SYSTEMATIC EFFICIENCY IMPROVEMENT BY OPTIMIZING THE ASSEMBLY LINE USING WITNESS SIMULATION SOFTWARE

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Abstract—Today’s customers demand high quality, customized goods and services, quickest delivery. This has made the design and management of systems more challenging. Simulation models are used to find various aspects of manufacturing systems. Manufacturing industries need plant layout improvements to meet their customer demands. This paper provides the use of Witness Simulation to design the production of a manufacturing company that reconditions Cam follower for export demand. The objective of the study is to increase the productivity and efficiency of the line. Detail knowledge of the assembly line is must and analysing the present needs is important. Cycle time data is collected by stopwatch for every station of respective assembly line. The bottlenecks of the production line, required man, machine and other major causes of the problems were identified. Modifications in the model structure to improve the assembly line is made to improve the total output. The analysis presented through the simulation here reduce the manpower of assembly line with the same production output of 2500 yield per month. Earlier 26 manpower were present per day, through simulation output, 6 manpower are reduced. The relevance of the study is by planning to optimize resources, cost of company is reduced with better profits. Also VSM and OEE study, helped improve the effectivity and productivity of assembly line. By eliminating the root causes for failure of product, the product has become more reliable. Overall the quality of product is improved to 96.00 percent.

Keywords— Witness Simulation, Assembly line, Value stream mapping, Overall Equipment Effectiveness, Bottleneck, Productivity improvement.

I. INTRODUCTION

Manufacturing is a competitive global market and the plant layout problems are found in every manufacturing industries. To maintain the plant layout is a major challenge and they are known for impacting the performance of the entire production system. Cam Follower is one of the complex part of engine and the acceptability performance of a cam follower system lies in its testing. There is a need of high accuracy of precision in processing. In this paper, the problem definition are the issues reported in Manufacturing Company. One of the Manufacturing product is Cam follower. They work for the International markets and provide the conditioned products with 100% quality assurance to Australia, Denver, Chile. Processing of the Cam follower has a process sheet to be followed. According to the investigation, some problems were detected that had severe impact on failure of engine field. This impacted delay in business. The hardware equipment’s drop behind comparatively, in addition the management efficiency is very low in this production line. From the production data, they produce 50 Cam followers per shift. And their yield is approximately 2,500 per month. The whole set up need to be redesigned again as there is addition of new machines in the setup. Therefore, the overall goal is to achieve quality product and to meet the customer demand and satisfaction. This business is a new concept introduced in India. Manufacturing means conditioning of the core parts. The Company offers a wide range of manufacturing and build up products that are like the new parts. A fixed standards maintained in the manufacturing process that make components and engines that do provide same quality with 100% inspection certification standards. The Customers for whom time is money and for whom the product demand is very urgent, in such case the Manufacturing Company provides the products in stock, rather than waiting for the new parts, the exchange business of core replacement is done.

II. ROLE OF SIMULATION IN MANUFACTURING

Recently, there is growing demand of simulation in manufacturing industries. Evidence of the use of simulation can be found out using the literature. Simulation has much to offer all large organizations, whether they are in manufacturing or in the service industries. The role of simulation is to evaluate practical alternatives available either in support of major strategic initiatives which might involve a large financial outlay, or in support of the continuous search for better performance at operational and tactical levels. Sayed Ali [1] evaluation included changes to the machine setups, increases or decreases in customer demand, improvements in cycle time efficiency, reduced lead times and improved customer response times, getting knowledge about the breakdowns in assembly line, the man power requirement analysis. G. Cheng [2] evaluated bottleneck operations in the assembly line. It is capable of handling the complexity of large systems, even a whole factory. The simulation approach supports critical analysis by allowing rapid changes to the model logic and data. From above discussion it can be said that Witness Software is user friendly. Lanner Group Manufacturing Book [3] suggested that the Simulation Software enables business process improvement for world leading organizations. With simulation business managers can model, analyse and optimize processes to make superior decisions in a risk free environment. Witness simulation is the key to improving productivity, efficiency and reducing cost. Ramasesh [4] provided research on dynamic job shop scheduling and sequencing problem to improve the
performance of flexible manufacturing systems. Yabin Li [5]the use of Witness simulation software in optimization of the thermal power plant. Transport of the coal was improved by improving the railway tracks. The model explains the construction of process and validates the feasibility of model.

III. MODEL BUILDING

This section explains the simulation study of the assembly line that is being practiced in the Manufacturing Company. As discussed earlier the main purpose is to improve the quality of the product.

A. Assembly Line

Assembly line has been used in a mass production system. The conceptual model has been shown in Fig 1. The assembly line includes a number of workstations arranged in a sequence. The workstations are semi-automated, where an operation is done by a machine and operator.

The parts are carried by trolleys from one station to next. The parts of Cam Follower are very fragile. Therefore to reduce any dents and to avoid crack marks, the operation department has done the material handling improvements as well. Separate bins are designed to keep subparts of the whole assembly.

![Fig 1. Conceptual Model of Previous Assembly Line](image1)

There are improvements in the future processing assembly line. Fig 2 shows the future conceptual model for the cam follower line. From the comparison of both the conceptual layouts, it can be observed that there is increase in workstations and machineries in the future assembly line layout. Also the man power requirements has increased. Therefore, we need to determine the optimum man power required in the future assembly line without affecting the production rate of Cam follower. Maintaining the same production rate as per previous model can be simulated using Witness Software.

The study showed that the previous model had problems. The bottleneck operations were studied. In the Fig1. OP-60 both used to get pressed on single station. There was only one press machine on which three operations were performed respectively. It was found that the set up time was more as every time the operator had to fit different fixtures for the particular operation to get performed. Also it was found that there was no failsafe method used. Therefore, it resulted into misalignment and wrong orientation of the cam follower assembly. There are long downtimes over assembly line. Also there were issues in quality inspection because of dent marks and cracks on the assembly parts. Redesign of the process flow was made.

![Fig 2. Conceptual Model of Improved Assembly Line](image2)

**Fig 2** shows the Cam Follower Process flow that is being practised. Here, the number of workstations are increased. It is made sure that the components passed from one station to other is dent free and is inspected thoroughly. There are 4 press machines installed on the assembly line for different part numbers. The OP-80 and OP-90 are separately mounted. There is no need to set the fixtures. The fixtures also has the failsafe method to avoid wrong orientation. Hence, the production rate is not hampered and the company can meet it’s per day target. There were further improvements made from the quality prospective of the product. OP-40 and OP-100 for every part was carried out. OP-120 and OP-140 station were introduced to improve the quality of subparts.

**B. Data Collection and Analysis**

The duration for developing the simulation model is all dependent on the amount of quantifiable and quality data that is being collected from the assembly line. The keen observation of every activity on the shop floor is equally important as it gives precise idea while designing the simulation model. In this Project stopwatch tool has been used for gathering data in the production line. The cycle time of each station has been captured as a sample for about 10 times.

**IV. EFFICIENCY IMPROVEMENT OF PROCESSING LINE OF CAMFOLLOWER**

**A. Value Stream Mapping of Cam Follower Line**

This process is a part of the continuous improvement toolkit, that helps determine the best ways to improve product flow through a facility. VSM is useful to find and eliminate waste. Assembly layout focuses on flow, and the logistics of getting the product to market most efficiently. When it is needed to expand, Value Stream Mapping can uncover valuable opportunities to streamline using Lean thinking. Hence it will be helpful in reducing cycle time and total work content. This sheet is also helpful for operator balance chart to make effective use of operators. **Fig 3** shows the VSM of an assembly line.
i. Time Calculations

Total available time = 780 mins in 2 shifts
Available time/ shift = 420 mins
Consider first work station, for OP-10 Station:

- Cycle time (min) /set = 3.6 min
- Uptime = 95%
- Yield = 85%
- Batch/ Single = Single
- Manpower = 1

Average time (A/T) = 780 * 0.95 = 741 mins (1)

Possible o/p (unconstraint) = \( \frac{\text{Available time}}{\text{Cycle time}} \) = \( \frac{741}{3.6} \) = 205.83 (2)

Output after yield consideration = \( \frac{\text{Possible output}}{\text{Yield}} \) = \( \frac{205.83}{0.85} \) = 173.95 (3)

ECT (mins) = \( \frac{\text{Total time per shift}}{\text{Yield}} \) = \( \frac{840}{0.85} \) = 4.80 mins (4)

In the similar way, other stations effective cycle time is calculated.

Two conditions were considered – with constraints and without constraints the effective cycle time is calculated and the demand is the output of the 2 shifts.

For the Packaging Station, the production target is of 100 cam followers from 2 shifts, therefore the takt time is calculated. Takt time simply reflects the rate of production needed to match the demand.

\[
\text{Takt time} = \frac{\text{Available time}}{\text{Desired output demand}} = \frac{780}{100} = 7.80 \text{ mins} (5)
\]

For each stations there is different demand and hence the takt time is different. Analysis sheet and graphs were discussed with top managers to fix the production target. As a result, the VSM of Cam Follower increased the production target from 100 cam followers to 120 cam followers in a day respectively.

ii. OEE Calculations for an Assembly Line

Overall Equipment Effectiveness (OEE) measurement quantifies how well a manufacturing unit performs relative to its designed capacity, during the periods when it is scheduled to run. It is a way of measuring the effectiveness of a machine which evaluates and indicates how effectively a manufacturing operation is utilized. Fig 5, is the OEE Model. It shows that OEE has 3 components – Availability, Performance and Quality. This components has six big losses that are tried to be reduced to the run machines efficiently.
The high-level formula for the lean manufacturing OEE is:

\[ OEE = \text{Availability} \times \text{Productivity} \times \text{Quality} \]

Calculation of Line Balancing:

Available time= 480 min per shift
Lunch Break= 90 min
Available Time= 390 min
Marketing Requirements= 2500 Cam followers/ month
Working Days = 25 Days
No. of shift in a month= 25 × 2
Per shift requirement of Cam Follower = \( \frac{2500}{50} = 50 \) Nos.

Ideal Run Rate = \( \frac{50 \text{ Cam Follower}}{6.5 \text{ hours per shift}} \)

=8 Cam follower/Hour \hspace{1cm} (6)

Total parts = 2500 / month
Planned production time (PPT) = Shift length – Breaks
= 480 – 90 = 390 min per shift
Operating time = PPT – Downtime = 390 – 10 = 380 min
Assume yield = 95%. Therefore 2 rejected per shift.
Good pieces = Good parts – Rejected parts
= 50 – 2 = 48 Cam followers.

\[ \text{Availability} = \frac{\text{Operating time}}{\text{PPT}} \]

\[ = \frac{380}{390} = 97.43\% \hspace{1cm} (7) \]

\[ \text{Performance} = \frac{\text{Total parts}}{\text{Operating time}} \times \frac{1}{\text{Ideal run rate}} \]

\[ = \frac{2500/390}{8} = 80.1\% \hspace{1cm} (8) \]

\[ \text{Quality} = \frac{\text{Good parts}}{\text{Total parts}} \]

\[ = \frac{2400}{2500} = 96\% \hspace{1cm} (9) \]

\[ OEE = 0.97 \times 0.80 \times 0.96 = 0.74 \hspace{1cm} (10) \]

### Table: Comparison of World Class OEE Factor and Cam follower Assembly Process

<table>
<thead>
<tr>
<th>OEE Factors</th>
<th>World Class</th>
<th>Cam Follower Assembly Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>90.00%</td>
<td>97.43%</td>
</tr>
<tr>
<td>Performance</td>
<td>95.0%</td>
<td>80.1%</td>
</tr>
<tr>
<td>Quality</td>
<td>99.9%</td>
<td>96%</td>
</tr>
<tr>
<td>OEE</td>
<td>85.0%</td>
<td>0.74%</td>
</tr>
</tbody>
</table>

Table shows that average OEE rate in manufacturing plant is 74 percent. As shown above, a world-class OEE is considered to be 85 percent or better. The losses mainly are downtime losses, speed losses and quality losses which affect Overall Equipment effectiveness of the process. To minimize these losses and to achieve world class OEE there should be reduction in events. The main events which are responsible for losses in assembly process are:

- Tooling Failures
- Unplanned Maintenance
- Setup/Changeover
- Material Shortages
- Operator Shortages
- Incorrect Assembly

It is important to decrease these non-productive events which affect efficiency of the process. They can be reduce by implementing new techniques and tools, proper inventory storage, in line assembly, skilled labours, special purpose machinery etc.

### B. Witness Modelling and Ameliorating

The design route are as follows for Witness Simulation table:

Analysis of practical production system → Setting up Witness Model → Discussing the model structure → Finding problems → Putting every parameter in VSM to Witness Model → Establishing witness model after optimizing (according to the VSM and then optimizing again) → Simulation running.

Fig 6.shows the simulation of cam follower production in Witness Model. The total simulation time considered is 56800 seconds. The total output is 110 cam followers per day (100 cam followers approximately). It is targeted that the new improvements in the assembly line does not affect the production rate. Table II shows the statistic report of 13 manpower. There idle and busy percent is known and based on it the operators can be optimized in Witness.

Structuring previous assembly line through witness simulation:
1) As shown in Fig. 2 some stations were added into the Cleaning area.

2) It is being noticed that the manufactured cam follower is having rust and dent marks on its assembled parts. Therefore, there is a need to work on quality of product.

3) The quality team improved it by ordering new inspection gauges, by adding the workstations such as dye penetrant testing, de-watering method, rust prevention method and oil flow test and lastly by giving proper training to the operator.

4) New press machines were introduced so that there is a reduction in setup time of fixtures.

5) There is a failsafe method used on every fixture to avoid misalignment of parts.

6) With the help of VSM of cam follower line demand of new line per shift is determined. Hence, the new improved assembly line is setup.

C. Suggested Model through Witness Simulation

Witness model of improved layout targeted two things:

- Manpower requirement per shift and
- Production output per day.

The total simulation time considered is 56,800 seconds (i.e. 976 minutes in a day). Total time considered by excluding the break and lunch time is 390 mins per shift and 3 hours in night shift. In this company, there is more human involvement. Although there are machines but the man capacity is equally important and is needed to be always maintained to meet daily production capacity.

Trials were held many times. Firstly, the line is set up. Next the manpower needed to determine. The line simulated as per the planning of team. The Production team demanded 26 people per day (i.e. 13 people per shift). The Operation team felt that unnecessarily there is extra use of labour. So they asked to release the labour. Here, the virtual simulation in Witness role came in. The statistic reports from the simulation showed the actual busy and ideal time of individual operator in process. Trials were being held to combine the work of operators. These reports helped optimize the manpower. Results showed that 3 manpower can be released to other assembly lines without affecting the production rate.

There is major cost saving to the organization. This can be shown through the following calculations.

Total Manpower = 26 per day
Assume: Cost of one Cam follower = Rs. 16,000
Cam follower production per day = 100
Production of cam follower per week = 600
Cost per week = 600 x 16,000 = Rs. 9,600,000 = $1,51,286

Labour Productivity = \frac{\text{Input}}{\text{Output}} \quad (11)

Case I: The company generated $1,51,286 worth of Cam follower in one week with 26 operators.
Labour productivity can be calculated by giving input as hours of work per week:

Labour Productivity = \frac{\text{Total cost per month}}{\text{Total No.of working Hours}}
To calculate the labour productivity in terms of individual operator’s contribution:

\[ \text{Labour Productivity} = \frac{\text{Total cost per month}}{\text{Total No.of Employees}} \]

= \$1,51,286

= \$ 5,818 per Employee per week (13)

Case II: The company generated $1,51,286 worth of Cam follower in one week with 20 operators. To calculate the labour productivity in terms of individual operator’s contribution:

\[ \text{Labour Productivity} = \frac{\$1,51,286}{20} \]

= \$ 7,564 per Employee per week (14) which means each employee produces \$ 7,564 for the company per week).

From equation (13) and (14), the labour productivity effects the cost. The cost per employee per week is increased when the labour is optimized. The same amount of production is done by 20 operators that produces more amount of cost. That ultimately reduction in cost benefits the organization.

The aim of the entire project is to reduce the manpower level without harming the production. Through simulating the assembly line, by giving the inputs and analysing the outputs, the manpower is reduced by 3 based on the busy and idle time statistics reports. This analysis was possible through the Witness Simulation Software.

### D. Results of the end of optimization

Although the efficiency of time, monthly yield and manpower is higher, there are still imbalance of time. It needs to be continuously improved. For 56,800 seconds per day the production rate is same as the previous assembly line i.e. 100cam followers per day.
The work carried out in this project was to optimize the man power requirement. By releasing 3 manpower per shift to other assembly lines, the company resources are used effectively. Hence, there is major cost saving to the organisation. Through the OEE calculations, the area in which there is need of improvement is determined. Different losses needs to be reduced to improve the efficiency of assembly line to meet World Class OEE factor. New line set up plan resulted intoreduction of major expensive assets and quality of the product is improved. Ultimately it gives profit to the company. In this paper, two methods are used that are Value stream mapping and Witness simulation. These two methods combined “completing each other” to improve the efficiency of Cam follower production line in Manufacturing Company. After VSM optimizing, month-yield is increased from 2,500 to 3,000. And then by witness optimizing, the yield remains 2,500. Work in progress to reach the target of 3,000 month-yield.

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