Scientific Journal of Impact Factor(SJIF): 3.134

e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 5, May -2015

OPTIMIZING & ANALYZING OVERALL EQUIPMENT EFFECTIVENESS THROUGH TPM APPROACH: A CASE STUDY IN CEMENT INDUSTRY

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Abstract :*Continuous availability of reliable sophisticated equipment with precision is need of the competitive market. Overall equipment effectiveness (OEE) is important measurement tool for equipment effectiveness. An attempt has been done to measure and analyze existing overall equipment effectiveness of machinery producing pozolona portland cement. Which is used in construction work. By measuring the performance of existing system, reference values are obtained for design of experiments. By using Minitab 16 software an experimentation has been done on three factors and two level of OEE. Main effect plots and regression analysis provide information about which is most influencing factor and classic relationship between availability, performance rate and quality rate. Significance of each factor is indicted by P-values in the given analysis. Finally counter plots and response surface method results in to optimized value of three factors of OEE. Simulated values of the output will be useful information to industry.*

1. INTRODUCTION

Effectiveness and efficiency are very important in today's competitive market. Greater the effectiveness and efficiency more productive is the organization. Overall equipment effectiveness is such a performance measure, which indicates current status of production with least calculations. It also helps to measure losses and corrective actions can be taken to reduce it. Effective utilization of all four M's will result into higher productivity.

Overall equipment effectiveness (OEE) is a product of three important parameters, Availability, Performance Rate and Quality Rate. When higher productivity is expected the machine tool which are involved in manufacture of finished goods, must be reliable. Reliability includes availability of machines with least down time. If MTBF (Mean Time Between Failure) is more, it indicates machines are available for its desired performance. Attempt must be made to reduce mean time to repair (MTTR) and improve MTBF. It requires failure data analysis and root cause analysis. The failure data collected will help us to calculate availability of equipment.

The data collected of ideal cycle time with set up and adjustment ,results into performance rate. Quality rate can be obtained by subtracting rejected materials from total material produced. The product of mentioned three measures, will results into machine Overall Equipment effectiveness (OEE). Thus,

$$\text{OEE} = \text{Availability} \times \text{Performance Rate} \times \text{Quality Rate}$$

$$\text{Availability} = \frac{(\text{Loading Time} - \text{Down Time})}{\text{Loading Time}}$$

$$\text{Performance Rate} = \text{Operating speed} \times \text{Net operating rate}$$

$$\text{Quality Rate} = \frac{\text{Good parts produced}}{\text{Total Parts produced}}$$

OEE is a measure of machine capability. It indicates where is scope of improvement. Statistical data collected from manufacturing plant results into useful information for improvement area.

Nakajima introduced OEE in Total Productive Maintenance. Researchers have noted that this definition varies with different processes. A.J. de Ron and J.E.Roda modified OEE by introducing operational efficiency and rate efficiency in performance rate. Tom Pomorski defines OEE in terms consistent with SEMI E-10-96. OEE as one element of which measures the performance of equipment, but can OEE measures the performance of the entire manufacturing process. The productivity metric standard proposal defines variation of OEE as production OEE, demand OEE, Simple OEE, etc. P.Muchiri and L.Pintelon evolve OEE 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 OEE, contribute to overall OEE in a different manner, has significant effect on improving the performance. Use of Design of Experiment (DOE) is explored in this paper. Obtained values are used as an input to simulation model. Observed values are plotted in the form of counter plots. Response surface method is used to determine optimized value.

2. METHODOLOGY USED:

Literature review in the field of overall equipment effectiveness shows that there is strong need of performance measurement system. It indicates to reduce down time losses for performance improvement.

A survey in cement manufacturing plant has been conducted. It has been observed that there is no or little idea to maintenance crew about mean time to failure (MTTF) and mean time to repair (MTTR). There are most important parameters for availability of machine. It indicates that accuracy level of failure data recorded, is very less. Skill level of maintenance crew is not upgraded. Real time data collection is a need of us for applying corrective action.

From the above survey, an attempt has been done to model a manufacturing scenario of leading cement manufacturing company by simulation. Where focus is to improve capacity of manufacturing facility.

2.1 Model Development & Experimentation: A model has been developed for a company, which supplies pozolona portland cement to its consumers.

Material flow in manufacturing plant:

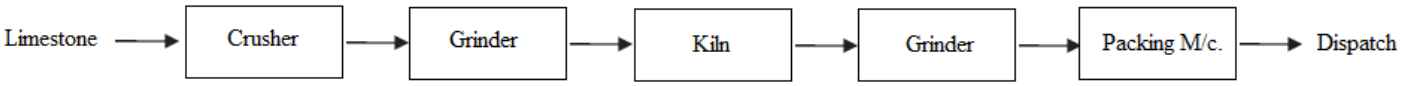


Fig.1 Model of a manufacturing line

Table 1: Actual cycle time of manufacturing equipment

Name of Machine	Actual cycle time(hr.)
CRUSHER	200 tons/hr
GRINDER	150 tons/hr
KILN	150tons/hr
GRINDER	80tons/hr
PACKAGING MACHINE	30bag/min, 36tons/hr (One bag of 50Kg)

2.2 Data collection by Excel Sheet:

A systematic approach of collecting true data is given in the table below. Excel tool is used to collect data of all the manufacturing equipments. Daily calculation of OEE is possible if given format is used to record data. Following table specify format of true data collection of one day required to calculate OEE.

Table 2: Excel Sheet format for Availability Calculations

Name	Shift length (min)	Scheduled D.T. (min)	Unscheduled D.T.(min)	Actual Up Time(min)	Availability(%)
Crusher	1440	166.02	0.98	1337	92.90%
Grinder	1440	167.50	53.75	1246	86.41%
Kiln	1440	178.84	142.68	1116	77.50%
Grinder	1440	171.12	47.17	1300	90.27%
Packaging Machine	1440	169.47	24.49	1328	92.22%

Table 3: Excel Sheet format for Performance Rate Calculations

Name	I.C.T. (min)	A.C.T. (min)	Performance	P.R.(%)
Crusher	60	54.8	0.9666	92.66%
Grinder	60	56.4	0.93	93%
Kiln	60	52	0.8666	86.66%
Grinder	60	54	0.9	90%
Packaging Machine	60	54	0.9	90%

I.C.T.: Ideal Cycle Time; A.C.T.: Actual Cycle Time; P.R.: Performance rate

Quality is not a problem for this industry as rejection rate is very low. so Quality rate found to be 97% to 100%.

3. DESIGN OF EXPERIMENT (DOE):

It is a systematic approach to analyze any process by changing some of input variable purposefully to determine its effect on output of the process. The objective in many cases may be to develop a robust process, that is, a process affected minimally by external source of variability.

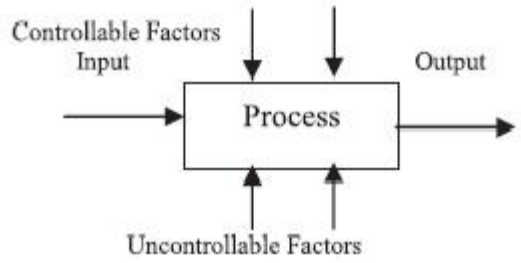


Fig.2 General model of Process or System

OEE system or process is studied under this model as indicated in fig 2 input variables are mean time between failure (MTBF) and mean time to repair (MTTR), setup and adjustment for Availability rate, Actual cycle time, ideal cycle time, small stops, reduced speed for performance rate and startup rejects, production rejects for Quality rate. Output of the process is OEE. Uncontrolled factors in this process are ideal cycle time, unscheduled breakdown operator.

From above data collection and calculation for availability and performance rate measurement, Kiln section is found to be low performing machine with availability 77.5% and performance rate 86.66%.

Design of experiment is used to analyze, which factor of kiln section affect output significantly and at what rate. Three variable such as Availability, Performance Rate and Quality Rate are taken with variation of two level. Reference values are Availability 72% to 77%; Performance rate 86% to 91%; Quality Rate 97% to 100%. A full factorial Design has following details by using MiniTab 16 software. Experiment has designed for 3 factors and 2 levels.

Factors: 3 Base Design: 3,8

Runs: 8 Replicates: 1

Blocks: 1 Center pts (total): 0

Table 3: Experimental setup for OEE.

AVAILABILITY (%)	PERFORMANCE RATE (%)	QUALITY RATE (%)	OEE (%)
77	86	97	64.23
77	**91**	**99**	**69.36**
77	86	99	65.55
72	86	97	60.06

72	86	99	61.30
72	91	99	64.86
72	91	97	63.54
77	91	97	67.96
77	91	97	67.96

4. REGRESSION ANALYSIS: OEE VERSUS AVAILABILITY, PERFORMANCE RATE, QUALITY RATE:

The regression equation is

OEE (%) = -129 + 0.867 Availability (%) + 0.729 Performance Rate (%)

+ 0.660 Quality Rate (%)

Table 4: Variables and its significance value (P)

Predictor	Coef	SE Coef	T	P
Constant	-129.180	3.718	-34.75	0.000
Availability	0.86700	0.01372	63.19	0.000
Performance Rate	0.72900	0.01372	53.13	0.000
Quality Rate	0.66000	0.03430	19.24	0.000

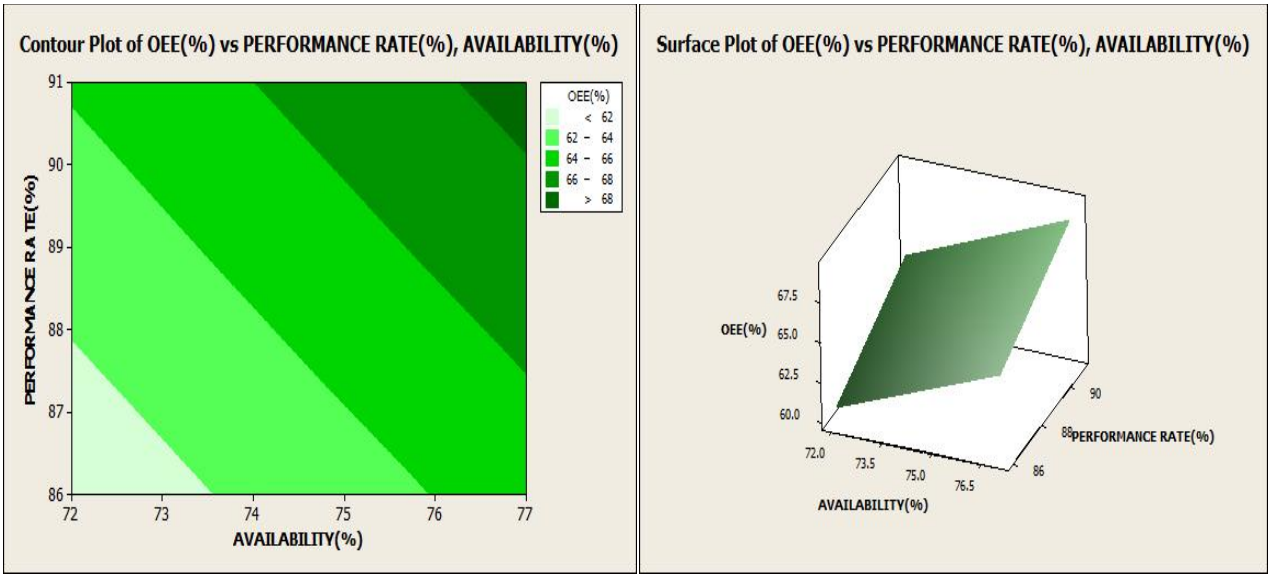
S = 0.0970180 R-Sq = 99.9% R-Sq(adj) = 99.9%

Table 5: Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	67.641	22.547	2395.44	0.000
Residual Error	4	0.038	0.009		
Total	7	67.679			

Table 6: Ranking most Significant factor with SeqSS as Performance Rate

Source	DF	SeqSS
Availability	1	37.584
Performance Rate	1	26.572
Quality Rate	1	3.485



MiniTab 16 is used to plot a contour & surface plot of experimented values. Variation of OEE with respect to availability and performance rate can be observed in surface plot.

5.CONCLUSION:

As 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. A regression analysis gives classic equation of OEE. An attempt has been done in this study to predict the OEE by using Design of Experiments (DOE). This study indicates that OEE will be significantly improved if focus is given on performance rate improvement. To achieve OEE of 69.39%, optimized values are Availability 77%, Performance Rate 91%, and Quality Rate 99%. Simulated values of above scenario will add more valuable information to industry.

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