Overall Equipment Effectiveness improvement by reducing Non Value- adding Activities using Lean Tools

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ABSTRACT

The industrial development which has been connected to the financial condition over the world brings the manufacturing companies to enhance their production level so as to sustain in the competitive market. Changing an organization to raise its production level or profit is not a one day journey, but requires some time.

Overall Equipment Effectiveness (O.E.E) is a powerful and easy to use metric incorporating measure of the utilization, yield and efficiency of a given process, machine or manufacturing line. For even better improvement of the O.E.E (Overall Equipment Effectiveness) of machine, a tool like S.M.E.D (Single Minute Exchange of Dies) reveals to be really powerful when improving the productivity of the machine.

Lean manufacturing aspects such as 5 S's and Kaizen for example are tools that are also applied to improve the production rate, by reducing the non value adding activities including 3 M's (Muda, Muri, and Mura)

The research project developed inside this present report aims to investigate all the possibilities to improve the O.E.E of C.N.C Machines Equipment, facing theoretical aspects and reality issues.

Keyword: - *Overall Equipment Effectiveness (O.E.E), Single Minute Exchange of Die (S.M.E.D), Kaizen, Lean Engineering, Non Value-adding Activity (N.V.A).*

1. INTRODUCTION

O.E.E is an effective tool to analyze, and improve a production process. O.E.E tool gives the ability to measure the machine for productivity improvements.

For particular equipment (or machine):

O.E.E = Availability * Performance * Quality

Where,

1. Availability = Run time / Total time = [(Planned Production time – Downtime)/ Planned Production time] = Machine Operating time/Planned Production time

By Definition: Percentage of the actual amount of production time the machine is running to the production time the machine is available.

2. Performance (or Throughput rate) = Total Count / Target Counter = [(Ideal run rate* Total Components made)/Machine Operating time]

By Definition: Percentage of total parts produced on the machine to the production rate of machine.

3. Quality = Good Count / Total Count = [(Total Components made – Machine Rejects)/Total Components made]

By Definition: Percentage of good parts out of the total parts produced on the machine.

O.E.E is a really powerful concept to interpret how well a machine is utilized for a given process in order to optimize it latter.

A firm is said to have world class O.E.E levels if it has:-

1. Availability = 90%
2. Performance = 95%
3. Quality = 99%

And hence, **Word class O.E.E = 90 % * 95 % * 99% = 85%**

Note: - Sometimes individual Performance levels may go beyond 100%, if an operator executes a particular operation, better (say in less time) than its designed way.

2. LITERATURE SURVEY

Nakajima presented O.E.E in Total Productive Maintenance. Researchers have noted that this definition varies with different processes. A.J. de Ron and J.E. Roda modified O.E.E by introducing operational efficiency and rate efficiency in performance rate. Tom Pomorski defines O.E.E in terms consistent with SEMI E-10-96. O.E.E as one element of which measures the performance of equipment, but can O.E.E measures the performance of the entire manufacturing process. P.Muchiri and L.Pintelon evolve O.E.E as tool to track improvement and enlarge this tool with different terminologies. Such as at equipment level- production equipment effectiveness (PEE) and total equipment effectiveness performance (TEEP) at factory level, overall factory effectiveness (OFE) and overall plant effectiveness (OPE). It is observed that various parameters of O.E.E contribute to overall O.E.E in a different manner, has significant effect on improving the performance. **Meet Lalkiya and Deepak Kumar Kushwaha** did a research work to optimize and analyze Overall Equipment Effectiveness through T.P.M approach in a Cement Plant in which a regression analysis was done in an attempt to predict the O.E.E by using Design of Experiments (D.O.E). The study indicated that O.E.E will be significantly improved if focus is given on **performance rate improvement** (one of the metric of O.E.E calculation). To achieve O.E.E of 69.39%, optimized values are Availability 77%, Performance Rate 91%, and Quality Rate 99%. [1]

Harsha G. Hegde, N. S. Mahesh, Kishan Doss collectively did a research work on Overall Equipment Effectiveness improvement by T.P.M and 5S Techniques in a CNC Machine Shop and got result in the form of cost and efficiency improvement. The O.E.E was found to be 43% in the identified bottleneck machine. Further, a T.P.M team was formed to devise a systematic approach to improve the effectiveness. The T.P.M techniques such as Preventive Maintenance, Cleaning with Meaning, Pokayoke & Kaizen were effectively applied on the machine. The result obtained from the T.P.M approach showed that the O.E.E was improved from 43 % to 72 %. To sum up, total saving per annum due to increased effectiveness was around Rs 4,53,000/-.[2]

M. McLeod, T.J. Turner, U.S. Bititci, A. Reid, G. Crawford selected Overall Equipment Effectiveness (O.E.E) as an appropriate performance measure to identify losses in the current operations. A decoupling point was identified to separate lean and agile manufacturing systems and recommendations made to reduce losses whilst maintaining the responsiveness and delivery reliability demanded by the customer base comprising of large food retailers.

They concluded that using **DMAIC** (Define, Measure, Analyze, Improve, and Control) to introduce a performance measurement system to the shop floor of a small fast-moving food company has been an effective and beneficial tool to use. A '**Leagile**' supply chain strategy was identified as the basis for improving business performance of **Korway Foods** in the future. [3]

Pradeep Kumar, Raviraj Shetty under the guidance of **Lewlyn L.R. Rodrigues** did the empirical study at **Manipal Press** or the daily Udayavani which is the provider of the daily Kannada Newspaper for the people of the Udupi District, and revealed the varying trends in the Overall Equipment Effectiveness (O.E.E).Fluctuation of O.E.E is seen, O.E.E is Low in KBA C213 (printing machine) and O.E.E is high in New city line express (NCL), where downtime is more and performance also varies compared to availability and quality, which will affect O.E.E of the printing machines. The average values of O.E.E were found to lay between the ranges of 63% to 71% against world class standards of 85%. The results highlighted the major causes resulting in the downtime and decrease in the productivity. [4]

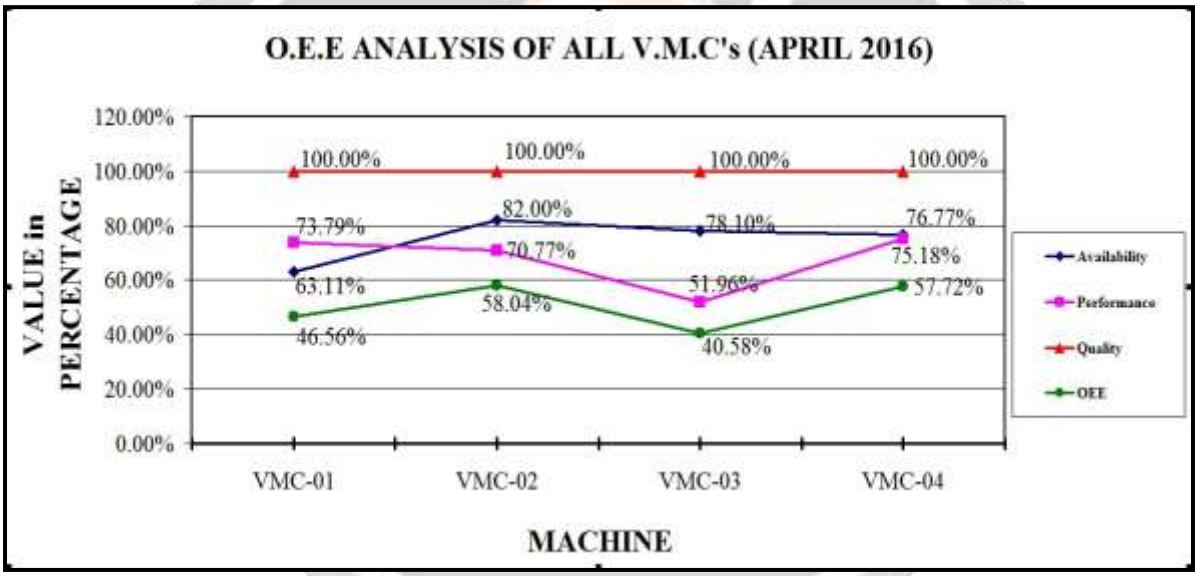
V. Manojkumar, Dr. R. Kesavan and S. Kalyanakumar collectively did a study intended to apply overall equipment effectiveness (O.E.E) as a performance measurement tool to measure the effectiveness and

performance of the **Automatic Fettling machines in a foundry plant**. The primary findings of the study were the possible factors that dominantly affect the equipment effectiveness in the machine. These findings were used to serve as a guideline to improve the O.E.E for the selected machines. In this project, the O.E.E level was analyzed and found out that Availability and Performance level of the machine is very low, which lower the O.E.E Levels. [5]

S Amith kumar, P.M. Nagaraj, Rao Srinivas and Vijaykumar from Department of Industrial Engineering and Management, Siddaganga Institute of Technology, Tumkuru, Karnataka did a study to improve O.E.E in the Piston machining line through the implementation of Single Minute Exchange of Die (S.M.E.D) and Design of Experiments (D.O.E). S.M.E.D is implemented on the bottleneck machine of the machining line and calculated the setup time before and after the S.M.E.D implementation. The variables affecting the rejections of the piston skirt diameter were analyzed and optimized in the Minitab17 software and increased the Quality factor of O.E.E. The optimized values From the DOE were suggested to the industry. [6]

3. PROBLEM DEFINITION

Historical organizational data showed the Overall Equipment Effectiveness (OEE) value was very low compared to the general manufacturing scenario for the bottleneck machines, which were figured out on the basis of Annual Operating Plan. Due to which the machines were not utilized effectively and hence production rate and volume was affected. Figure 2 shows the OEE value of Vertical Machining Centre (V.M.C) 1, 2, 3 and 4. These machines had lower OEE values compared to other machines. These machines were a part of cell in line production. They were hindering line efficiency.



Graph – 1: O.E.E of machines for the month of April'2016

The graph showed the OEE values of the machines found to be 51% efficiency which was far below world class performance of 85%. Similarly other Jan-March'16 data was computed, leading to near about same results.

4. PROJECT OBJECTIVE

The main objective of this research work is to improve the machine shop Overall Equipment Effectiveness by identifying wastes and providing solution to reduce or eliminate them.

1. To make constraint or "Bottleneck" equipment run more effectively.
2. Online study of production activities to identify different non value adding activities occurring while operation.
3. Identify the causes of wastes, thereby reducing those using Lean Tools.
4. And final goal is to bring out the best possible O.E.E levels, in the plant machine shop.

5. METHODOLOGY

Initial study includes, analyzing the existing layout, and bottleneck machine identification, as per the annual operating plan, then understanding the current component operation and figure out the problems faced, quite frequently, and finally study the operation of various components, and find out the losses which were otherwise going unnoticed as per the current company methodology, thereby checking the areas of improvement in the research domain.

To attain the above mentioned objective calculations regarding existing O.E.E values is to be done and identify the potential areas of improvement by plotting Month wise, Machine wise and Day wise O.E.E graphs, and then plotting the 'Pareto charts' and figure out 'Cause and effects' of the existing Non Value adding activities, Tabular formations and Pareto chart generation for the same.

From there on use the lean engineering tools to derive some results by calculations, using Lean engineering tools and suggest improvement by justifying it with support of the study.

Finally suggestions are given in the form of areas for cycle time reduction, and to minimize the external work load as much as possible, operating procedure changes such as fixture settings, tool path modifications, and layout modifications (if any) and at last synchronization of operations for uniform production.

And finally come up with conclusions/ results on the basis of implementation of suggestions.

6. MODEL CONSTRUCTION

The project focused on improving the O.E.E of the bottleneck machines as it was the major concern for lower productions, loss of time and money. After plotting a specialized sheet containing all the loss attributes which were to be recorded, it was given to all operators to calculate the availability losses which were otherwise going unnoticed.

From the sheets thus generated, all the losses were collectively studied and found out that a total of approx.139 Hr's were lost for all the 4 V.M.C's throughout the month of 25 shifts, as an availability loss (excluding performance losses).

Now, plotting the Pareto chart for the losses:

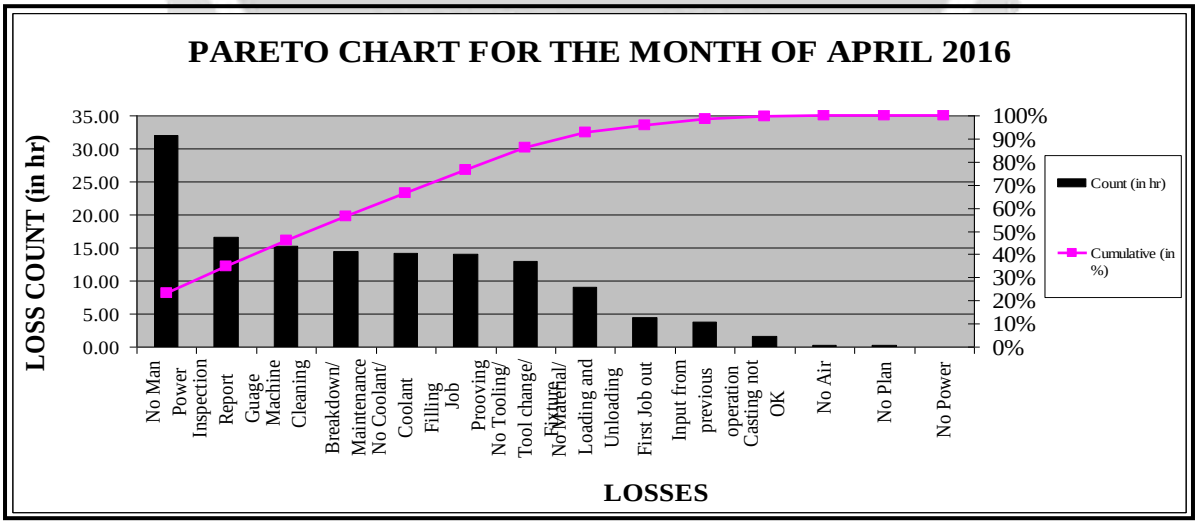


Chart - 1: Pareto Chart for all V.M.C's during April 2016

From the chart above it is clearly visible, No man power and Inspection report preparation, were the most contributing losses observed. Also on plotting the day wise O.E.E graphs it was found out that on an average there were at least 5-6 days/ month (excluding holidays), Absenteeism and No plan event occurred collectively for the whole day, solution to which is out of the research domain.

Although Machine cleaning, Breakdown maintenance, No coolant/coolant filling, Job proving or First job out losses were able to be reduced, which comprised of the further part of the research work.

7. REDUCING N.V.A

Corrective action was taken to improve the O.E.E one of which was:

7.1 Kaizen team was made including shop floor associates, and Kaizen work was done leading the team as when feasible, without hampering the production work.

The work was specifically done during "No plan period". Team members were selected, keeping in mind there experience in machine shop, because the time spent by an individual operating the machines is directly proportional to the problem known to them.

One of such kaizen sheet is mentioned in Fig. 1

KIRLOSKAR BROTHERS LIMITED		KAIZEN SHEET			KAIZEN No:	3
Location	Sanand, Gujarat	Zone Name	Machine Shop		Register Date	27-04-16
Workplace	All Machines	Sub-zone Name	All Cells		Completion Date	27-04-16
Problem Statement : Priming of pump required every time before filling coolant in tank. Also motor wire is too long and creates unsafe condition in gangway since power plugs are located at defined locations.		Sketch/Photo/Description **BEFORE** Improvement			Sketch/Photo/Description **AFTER**	
Kaizen Idea: Can pump be eleminated.						
Problem Analysis: (Why? Why?) Long wire creating unsafe condition. Power plugs on fixed locations. Priming required for pump before motor start.						
Counter Measure: Height of tank increased above coolant tanks of machines. Motor is removed and direct flow control valve is placed to on/off supply of coolant. Potential energy of coolant is used to flow itself into tank at lower height.		Problem related to:-		(✔)	KAIZEN TEAM- PACIFIC	
		MUDA	Over Production		Name/ Employee Number/ Photograph	
			Inventory/Stock		Kalpesh Hota	Rajendra
			Conveyance/Transportation	✔		
			Waiting	✔		
			Processing/ Operation	✔		
			Motion/ Man Movement	✔		
			Correction/Inferior Goods			
		MURI (Overburden)				
		MURA (Unbalance)				
Benefits/ Results:		Improvement Area :-				
First of all operator engagement in coolant filling procedure is almost nulified, and also coolant filling time got saved. No priming needs to be done now.		(P) Productivity		✔		
		(Q) Quality improvement				
		(C) Cost Reduction			Aditya Sinhal (Team Leader)	
		(D) Delivery				
		(S) Safety				
		(M) Morale		✔		

Fig. - 1: Kaizen 3 (Coolant filling procedure simplification)

This kaizen was in a need to be done as soon as possible, but a reliable and genuine method was not visible so as to perform the same. Hence finally after visualization and a bit of energy conservation methodology application, use of gravity was undertaken.

Similarly many other Kaizen work were done during the month of April and May'16 for waste reduction which were otherwise reducing O.E.E levels.

7.2 Single Minute Exchange of Die (S.M.E.D) was applied on Vertical Machining Center (V.M.C) 4 in which all the internal and external activities were studied through activity chart and finally concluded with a scope of internal activity time reduction.

V.M.C 4 used to operate to component Upper Bearing Housing (U.B.H) and Suction Housing (S.H.) 4" alternatively on both the pellets. There was a scope on tool path simplification for U.B.H, some of the example of such modification is mentioned below.

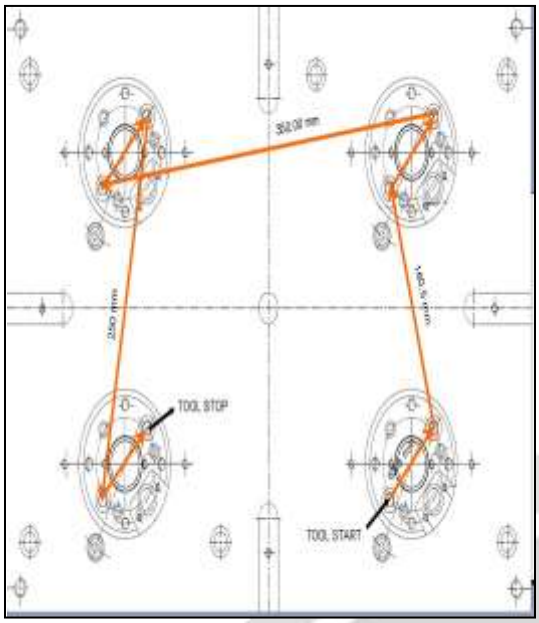


Fig. – 2: Existing Tool path

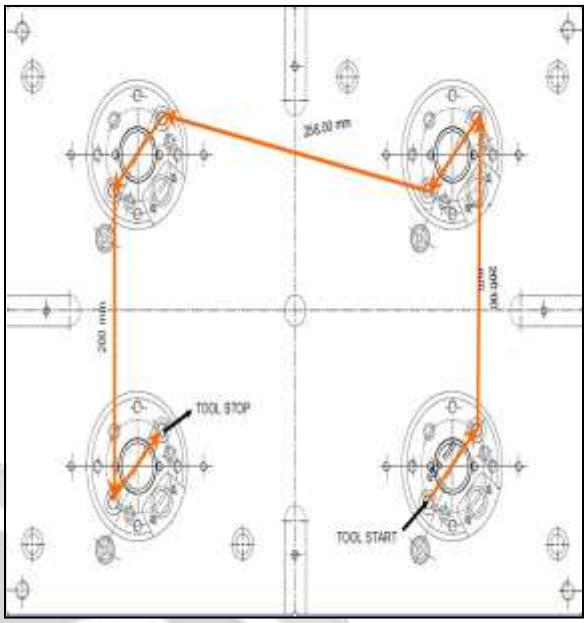


Fig. – 3: Modified Tool path

Similarly tool paths for a total of 6 other tools were suggested to be modified via programme change which resulted in following time saving:

CYCLE PATH IMPROVEMENT					
Tool No.	Distance travelled by tool during rapid			Machine Feed mm/min	Reduction in rapid travel time (in sec.)
	Before (mm)	After (mm)	Difference (mm)		
1	1022	920	102	35000	0.17
2	1750.2	1523.2	227	35000	0.39
3	1750.2	1523.2	227	35000	0.39
4	1127.7	979.7	148	35000	0.25
5	1127.7	979.7	148	35000	0.25
6	540	540	0	35000	0.00
7	540	540	0	35000	0.00
8	830.9	772	58.9	35000	0.10
9	830.9	772	58.9	35000	0.10
	TOTAL		**969.80**		**1.66**

Table – 1: Tool path improvement calculations

Hence it can be calculated that:-

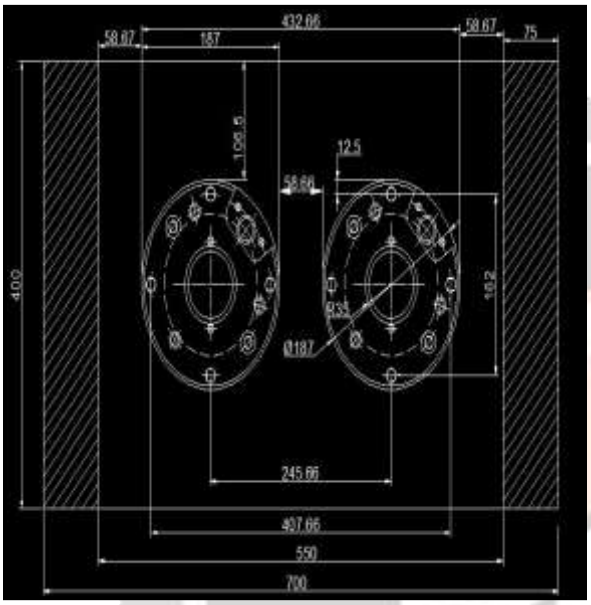
Total Production time available per day	460 Minutes = 27600 Sec.
Time after which every new cycle starts	8 Min 44 Sec. = 524Seconds
Number of cycles per day	=27600/524 = 52.67 ≈ 52 Cycles
Time saved per day	= 52 * 1.66 Sec ≈ 86 seconds

Table – 2: Saving in time after Tool path modification

Hence reduction in operator idle time is 02 seconds per cycle, which is one of the eight wastes (i.e., waiting time).To which single cycle for Suction Housing (Cycle time 75 sec.) can be made to run producing 4 extra components per shift, and hence 25*4 = 100 extra components can be made per month (considering 25 shifts per month), or 100*12 = 1200 per year.

7.3 After closely analyzing all the parameters for fixture designing, it was figured out that on V.M.C 1; more than 2 (i.e. 5) components can be placed at a time for 1 particular cycle, by modifying the fixture plate.

Now first of all existing fixture setting was plotted on AutoCAD software as follows



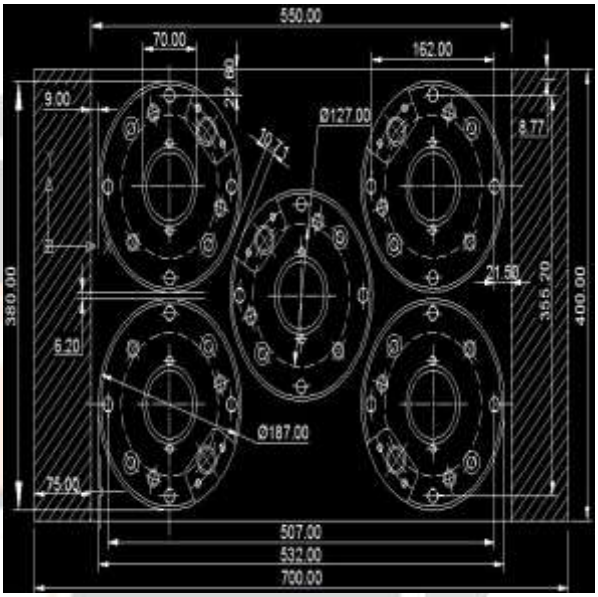


Fig. - 4: Existing Fixture arrangement

Fig. - 5: Modified Fixture arrangement

Now after comparing both the fixture placements, following comparison table was made:

Table - 3: Fixture modification comparison.

PARAMETER	CAPACITY	EXISTING UTILIZATION	MODIFIED UTILIZATION	CLEARANCE
X Direction Cutting Length	550 MM	[162*2 + 12.5*2 + 58.66] = 407.66 MM	507 MM	[550 - 507] = 43 MM
Y Direction Cutting Length	400 MM	162 MM	[162*2 + 12.5*2 + 6.2] = 355.20 MM	[400 - 355.20] = 44.8 MM
Z Direction Cutting Length	350 MM	250 MM	250 MM	[350 - 250] = 100 MM
Machine Bed Load	500 Kg	[8*2] = 16 Kg	[8*5] = 40 Kg	[500 – 40] = 460 Kg
Bed Dimension in X Direction	700 MM	[187*2 + 58.66] = 432.66 MM	532 MM	[700 - 532] = 168 MM
Bed Dimension in Y Direction	400 MM	187 MM	[187*2 + 6.2] = 380.20 MM	[400 – 380.20] = 19.8 MM

FIXTURE SETTING FROM 2 TO 5											
Component	Cycle time for 2 parts	Cycle time per part	No. of Tools (T)	Tool change time/tool (A)	Door open/close time (B)	Total Non Machining time for 2 parts (D) = (A * T)+B	Total Non Machining time for 1 parts (E) = (D)/2	Actual Machining time for 1 parts (F)	Cycle Time For 5 parts after modification = (F X 5)+(E)	Cycle time per part after modification	Saving/ part (in Sec.)
Upper Bearing Housing (6")	240	120	11	3	4	37	18.5	101.5	526	105	15

Table - 4: Time saving after Fixture modification calculation

Now, let us find out final saving in terms of extra components.

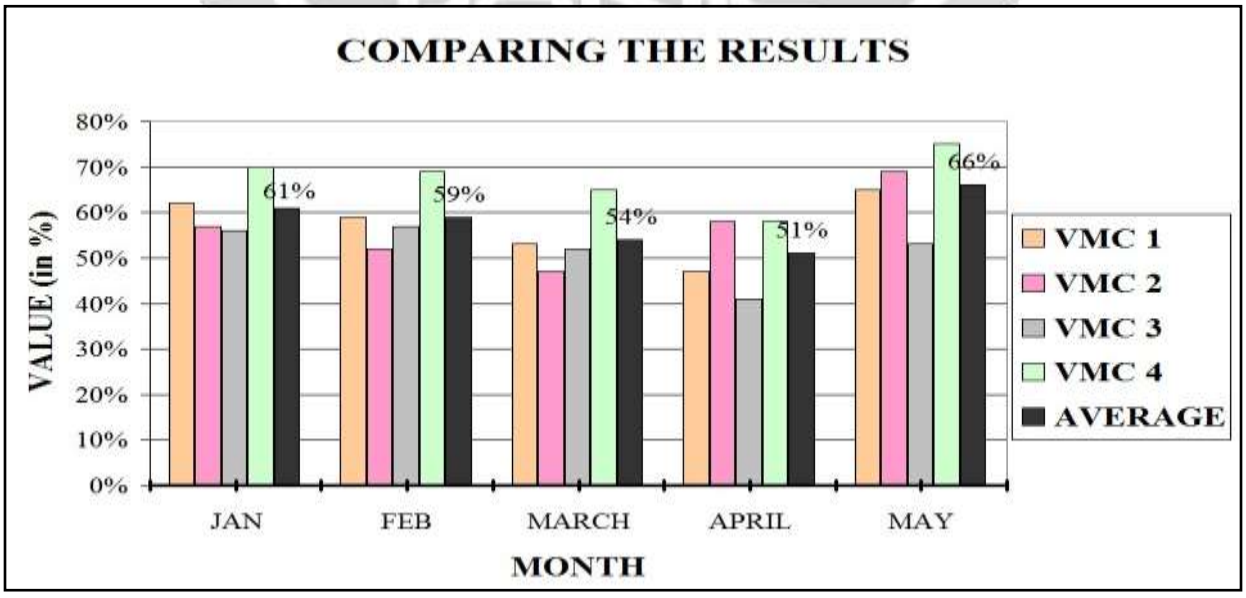
	Planned Production Time (in sec.)	Cycle Time/ Component (in sec.)	Total Components
Total components operated per day (Initial)	27600	120	230
Total components operated per day (After Modification)	27600	105	262.0
Extra Components per day			**32**

Table - 5: Extra component calculation

Though installing new fixture plate will definitely incur some cost of investment from the company, but the modification will prove a good source of saving in long term which is easily justified from the above calculations.

8. RESULTS AND CONCLUSION

After doing all the necessary modifications and improvements, the best way to analyze the results is to plot them together. After calculating O.E.E for all the V.M.C's in the month of May 2016, as done before for all the months, following results came :-



Graph - 2: Final O.E.E Comparison

Loss	May Count (in hr)	April Count (in hr)	Cumulative Count for May (in hr)	Cumulative for May (in %)
No Man Power	27.75	32.00	27.75	22%
Inspection Report Guage	15.17	16.58	42.92	35%
No Material/ Loading and Unloading	13.67	9.08	56.58	46%
No Tooling/ Tool change/ Fixture Setting	11.50	13.00	68.08	55%
Breakdown/ Maintenance	8.67	14.50	76.75	62%
Machine Cleaning	8.67	15.25	85.42	69%
Casting not OK	8.25	1.67	93.67	75%
No Coolant/ Coolant Filling	7.33	14.25	101.00	81%
Input from previous operation	7.08	3.83	108.08	87%
Job Prooving	5.92	14.00	114.00	92%
No Plan	4.58	0.25	118.58	95%
First Job out	3.75	4.42	122.33	98%
No Power	1.67	0.00	124.00	100%
No Air	0.25	0.85	124.25	100%

Table - 6: Final loss comparison.

From the above graph it is clearly visible that average O.E.E value has improved to all time best **66 %** for the month of May, as compared to **56 %** (Average O.E.E value for all the previous 4 months under consideration), and loss sum from 139.68 Hr to 124.25 Hr.

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