times 1E - 9 \times 7800\right]$$

= **87g**

The weight required as per specification

$$= \left[\frac{[\pi(72^2 - 57^2)]}{4} \times 5.5 \times 1E - 9 \times 7800\right]$$

= **65g**

Thereby, weight reduction = 87-65 = **22g**

Cost reduction = 0.022x600x75 = **Rs. 1000/- per month**

3. In case of inner diameter, the allowance is changed to 58mm (i.e., with no allowance) instead of 56.65mm, reducing by 1.35mm.

Present weight in casting

$$= \left[\frac{[\pi(62^2 - 56.65^2)]}{4} \times 31.7 \times 1E - 9 \times 7800\right]$$

= **123g**

The weight required as per specification

$$= \left[\frac{[\pi(62^2 - 58^2)]}{4} \times 27.5 \times 1E - 9 \times 7800 \right]$$

$= \underline{\mathbf{81g}}$

Thereby, weight reduction = 123-81 = **42g**

Cost reduction = 0.042x600x75 = **Rs. 1890/- per month**

Similarly, few more components were found with excessive stock materials which led to high machining time.

2.4 Improve phase

According to cause and effect and histogram analysis, following solutions are proposed

Table 7 Possible solutions to causes leading to high cycle time

Critical causes	Solutions
Lack of training/Lack of Multi skill operator's.	Training provided to operators about 5S, and other basic tools.
Less experienced workers were finding it difficult to work on the machine.	SOP is implemented and it is displayed near the machine.
Searching Tools/inserts/jaws leading to non-added value activities.	Provided pre-kit tool tray.
Certain component drawings are not available at the machine.	Drawings are made available to the operator on his table.
Lack of support from supervisor	Informed about problem to the management.
Poor storage system	Enforce daily preventive maintenance, place tool holder and jaws near designated cell.
Inadequate number of instruments.	Informed about problem to the management.
Extra stock material on components	Examined the components and new improved drawings are prepared.

Tool Trolley: Another factor that came up during the analysis of the time study which contributed to the high non value added time was the time wasted looking for tools. By providing tool trolley time wasted looking for tools and accessories was eliminated.

Figure 3 Before: Tools not place accordingly

Figure 4 After: Tool trolley implemented

A time study was conducted to validate the results. The cycle time for individual operations were collected. The result of the time study validates a significant reduction in the cycle time of the components after the implementation of improvements.

After implementing the solutions new cycle times are as follows:

Table 8 Improved Cycle time for various components on DMG ECO 1 Machine.

SI No.	Component	Old Cycle time (Minutes)	New Cycle Time (Minutes)
1	ADAPTER FLANGE	41.5	40.3
2	BEARING FLANGE GK30.1 SQ 370x88	44.4	43.3
3	BEARING FLANGE GK35.1 SQ 450x105	28.5	28.4
4	MOUNTING FLANGE A200-F25 DIA 300x98	41	40.6
5	MOUNTING FLANGE GS160 F30 FG	33.2	33.1
6	MOUNTING FLANGE GS200 F35 FG	52.1	51.4
7	MOUNTING FLANGE SA100AB DIA 289x110	37.5	35.6
8	MOUNTING FLANGE SA50 AB	29.6	28.1
9	BEARING FLANGE SA100 SQ 230x50	20.1	19.1
10	MOUNTING FLANGE	69.1	68.1

Table 9 Improved Cycle time for various components on DMG Beta Machine.

SI. No.	Component Load Schedule	Old Cycle time (Minutes)	New Cycle time (Minutes)
1	WORM GSD250 DIA 100 LENGTH 636 RH	19.2	18.4
2	WORM GSD315 DIA 125 LENGTH 788 RH	23.4	22.9
3	WORM GS160 DIA 60 LH-1/00-1350	21.2	
4	WORM GS200 DIA 75.6 RH-1/00-1350	21.3	20.1
5	ADAPTOR SA50 DIA 140x33	16.6	15.1
6	AI90 MOTOR HSG PDC	6.4	5.9
7	BEVEL WHEEL ABG30.1 Z=72 DIA 324x46	31.6	30.4
8	SLEEVE ABG DIA 230x225	36.3	35.1
9	ADAPTOR FLANGE GS400/SA DIA 415x132	23	22.1
10	MOTOR FLANGE MD112 SQ 200x99.5	29	28.1

Table 10 Improved Cycle time for various components on DMG Eco 2

SI No.	Components	Old Cycle Time (Minutes)	New Old Cycle Time (Minutes)
1	BEARING FLANGE SA6	4.4	3.4
2	BEARING FLANGE SA12	4.4	3.5
3	WORM WHEEL SA25 Z=40 DIA 129.5	6.5	5.9
4	HOLLOW DRIVE SHAFT SA6 Z=29	5.4	4.6
5	CLUTCH RING SA25 Z=45	6.2	5.1
6	WORM WHEEL SA6 Z=42 DIA 78.8	5	4.1
7	WORM WHEEL SA100 Z=40 DIA 167	11.5	10.6
8	BEARING FLANGE SA25	11.5	10.5
9	MOTOR FLANGE EX-AI71 (SA6EX)	11.6	10.1
10	BEARING FLANGE	14.5	13.4

A time study was conducted to validate the results. The cycle time for individual operations were collected. The result of the time study validates a significant reduction in the cycle time of the components after the implementation of improvements.

2.4 Control phase: In control phase, the gains have been achieved by improving cycle time of machines.

Standard Operating Procedures: Standard Operating Procedures, also known as SOP's, are created to provide specific documentation for various processes, usually highly-technical processes. The purpose of a SOP is to carry out the operations correctly and always in the same manner.

The following SOP was made and implemented to overcome the problem of long inspection time, lack of preparation, Jaw preparation which was leading to long set up time.

The first half of the following SOP describes required/drawing dimensions of a particular component on a specific machine. These dimensions are then checked with the help of suitable gauges and measuring instruments and hence compared with the required values by the quality personnel.

The second half of the SOP describes all the details related to the tools to be used on that particular machine by the operator. The advantage of this being that the operator can be ready with all the tools required with suitable tool off-set, tool station details, machining operation of each tool, jaw holding pressure and type of jaw before commencing the setup of the next component.

Table 11 Standard Operating Procedure

First Piece inspection report							auma®
Machine Name:							
Article No :				Description of Operation:			
Drawing No:				Work Order No :			
Description:				Operator Name :			
Process Sheet : of				Shift: : 1st 2nd 3rd			
Sln	Specification	Act.Value/Observation	Remarks	Sln	Specification	Act.Value/Observation	Remarks
1				5			
2				6			
3				7			
4				8			

Supervisor Signature/QM Inspector Date:

Supervisor Signature/QM Inspector **MACHINE SHOP COPY** MT/FM.001.R01

Tool setting Details **Machine:** 0

Article No:			Material:		Jaws:		
Drawing No:				Chuck:	Chuck Pr:		
Description:							
Program No:			Std. Setup Time:	Clamping Dia:			
ToolWArt.No	Shkø	Tools Description:	InsrtWArt.no	Insert Dis. & Grade	Tool Stn X/ZOffset	Remarks	
1							
2							
3							
4							

Outcome

- Skilled and semiskilled operator can load the component.
- Rejection of the component is eliminated.
- Setting time for component setting will be reduced.
- Chance of errors and accidents get reduced.

3. RESULTS

This section discusses the result obtained after the implementation of the improvements.

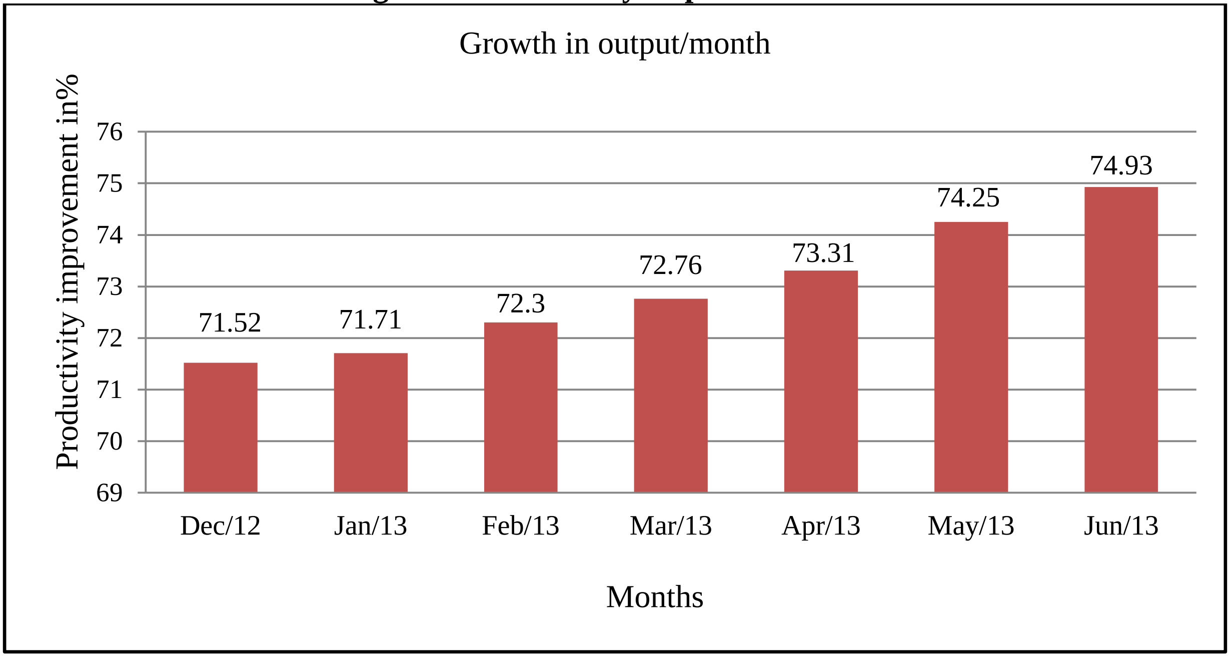
Productivity Improvement after DMAIC Application

Table 11 Productivity improvements/month

SI.No.	Month/Year	Phase	Components produced/month
1	Nov 12	Measure	2645
2	December 12	Analyse	2659
3	January 13	Analyse	2678

4	February 13	Improve	2713
5	March 13	Improve	2761
6	April 13	Improve	2825
7	May 13	Improve	2917
8	June 13	Control	3061

Figure 5 Productivity Improvement



- Before DMAIC application the average productivity per month was found to be 71%.
- After reducing cycle time of CNC machines by using DMAIC methodology, the productivity per month increased from 71% to 75%.

4 CONCLUSIONS

- Cycle time of the components has been reduced to about 20 %.
- Productivity of CNC machines has been improved from 71% to 75% per month.
- An annual savings of Rs 19 lakhs is achieved by the elimination of excess stock material on components.
- Improved Operator Morale (Less monitoring) and better working conditions achieved.

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