

Implementing Successful Total Productive Maintenance (TPM) in a Manufacturing Plant

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Abstract — This study examines the impact of Total Productive Maintenance (TPM) implementation on an organization in terms of productivity and quality levels. The human resource aspect was investigated to assess motivation of operators through training to reduce set up times, change over stoppages, defects rate and resource wastage on the shop floor. Total Productive Maintenance (TPM) implementation case study was evaluated in addressing these short comings in a confectionary manufacturing plant.

Index Terms — TPM, waste, autonomous, maintenance, multi-skilling, losses

I. INTRODUCTION

To survive in this global marketplace, companies should respond to the rapidly changing stakeholder expectations, which include a growing awareness of the connection between maintenance and quality performance [1]. The extent to which equipment failure affects safety and the environment, and increasing pressure to achieve high plant availability in response to the market, and to contain costs; all of which are poignantly pertinent to Zimbabwe today. In a highly competitive market, companies resort to various tactics to stay alive. The five performance objectives used by companies to stay competitive and maintain their market share are speed, pricing, dependability, flexibility and quality [2]. Thus, there is now need to measure the efficiency of business operations and discuss how to increase it.

To achieve quality in all facets of manufacturing operations, implementation of Total Productive Maintenance (TPM) is required [3]. TPM seeks to put together best practices for capital-intensive continuous batch production processes to improve equipment efficiency and material yield [5]. In the end the overall equipment efficiency (OEE) will lead to a firm's improved productivity and competitiveness [4].

II. BACKGROUND

The focal point of the study was to find a balance between the machines that the operator uses, the operator himself and the human resource strategy used to facilitate this balance.

Manuscript received February 27 2015

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The question to be addressed is how a human resource strategy can be used together with Total Productive Maintenance (TPM) towards TQM improvement.

TPM concept is based on the notion that productivity can be improved if operators perform daily inspections, lubrication, parts replacement, troubleshooting, accuracy checks and so forth on their equipment with the aim of "keeping one's own equipment in good condition by oneself". In this way, the machine reliability is greatly improved [6].

The resultant de-motivation in the operator workforce has been suggested to be responsible for the observed poor house-keeping, high defect rate, associated frequent breakdowns and unplanned work stoppages in the case study plant. To address these challenges, a human resources based maintenance approach is required to provide employees with confidence which in turn will be imparted towards overall equipment/machine efficiency and profitability as put across in the Total Productive Maintenance (TPM) philosophy [11]. In all this, higher level of production effectiveness is attained in terms of cost effectiveness, safety, employee motivation, product quality, reduced defects rate and market positioning in order fulfillment [10].

III. TOTAL PRODUCTIVE MAINTENANCE (TPM) REVIEW

TPM is defined as productive maintenance carried out by employees through small group activities. Thus to say TPM succeeds not because of its engineering techniques but because of its reliance on training and team empowerment [9]. It addresses the maintainability of the machine that ultimately leads to improved productivity. It also captures the need to produce the technical and skill training needed to meet the sophistication of operation and maintenance arising from equipment automation, and to foster worker proficiency in the plant [8]. The goals of TPM include the maximizing of overall equipment efficiency (OEE) in a multiple model, small lot production system that eliminates equipment failures, defects and accidents. General improvements in quality and productivity and the creation of a more positive atmosphere in the workplace are also central to TPM philosophy [6].

The history of TPM is traced back to the 1960's in Japan when it was developed from preventive maintenance. The Japan Institute of Plant Engineers (JIPE) realized that it was a new maintenance system tailor made for Japanese corporate culture. After defining and systematizing it, the institute set out to spread the word to the industry [7].

The rapid spread throughout the Japanese industry and the world, of TPM was a testimony of guaranteed dramatic results. As its implementation visibly transformed the workplace, and raised the level of knowledge and skill in both production and maintenance workers.

A. Effectiveness of TPM in achieving TQM

When implemented, the effectiveness of TPM can achieve zero breakdown and zero defects. Once breakdown and defects are eliminated, equipment operation rates improve, costs are reduced, inventory can be minimized, and as a consequence, labour productivity is increased. Such results cannot be achieved over-night, typically three years are required from the introduction of TPM to achieve prize winning results [5].

In the early stages of TPM, companies that are practicing TPM must bear the additional expenses of restoring equipment to its proper condition as well as educating personnel about the equipment [2]. The actual costs depend on the initial quality of equipment and the technical expertise and experience of maintenance staff. As productivity increases, however, these costs are quickly recouped. That is why TPM is often referred to as a “profitable” initiative [8]. The power of TPM consists of continuous improvement, application of technology and people motivation to achieve Total Quality Management.

The effectiveness of TPM in supporting TQM is in achieving efficiency by eliminating losses resulting from equipment failure, set up and adjustment, minor stoppages, process scrap and defects, and reduced yield.

B. Improvement Activities to avoid major Losses

Eliminating loss due to failures: Machine efficiency deterioration is major reason for failures in the plant. This problem can be addressed through exposing hidden flaws by stopping the machines in a planned manner before defects occur and to deal with the flaws properly. Measures have to be taken to handle this include: establish the basic condition (clear, lubricate, tighten), maintain the basic operating condition, restore all deterioration functions at the original level, improve the design weakness of the machinery; and strengthen operation and maintenance skills [10].

Eliminating loss due to defects and rework: Steps have to be taken as well to eliminate loss due to defects and rework of products by classifying the manifestation of problems and clarify their particulars. This can be followed by analysing the manifestations physically. And from this all factors that are connected with the manifestation, and causes are identified individually. Then, if possible corrections are made as part of a unified whole [11].

C. Autonomous Maintenance

Operator skill development strengthens the communication and cooperation between the production and maintenance departments. Thus autonomous maintenance is about machine maintenance, and focuses on a TPM activity such as improvement, education and training [10]. It is implemented gradually in well-defined steps such as cleaning, taking measures at source of problem, making inspection routines, improving work organization and tidiness.

As these steps are taken, over an agreed and achievable time span, operators will develop skills which enable them to play a greater role in ensuring optimum availability of machines. Activities of autonomous maintenance are aimed at inhibiting equipment deterioration and to detect problems [5]. Some of these problems, like cleaning and lubrication can be easily

corrected by the operator, whereas more complicated problems can be handled by a skilled technician.

D. Overall Equipment Efficiency (OEE)

Overall Equipment efficiency (OEE) as a statistical measurement of the efficiency of a machine, it is a key metric of TPM. Correct OEE percentage typically indicates whether a machine is running at optimum capacity and producing quality output or experiencing unnecessary downtime. It is a comprehensive indicator of a plant condition that takes into account operating time, performance and quality. It can be used to judge the efficiency with which the plant is being used to add value [8].

Most companies have some kind of gauge system on their equipment that measures quantities such as time, units produced, and sometimes even the production speed. These are appropriate parameters to monitor if the focus is only on what is coming out of the machine. TPM takes a slightly different approach. Besides what is coming out of the machine, the focus is also on what could have come out, and where the loss in effectiveness occurs. Overall Equipment Efficiency (OEE) offers a simple but powerful measurement tool to probe information on what is actually happening [9].

OEE measurement formulae [2]

Availability (A) – is the total percentage of time for which a specific machine will be available/scheduled for production purposes

$$A = \frac{\text{Loading time} - \text{downtime}}{\text{Loading time}}$$

Performance rate (P) – is the percentage of units produced per time frame of maximum rated production speed. It is determined by how much waste is created through running at less.

$$P = \frac{\text{Theoretical cycle time} \times \text{processed amount}}{\text{Operating time}}$$

Quality Rate (Q) – this determines the percentage of sellable units produced per time frame. It focuses on identifying time that was wasted by a product that does not meet the quality standards. It is quite obvious that the higher the reject rate, the poorer the performance of the equipment.

$$Q = \frac{\text{Processed amount} - \text{defects amount}}{\text{Processed amount}}$$

E. World Class Manufacturing

World class manufacturing (WCM) refers to a quest for continual improvement of quality and to achieve customer satisfaction. It is one that fulfils customer demand for high quality, low costs, short lead times and flexibility [7]. This is a concept that the manufacturing company needs in order to be competitive with other companies in its related field. If WCM is a destination, then Total Productive Maintenance is a vehicle, which should drive companies towards WCM. TPM

is the first known successful model, which addresses machine efficiency and maintainability of those machines. It was observed that once this practice is maintained, the organisation can increase machine efficiency and hence productivity [1].

F. Man / Machine Relationship

The overall purpose of any man-machine systems is to provide a certain function, product or service as an output with reasonable costs, even under conditions of disturbances influencing man, machine or both. The main goals of a man machine system are expected levels of performance, costs, reliability and safety [3].

People are the most important component of a firm's TQM thrust and the manner in which they are managed, treated and respected will have a bearing on their performance and the turnover and financial viability of a firm. Growing evidence strongly suggest that without the effective management of people, the full potential benefits of technology cannot be completely realised.

Qualities of work life programs, quality circles and labour management teams are all forms of participation that allow employee to have direct input into the production process. Likewise, information sharing programs, formal grievance procedure, and profit and gain sharing plans help to increase the probability that employee participation efforts will be effective because such programs will provide a formal mechanism for employer-employee communication on work related issues [3]. Specifically, a formal job design program and enhanced selectivity will help ensure employee-job fit and the provision of formal training will enhance the knowledge, skills, and ability of both new and old employees [7].

The use of effective human resource management practices enhances firm's performance, extensive recruitment, selection and training procedure, formal information sharing, attitudes assessment, job design, grievance procedure and labour management participation programs, performance appraisal, promotion and incentive compensation systems that recognise and reward employees on merit, have all been widely linked with valued firm outcome [9]. It is in this regard that TPM initiative, becomes a vehicle through people to make progress to achieve higher level of productivity.

IV. METHODOLOGY

The plant survey was done and structured so as to improve operations through Total Productive Maintenance (TPM) implementation, with main focus on machine operations, management support, skills-training for operators, and human resource input for its success. TPM is concerned more with more equipment efficiency and, hence need for analysing prevailing maintenance system. The case study organisation had a human resource department that deals with personnel issues across the firm, however team integration was not visible to handle TPM related productivity issues. Thus low TQM level was witnessed in terms of quality deployment. The research study evaluated the impact of TPM when practised together with an innovative human resource element to yield positive results. The sweets manufacturing line within the confectionary plant was singled out for the study, to compare TPM results with previous period performance. Interviews

were conducted with the managers, supervisors, operators and technicians on gathering key information and aspects to be addressed by TPM and achieve acceptable levels of TQM.

V. CASE STUDY REVIEW

The study was based on Candy (Pvt) which is a division of a multinational firm that manufactures several products that includes chocolates and sweets, and it employs 205 people. It currently uses an estimated base denominator activity, when calculating the resource capacity overhead absorption rate, which is based on expected sales volume when generating the annual production budget. Thus the focus is on the projected sales compared to the actual capacity of the business's resources. This approach ignores spare capacity and, more importantly product costs and how it affects productivity. The company was also in the processes of implementing a 5S's system on all production operations to eliminate waste in its manufacturing processes shown in Fig 1 to achieve higher levels of TQM in the plant.

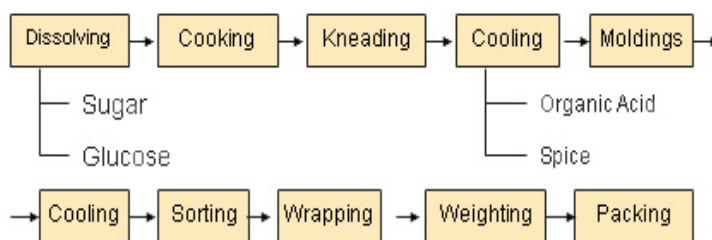


Fig 1 Sweet making process flow

The firm introduced key performance indicators (KPI's) as it sought to improve high productivity to maximize the utilisation of available plant and equipment. Thus, there was a need to measure the efficiency of business operations and discuss how to increase it. Hence adoption of Total Productive Maintenance (TPM) to introduce a collection of best practises available to improve their batch production process to high equipment efficiency and material yield.

VI. FINDINGS AND DISCUSSION

Data was collected from the TPM role players involved in manufacturing through an extensive survey process which included various kinds of questionnaires coupled with personal interviews as well telephonic follow-ups. The key management areas looked at were:

- Skill acquisition and training
- Decision making, problem solving and job design
- Recruitment, selection and promotion
- Performance appraisals
- Management support system in the form of motivation and incentive compensation system that recognizes and rewards employee on merit.

A. Skill Acquisition and Training

It was indicated that the operators were happy with the content and scope of TPM to improve operations. The reason cited in the open-ended questionnaire is that the operators were able to apply the knowledge they acquired from training adequately without further assistance from management.

Training was required as a multi-skilling aspect to enable operator-based maintenance. This was going to inculcate a sense of pride in staff members, as they would feel that they are part of the organisation and not people just to sell their labour to the company.

Management was also called to support staff members who strive to improve their education outside the company through provision even of financial assistance to institutions of higher learning. However, some members of management did not see the value of training as employees did not seem to improve after they had attended the training session.

There was great emphasis for operator training requirement on the job. On the job training was viewed as important since it exposed the operator to new skills within a working environment, without losing useful man-hours of work.

The company did not recruit operators with a high level of education, and it had to promote the same operators from within the company to assume more responsibilities. Hence it faced a challenge in providing high-level technical training to some of these employees.

In view of the low level TQM standards, the main thrust of TPM trainers' early work involved improvements to routine maintenance and work practices. They worked with elected individual production teams to identify all areas of the machines that had to be lubricated, cleaned, adjusted or otherwise regularly maintained. A picture of a clean and well-maintained machine is shown in Fig 2 below.



Fig 2 Typical automated manufacturing sweet wrapping machine

The TPM practice required that operators identify places on the machine where there was an oil leakage, dirty area, a place where there was an abnormal noise or vibration. These areas were labelled so that they could be clearly identified by everyone.

Then each team prepared comprehensive working instructions that clearly set out responsibilities and operations routines. Not only did this release the plant technicians to undertake other more complex work, but also ensured that the day-to-day condition of the plant was greatly improved. This led to operations teams owning the routine tasks as well as machines they operate on and this resulted in great improvements in productivity. Overall Equipment Effectiveness (OEE) improved as a result of the TPM activities.

The skill transfer allowed technicians to pass over the skills to operators. Over time these operators were able to

operate and fix those machines releasing technicians to do more challenging jobs like designing machines, re-engineering as well as concentrating on research and development.

TPM training being a continuous process, hours were set aside to train operators on TPM skills. Weekly meetings involving all two shifts were held. Problem solving was done in the form of 'root-cause-analysis' using a combination of more experienced operatives and good technicians to address challenges on individual machines.

The numbers of short stoppages have been reduced from 1.5 hrs to 0.5 hrs per shift. Investment has been made in people development which has enabled the company to solve problems at low engineering costs in line with TQM requirements.

TPM introduction brought with some structural changes. The manufacturing organisational structure changed significantly. The company adopted a lean structure. This situation did not make everyone happy especially supervisors who came from the "old school", who were good at following routines such as record keeping, and focused on the immediate output of their shift, which is often referred to as "getting pallets out of the door".

B. Decision Making and Job Design

The ability to make decisions is an important factor by an employee. The survey indicated that employees at the company were not trained to take decision with a resulting negative bearing towards company productivity. Typically employees only provided input and recommendations, they did not make substantial decisions, nor did they have the budget or power to implement their recommendations.

The operators were given powers to make some changes without consulting with their supervisors/managers. This employee empowerment encouraged the firm to have a positive bearing on employee motivation, performance and quality improvement.

Many situations in the future would require employees to implement decisions in high stakes environments, which makes it critical that they receive training in decision making capabilities. One of the many tasks of operator is that of a problem solver. It is therefore important that the employee be empowered to make decisions and be allowed to solve operations related problems.

C. Staff Recruitment

There was a minimal recruitment over the period under review (February –December 2014). The main reason was that in both periods there had been extensive automation of some processes. This means that automation replaced labour force by greater percentage. The firm resorted to training personnel internally in order to equip them for the new automation challenges.

D. Performance Appraisals

Performance appraisal was used by the company to assess the performance of employees. The appraisal job was pushed down to workers by supervisors who were never exposed to any kind of performance appraisal systems. Appraisals were sometimes used as a 'stick' to punish employees and not as a

feedback to address problems and to help employees to improve their performances. Appraisals were regarded with suspicions and there was always tension during the appraisal period.

E. Management Support, Motivation and Incentive Compensation Systems

The survey carried out at the company indicated that motivation to produce was positively related to employee performance and subsequently an increase in the company productivity.

It was determined that the problems causing lack of success in operations at the case study organisation, were human resource related problems. There were no real operational problems and if they occurred they were easily discovered and dealt with immediately by operators.

It was established by that motivation could be considered as a force which can pull individuals towards a desired objective. This force can be created by the introduction of motivational factors and proper human resource strategy. The issue of empowering workers to enable them to make decisions is what TPM encourages. This element is more evident at the company now ever since the Super Operator (TPM) training was introduced.

There was an improvement in labour relations during the periods under review. This is evident as the company introduced a number of motivational incentives to workers. The main one is training followed by management making the working environment conducive to work. These have benefited TPM in the sense that workers were allowed to run the plant as if it belonged to them. There was a sense of responsibility and independence making workers flexible in operation processes. The records showed an increase in company performance as a result of motivated workers as given in Table I below

TABLE I
SUMMARY OF TPM KEY PERFORMAMANCE INDICATOR (KPI'S)

Performance Measure	2013	2014
Short stoppages per shift (hours)	1.5	0.5
Plant availability (%)	57	68
Operator turn over (per 3 months)	6	4
Overtime per shift (hours)	8	5

Total Productive Maintenance (TPM) needs management support system and other human resource input to able to function well. Therefore, good human resources management practices, can affect employee motivation by encouraging them to work both harder and smarter. Highly motivated and well-trained people with skills contribute to organisational performance to achieve high level of TQM.

VII. RECOMMENDATIONS

TPM should not be a stand-alone process but it must include the best application of human resource strategies in

order for it to be effective to realize high productivity oriented results.

The survey analysis conducted on skill acquisition and training revealed that there were obstacles in terms of passing skills from technicians to operators as required TPM guidelines. These included the reluctance of technicians to pass these skills. As such this could have slowed down the implementation of TPM in that factory. This could be overcome by declaring worker participation in the TPM direction of the organisation and get an employee buy-in.

Most employees were never taken for intensive mechanical training and therefore lacked through knowledge of machines. This posed a challenge in deriving root causes of machine break downs. The company should develop the skill matrix plan that records the training levels of all personnel. The matrix help to map the training path of workers. It sometimes gives a history of the training that an operator has undergone. Keeping track of training prevents workers from receiving unnecessary repetition of training.

TPM espouses that operators become more closely involved in getting the very best from their machines by self-directed maintenance steps. The ability to take decision to solve problems on the spot, especially as a group, is vital to its success. To instil the practical aspects of the program, a team of TPM instructors may be required to give a hands on learning points through explanation, demonstration, practice and confirmation on the shop floor. This will put the onus on the operators or group to act on the spot and solve the problems even at night when managers are away.

The survey indicated that many appraisal problems were recorded in the company where the relationship between managers and employees, according to one respondent, been strained. This strained relationship is a breeding ground for hostility and that is where prevalence of unfair performance appraisal emerges. The impact of appraisal performance process on TPM is that performance appraisal should "level the playing field or the working environment" for workers to be able to exercise what they have been trained to do as required by TPM procedures.

The company can reach the highest level of TPM manufacturing process, if the company concentrate on improving the skill of the operators and they should even go an extra mile by giving operators external training to enhance their skills. Besides management support system, the company can exercise worker flexibility as an element of trust that is shown by management to its employees. Financial incentives are always immediate motivation factors, but management at the company should not only use this as incentive, but other incentives which give a sense of belonging to the worker.

VIII. CONCLUSION

This study has shown that companies should not only concentrate on machine or equipment to achieve TPM for higher profits and productivity, but must also focus on their work force; the very work force that is driving its production functions. In hierarchical companies, the shop floor level is regarded as low with limited say in solving problems or taking decisions. This has been found to detrimental towards the company growth and leads to a demotivated workforce which

may have an adverse impact on productivity. An integrated management system which includes technicians and operators into one body can benefit the company. This will facilitate information sharing, core-decision making and transparency which will benefit the company at the end in its bid and mandate to achieve high quality deployment through TPM philosophy.

Management Business & Business Excellence. Routledge, London WIT,UK. Vol. 17 (5): 655-667.

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