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Influence of Machining Attributes in Refining Overall Equipment Effectiveness

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Abstract*: Unremitting readiness of consistent erudite equipment with precision is need of the competitive market. The manufacturing data must be analyzed and acquired automatically due to increase in digitization of industry in present era. Industrial establishments continuously converging on refining the productivity output as this is direct linked with the equipment efficiency and the process. Lack of the productivity measurement attributes leads to industrial firms at strange line concert. The overall production performance affected by the production of nonconforming product. Overall equipment effectiveness, vigorous key performance indicator(KPI) of this incorporation. This paper investigates the finding of serious factors. The experiments were conducted with different machining attributes and suggestions were implemented in Micro Small and Medium Enterprises (MSME)automotive manufacturing unitto counter OEE.This learning reveals that the machining attributes of process is not known to the operators which results in low OEE of the machines. Result of the study presents that the implementation of suggestion has successfully increased the availability from 90.6% to 96.5 %, Performance from 76.90% to 81.30% and Quality from 90 % to 94.8 %. The OEE has been improved from 62.70 % to 74.30%.

***Keywords*: Automotive,KPI, Overall Equipment Effectiveness and Productivity.**

I. INTRODUCTION

The efficiency of industrial firms directly related with the measuring of productivity. Consequently, the overall performance of process capacity (5M) affected by the productivity. In manufacturing industry, specifically in automotive industry the estimation of effectiveness of machine is acting as KPI. These daysequipment breakdown, repair, maintenance and quality defects are the major problems that encountered on daily basis in most of the industrial firms.

The cost and customer satisfaction index are very much influenced by these problems.To counter these problems effectively Nakajima [1]wasfamiliarizedthe idea of Total Productive Maintenance (TPM), which includes six big lossessetup and adjustments,breakdowns,start-up rejects, small stops, production rejectsand the reduced speed for evaluating machine effectiveness. Overall Equipment Effectiveness (OEE) was alsohosted in addition to six losses. The actual and theoretical performance of machine measured with the parameters accompanying Overall Equipment Effectiveness [2]. OEE incorporates three vital attributes Availability(A), Performance rate(P), andQuality rate (Q) which evaluates the machine effectiveness concisely. P. Muchiri and L. Pintelon [3] shows how the OEE has grown with time differing on individual needs of industries.OEE forms a respect full place in evaluating the overall performance as shown by their case studies. XYZ automotive company categorized under MSME (Micro, Small and Medium Enterprises) in Ludhiana, Punjab has been chosen for the case study. This company is vendor to various automobile manufactures and make auto components as per their requirements. This MSME company encounters low efficiency with more losses. The use of OEE as a statistical tool reveals the significant increase in the effectiveness of machines as well as it provokes tangible benefits as much as concern with efficiency of company. OEE plays crucial role in increasing utilization of machine by eliminating the losses and promote the concept of autonomous maintenance among the work force for increasing the performance of company.

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II. LITERATURE REVIEW

The sound production facilities of manufacturing industries lead to stay in a competitive market, this to happen, only if industry strives to search unwanted production losses and immediately make efforts to get rid of them. Thiseffort facilitatesin meeting customer demands, cost cutting of product and staying viable in the market. Chakravarthy [4] introduced Modified OEE to be used in semiconductor industry in which two-dimensional methodology was proposed and is termed as Overall Equipment Productivity(OEP). Relkar and Nandurkar [5] suggested that OEE can be optimized and analyzed through Design of Experiments (DOE), which describes the studyof three parameter were analyzed and whichever is higher and confirms significant. Study reveals that the performance (P) is key parameter and put emphasis to improve the OEE. The semiconductor industries adhere to the SEMI E79 and E10procedures to counter OEE Wang T et al [6]. The equipment

reliability analyzed through the big prospective of OEE.

The studies have been conducted for finding the best and easy to fit various indicators with OEE.The literature incorporates various ways to increase the competence of plant through implementation of OEE. The literature review reveals the gap in finding the correlation between the machining attributes and effectiveness of equipment.

In this paper new parameter introduced to find out the relation between these attributes and effectiveness. The vividness of OEE can't be utilized perfectly as uncovered by the academicians because itvides range in the practical situation remains unpredictable according to the literature review.

III. METHODOLOGY

A. Overall Equipment Effectiveness

The OEE implementation varies as the variation with industrial application. As far as basics of OEE never changed with respect to industrial utilization, industries customized own OEE to fit their individual conditions.The endless function of production line is the main necessity of today manufacturing industries.The quality and the production rate of product is very much influenced by miniature failure or minimal stoppage at the production line. These fluctuating level of operation at the production line determined the productivity of manufacturing industries. For proper operation at the production line maintenance practices are continuously carried out in the system. Customer satisfaction and quality leads to success and inadequacy in planning, downtime losses go ahead with failure and consequently results in lower efficiency of plant. Thus, efficiency of the plant increases with decreases in down time loss and adequate planning.

The monitoring and improving the efficiency of manufacturing processes like machines, cells, production lines by OEE effectively because of its easiness (gathers convoluted production data into minimal plausible metrics that suitable for assessing genuine manufacturing efficacy), functional and powerful characteristics.It categorized into three categories: Availability, Performance and Quality which covers practically ordinary traces of productivity shortfalls[7].

Table I: Categories of OEE

Availability	belongs to the amount of actual time in which a work unit is in operation and keenly producing material, commencing with the set-up time of the post.
Performance	considers the unrecorded downtime, comparing the actual against the theoretical quantity of produced parts, which should have been produced during the ideal cycle time
Quality	measures losses from manufactured parts that do not meet quality requirements

Merging of these factors results in unique OEE number that delivers extensive measures of manufacturing effectiveness.

For streamlining the functions of manufacturing industries and other relevant tasks, TPM can be the game changer for gaining profits. Implementation of OEE help the organisation in improving equipment effectiveness and lowered equipment expenditure of ownership. The quantitative technique like OEE itself measures the performance of system simultaneously measures the traces of success to TPM enactment so that objective of TPM can be effectively traced. To become world class manufacturer is big dream for any industry and 85% OEE is considered as world class performance which is result of 90% availability, 95% performance and 99% quality.

Table II: OEE score

OEE Score	Level	Status
85%<OEE	Excellent	High Competitiveness
70% < OEE <85%	Good	World Class Manufacturing
60% < OEE <70%	Fairly	Intermediate level
OEE<60%	Bad	Low Competitiveness

B. OEE Parameters

OEE assigns numerical value to improvement opportunity.

"There is always adequate time to fix a problem but rarely enough time to prevent it"

1) Plant Operating Time (P_O):

It is the amount of time plant is open and available for equipment operation.In this study 8-hour (480 Min) shift considered for calculating the rest of the variables.

$$\text{Plant Operating Time}(P_O) : 8 \text{ Hour or } 480 \text{ Min}$$

2) Planned Production Time (P_T):

The plant cannot operate 24X7 days, it requires shut down (breaks, scheduledmaintenance, periods where there is nothing to produce)and duringshut down there is no purpose of running production.The planned production time is effective time which is available for production. In this study two short breaks of 10 minutes and one Meal break for 30 minutes included for calculation. Total 50 minutes planned shut down time (P_S)available for one shift.

$$\text{Planned Production Time}(P_T): \text{Plant Operating Time}(P_O) - \text{Planned Shut Down Time } (P_S)$$

3) Operative Time (O_T):

The plant is made to run smoothly and efficiently without any losses. Ideally plant is 100% efficient but when it goes under operation variety of inadequacies known as down time loss (Tooling Failures, Unplanned Maintenance, General Breakdowns, Equipment Failure,Setup/Changeover & Material Shortages) occur during the production which affect the performance and also reduces the time for production. Planned production time reduces after deducting down time lossesand referred as operative time.

$$\text{Operative Time } (O_T): \text{Plant Production Time}(P_T) - \text{Down Time Loss } (D_T)$$

4) Net Operating Time (N_T):

During plant operation due to speed loss (Hampered Product Flow, Component Jams,Misfeeds, SensorBlocked, Delivery Blocked&Cleaning/Checking) the productivity differs from actual target. When speed loss deducted from the operative time,represented as net operative time for production.

$$Net \text{ Operative Time } (N_T): \text{Operative Time}(O_T) - \text{Speed Loss Time } (S_T)$$

5) Fully Productive Time (F_T):

The production mostly affected by quality concern, as its direct link with customer satisfaction and numerous Quality Loss(Scrap, Rework, In-ProcessDamage,In-Process Expiration & Incorrect Assembly)factors put down the effective production time. Quality loss time deduce from net operative time represented as fully productive time for production.

$$Fully\ Productive\ \text{Time}\ (F_T)\text{: Net Operative Time}(N_T) - \text{Quality Loss Time}\ (Q_T)$$

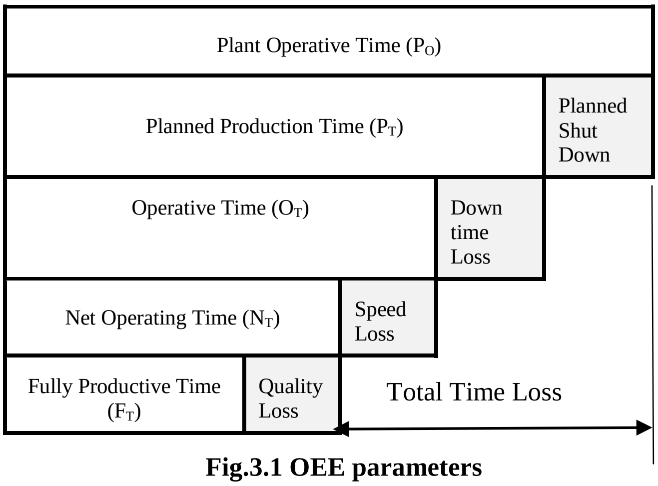

Fig.3.1 OEE parameters

C. OEE Calculation

OEE is computed by acquiring the product of three categories i.e. availability, performance and quality rate of product and calculated from the gathered data of plant.

"The correct approach and suitable improvement tools and technique makes it possible to amount precise OEE"

1) Availability(A):

The percentage of scheduled time that the plant is availablefor production. Availability purely result of measurement of uptime excluding the effects of other possible losses. It only includes the time for which the machine was assigned to run.100% availabilitymeans the process has been running without any noted stops and it is calculated as:

$$\text{Availability (A)} = \text{Operating Time}(O_T)/\text{Planned Production Time}(P_T)$$

2) Performance(P):

As described earlier that speed loss affects the performance of plant so it equates the notional machine rate with the actualmachine rate of machine it is calculated as:

$$\text{Performance(P)} = \text{Net Operating Time}(N_T)/\text{Operative Time}(O_T) = \frac{[Ideal\ Cycle\ Time(C_T) \times Total\ Pieces(N)]}{\text{Operative Time}(O_T)}$$

Ideal Cycle Time is the least cycle time for a given part that can be anticipated to achieve under optimal conditions.

3) Quality(Q):

The production of good units per total units represents the quality of the OEE measurement. This is also known as Yield.

$$\text{Quality(Q)} = \text{Good Units/Total Units} = \frac{Fully\ Productive\ Time\ (F_T)}{\text{Net Operative Time}(N_T)}$$

OEE is result of three metric and mathematically it is calculated by the following formula.

$$OEE = Availability\ (A) \times PerfprmenceRate\ (P) \times QualityRate\ (Q)$$

$$\text{OEE} = \frac{Fully\ Productive\ Time\ (F_T)}{\text{Planned Production Time}(P_T)}$$

After substitute all the relation for availability, performance and quality then OEE reduced to its easiest term and result is:

$$\text{OEE} = \frac{Good\ Units\ \times Ideal\ Cycle\ Time\ (C_T)}{\text{Planned Production Time}(P_T)}$$

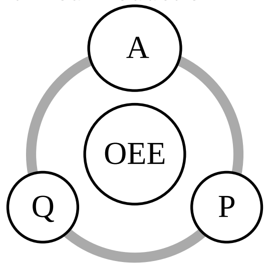

Fig.3.2 OEE terminology

D. Losses in OEE

The three losses viz down time loss, speed loss and quality loss result in lowering the overall OEE of plant. These losses must be address in proper manner so that their affect can be either minimized or neutralized. OEE track these losses by structured framework and underlying issues with their root cause.

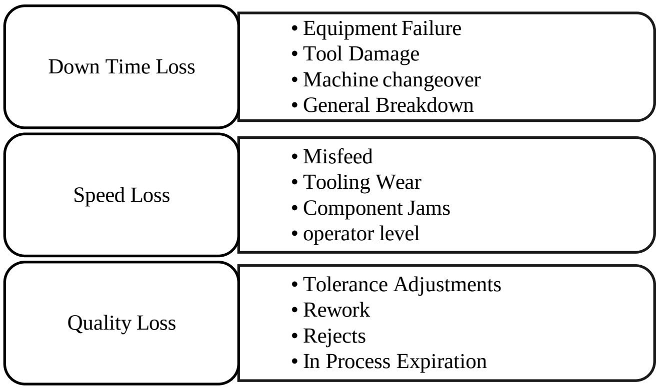

Fig. 3.3 Losses associated with OEE

Fig 3.3 shows the various losses and their examples of loss category summarized. The down time loss, speed loss and quality results from any equipment failure, tool damage, machine changeover, misfeed, tooling wear, rework etc. rises due to poor maintenance and using the wrong machining attributes (speed, feed and depth of cut) over machine. The machining attributes plays a vital role in maintain the health of machines as well reducing the losses occurred during the operation. Using right machining attributes over machine also minimize the risk of unplannedbreakdown, which is the main culprit of decreasing the OEE of any plant. OEE is directly proportional with time available for production and our main concern to make the plant more and more available for the production by making efforts in reducing the time loss. Right from the plant production time to fully productive time as the production starts in each step's losses occur and force to reduce the fully productive time. The mathematical relation shows the importance of time in calculating OEE.

E. Existing OEE

1) Production Data

The present production data of the plant for single shift is summarized as follows. The data pertains all the information regarding calculating present OEE of the automotive manufacturing plant.

Table: III Production Data

Shift Length	**8 Hrs. = 480 minutes**
Short Breaks	2@ 10 min.= 20 minutes
Meal Break	1@ 30 min.= 30 minutes
Down Time	40 minutes
Ideal Cycle Time	1 minute per piece
Total Units	300
Rejected Units	30

Support variables for calculating OEE using the above production data:

Table: IVSupporting Data

Plant Operative Time (P_O)	**480 minutes**
Planned Shutdown Time (P_S)	50 minutes
Planned Production Time (P_T)	480 – 50 = 430 minutes
Down Time (D_T)	40 minutes
Operative Time (O_T)	430-40 = 390
Ideal Cycle Time (C_T)	1 minute per piece
Total Units (N)	300
Good Units (G)	300- 30 = 270

OEE factors from the supporting data calculated and tabulated.

Table: VOEE Factors

Availability (A)	O_T/P_T	**90.6%**
Performance (P)	$(C_T \times N)/O_T$	76.9%
Quality (Q)	G/N	90 %
OEE	$A \times P \times Q$	62.70 %

The existing plant shows 62.70% OEE, it reveals sign of expansion for shifting OEE from intermediate level to World class Manufacturing as shown in fig 3.4. The above calculation is entirely based for single component manufactured in job floor.

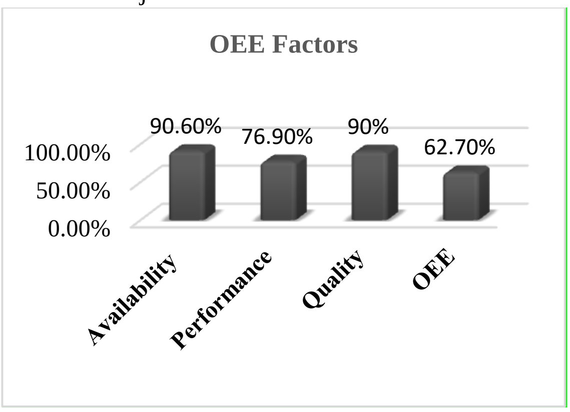

Fig 3.4 OEE calculation and comparison

F. Practices to Improve OEE

To categorize and assess losses of this process were other objective of the research. The OEE very much affect by these losses like downtimelosses, speed losses& quality losses. The events which are discussed under the category of losses must ne minimized to achieve world class OEE. The main happenings which are responsible forlosses in manufacturing plant were equipment failure, operator level, tool damage, misfeed, tool wear, rework and scrap etc. These nonproductive happenings which generally affects the performance of plant must be diminished or excluded from the system. The suggestions are advised and implemented in the plant and improved OEE calculated. These suggestions as shown in fig 3.5 were commonly used practices which shows big influence on the performance of plant as well as helps to increase the OEE.

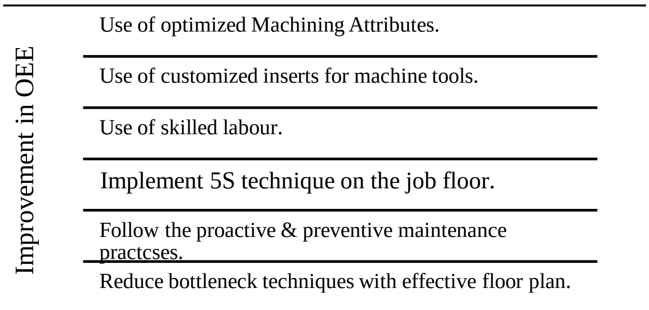

Fig 3.5 Suggestion for OEE improvements on job floor

IV. RESULTS AND DISCUSSION

The three mechanical machining attributes in metal removal process are feed, depth of cut and cutting speed. These parameters typically defined by required production rate, quality consideration as well as maximum power available in the machine tools. These attributes play a vital role in maintain the sound and healthy environment in and around job floor. As in previous section various losses discussed, which affects the efficiency and OEE of the plant. These losses must be addressed properly to know the affect caused by them on the OEE. The fig 4.1 shows that most of the losses directly or indirectly connected with the machining attributes.

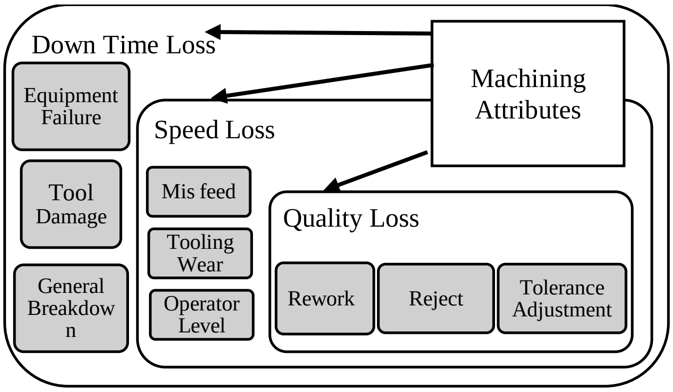

Fig 4.1 Losses associated with machining attributes

The events under different losses depict that if the machining attributes selected properly then these losses can be minimized or eliminated from the job floor. The lot of experiments conducted by the researcher on investigation of finding the effects of machining attributes on tool life, surface roughness, cutting forces and power requirements.

1) Effect of Speed, feed and depth of cut on OEE:

The short cutting time, long tool life and high cutting accuracy are the standard conditions for machine and productivity. The right and efficient selection of cutting condition and tool must be based on work material, hardness, shape and machine capacity. Cuttingspeed for lathe work can be recognized as the rate of point on the work circumference travels past the cutting tool. It is always conveyed in meters per minute (m/min) or in feet per minute (ft/min.). The cutting speed must be precisely selected based on the material to be cut on job floor because industry demands that machining operations be completed as swiftly as feasible.Cutting speed determines the effectiveness of process, too high-speed result in rapidly breakage of tool edge, resulting in time lost due to recondition the tool.

Too slow cutting speed result in low production rates which effects the machining operation as well as performance of plant. Based on the data available in the handbook and machining catalogue available by cutting tool manufacturer, appropriate cutting speed was chosen for the material machined on job floor as shown in fig 4.2

Cutting Tool	*Mild Steel*	*Carbon Steel Annealed*	*Aluminum*	*Soft Brass*	*Cast Iron*	*Annealed Stainless*
HSS	100	80	250 to 350	175	100	80 to 100
Carbide	300	200	750 to 1000	500	250	200 to 250

Fig 4.2 Cutting speed for different material

Feed is the rate at which the tool is moved into part or part into tool. Feed also influences the performance of machine. Too much high feed rate result in increasing the machine load as well as power requirement also increases. It is influencing the surface finish and tool life and surface finish of the workpiece.

The rigidity, power and tool rigidity determine the depth of cut of the required stock removal.Too much high depth of cut result in rapid tool wear and poor surface finish. This results in heavy machine load also which affects the bearing capacity of machine. Too much low depth of cut results in increasing the number of passes for cutting material, machine time lost consequently decrease the performance of plant.

The detailed affects of machining attributes on the output responses tool life, surface finish, dimensional accuracy, power requirement, machine loading and cutting forces tabulated in table IX.

2) Use of customized cutting tool:

The use of customized tool affects the performance on system availability and counter the losses effectively. Generally manufacturing plant negotiates performance in respect of cost. The use of single piece cutting tool considerable reduces the direct cost, but it contains hidden obstacles like reconditioning, breakage of tool, poor acceptability of machining attributes. These effects cause more loss of availability, performance and quality loss. Ultimately loss to OEE. Inserts made of different material as per the requirement of job specification suggested and used positively by the shop floor personnel as shown in fig 4.3. The effects were visualized and accepted by the plant.

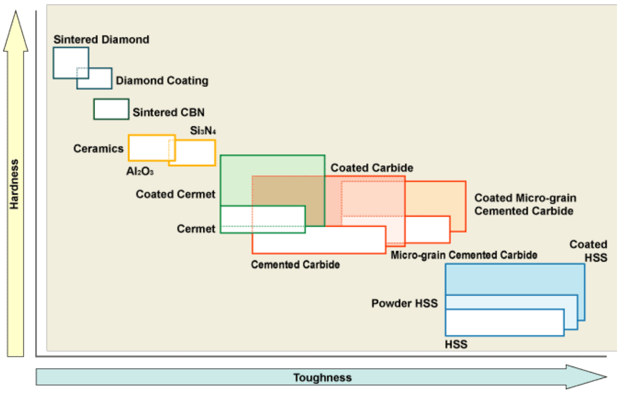

Fig 4.3 Tool material selection chart

(courtesy: http://www.mitsubishicarbide.net)

3) Skilled labour, 5'S and Maintenance:

Working force influenced more on the environment because if labor is well skilled then half of the hurdles automatically diminished from the job floor. Skilled labor very well knows about the effect of process parameter during operations. Unskilled labor in the plant undergo specialized training for improving their skills. The effect of these small changes clearly envisaged and observed effectively.

The 5s technique is not just learn the only 5 type of words starting with "S", but these five words are very much effective to customize the job floor as per the requirement. The time taken for changeover, setup on machine very much influenced by arranging the premises orderly. Small changes result big in improvement of shop floor. The 5s implemented on the specific job floor for single shift the result obtained was remarkable for improving OEE.

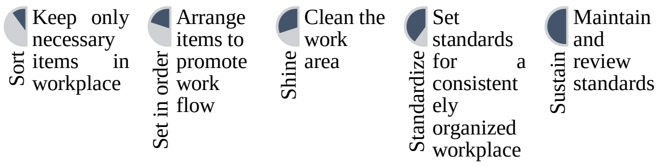

Fig 4.4 5'S terminology

The machine tool is very important and behave as heart for every plant. Heart must be sound and effective for better results. In the plant more focused on breakdown maintenance which seriously affects the performance and lower down the OEE. The proactive and preventive maintenance concept was initiated. Initially plant have 50 minutes planned shut down as tabulated in table III. These 50 minutes utilized for maintaining the machines as per the framed preventive maintenance schedule. The maintenance department was asked to depute specific worker during planned shut downtime for fixing small things. This concept was properly addressed among the job floor worker and implemented properly. This procedure not only result in increased plant performance but also built the security among the operator operating the machine. Operator attitude shifted from 'I operate You maintain' to 'I operate We maintain'. This approach shows very much positive result on job floor.

A. Improved OEE Calculation

The suggestion was successfully executed on the job floor and thoroughly visualized. The results speak the remarkable improvement in availability, performance and quality loss, which further increased OEE of the job floor. The improved data was captured and used to calculate the OEE.

Table: VI Production Data

Descriptions	Past Data	Present Data
Shift Length	8 Hrs. = 480 minutes	8 Hrs. = 480 minutes
Short Breaks	2@ 10 min.= 20 minutes	2@10min.= 20 min.
Meal Break	1@ 30 min.= 30 minutes	1@ 30min.= 30 min.
Down Time	40 minutes	15 minutes
Ideal Cycle Time	1 minute per piece	0.75minute per piece
Total Units	300	340
Rejected Units	30	18

The shift length, short breaks, meal break remains same and ideal cycle time remain same.Down time decreased from 40 to 15 minutes, total units produced in single shift increased by 30 units and rejection decreased by 12 units. the data revealed that decrease in down time, increase in units and rejection decreased had a great impact on the overall equipment effectiveness.

The supporting data calculated from these observations as tabulated in table VII.

Table: VIISupporting Data

Description	Past	Present
Plant Operative Time (P_O)	480 minutes	480 minutes
Planned Shutdown Time (P_S)	50 minutes	50 minutes
Planned Production Time (P_T)	480 – 50 = 430 minutes	480 – 50 = 430 minutes
Down Time (D_T)	40 minutes	15 minutes
Operative Time (O_T)	430-40 = 390	430-15 =415
Ideal Cycle Time (C_T)	1 minute per piece	1minute per piece
Total Units (N)	300	350
Good Units (G)	300- 30 = 270	350-18 = 332

The supporting data shows considerably improvement in the OEE parameters and had remarkable increment in the numeric value of OEE.

Table: VIIIOEE Factors

Metrics	Formula	Past	Present
Availability (A)	O_T/P_T	90.6%	96.5 %
Performance (P)	$(C_T \times N)/O_T$	76.9%	81.3%
Quality (Q)	G/N	90 %	94.8%
OEE	$A \times P \times Q$	62.70 %	74.3%

The results show that considerably improvement had been placed on the job floor w.r.t OEE.

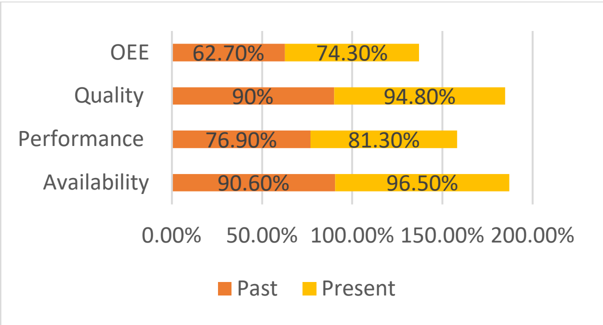

Fig 4.5 Comparison of OEE

V. CONCLUSIONS

OEE works best when it became a part of overall organization and Any policy deployment should cascaderelevant elements of OEE data down to individual department managers and staff. The OEE improvement result in the involvement of whole organization. This is not responsibility of production and maintenance personnel to take care of their part only. Otherwise OEE is of no importance, thusit is necessary to ensure that itsother departments are also equally involved.OEE is a measure of overall efficacy of an organization. The bottom line very much influenced by OEE. A greater return on investment is expected by improving OEE. It is also avaluable tool of comparison within and around plant.

This paper investigates the structured framework with real example in automotive manufacturing plant. This framework isbeneficial to the engineer especially the beginner to start measure their machine performance and laterimprove the performance of the machine.

1. The effect of machining attributes were analyzed on Overall Equipment Effectiveness.
2. The use of optimized machining attributes results in increased value of availability, performance and quality factors in the plant.
3. The overall equipment effectiveness considerably increased from 62.70 % to 74.3 %.
4. The attitude of workers shifted from “You” to “I” with regards to maintenance and other job floor operations.

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Table IX: Effect of Machining attributes on response parameters.

Machining Attributes	Value	Tool Life	Surface Finish	Dimensional Accuracy	Power Requirement	Machine loading	Cutting Forces
Cutting Speed	Low	↑	↑	↑	↑	↑	↑
	High	↓	↓	↓	↓	↓	↓
Feed	Low	↓	↓	↓	↓	↓	↓
	High	↑	↑	↑	↑	↑	↑
Depth of Cut	Low	↑	↑	↑	↓	↓	↓
	High	↓	↓	↓	↑	↑	↑

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