ZIBELINE INTERNATIONAL PUBLISHING

Advances In Industrial Engineering And Management (AIEM)

DOI: *http://doi.org/10.7508/aiem.02.2020.33.42*

ISSN: 2222-7059 (Print)
EISSN: 2222-7067 (Online)

CrossMark

ARTICLE

REDUCING WORK IN PROCESS INVENTORY TO IMPROVE BUSINESS PERFORMANCE

Arun Rane

Department of Mechanical Engineering, Fr. Conceicao Rodrigues College of Engineering, Mumbai 400050, India
[*]Corresponding Author E-mail: arunbrane@gmail.com

ARTICLE DETAILS

Article History:

Received 25 February 2021
Accepted 18 March 2021
Available online 12 April 2021

ABSTRACT

The material must roll and should not be stagnant. Just in Time (JIT) manufacturing believes in zero inventories. Practically it is not possible to keep Work in Process inventory (WIP) zero due to perturbations in manufacturing and logistics. Albeit WIP has reduced from months to days to hours, some plants still have huge WIP. This report analyses the data for the WIP inventory collected from Enterprise resource planning (ERP) software in reputed tyres manufacturing plant. Brainstorming, Why-Why analysis, Pareto analysis, Fishbone diagram was conducted. It was identified that there are uneven production rates, overproduction, over-stocking of raw materials, and failure to strictly adhere to the Pull and First-In-First-Out (FIFO) system. By using JIT, locating bottlenecks, upgrading, organizing, and coordinating, WIP was reduced from 3.2 days' worth to 3 days' worth.

KEY-WORDS

Work-In-Process (WIP) inventory, Just-in-Time (JIT), Pull-push, Bottleneck.

1. INTRODUCTION

Companies today must be fast enough to react quickly to changes in customer demand with little inventory. The old ways of stockpile, blocks too much working capital. Inventory management concerns the flow to, within, and from the company and the balance between shortages and excesses in an uncertain environment. Inventories are broadly classified into Raw material inventory, Work in process inventory (WIP) and finished inventory. Lot of literature is available on Raw material inventory but not on WIP inventory.

Behaviour of lines buffered with inventory was investigated [1]. By data collection and data analysis, author explored the distribution and quantity of WIP inventory that accumulates. Historical data of 52 Japanese companies was used to achieve 10% reduction in inventory which led to about 1% gain in labour productivity [2].

Excess WIP inventory, will have a negative effect on the production measurements [3]. Variables of throughput and lead-time requirements were compared based on the WIP inventory control, through computer simulation [4]. Mixed Integer Programming model was presented for controlling the WIP inventory to restrict the excessive production of un-finished products, while the manufacturing productivity is kept at a certain high value [5]. A theoretical formulation of a scheduling problem without buffer is derived, and heuristic procedure is adopted to plan a feasible schedule. The proposed control methods are verified by computational simulations. WIP control model was simulated in Witness which provides an effective, workable solution for small-batch and multi-varieties production under the control of the production mode for gear production line [6].

Six step processes was demonstrated to reduce WIP [7]. It includes 1) conducting the primary survey, 2) Observing the system, 3) Preparing primary questionnaire and modification of the questionnaire, 4) Performing the case study and conducting interview 5) Data collection and processing and 6) analysis. An inventory model was developed which incorporate inspection, rework, and rejection quality costs in optimum lot size calculation focusing work in process inventory [8]. Impact of quality costs on lot size has not been considered till now.

Effect of WIP inventory for performance improvement of assembly line was exhibited [9]. Valur Stream Mapping (VSM) was used in bearing industry to reduce WIP by 50% in Computerised Numerical Control (CNC) machining, 69.7% in Annealing and 65.4% in Inspection by focusing both on processes and their cycle times for a product UC- 208 inner race which is used in plumber block [10].

Good inventory management is mandatory to prevent any stock outs [11]. Inaccurate stock records will lead manufacturing plants to unexpected stock outs. WIP inventory was reduced by proper vendor selection [12]. Maintaining accurate WIP inventory records is a prerequisite to improve plant's inventory situation, with direct positive impacts on both plant's efficiency and financial health [13]. Development and application of a WIP control approach was presented to manage inventory in order to reduce manufacturing throughput time and its variation in a high product mix case study company [14]. It is applied under the CONWIP and the Push production control mechanisms. Genetic Algorithm (GA) was used to seek out the optimal set of stations to hold WIP inventory to minimize the total inventory holding cost, while meeting the required due date [15].

Effect of inventory of electronics parts on manufacturing of CNC machine was demonstrated [16, 21]. Increasing the rate of converting raw material into finished product and delivering it on time is a main driver for each manufacturing industry to achieve continuous improvement in its business operation [17]. Author applied VSM, Kanban card, supermarket racking and one-piece flow to control and monitor the WIP inventory. The fluctuation of WIP inventory has been resolved by the implementation of supermarket racking.

Effect of WIP inventory was demonstrated for developing and optimizing vehicle assembly line [18]. Systematic material study was done to reduce the WIP for portable helmet [19]. Productivity was improved by WIP reduction and by eliminating back chipping in welding of Pressure vessels [20]. WIP inventory plays important role in improving business performance [22]. Core manufacturing in foundry was increased considerably by controlling WIP inventory [23].

WIP inventory includes the raw materials and unfinished goods in the plant after the manufacturing process has started. Different ways to reduce WIP in Manufacturing are:

①Just in Time Manufacturing (JIT)

It is a method of production where materials are brought and used only when required in the manufacturing process to get rid of overproduction, waiting, and excess inventory.

②Locate Bottlenecks

As shown in Figure 1, Stage C is called as bottleneck as it takes more time. When bottleneck occurs, it slows down the work and requires employees to sacrifice other tasks or to work overtime. By allocating more resources to that stage, bottlenecks can be removed. Removing these bottlenecks will reduce the WIP inventory maximizing output.

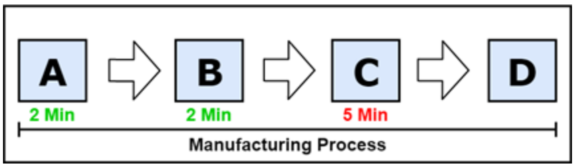

Figure 1: Bottleneck stage

③Coordinate, Upgrade and Organize

Everyone should understand and perform their respective tasks more efficiently. Upgrading machinery and training employee can reduce WIP inventory in manufacturing environments. Other methods include hiring more employees, fixing network issues, and offering incentives to employees. Disorganization is one of the most common bottlenecks. Labelling storage bins and organizing them will reduce WIP inventory. Unused inventory consumes floor space, causes congestion and blocks capital of the company.

2. OBJECTIVE

Analysis of the inventory data revealed that the plant has around 3.2 to 3.5 days' worth of WIP inventory. Objective of this work is to reduce it to 3 days' worth or lower which can improve the overall efficiency of the plant.

3. METHODOLOGY

After understanding the manufacturing process, preliminary analysis is done to find inventory throughout the plant followed by questionnaire.

3.1 Understanding process

Existing Tyre Manufacturing Process flow is shown in Figure 2. The production starts with the mixing of raw materials to form rubber sheets. These sheets are then sent to various departments viz. extruding, band building, bead winding, 3-roll and 4-roll calendering. The treads and sidewalls for tyres are manufactured in the extruding department and the plies are manufactured by the 4-roll calendering department. The plies are then turned into cylindrical bands. The beads are made by the bead winding department and finally all the components of the tyre like the band, bead, tread and sidewall go to the tyre building machine where they are assembled together to form a 'green tyre'. This green tyre is then cured using steam in a press mould, and the final product is obtained.

3.2 Preliminary analysis

Here the raw materials and unfinished materials lying on the shop floor are inventoried at the end of every month. The locations include viz. Final Batch, RM Locations, Extruder out, Calender out, mixing in, curing out, Tyre Building Out, 59 J out and Others. The 'Final Batch' inventory refers to the final sheets of rubber mixed in the mixing department, and awaiting transfer to the customer departments, viz Extruding, 4-Roll Calendering, 3-Roll Calendering and Bead Winding. The 'RM Location' inventory refers to the unused raw materials like rubber, carbon and diproll fabric lying on the shop floors of Mixing department and 4-Roll Calendering department. Others include inventory of Bead Out and green tyres.

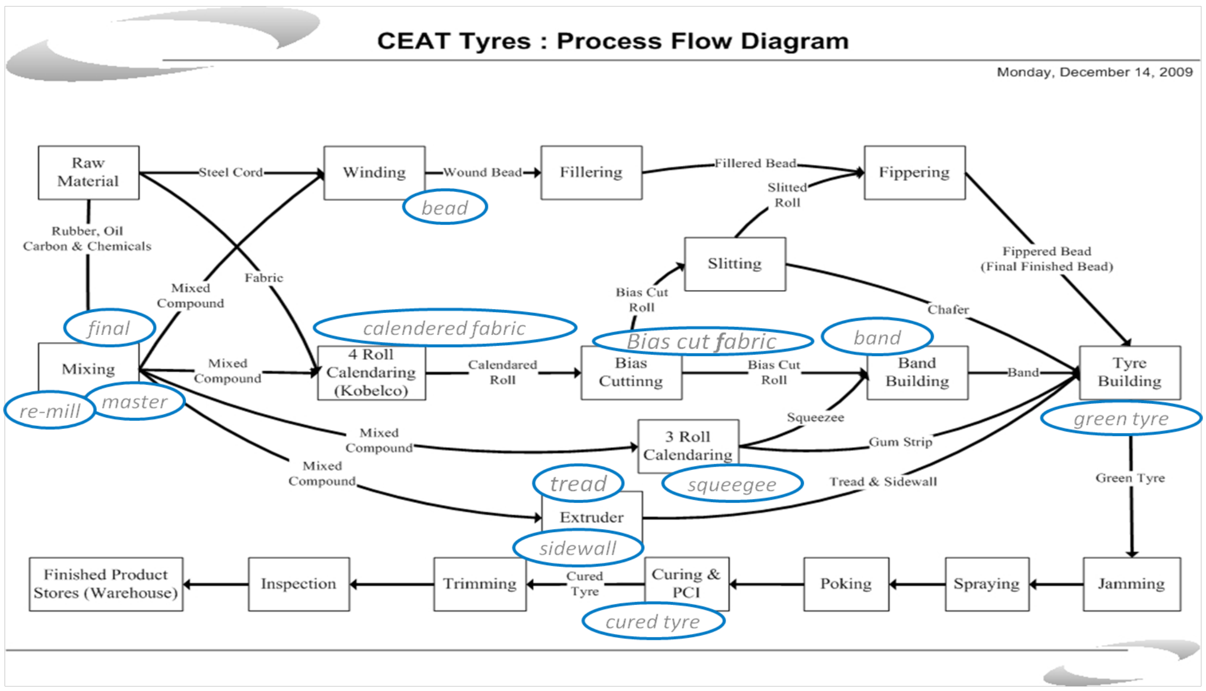

Figure 2: Process flow diagram.

3.3 Preparing questionnaire

It is divided into two parts.

Questionnaire Part I:

①What are the current inventory levels of various departments in the plant?

②Which materials have the highest levels of inventory?

③What are the minimum levels of inventory required for smooth functioning?

④What is the root causes of the high inventory?

Questionnaire Part II:

①What are the possible solutions to the root causes of high inventory?

②How should these solutions be implemented?

③What are the expected benefits of implementing these solutions?

4. DATA RETRIEVAL AND ANALYSIS

In this plant, the software SAP (Systems, Application & Products), is used for Enterprise Resource Planning. All the data is entered into SAP, which is easily available through any computer in the plant to answer the questionnaire. Initially, the value of the inventory in lacs of rupees was calculated, and the average value of inventory for each of these inventory locations, for the 8-month period was calculated as given in Table 1. The percentage of inventory out of the total inventory, occurring in each of these departments was calculated and a Pareto Chart was plotted as shown in Figure 3.

The Pareto Principle states that 20% of the factors have an influence on 80% of the outcome. According to this principle, if we were to concentrate on only the materials leading to 80% of the WIP inventory, and come up with solutions to reduce the inventory of the said materials, the optimum result could be obtained. Once the cumulative percentage of the inventory held in the various manufacturing locations has been calculated, the five locations in which 80% of the inventory occurs are highlighted in red shown in Figure 3. In this work, top two inventory causing locations, namely Final Batch and RM locations are focused.

Table 1: WIP inventory at various departments.

Inventory locations	Value of inventory (lacs/month)	Percentage	Cumulative percentage
Final batch	184	20	20
WIP RM location	161	18	38
Extruder out	128	14	52
Calender out	124	14	65
Mixing in	103	11	76
Curing out	93	10	87
Tyre building out	72	8	94
59 J out	34	4	98
Others	16	2	100

4.1 WIP inventory of final batch

The final batch includes rubber sheets heading out to Extruding (tread and sidewall), Bead Winding (bead), 4-Roll Calendering (band), and 3-Roll Calendering (squeezee).

What are the current levels of WIP inventory in Final batch?

In order to find hours' worth of inventory it is necessary to find average consumption per hour of every material under consideration. To start with, the average consumption of the compounds in the Final Batches can be calculated. The consumption of every final sheet was first acquired through SAP. Then this was divided by the number of working days of the particular month, and by 24 to get the average hourly consumption for that particular month. The hourly consumption, once obtained was then compared with the WIP inventory of that particular material to understand how many working hours of inventory of that material is lying on the shop floor. Table 2 gives the inventory, Consumption data for August with 27 working days. The number of hours of inventory was calculated by the following formula:

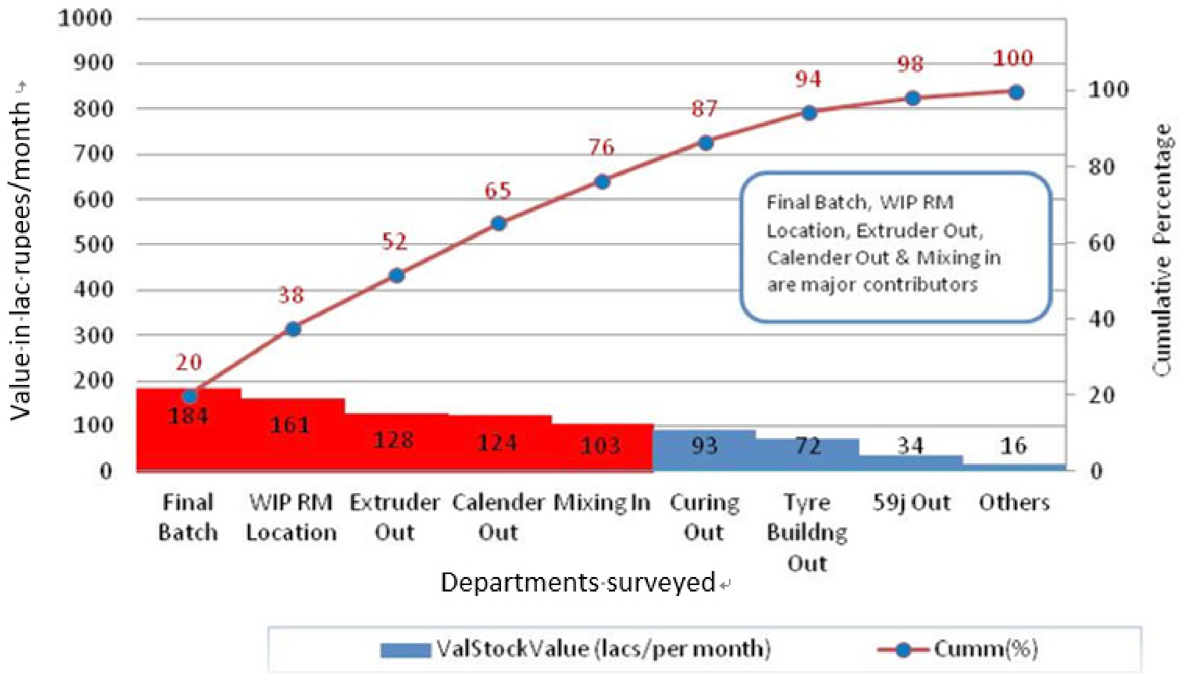

Figure 3: Pareto analysis.

Table 2: WIP inventory at various departments.

Compounds	WIP inv (kg)	Cons (kg)	Hours of Inventory	Reqd. hours	Extra hours of inventory	Extra inv in kg
B33	8930.16	298350	19.40	12	7.40	3405.155
B34	346.84	126555	1.78	12	0	0
BC	2452.45	41580	38.22	12	26.22	1682.452
BU104	526.05	32760	10.41	12	0	0
BU108	1738.00	12780	88.12	12	76.12	1501.33
K27	6227.63	89640	45.02	12	33.02	4567.634
K28	10005.11	596520	10.87	12	0	0
K760	1125.00	18620	39.15	12	27.15	780.185
K761	4813.04	40385	77.23	12	65.23	4065.169
KU82	4425.19	96427	29.74	12	17.74	2639.506

Figure 4: Final Batch inventory awaiting quality checks.

Number of hours of inventory = WIP inventory in kgs/hourly consumption

Which materials have the highest amount of WIP inventory?

Data was sorted in a descending order to determine largest amounts of inventory.

What are the minimum levels of WIP inventory required for Final Batch Compounds?

As the plant follows batch production system, and not a continuous production cycle, some amount of WIP inventory is unavoidable. For the Final Batch compounds, the minimum required hours of inventory was decided to be 12 hours. Each and every sheet of the final batch compound has to be aged at least 4 hours before it can be sent to its customer department. In addition, a buffer time of 8 hours is assumed so as to have sufficient supply of working materials, should a certain sheet be required abruptly. The buffer time also includes the time required for the quality testing of the sheets (without which the sheet doesn't progress to the next department), and also the transportation time required for the material to reach the customer department. Thus, once the minimum hour's inventory was decided, the materials with an inventory of longer than 12 hours was shortlisted. Table 2 is a sample taken from the Excel sheet in which the possible savings from the reduction of inventory was calculated. The possible savings are not the scope of the first part of the working questions, so it will be addressed later. As the average consumption per hour had been calculated earlier, the weight of the extra inventory was also estimated in kg.

The possible factors are as follows:

①Final Batches held-up by the testing department for not meeting required criteria as shown in Figure 4.

②Customer department(s) running behind schedule.

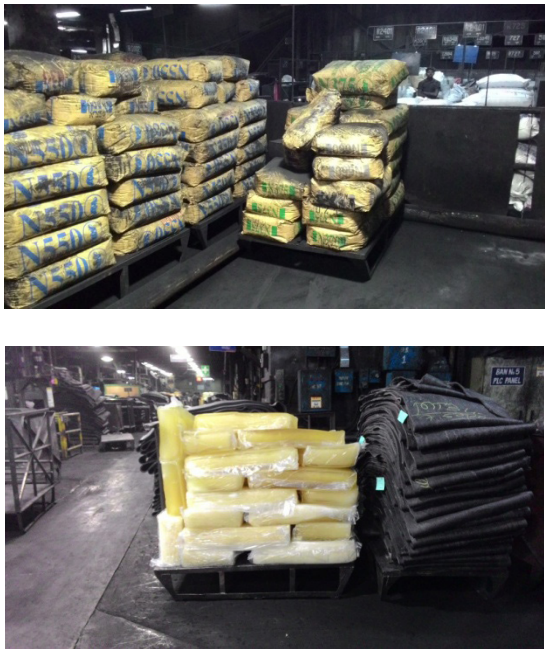

Figure 5: Carbon and Synthetic rubber inventory lying on mixing floor.

③Extra batches of unwanted material mixed, due to scheduled material being unavailable.

④Absenteeism in customer departments leading to slow production.

⑤Compound is over-aged, hence can't be used further.

⑥Wrong inventory taken.

⑦Quality testing of the final batches delayed.

⑧Uneven production rates of customer departments.

Each factor was investigated in detail e.g. uneven production rates of the main customer departments of the Final Batch compounds. These were the Extruding department and the 4-Roll Calendering department.

4.2 WIP inventory of raw material (RM) locations

Raw material locations are the departments which receive the raw materials directly, unprocessed form the Raw Material Stores as shown in Figure 5. These locations are, in effect, the starting blocks of the tyre manufacturing process.

Thus, the amount of raw material inventory lying on the shop floors of these departments before any processing takes place on them, has to be acquired. Even though these materials aren't technically, "in process",

Table 3: Cost per kg at RM location.

Material name	Sum of value in Rs.	Sum of stock wt. in kg	Cost in Rs./kg
102016FMSUPER	65576.48	8	8197.06
102016HCLMILER	8024.09	1	8024.09
102016HCLSUPER	260636.05	29	8987.45
102016LUGPLUS	15115.68	2	7557.84
102016LUGXL	412803.08	46	8973.98
102016 LUGXLPRO	342947.15	35	9798.49
102016MILEXL	56126.34	6	9354.39

Table 4: Minimum and extra inventory for RM locations.

Compounds	WIP inv (kg)	Cons (kg)	Hours of inventory	Reqd. hours	Extra hours of inventory	Extra inv in kg
R272	31.909	60	306.33	4	302.33	31.49
R146	9.34	0	0	4	0	0
600SE	175	131.8	764.8	4	760.8	174.08
550SE	0	2	0	4	0	0
R6300	161.632	525	177.33	4	177.33	157.99
400SE	0.448	0	0	4	0	0
12003	36.921	175	121.52	4	117.52	35.71
R327	0.641	160	2.31	4	0	0
R235	102.48	240	245.95	4	241.95	100.81
1Green paint	10.0	20.0	288.0	4	284.0	9.86
R267	125.365	275	262.58	4	258.58	123.46

they have been included in the scope as they are already on the floor and also because very high amounts of inventories were observed in these locations.

These are Mixing Department (rubber, carbon, chemicals, etc.), 4-Roll calendering (fabric Diproll) and Bead Winding (steel wires).

What are the current levels of WIP inventory in RM locations in the plant?

To find the current levels of WIP inventory in RM locations, once again, the levels of WIP inventory were obtained. The total inventory however is only mentioned in terms of kgs and monetary value. This information can be used to find out the cost of materials per kg, which will ultimately be useful in estimating the savings that can be obtained from the reduction of inventory.

Table 3 is a sample taken from the SAP showing the WIP inventory in terms of weight and also in terms of monetary value. Last column is the calculation of cost in Rs/kg.

Which materials have the highest inventory levels in RM Locations?

It can be calculated the same way it was, for the Final Batch Compounds.

What are the minimum levels of inventory required in RM locations?

After going through the manufacturing process at the 3 RM locations in the plant, it was difficult to come up with one single figure which denoted the required inventory levels for Raw Materials on the shop floor, to ensure smooth production. This happened because of the following reasons:

①The operations carried out at the three RM locations vary significantly in terms of operating time, ageing time, and material transfer time

②The buffer time also changes for every operation carried out in the RM locations.

Figure 6: Fabric Roll lying on 4-Roll Calendering Floor.

③The 4-Roll calendering department operates only in 2 shifts, due to which the consumption characteristic vary greatly throughout a working day.

In spite of this, for the sake of simplicity, it was decided to choose a minimum inventory time of four hours applicable to all three recipient departments of Raw Materials. This was done by taking operation time to be 1 hour, 1 hour for material transfer, and 2 hours' worth of inventory as a buffer. However, there are some materials for which, the inventory simply can't be reduced any further. These materials are mainly the diprolls of fabric stacked in the shop floor of the 4-Roll Calendering Department. These fabrics come in rolls of 2000 metres as shown in Figure 6, and the daily consumption isn't more than a few dozen metres. Since the entire 2000 metre diprolls have to be brought to the shop floor, it is not possible to reduce the inventory.

Also there were chemicals used in the Banbury Department, which were loaded into the machine in bulk quantities, and there was no possibility of reducing this inventory, either.

Table 4 shows inventory for compounds with inventories longer than 4 hours' worth. The extra inventory in kgs is also calculated from the hourly consumption obtained from SAP.

What are the root causes for the high inventory levels in RM Locations?

The possible causes for the high inventory levels could be:

①High quantities of raw material sent to the mixing floor due to inefficiency.

②Wrong inventory taken.

If the second cause is ruled out, only the possibility of inefficient inventory maintenance remains. This was further strengthened by the observation of high amounts of raw materials seen lying on the Mixing shop floor, and the fact that the monthly requisition of materials by the Mixing department hardly changed.

This meant that either the Mixing Department were requisitioning materials in much higher quantities than needed, or the inventory of raw materials on the Mixing shop floor was inefficiently maintained, or both.

Thus, inefficient inventory maintenance was decided to be the root cause of the high inventories in RM Locations, mainly on the Mixing Shop floor.

Conclusion from Part I of the Working Questions:

Even though many possible root causes for the high inventories of both Final Batches, and RM locations were observed, following major causes were considered in this study.

Root cause to be investigated for inventory levels in Final Batches is the uneven production rate in the customer departments and for RM Locations is inefficient inventory maintenance.

5. POSSIBLE SOLUTIONS

The fishbone diagram shown in Figure 7 includes the possible root causes of high inventory in all the major problem causing departments, but as stated earlier, the scope of this work is only to investigate the root causes of Final Batches and RM Locations

5.1 WHAT ARE THE POSSIBLE SOLUTIONS FOR MITIGATING ROOT CAUSES OF HIGH INVENTORY OF FINAL BATCHES?

The root cause of high levels of WIP inventory in Final Batch compounds was found to be the uneven production system of customer departments. The 4-Roll Calendering department works only in two shifts, while the other customer departments, namely Extruding and Bead Winding work in all three shifts.

The 4-Roll calendering department works in only 2 shifts because it has a very high work output, and the other departments cannot keep up with its production rate. This means that there is existence of Mura (unevenness) in the plant. Thus the main objective should be the removal of Mura from the plant.

Steps are already taken for the removal of mura by increasing the work output speeds of other departments. One such project that is in process is the usage of automated systems to load the carbon compounds in the Banbury Mixing Machines.

Similarly, if the production rates of all customer departments of the Mixing department are increased, not only will it allow the 4-Roll Calendering Department to work in all three shifts and fulfil its potential, but it will also increase the overall productivity of the plant.

5.2 What are the possible solutions for mitigating the possible causes of high WIP inventory in RM Locations?

The major cause of high inventory in RM Locations was found to be inefficient inventory maintenance practices as well as excessive material requisition by the Mixing Department.

Both of these root causes can be eliminated by the implementation of KANBAN as well as by a more efficient implementation of the Pull System in manufacturing.

6. ESTABLISHMENT OF BEST PRACTICE FOR REDUCTION OF INVENTORY

How should the solutions for the reduction of WIP inventory in Final Batches and RM locations be implemented?

The solution to the high inventory levels in Final Batches and in RM Locations was found to be the removal of mura between the customer departments, the establishment of a more efficient inventory maintenance method, and also a more rigorous implementation of the Pull System, that is already in use in the plant. Thus, the best practice for the removal of excess WIP inventory is the implementation of the KANBAN system of manufacturing which ensures that all production is done strictly on a pull basis, and has a goal of implementing Lean Manufacturing.

Even though the plant is theoretically said to be working on a FIFO basis and on a pull system, careful analysis of the WIP inventory has already revealed that a lot of materials are being manufactured before hand and then are waiting for transfer to the next department. So as some departments are overproducing, there is high inventory, hence high financial losses.

Therefore, there needs to be a better communication system between every subsequent department, so that the pull system is strictly followed,

.

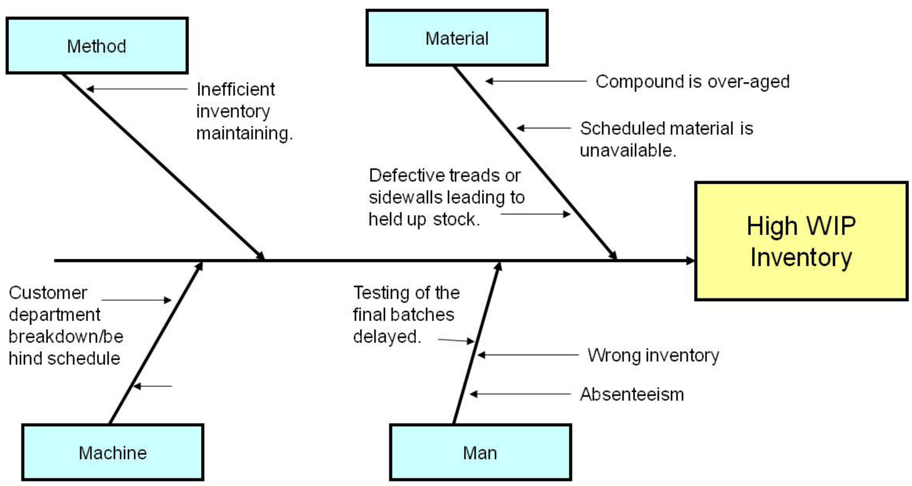

Figure 7: Fishbone Diagram for Possible Causes.

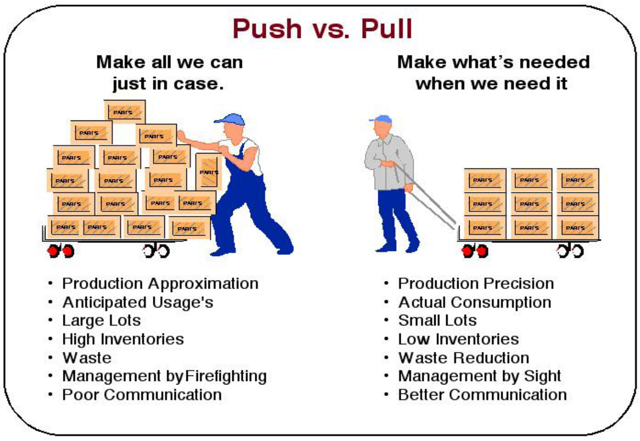

Figure 8: Push vs Pull system.

and inventory stays at a bare minimum. Figure 8 shows the difference between Push versus Pull system. Identification Cards are issued at all manufacturing locations, which detail the type of material, the date and shift/time of manufacture. Actually in Plant, material doesn't flow as per FIFO. SO, another solution to decrease the WIP inventory is a rigorous implementation of the FIFO system in manufacturing, based strictly on the Kanban cards attached to the finished goods at every manufacturing location.

7. EXPECTED BENEFITS OF SOLUTION IMPLEMENTATION

If all the departments are investigated, benefits will be more. This work is focussed on Final Batches and RM Locations.

7.1 Expected gains from WIP inventory reduction of final batches

The total extra hours of inventory for each compound of the Final Batches, the weight of the excess compounds, and also the cost per kg of each of these materials had been calculated.

Using this information, it is possible to calculate the total monetary savings of reducing the inventory to the bare minimum levels. Table 5 is a sample taken from the possible savings reduction of inventory to a bare needed minimum of 12 hours' worth, for the month of August. This sample only shows the 10 compounds, but the total savings is obtained from calculating the savings for all 40 compounds. Similarly the total savings for all other months from May to December were calculated. Table 6 gives the possible savings in rupees.

Table 7 gives WIP inventory of the plant in crores of rupees, for every month from May to December, and the proposed inventory. It also shows the inventory in days, and the proposed expected inventory in days, should the countermeasures be successful.

The inventory in terms of days was calculated by the following formula:

Inv. in terms of working days = Total inventory cost/ (monthly consumption/working days)

Table 5: Expected Savings for Final Batch.

Compo-unds	WIP Inv (kg)	Cons (kg)	Hrs of Inv.	Reqd. Hrs.	Extra hrs of Inv.	Extra Inv in kg	Cons/hr In kg	Cost /kg	Savings in Rs.
B33	8930.16	298350	19.40	12	7.40	3405	460	142	482681
B34	346.84	126555	1.78	12	0	0	22	138	0
BC	2452.45	41580	38.22	12	26.22	1682	64	142	239346
BU104	526.05	32760	10.41	12	0	0	43	145	0
BU108	1738.00	12780	88.12	12	76.12	1501	20	145	217453
K27	6227.63	89640	45.02	12	33.02	4567	138	139	633257
K28	10005.11	596520	10.87	12	0	0	16	139	0
K760	1125.00	18620	39.15	12	27.15	780	29	125	97398
K761	4813.04	40385	77.23	12	65.23	4065	62	194	790554
							Total saving		10538689

Table 6: Total Savings for Final Batch over eight months.

Month	May	June	July	Aug	Sept	Oct	Nov	Dec
Saving in Rs.	6357739	7125380	6785426	10538689	9602116	13634455	14424975	6331542

Table 7: Proposed WIP inventory for Final batch.

Month	WIP (Cr)	WIP-Proposed (Cr)	WIP per day (Cr)	WIP-Proposed per day(Cr)
May	8.96	8.32	3.2	2.97
June	9.13	8.42	3.23	2.98
July	7.93	7.25	2.85	2.61
Aug	8.23	7.18	3.14	2.74
Sept	8.19	7.23	3.35	2.95
Oct	8.35	6.99	3.15	2.64
Nov	9.09	7.65	3.45	2.90
Dec	8.74	8.11	3.18	2.95
Avg	8.58	7.64	3.20	2.84

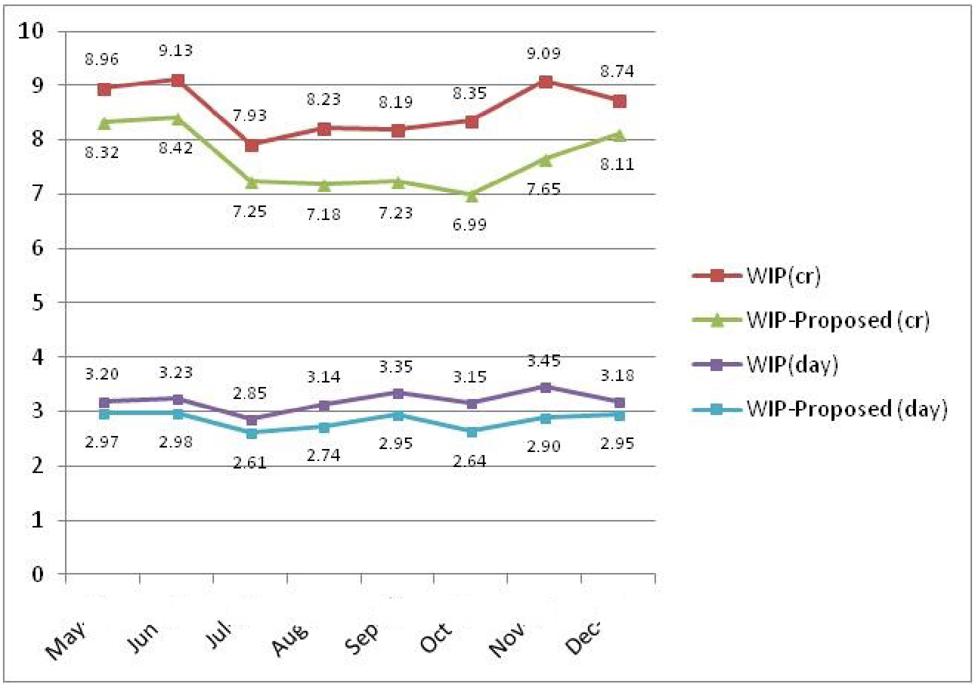

Figure 9: WIP inventory before and after the implementation for Final batch.

Table 8: Expected savings for RM location.

Compo-unds	WIP Inv (kg)	Cons (kg)	Hrs of Inv.	Reqd. Hrs.	Extra hrs of Inv.	Extra Inv in kg	Cons/hr in kg	Cost /kg	Savings in Rs.
R272	47.818	20	1491.9	4	1487.92	47.69	0.03	176	8377
R146	0	0	0	4	0	0	0	0	0
600SE	49.068	66	463.92	4	459.92	48.64	0.11	329	16026
550SE	8	40	124.80	4	120.80	7.74	0.06	196	1516
R6300	188.22	500	234.90	4	230.90	185.01	0.80	155	28679
400SE	53.584	245	136.48	4	132.48	52.01	0.39	180	9347
12003	47.806	475	62.80	4	58.80	44.76	0.76	447	19994
R327	55.873	280	124.52	4	120.52	54.08	0.45	347	18774
R235	41.2	260	98.88	4	94.88	39.53	0.42	295	11664
							Total saving		5689558

Table 9: Total Savings for RM location over eight months.

Month	May	June	July	Aug	Sept	Oct	Nov	Dec
Saving in Rs.	5665143	5964982	8310063	7701513	4700245	5689558	5120179	9510833

Table 10: Current and Proposed WIP inventory at RM locations.

Month	WIP (Cr)	WIP-Proposed (Cr)	WIP per day (Cr)	WIP-Proposed per day(Cr)
May	8.96	8.39	3.20	3.00
June	9.13	8.53	3.23	3.02
July	7.93	7.09	2.85	2.55
Aug	8.23	7.46	3.14	2.84
Sept	8.19	7.72	3.35	3.15
Oct	8.35	7.78	3.15	2.94
Nov	9.09	8.57	3.45	3.25
Dec	8.74	7.79	3.18	2.84
Avg	8.58	7.92	3.20	2.95

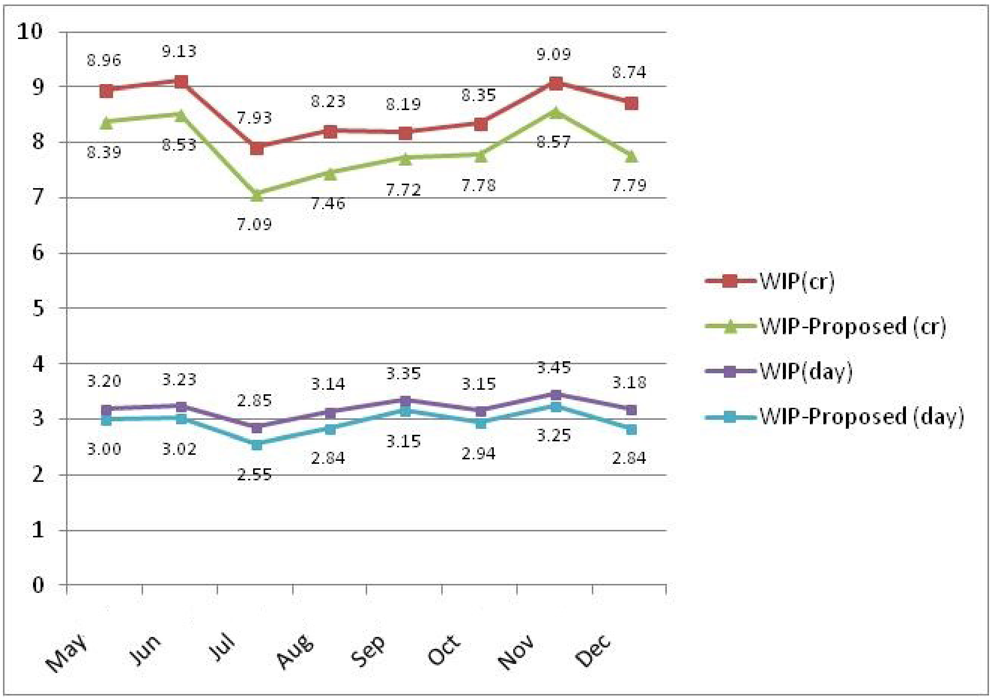

Figure 10: WIP inventory before and after the implementation for RM location.

Thus it can be seen that the average savings in terms of money can be 0.94 crore rupees and the inventory of the plant can be brought down to 2.84 days' worth, from 3.20 days' worth.

Thus, even if the countermeasures are partially successful, it is possible to meet the objective of bringing down the WIP inventory to 3.0 days' worth. Figure 9 is based on Table 7.

7.2 Expected gains from WIP inventory reduction in RM locations

Similarly expected savings in rupees for RM Locations were calculated should a bare minimum inventory of 4 hours be maintained. Table 8 is a sample taken from the excel sheet used to calculate the possible savings which is almost Rs. 59 lacs for the month of October. Accordingly the possible savings for eight months is given in Table 9.

As seen from the Table 10, the average financial profits from inventory reduction are found to be 0.66 crore rupees. The inventory in terms of working days can also be reduced to 2.95 days, which is well within the margin of this work.

Figure 10 is based on Table 10.

8. RESULTS AND DISCUSSION

The focus of this study is to reduce high WIP inventory levels in the plant. The WIP inventory levels were found to be 3.2 days' worth. Five major locations of WIP inventory, totalling 80% of losses were shortlisted, according to a Pareto Analysis. However, only the top two were considered for further study.

Several possible root causes were considered for the occurrence of inventory, out of which two most significant causes were investigated.

The solutions found for the root causes of high Mura (imbalance or unevenness) in final batch customer departments, was to introduce measures to increase the production rates in Extruding, Bead Winding, and other subsequent processes, to keep up with the high production rate of the 4-Roll Calendering Department. Output is improved by using automated system to load carbon compound in Banbury mixing machine.

The solutions for high levels of inventory in RM locations was to strictly implement the Kanban system of manufacturing, so as to reduce production of unwanted materials, and also rigorous implementation of the FIFO system in material flow. This improved existing inventory maintaining practices and mitigated excessive material requisition. These solutions are expected to reduce the Muda (which is any process that doesn't add value) throughout the plant when it comes to WIP inventory.

Average monthly financial profits were calculated to be between Rs. 66 lacs equivalent to 2.95 days in RM locations and Rs. 94 lacs equivalent to 2.84 days in Final batch location. It was found that the expected gains from implementing the solutions to mitigate root causes would reduce the WIP inventory of the plant to well below the objective of 3 days.

9. CONCLUSION

Objective of this study is to examine the production system from an Operations Management perspective, and to investigate the factors influencing the current levels of inventory, as well as to examine the relationship between certain production processes, which leads to high inventory. Study suggests a feasible solution for the reduction of the inventory to the minimum required levels and management was able to achieve acceptable levels of inventory. The expected gains are not only limited to the monetary gains and space savings, but there are intangible gains as well. The strict adherence to the Kanban System and FIFO method of material flow will enable smooth material flow throughout the plant and increase overall efficiency.

10. FUTURE SCOPE

Some of the solutions suggested in this study may require financial investment from the management. These solutions are mainly to balance the production rates. This may need ordering of newer hardware or modifying the present hardware to give higher outputs. However, it is not the scope of this work to estimate the costs of the implementation, and a separate study might be required to estimate the costs and the possible Return on Investments. However, the solutions for reducing the inventory in RM locations by implementing the Kanban system more rigorously can be executed at minimal costs.

REFERENCES

[1] Conway, R., Maxwell, W., McClain, J., Joseph Thomas, L. The role of work-in-process inventory in serial production lines. Operations

Research (1988) 36(2):229-241. doi.org/10.1287/opre.36.2.229

[2] Lieberman, M.B, Lieven, D. Inventory reduction and productivity growth: linkages in the Japanese automotive industry. Management science (1999) (9).

[3] Taylor Lloyd, J. A simulation study of wip inventory drive systems and their effect on production measurements. British journal of management (2000) 11(1): 47-59.

[4] Taylor Lloyd, J. A simulation study on protective wip inventory and its effect on throughput and lead-time requirements. Problems and Perspectives in Management (2004) 3:144-152

[5] Hino, R., Suzuki, N., Shamoto, E. A new method to control work-in-process inventory for high manufacturing productivity. Manufacturing Systems and Technologies for the New Frontier. Springer, London (2008). https://doi.org/10.1007/978-1-84800-267-8_45

[6] Wang, Y.C. The work in process (WIP) control model and its application simulation in small-batch and multi-varieties production mode. Modern Applied Science (2009) 3(6).

[7] Iqbal, M., Shibbir, A., Shamsuzzoha, A.H.M., Roomi, M. Inventory reduction by applying inventory management tools of a selected tannery factory. Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management, Bali, Indonesia, January 7 – 9, 2014.

[8] Ullaha, M., Kang, C.W. Quality costs (IRR) impact on lot size considering work in process inventory. Int. Journal of Engineering Research and Applications (2014) 4(6): 177-183.

[9] Rane, A.B., Sunnapwar, D.S.S.S. Regression modelling for performance improvement of Assembly line. Journal of Basic and applied research international (2015) 11(1): 22-33

[10] Saraswat, P., Deepak, K., Manoj, K.S. Reduction of work in process inventory and production lead time in a bearing industry using value stream mapping tool. Int. J. of Managing Value and Supply Chains (IJMVSC) (2015) 6(2).

[11] Leung, N.Z., Chen, A., Yadav, P., Gallien, J. The impact of inventory management on stock-outs of essential drugs in sub-saharan Africa: secondary analysis of a field experiment in Zambia. (2016). https://doi.org/10.1371/journal.pone.0156026

[12] Rane, A.B., Gawandalkar, C.H. Case study based vendor selection by TOPSIS and Pugh matrix approach (2016) 4 (9): 435-445

[13] Barrak, F.A., Youssef, A.M., Meriem Zniber, E.M. Work in process stock integrity in the automotive industry. Production & Manufacturing Research (2017) 5(01):2-14

[14] Olaitan, O., Quan, Y., Erlend, A. Work in process control for a high product mix manufacturing system'. Procedia CIRP 63 (2017) 277 – 282.

[15] Jiang, J., Suk-Chul, R. Strategic WIP inventory positioning for make-to-order production with stochastic processing times. https://doi.org/10.1155/2017/8635979

[16] Rane, A.B., Sonawane, D.S.S.S. Development of 3 axis CNC milling with an open source controller. Int. J. of Research in Engg. & Tech (2017) 06(08):9-15

[17] Tan, H.W., Khairur, R.J., Hamzah, H.S. Work-in-Progress inventory control- case study in lean management. International Journal of Engineering & Technology 7 (3.4):181-187, (2018)

[18] Rane, A.B., Sunnapwar, Sharma, Jorapur. Development and optimization of vehicle assembly line: a literature review. Journal of Basic and Applied Research International (2019) 25(1):38-52

[19] Rane, A.B., Kamble. Material study for designing portable helmet. Int. J. of Research in Engg. & Tech (2018) 07 (05):132-136

[20] Rane, A.B. Enhancement of productivity by eliminating back chipping. Open Journal of Mechanical Engineering (OJME) (2019) 4(2):01-05

[21] Rane, A.B. Low-cost CNC machine by using Microcontroller. Open Journal of Mechanical Engineering (OJME) (2020) 5(1):01-04,

[22] Rane, A.B. Simulation of a manufacturing system to improve business. Advances in Industrial Engineering and Management (2020) 9(2): 27-32.

[23] Rane, A.B. Improvement of core manufacturing in foundry. Frontiers in Manufacturing Engineering (2020) 4(2): 01-06.