Overall equipment efficiency of Flexographic Printing process: A case study

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Abstract. This paper reports the efficiency improvement of a flexographic printing machine by reducing breakdown time with the help of a total productive maintenance measure called overall equipment efficiency (OEE). The methodology is comprised of calculating OEE of the machine before and after identifying the causes of the problems. Pareto diagram is used to prioritize main problem areas and 5-whys analysis approach is used to identify the root cause of these problems. OEE of the process is improved from 34% to 40.2% for a 30 days time period. It is concluded that OEE and 5-whys analysis techniques are useful in improving effectiveness of the equipment and for the continuous process improvement as well.

1. Introduction
To remain competitive in the global world, organizations seek to produce better quality and cost-effective products. This need forces the organizations to adopt several approaches related to production process and plant maintenance in order to run the plant at its full capacity by increasing productivity hence reducing the cost of manufactured parts. These approaches include Total Quality Management (TQM), Total Productive Maintenance (TPM) and Lean Manufacturing. Plant maintenance is playing an important role in the organization’s profitability as 15-60% manufacturing cost is associated with the maintenance activities [1].

Overall equipment efficiency (OEE) is a quantitative TPM tool which is employed to investigate and analyze the production processes. OEE provides a metric to gauge the machine efficiency in order to improve the productivity through identification of potential areas for improvement. OEE evaluates three main factors related to equipment and process i.e. availability, performance and quality [2]. OEE mainly concerns with six main categories of losses which are: breakdown, reduced speed losses, minor stoppage losses, setup adjustment losses, rework and yield losses [3].

OEE can be defined as

\[ \text{OEE} = \text{Availability} \times \text{Performance} \times \text{quality} \]

Whereas;

\[ \text{Availability} = \frac{(\text{loading time} - \text{down time})}{\text{loading time}} \]

\[ \text{Performance} = \frac{(\text{ideal cycle} \times \text{time output})}{\text{actual operating time}} \]

\[ \text{Quality} = \frac{\text{input} - \text{volume of quality defects}}{\text{input}} \]

Today’s manufacturing industry focuses on the importance of equipment efficiency and effectiveness in order to access organization’s performance in terms of productivity. TPM plays a significant role in enhancing the productivity of an organization aiming at OEE [4]. Dogra et al give a study on implementation of TPM in rolling and HPH annealing machines. The study concludes that major downtime losses are caused by process adjustment. After one month TPM training to top management and the employees, the OEE of rolling and HPH annealing machine has been increased to 80% and 83%
respectively. It is also revealed from the study that maintenance cost has also reduced by the implementation of TPM [5]. Almeanazel et al present a study based on a steel manufacturing company. The main study is carried out by selecting three processes named ovens, dies, cutting and cooling bed. It is revealed through the research that OEE was 72% before the implementation of TPM. It is then decided by the company that TPM should be implemented in order to improve the company’s performance. After the implementation of TPM, company becomes able to mark out potential areas for waste reduction and improvements [6]. Parihar et al calculate the OEE for assembly process of a tractor manufacturing company. The OEE of the process is found 62% which is very low as compared to the world class standard of 85%. It is recommended by the study that in order to improve the OEE, attention should pay to reduce unplanned maintenance, setup and changeover losses through implementing new techniques, tools, employee training and inventory storage systems [7]. Tsarouhas et al conclude a study related to the implementation of TPM in food industry. The study is carried out on a pizza production line as this line requires continuous operation and transfer lines. Any interruption or stoppage in the production can make the pizzas present in the work stations useless. OEE is calculated on the basis of previous five years data after implementing the TPM and data shows an increase in OEE from 62% to 80% within five years. TPM implementation is not only influenced the reduction of downtime losses, also improves the quality of the product, safe workplace, reduced product lead time [8]. Sharma et al carry out a study on TPM in piston manufacturing industry. The study is carried out in two phases comprised of qualitative and quantitative analysis. Qualitative analysis reveals that availability of machines differs between 65-70% due to recurrent breakdowns and shortage of spare parts. Likewise, quantitative analysis also reveals that 70% downtime losses are unplanned and 15% are planned [9].

Mhetre et al report a study on TPM review for fabricated parts manufacturing company. The study aims at evaluating company’s effectiveness through OEE evaluation. The main process is comprised of six operations and their computed OEE are 66.95, 52.79, 20.67, 15.12 and 47.97% respectively. It is obvious that process five which is bending needs improvement in order to improve OEE. It is also revealed from the study that workforce management is the reason behind reduced OEE for bending operations. Therefore, company advised to focus on preventive maintenance to train the workers [10]. The 5-why analysis is widely used in lean manufacturing for root cause analysis. Taiichi Ohno “the father of Toyota Production Systems” is considered one of the pioneers who used 5-why method as a root cause solving method during his days in Toyota. He noticed that people used to blame each other whenever problems occurred during production. Therefore, he figured out the best approach that is to find out the root cause of the respective problem and work on it rather than blame each other. Traditionally 5-whys analysis requires the “why” question to be asked five times in order to identify the root cause, however, the asking of the “Why” can be stopped if common sense tell us that no more “Why” questions are needed to solve the problem [11]. Five whys method is used for root cause analysis in order to investigate cause-failure relationship for a failure problem [12]. Banjamin et al use five why approach to investigate the root causes of wastage for a Toyota production system. The study suggests that use of 5whys in manufacturing industry gives a realistic approach to the problem from its identification to correction in order to reduce and eliminate the defects [11]. Breakdown time of equipment and quality losses are the two major concerns for any organization in order to achieve production targets and remain competitive.

This research is carried out in a renowned paper board and packaging company located in Lahore, Pakistan. The company is pioneer and the biggest supplier of packaging product to different industries all across Pakistan such as beverages, food and fast moving consumers goods etc. The present case study reports the OEE improvement for a flexographic printing machine aiming at reducing the breakdown time of the machine. Main problem areas are identified using Pareto diagram followed by 5-whys analysis approach used for root cause analysis.

2. Research Methodology

In the current study, a flexographic printing machine from Business Unit has been selected. The machine specification and production capacity are listed in table 1
There are five basic steps involved in flexographic printing. A fountain roller is dipped in ink tray that is transferred to next anilox roller. Anilox roller transfers the ink to the flexible plates. In the next step a doctor blade removes an excessive amount of ink pasted in the previous step. In the next step uniform distribution of ink is achieved using a soft rubber like printing plate. The process completes when a pressure is applied by the last cylinder called print anvil. The schematic of process under study is shown in the figure 1.

For OEE calculation, data for last one year breakdown time for each machine was selected. Calculated OEE based on the one year breakdown time data was analysed with the help of 5-whys analysis approach and Pareto charts were used to prioritize the failures in order to rectify these failures in future to improve the OEE. After the analysis, the data was collected on the same machines for 30 days.

3. Experimental results and analysis

3.1 OEE calculation
Initial OEE was calculated on the basis of one year downtime data which was maintained by the production department of the organization. OEE was calculated by using equation 1-4 mentioned above which was found 34%. To improve OEE, four main problem areas were identified for the flexographic printing process by using Pareto diagram as shown in table 2.

| Sr # | Problem Area               | Major Effects       | Total Breakdown Time/Year |
|------|----------------------------|---------------------|---------------------------|
| 1    | Matching with Lacquer      | Duplicate Printing  | 15065 min                 |
| 2    | Shade Card Preparation     | Fade prints on poly sheet | 13474 min               |
| 3    | Doctor Blade Problem       | Grainy dots on poly sheet | 14407 min               |
| 4    | Ink Mottling Problem       | Missing of even and smooth prints | 20895 min             |
To avoid failures occurred due to the above-mentioned problems, root cause analysis was carried out using 5-why analysis technique. During the present study, the “why” question was asked only three times because the root cause was clearly identified. Figure 2 illustrates the root cause analysis for problem 1 i.e. matching with Lacquer using 5-why technique.

**Figure 2.** 5-why analysis for matching with lacquer.

**Figure 3.** 5-why analysis for shade card problem.

**Figure 4.** Uncovered drum.

**Figure 5.** 5-why analysis for doctor blade problem.
Lacquer performs solvent evaporation from poly film to give the best and durable printing finish. The malfunctioning of this step may result in duplicate printing on the product. It is evident from the figure 2 that the cause of the problem is primarily due to improper alignment of the impression roller caused by worker’s negligence.

Ink and solvent are mixed together in a drum to prepare shade card before printing. As drums are exposed to air during mixing causing the evaporation of solvent, consequently reducing sticking effect of ink that results into fade printing on the poly sheet. It can be seen from the figure 3 that evaporation is the main cause for the problem due to uncovered drums and improper stirring of ink and solvent as shown in figure 4. Looseness in doctor blade causing vibration due to interaction with the Anilox roller resulting in grainy dots on the impression patterns. Figure 5 reveals that air pasting pressure is the possible reason for the looseness of doctor blade as shown in figure 6. Ink mottling problem results in poor printing and figure 7 shows that lower pressure between the sleeves is the main cause of this problem.

3.2. Remedial actions

Lean manufacturing tool, in general requires small quantitative analysis than six sigma analysis tools. 5-whys is widely used analysis tool for root cause analysis without performing statistical analysis. During this 5-why technique, a question is asked five times to identify the main cause of the failure. During the present study, root cause analysis is carried out to three whys as compared to the traditional 5why technique. The reason behind this is the clear identification of root cause for above cited problem which requires no further why question to be asked.

Corrective measure implemented after 5-why analysis to reduce the problems:

- Proper inspection via Preventive Planned Maintenance after every shift so to have a regular check for not going towards the breakdown while running.
- Drums were covered.
- A proper channel flow rotation should be made to keep in movement so that the solvent would not be evaporated, otherwise keeping it idle, will lessen its concentration.
- Proper procedures for clamping and waxing the doctor blade on the jaw type die to the workers.

Figure 6. Looseness in doctor blade.

Figure 7. 5-why analysis for Ink Mottling problem.
- Proper planned maintenance schedule and formation of critical control points (CCP) for the future hazard concerns.
- Inspection of required pressure to be maintained during the job setting.
- Critical control points should be displayed above the machine on a readable location.

3.3. Post implementation results
These proposed solutions were implemented and final OEE was calculated for a time period of 30 days. The improved results are given in the table 3.

| Sr.# | Problem Areas       | Current Breakdown Time (min) | Percentage Improved Breakdown Time | Time Saved (min) |
|------|---------------------|-----------------------------|------------------------------------|-----------------|
| 1    | Matching with Lacquer | 15065                       | 53 %                               | 7985            |
| 2    | Shade Card Preparation | 13474                       | 31 %                               | 4177            |
| 3    | Doctor Blade Problem   | 14407                       | 42 %                               | 6051            |
| 4    | Ink Mottling           | 20895                       | 80 %                               | 16716           |

By using the equation 1-4 and data available in table 3, the final OEE was found 40.2%. A positive trend has been observed in OEE and if overall equipment efficiency is considered as a continuous process improvement tool than further improvement in OEE can be made by rectifying the problems and their root cause analysis.

4. Conclusions
Following conclusions are drawn from the study:
1. OEE behaves as the quantitative measurement for total productive maintenance which is used to identify major areas of improvements for a process.
2. It is also concluded that 5-why approach is a useful technique for root cause analysis which ultimately improved the OEE from 34% to 40.2% within time period of 30 days.
3. Overall equipment efficiency can be used as measure of continuous process improvement.

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