International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 09 Issue 10 ǁ 2021 ǁ PP. 32-37

Implementation of OEE in Process Based Conditional Maintanence (PBCM)

R.Prasanna Lakshmi [1]*, P.Nelson Raja[1], H.Ganesh[1], P.Marimuthu[2#], S.Bridget Nirmala[3#], M.Stalin Arockiyaraj[3#]

[1]Department of Mechanical Engineering, Fatima Michael College of Engineering & Technology, Madurai-625020
[2] Department of Mechanical Engineering
[3] Department of Computer Science & Engineering
[#]St Michael College of Engineering and Technology, Kalayarkovil – 630551

Abstract

In a continuous-flow production system, a proper material movement is required to have a balanced productive and quality. To have an uninterrupted production especially in multi stage systems, proper preventive maintenance of equipment is required. Even though there are various methods to have control over this preventive maintenance, there were some cases where production failure occurs when the maintenance system fails to meet the production needs. This is because of time gap between preventive scheduled maintenance and machine utilization. In this paper a concept of PROCESS BASED CONDITIONAL MAINTANENCE (PBCM) is introduced which minimizes this time gap. When this system is integrated with ERP then a smooth flow of preventive maintenance can be achieved. Analytical Hierarchy Process (AHP) is linked with this method to have a decision-aid on PBCM. The idea of the proposed model is to have control over preventive maintenance through process and to minimize the cost incurred in the machines which are not in use.

Keywords: *Process based conditional maintenance; Conditional based maintenance; Analytical hierarchy process; Waterwall.*

Date of Submission: 25-09-2021 Date of acceptance: 10-10-2021

I. INTRODUCTION

Maintenance system is a set of activities performed on a system to sustain it in operable conditions [1]. Maintenance strategies can be classified as reactive, time based or condition based [2]. However previously, the method of maintenance is "fix it when breaks" [1]. Since this requires no planning, break down maintenance has increased. Research detailed by Mobley (1990) says that Corrective action is about three times higher than the same repair made in a preventive mode [3]. And further preventive maintenance was introduced which considerably reduced the unpredictable break down time. In this type of maintenance, appropriate maintenance task is done only when warranted by equipment condition [4]. In the present technological world, the maintenance technology has changed from time based to condition based. Even though preventive maintenance reduced the down time, at some scenario severe break down occurred due to several factors like wear of components and aging. This is due to the reason that preventive maintenance is conducted mainly for the running condition of the machine but not the aging and wearing of parts in that particular machine. Another practical difficulty faced in this method is that due to scheduling of maintenance, it is not guaranteed that machine will work properly at the time requirement. This is due to the time delay of scheduled maintenance and machine requirement time. For example, if a machine is required today and the maintenance schedule date is previously before one week of after the same day, then there may be chance of facing break down maintenance.

This problem cannot be neglected since a small hand grinding machine can make a delay of half shifts or two hours which accounts cost in it and affects smooth flow of forthcoming activities. This can be particularly seen in multistage production systems. This process is overcome by an idea of condition based maintenance (CBM) which is to monitor the equipment using various sensors to enable real-time diagnosis [1]. This system reduces time delay but this is being costlier when applying for handy machines. In this paper, a systematic approach is tried to reduce the delay time which analysis the process and manipulates the priority thus instructing which machine to act for maintenance. By just following the instructions of this methodology, it is being believed to have right machines at right time with proper maintenance. This process is said as PROCESS BASED CONDITIONAL MAINTENANCE (PBCM).

In this process, there may be a situation arrive where a decision has to be made for which machine to undertake maintenance. This situation occurs when there is scarcity of machines or man power. For example, if there are ‘n’ no of machines for ‘n+1’ products and decision should be taken as which machine to be allocated for which products. And in other side if there is ‘m’ worker and if there is ‘m + 1’ machines, a decision should be takes as which machine to left. This is done by giving priority of machine for preventive maintenance according to the process cycle time and other factors that influence the importance of this product. This PBCM is said to be highly useful in fabrication industry.

1.1 Problem definition

In fabrication industries there are no particular products with particular cycle time. The cycle time varies for each and every component according to the sizes. And many machines like welding machine, grinding machine, lathes, Hand lathes, cranes, bend machine, rolling machine, drilling, hydro test machines are to be used in each product. There should not be scarcity for any machine for any job which in turn will delay many other products. All these machines should be properly maintained and be ready for all the times. Preventive and periodical maintenance is followed to meet these requirements.

In some cases, a hand machine may cause a trouble which in turn will make a drilling machine to wait for this component. This may happen due to difference between last maintenance time and process time. So it is necessary that a machine should always be ready with proper maintenance. In order to make it happen it might be better if preventive maintenance is done just before the process for which that machine is going to be utilized. Process Based Conditional Maintenance (PBCM) methodology calculates this delay time and requirements to find an optimum approach to sequence the preventive maintenance for machines. These problems shall be often found in the areas of fabrication and especially in boiler component manufacturing companies. We have taken a boiler component Water wall into account and tried to implement this methodology. We have assumed the number of machines for water wall by considering total available machines and allocating separately for Waterwall.

1.2 Condition Based maintenance (CBM)

CBM is a decision making strategy where the decision to perform maintenance is reached by observing the “condition” of the system and or its components [1]. Conditional based Maintenance (CBM) or Predictive maintenance differs from Preventive maintenance by basing maintenance need on actual condition of the machine rather than on some preset rules [4]. Preventive maintenance is a time based control which prevents the problem as like changing the oil, grease and checking level of pressure factors with certain time interval. But CBM identifies the faults before they become critical which enables more accurate planning of preventive maintenance. CBM is a real time assessment which includes sensors, online test equipment. Since this CBM requires some real time monitoring components, they are costlier to some extent. CBM offers many advantages over a traditional time-based strategy [7].In industry, usually production is accompanied by several vibrations which cause machine to fail. These vibrations are monitored by test equipments as a real time and indicate the prediction of failure of that particular machine. CBM is being proactive process, requires the development of predictive model that can trigger the alarm for maintenance [1]. This model should be precisely and accurately since this plays a major role in conditional based Maintenance (CBM). There were many models created in mix with fuzzy logic. And more over this CBM cannot be applied for small handy machines since the cost of the machine may increase highly. Some of the advantages of CBM are prior warning of impending failure and increased prediction in failure prediction [1].

1.3 Analytic Hierarchy Process (AHP)

AHP is developed first by T.L Satty (1991) which is a tool for decision making in scenario which includes multi criteria[5]. It is similar to human thinking which facilitates in complex decision making. For example, if a job has to be allocated to a sub- contractor from many decisions has to be made as to which sub-contractor this job has to be allocated. For simple jobs usually human brain thinks first criteria as cost. But delivery time shall also be major criteria. In some cases, these should be in an optimized way. If the situation occurs for many criteria, then it shall be of tedious jobs. At this case AHP helps us to take scientific decision in an optimized way.

AHP starts creating a pair wise comparison matrix. For example, when matrix A is a m×m real matrix, where m is the number of evaluation criteria considered. Each entry ajk of the matrix A represents the importance of the jth criterion relative to the kth criterion. The ajk and akj satisfies the constraint ajk .akj= 1. Then relative importance is measured according to numerical scale from 1 to 9 hierarchies from equal importance to more importance. Then the matrix A is normalized by computing each entry as Ajk $= \frac{\mathrm{ajk}}{\sum_{n=1}^{m} \mathrm{ajk}}$

Finally Criterion vector w is built by averaging the entries of each row of Anorm

$$Ajk = \frac{\sum_{n=1}^{m} Ajk}{m}$$

By T.L.Satty, the final decision matrix equation model is given asin[6]

1.4 Methodology and Discussion

In this PBCM, preventive maintenance of the dynamic machines was done according to their requirements through process monitoring. In this study, multi stage production system of Waterwall (boiler component) is taken as a case study. This study was taken in a firm containing many departments like Design, Central Planning, Material Planning, Stores, Quality, R & D, and unit Planning, unit Production and unit Maintenance. These departments were integrated through ERP for controlled process. Our mode of study is in unit production, planning and maintenance. The main objective of unit production is to convert the raw material to components for allocated boiler components and objective of planning is to support production in all dimensions including monitoring of utilization and efficiency. The process was monitored by planning department and status of the job was continuously updated in ERP. By doing this status of the component, delivery time of the component is monitored.

The total cycle time for completing single waterwall is around 45 Days. In this quality check and rework is not considered. Flange fit-up and welding is not shown in this tabulation since it is made from sub-contractors. From the above tabulation cycle time column represents the number of shifts required to complete particular process and the day count represents the number of day to complete the process for starting of waterwall. The requirement of dynamic machines is also given and it is clear that many handy machines play a major role in many processes (in some cases major machines like overhead crane). Likewise a tube bending machine is used only one in the process. So it is clear that requirement of preventive maintenance is least required than handy machines. The requirement of machines chart for process is given in Fig. 1.

From Fig. 1, we can clearly see the criticality of dynamic machine failure against the process. The first and foremost machine to be checked for preventive maintenance is CO2 welding and Arc welding machine. And further hierarchy follows as Overhead crane, Grinding cutting Machine, Portable wire brush, Portable Edge preparation, Grinding Machine. So we can conclude that both CO2 welding and Arc welding machine has to be done with preventive maintenance with top priority. General Preventive maintenance frequency is given in below Table. 2.

Cycle time of this particular Waterwall is 35 Days. Only the process involving dynamic machines are taken into consideration. We consider the first to have preventive maintenance for all portable machines. Then the next PM comes at the stage of 7th day. Between the seventh day there may be two processes involving one machine. For example the Gas cutting machine has to undergo two processes namely on 2nd day and 7th day. But the Preventive maintenance has to be done only on the eighth day. There is a chance of getting some interruption by this machine due to previously operated conditions. In the same way over head cranes is used in this process at 5th, 8th, 14th, 15th and 24th day. But the PM is usually done for every 90 days. This again may cause a problem. So by this PBCM, maintenance should be done in intervals based on these intervals. Here by expert system study, it has been found that machines are highly believed on some intervals to have smooth runs. With these intervals this manipulation is done to have a smooth operation for every process.

Table.1.Process steps of Waterwall & its day wise dynamic machines requirement.

Process No	Process	Required Dynamic Machines for process	Cycle Time (No of Shit)	Day Count	Remarks
1	Header Marking (8 Nos)	Not Applicable	2	1	
2	Header Edge cutting	Gas cutting Machine	1	2	
3	Header Edge preparation	Grinding Machine, Wire brush, Boring	0.5	2	
4	Header Drilling (Ø273)	Vertical Drilling Machine & overhead cranes	4	5	(2 + 3) Days
5	Panel Cleaning	wire brush	1	6	
6	Panel Marking	Not Applicable	1	6	
7	Panel edge cutting	Gas cutting Machine	1	7	
8	Panel Edge preparation	Portable EP Machine	2	8	(0.5 + 1) Days
9	Header location	overhead crane	0.5	8	
10	Stub marking and cutting (Ø51.0)	Gas cutting Machine	2	9	
11	Stub Edge preparation	Portable EP Machine	2	10	

12	Stub fit-up	Co2 welding Machine	3	11	(10 + 1.5) Days
13	Stub Welding	Arc welding Machine	2	12	80 Stubs / Shift
14	Panel Matching with header	overhead crane and CO2 welding Machine	2	14	For Single Match
15	Panelfit-up with Header	overhead crane and CO2 welding Machine	1	15	For Single Match
16	Panel Welding with Header	Arc welding Machine	4	17	(15 + 2) Days
17	Branch Header Marking and cutting (Ø273)	Gas cutting Machine	1	18	
18	Branch Header Grinding and Edge preparation	Grinding Machine, Wire brush	1	18	
19	Branch Header fit-up	Co2 welding Machine	1	19	
20	Branch Header welding	Arc welding Machine	2	20	(19 + 1.5) Days
21	Bend tube Marking and cutting	Gas cutting Machine	1	20	
22	Bend tube Edge preparation	Portable EP Machine	2	21	(20 + 1) Days
23	Tube bend (Bend tube)	Tube bending Machine	0.5	21	
24	Bend tube fit-up	Co2 welding Machine	1	22	
25	Bend tube welding with header	Arc welding Machine	1	23	
26	Header to Header Matching	overhead crane and CO2 welding Machine	2	24	(23 + 1) Days
27	Header to Header welding	Arc welding Machine	1	25	

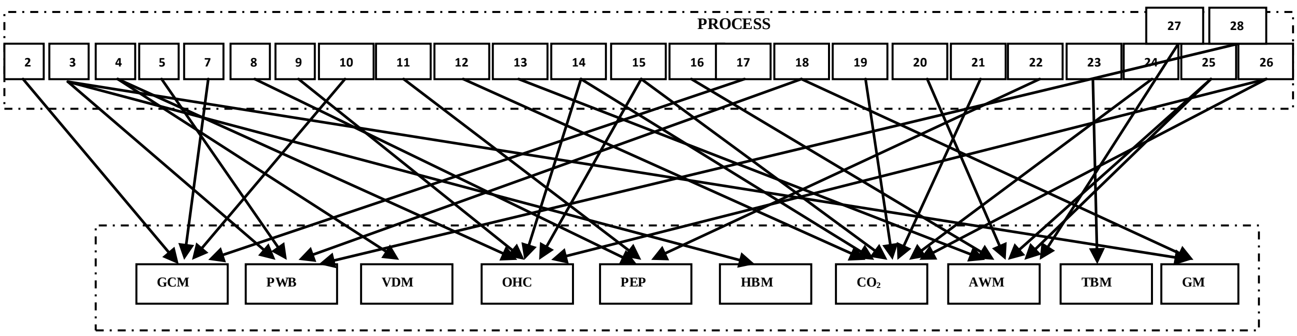

Figure. 1: Schematic representation Distribution of Dynamic machines for waterwall processing.

Table. 2. Frequency of preventive Maintenance

SI No	Dynamic machines	frequency
1	Gas cutting Machine	7
2	Portable Wire brush	7
3	Boring Machine	60
4	Vertical Drilling machine	90
5	Overhead cranes	90
6	Portable EP Machine	7
7	CO2 Machine	7
8	Arc Welding Machine	7
9	Tube bending Machine	30

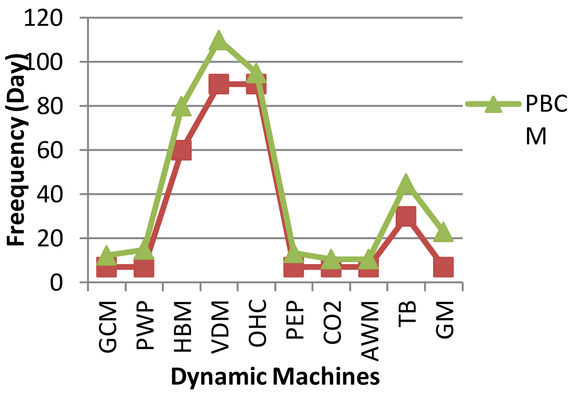

Figure 2: Graph Showing the PBCM & PM. 1

II. RESULT AND DISCUSSIONS

2.1 OEE

OEE methodology incorporates metrics from all equipment manufacturing states guidelines into a measurement system that helps manufacturing and operations teams improve equipment performance and, therefore, reduce equipment cost of ownership [11]. According to [14, 15, and 16], OEE is widely known to be a function of equipment availability, performance efficiency, and rate of quality. The formulation of OEE and relationship between the six major losses are given in Figure 2 [8,17]There are six parameters involved in the OEE calculations, namely, (a) Loading time; (b) Down time; (c) Processed amount; (d) Operating Time; (e) Theoretical Cycle Time; and (f) Defect Amount.
OEE = Availability (A) x Performance Efficiency (P) x Rate of Quality (Q)
Figure 3. The OEE formulation and the six losses

2.2 THEORETICAL FRAMEWORK

OEE is basically a multiplication of three component efficiency percentages: percent availability efficiency, performance efficiency percentage, and quality efficiency percentage. He showed that even if a tool is available almost 100% of the time and is utilized almost 100% of the time, its OEE could be extremely low. This could be due to the tool's performance or to the tool's quality of output. Nakajima also defined "six big losses" of OEE and equated two of the losses to each of his performance metrics of availability, performance and quality. Figure 1 shows this relationship.

Overall Equipment Effectiveness (OEE) Components

6 Big losses	Efficiency Measurement
Breakdowns Setups/Adjustments	AVAILABILITY
Reduced Speed Idling/Minor Stoppages	PERFORMANCE
Defects/Rework Yield	QUALITY

Reference: S. Nakajima, Introduction to TPM Total Productive Maintenance

Figure 3 Components of Overall Equipment Effectiveness (OEE)

Using OEE offers significant advantages for improving throughput in a semiconductor manufacturing line over traditional utilization reports. Utilization reports have concentrated mainly on availability of tools as its principle measure, but OEE measures quality and performance in addition to availability. OEE allows one to view several aspects of semiconductor equipment simultaneously.
Efficiency Analysis Framework &CUBES
To analyze OEE, we use the efficiency analysis framework developed by Konopka (1995). This framework views tool efficiency as a function of speed and time. If one can calculate the effective processing speed of a tool and the net production time the tool was processing, the multiplication of the two will be the efficiency of the tool. In this framework, an efficiency and throughput level are associated with each bottleneck tool. In addition, an efficiency loss and throughput loss are associated with each time, speed or quality based efficiency factor. This allows groups to work together to determine where effort should be focused to maximize a tool's output. This framework has been put in a model developed by Konopka called CUBES, Capacity Utilization Bottleneck Efficiency System. Details of CUBES are available in that paper. Below is an analysis in CUBES. Figure 2 is called the CUBES-OEE template. This template is divided into three major parts: (1) Summarized Inputs, (2) Summarized Outputs that analyze the entire tool's efficiency and throughput, as well as the

individual efficiency loss and associated throughput loss for each efficiency factor, and (3) a graphical representation of the tool's efficiency and efficiency losses.

2.3 Efficiency Analysis Framework &CUBES

To analyze OEE, we use the efficiency analysis framework developed by Konopka (1995). This framework views tool efficiency as a function of speed and time. If one can calculate the effective processing speed of a tool and the net production time the tool was processing, the multiplication of the two will be the efficiency of the tool. In this framework, an efficiency and throughput level are associated with each bottleneck tool. In addition, an efficiency loss and throughput loss are associated with each time, speed or quality based efficiency factor. This allows groups to work together to determine where effort should be focused to maximize a tool's output. This framework has been put in a model developed by Konopka called CUBES, Capacity Utilization Bottleneck Efficiency System. Details of CUBES are available in that paper. Below is an analysis in CUBES. Figure 2 is called the CUBES-OEE template. This template is divided into three major parts: (1) Summarized Inputs, (2) Summarized Outputs that analyze the entire tool's efficiency and throughput, as well as the individual efficiency loss and associated throughput loss for each efficiency factor, and (3) a graphical representation of the tool's efficiency and efficiency losses.

III. CONCLUSION

From Fig. 2, it is clear that there is not much deviation between frequency of existing Preventive maintenance and PBCM. But more precisely we can say that PBCM can eliminate some unpredicted maintenance that would incur hidden cost. In this paper, only single component of Waterwall is taken into consideration. That is why this process seems to be somewhat simpler. But when we implement this PBCM for all components then it becomes more complicated. At that stage there always comes a situation of same machine allotted for several processes. At this critical decision making situation, we utilize AHP as decision making tool and decide which machine to allocate for which process. This shall be next stage of this research work where many brain storming with exerts and hurdle regarding the process control. The main disadvantage of PBCM is that this system is useful only linked with ERP. This is because manual manipulation may lead to several errors when taking many criteria to consideration. Future research of this PBCM would be formulating a several models to incorporate this as a general method especially multistage production system. Also by implementing OEE during the bottleneck maintenance in maintenance of machines we can utilize the maximum availability of machines.

REFERENCES

[1]. Samuel H.Huang (2007), Adaptive Mamdani fuzzy model for Condition-based maintenance, Elsevier – Fuzzy sets and systems 158(2007) 2715-2733.
[2]. J.C. Aurich (2011), Quality oriented maintenance scheduling. Elsevier – CIRP Journal of manufacturing science and Technology 4(2011) 15-23.
[3]. F.T.S. Chan (2005), Implementation of Total Productive maintenance: A Case study. Elsevier – International Journal of Production Economics 95 (2005) 71-94.
[4]. S.K.Sethiya, Condition Based Maintenance (CBM) – IRSME.
[5]. Ling Wang (2007), Selection of optimum maintenance strategies based on a fuzzy analytic hierarchy process – Int. J. Production Economics 107 (2007) 151-163.
[6]. EvangelosTriantaphyllou and Stuart H. Mann (1995), Using the analytical Hierarchy process for decision making in Engineering Applications: Some Challenges – International Journal of Industrial Engineering and Practice, Vol. 2, No.1, PP. 35-44, 1995.
[7]. D.H. Stamatis (1995), Failure mode effect Analysis: FMEA from theory to Execution, ASQC Quality press, Milwaukee.
[8]. M.Faccio (2012), Industrial maintenance policy development: A quantitative framework, Int. J. Production Economics.
[9]. BabakSohrari (2008), Prioritizing equipments for preventive maintenance (PM) activities using fuzzy rules, Elsevier – Computers and Industrial Engineering 54(2008) 169-184.
[10]. Shahrulkamaruddin (2012), An overview of time-based and condition based maintenance in industrial application, Elsevier – Computers and industrial engineering 63(2012) 135-149.
[11]. Konopka, John M., "Capacity Utilization Bottleneck Efficiency System (CUBES)," IEEE Transactions on Components, Packaging and Manufacturing Technology, Sept. 1995.
[12]. Nakajima, S. (1988), Introduction to TPM, Total Productive Maintenance. ProductivityPress, Cambridge, MA. Vadgama, A. and W. Trybula., "Activity Based Enterprise Analysis Through Modeling," to appear in IEMT'96 proceedings (this issue). 140
[13]. I.P.S.Ahuja, and J.S.Kamba, "Total productive maintenance: literature review and directions", International Journal of Quality & Reliability Management, Vol. 25 No. 7, 2008.
[14]. S.J.Robert and M.H.Marilyn, "Total Productive Maintenance and Its Link to Total Quality Management", Work Study, Vol. 43(7), pp. 18-20, 1994.
[15]. D.Kotze, "Consistency, accuracy lead to maximum OEE benefits", TPM Newsletter, Vol. 4 No. 2, AITPM, Productivity, Inc., Norwalk, 1993.
[16]. O.Ljungberg, "Measurement of overall equipment effectiveness as a basis for TPM activities", International Journal of Operations & Production Management, Vol. 18 No. 5, pp. 495-507, 1998.