IMPROVING PRODUCTIVITY FOR ENGINE CRANK SHAFT MACHINING LINE USING TPS TECHNIQUES AND SIMULATION

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ABSTRACT

Process optimisation is a major decision problem when drawing a balance between work distribution of workers during processing and maintaining requirement (Output) as per demand of customer. Toyota Production System (TPS) techniques are useful tool to optimise the process parameters in process type of industry. The validation of optimum process result from TPS techniques is done with the help of simulation modelling using ARENA as simulation software. Simulation methods of analysis, supported by increasingly powerful and user-friendly software tools, are gaining greater acceptance as an indispensable aid to business managers, engineers and analyst seeking productivity improvement. Within this paper TPS techniques are used to optimisation of Engine Crank-shaft machining line (fully automated) where single operator operates multiple machines to load and unload the work-piece to and from the machines. Simulation methodology has been conducted to verify and validate the existing situation as well as proposed results i.e. for predicting line output. For simulation of line, ARENA simulation software is used.

Keywords: ARENA Simulation Software, Time Study, Method Study, Standardised work combination table, Heuristic Method of Line Balancing.

1. INTRODUCTION

Present business conditions are forced production companies which want to achieve and to detain its concurrent abilities on the global market to continuously optimise internal organisation of theirs production systems with the aim to increase capacity, decrease costs of production simultaneously and keep products quality at least on the same level. To global business trends are expose production companies in India too. To fulfill above mentioned requirements, Company must improve their mostly inefficient production processes.
1.1 **Toyota Production System (TPS)**

The practical expression of Toyota's people and customer-oriented philosophy is known as the TPS [1]. In TPS house, there are two primary pillars of the system. The JIT concept aims to produce and deliver the right parts, in the right amount, at the right time using the minimum necessary resources. This system reduces inventory, and strives to prevent both early and over production. There are several important components to TPS: takt times, flow production, pull via kanban, and leveling (heijunka) [1]. Jidoka (Build in quality) is the second pillar of the system. The driving force of the Toyota Production system is the elimination of waste aimed at ever improving quality, cost, productivity, safety and morale [1]. Many other tools and techniques that were developed in Toyota such as 7 Waste, Standardized Work, 5S, SMED, Visual Control, Error Proofing and many others [2]. The goal of the TPS is to provide products at world class quality levels to meet the expectations of customers, and to be a model of corporate responsibility within industry and the surrounding community [3, 4].

1.2 **Simulation Software (Arena)**

The ARENA modeling system from Systems modeling Corporation is a flexible and powerful tool that allows analysts to create animated simulation models that accurately represent virtually any system.

![Diagram](image)

**Fig. 1** Existing man-power deployment of Engine Crank-shaft Machining Line

ARENA is built on the SIMAN simulation language [5]. The ARENA template is the core collection of more than 60 modules provided as part of the general ARENA system. It was designed to provide a general purpose collection of modeling features for all types of applications. In addition to providing core features for resources, queuing, inspection, system logic, and external file interface, the ARENA template provides modules specifically focused on specific aspects of manufacturing and material handling [6].
1.2 ENGINE CRANK-SHAFT MACHINING LINE

A product taken for case study from Oil Engine company, which is one of the leading company in the area of off-Road vehicles engines production. In company, 5’C (Crank-case, Cylinder-head, Crank-shaft, Cam-shaft, and Connecting-rod) engine components are to be machined. Out of this, paper is concerned with optimisation of engines Crank-shaft machining line. The existing man-power i.e. Team Associate (TA) deployment of this line is shown in fig. 1.

2. PROBLEM FORMULATION AND ANALYSIS

During Planning of capacity of worker and their operation, management predicts the sequence of operation as well as worker capacity in Crack-shaft machining line. But after implementation the plan, the capacity of worker increased and man-power deployment is not optimum. The distribution of work as well as time during processing is imbalance in existing layout and it results as increasing idle time as well as waiting time during operation. So it affects the productivity and efficiency of machining line. TPS techniques and Simulation Software need to be study as well as implemented in order to optimise process parameters.

3. DATA COLLECTION

For existing work element, data are to be collected and their analysis has been done by following tool shown in fig. 2.

3.1 TIME STUDY AND METHOD STUDY

Time study and Method study are important tools to analyse the process parameters. By using this, idle time, waiting time as well as man-power deployment time can be easily calculated. To collect required data, the particular process should be captured and capturing done with the help of video camera & stop watch. After data collection, the whole activities are split into small activities (like pick Crank-shaft, put crank-shaft and so on) with activities time and machining time also. This data help to analyse the process which includes activities (value added, non value added and non value added but necessity activities). Time study and method study gives total time required to perform each activity during process.

3.2 STANDARDISED WORK COMBINATION TABLE

Standardised Work Combination table is an important tool used in TPS, which help to analyze the existing operational activities during actual process [4]. After data collection through time study each big activities split up into small activities including value added activities and non value added activities (Loading & unloading of Crank-shaft, TA walk with Crank-shaft and TA walk without Crank-shaft) are noted with their corresponding time into standard format given by TPS. Then draw chart as per standardised table format shown in fig. 2 for each TA working on crank-shaft machining line. Standardised work combination table shows waste activities, waste movement, TA walking distance and their corresponding time also. From that, engage time, idle time and waiting time are calculated.
ARENA 10.0, which is one of the most powerful software for simulation, is used to build the model. Fig. 3 shows the simulation model of existing Engine crank-shaft machining line. This model consists of 30 Process module (number of process on line) with their machining time, Station & Route module to transfer Crank-shaft from one machine to another station with respective transfer time, Create module to enter Crank-shaft on to line and Dispose module to exit Crank-shaft from machining line. Data on arrival rates, inter-arrival times and activity times are collected from time study database. The data were fed to the Input Analyzer application of ARENA for analysis to obtain the statistical parameters of raw data as shown in fig. 3.

**Fig. 3 ARENA Simulation model of existing engine Crank-shaft machining line**

### 3.3.1 Verification and Validation

In the Crank-shaft machining line, model verification and validation steps are implemented using ARENA model. For verification, the animation is used to show the Crank shaft movement inside the ARENA simulation model and to ensure that the movement is similar to existing process. Validation of the ARENA model is done by comparing the model output with real system output. For sake of validation, the number of Crank-shaft produced...
per shift is 123, while the real production rate per shift is 121 Crank-shaft which is approximately same. After analysis of existing process through simulation as well as TPS techniques (Standardised work combination table, Time study, and Method study) the results for each TA are as shown in fig. 4.

For the purpose of analysis of work element i.e. operators time study through simulation, it is necessary to making a individual model for each operator which shows engage time, waiting time and idle time of operator during operation. So this done with the help of ARENA simulation software which give required parameters for analysis.

![Fig. 4 Analysed results of existing man-power deployment for engine Crank-shaft machining line](image)

![Fig. 5 Proposed man-power deployment for Engine Crank-shaft machining line](image)

### 4. PROBLEM SOLUTIONS

Depending on the analysed results of man-power deployment on machining line, we came to conclusion that:

i. The line is more imbalances.
ii. Online TA idle time is more = Avg. 73 minute per shift.
iii. Online TA waiting time is more = Avg. 14 minute per Shift.
By using Heuristic Method of line balancing calculations for idle time and waiting time, we reconstruct and reallocate man-power deployment (Proposed loop) as shown in fig. 5 for same line with 6 number of TA [8, 9]. For proposed man-power deployment, time study and motion study has been done. Standardised work combination table for each TA (6 number) drawn to perform the analysis of proposed man-power deployment and then simulate this layout to predict the output. After simulation it gave same output (123 numbers). The analyse results of proposed man-power deployment shown in fig. 6.

![Image of bar chart showing time in seconds for each task]

**Fig. 6** Analysed results of proposed man power deployment for engine Crank-shaft machining line

**Table 1** Productivity and Cost comparison

<table>
<thead>
<tr>
<th>Loop</th>
<th>Output /shift</th>
<th>Online TA</th>
<th>Man hrs/shift</th>
<th>Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>121</td>
<td>7</td>
<td>45.62</td>
<td>2.65/hr</td>
</tr>
<tr>
<td>Proposed</td>
<td>121</td>
<td>6</td>
<td>39.1</td>
<td>3.09/hr</td>
</tr>
</tbody>
</table>

- Decrease man-hour by 14.3%
- Productivity increase by 16.6%
- 2 Online TA decrease per day (1 TA per shift)
- Approximate salary per TA 156000 per Yr.
- Annual cost saving (Rs.) 312000

5. **CONCLUSIONS**

The achievements in productivity improvements can be noticed as follows:

i. Online TA reduced by 1 i.e. from 7 to 6 no’s without changing output per shift.
ii. Man-power deployment is approximately balanced.
iii. Online TA idle time reduced by 30 minute per shift, i.e., from 73 to 43 minute per shift.
iv. Online TA waiting time is constant i.e. 14 minute per shift.
v. The productivity improved by 16.6% as shown in table 1.
REFERENCES

[1] Toyota Production System Basic Handbook (Published by Art of lean, Incorporation, pp.1-33).