USE OF MULTIPLE ACTIVITY CHARTS FOR PROCESS IMPROVEMENT IN RUBBER WIRE CABLE MANUFACTURING

M. Dewa*

1Department of Industrial Engineering
Durban University of Technology, Country
mendond@dut.ac.za

ABSTRACT

Waste reduction becomes an increasingly dominant topic for companies that strive to survive in the modern manufacturing world. This paper applies multiple activity charts for process improvement in rubber cable manufacturing at a case study company. The process is first mapped to outline the basic manufacturing process which included mixing, milling, straining and cooling. Tasks were then categorised as value-adding task, non-value adding but necessary, and non-value added. The non-value adding waiting was noted where the mixer operator waited for the miller operators to complete rolling a batch before mixing a new batch. Two scenario, where mixer waits for miller and where miller waits for mixer, were analysed through the use multiple activity charts. The analysis revealed that the current method employed was unbalanced since more time was wasted in waiting since the mixing time was longer than milling time. It was thus proposed that the mixer operator continuously works while the miller milled the batches as they became available. The mixer waiting time was eliminated as the mixer was continuously loaded, leading to productivity improvement. It was also recommended that the technique of job rotation should be employed due the disparity in workloads for mixing and milling operators.

*Corresponding author
1. **INTRODUCTION**

Waste reduction becomes an increasingly dominant topic for companies that strive to survive in the modern manufacturing world. One of the most significant challenges that is faced by manufacturing organisations is the continuous process improvement that entails new insights about the behavior of processes in order to understand their potential for optimization or improvement [1]. Multiple activity charts are used as tools for process improvement to describe activities of more than one subject, recorded on a common time scale to show their interrelationship. The objective is to rearrange activities, organise teamwork, minimise maintenance time, reduction of change-over time and idle time [2]. The case-in-point cable manufacturer produces its own rubber compounds which is used for insulation and sheathing. Rubber is the only raw input material that is produced on site and other materials such as copper for the cable making process are outsourced. Rubber is produced in batches and there are various compounds with different properties that are used for different types of cables. The problem that was being faced by the case-in-point cable manufacturer is that it was failing to achieve its target of 60 batches per shift and it was argued from the operators’ perspective that the target was unattainable. Therefore, the aim of the study was to determine if the target could be achieved and to find ways to increase the output by reducing or eliminating waste.

2. **LITERATURE REVIEW**

2.1 **Types of waste**

The principle of lean manufacturing is grounded on the identification of value, elimination of waste, and generation of flow of value to the customer. Waste is described as any process activity that does not add value to the customer [3]. The expenditure of resources for any objective that does not create value for the end customer is considered to be wasteful, and thus should be targeted for elimination [4].

The seven most common types of waste include:

- **Transport** - This activity relates to transport of materials, which is often indispensable, but does not create value. It is worth noting that there are more chances of delays or an increase of damage and loss when a product is transported more often.

- **Motion** - These are unnecessary movements by people or equipment moving or walking more than is necessary when performing activities. Excessive travel between workstations and machine movements cause stress to employees and machines and can cost time and money, as well. Movements that are done more than is required may also cause damage and injury to the operator [5].

- **Waiting** – This form of waste happens when people, equipment or products waits to be processed, and it does not add any value to the customer. Operators may stopped waiting for parts, machines, or other workmates.

- **Defects** - These are errors that occur during processing and may require re-work or additional work. Defects are the most visible of the seven types of waste, yet are not easy to catch before they reach the consumers. Defects retard production and increase lead time. Since every defective part needs a replacement or repair, which wastes materials and time, in terms of quality, defects tend to cost more and thus, waste of defects should be reduced or eliminated. There should be systematic and valid control methods in place so that defects can be identified before the product is unnecessarily processed, causing an unnecessary cost to the company [4].

- **Inventory** - this type of waste comprise of raw materials, work in process, or finished goods in the shop-floor, warehouse and other areas of a production plant. Inventory must be stored, and this requires space, packaging and transportation. Inventory has a possibility of being damaged during transport. Waste of inventory tends to hide other production waste such as machine breakdown, poor scheduling, quality problem, transportation time of raw material, poor vendor delivery times, lengthy set up times and line imbalance. Thus, minimum inventory is encouraged since it exposes all other types of waste [6].

- **Over-processing** - It occurs when a particular process step does not add value to the product and more work is done on a process than is required.

- **Overproduction** - It is created by producing more products than are required by the customer. Overproduction is related to inventory waste and producing in excess consumes an organisation’s resources in advance, resulting in extra inventory. [5].
2.2 Process Improvement

Process improvement is the proactive task that is characterised by identification, analysis and improvement of existing business processes within an organization for optimization and to meet standards of quality [7]. There are different approaches to process improvement such as lean manufacturing, business process re-engineering and benchmarking, and a systematic methodology is followed for each, of which the process can either be complemented with sub-processes, modified or eliminated for the ultimate goal of improvement. It is an ongoing practice of continuous improvement and should be expedited with the analysis of tangible evidence of improvement from performance measurement. Process improvement is characterised by initially understanding the purpose of a process, workflow or activity and then analysing to identify major problems and how they can be eliminated. It also embraces comprehension of the standards that must be achieved and activities should be monitored to ensure that performance targets are met [8].

Improving operation procedures is a simply method that make optimum use of the raw materials that are used in the production processes. Standard operating procedures reduce system variation and thus are crucial in ensuring consistent quality, and they support training and reduce risk [9].

2.3 Multiple Activity Charts

Multiple activity charts are used to show the interrelationships of individuals in teams of workers, or the relationships between workers and equipment. They are used to illustrate parallel activities and time relationships between two or more resources and are useful where the interactions between workers, equipment and materials repeat in periodic cycles. The charts can aid in identifying bottlenecks and idling resources by showing the utilisation profile of each resource in parallel bars. They can also provide a valuable tool for monitoring progress in critical situations where a detailed understanding of the workflow is needed [10].

3. METHODOLOGY

The methodology that was adopted is characterised by 5 steps that include the following:

**Step 1: Communication with all concerned**

In order for the project to be successful, the co-operation of the operators and the team leaders is required. This is because they have authority and control over the tasks to be improved. If the operators and relevant supervision have the correct understanding of the study then they will co-operate accordingly instead of being against the study. This means that there will be fewer human error factors that would occur, the study would show the true potential and substantial improvements can be made at the case-in-point plant.

**Step 2: Understanding the machine processes**

There are 3 ways to identify waste by classing each process step under the following categories:

- **Value-Added task**: The actual process that transforms the input material into the desired output.
- **Non-Value Added task but is necessary**, e.g. transportation of WIP from process to process.
- **Non-Value Added task but is unnecessary**, e.g. waiting for the process 2 to be complete the first batch before process 1 starts the next batch, tasks can be completed simultaneously so that there is a continuous flow of production.

Therefore is essential to understand the process so that the correct improvement and waste areas can be identified.

**Step 3: Study of the process and data collection**

A production and time study was conducted for a month, with the aim to monitor and study the process in order to collect a reliable amount of data that would be used to calculate a standard time to produce one complete batch. The necessary trials were done in order to determine the actual output, cycle time and improvement areas at the case-in-point plant.

**Step 4: Summarise and analyse the study results and outcome**

The study was analysed in stages so that each stage was monitored and improved accordingly. Creating point improvements was avoided as it may not influence the process as a whole and would not necessarily cause an improvement in the ability to reach the target or increase overall output.
Step 5: Presentation of results and recommendations to production
The results and improvement areas that were found were presented to production department so as to aid in meeting targets, improving efficiency and daily output.

4. PROCESS ANALYSIS

4.1 Basic stages in rubber production

The basic stages at the case-in-point plant are:

- **Mixing** - This is where the necessary compounds are mixed. The rubber output batches are made up of the following compound groups that are added to the mixer accordingly: Polymers, Fillers, Chemical additives, Accelerators. The operator loads the mixer which independently mixes the compound. It also automatically opens at specific set temperatures to allow for the necessary compounds to be added. Once the batch has been mixed for the necessary time it drops onto a conveyor which leads to the next process. Although they do not necessarily work with set times for mixing but instead they work with specific temperatures.

- **Milling** - This operation is when the mixed batch is blended/milled between rollers to further mix and blend the rubber compound. There are specific blending times and temperatures to be set in order to ensure proper blending. It is then cut into strips and feed to the next stage via a conveyor system.

- **Straining** - This is when the rubber compound is fed into a strainer which strains the rubber (to remove contamination) and then extrudes the rubber which is cut into 2 strips.

- **The cooling system** - This is when the rubber strips pass through a water trough and then onto a series of conveyors which pass by fans which cool the rubber down. This is done so that the rubber cools down and does not stick to each other when packed onto the pallet.

The case-in-point plant has the target of producing 60 batches per shift and has not been meeting this target. It produces various types of rubber that have different properties, i.e. outer/inner sheathing, outer/inner insulation; heavy-duty cables; light duty cables; and other rubber product.

4.2 Pareto Analysis

Pareto analysis is a formal technique that can be used by Industrial Engineers to identify key areas to derive better benefits after some course of action. Figure 1 shows the Pareto results for percentage monthly demand for different types of rubber by the plant.
Figure 1: Pareto results for demand of different types of rubber

Pareto analysis revealed that high voltage cable (RM 111), extra heavy duty CR sheathing material (RM 230) and heavy-duty CR sheathing material (RM 229) were the most utilised rubber compounds, and thus the study focused on RM 111.

4.3 Multiple Activity Charts

Table 1 shows the time study results for RM 111 which is characterised by 4 elements that include loading compound, first mixing, loading accelerator and second mixing.

<table>
<thead>
<tr>
<th>El. No.</th>
<th>Element</th>
<th>Total basic time</th>
<th>No. of elements</th>
<th>Average basic time</th>
<th>Allowance</th>
<th>Std time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Load Compound</td>
<td>15.54</td>
<td>10</td>
<td>1.55</td>
<td>25</td>
<td>1.94</td>
</tr>
<tr>
<td>2</td>
<td>First mix</td>
<td>20.52</td>
<td>10</td>
<td>2.05</td>
<td>0</td>
<td>2.05</td>
</tr>
<tr>
<td>3</td>
<td>Load Accelerator</td>
<td>2.98</td>
<td>10</td>
<td>0.30</td>
<td>25</td>
<td>0.37</td>
</tr>
<tr>
<td>4</td>
<td>Second mix</td>
<td>22.40</td>
<td>10</td>
<td>2.24</td>
<td>0</td>
<td>2.24</td>
</tr>
</tbody>
</table>

4.3.1 Multiple Activity Chart 1

Figure 2 shows the current method employed for the high voltage cable (RM 111). The mixer operator waits for the batch to be milled before mixing a new batch. The chart shows that in 1 hour, 6 batches (as per target) can be produced, given that there are no disturbances. With cycle times longer than that of RM 111, in an hour, less than 6 batches can be made and this is below the hourly target. The mixer waits for 21 minutes in a 60 minute
time frame. The mixer operator idles for 38.5 minutes in a 60 minute time frame. The miller and the miller operator wait for 39 minutes in a 60 minute time frame.

**Figure 2: Multiple Activity Chart if mixer waits for miller**

It was noted that the mixer operator waits for the miller operators to complete rolling a batch before mixing a new batch. Time is wasted waiting because the mixing time is longer than the milling time. Therefore batch B can be mixed while batch A is milled and the miller should complete batch A before batch B is dropped. This will create continuous flow of batches and eliminate idle time.

### 4.3.2 Multiple Activity Chart 2

Figure 3 shows an improved state where the mixer operator continuously works and the miller mills batches as it is dropped. In one hour 8 batches of RM 111 can be made considering that there are no disturbances. This is 2 batches more than the target. With cycle times longer than that of RM 111, in an hour 6 batches can be made. The mixer waiting time is eliminated as the mixer is continuously loaded. The mixer operator idle time is reduced to 29.5 minutes. The idle time is reduced by 9 minutes. This is only a 23.4% improvement but is still positive because the number of batches produced in an hour increased from 6 to 8.

The miller and miller operator idle time decreased to 27.5 minutes. The idle time decreased by 11.5 minutes (29.5% improvement). Table 2 shows the machine and labour capacity utilisation of the before-and-after scenario.
implementation of the method study. When scaled up, according to chart 1, 48 batches, of RM 111, can be produced in an 8-hour period where a single material is continuously mixed. According to chart 2, 64 batches, of RM 111, can be produced in an 8 hour period where a single material is continuously mixed. This is 16 batches more which is a 33% improvement.

Table 2: Machine and Labour capacity utilisation

<table>
<thead>
<tr>
<th></th>
<th>Before state</th>
<th>Improved state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixer</td>
<td>65%</td>
<td>100%</td>
</tr>
<tr>
<td>Mixer Operator</td>
<td>65%</td>
<td>51%</td>
</tr>
<tr>
<td>Miller</td>
<td>35%</td>
<td>54%</td>
</tr>
<tr>
<td>Miller operator</td>
<td>35%</td>
<td>54%</td>
</tr>
</tbody>
</table>

Figure 3: Improved state for multiple activity chart

These results demonstrated that the target could be achieved and method study can be deployed to increase the output by reducing or eliminating idling time.

4.4 Areas for concern

Kaizen is an excellent strategy that can be adopted in Industrial Engineering to create continuous improvement by adopting small, ongoing positive changes to reap major improvements. It was noted that there was also room for improvement concerning the standard operating procedures (SOPs) that were not followed correctly, thereby
resulting in increasing cycle time increasing. The mixing cycle time increased because the ramp was not functioning properly. The ramp was sitting at a single position (960) instead of fluctuating in position (1100 - 920) to create the necessary pressure to mix the batch and increase the temperature. Figure 4 shows the fluctuation in cycle times for RM 111 and it was crucial to understand the reason behind the fluctuation of the cycle times. The cause was poor preventive maintenance frequency since it was noted that there was a build-up of dust in the mixer ramp causing a blockage. The ramp was supposed to be cleaned/dusted every time the mixer is loaded to ensure the build-up is avoided. At cycle 4, the time to reach temperature had increased by approximately 0.5 min. From cycle 4 to 10, the time to reach temperature continued to increase. At cycle 9, a technician from the maintenance department was called to check the mixer ramp that was not functioning correctly to create the necessary pressure. At cycle 10 the ramp was given a quick clean before being loaded. It is noticed that the time to reach temperature dropped but not down to the usual time taken. From cycle 12 onwards the ramp was cleaned after loading, the dust on, in and around the mixer was brushed down. The time to reach temperature dropped down to the “normal time” usually taken. The time taken to reach optimal operating temperature decreased after the interventions and the ramp operated without problems.

The second area of concern was time lost due to low morale since it was noted that the operators took longer breaks than the allowed time. For a final stage to stop exactly at or few minutes before break, the operators have to stop mixing at approximately 10 minutes. A comparison was made between Number of batches made considering extra break times taken versus Number of batches that can be made if standard times are followed. The base information for the times for the two scenarios are:

Number of batches made considering extra break times taken:

- Cycle time taken 10 minutes
- Actual Break times taken = 60 minutes lunch, 20 minutes tea time (x2)
- Meeting Time = 30 minutes
- Wash up Time = 30 minutes
- Set up time = 30 minutes

Number of batches that can be made if standard times are followed:

3786-8
Cycle time taken 10 minutes
Break time = 45 minutes lunch, 10 minutes tea time (x2)
Meeting Time = 15 minutes
Wash up Time = 15 minutes
Set up time = 30 minutes

An output trial was conducted to determine the output of the strainer which was unknown. The trial was conducted at 6 and 5 RPM, the results were as follows
- 8.42 kg/min at 6 RPM
- 6.9 kg/min at 5 RPM

Using the output trial results the strainer cycle time was calculated as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass (kg)</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6 rpm</td>
</tr>
<tr>
<td>RM 111</td>
<td>79.79</td>
<td>9.476</td>
</tr>
<tr>
<td>RM 229</td>
<td>71.99</td>
<td>8.550</td>
</tr>
<tr>
<td>RM 230</td>
<td>70.53</td>
<td>8.376</td>
</tr>
<tr>
<td>RM 235</td>
<td>80.60</td>
<td>9.572</td>
</tr>
</tbody>
</table>

Using the study results, the average batches to be produced when using standard times, was determined and is indicated in Table 3.

<table>
<thead>
<tr>
<th>Material</th>
<th>Standard Time (min)</th>
<th>Batches Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mixing</td>
<td>Mill</td>
</tr>
<tr>
<td>RM 229</td>
<td>6.270</td>
<td>3.880</td>
</tr>
<tr>
<td>RM 230</td>
<td>4.000</td>
<td>3.840</td>
</tr>
<tr>
<td>RM 111</td>
<td>6.610</td>
<td>5.540</td>
</tr>
</tbody>
</table>

From the results it was concluded that the strainer is the bottleneck process at the rubber production plant. The operators stop mixing batches when the strainer pot is full and start mixing again when the pot is almost empty. The operators should rather monitor the pot level and mix accordingly instead of waiting for the strainer pot to empty. The operators were abuse lunch times. They left early for lunch and arrive late from lunch. The operators would also take breaks at different times. The strainer operator could take a later lunch so that rubber in pot is not left to get cold. The mixing and mill operator can take lunch when the pot is full.

5. RECOMMENDATIONS

The following is suggested based on the results and analysis to improve the Case-in-point plant performance:

- Continuously mix batches so that the milling operation waits for the next batch instead of the mixer standing until the milling operation is completed.
- Ensure that the standard operating procedures are followed correctly so that batches can be continuously and consistently mixed.
- Discipline operators so that they do not take advantage of break times and stick to the stipulated times instead of leaving early for breaks and arriving late from breaks.
- The operators can take their breaks at different times so that the output is maximised and there will be a continuous flow of operations.
• The technique of job rotation should be employed due the disparity in workloads for mixing and milling operators.

6. CONCLUSION

In today’s business environment, the expenditure of resources for any objective that does not create value for the customer is wasteful, and thus should be targeted for elimination. With constant pressures to cut costs and innovate, process improvement can be deployed to identify and eliminate major problems and embraces comprehension of the standards that must be achieved and activities should be monitored to ensure that performance targets are met. Multiple activity charts can provide a valuable tool for monitoring progress in critical situations where a detailed understanding of the workflow is needed. SOPs must make bottom-line economic sense, especially if an organisation invest the time and energy to develop and implement effective SOPs. The study revealed that the target of 60 batches a shift is achievable under ideal situations. It also revealed that there is excessive time wasted in areas that are unnecessary and the operators need to follow the correct methods and operating procedures to avoid time wastage.

REFERENCES