Enhancing OEE as a Key Metric of TPM Approach-A Practical Analysis in Garments Industries

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Abstract — Ready Made Garments (RMG) sector has been the biggest earner of foreign currency for Bangladesh since the last few decades. Garments industries have been playing a major role in redefining the infrastructure and economy as well. Today's world of competition brings both opportunities and challenges in this sector. Productivity, efficiency of these industries can be achieved through implementation of perfect maintenance strategy and design. This paper aims to enhance the existing Overall Equipment Effectiveness (OEE) for the pitfall areas in the plant. After examining the current loophole, the research focused on improving OEE factors by adopting a hybridized Total Maintenance (TPM) scheme. To achieve a better outcome, the company agreed to implement the recommended plan appropriately. The OEE has been upgraded from about 57% to 69% due to the proper management and execution of the proposed TPM model. The result has provided an indication of maintaining sustainability to achieve the world class benchmark and founded a solid basis to implement the exploratory TPM model in the plant.

Index Terms — Ready Made Garments, Productivity, Overall Equipment Effectiveness, Total Productive Maintenance.

I. INTRODUCTION

In Bangladesh the RMG sector began its business in the 70's but it was then solely an unpretentious effort. Subsequently it has become a sustained success story for the Bangladesh RMG sector [1]-[2]. Currently according to the latest statistical review in Geneva (2020) of the World Trade Organization (WTO), Bangladesh's global clothing export market share has increased to 6.80 percent where annual export of clothing or readymade garments was around \$34 billion which holds the second position only behind of China [2]. Besides, this sector also provides employment for over four million people. Observed such bright potential, the Bangladesh government has set an RMG export target of \$50 billion by 2021 which will undoubtedly difficult to achieve; because, there are so many obstacles which could impact on this growth like development of other garment production hubs, digitization and mechanization of the production process, the entry of new competitors, improper utilization of every resources and the dynamicity of the international apparel industry [3]. To obtain governments

above targeted value and sustainability in this competitive business environment, both public and private enterprise should provide concentration on some factors such as proper utilization of every resources, availability of production equipment's, modernization of mechanism and elimination of wastages so that the production can be cost effective as well as the better performance of an organization [4]. One of the key factors to resolve above problems is proper maintenance of production equipment's which plays a significant role in every aspect of production system. This is because sudden break down of equipment's can interrupted many other factors [5]. For pursue of relieving from sudden break down or enhance machineries performance and/ or increase available running time, this research deals with implementation of Total Productive Maintenance (TPM) which was first initiated by Japanese in 1971 [6]. Total Productive Maintenance is a holistic approach to equipment maintenance that strives to achieve perfect production by eliminating breakdowns and defects, avoiding slow running, optimizing equipment's effectiveness and promotes autonomous maintenance by operators through day-to-day activities involving in the total workforce [7]. To observe the effects of TPM in an organization, the key metric called Overall Equipment Effectiveness (OEE) must be encountered. This OEE was first introduced by Nakajima (1988) in the context of TPM and is focused on equipment's or machineries [8] which provides benefits to monitor, control and improve the equipment's effectiveness of manufacturing by encompassing all three measuring factors of availability, performance and quality [1]. This three factors calculation procedure described in details on research methodology of this study. In existing scenario and according to the statement of employees in the organization, the organization was capable to practice some pillars of TPM initially. But in the long run the remaining pillars was unimplemented due to some barriers i.e., manpower costs, organization resistance to change, unwillingness to commit resources, resistance by employees, lack of knowledge regarding TPM, lack of training, improper constitution of teams, inappropriate tools and instrument, repair driven maintenance, issues in design modification and unavailability of standard operation procedure etc. So, this research provides an outcome of a proposed TPM model implementation in terms of OEE by overcoming above mentioned challenges for a garments industry and allows the organization to benchmark and monitor them. The research will be applicable for any small to medium scale manufacturing industries.

Nayak M.D. et al. [9] conducted a research and concluded that six major losses have significant effect on OEE calculation and were also capable to identify loss

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minimization factors to achieve the world class standard value of OEE. Gupta K.A. and Dr. Garg K.R. [10] executed a study in an automobile industry to observe that whether TPM implementation improves OEE or not. Jain A. et al. [11] believed that for medium to small scale industries enterprises apply some positive changes in proper way like shifting the inventory room, cleaning the machines before and after working, trained local people as a backup of the absence of the operators resulting improves OEE significantly. Eldridge S. et al. [12] directed a research and concluded that there was strong correlation between Process Capability (PC) and Overall equipment effectiveness (OEE) by considering Cp/Cpk value 1.33 as an ideal target for OEE. Vijayakumar S.R. and Gajendran S. [13] focused on improving the Overall Equipment Effectiveness of Injection Molding Machine (IMM) through the implementation of availability, better utilization of resources, high quality of products and also raising employees' confidence. The research concluded with the huge change that was the OEE of Injection Molding Machine was increased significantly which is considered as world-class OEE [13]. According to the research of Singh M. and Dr. Narwal M.S. [14] it can be stated that OEE can be increased not only by minimizing the breakdowns and changeovers losses which are associated with availability but also by minimizing the defects and setup scraps losses which are associated with quality. Elevli S. and Elevli B. [15] showed that possible time losses for mining equipment, more specifically shovel and trucks, and how they could be used to calculate OEE. They used two methods called loading time-based approach and calendar time-based approach to estimate OEE and concluded that the first one is better. Eswaramurthi K.G. and Mohanram P.V. [16] developed Overall Resource Effectiveness (ORE) for pursuing of improvement of Overall Equipment Effectiveness (OEE). ORE was used to overcome the challenges of resource related losses. Dal B. et al. [17] demonstrated with three major points. 1) OEE as an indicator of performing ability 2) The contribution of OEE within the context of performance 3) Implementing OEE with some specific observations. Nallusamy S. et al. [18] defined some factors like lack of knowledge, operator awareness, not having standard operating procedure (SOP) for maintenance is the key obstacles to TPM implementation. After eliminating these obstacles and implementation of TPM showed that the performance levels of machines and their productivity were enhanced and the OEE were improved by reducing the rejection rate.

II. METHODOLOGY

This research is mainly performed to measure the existing situation of OEE and then improve it by comparing with world class standard in a garments industry. OEE analysis is mainly done to determine the existing effectiveness of the industry resources and then emphasize on pitfall areas. Overall Equipment Effectiveness (OEE) is a key measure of TPM.

A. Data Processing and OEE Calculation

Availability = Total available operating time / Total planned production time.

Where, Total operating time = Total planned production time – (time consumed/wasted in unplanned/sudden breakdowns and startup losses).

And, Total planned production time = Total operating time – (time allotted for planned breaks and machine breakdowns for scheduled maintenance)

Performance = Total minute produced / Total operating time

Quality = (Amount produced – Amounts defects – Amount reprocessed) / Amount produced

Therefore, Overall Equipment Effectiveness (OEE = Availability X Performance X Quality [4].

TABLE 1: WORLD CLASS OEE

OEE Factors	World Class
Availability	90.0%
Performance	95.0%
Quality	99.9%
OEE	85.0%

B. Root Cause and Effect Analysis

Cause and Effect analysis also known as fishbone diagram is a technique used for quality improvement by identifying its main causes and hindrances. By compared between world class value and existing scenario of OEE, this step helps to identify major causes of poor OEE and what factors or sub factors should provide more concentration. According to this, a modified TPM model (Pyramidal Model) was developed and suggested for the company to implement [21].

C. Modified TPM Model (Pyramidal Model) Implementation

The meteoric altering requires of modern manufacturing and the ever-increasing global competition has focused on the re-observed the role of improved maintenance management towards enriching enterprises competitiveness. A modified TPM model is proposed to improve their OEE. In This developed model in shown in the following figure:

(a) Quality Maintenance: This step focuses on effective implementation of operator quality assurance and detection and segregation of defects at the source

(b) Kaizen: The kaizen event was used to reduce the waste and non-value-added activities in order to minimize the time needed to flow through the processes. This step was implemented and the effects was investigated during implementation [11].

(c) Planned Maintenance: For the implementation of this step first of all, Evaluate and record present equipment status; second, restore deterioration and improve weaknesses; third, build information management system; fourth, prepare time-based data system, select equipment, parts, and team, and make plan; and finally, Evaluate planned maintenance.

(d) Autonomous Maintenance: To implement Autonomous maintenance successfully various approaches were taken like giving training to operators on their daily maintenance by floor in-charge. An operator will take good care of machines only if he feels ownership of the machines. Prepare Autonomous maintenance check list by floor in-charge and make it mandatory for all the operators [19].

Fig. 1. Proposed TPM Model.

(e) 5S: This is known as the basement of proposed or modified TPM model (Pyramidal Model). 5S refers to five steps – sort, set in order, shine, standardize and sustain. This is the first initiative for the OEE improvement of this research. This step deals with proper organization of the workplace so work can be performed efficiently, effectively and safely. This 5S philosophy focuses on putting everything where it belongs and keeping the workplace clean, which makes it easier for people to do employee jobs without wasting time or risking injury [7].

(f) Education and Training: This point embrace and angularly integrate and empowered others in the pyramid. Training should be provided to the operators and floor in-charge on the regular basis at aims to have multi-skilled revitalized employees whose morale is high and who are eager to come to work and perform all required functions effectively and independently. It is necessary to train them to enable the operators to maintain their own machines, understand why failures occur, and suggest ways of avoiding the failures occurring again.

D. Observation and OEE Reevaluation

After implementation of Pyramidal shape TPM or derivative Model, the scenario of the industry was observed and the relevant data was recorded for the next successive six month to see above proposed model's effect. After then, this recorded data was processed and analyzed by using MS excel to reevaluate the OEE.

III. RESULTS

Firstly, it was obligatory to find the existing Overall Equipment Effectiveness (OEE) of different sections in the studied plant. Data was collected with careful observations in the month of July 2020.

A. Data Collection

Working Day =24 days, No. of Shift in a day =01, Short Break =0 [Machine will not stop], Meal Break =1 Hour, Shift Length =8 Hours, Planned Production Time = Shift Length– Break = (8-1) hour =7 hours. The OEE was calculated for Cutting and Sewing sections of the plant which was summarized in the following table:

TABLE 2: OEE CALCULATION FOR CUTTING AND SEWING SECTION

SL	Parameters	Cutting Section	Sewing Section
1	Planned Production Time	168 Hours	168 Hours
2	Total Downtime	14 Hours	30 Hours
3	Operating Time	154 Hours	138 Hours
4	Availability	92%	82%
5	Total Produced Products	228,019 Pcs.	223,461 Pcs.
6	Ideal Run Rate	26.34 Pcs. /min	36.9 Pcs. /min
7	Design Cycle Time	0.038	0.027
8	Performance	94%	73%
9	Rejected Products	5,000 Pcs.	10,260 Pcs.
10	Good Products	223,019 Pcs.	213,201 Pcs.
11	Quality	98%	95%
12	OEE	84%	57%

From the table, it resembles the weakness of the Sewing section because of its low OEE in comparison with World Class. The OEE of cutting section almost touched the standard level because of which it required to work for only sewing section.

B. Proposed Model Implementation:

A robust Pyramidal Total Productive Maintenance (TPM) Model was developed for the improvement in overall performance in this section. At the peak point of the proposed model Quality Maintenance was focused. It can be easily maintained by Cause Effect Diagram or Fishbone diagram which can find out the possible reasons behind the loophole of the whole system. Therefore, a root cause analysis was performed for the sewing section so that necessary steps can be taken for the enhancement.

Kaizen:

Kaizen is a Japanese word that means 'Change for good' and refers to the concept of small continuous improvements. At ABC, we specified some areas where some sort of small and continuous improvements can be done by the lower management and workers. Like,

- Workers must have a clear concept of the machines that they are operating, so that they can handle the minor problems of the machines.
- Workers should clean their workspaces with their own responsibility.
- They should be provided with a scrap bag or basket for the continuous formation of scrap which will ultimately reduce the time consumption of overall cleaning process.

Planned Maintenance:

Accurate checklist has been prescribed for preventive maintenance for each machine.

- Checking to see whether the machine is being kept all the time: Machine should be blown off at a regular interval to remove its lint and trash.
- Inspecting to see that the machines are being lubricated regularly. Oil levels should be checked daily or randomly. It is very important to use high quality oil that will not stain. Beside that the oil availability should also be monitored to avoid the oil shortage. Not only this, oil reservoir pump filters are needed to be cleaned properly.

Fig. 2. Cause and Effect Diagram for Sewing Section.

- All the rusted areas due to excessive moisture in the production area must be washed.
- Checking Machines wear on critical moving parts like needle, stitch forming devices etc.
- Every machine operator should check the critical screws daily before starting the operation. To monitor the defective screws can avoid the whole operation being stopped for a long time which ultimately hampers the availability of the Machine.
- Every sewing machine has three main system: (I) Stich forming system (I'I) Thread handling system and (III) Feed system. It is a must for the workers to monitor each system independently.

Autonomous Maintenance: Firstly, Employees should be trained about the steps of Autonomous Maintenance (AM), its advantages-disadvantages and day to day maintenance activities required to keep the machine active overcoming abnormalities. Then, a cleaning circle can be adopted which is shown below:

Fig. 3. Cleaning Circle

A standard schedule has to be developed regarding regular cleaning, inspection, lubrication and it should have detailed information about the timing and procedure. Every worker must have to follow strictly for minimizing break downs of machines. Another crucial thing in Autonomous Maintenance is that the employees are required to educate about the hydraulics, pneumatics, electrical and mechanical failure, coolant drivers and machine parts. Each employee can make his autonomous schedule consulting with the supervisor. Parts which have to maintain frequently and those which need not maintain at this level should be categorized in a prioritizing basis. The equipment that are needed for autonomous maintenance should be available in the right time and right place for reducing the time for searching.

Education and Training:

During the study, one of the most noticeable factors was that the lack of technical knowledge and inexperience of the employees were associated with most of the vital defects. Therefore, defective products had to send back for rework which incurred extra time and effort of the workers. To overcome this, a strong and robust training plan should be carried out.

At first checking current status of training and then setting up policies for regular training program

- Preparation of training calendar for the workers
- Managers can learn to prepare for greater reliability of equipment and incorporate adjustments aimed at achieving zero breakdowns and zero defects.
- Maintenance workers can learn the basic maintenance concepts and techniques and acquire advanced skills concerning the equipment of the organization.
- Operators of equipment will learn how to recognize equipment anomalies as such during their everyday service.

TABLE 3: 5S IMPLEMENTATION IN SEWING SECTION

SL	Stages	Before Implementation	Recommended to Implement
1	Sort	1.Lack of rack: due to insufficient rack, fabric bundles and rolls were mounted on the floor which ultimately caused unplanned motion, space and time consumption. 2.Lack of fabric resting area: as no specific resting area or fabric relaxation rack arrangement, the work space remains quite hazardous. The bundles of different parts of the garments were not arranged and the rack was not labeled according to the unsewed fabric parts, which was causing unnecessary time loss to find out the right bundles. It was also creating confusion among the employees.	Sufficient racks (for regular use and for fabric relaxation) should be provided to the cutting and finishing area. The racks should be labeled with colors specifying the types of fabric bundles it contains. Proper marking can be helpful to minimize the time loss.
2	Set in Order	The scrap cleaning procedure was visible at the industry but that didn't help very much as the working floor was crowded with empty and finished product cartoons and fabric bundles.	The extra materials on the floor (cartoons and fabric bundles) must be delivered to the proper unit as fast as they are prepared, i.e. The finished goods to the warehouse, the unsewed fabric bundles to the sewing unit and the sewed bundles to the finishing unit.
3	Shine	Standardization helps to keep the 3S and make it a standard. Also, it ensures industrial safety and pollution. ABC has developed their safety arrangements quite well as a new industry. But they need to obtain a system that is followed by most of the successful industries.	Research should be carried out to find out the standard methods. The previous 3Ss should be compared to the bench-marked industries and developed accordingly.
4	Standardize	Most of the industries that fail to achieve the desired output of 5S are often ignorant of making the 4Ss sustain. Creating improvements and letting it sustain, helps the industry to grow faster.	Keeping the 4Ss and making further progresses basing on them.
5	Sustain		

IV. DISCUSSION

After deploying the proposed Pyramidal TPM model, each parameter of OEE has been re-evaluated to distinguish the scenario of before and after implementation. From the following graph, it can be concluded that the availability in sewing sections improved from 82% to 84% after five months. The September month produced the highest availability percentage which reflects the validity of the model.

Fig. 4. Availability Improvement.

TW= Total Working Hours, PDT= Planned Downtime, POT= Planned Operating Time, UDT= Unplanned Downtime, OPT= Operating Time

The following table provided the proof of improvement of Performance over the course of five months' time period. The management easily can judge the current situation from

the previous one discerning the fact that the Performance accelerated and increased by approximate 13%.

TABLE 4: PERFORMANCE IMPROVEMENT

Period	Output	OPT	Design Cycle Time	Performance
July	223,461	138	0.027	73.1%
August	252,450	159.6	0.029	75.3%
September	243,802	158.8	0.030	76.5%
October	223,680	141.6	0.028	74.2%
November	244,244	156.4	0.031	81.3%
December	235,025	147.2	0.032	85.8%

The Quality Management which was manifested on the top position of the proposed model had been upgraded by vigorous endeavor taken through the whole sewing sections in the plant. From the above graph, it can be identified without any difficulty that the less products were rejected and Quality increased accordingly.

Fig. 5. Quality Improvement.

V. CONCLUSION

In the today's competitive world, every company is looking for the excellence in achieving their main goals. To bring enhancement in every sector of a plant, company must need to set a target and adopt strategies to overcome challenges and impediments. This paper has shown to the top management if a strong TPM model can be utilized it can bring the required result. For this, proper management and supporting activities are mandatory for every organization. A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Fig. 6. Before and After Comparison.

After overcoming all of the challenges mentioned earlier, the new derivative model of TPM provided the improved outcome which every company expects. From the above comparison figure, it reflected the improvement scope in achieving world class OEE.

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