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Evaluation Improvement of Production Productivity Performance using Statistical Process Control, Overall Equipment Efficiency, and Autonomous Maintenance

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Abstract

Manufacturing firms are more focusing on improving the production performance in term of productivity output in order to survive in the competitive market, because a high productivity performance has a direct relationship with the equipment efficiency and process control. Absence of the proper productivity measurement indicators locates manufacturing firm at an unknown production line performance. Unstable and uncontrollable process causes producing nonconforming product, which affect the overall production performance. The integration between the Statistical Process Control (SPC), Overall Equipment Efficiency (OEE), and Autonomous Maintenance (AM) is proposed to achieve continuous improvement in the production capability. This integration can enhance the productivity performance of manufacturing firms. The purpose of this study is to evaluate production productivity by continuously improve the equipment efficiency and process control in tiles manufacturing industry. For this purpose, OEE is proposed as the indicator to measure the equipment efficiency. Analysis and efficiency improvement are carried out using Define, Measure, Analyze, Improve and Control (DMAIC). SPC is suggested as monitor function for evaluating the process quality performance and the seven basic tools are used to tackle the manufacturing process variations. AM is applied in the glazing line to improve the machine efficiency by giving more responsibility and authority to the operators to do more improvement and preventative actions to their own machines. This study shows that loss mechanism of the equipment is unknown to the company's employees even though the condition of low production performance has been observed. Result of the study presents that the implementation of AM has successfully reduced 8.49% of the defect rates of glazing line from 14.61% to 6.12%. Machine breakdown time has been decreased from 2502 minutes to 1161 minutes whereas the OEE has been improved 6.49% from 22.12% to 28.61%.

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Keywords: Overall Equipment Efficinecy; Statistical Process Control; Kaizen; Productivity Evaluation; Autonomous Maintenance

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1. Introduction

Nowadays, the major daily problems that encountered by many manufacturing companies are equipment breakdown, repair, and quality defects. These problems have great impact on the quality cost and delivery time [1]. The quality of maintenance significantly affect the company profitability as 25- 30% of total production cost that is attributed to maintenance activities in the plant [2]. Statistical Process Control (SPC) is the statistical method to monitor and control the production performance as well as continuously improve the quality of the product [3]. The purpose of SPC implementation is to improve the product quality, improve productivity, reduce wastes, reduce defects and improve customer values [4]. Overall Equipment Effectiveness (OEE) measures how effective the machine used for manufacturing in practically as opposed to in theory [5]. Availability, performance rate, and quality rate are the three important parameters which form the product of OEE [6]. The six big losses such as breakdowns, setup and adjustments, small stops, reduced speed, start-up rejects and the production rejects are the main contribution that affect the performance the machines [7]. A case study has been conducted in XYZ tiles manufacturing company in Pahang, Malaysia. This company manufactures and sells tiles and mosaics to worldwide. The major problem of this company in the production process is low production productivity performance caused by the high machine breakdown. The purpose of applying SPC in the process is to identify the significant defect and reduce the process variations to consistently produce more conforming products whereas OEE is used as a key performance indicator to measure the effectiveness of the machine. Total Productive Maintenance (TPM) is crucial to maximize the utilization of the machine by eliminating breakdown, and promote Autonomous Maintenance (AM) by operators through day to day activities involving total workforce.

2. Literature review

This study reviews the application of seven quality control tools, six big losses of OEE, and DMAIC for analyzing the solutions to the existing problems. Seven quality control tools are Pareto diagram, cause and effect diagram, control chart, scatter diagram, check sheet, flow chart, and histogram [9]. TPM aims to maximize the effectiveness of equipment throughout its entire life by the participation and motivation of the entire workforce [14]. The maintenance activities can be grouped into three categories which are reactive or corrective maintenance, preventive maintenance, and predictive maintenance [5].These six metrics of OEE are shown in Table 1.

Table 1.OEE metrics [8]

OEE Loss Classifications	Six Big Loss Category	Computation of OEE
Availability Rate	1. Equipment failure 2. Setup and adjustment	Availability rate = operating time/ loading time
Performance Rate	3. Idling and minor stoppage 4. Reduced speed	Performance rate = Net operating time/ operating time
Quality Rate	5. Defects in process 6. Reduced yield	Quality rate = (processed amount – defect amount)/ processed amount

DMAIC is a closed-loop process, which eliminates those unproductive steps and focuses on new measurements, and applies technology for continuous improvement [10]. DMAIC methodology follows the five phrases [11,12,13];

1. Define phase; the processing mapping and matrix are the tools used to identify customer requirements and project scope.
2. Measure phase; cause and effect diagram and failure mode effects analysis are the tools applied in rolled throughput yield.
3. Analysis phase; hypothesis testing, correlation, and regression are used to identify the sources of variation.
4. Improve phase; design of experiment and optimization are used to generate the best solution and validate it.
5. Control phase; control charts are used to monitor process performance and maintain control with adjustments.

3. Methodology

Firstly SPC is applied to analyze the defect rate using the seven quality control tools. Secondly OEE is applied to measure the machine performance. The integration of SPC, OEE, and AM are examined to improve the productivity in term of production output by increasing machine performance and monitoring process defect. The cause and effect diagram and why-why analysis are also applied to justify that our investigation is aligned with the current production productivity performance.

3.1 Case Study

The XYZ tiles manufacturing company has two production lines, which are A and B. The difference between these two lines is the machines and layout. The case study was carried out in A line instead of B line because the machines already have 50 years history and the frequency of the machine breakdown is very high. It indirectly affects the product quality especially the green tiles, which are very fragile. Type of tile with a dimension of 30 x 30 cm is considered because the production quantity of this type is 60% of the total production. There are totally seven processes and each process has its own parameter. Fig.1. presents the process flow of glazing line

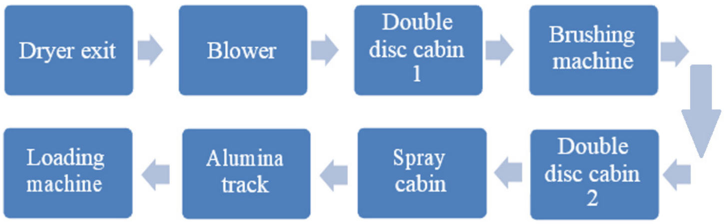

Fig. 1. Glazing process flow

Flow chart of the study is presented in Fig. 2.

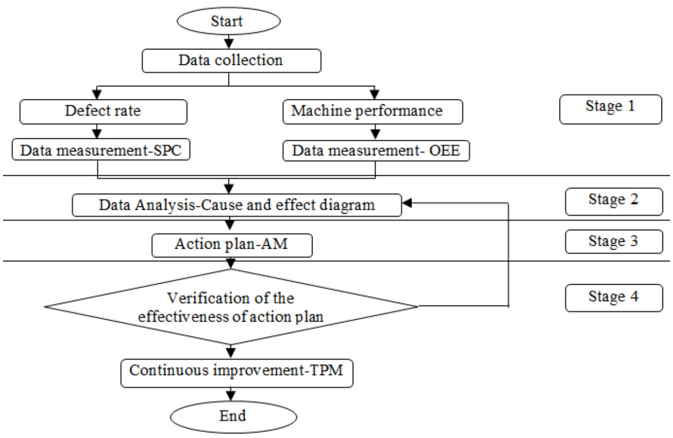

Fig. 2. Process flow chart of the study

Stage 1- Defect rate data and machine performance record are collected for six months through the overall tile production process in A line using check sheet from April to September 2014.
Stage 2- The data is analyzed using SPC to observe the quality performance. OEE is applied to measure the machine performance by identifying its loss mechanism. The cause and effect diagram is applied to analyze the root causes of the high defect rates of chipping Before Fire (BF). The effects are categorized into four; man, machine, method and material. AM workshop is conducted to train the operators for problem solving.
Stage 3- AM is implemented in glazing line starting from June 2014. Fig. 3 presents the seven steps in conducting AM workshop before implementation of AM in glazing line.

Fig. 3. AM procedure

1. *Cleaning and inspection* - remove all the dirt and dust from the machine to expose and highlight the hidden problems related with the machine.
2. *Countermeasures to sources of contamination* - implement why-why analysis to identify the root causes of source of the contamination.
3. *Cleaning and lubrication standards* - standardize a method of cleaning including relevant tools for cleaning and the frequency of cleaning.
4. *Train for Overall inspection –aware* operator about the need of the standard inspection.
5. *Conduct autonomous inspections* - perform maintenance task on machines to improve the standard with information given in stage 4.
6. *Continuous improvement* - repeat all the steps that have been done for continuous improvement.
7. *Autonomous maintenance* - *c*heck for abnormities to prevent breakdowns and defects as shown in Table 2.

Table 2. Root causes and action plan

Root causes	Action plan
Poor condition of pulley and belt	Operators need to check pulley and belt by checklist and change if necessary
Poor condition of roller in kiln exit	Operators need to check the condition of the roller every two months.
Speed and space not uniform	Operators need to follow standard operation procedure to adjust motor speed
Poor condition of Teflon rubber on guide	Operators requires to check the guide condition every shift for changing
Poor alignment of loading machine	Calibrate the box car, box loading and box unloading.

Stage 4- The effectiveness of the action plan can be measured by comparing defect rates and machine performance in glazing line from April to September 2014.

4. Results and Discussion

Table 3 presents the effectiveness of AM implementation on overall production productivity performance. These results have proved that the defect rate and the machine performance are interdependent on each other. The data of defect rate indicated that the chipping BF contributed the highest defect frequency. We found that the main roots of chipping BF are man and machine. We have discovered that frequent machine breakdown directly impact on production productivity performance after analyzing the root causes.

Table 3. The result before and after AM implementation

Parameters	Before AM (May)	After AM (September)	Result
Defect rate (%)	14.61	6.12	Defect rate has been reduced to 8.49%.
Breakdown (min)	2502	1161	Machine breakdown time has been decreased for 1341 minutes
OEE (%)	22.12	28.61	OEE has been increased 6.49%.

Fig. 4 shows that the defect rate is decreased after AM is implemented, which reflects the improvement in overall production productivity performance in term of conforming output when the OEE is increased. The brushing machine shows the highest breakdown time compare to other types of machines. The main problem that caused the brushing machine breakdown frequently is because the excessive dust removed by the brusher always blocks the rotational of the brusher. An average of 500 minutes breakdown time per month on the brushing machine occurred from June to September 2014.

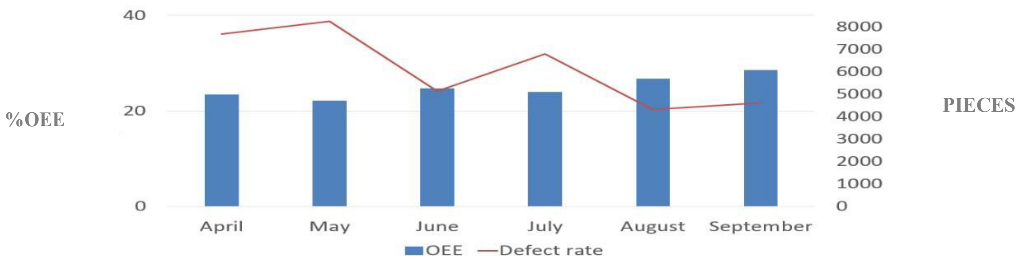

Fig. 4. Relationship between defect rate and OEE in glazing line

5. Conclusion

This study focused on evaluation improvement of production productivity performance. A tile manufacturing company has been considered for this study. The implementations of SPC, OEE, and AM have minimized the defect rates of chipping BF and maximize the brushing machine performance, which improves the production effectiveness performance. SPC could identify and control the defection rate of tiles in glazing process. OEE could measure the machine performance by identifying the loss mechanism of machine. AM was able to be practiced in seeking for higher machine performance which aims to yield a higher production productivity performance. The defect rate data and machine performance in glazing line are interdependent of each other. SPC contributed to decrement of defect rate from 14.61% to 6.12%, and reduction of machine breakdown time from 2502 minutes to 1161 minutes taht resulted in enhancement of OEE from 22.12% to 28.61%. The production productivity performance has been increased by implementing AM and reducing the defect rate. The integration of SPC, OEE, and AM is strongly recommended to improve the production productivity performance for tile manufacturing industry.

6. References

[1] E.G. Tsacle, N. A. Aly, An Expert System Model for Implementing Statistical Process Control in The Health Care Industry, Computers industry engineering, 1996, Volume 1, Issue 1, pp. 447-450.
[2] R. K. Mobley, An Introduction to Predictive Maintenance, New York, 1990.
[3] M. Tajiri, F. Gotoh, TPM Implementation: A Japanese Approach, McGraw-Hill, New York, 1992.
[4] S. Mirko, J. Jelena, K. Zdravko, V. Aleksandar, Basic Quality Tools in Continuous Improvement Process, Journal of Mechanical Engineering, 2009, Volume 55, Issue 5, pp 1-4.
[5] A. Heba, X. Qiu, A Model For Assessing Cost Effectiveness of Applying Lean Tools, School of Technology and Design, Växjö University, 2007, Volume 46, Issue 73, pp.
[6] R. Raguram, Implementation of Overall Equipment Effectiveness (OEE), Middle-East Journal Science Research, 2014, Volume 20, Issue 5, pp. 567-576.
[7] W. Ratapol, Implementation of Overall Equipment Effectiveness in Wire Mesh Manufacturing, Chiang Mai University, Thailand, 2011, pp 1-5.
[8] A. J. Deron, J. E. Rooda, OEE and Equipment Effectiveness: An Evaluation, International Journal of Production Research, 2006, Volume 44, Issue 23, pp 4987-5003.
[9] H. F. Rami, M. Adnan, Statistical Process Control Tools: A Practical guide for Jordanian Industrial Organizations, Jordan Journal of Mechanical and Industrial Engineering, 2010, Volume 4, Issue 6, pp. 693-700.
[10] A. A. Anup, P. N. Shende, Minimization of Rewok In Belt Industry Using Dmaic, International Journal of Applied Research in Mechanical Engineering, 2011, Volume 1, Issue 1, pp. 54.
[11] J. Antony, R. Banuelas, “Six Sigma: A Business Strategy for Manufacturing Organizations”, Manufacturing Engineering, 2001, Volume 8, Issue 3, pp. 119-121.
[12] H. Wang, A Review of Six Sigma Approach: Methodology, Implementation and Future Research, Zhejiang Normal University, China, 2008, pp. 2.
[13] C. Hagemeyer, J.K. Gershenson, D.M. Johnson, Classification and Application of Problem Solving Quality Tools: A Manufacturing Case Study, The TQM Magazine, 2006, Volume 18, Issue 5, pp. 455-483.
[14] B. Bhadury, Management of Productivity Through TPM, 2000, Volume 41, Issue 2, pp. 240-51.
[15] W.W. Melesse, P.S. Ajit, Total Productive Maintenance: A Case Study in Manufacturing Industry, Global Journal of researches in engineering Industrial engineering, 2012, Volume 12, Issue 1, pp. 2.