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Total Productive Maintenance Implementation in a Beverage Industry: A Case Study

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Abstract: This study examines the production performance of a beverage manufacturing plant. A 7 weeks study was undertaken at a beverage industry to gather various losses data associated with the functioning of the production line. A Total Productive Maintenance (TPM) Kobetzu Kaizen Technique was adopted to eliminate these losses and the concept was later compared with the plant's existing maintenance methods. Test results showed that a 7 day implementation of TPM increased the Overall Equipment Effectiveness (OEE) by 50% >7 weeks adoption of the in-house maintenance practices and with a high tendency of achieving >85% on overall equipment effectiveness if fully executed. Total productive maintenance was also found to be superior in reducing or eliminating losses as well as increasing equipment uptime.

Key words: Overall equipment effectiveness, total productive maintenance, Kobetzu Kaizen, Why Why Analysis, beverage industry, Nigeria

INTRODUCTION

The manufacturing industry is the leading sector of any country. It does not only make provision for various productions of human needs but also provides the material base for international competition. Establishing and coordinating production systems for the creation and exchange of utilities has therefore, always been the rationale behind the industry. Consequently, manufacturing excellence is needed to achieve cost, quality and delivery improvements in any productive setup in order to maximize profits without increasing the sales price of products. However, due to the increasing complexity of facilities coupled with equipment and systems needed to achieve these feats, the efficiency and effectiveness of operations can be achieved mainly through the improvement of existing maintenance management practices and operations.

Many industries in Nigeria operate productively for <50% of the functioning hours per year (Ogaji *et al*., 2004) while many others have become moribund due principally to excessive downtime, supply failures for input resources and low spare-capacity. Hence, the technology of maintenance is about finding and applying cost-effective ways of avoiding or overcoming performance deterioration while ensuring that its quality positively and significantly affects business profitability by eliminating downtime which reduces average rate (speed) of output, thereby increasing operating costs and subsequently leading to a lowering of average customers satisfaction (Ogaji *et al*., 2004). Hence, there is need to consider maintenance options appropriate in improving asset performance, safety, end-product quality, environmental health, process control and reduction of overall costs. Willmott and McCarthy (2001)'s comprehensive strategy that supports the purpose of equipment, plant or system's improvement in order to maximize its efficiency and product quality is the Total Productive Maintenance (TPM) which is built on the concepts of lean management, Just-in-Time (JIT) and Total Quality Management (TQM). It is carried out with a goal to hold emergency and unscheduled maintenance, to a minimum (Ogaji *et al*., 2004). It is also a companywide equipment maintenance system that stands on the following eight pillars: 5S, Jishu Hozen (autonomous maintenance), Kobetsu Kaizen (focused improvement), planned maintenance, quality maintenance, education and training, office TPM, safety-health and environment. Management, operational and maintenance staff come together as a team to develop schemes needed to reduce wastages thereby leading to an improvement in the end-product quality and minimizing equipment or plants idleness. TPM embraces planning and scheduling by supplying structures to facilitate assessment and mitigation of obstacles in order to increase the system's Overall Equipment Efficiency (OEE) and thereby having leaner organizational structure, multi-skilled workforce and rigorous appraisal of operations (Ogaji *et al*., 2004). These obstacles are also referred to as the six big losses as discussed (Tsarouhas, 2007):

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- Breakdown losses, it include time losses due to equipment failure and quantity losses caused by defective products
- Set-up and adjustment losses which refers to time losses from the end of the production of the previous item, cleaning through product-change adjustment to the point where the production of the new item is completely satisfactory
- Idling and minor stoppage losses which occur when production is interrupted due to a temporary malfunction or idling of the machine
- Reduced speed losses are the difference between design speed and actual operating speed
- Quality defects and rework losses are caused by malfunctioning production equipment
- Start-up losses occur during the early stages of production

According to Tsarouhas (2007), numbers (i) and (ii) are time losses, (iii) and (iv) are speed losses while losses (v) and (vi) are regarded as quality losses. These losses directly affect the quality rate of the equipment.

MATERIALS AND METHODS

The concept of TPM is applied to a bottling production line of a beverage bottling company situated in Lagos, Nigeria. Preliminary investigations were carried out to ascertain the previous performance of the production line with a view to developing appropriate improvement technique for the process. The plant's past production records were reviewed and data recorded in line with information indicated in the production analysis form shown in Appendix. The following steps were thereafter undertaken in conducting the study.

Identification of losses: The products of the organization undergo a continuous process of uninterrupted flow of operations. The major section of the entire production line was studied for 7 weeks during the morning and afternoon shifts. Equipment loss data collected during the period include: breakdown, speed loss, yield loss, defect loss and minor stoppage.

Identification of chronic losses through Pareto analysis: The ranking of these losses is based on the histogram (Fig. 1a) and Pareto chart for the losses in the morning and afternoon shifts as shown in Fig. 1b and c respectively. This principle also referred to as the 80:20 rule was used to analyze recorded failure data for classification, according to the level of significance.

Measurement of system performance: The plant's production performances were computed according to the following parameters:

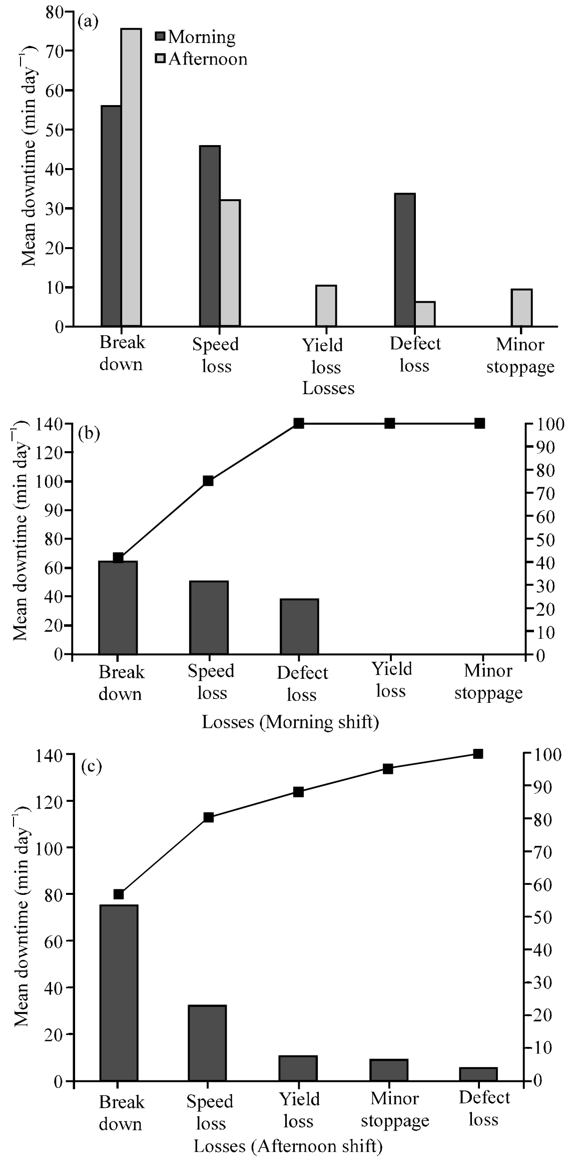

Fig. 1: a) Histogram for losses and Pareto chart for losses during; b) morning; c) afternoon shifts

$$\text{Line utilization (\%)} = \frac{\text{Net cases produced for a period}}{\text{Potential expected cases}} \times 100 \quad (1)$$

$$\text{Earned hours} = \frac{\text{Line utilization} \times \text{Paid production hours}}{100} \quad (2)$$

$$\text{Mechanical performance efficiency (\%)} = \frac{\text{Earned hours}}{\text{Schedules production hours}} \times 100 \quad (3)$$

$$\text{Line bottle breakage}(\%) = \frac{\text{Line breakage in cases}}{\text{Line net production in cases}} \times 100 \quad (4)$$

$$\text{Line defective products}(\%) = \frac{\text{Cases of defective product}}{\text{Line net production in cases}} \times 100 \quad (5)$$

$$\text{Line downtime}(\%) = \frac{\text{Line downtime (hours)}}{\text{Line production paid hours}} \times 100 \quad (6)$$

$$\text{Crown wastage}(\%) = \frac{\text{Theoretical no. of crown for net production}}{\text{Actual no. of crowns used}} \times 100 \quad (7)$$

However, using Eq. 1-7 on the data gathered, the plant's mechanical efficiency, stoppage losses per week, loading time per week, rate of quality product, availability and OEE is calculated for the period under study and shown in Table 1.

Calculation of OEE : From the data collected during the 7 weeks period of study, total defects per week (i.e., summation of bottle breakage, defective crowns and defective products) is 4149 while the stoppage losses per week expressed as the difference between scheduled production hours (running time per week) and earned hours give 37.8 h. Loading time per week which is running time per week less downtime per week is 62.3 h, leading to an availability of 57.7% (i.e., loading time per week/running time per week×100). Rate of quality product (i.e., difference of net cases produced per week and total defect per week divided by net cases produced per week) is 94.1%. Therefore, OEE (expressed as mechanical performance efficiency x rate of quality product x availability) becomes 35.3%.

Losses reduction through Kobetsu Kaizen analytical techniques: The Why Why Analysis (WWA) for TPM improvement is used in this study to eliminate the losses. This technique is a worksheet which focuses on logical reasoning to discover the whole chain of cause-effect so as to devise holistic multiple solutions (TPM, 2010). In Table 2, a cause is identified for the major problems and referred to as 1st factor for problem; this is verified if it can be broken down into further root causes.

Table 1: Calculated performance ratios and indicators for the 7 weeks plant study

Weeks	Total defect	Scheduled production (h)	Line downtime (h)	Earned hour (h)	Stoppage losses (h)	Loading time (h)	Rate of quality product (%)	Line utilization (%)	Mechanical performance efficiency (%)	Availability (%)	OEE (%)
1	4149	108	45.7	70.2	37.8	62.3	94.1	58.5	65.0	57.7	35.3
2	4494	110	48.5	67.0	43.0	61.5	93.3	55.8	60.9	55.9	31.8
3	4376	98	44.7	59.0	39.1	53.3	92.6	54.6	60.2	54.4	30.3
4	5164	107	51.6	63.6	43.4	55.4	91.9	53.0	59.4	51.8	28.3
5	4715	97	47.9	55.4	41.6	49.1	91.5	51.3	57.1	50.6	26.4
6	5584	106	54.8	59.6	46.5	51.2	90.6	49.6	56.2	48.3	24.6
7	4498	84	46.2	45.3	39.0	37.8	90.1	47.2	53.9	45.0	21.8

Table 2: Why Why Analysis (WWA) worksheet

Breakdown	First factor for problem	Verification	Second factor for problem	Verification	Third factor for problem	Verification	Counter measures
Filling valves failure	Air leakage	G	Worn out area of fillers fixed and moving unit	NG	-	-	Metal filling of the affected area; Replaced with new one
	Worn-out rollers on conveyer guides	NG	-	-	-	-	Replacement of worn-out guides
	Operators negligence	NG	-	-	-	-	Avoidance of visitors at sensitive sections; Training of production staff; Setting up of monitoring and inspection team
Washer failure	Washer (outlet and inlet delay)	G	Washer feed stoppage	G	Weak and worn-out bottle fingers	NG	Replacement with new one
			Discharge finger stoppage	G	Weak and worn-out Bottle in feed and discharge fingers	NG	Replacement with new one
	Operators negligence	NG					Avoidance of visitors at sensitive sections; Training of production staff; Setting up of monitoring and inspection team

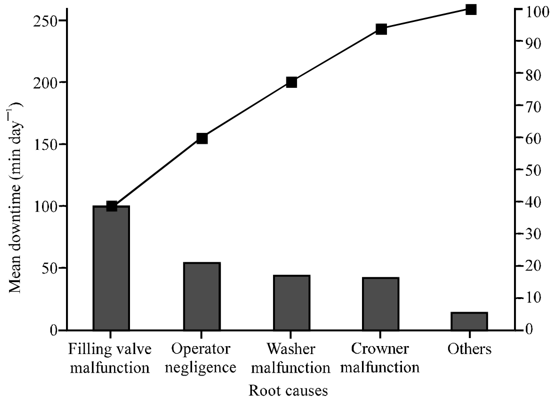

Fig. 2: The Pareto chart for root causes

It is then marked as G (Go) if possible and NG (Not Go) if impossible. If subdivision is possible, it is then continued to the 2nd factor verified and extended to the 3rd-5th until it is not possible again for further subdivision into root causes. Countermeasures are then identified for each root cause of the problem (Masud *et al*., 2007). It can be observed from the Pareto chart in Fig. 1 that breakdown and speed losses comprising approximately 78% of the total losses in both the morning and afternoon shifts are the two chronic losses affecting the performance of the production line. Hence for a significant improvement in OEE, considerable effort is needed in minimizing the two mentioned losses. The beverage bottling industry under consideration is made up of the following machines: fillers, bottle washers, crowners and conveyors in the entire production line. It can be asserted from (Fig. 2) that malfunctioning of the filling valves, washers in-feed and discharge fingers, crowners cone and operators negligence are primarily responsible for failures encountered in the plant, although the dominant root cause is the malfunctioning of the filling valves. WWA is thus employed in finding all root causes and appropriate countermeasures to the effect (Table 2).

RESULTS AND DISCUSSION

Breakdown losses were considered for reduction between the two significant losses. From the root causes shown in Table 3 and Fig. 2 filling valves and washers malfunctions were minimized using countermeasures provided by the WWA Technique to measure the effectiveness of implementing TPM on the plant for a 7 days period (Table 2). The performance indicators in Table 2 shown graphically in Fig. 3 revealed a consistent downward trend in scheduled production, line downtime, earned hour, stoppage losses, loading time, rate of quality product, line utilization, availability,

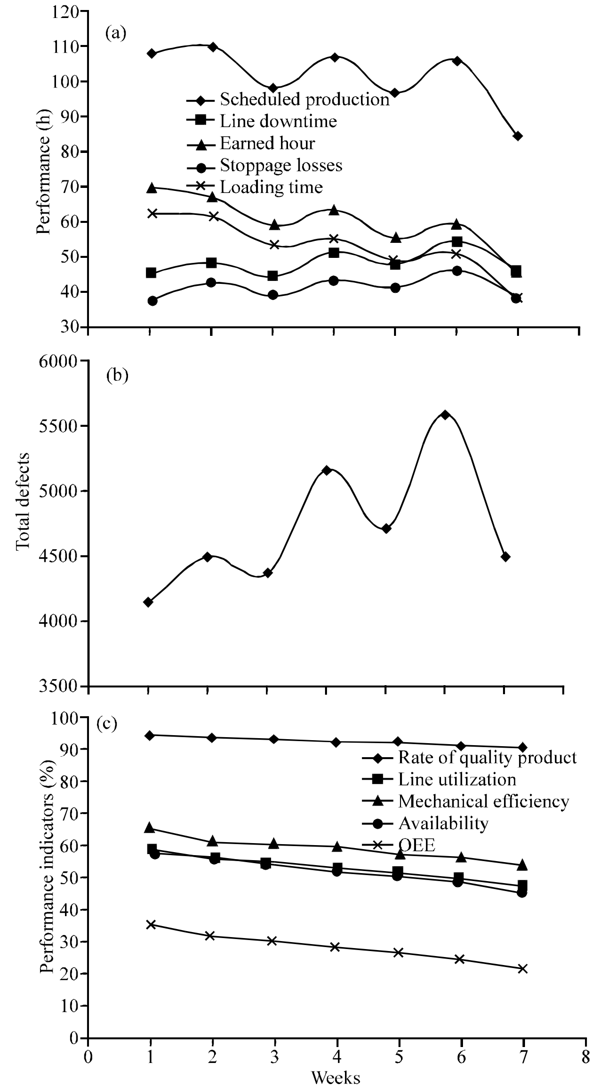

Fig. 3: a) Plant performance; b) total defects; c) performance indicators for the 7 weeks plant study

Table 3: Pareto analysis for the root causes

Major causes of breakdown and speed loss	Mean downtime (min)	Composition (%)	Cumulative (%)
Filling valve malfunction	100.20	38.96	38.96
Operator negligence	54.43	21.17	60.13
Washer malfunction	45.11	16.50	76.63
Crowner malfunction	42.42	17.54	94.17
Others	15.00	5.83	100.00
Total	257.16	100.00	-

mechanical performance efficiency and OEE with an increasing trend in the quantity of defects for the 7 weeks of monitoring the plant. However, it was shown that the production line witnessed a significant improvement in the indicators with the reduction of only the breakdown losses as shown in Table 4 and the upward trend of Fig. 4. The plant also witnessed a decreasing trend in

Table 4: Calculated performance ratios and indicators for the 7 days TPM implementation plant study

Days	Total defect	Scheduled production (h)	Line downtime (h)	Earned hour (h)	Stoppage losses (h)	Loading time (h)	Rate of quality product (%)	Line utilization (%)	Mechanical performance efficiency (%)	Availability (%)	OEE (%)
1	457	18.4	6.00	14.0	4.42	12.40	96.7	69.9	76.0	67.30	49.5
2	436	18.6	5.60	14.4	4.24	12.98	97.0	71.8	77.5	69.79	52.4
3	414	18.7	5.30	14.7	4.04	13.37	97.2	73.3	78.4	71.40	54.5
4	392	18.8	5.11	14.9	3.92	13.70	97.4	74.3	79.1	72.80	56.1
5	373	18.9	4.85	15.1	3.76	14.10	97.5	75.7	80.1	74.34	58.1
6	360	19.0	4.57	15.4	3.58	14.43	97.7	77.1	81.1	75.95	60.2
7	335	19.2	4.15	15.8	3.36	15.10	97.9	79.2	82.5	78.40	63.3

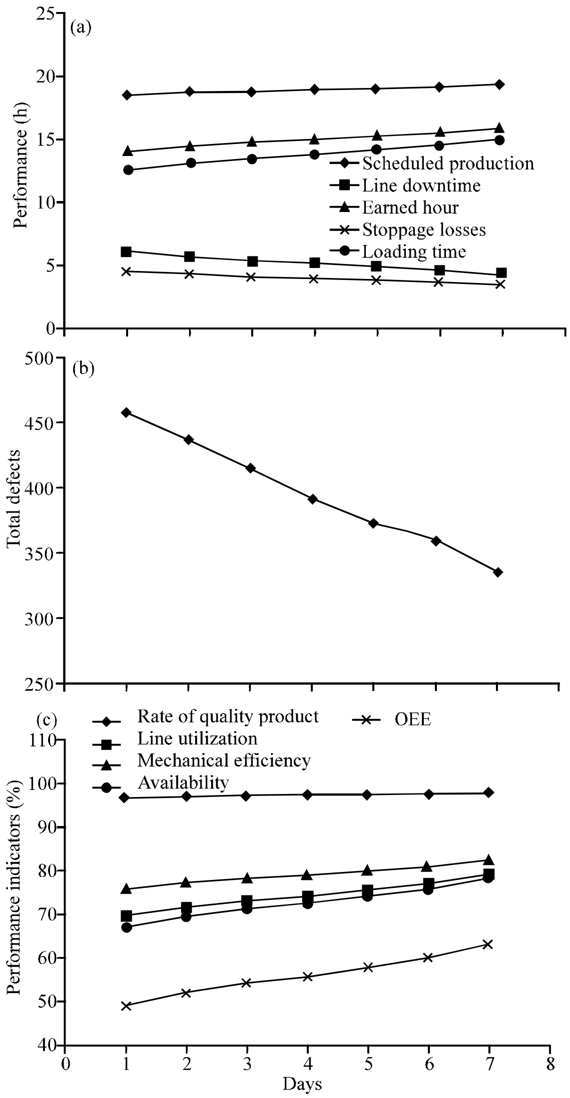

Fig. 4: a) Plant performance; b) total defects and c) performance indicators for the 7 days TPM implementation study

the stoppage losses, line downtime and quantity of defects. It was also observed through the implementation of the countermeasures provided in Table 2 that the plant experienced approximately 5.5, 29.1, 25.6, 28.7 and 50% upturn in the rate of quality, line utilization, mechanical efficiency, availability and OEE, respectively. The cumulative effect of removal of the remaining losses shown in the Pareto chart is under investigation. However, it is expected that complete elimination of the root causes responsible for all the losses will significantly increase the OEE.

CONCLUSION

The implementation of TPM using the Kobetsu Kaizen Technique has been shown to improve the OEE by 50% via reduction of only one of the big losses. The quality of products was also observed to have increased through the good condition of the machines. However, the involvement of the remaining TPM pillars as complement to the Kobetzu Kaizen principle and removal of the remaining losses, coupled with the following recommendations: high spare parts on-time delivery, the practice of using checklists with autonomous maintenance plan to strengthen TPM implementation will further lead to a significant increase in production performance, employee morale and job satisfaction, thereby increasing the OEE to the world class levels which are expected at 85% and before discussed.

APPENDIX

Production analysis form

Weeks	1	2	3	4	5	6	7
Date							
Paid production hours							
Net cases produced							
Expected potential cases							
Line utilization							
Line downtime (h)							
Percentage downtime to paid production hours							
Scheduled production hours							
Line mechanical efficiency (%)							
Number of direct employee on line							
Total line direct man-hour							
Man-hour utilization							
Line breakage (cases)							
Line breakage to net production (%)							
Cases of crown wastage							
Crown wastage to net production (%)							
Cases of defective product							
Defective product to net production (%)							
Product on line							

REFERENCES

Masud, A.K.M., A. Al-Khaled, S. Jannat, A.K.M.S.A. Khan and K.J. Islam, 2007. Total productive maintenance in RMG sector a case: Burlingtons limited, Bangladesh. J. Mech. Eng., ME37: 62-65.

Ogaji, S.O.T., M.C. Eti and S.D. Probert, 2004. Implementing total productive maintenance in Nigerian manufacturing industries. Appl. Energy, 79: 385-401.

TPM, 2010. TPM Overview: Manufacturing and administrative excellence. ZenPower International. http://www.plant-maintenance.com/articles/QuickTPMInotrduction.pdf.

Tsarouhas, P., 2007. Implementation of total productive maintenance in food industry: A case study. J. Q. Maintenance Eng., 13: 5-18.

Willmott, P. and D. McCarthy, 2001. TPM: A Route to World Class Performance. 1st Edn., Butterworth-Heinemann, UK.