Development of an effective maintenance concept for enhancement of competitive advantage: a case study of East African Portland Cement Company

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Abstract

Due to global competition, many organizations are coming up with ways of sharpening their competitive edge. This has been achieved through cost leadership, differentiation of goods and services and lastly, through quick response to the needs of the customers. To respond to these market requirements, manufacturers are using high-tech equipment. They are also adopting new material control methods such as Just-In-Time philosophy. Set-up costs are also being minimized to a minimum. All these factors are shifting the focus to maintenance since unreliability and availability of manufacturing equipment will result in high maintenance costs, low profitability, low production and an increase in customer dissatisfaction. At East African Portland Cement Company, the raw mill plant has led to the above problems which in turn lead to negative feedbacks from the customers and as a result, there is need to develop a maintenance concept that will respond to the challenges mentioned above. Consequently, in this research an analysis of various the maintenance concepts were investigated.

Overall Equipment Effectiveness of the Raw mill plant was evaluated and analyzed. Downtime analysis was also done to establish the major causes of low plant availability. From the research, it can be deduced that East African Portland Cement Company requires a harmonized maintenance concept regarding inspection, regular maintenance; repair and overhaul, scheduled and preventive maintenance of the main components as well as environmental auditing during operation to ensure that the plant is fully operational and efficient. Total Productive Maintenance concept therefore has been identified as key to the meeting of organizational objectives of the company. A customized framework of Total productive maintenance deployment at East African Portland Cement Company has been developed with six step transformation steps used in embedding high performance culture. It is expected that an implementation of this project will lead to a reduction in failures, time to perform a repair and an elongation in the mean time between failures hence higher plant availability and reliability for improved productivity.

Introduction

The ever-increasing competition in today's industry has compelled delivery commitments and operating costs to be an important consideration when securing customers. Costs associated with equipment breakdowns, degraded equipment and unavailability of spares and data, lead to downtime of the plant, production losses and wasteful activities. In order to meet increased market expectations and reduce operating costs, industries have focused efforts on reducing unplanned downtime. The maintenance department is being increasingly viewed as an indispensable function of the production system.

Maintenance has been largely considered as a support function which is none productive since it does not generate cash directly. However for industry to produce goods of the right quality and quantity for the customers and be able to deliver them at the right time, its plant or equipment must operate efficiently and accurately. For every manufacturing company the objective is to produce goods at a profit and this is only achieved by using an effective maintenance system that helps maximize availability by minimizing machine downtime due to unwarranted stoppages. Without an effective and economically viable maintenance system, equipment reliability suffers, and the plant pays the price with poor availability and increased downtime. All these mentioned poor key performance indicators (KPIs) could be as a result of poor machine condition and sometimes low employee morale. Low plant availability and overtime costs will negatively affect an industry's operational efficiency. Plant Engineers must therefore design an effective maintenance system for the plant and its equipment.

Frequent machine breakdowns, low plant availability and increased overtime are a great threat to East Africa Portland Cement Company (EAPCC) as they increase operating costs of an industry. EAPCC has initiated a maintenance improvement plan to minimize equipment downtime and increase equipment availability. The plant's current maintenance program is reactive and plant machinery suffers from a high level of downtime. Consequently, the 2009/2010 financial year was characterized with a loss of three hundred million shillings as a result of operation inefficiencies. This has necessitated this study because an increase in the availability will lead to increase in production, reduction in costs and consequently an increase in the profitability of the organization. The objective of this research is to investigate how to improve Overall Equipment Effectiveness of the raw mill plant through implementation of an effective maintenance concept.

By developing an effective maintenance concept that binds together all the maintenance policies, maintenance actions and strategies for maintenance, the number of stoppages in the raw mill will greatly be reduced by increasing the mean time between stoppages. This will increase the monthly production for the company as a result of improved raw mill availability and reliability. With increased production, the revenue will be greatly increased resulting into increased profitability.

Literature review

Due to increase in competition, companies are coming up with different methods to remain competitive. One of the common methods adopted by many organizations is minimizing the manufacturing costs. Another strategic thinking in improving the quality, and minimizing the cost, is through maximizing the efficiency of the production process. One of the efficient methods of reducing costs is by efficient planning and controlling of the maintenance strategies and concepts. According to Gilberts, maintenance constitutes of a set of all activities aimed at keeping an item in, or restoring it to, the physical state considered necessary for the fulfillment of its designed functions (Gilbert, 1985).

The traditional way of managing maintenance was fixing a broken item only after a failure has occurred. This practice is ineffective with disadvantages such as unscheduled downtime of the machinery, possibility of secondary damage, safety risks, production loss or delay and the need of standby machinery.

From being seen as a necessary-evil to now a profit contributor, maintenance can be used to sharpen the competitive edge of an organization. Breakdowns are costly and effective maintenance policies should aim at keeping them to the minimal. According to Walker, for each dollar ($ 1.00) spent on proper maintenance, the company saves the equivalent of twenty dollars ($ 20.00) of extra profit without extra needed sales when the cost of a breakdown is considered (Walker, 1994). This is because breakdowns are very expensive. According to Pintelon, the cost of maintenance is more than just labor and material used to return the failed equipment back to its normal working conditions (Pintelon, 2006). A recent survey showed that the actual cost of a breakdown is four to fifteen times that of normal maintenance costs. This is because breakdowns cause production to stop.

According to a study done by Mobley, between 15-40% of the total cost of finished goods can be attributed to maintenance activities in the factory (Mobley, 1989). Thus, the integration of maintenance actions into production is an efficient way of enhancing a company's capability of handling production losses and quality defects. However, Mobley did not put into consideration the "tip of the iceberg" as discussed by Pintelon (2006).

The role of maintenance in the long run should be seen as an essential function in the business strategy of an organization. Proper maintenance concept will increase the reliability and availability of equipment. This will lead to providing the market with higher quality goods, with low cost and less lead-times.

Maintenance concepts

Pintelon defines a maintenance concept as a set of maintenance actions and policies of various types. The most common types of maintenance policies are Quick and Dirty decision charts (Q&D), Total Productive Maintenance (TPM), Life Cycle Costing (LCC), Reliability-Centered Maintenance (RCM) and customized mainteinance concepts (Pintelon, 2006).

As the name suggests, a Q&D approach allows for a quick selection of the maintenance policy to be applied in a given situation. Several Q&D charts are available as Commercial-Off-The-Shelf (COTS). However, many organizations prefer coming up with customized charts. This is done by defining specific questions affecting the organization, deleting some of the questions in the original concept, editing the decision procedures, and adding and deleting maintenance policies (Pintelon, 2006).

LCC is a maintenance concept that tries to calculate the total ownership of an asset from the time of its inception to its disposal. This concept is also referred to as "cradle to grave" or "womb to tomb" costs. Blanchard warns that purchase cost of equipment is only a tip of the iceberg (Blanchard, 2003). Some of the costs that should be put into consideration are the purchase costs, installation costs, maintenance costs, replacement costs, salvage value, operational, financial charges such as loans among others. However, Blanchard did not provide a framework for analysis of the hidden costs. Some indirect costs are difficult to quantify and compute. For example, the costs associated with safety in maintenance may be very difficult to quantify.

RCM is a valuable maintenance concept that takes into account the system functionality and not just the system. Its focus is on reliability; safety and environmental integrity are considered more important than costs (Pintelon, 2006). RCM provides a structured framework for analyzing the potential failures of a facility with focus on preserving the system functions instead of the facility itself (Moubray, 1997). It comprises of all processes that ensures that an asset continues to perform its designed functions.

According to Nakajima, TPM is a plant improvement methodology, which enables continuous and rapid improvement of the manufacturing process by employee involvement, employee empowerment and closed-loop measurement of results (Nakajima, 1989).It requires company-wide participation and support by everyone ranging from the top executive to the shop floor personnel. Total Productive Maintenance (TPM) is a maintenance program with a newly defined concept for maintaining plants and equipment. It brings maintenance into focus as a necessary and vitally important part of any business or manufacturing operation. It is no longer regarded as a non-profit activity. Down time for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process (Nakajima, 1989). The roles and objectives of TPM have been identified by different scholars. According to Takahashi, the goal of TPM is to hold emergency and unscheduled maintenance to a minimum. This will in turn increase production and at the same time increase employee morale and job satisfaction (Takahashi, 1990).

Methodology

A detailed literature study of maintenance concepts was done to provide information for better knowledge and understanding of the theory. Overall Equipment Effectiveness (OEE) was used to determine raw mill performance and downtime analysis was also carried out to establish the causes of low availability.

Secondary data was a pre-requisite for this study and was sourced from EAPCC's data room documents, archival records, journals and websites. Secondary data was used in determining metrics such as OEE, Availability, Performance, Quality, Equipment reliability, mean time to repair, Mean Time between failures, Capacity Utilization, Maintenance Effectiveness and Cement production. Direct observations within the raw mill plant were also used in determining parameters such as Attitude of employees towards their jobs, the level of autonomous maintenance and the level of machine cleanliness.

The data collected for this research study were coded, tabulated and analyzed using Microsoft Excel software. This was done with the aid of a computer and it made interpretation of the results to be more meaningful to this study. The study also contains tables and graphs that were used to capture numerical details and represent them diagrammatically.

Data analysis

Selection of critical plant

Pilot studies on the Overall Equipment Effectiveness (OEE), mean time between stoppages (MTBS), reliability and capacity utilization on various lines were carried out for a period of seven months. The results are summarized as shown table 1 below:

Table 1: Average Plant key performance indicators (August 2012 – February 2013)

Plant	OEE (%)	No of stops	MTBS (hours)	Total stop (hours)	Availability (%)	Reliability (%)	Capacity utilization (%)
Kiln	72.5	12	43.5	204.21	95.9	72.9	99.3
Raw mill	56.9	159	3.11	317.8	87	59	94
coal mill	60	54	9.69	228.7	97	67	72
cement mill 5	87.21	52	11	188	88	88	98
07PK01	51.7	23	26	129	92	96	44
07PK11	55	24	25	134	90	95	47

One thing that can be noted from table 1 above is that the raw mill machine is greatly affected by not only many number of stoppages, but also the least mean time between stoppages. Therefore, the subsequent section will deal with the analysis of the raw mill since is is the most critical plant.

Availability analysis

Availability is essentially a measure of the equipment's actual up-time, relative to the planned up-time. Availability and downtime have a strong negative relationship. A lower availability means the downtime of the equipment is higher. Downtime is any appreciable length of time the equipment is not working as a result of lack of input materials, lack of operators and machine failure. Usually, availability is given as a ratio between the operating time and the total loading time. The table below shows a summary of the calculated monthly availability of the raw mill from the year 2010 to 2013.

Table 2: **The calculated monthly availability for three years**

Year	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
2010/2011	80.5	83.3	79.6	97.3	73.8	71.4	66.6	81.1	80.9	81.1	77.6	84.6
2011/2012	90.9	73.9	75.3	80.3	88.8	89.4	93.1	90.6	84.1	83.8	93.2	89.5
2012/2013	89.4	85.6	93.2	90.4	80.6	81.3	88.5	64.1	75.9	80.2	54.3	76.7
Target(%)	92.0	92.0	92.0	92.0	92.0	92.0	92.0	92.0	92.0	92.0	92.0	92.0

Mean time between stoppages (MTBS)

Table 3 below shows the monthly MTBS on the raw mill for a period of between June 2010 and May 2013.

Table 3: MTBS for the raw mill

Year	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
2010/2011	2.6	6.3	3.7	5.5	2.7	2.2	2.2	3.6	4.4	3.3	3.8	3.5
2011/2012	3.9	2.9	3.1	2.7	2.1	2.6	3.4	1.8	4.4	3.2	2.8	3.7
2012/2013	2.9	5.0	3.9	3.1	3.0	1.5	2.4	2.4	2.0	1.7	2.7	3.7
Targer(hrs)	120	120	120	120	120	120	120	120	120	120	120	120

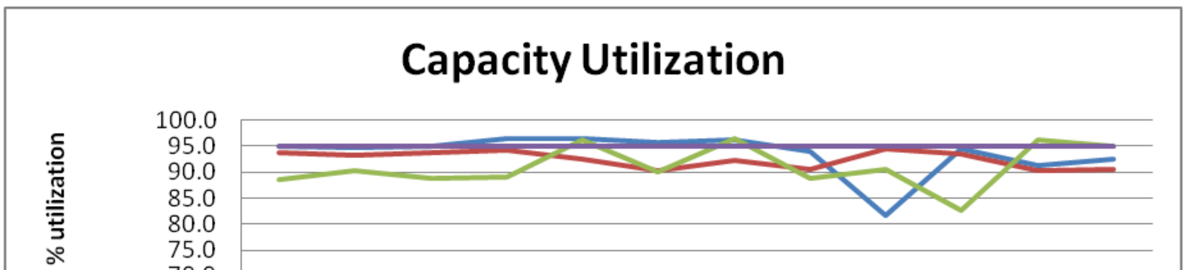
From table 3 above, we can notice that the MTBS is much smaller as compared to the targeted figure of more than 120 hours. The MTBS is usually calculated by dividing the run hours and the total number of stoppages. Therefore a low MTBS at EAPCC can be attributed mainly to the higher number of stoppages on the raw mill.

Performance analysis

Performance reflects whether the equipment is running at its designed full capacity. Performance is the ratio between the actual quantities produced during the actual running speed and the quantities that could have been produced if the equipment was running at its designed capacity; it takes into account speed losses. Speed losses are losses that make an equipment to operate below the rated capacity. Therefore, a low output means fewer quantities are produced.

By comparing the achieved values and the targeted world-class value of 95%, the figure below was drawn to highlight the differences.

Figure 1: The achieved and the targeted values for the performance of the raw mill



	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
2010/2011	95.0	94.7	95.0	96.4	96.4	95.7	96.1	94.0	81.7	94.4	91.3	92.4
2011/2012	93.7	93.1	93.5	94.1	92.5	90.2	92.1	90.4	94.4	93.3	90.3	90.5
2012/2013	88.5	90.3	88.6	88.9	96.2	90.0	96.4	88.7	90.5	82.5	96.2	94.9
Target	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0

From figure 1 above, we can conclude that performance is not a serious problem on the raw mill. This is because in some months the achieved performance is much greater than the targeted performance.

Reliability as a KPI

Reliability is also used as a KPI in the maintenance department at EAPCC. The information about reliability can be used in RCM analysis. The table below shows the monthly reliability of the raw mill for the last 36 months.

Table 4: The monthly reliability of the raw mill

Year	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
2010/2011	57.9	68.3	64.4	12.5	23.4	52.1	32.3	59.0	50.5	73.7	55.6	57.7
2011/2012	45.0	58.8	61.2	73.6	12.9	74.9	29.5	32.4	55.8	43.1	51.8	77.0
2012/2013	67.5	65.6	55.0	28.9	79.2	74.3	49.3	58.0	54.6	50.0	51.9	50.9
Target %	100	100	100	100	100	100	100	100	100	100	100	100

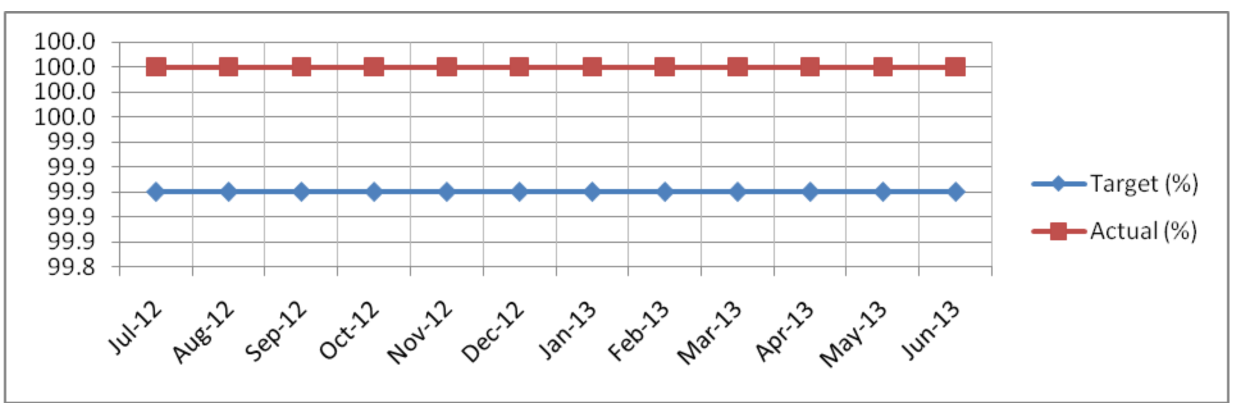
The quality factor

The quality factor is a measure of the processes ability to produce products without producing defective parts. It measures the actual yield of the process by excluding availability and performance of the production equipment. It takes into account scraps, wastes and the components that were reworked.

$$Q = \frac{Total\ throughput - Defects}{Total\ throughput}$$

A comparison between the achieved quality factor and the world-class target is as shown in the figure below.

Figure 2: The achieved and the targeted quality factor in the OEE analysis

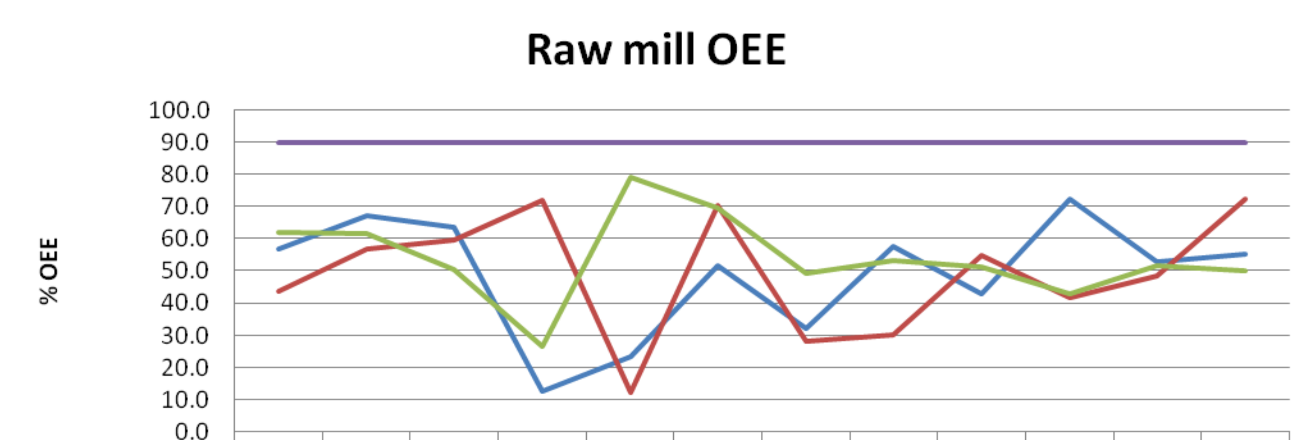


From the figure above, we can note that quality is not a major problem at EAPCC because the achieved target is higher the world-class metric of 99.9%.

OEE calculation

As mentioned above, the OEE is a product of the availability, performance and the quality factors. However, at EAPCC OEE is a calculated using capacity utilization, quality and reliability factor. A comparison between the world-class OEE, company target and the achieved OEE on the raw mill at EAPCC is as shown in the figure 3 below

Figure 3: The targeted and achieved OEE on the raw mill



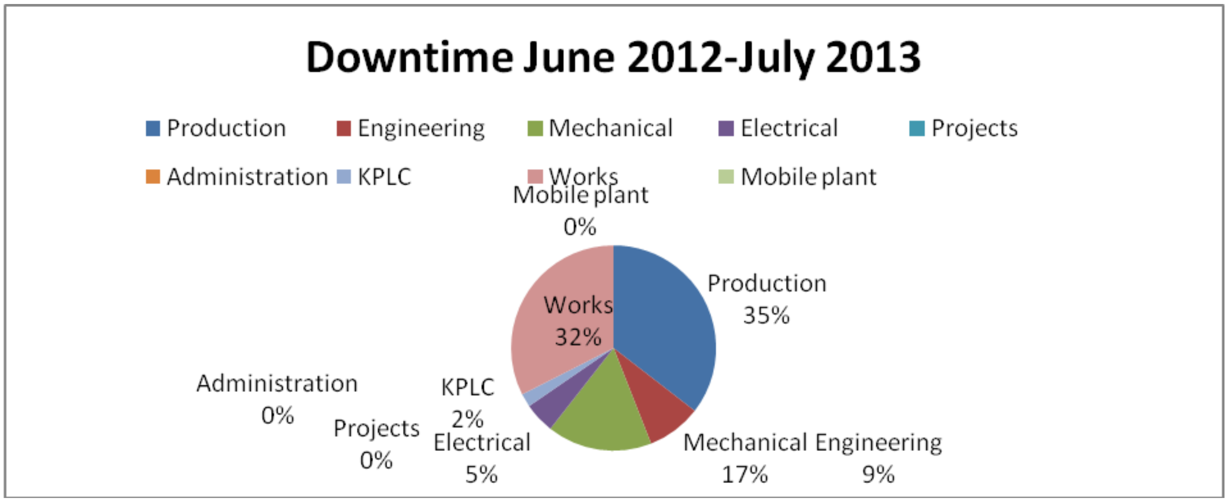
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
2010/2011	56.5	67.1	63.4	12.5	23.4	51.7	32.2	57.6	42.7	72.2	52.7	55.2
2011/2012	43.7	56.7	59.4	71.8	12.4	70.1	28.2	30.3	54.7	41.8	48.5	72.2
2012/2013	62.0	61.4	50.6	26.7	79	69.3	49.3	53.4	51.2	42.8	51.8	50.1
Target	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0

The achieved OEE value has a huge variance with the targeted OEE value. By comparing with the world-class value for OEE which is 85.41%, there was no single month for the last 36 months in which the targeted OEE value was achieved as shown in figure 3 above.

Raw mill downtime analysis

On the raw mill plant at EAPCC, the downtime ownership is grouped into eight categories: downtime due to production (scheduled cleaning, start ups, rework), engineering (planned maintenance), electrical breakdown, mechanical breakdown, projects, Kenya Power (power outage), administration and works (planned shutdown maintenance). The figure 4 below shows a summary for the contribution of each factor to the downtime on the raw mill.

Figure 4: **Raw mill downtime June 2012 – July 2013**



From the figure 4 above, we can conclude that production plays a big role in downtime of the raw mill (35%). It is followed by works at 32% and mechanical at 17%. A Pareto analysis reveals that by a reduction in the downtime of the three can greatly reduce the overall downtime of the raw mill.

Deductions from the data analysis

A best practice blend of maintenance strategies is 10% corrective, 30% preventive, 50% predictive, and 10% proactive. Current practice, however, has much room for improvement, with an average unplanned maintenance being over 60%.

From the analysis, we can conclude that OEE and MTBS metrics are the KPI that has a wide variation between the expected and the targeted value. TPM would be used to improve equipment reliability by redesigning the workforce in equipment care and improve maintenance function for continuous improvement.

Development of a maintenance concept

The study reveals that successful implementation of TPM requires top management support and commitment, a greater sense of ownership and responsibility from operators, cooperation and involvement of both operators and maintenance workers and an attitude change from "not my job" to "this is what I can do to help". The study shows how TPM can significantly contribute to improve the productivity, quality, safety and morale of workforce. In EAPCC, if there was any practice of TPM and team working between the maintenance and production people, this practice only existed informally, based upon personal relationship rather than taking it as TPM initiative. The study reveals the need for a more proactive approach to maintenance management and greater integration between maintenance and production departments. In EAPCC, the driving force came mainly from the maintenance department, which was keen to transfer some of basic maintenance tasks to their production fellows. But production operators resisted towards these changes as they have productivity pressure from middle management and they treat it as an additional workload. The study shows that implementing TPM is by no means an easy task without strong backup from the top management.

The following six step transformation approaches will be used in embedding high performance TPM culture within EAPCC.

Step 1: Workplace Review

This step will entail reviewing existing maintenance and asset management systems, processes, performance and maintenance data. The obtained data will be benchmarked against best practices and also compare with design capacity and subsequently make recommendation and develop action plans for improvement to bridge the gap.

Step 2: Change management process

Change management approach must be incorporated to minimize resistance by ensuring top management support and cultivating acceptance and ownership at operational level. This will involve On-job coaching to identify and resolve organization critical issues, Building skills and confidence through FET teams, Formal training and the Establishment of steering committee.

Step 3: Leadership workshop for senior managers

The Managing Director and some of his direct reports as well as senior leadership team in maintenance department need to understand the TPM principles and develop the key pillars of a successful TPM transformation strategy and implementation plan, this is one of the most important factors for success. Additionally leaders are involved in policy deployment process and become responsible and accountable for the outcomes. Policy starts with the vision and mission of the implementation and then the objectives are cascaded down to individual KPIs.

This step is the most important of all. The primary reason that TPM implementation fail is when senior managers are not fully supporting and driving the process.

Step 4: Translate strategy into a roadmap workshop

TPM deployment defines maintenance' strategic mission, determine what commitment is inherent in that mission, set goals for each commitment and determine how the company should measure performance against those goals. The aim of these programs is to enable more senior personnel to use the workshop outcomes and develop plans for their group input into the project.

Step 5: Training

An FET should consist of Operators, Technicians, Electricians, Electrical Engineer, Mechanical Engineer, Stores representative, Electrical supervisor and Mechanical supervisor.

The above group develops action plans and teams necessary to fix two top issues identified during the review process. The members in these teams must be given the time necessary to lead, organize and communicate changes to the practices and equipment. Improvement should be expected almost immediately (within two weeks to two months). Improvement team should report on fortnightly or monthly basis to senior management. This meeting would be used to monitor progress, show commitment of senior management team to the project, act as a development opportunity for the frontline team.

Step 6: Piloting area (Raw mill plant)

Raw mill plant will be used for piloting. Once successful the same process will be used for other areas. FET members gain practical experiences of TPM as they apply, adapt the concepts and tools. The practical experience forms the bedrock of the TPM learning not only for the individual team but also for the organization as a whole.

Step 7: Plant-wide roll out – Implement and standardize

Managers of each of each area will introduce the vision and the burning platform to team leaders and staff. Leaders need to demonstrate their commitment to the transformation, clarify and reach consensus on key lead and lag indicators that measure progress and actively engage workforce to deliver the outcome

Conclusion

The Overall Equipment Effectiveness (OEE) has been analyzed for three financial years (2010/2011, 2011/2012, 2012/2013) and it was established that the achieved OEE value has a huge variance compared with the targeted OEE value of 90%. By comparing with the world-class value for OEE which is 85.41%, there was no single month in which the targeted OEE value was achieved for the 36 months period

It was also established that the three major causes of low availability of the Raw mill plant are downtime due to production (scheduled cleaning, start ups, rework), works (planned shutdown maintenance) and mechanical breakdown. A Pareto analysis reveals that a reduction in the downtime of the three can greatly reduce the overall downtime on the raw mill hence resulting into improved availability

A customized framework of TPM deployment at EAPCC has been developed to improve Overall Equipment Effectiveness (OEE) to 85% and this will result into improved productivity and profitability.

The developed customized framework of TPM deployment at EAPCC could be adopted by other similar manufacturing plants and also be used along other literature. Comparative analysis of the various maintenance concepts has been done and OEE methodology explored to determine the need for TPM deployment. By developing an effective maintenance concept that binds together all the maintenance policies, maintenance actions and strategies for maintenance, the number of stoppages in the raw mill will greatly be reduced by increasing the mean time between stoppages. This will increase the monthly production for the company as a result of improved raw mill availability and reliability. With increased production, the revenue will be greatly increased resulting into increased profitability.

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