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A Review on Improvement in Overall Equipment Effectiveness

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Abstract*— Global performance evaluation is the most important in the field of continuous improving of the production process. Overall Equipment Effectiveness is one of the performance evaluation methods that are most common and popular in the production industries. Overall Equipment Effectiveness (OEE) plays a vital role where performance and quality of the product are of importance to the organization. The OEE is intended at minimizing the breakdowns, increasing performance and quality rate and thus improving the effectiveness of the machine/system. The availability rate of the machine, performance rate of the machine and quality rate of the products are considered as main parameters for maximizing the Overall Equipment Effectiveness (OEE) of a manufacturing system. It is found that poor performance rate contributes more than availability rate and quality rate. The objective of this work is to enhance the overall equipment effectiveness (OEE) in a manufacturing company.

Keywords*— Overall Equipment Effectiveness, Availability, Performance, Quality Rate

I. INTRODUCTION

Overall Equipment Effectiveness (OEE) is a way to monitor and improve the efficiency of manufacturing process. Developed in the mid 1990's, OEE has become an accepted management tool to measure and evaluate plant floor productivity. OEE is broken down into three measuring metrics of Availability, Performance, and Quality. These metrics help gauge plant's efficiency and effectiveness and categorize these key productivity losses that occur within the manufacturing process [9].

The Downtime losses incudes setup time and adjustment time is reduce using the work study. Work study is the systematic examination of the methods of carrying out activities so as to improve the effective use of resources and to set-up standards of performance for the activities being carried out. It is one of the most powerful tools that management can use to improve productivity [3]. There are a number work study techniques such as ergonomics, operations research, work study and time-and motion study to minimise setup and adjustment time to improve Overall Equipment Effectiveness.

Maintenance Management is an orderly and systematic approach to planning, organizing, monitoring and evaluating maintenance activities and their costs. A good maintenance management system coupled with knowledgeable and capable maintenance staff can prevent health and safety problems and environmental damage; yield longer asset life with fewer breakdowns; and result in lower operating costs and a higher quality of life [3].

The good performance indices of each work study technique should yield improved productivity, improved quality, improved efficiency, reduced downtime, improved employee Morale, reduced turnover and absenteeism.

II. LITERATURE REVIEW

The Overall Equipment Effectiveness is improving using various methodologies like Total Productive maintenance, Work study. Total Productive Maintenance is using Eight Pillars to improve OEE. The Eight Pillar is Autonomous Maintenance, Focused Improvement, Planned Maintenance, Quality Maintenance, Training, Office TPM, Safety, Health and Environment, Initial Flow Control. The Work Study improves setup time and adjustment time. The term 'work study' includes method study and work measurement. Method study being the systematic recording and critical examination of ways of doing things in order to make improvements whereas work measurement involves application of techniques designed to establish the time for a qualified worker to carry out a task at a defined rate of working[3].

A. Basic Procedure of method study

There are eight steps involved in performing a complete method study:

1) Select the job or process to be studied.

2) Record or collect all relevant data about the job or process, using the most suitable data collection techniques so that the data will be in the most convenient form to be analysed.
3) Examine the recorded facts critically and challenge everything that is done, considering in turn, the purpose of the activity; the place where it is performed; the sequence in which it is done; the person who is doing it; the means by which it is done.
4) Develop the most economic method, taking into account all the circumstances and drawing as appropriate on various production management techniques as well as on the contributions of managers, supervisors, workers and other specialists with whom new approaches should be explored and discussed.
5) Evaluate the results attained by improved method compared with the quantity of work involved and calculate a standard time for it.
6) Define new method and related time and present it to all those concerned, either verbally or in writing, using demonstrations.
7) Install the new method, training those involved, as an agreed practice with the allotted time of operation.
8) Maintain the new standard practice by monitoring the results and comparing them with the original targets [4].

The Eight steps should be able to improved productivity, improved quality, improved efficiency, reduced downtime, improved employee morale, reduced turnover and absenteeism time.
Improved maintenance management systems will help to reduce downtimes losses which lead to improve Overall Equipment Effectiveness.
There are a number work study techniques such as ergonomics, operations research, work study and time-and motion study. All of them produce the same output if properly implemented – improved productivity [3].

TABLE I
RELATIONSHIP BETWEEN MAINTENANCE AND ERGONOMICS [3]

Maintenance Management principle	Benefits of ergonomics and Maintenance management (intersection)	Ergonomics principle
Scheduled planned maintenance actions	Increased productivity	Promotion of effective maintenance work processes
Enhancing equipment reliability and improving on plant availability by way of inspecting, testing, reconditioning a system and replacing worn components	Increased efficiency	Design of effective maintenance work processes
Inspecting, testing and reconditioning a system at regular intervals. Inspections, test results and a reconditioned system will help in producing quality product.	Improved quality	Providing on going feedback and follow-up. Even with the best up-front planning there will be unintended results or consequences, something will vary from the plan hence deviations from the quality specifications. Providing feedback as part of follow-up process is critical to maintain quality within specified range.
Scheduled equipment restoration tasks and scheduled discard tasks help reduce stoppage time	Reduced downtime	Providing competency based training and design of effective maintenance processes help to reduce stoppages
Preserving and enhancing Equipment reliability by replacing worn components before they actually fail. Employees are motivated if the plant is running smoothly and reliably	Improved employee morale	Provision of competency based training and promoting health and wellness. A trained and healthy employee is well motivated to execute their duties.

Enhancement of equipment reliability and plant availability by way of equipment checks, oil changes, lubrication, painting, cleaning and adjusting, partial or complete overhauls at specified periods to reduce stoppages. Employees are motivated when the plant is running and Good quality product is coming out.	Reduced turnover and absenteeism	Effective work processes, provision of competency based training and promotion of health and wellness helps to keep employees in their work places. Employees feel motivated to work in well-coordinated and effective maintenance work processes design

III. OVERALL EQUIPMENT EFFECTIVENESS

Overall Equipment Effectiveness (OEE) is a way to monitor and improve the efficiency in manufacturing process. OEE has become an accepted management tool to measure and evaluate plant floor productivity. OEE is broken down into three measuring metrics of Availability, Performance, and Quality. These metrics help gauge to the plant's efficiency and effectiveness and categorize these key productivity losses that occur within the manufacturing process [9]. OEE highlights the actual "Hidden capacity" in an organization. OEE is *not* an exclusive measure of how well the maintenance department works. The design and installation of equipment as well as how it is operated and maintained affect the OEE. It measures both efficiency (doing things right) and effectiveness (doing the right things) with the equipment [17]. OEE is calculated by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products. Thus OEE is a function of the three factors mentioned below.

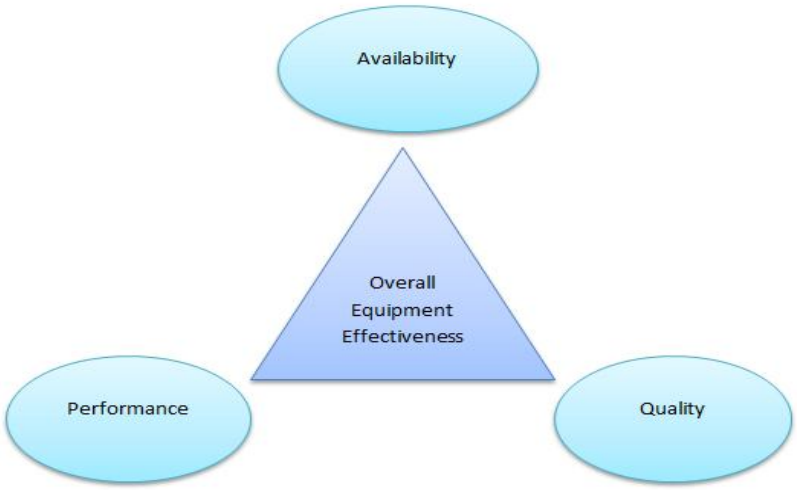

Fig. 1 Components of OEE

A. *Availability*

This can be defined as uptime, i.e. when the equipment is available to operate.

B. *Performance*

This is the speed at which the manufacturing unit operates as a % term of the capacity of the unit.

C. *Quality*

This is often referred to as being FPY, which is the First Pass Yield and is the number of good i.e. perfect items that are produced with no defects.

D. *OEE %* = Availability X Performance X Quality %

IV. SIX BIG LOSSES

The losses are divided into six major categories, which affect the overall performance of the equipment.

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TABLE 2
SIX BIG LOSSES

Six Big loss Category	OEE Loss Category	Event Examples
Breakdowns	Down Time Loss	• Tooling Failures • Unplanned Maintenance • General Breakdowns • Equipment Failure
Setup and Adjustments	Down Time Loss	• Setup/ Changeover • Material Shortages • Operator Shortages • Major Adjustments • Warm-Up Time
Small Stops	Speed Loss	• Obstructed Product Flow • Component Jams • Miss-feeds • Sensor Blocked • Delivery Blocked • Cleaning/Checking
Reduced Speed	Speed Loss	• Rough Running • Under Design Capacity • Equipment Wear • Operator Inefficiency
Start-up Rejects	Quality Loss	• Scrap • Rework • In-Process Damage • In-Process Expiration • In-correct Assembly
Production Rejects	Quality Loss	• Scrap • Rework • In-Process Damage • In-Process Expiration • In-correct Assembly

A. The first two losses are known as down time loss and are used to calculate availability of a machine.
B. The third and fourth are speed losses that determine the performance efficiency.
C. The final two losses are considered to be losses due to defects in the products.
D. OEE is measured in terms of these six losses, which are function of availability, performance rate and quality rate of the machine, production line or factory.

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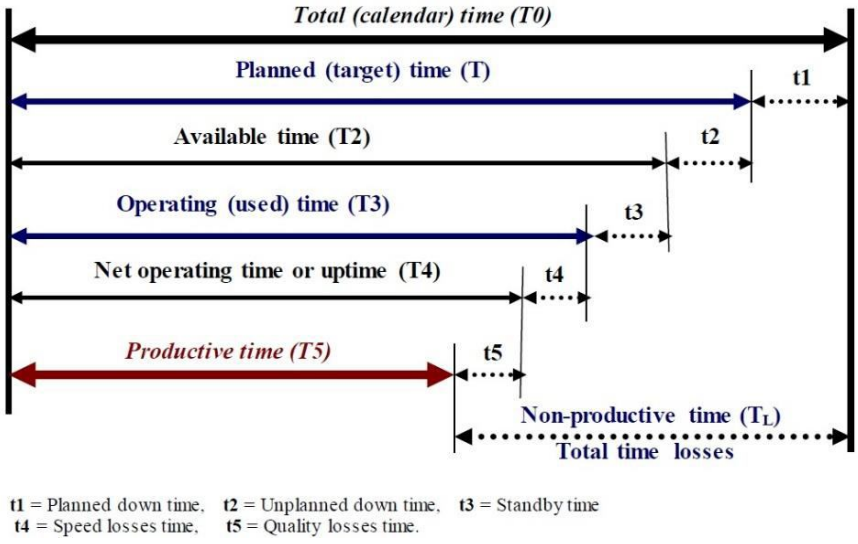

Fig. 2 Productive and Non Productive Time

A - Availability of the machine. Availability is proportion of time machine is actually available out of time it should be available.
Availability = Production Time ÷ Planned Production Time
Production Time = Planned Production Time – Downtime
Gross available hours for production include 365 days per year, 24 hours per day, and 7 days per week. However this is an ideal condition. Planned downtime includes vacation, holidays, and not enough loads. Availability losses include equipment failures and changeovers indicating situations when the line is not running although it is expected to run.
PE - Performance Efficiency. The second category of OEE is performance. The formula can be expressed in this way:
Performance = (Ideal Cycle Time × Number of products processed) ÷ Production Time
Q - Refers to quality rate. Which is percentage of good parts out of total produced. Sometimes called "yield". Quality losses refer to the situation when the line is producing, but there are quality losses due to in-progress production and warm up rejects. We can express a formula for quality like this:
Quality (Yield) = Good Products Processed (Pieces) ÷ Number of products processed
Good Pieces =Number of products processed - Number of products rejected

V. SAMPLE CALCULATION OF OEE

A simple example on how OEE is calculated is shown below.

Shift Length = 8 hours = 480 minutes
Lunch breaks = 30 minutes
Tea breaks = 20 minutes
Total breaks = 50 minutes
Downtime = 10% of shift = 48 minutes
Ideal Run rate = 7000 pieces/minute
Total pieces produced = 24,00,000
Rejected pieces = 48,000

Assure the equipment works only under the supervision of its operator.

OEE % = Availability X Performance X Quality %

A. *Availability* = Operating Time ÷ Planned Production Time
Operating Time = Planned Production Time – Downtime Loss
Plant operating Time = 8 hours × 60 = 480 minutes
Planned Production Time = 480 – 50 = 430 minutes

Downtime Loss = 10% of shift length = 480 × 0.10 = 48 minutes
Operating Time = 430 – 48 = 382 minutes
Availability = 382 ÷ 430 = 0.8883

B. *Performance* = (Total pieces ÷ operating Time) ÷ Ideal run rate
Performance = (24,00,000 ÷ 382) ÷ 7000 = 0.8975

C. *Quality* = Good pieces ÷ Total pieces
Quality = (24,00,000 – 48,000) ÷ 24,00,000 = 0.98

D. *OEE* = 0.8883 × 0.8975 × 0.98 = 0.7813
Overall Equipment Effectiveness = 78.1%

VI. WORLD CLASS OEE

World class OEE is a standard which is used to compare the OEE of the firm. The percentage of World Class OEE is given in Table.

TABLE 3
WORLD CLASS OEE LEVEL [17]

OEE Factors	OEE world class
A%	90.0
PE%	95.0
Q%	99.9
OEE%	85.0

These values of OEE factors are generally accepted but the values are different for different industries. For Manufacturing, the value of World Class OEE is 85% but for Paper Industry and Cement Industry, the value is 95% and 80% respectively. The aim of the firm is to achieve this value of OEE by continuous improvement.

VII. REVIEW OF RESEARCH ARTICLES

A. *Ashokkumar A. (2014)*
Have suggested in their study, the implementation of overall equipment effectiveness (OEE) at a small enterprise finishing product specifications according to customer specifications in the developing country of India. OEE is employed as a simple indicator, but it is still an effective method for analysing the efficiency of a single machine and an integrated system. The case study of OEE was carried out from set-up stage to full implementation. The management made the decisions by relying on OEE results and its details, and mandated the elimination of the root causes of breakdown losses and speed losses. Finally, after full implementation, OEE performances improved by over 75 percentages, since availability rate and performance efficiency were improved over 79 percentages, and quality rate was maintained at the same level.

B. *Pavan Kumar Malviya , Prof. Ravi Nagaich (2015)*
Have suggested in their study, the implementation of overall equipment effectiveness (OEE) at a small enterprise through TPM methodology. To be successful and to achieve world class manufacturing, organizations must possess effective maintenance. Overall Equipment Effectiveness (OEE) quantifies that well working of manufacturing unit and performs relative to its designed capacity, during the periods when it is scheduled to run frequent machine breakdowns, low plant availability, increased rejection are a great threat to increase operating cost and lower productivity. Finally the availability of machine has been increased from 69% to 85%, performance from 79% to 98%, quality from 90% to 96% and the OEE of machine increased from 65% to 80%.

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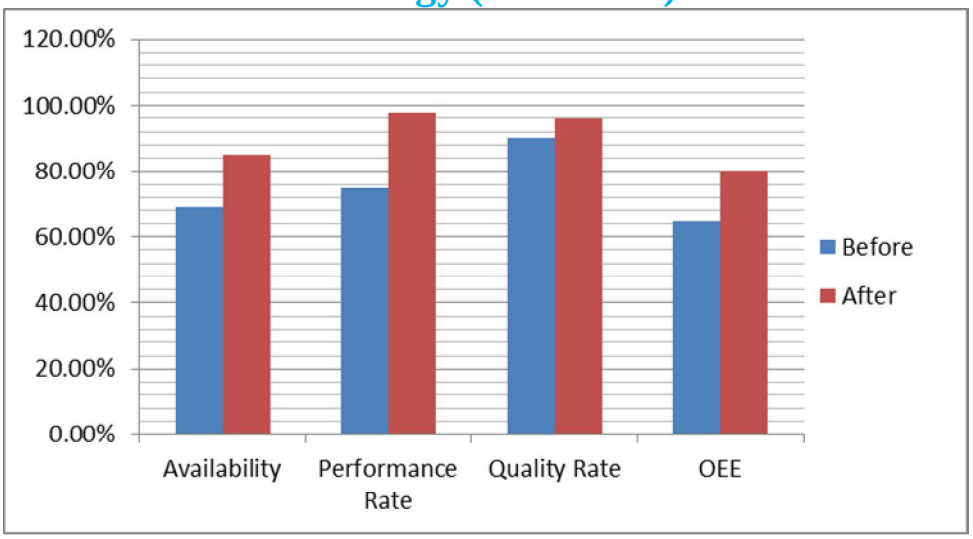

Fig. 3 OEE Before and After Improvement

C. Ramesh C.G, Mohammedasif Mulla (2014)

Have mentioned in their study and they have implemented TPM and 5S techniques to improve the availability, performance and quality of the machines. Though TPM, 5S technique, design of multi-fixture were focused, the availability and performance were improved significantly by minimizing the equipment deterioration and failure. After the implementation of TPM, 5S techniques and design of multi-fixture, the availability of machine has been increased from 67.73% to 70.78%, performance from 60.63% to 63.91% and the OEE of machine increased from 40.08% to 44.41%.

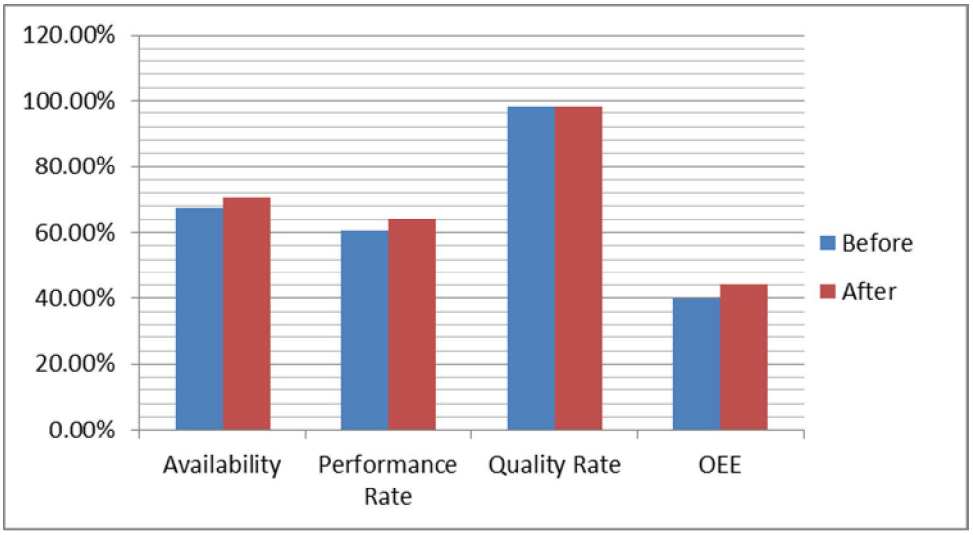

Fig. 4 OEE Before and After Improvement

D. M. VivekPrabhu, R. Karthick, Dr.G. Senthil Kumar (2014)

Have stated that an OEE is an important performance measure for effectiveness of any equipment, careful analysis is required to know the effect of various components. A excel sheet can be used as simplest tool to measure and monitor true data collection. An attempt has been done in their study to optimize the OEE by using Genetic Algorithm (GA). Their study indicates that OEE will be significantly improved if focus is given on performance rate improvement. To achieve the OEE of 84.645%, optimized values are Availability 90%, Performance Rate95% and Quality Rate 99%.

E. Binoy Boban, Jenson Joseph E (2013)

Have suggested in their study that, presently competition in industry at an all-time high, TPM may be the only thing that stands between success and total failure for some companies TPM can be adapted to work not only in industrial plants, but also in

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construction, building maintenance, transportation, and in variety of other situations. Employees must be educated and convinced that TPM is not just another "program of the month" and that management is totally committed to the program and the extended time frame is necessary for full implementation. If everyone involved in a TPM program does his or her part, a usually high rate of return compared to resources invested may be expected. TPM success requires strong and active support from management, clear organizational goals and objectives for TPM implementation.

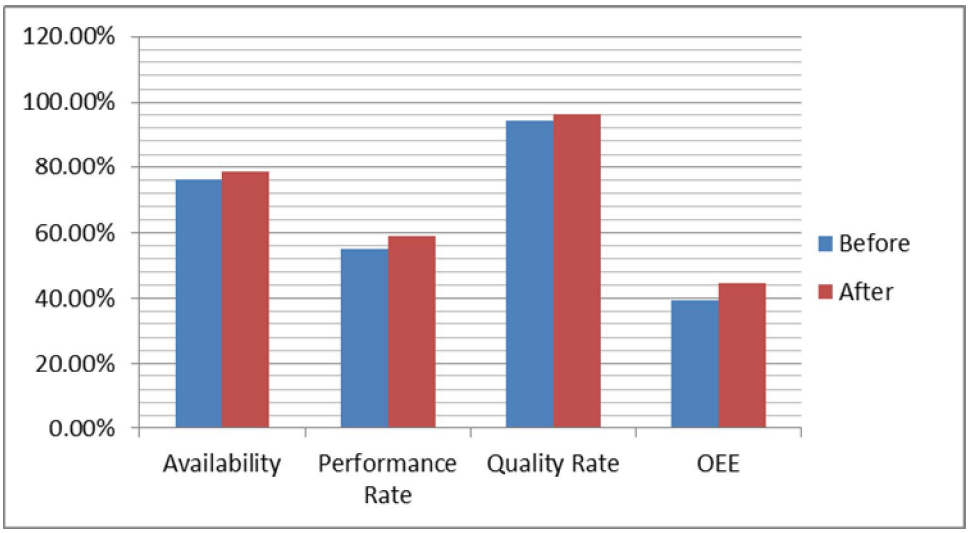

Fig. 5 OEE Before and After Improvement

F. Amit Kumar Gupta, Dr. R. K. Garg (2012)

Have mentioned in their study the effectiveness and implementation of TPM programme in an automobile manufacturing organization. Through the case study of implementing TPM in an automobile manufacturing organization, the increase in efficiency and productivity of machines in terms of Overall Equipment Effectiveness (OEE) are discussed. the Increased OEE of Broaching machine-1 is 59% to70%, Broaching machine-2 is 60% to 69% , Cylindrical grinder is 53% to 67% and Surface grinder is 50% to 65%.

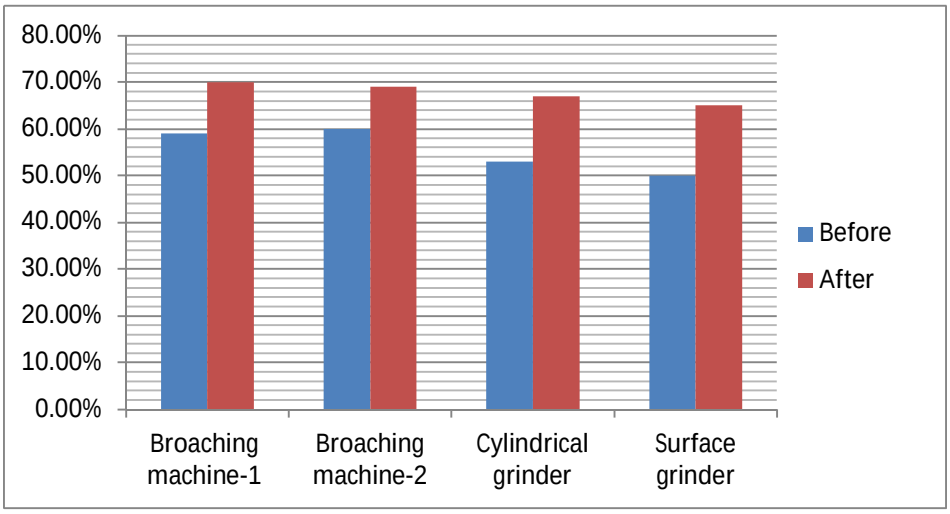

Fig. 6 OEE Before and After Improvement

VIII. CONCLUSIONS

A. The Key Successful improvement of Overall Equipment Effectiveness (OEE) depends on the elimination of three OEE loss categories like Downtime Loss, Speed Loss and Quality Loss. The key factors for this implementation are workers involvement and top management support.

B. To improve productivity it is essential to improve the performance of the manufacturing systems. The desired production output

is achieved through high equipment availability, which is influenced by equipment reliability and maintainability.

C. Overall equipment Effectiveness (OEE) is not a statistically valid metric, but it has been used widely used over the years.

D. Overall equipment Effectiveness (OEE) does not diagnose a specific reason why a machine is not running as efficiently as possible, but it helps to categorize the areas for initiating the equipment improvement.

E. Overall Equipment effectiveness (OEE) is a structured continuous improvement process that strives to optimize production effectiveness by identifying and eliminating losses associated with equipment and production efficiency throughout the production system life cycle through active team-based involvement of employees across all levels of the operational hierarchy.

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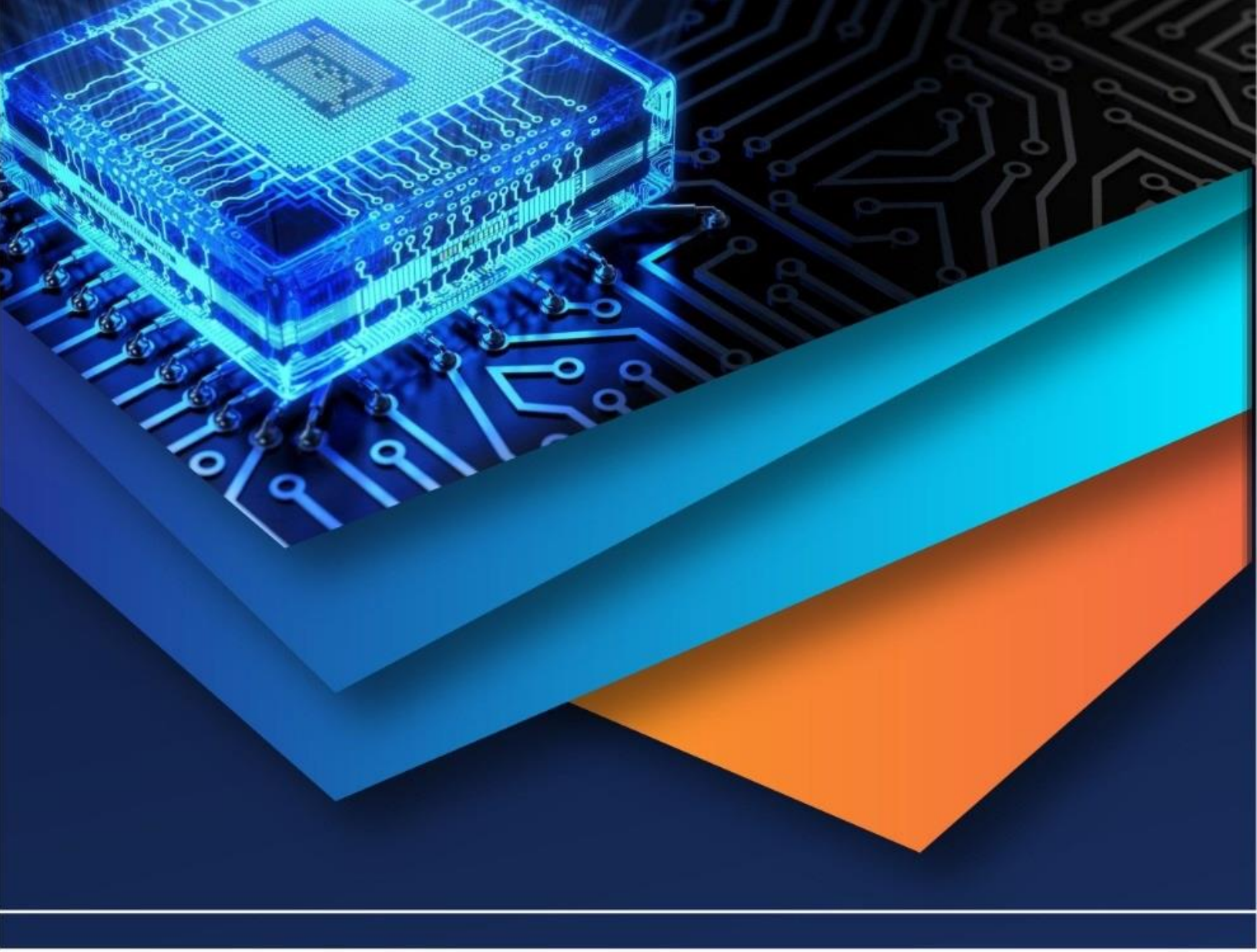

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