International Conference on Mechanical, Industrial and Materials Engineering 2017 (ICMIME2017)
28-30 December, 2017, RUET, Rajshahi, Bangladesh.

Paper ID: 154

Performance Assessment and Improvement of a Printing Press in Terms of Effectiveness and Efficiency

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Abstract

Overall Equipment Effectiveness (OEE) is one of the performance evaluation methods that are most popular in manufacturing industries. The objective of this study is to measure and improve process performance in terms of OEE as well as Process Equipment Utilization and Lost Capacity of machineries for label printing process. Pareto chart is used here to find out the significant responsible event for the losses. The potential causes of these losses are explored with the help of cause-effect diagram. The 5-why technique is applied to drill down the root causes. Single minute exchange die (SMED) and super-shop technique are applied to improve the current scenario. This study identifies six big losses with a particular focus on downtime, speed and quality loss. Finally, the performance of the existing and improved system is evaluated. The compared results show the certain increase in OEE by 10.49%, Process Equipment Utilization was increased by 10.77% and lost capacity was reduced by 11.84%.

Keywords: Performance measurement, OEE, equipment utilization, lost capacity, SMED

1. Introduction

Performance measures quantitatively say to know something important about products, services, and process. It means how well an organization is doing and whether the organization meets their goals, customers are satisfied, the process is in statistical control and where improvements are necessary. All these provide the information necessary to make intelligent decisions about what organization do. Additionally, performance measurement is concerned with process optimization. OEE is one of the most accepted metrics in this field which is applied to many manufacturing industries. OEE indicates the relationship among the availability, performance, and quality factor. The OEE metric can measure the level of equipment effectiveness, and also identify loss elements. Besides OEE, Process Equipment utilization and Lost Capacity are also used for evaluating performance. Most performance measures can be grouped into one of the six general categories: Effectiveness, Efficiency, Quality, Timeliness, Productivity, and Safety. However, certain organizations may develop their own categories depending on the organization's mission. Such as measurement of equipment efficiency in most American semiconductor manufacturers traditionally emphasizes the use of two basic metrics, equipment availability and equipment utilization [1]. This study is aimed towards the performance measurement and process improvement of label printing process of a selected company in terms of OEE, Process Equipment utilization and lost capacity. The objectives of this study are stated below:

- Identification of major category of losses affecting performance of label printing process
- Investigation of responsible reasons for the identified losses
- Possible implementation of lean techniques to recover or minimize the identified losses
- Performance assessment in terms of OEE, process equipment utilization and lost capacity at existing and improved state

2. Research background

Taticchi et al. (2008) review the literature in the field of performance measurement and management for small and medium enterprises (SMEs) [2]. They proposed an integrated framework that rectifies the drawbacks in previous frameworks while incorporating their strengths. The proposed framework is a contribution to enhance SME adoption of PMM systems and provides milestones for PMM system design. Kurien and Qureshin (2012) applied performance measurement systems for green supply chains using modified balanced scorecard and analytical hierarchical process and found properly planned, implemented and managed green SCs enable organizations to be responsible corporate citizens, resulting in higher profitability and retain competitive advantage [3]. Striteska and Spickova (2012) analyzed, compared and summarized the strong and weak points of the most widely cited performance measurement systems on the basis of literature review [4]. Specifically, the literature review was conducted with the goal of searching papers and case studies that are directly or indirectly concerned with performance measurement systems or models. Most of the previous studies have attempted to explain the importance of performance measurement. In the present study the assessment of the performance of printing press will be performed.

OEE is a best practices way to monitor and improve the effectiveness of manufacturing processes. Various researches were conducted on this topic to analyze the effectiveness of a manufacturing unit. Mhetre and Dhake (2012) examine TPM review and OEE measurement in fabricated parts manufacturing company [5]. The result shows that there is a problem in the machine utilization. Most of the time the machines remain idle or wait for the maintenance if it fails. Zandieh et al. (2012) evaluated the OEE index on stabilization units in a refinery and found OEE coefficients of the investigated processes are not at the world class level [6]. However, continuous improvement can make the performance acceptable. Kumar et al. (2012) conducted an assessment to avoid wastage of money due to the false decision of equipment condition by OEE calculation in industry where cereals are processed and packed [7]. The packaging machine had less OEE comparing other processing machinery. Mahboob (2011) conducted a study to calculate Overall Efficiency of Rolling Stock (RS) for an Urban Rail Transit System and found availability of the RS is the main factor responsible for the lower OEE [8]. From the literature review, it is revealed that successful implementation of OEE can track the achievement through the factor of availability, performance, and quality. In this work, OEE is used for measuring the performance of printing press. As it was reviewed, no work of OEE on the printing press was found.

Different lean tools were applied in many organizations to improve the OEE. In today's globalization, manufacturers face many challenges in diversified, low-volume production. This results a significant increase in setup and tool change frequencies. That's why it is important to provide a quick changeover to reduce the time spent in the setups which considered as waste and negatively affects the overall performance. Most of the previous studies have attempted to explain the successful implementation of SMED to reduce setup and changeover time in various sectors like textile, construction industry, automobile etc. As the printing press requires frequent tool change for diversified product; there is a chance of occurring so many changeovers where SMED tool can be applied. Moreira and Pais (2012) recommended SMED as a successful implication in a mold making firm for performance improvement [9]. Singh and Khanduja (2012) made the design rules specifically for foundry dies and tooling by using SMED concept in their study [10]. Joshi and Naik (2012) applied SMED in an automotive small-scale industry with a view of increasing output and reducing quality losses [11]. Kumar and Abuthakeer (2012) enhanced productivity in a machining section in an automotive industry by implementing SMED [12]. Abraham et al. (2012) analyzed BMS press for the production of hose clamps [13]. The main objective was to reduce the setup time. Their implemented SMED methodology to reduced tool change time reduced by 5 hours. This leads to the productivity improvement of the machine.

The aim of the present study is, therefore, to minimize the existing changeover time and to evaluate its effect on performance improvement in the printing industry.

3. Research methodology

The case study was chosen as a research strategy in this study. This research was carried out in a selected label printing factory. The investigation was conducted through monitoring the printing process, collecting data by direct observation, inspecting at the weak performance and interviewing the concerned persons when necessary. Then the collected data was processed in terms of OEE, Process Equipment Utilization and Lost Capacity of machinery for label printing process. Besides, different tools and techniques were used to analyze the occurred losses. At last, some improvement strategies were taken based on the result and the comparative analysis was performed between existing and proposed system.

3.1 Computation ways and means

OEE shows the effectiveness of a machine or production line compared to the ideal machine as a percentage [4]. OEE takes into account all three OEE factors- availability, performance, and quality. It is calculated as:

$$\text{OEE} = \text{Availability X Performance X Quality} \tag{1}$$

Where,

$$\text{Availability} = \text{Gross Operating Time} / \text{Planned Production Time} \tag{2}$$

$$\text{Performance} = \text{Net Operating Time} / \text{Gross Operating Time} \tag{3}$$

$$\text{Quality} = \text{Good Pieces} / \text{Total Pieces} \tag{4}$$

Here, availability and performance are dependent on the planned production time and operating time. As well as several loss times are also essential to measure the OEE. In this study downtime, speed and quality losses were identified as OEE loss. These major categories are then classified into six big losses. All these respective loss categories are shown in table 1. Now in consideration of process equipment utilization; this is defined as the percentage of plant operating time during the process or producing time of the equipment. This excludes non-process production activities required as part of the production operation. Again, lost capacity is the percentage of the scheduled operating time lost to repair time, delay time and non-process production time as it was encountered. The calculation formulas for these two are given below:

$$\text{Process Equipment Utilization} = (\text{Process Time} / \text{Plant Operating Time}) \times 100 \quad (5)$$

$$\text{Lost Capacity} = [\text{Delay Time} + \text{Repair Time} + \text{Non-Process Production Time}] / \text{Scheduled Operating Time} \quad (6)$$

Table 1. Classification of OEE loss

OEE Loss Category	Six Big Losses	Explanation
Downtime Loss	Breakdown Losses	Sudden, dramatic failure in which the equipment stops completely
	Setup and Adjustment Losses	The production of one product ends and the equipment is adjusted again to produce another product.
Speed Loss	Small Stops Losses	Occur when equipment stops for a short time as the result of a temporary problem.
	Reduced Speed Losses	Difference between designed speed and actual operating speed.
Quality Loss	Startup Rejects	Occur in the early stages of production, from machine setup to stabilization of product quality.
	Production Rejects	Occur when produced products do not meet to the specifications, required any kind of reworks.

3.2 Analysis tools and techniques
Cause-effect diagram was used here to identify and list out the different causes that can be attributed to a problem. Typically, causes are grouped into major categories to identify these sources of variation. In this study, the categories include: Man, Method, Material, and Machine. Based on these, the reasons behind the loss of downtime, speed and quality were investigated. Following cause-effect diagram, Pareto chart was used for selection of a limited number of tasks that produce the significant effect. It uses the principle that, a large majority of problems (80%) are produced by a few causes (20%). This technique has helped here in sorting the highly responsible sources of causes for the stated losses. Afterwards, the 5-Why Analysis was performed. This technique requires interrogator to pose the question “Why?” five times. In this study, this analysis was done up to more detailed level with each “Why?” and tried to come close to locating the root cause of the problem.

3.3 Improvement strategy
SMED is the term used to represent the setup time that can be counted in a single digit of minutes. This rapid changeover is a key to reduce production lot size and thereby improve production flow. There are two types of setups: internal and external. The basic idea is to make as many activities as possible from internal to external. The implementation of SMED in this study was done through in three steps. At first, current changeover method was observed for targeted process and recorded this on videotape. Then, separation of the internal and external activities was performed. At last, the changeover process was substantially improved by several iterations. Other than SMED some other possible measures such as supershop placement, length calculation omitting were taken to improve the availability and performance of label production.

4. Results and discussion
The investigation was carried out in a label printing industry and studied the process of label printing of a selected workstation. The field data were collected for various OEE metric i.e. availability, performance, and quality. Data for downtime and speed loss was collected directly from the job station for 5 days (12 hr. in a day). The required information on quality loss was obtained from the Quality Control Department. These data were then screened and formatted into the usable form.

4.1 Loss analysis
4.1.1 Downtime loss analysis: From the observation it was found that downtime loss occurred for breakdown and various setup and adjustment activities. The breakdown was due to gear and intake failure, setup and adjustment activities include ink preparation, ink plate adjustment, registration, and unavailability of raw roll, cylinder, and operator. The study reveals that only 52% of total time is utilized for production and 17% of the time is spent on scheduled break. Rest of the time (31% of total time) production is stopped due to downtime. Figure 1 shows different causes and their percent contributions to the downtime loss.
Initial setup of each new label includes the activity of ink preparation, ink plate adjustment, and registration. It is not possible to determine the requirement for next production before receiving the sheet. Hence the ink preparation cannot be done prior to the production. Moreover, ink plate adjustment and registration are done

after preparing the ink. Thus, these activities cause a significant amount of downtime loss (63.20%). Gear and intake failure were found as the main reasons of machine breakdown. In order to find the reason of gear and intake failure the performed “5-why” analysis shown in the following table 2. The company’s maintenance policy is- change the grease of gears once a year, clean up the intake after finishing the job and inspect it in every 3 months. From table 2 it is evident that both of gear and intake failure were caused due to negligence in maintaining the maintenance policy of the company.

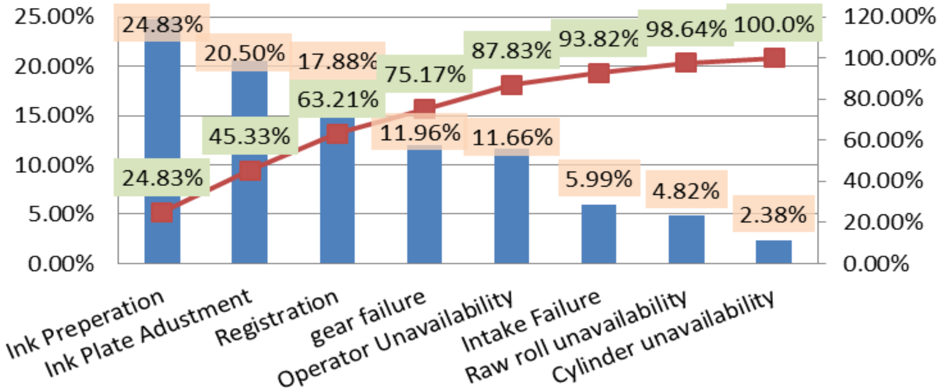

Fig. 1. Pareto chart for downtime loss

Table 2. “5-why” analysis for gear failure, intake failure and ink preparation

Gear failure	**Why**	**Why**	**Why**	**Why**	**Why**
	bearing and bush damaged	Pinium bush became hard and damage the bearings	grease inside the bearing became dry	old grease was not changed timely	maintenance policy was not maintained
Intake failure	**Why**	**Why**	**Why**		
	Due to blade failure	Old blade was not replaced on time	Maintenance policy was not maintained		
Ink preparation	**Why**	**Why**			
	Ink color is adjusted visually by operator	Color code is not available to the operators			

4.1.2 Speed loss analysis: There were mainly two categories of speed loss: small stops and reduced speed. 51% of the gross operating time is lost due to speed loss during the study period. The investigated major causes of small stops were: cleaning intake, changing plate, raw roll and finished roll, waiting for quality check, and calculation of production length. Machine speed decreased due to wear on ink plate and gear teeth.

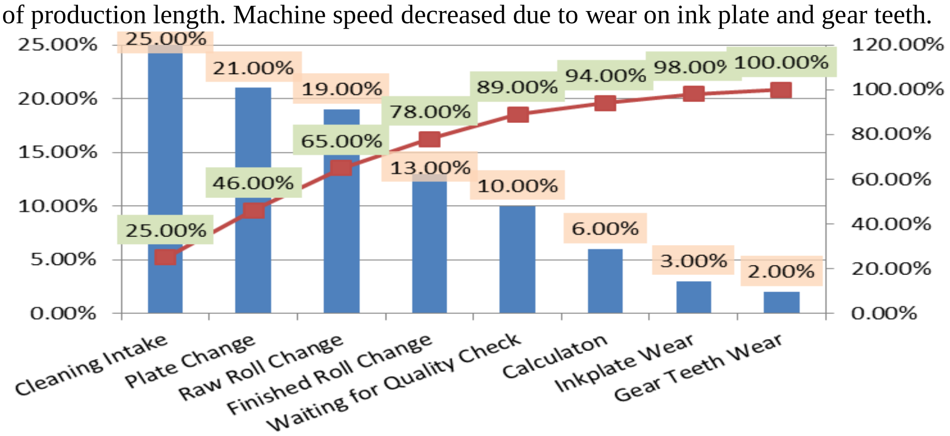

Fig. 2. Pareto chart for speed loss

From the Pareto chart (figure 2) it is clear that the activities like cleaning intake, changing plate, raw roll and finished roll cause almost 78% of speed loss. It is essential to clean the intakes during the ink preparation and after every production. As there are fixed numbers of intakes for every printing press and keeping extra intakes for every press requires extra investment; so it is a prerequisite to clean the intakes. Again, every plate changing activity consumes about 7sec and it is mandatory to use separate plates for every printing. So it is hardly possible to reduce the time of cleaning intake and changing the plate. However, changes of raw and finished roll are the most vital reasons for speed loss. In existing system, every raw and finished roll changing activity requires 35sec and 47sec respectively. That means 25% and 19% of total speed is lost due to changing raw and finished roll respectively. After preparing the ink and the sample label, the operator needs to wait for quality checking of factory sheet. 2% of total speed loss occurred due to this reason. Again, throughout the study, 6% of speed loss was caused due to production length calculation. Each factory sheet contains the measurement of particular label includes length, width etc. in centimeters But, the press tracks the production in meters. The operators did this unit conversion calculation during operation which ultimately reduces the production speed.

4.1.3 Quality loss analysis: It was found that quality loss occurred for startup rejects and production rejects. Main causes for startup rejects are incorrect registration, scrap while changing roll, and rework. Production rejects include scrap and in process damage. During the observation, 16% quality loss was caused by incorrect registration. A piece of ribbon is discarded as scrap from every roll changing. 11% quality loss was found due to this scrap. Sometimes rework have to do for a mismatch in color, font, printing contents etc. Reworking caused 13% of defects during the study. Scrap and in process damage are produced for various reasons like faults in raw materials, intakes, ink blades, color composition, problems in the adjustment of cylinder, plate and so on.

4.2 Improvement works

4.2.1 Improvement in availability: Operators need to bring raw rolls and cylinders from remote location due to unavailability of raw roll beside work area. Unavailability of these two was reduced by placing a small table beside the workstation which serves as a supershop. Raw roll unavailability and cylinder unavailability caused (4.82+2.38) % =7.2% of total downtime loss during the study period. When a supershop is placed, the time is saved by 79.67min assuming other events are fixed. It indicates an increase of 2.66% availability.

4.2.2 Improvement in performance: Measures were taken in three activities to improve performance. The regular raw roll changing and finished roll changing procedure took about 35sec and 47sec correspondingly to set the roll and start the process. SMED technique was applied to reduce the changing time. The proposed system takes 14sec and 28sec to set new raw roll and finished roll respectively. The time of the existing and proposed system with corrective measures of change over time is summarized in table 3. A very little modification in the existing length calculation system was done. Whenever a factory sheet arrives at the job station, the required production length calculated before. So that the operator gets the measurement directly and thus system does not consume any calculation time.

4.2.3 Comparison between existing and improved OEE: Improvement of the availability and performance was emphasized over the quality as the percentage of quality (88%) was satisfactory among this two. Assuming other events unchanged the comparison between existing and improved availability and performance scenario is shown in table 4. It indicates an increase of 2.66% in availability and 16.05% improvement in performance. So that, the value of OEE for proposed system also increased by 10.49%.

4.2.4 Comparison between existing and improved Process Equipment Utilization and Lost Capacity: From table 5, it is evident that the value of Process Equipment Utilization for the improved process is 38.65% which indicates an increase of 10.77%. Whereas the lost capacity is decreased by 11.85% in the proposed system.

Table 3. Existing procedure of raw roll changing: Comparison between existing and proposed raw roll changing and finished roll changing procedure

Operations (internal and external)		Execution time (sec)		Corrective Measures
		Existing	Proposed	
Raw Roll Changing	1. Taking out the old paper roll	6	6	cannot be reduced
	2. Keeping the paper roll on the table	3	-	switched to external
	3. Cutting the two side adhesive tape	2	-	switched to external
	4. Attaching adhesive tape with new raw roll	13	-	switched to external
	5. Placing the new raw roll on shaft	4	4	cannot be reduced
	6. Attaching ribbon	7	4	time is reduced
	Total	**35**	**14**	**Reduced time = 21 sec**
Finished Roll Changing	1. Taking out the finished roll	6	6	cannot be reduced
	2. Keeping the paper roll on the table	3	-	switched to external
	3. Cutting the two side adhesive tape	5	-	switched to external
	4. Setting the paper roll on shaft	7	7	cannot be reduced
	5. setting the ribbon with paper roll on shaft	26	15	time is reduced
	Total	**47**	**28**	**Reduced time=19 sec**

Table 4. Comparison between existing and improved OEE

OEE factors	**Computation Equation No.**	**Existing**	**Improved**	**Change**
Availability	(2)	63.11%	65.77%	Improved 2.66%
Performance	(3)	48.59%	64.64%	Improved 16.04%
Quality	(4)	88.57%	-----	Unchanged
OEE	(1)	**27.15%**	**37.64%**	**Improved 10.49%**

Table 5. Comparison between existing and improved Process Equipment Utilization and Lost Capacity

	Computation Equation No.	Existing	Improved	Change
Process equipment utilization	(5)	27.88%	38.65%	10.77% ↑
Lost capacity	(6)	69.33%	57.49%	11.84% ↓

5. Conclusion

This study presents the OEE method for performance assessment. This leads to the improvement required to enhance the effectiveness of label production system. It provides a useful insight into the production process where losses are targeted which are created by the equipment. The identified major causes of downtime loss in the printing press are ink preparation, ink plate adjustment, registration, and gear failure. Speed loss was occurred due to cleaning intake, plate change, raw roll and finished roll change, waiting for quality check and production length calculation. Quality loss was occurred due to scrap while changing roll, incorrect registration, rework, scrap, in process damage. The results of the study show that incorporation of a supershop in the system results in elimination of raw roll unavailability and cylinder unavailability. In this way equipment availability was increased by 2.66%. Roll changing time was reduced by applying SMED technique and hence, performance was increased by 16.05%. As a measure of equipment effectiveness and efficiency, OEE was improved by 10.49%, and process equipment utilization increased by 10.77% whereas, lost capacity was reduced by 11.84%.

6. Limitation of the Study

The amount of loss was measured only in terms of time, but it can be further analyzed in terms of money. This research was confined to the label printing press only so there is scope to extend it to the whole production department. The quality loss was not improved as it was comparatively satisfactory over availability and performance. So, quality improvements are yet to uncover the complete scenario of the improved system.

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