Increased Productivity of Tyre Manufacturing Process using Lean Methodology

Ajit Chavda, Prof. M.Y. Patil

Abstract—The tyre manufacturing process consist of 6 steps, sequentially starting from Mixing→Extrusion→Bias cutter→Bead preparation→Tyre Building→Tyre Curing. Kanban (Replenishment system), Cycle time reduction and standard work practice methodology is used during extrusion to tyre building to reduce shortage of material which leads to increase in productivity of a tyre manufacturing process. This paper explains use of lean methodology like kanban, cycle time reduction and standard work practice for the above process.

Index Terms--Cycle time reduction, Kanban, Standard work practice

I. INTRODUCTION

Apollo Tyres Ltd. is a multinational company. As a part of its drive to become a significant global player in tyre industry by achieving customer delight, brand of choice and continuously enhancing stake holder’s value. Inspiring from vision statement of R & D team, new products are developed, due to this number of SKU’s (Stock keeping unit) are increases at all processes, which result in decrease of productivity of tyre manufacturing process. In order to improve the productivity, Kanban (Replenishment system), Cycle time reduction and standard work practice methodologies are implemented during extrusion to tyre building process, which results in reduction of shortage of material.

Just in time manufacturing system was developed by Taiichi Ohno which is called in Japanese “Toyota production system”. Kanban system is a new philosophy which plays a significant role in the JIT production system. This system has the primarily goal of continuously reducing and ultimately eliminating all form of wastes [1], [2] based on this principle. Japanese companies are operating with very low level of inventory, high level of quality and productivity [3]. Therefore material requirement planning (MRP) was changed to pull type JIT–Kanban production system, to meet the global competition, where the work-in-process (WIP) managed and controlled more accurately than the push production system [4].

1) Cycle time reduction

Cycle time reduction is the strategy of lowering the time it takes to perform a process in order to improve productivity. In addition, cycle time reduction often improves quality. When a cycle time is too close to the takt time, there is little margin for error.

Cycle time reduction is accomplished through a variety of kaizen methods—jidoka (separating people from machines), improving manufacturing fixtures, redesigning parts to make them easier to assembly, improving software, poka yoking processes.

2) Standard work practice

Standardized Work is a tool centered on human movement that combines the elements of a job into the most effective sequence, without waste, to achieve the most efficient method of production.

Standardized work effectively combines people, product, and process under the current conditions to improve quality, cost, safety, ease of operations, etc. Furthermore, it forms part of the base for Just-In-Time production by preventing over-production. Finally, standardized work functions as a basis for comparison enabling us to drive meaningful continuous improvement.

Elements of standardized work practice

• Takt time, which is the rate at which products must be made in a process to meet customer demand
• The precise work sequence in which an operator performs tasks within takt time
• The standard inventory, including units in machines, required to keep the process operating smoothly

Benefits of Standard work practice

• Maximized the flow
• Reduction in variability
• Easier training of new operators
• Develop safe working environment
• Reducing strain
• Provide a baseline for improvement

3) Kanban (Replenishment system)

Kanban is a Japanese word that means "visual card". It is the term used for the visual & physical signaling system that ties together the whole Lean Production system. Kanban is the means of signaling to the upstream workstation that the downstream workstation is ready for the upstream workstation to produce another batch of parts.

A kanban system allows a company to use just in time production and ordering systems, which allow them to minimize their inventories while still satisfying customer demands with improved services and quality [5].

Types of kanban

• Withdrawal kanban

The main function of a withdrawal Kan-ban is to pass the authorization for the movement of parts from one stage to
another.

Once it gets the parts from the preceding process and moves them to the next process, remaining with the parts until the last part has been consumed by the next process.

The withdrawal Kanban then travels back to the preceding process to get parts thus creating the cycle.

- **Production Kanban**

  The primary function of the production Kanban is to release an order to the preceding stage to build the lot size indicated on the card. It gives information about materials required as inputs at the preceding stage.

*Uses of Kanban*

- Reducing inventory
- Eliminating stock-outs
- Replacing massive computers
- Slashing overheads
- Improving service and product quality [6]

*Determining Number of Kanban*

\[
N = \frac{DL + C}{S}
\]

Where,

- \( N \) = number of kanbans or containers
- \( d \) = average demand over some time period
- \( L \) = lead time to replenish an order
- \( S \) = safety stock
- \( C \) = container size

**II. PRESENT SCENARIO OF INDUSTRY**

*Extrusion process*

Extrusion is the technique of pre-forming unvulcanized rubber compounds by forcing material through fixed apertures or dies, to obtain definite shapes and sizes. An extruder is a machine designed to produce a continuous length of material of desired cross section by forcing the material through an orifice or die under controlled conditions of temperature, pressure, rate and homogeneity.

*Tyre Building process*

Tyre building is the assembly of the various tyre components. The beads, plies, breakers, treads, sidewall and drum squeegee are assembled on a collapsible cylindrical drum. After the assembling, the drum inner diameter collapsed to take out the green tyre from the drum. Then after this green tyres are delivered to internal customer curing process.

Daily Physical inventory of tread is taken at end of C shift and based on this production planning and control (PPC) is prepared for a schedule of the day. A review of the process by PPC team with production is carried at 11.30 am. Based on tyre building & production of B & C shift, schedule of extruder is revised.

Following problems encounter in present system

- Insufficient tread inventory
- Line speed constrain at dual extruder due to increase in tread booking temperature
- Leaf truck shortages
- High time taken for Rear Tractor tread extrusion

- Only 8 dies and perform change per shift
- Tread storage in mix up manner
- High searching time
- Poor communication

*Proposed System*

1. Reduction in Cycle time by line speed increase
2. Standard work practice for leaf truck availability
3. Kanban (Replenishment system) for TR1034, TR1038, TR1090, TR1094 and TR 1105

   1. Reduction in Cycle time by increasing line speed

   1.1. Dual extruder output will increase by modifying preform

- New Preform Design developed
- Procurement of new preform as per new design
- Insert fixing in new preform
- TR1105 tread die modification for high flow
- Trial at extruder for new design preform
- Profile checking

![Fig.1. Comparison of preform modification in Preform](image1)

![Fig.2 Preform modification design](image2)

- **Fig.1** Comparison of preform modification

- **Fig.2** Preform modification design

<table>
<thead>
<tr>
<th><strong>Before</strong></th>
<th><strong>After</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cap opening 195 mm</td>
<td>Cap opening 400 mm</td>
</tr>
</tbody>
</table>

*Taper angle is designed for better flow of the compound without any restriction from preform*
• Data collection and monitoring

Fig. 3. Modification in die design

Trial data collection

TABLE I
TRIAL -1 DATA FOR TREAD CENTER LINE GAUGE

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Spec.</th>
<th>Overall Width</th>
<th>Weight</th>
<th>Ext. Temp</th>
<th>Center Gauge</th>
<th>Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>999999</td>
<td>300 ± 6 MM</td>
<td>20.47 ± 0.27 KG</td>
<td>136°C ± 1°C</td>
<td>35.7 ± 0.6</td>
<td>OK</td>
</tr>
</tbody>
</table>

Action taken after trial 1 results
• Die opening to be modified as per the required dimensions to get tread profile as per the master.

TABLE II
TRIAL -2 DATA FOR TREAD CENTER LINE GAUGE

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Spec.</th>
<th>Overall Width</th>
<th>Weight</th>
<th>Ext. Temp</th>
<th>Center Gauge</th>
<th>Profile</th>
</tr>
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<td>35.7 ± 0.6</td>
<td>OK</td>
</tr>
</tbody>
</table>

TABLE III
COMPARISON OF EXTRUSION LINE SPEED

Increased Dual Extruder Line Speed

<table>
<thead>
<tr>
<th>Category</th>
<th>Present Line Speed (mpm)</th>
<th>Implemented Line Speed (mpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck-Lug</td>
<td>10.0</td>
<td>10.7</td>
</tr>
<tr>
<td>Truck-Rib</td>
<td>12.0</td>
<td>13.0</td>
</tr>
<tr>
<td>LCV</td>
<td>12.5</td>
<td>13.5</td>
</tr>
<tr>
<td>Rear Tractor</td>
<td>6.0</td>
<td>6.2</td>
</tr>
</tbody>
</table>

TABLE IV
EXTRUSION OUTPUT DETAIL AFTER MODIFICATION

<table>
<thead>
<tr>
<th>EXTRUDER DETAILS</th>
<th>PREFORM</th>
<th>Modified</th>
<th>Existing</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR1105 (10.00-20 16PR XT7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEED WIDTH - (Cap / Base) - mm</td>
<td>457 / 250</td>
<td>445 / 250</td>
<td></td>
</tr>
<tr>
<td>RPM - (Cap / Base)</td>
<td>48 / 82</td>
<td>48 / 82</td>
<td></td>
</tr>
<tr>
<td>EXTRUDER OUTPUT TEMP (Min 150°C)</td>
<td>128°C</td>
<td>128°C</td>
<td></td>
</tr>
<tr>
<td>LINE SPEED - mpm</td>
<td>10.7</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>OUTPUT / MIN - KG</td>
<td>97</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

Improvement: Output increased to 7 Kg / Min (7.7%) without changing Screw RPM

2. Standard work practice for leaf truck availability

TABLE V
NO. OF LEAF TRUCK BLOCKAGE CALCULATION

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Leaf Truck blocked</th>
<th>No. of Leaf Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tread inventory at extruder</td>
<td>104</td>
</tr>
<tr>
<td>2</td>
<td>Tread inventory at tyre building</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>Non conformity tread</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Total no. of leaf truck</td>
<td>166</td>
</tr>
<tr>
<td>5</td>
<td>No. of leaf truck available for booking</td>
<td>5</td>
</tr>
</tbody>
</table>

Present system
In tyre building section 1 hour tread balance (7 Treads) ensure at each building machine. For this practice tread material mover taken a lift truck from extruder storage area and distribute 7 treads at each building machine. Due to this there is an always leaf truck shortage at extruder at start up of the shift. After 1 hour there is a no. of empty leaf truck available for extrusion process.

Leaf truck requirement at dual extruder for the shift = 64 nos.
Hourly requirement of leaf truck = 8 nos.

Proposed system
Truck Machines
• Ensure 7 Tread balance in 5 machines at shift end
• Ensure 14 Tread balance in 10 machines at shift end
• Ensure 21 Tread balance in 15 machines at shift end
• Ensure 38 Tread balance in 9 machines at shift end
Non Truck Machines
• Ensure 32 Tread balance in 8 machines at shift end
• Ensure 48 Tread balance in 7 machines at shift end
Rear Tractor Machines
• Ensure 20 Tread balance in 4 machines at shift end

3. Kanban (Replenishment system) for selected codes
• Tread booker put 2 tags on selected code leaf truck
• As building requirement comes tyre building material mover takes the leaf truck from tread storage area.
• One tag removed kept on kanban board. Another tag will go along with tread leaf truck
• From kanban desk tread booker easily understand consumption of tread and reorder level

When reorder level reach triggering to booker and he will immediate inform to operator for production scheduling for particular tread code.

Kanban calculation

<table>
<thead>
<tr>
<th>TABLE VI</th>
<th>KANBAN CALCULATION FOR SELECTED CODES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYRE CODE</td>
<td>ACTUAL CURE TIME</td>
</tr>
<tr>
<td>TR1010</td>
<td>306 39 40 60</td>
</tr>
<tr>
<td>TR1011</td>
<td>151</td>
</tr>
<tr>
<td>TR1012</td>
<td>151</td>
</tr>
<tr>
<td>TR1013</td>
<td>91 9 44 60</td>
</tr>
<tr>
<td>TR1014</td>
<td>72 6 39 60</td>
</tr>
<tr>
<td>TR1015</td>
<td>7</td>
</tr>
<tr>
<td>TR1016</td>
<td>23 2 38 60</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
</tr>
</tbody>
</table>

Kanban station

III. RESULTS

Data collection - Leaf Truck Shortages

Fig.4 Proposed Kanban system flow

Fig.5. Data collection Leaf truck shortages

Trial Data for implementing kanban in selected tread code & Standard work for Leaf truck

To Increase Truck Tyre Curing Utilization by 0.75% by reducing Tread loss from 2.70 to 1.35%

IV. CONCLUSION

The objective is implementation of kanban, standard work practice and cycle time reduction for extrusion to tyre building process. Then implementation of kanban, standard work practice and cycle time reduction resulted in easy tracking of material consumption, reduction of leaf truck shortages and increased output of extruder 7.0Kg/Min (7.7%) without changing screw RPM. Due to that increased in truck productivity 324 tread/day and Contribution of leaf truck shortages reducing from 1750 min/month to 442 min/month. Also now operator can schedule himself, resulting reducing PPC role, minimized Inventory and maximized flow (material & communication). In tyre building loss analyses, Contribution of selected Sku’s is 0.54% per day, resulting overall tread loss reduced from 2.7% to 0.90%.

V. REFERENCES