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Research Paper

INVENTORY CONTROL BY TOYOTA PRODUCTION SYSTEM KANBAN METHODOLOGY—A CASE STUDY

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In this paper, a single-item, multi-stage, sequential production system is considered. Materials in the system are controlled by Kanban discipline. And total number of Kanbans over a given number of serial workstations is allocated. Three main objectives, the average throughput rate (to be maximized), the average workin-process (to be minimized), machine idle time should be reduced due to lack of material are considered. We provide the optimal inventory control policy and characterize its structural properties for the single-period model. Through an extensive numerical study, we demonstrate that applied Toyota methodology policy is sufficiently accurate and close to optimal.

Keywords: average inventory; Inventory management; Toyota Production System TPS, KANBAN

INTRODUCTION

There is a real problem facing by bearing industry in deciding how to distribute buffer space to reach or maintain throughput, yet reduce the work-in-process (WIP) and flow time. One has to decide on the trade-of between these factors. Traditionally this has been done by using WIP inventory holding costs and lost order costs. We consider a single-item, multi-stage, serial production system. Kanban storage between sequential workstations is needed to support the smooth operation of manufacturing. A high throughput rate is often achieved at the cost of a large WIP, an undesirable relationship in today's manufacturing world. The paper is the first attempt to study and analyze the impacts of free shipping and free shipping quantity on inventory control policies. We focus on: (1) presenting structural analysis of optimal inventory policies, (2) proposing effective heuristic policies for multi-period inventory systems, and (3) quantifying the impacts of free shipping option and key parameters of the

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model. We conduct an extensive computational study and show that the heuristic policy is sufficiently accurate and it provides close-to-optimal solutions A Industrial Engineer must assess both the benefits from throughput and the cost of average work-in-process and the average flow time, before reaching any conclusions about increasing the throughput rate. Clearly, managers must consider the intangible costs of WIP, in order to make decisions that give a desirable balance between average throughput rate, average WIP and machine idle time. These costs include an increase in flow time. The obscuration of problems such as machine downtime and excessive setup times by WIP; quality effects; and, costs due to lost throughput such as lost orders if demand is high.

LITERATURE REVIEW

Kanban, a technique for work and inventory release, is a major component of Just-in-Time (JIT) and Lean Manufacturing philosophy. Kanban was originally developed at Toyota in the1950’s as a way to manage material flow on the assembly line. Over the last three decades, the Kanban process—a highly efficient and effective factory production system—has become a widely used tool in the manufacturing environment and global competition.

Kanban stands for Kan- card, Ban- signal. The essence of the Kanban concept is that a supplier, The warehouse or the manufacturer should deliver components only when they are needed so that there is no excess inventory. Within this system, workstations located along production lines only produce or deliver desired components when they receive a card and an empty container, which indicates that more parts are needed in production.

In case of line interruptions, measures are taken so that each workstation will only produce enough components to fill the container and then stop. Kanban also limits the amount of inventory in the process by acting as an authorization to produce more inventories. Since Kanban is a chain process in which orders flow from one process to another, the production or delivery of components is pulled through the production line, in contrast to the traditional forecast-oriented method where parts are pushed.

Advantages of Kanban Processing

- Provides quick and precise information
- Provides quick response to changes
- Avoids overproduction
- Minimizes waste
- Maintains full control
- Delegates responsibility to line workers

Through numerical studies, they show that the performance of the proposed Toyota policy is very close to that of the optimal policy and it significantly outperforms the policy under general conditions. In this paper, we consider a different and more complicated problem where the inventory system involves an order quantity requirement, a fixed cost as well as a balanced inventory.

PROBLEM IDENTIFICATION

The problem of 10 to 15% rise in WIP inventory for JC 8037 Cylindrical type of Bearing was reported by the higher-up of the company which was a starting point for the project. Therefore detailed study of the existing processes was undertaken to quantify the exact rise of WIP, the cause and solution to remove the bottleneck. And moreover to control raw materials, bought out components and finished goods of various bearings.

Study of Existing Process for the Selected Bearing

The company manufactures so many different types and ranges of bearings which have been discussed in the previous section, out of which following bearings have the more requirement.

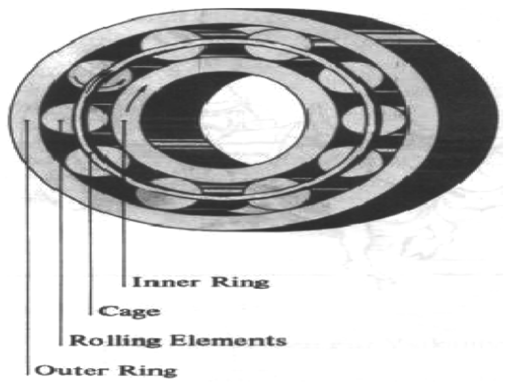
- JC 8037
- JC 8038
- JC 8033

For study of the process Bill of Material (BOM) is very important. The following Table 1 shows the BOM for the above mentioned components.

Table 1: BOM for the Selected Bearings

Bearing Description	Component Description	Component Qty
JC8037	6X12LP ROLERS-CRB	1.000
	JC 8037 INNER RINGSCRB	1.000
	JC8037 CRB MACHINED CAGESSTEEL (Drg. No. 3CA-196)	
	JC8037 OUTER RINGSCRB	14.000
JC8038	6X12LP ROLERS-CRB	15.000
	JC8037 INNER RINGSCRB	1.000
	JC8037 CRB MACHINED CAGESSTEEL (Drg. No. 3CA-196)	
	JC8037 OUTER RINGSCRB	1.000
JC8033	6X12LP ROLERS-CRB	15.000
	JC8037 INNER RINGSCRB	1.000
	JC8037 CRB MACHINED CAGESSTEEL (Drg. No. 3CA-196)	
	JC8037 OUTER RINGSCRB	1.000

Figure 1: Components of JC 8037/8038 Type Bearing



Note: JC = Jeau Circumferential (Gap between 1st and Last Needle).

Above Figure 1 shows varies components for the JC 8037. Outer ring, cage and needles are the components for this type of bearing.

Cage and needles are produced in the interplant and outer ring is manufactured in-house. So for outer ring we need to give operation scheduling for which we must know the material flow.

Block Diagram of Manufacturing Process of CRB Type

Material flow diagram shows various work stations along with machines, efficiency of the machine, cycle time and change over time.

Figure 2: Material Flow Diagrams for the OUTER RING JC 8037

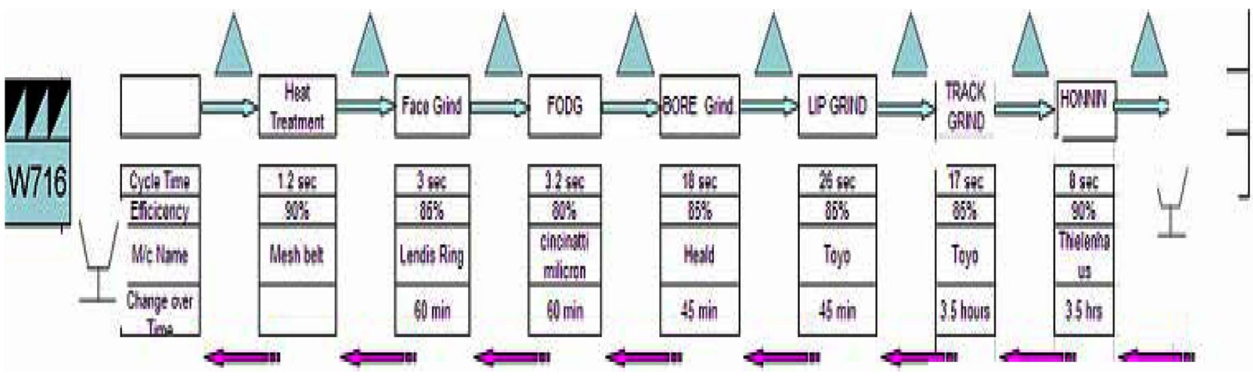
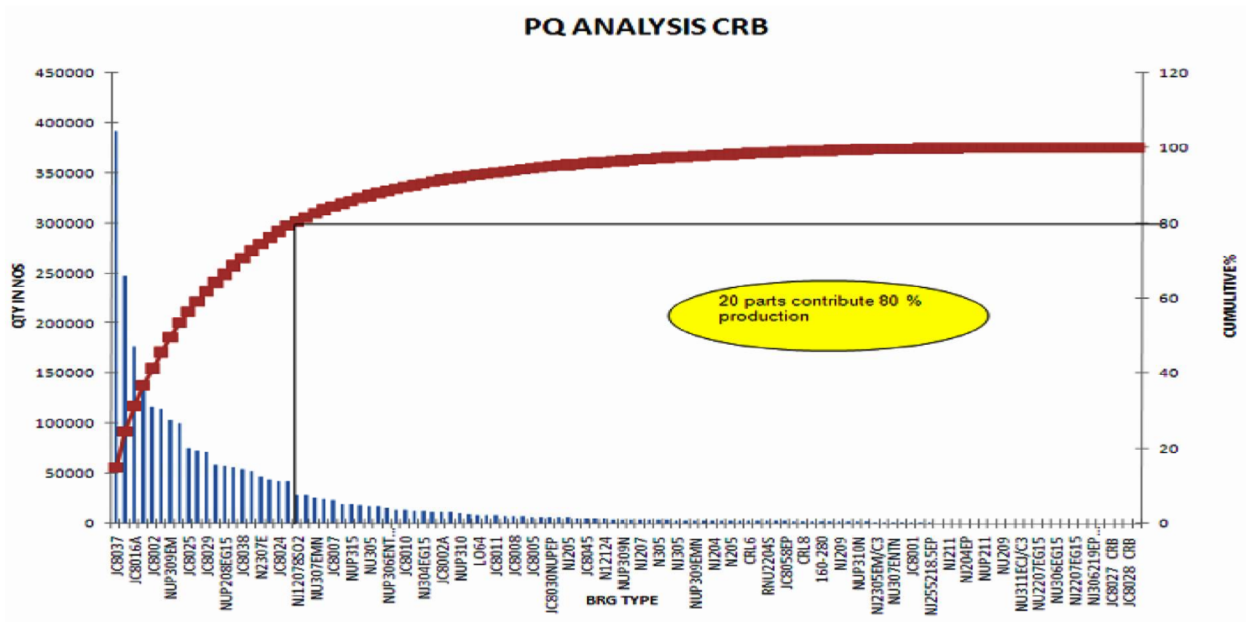


Figure 3: PQ Analysis for the CRB Bearings



After study of the manufacturing line following problems were observed.

- Increase in WIP inventory.
- Less utilization of available resources.
- Use of push system only.

The purpose of this project work is therefore to develop a mathematical model which gives optimized scheduling for a bearings manufacturing, identify wastes and make recommendations for improvement.

WIP Was Increasing

From the collected data of month wise WIP inventory for the three types of selected bearings as shown in the following Table 2 it is observed that the WIP inventory is above the targeted 6 days WIP inventory level as per the company standards.

As company was following 80/20 PQ analysis according to which 20% of components will contribute 80% of production such as nearly 135 varieties of bearings for

Table 2: WIP Inventory for Selected Components

Month-Wise Inventory Days of WIP on Shop Floor			
Month	**JC 8037 Outer**	**JC 8037 Inner**	**JC 8038/33B**
June	8.10	8.01	10.23
July	8.15	8.25	9.98
August	8.14	9.98	9.68
September	8.05	8.95	9.56
October	8.20	10.23	9.12
November	7.90	8.95	9.01
December	8.15	8.93	8.99
January	8.01	8.64	8.82

Figure 4: WIP Inventory for the JC 8037 Outer Ring in Days

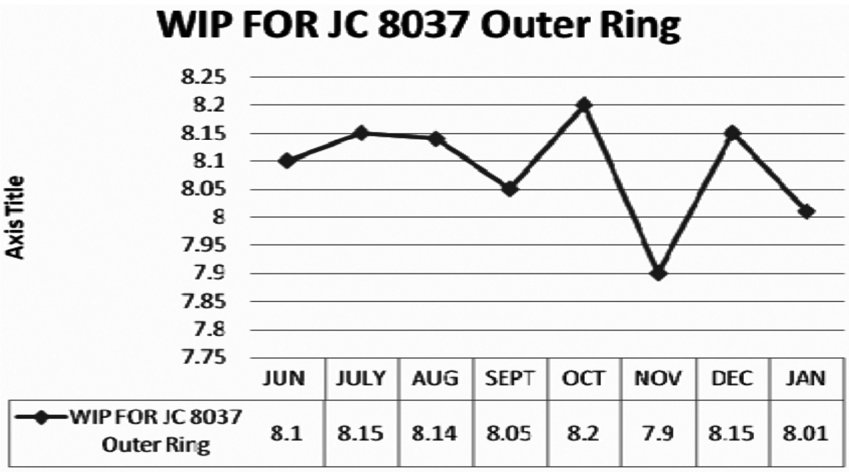
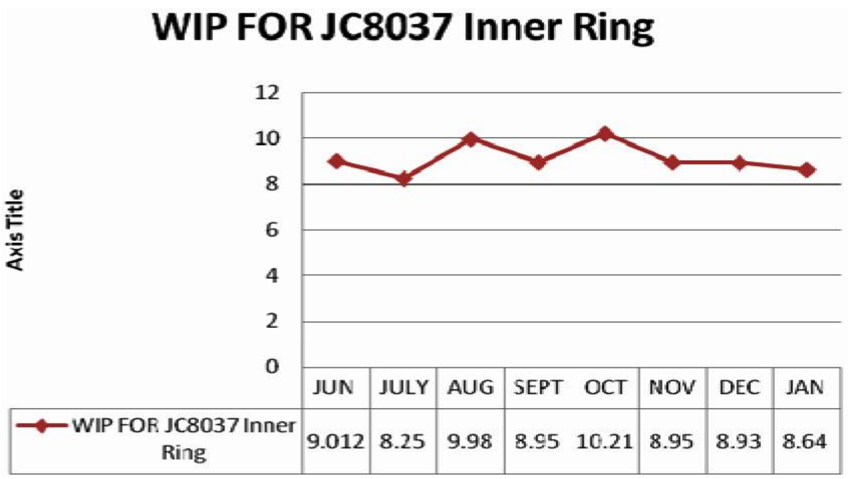


Figure 5: WIP Inventory for the JC 8037 Inner Ring in Days

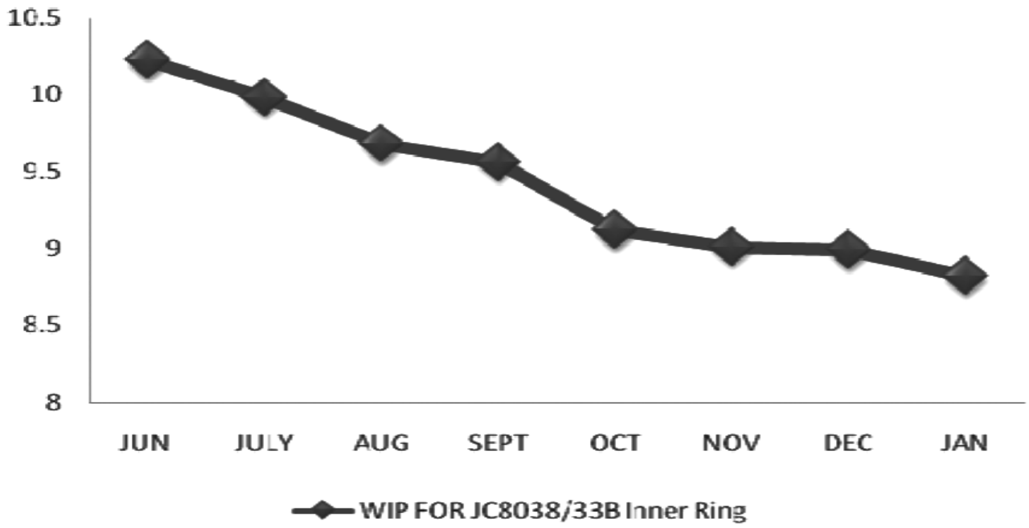


cylindrical roller bearings only 7 (seven) runners are there and remaining all varieties are strangers. Here that is reason why we are concentrating on Runner type components that is JC8037/ JC 8038/JC 8038 B.

Loss of Utilization of Available Resources Because of the No Meterial Condition

Another problem faced by the company is a loss of utilization of the machine hours which is shown Table 3 and graphs are generated to see the month wise variation.

Figure 6: WIP Inventory for the JC 8038/33B Inner and Outer in Days



The following Table 3 shows month wise loss of utilization of resources in percentage for the three components.

Table 3: Loss of Utilization of the Available Resources

	August	September	October	November	December	January
JC 8037 Outer	6.4	6.7	7.1	7.9	8.1	7.7
JC 8037 Inner	8.2	9.1	7.8	7.7	7.4	6.9
JC 8038/33 B	8.4	8.2	8.1	7.4	7.7	7.4

The following Figure 7 shows the graph for the loss of utilization of the M/c hrs for the JC 8037 Outer Ring component.

The following Figure 9 shows the graph for the loss of utilization of the M/c hrs for the JC 8038/33 B component.

Proposed Method

Proposed method is controlling inventory by Toyota KANBAN methodology. Before the implementation these techniques it is necessary to understand problems related to these techniques. Inventory will be kept in control according to monthly plan with keen control of KANBAN methodology.

When using Kanban discipline, a workstation has a fixed number of Kanbans (literally cards in Japanese) to use in requesting work from upstream sources.

Figure 7: Loss of Utilization of Available Resource for the JC 8037 Outer Ring in Percentage

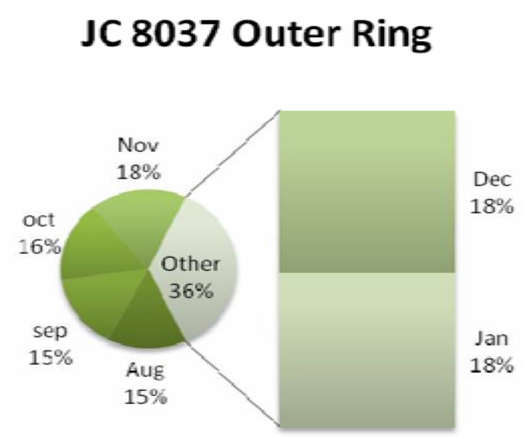


Figure 8: Loss of Utilization of Available Resource for the JC 8037 Inner Ring in Percentage

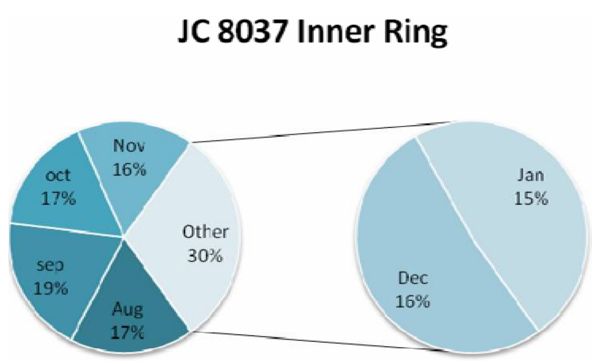
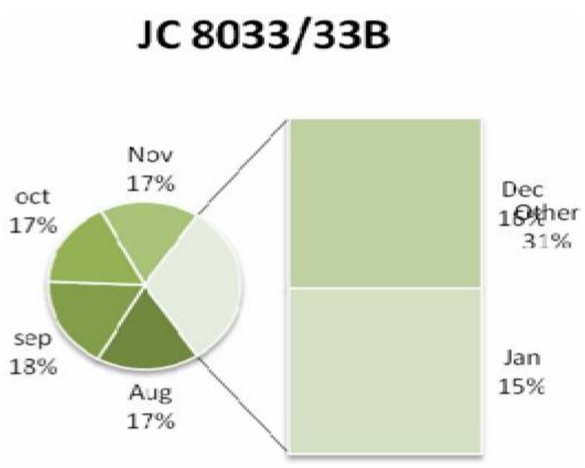


Figure 9: Loss of AMchine Utilized Hours for JC8037/38/33



Once an item arrives, the requesting Kanban is attached to the work unit until it leaves the work station. At that time, the work station can use the Kanban to request more items from upstream sources. This is referred to as a Kanban discipline by Mitra and Mitrani .Kanban discipline constitutes a—flexible system that promotes close coordination among workstations in repetitive manufacturing. The goal of the Kanban system is to achieve a total invisible conveyor system connecting all the external and internal processes. The number of Kanbans at a workstation determines its output buffer size.

Assumptions and Conditions

The following assumptions are used for all models:

- There is a single class (type) of items.
- The first workstation never waits for material on which to work (an unlimited availability of raw materials).
- The last workstation never waits for demand (there is unlimited finished goods storage capability).
- There is a single machine per workstation.
- There is no transportation time between workstations.

Demand on average must be bigger than or equal to the average throughput.

METHODOLOGY

Mathematical Model

As discussed earlier in the previous chapter the manufacturing process WIP inventory was increasing and there was increase in the loss of utilization of resources as well. So there is a need of proper scheduling technique which takes care of this problem.

The Gantt charts can be one of the techniques to tackle this problem but the problem with the technique is that it is a slow and time consuming process (Scarf, 1960). Each and every time we need to charts and also beyond a certain limit of time span it is difficult to read the charts. As the number of operations or number of batches in the scheduling increases in order to accommodate the larger time span either the Gantt charts have to be huge or the resolution has to be sacrificed. If there is a mathematical tool by which we can solve the above discussed problem then it will be much easier to get the schedule.

Inventory has problems. Too many kanbans indicate excess in-process inventory. By reducing the number of kanbans, problems area will come out of hiding so that they can be improved. In this way the kanban system becomes a valuable means to drive out waste and continually improve the production system.

The proposed technique requires the daily attainment of the track grinding that is the last operation of manufacturing process. Here the logic of process is reverse type of process, i.e., last process requests number of parts for before process. The same amount of parts are prepared and sent, no excess parts are send. So inventory levels are balanced and no excessive stocks are maintained.

Mathematical Model Formulation Logic

The main assumption here is daily attainment for the TG is 3500 components. Now following steps explain about other rows of the Table 4.

Table 4: WIP Inventory

Day	BGTG	ODG	FG	SB	Heat	GS	Total Inventory
1	3536	0	3438	–	30000	–	37974
2	3555	–	8000	–	**22000**	–	33555
3	3495	**8000**	–	–	14000	–	25495
4	3668	0	8000	–	6000	–	17668
5	3778	0	0	–	**36000**	–	39778
6	3356	0	0	–	28000	–	31356
7	3669	8000	0	–	**20000**	–	31669
		Average Inventory					29702

- On 1st day WIP is 3438 at FG and 3536 at TG. Then total inventory is 37974 as shown in the last column of the row.
- On 2nd day, in TG column it shows the 3555 because 3500 components the TG operation is completed on 1st day. So total inventory is now (13555 + 8000 + 22000) = 33555. So on the 3rd day at ODG operation remaining components are (11438 – 3438) = 8000 only.
- On 3rd day, in ODG operation it shows the 8000 components which is less than the safety stock. Then we need to increase the safety stock for that we need to do HT operation for the components. That means we need to do 30000 components HT on

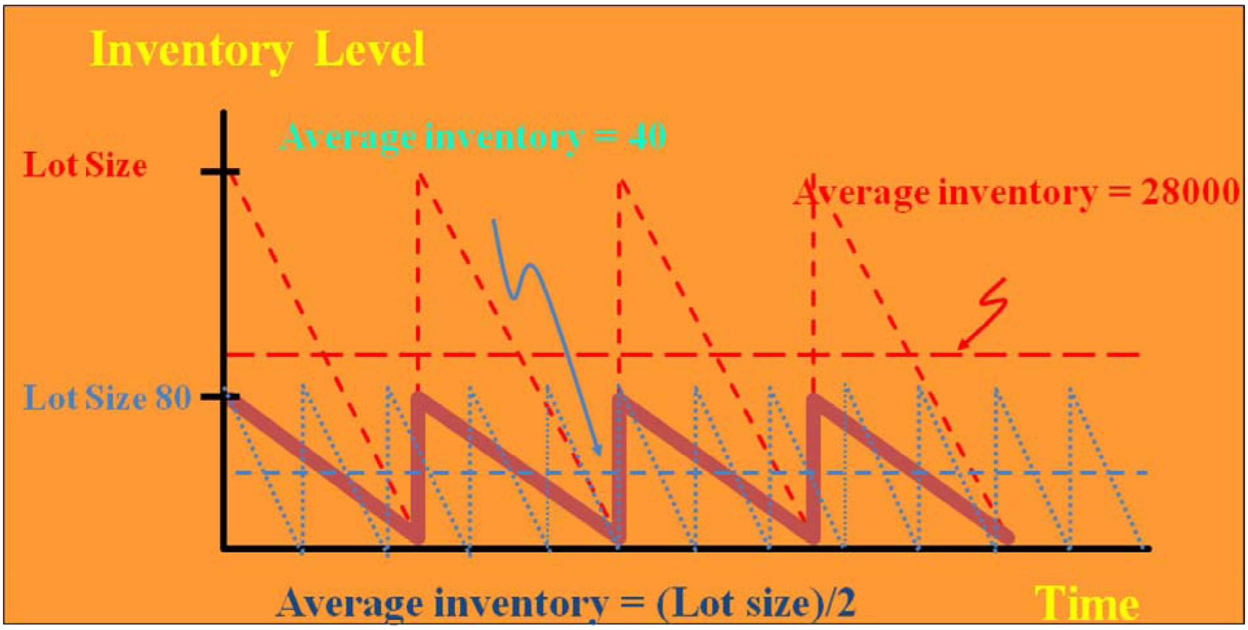
that day. Now inventory is (3595 + 8000 + 14000 = 25495).

- On 4th day, there is no problem because at FG there are less components and normal daily at track grinding components which are greater than the safety inventory level.
- On 5th day at FG we have only 3500 components which is less than the safety inventory level. Therefore we need to do 8000 components ODG operation on that day.
- On 6th day, there is no problem because at ODG 8000 FG 8000 components required for next day operation is being produced.
- On 7th day, there is 3500 components which is less than the safety inventory level. So it is necessary to do another 8000 ODG operation to fulfill the lack of safety inventory level.

So like this we can easily give the schedule. In this mathematical model we need to give track grinding daily attainment only then we get the operation scheduling for the day.

To Reduce Inventory Reduce Batch Sizes.

Figure 10: Calculation for Average Inventory Level



Calculation of Buffer Stock/ Inventory Levels

The Kanban system supports level production. It helps to maintain stable and efficient operations. The question of how many kanbans to use is a basic issue in tuning a kanban system. If your factory makes products using mostly standard, repeated operations, the number of kanbans can be determined using the formula

$$K = DR * RT * (1 + \alpha)/NC$$

where,

DR = Daily Requirement (parts/day)

RT = Replenishment Time (days)

α = Safety factor

NC = Number of parts per container

Inventory Level = [Daily Production Requirement * (1 + α)] where α = Safety

The number of kanbans you need dependent on the number of pallets or containers and their capacity. Lead times, safety margins or buffer inventory, and transportation time for kanban retrieval are also important factors.

Several questions must be answered when deciding the number of kanban to use.

- How many products can be carried on a pallet?
- How many transport lots are needed, given the frequency of transport?
- Will a single product or mixed products be transported?

1. Production must be done is small lots. Reduce setup times to a minimum Cut lead time to a minimum.
2. Buffer stocks that are kept as safety margins against market fluctuations and production instability must eventually be eliminated. Short setup times make it possible to respond quickly to change. A Short production cycle allows you to reduce the number of kanbans to the minimum since reliable information about changes are easily accessible and the system responds rapidly.

Inventory Level

Inventory level is very important in between the process. That is also called as safety stock level which is calculated as below.

Inventory Level = [Daily Production Requirement * (1 + α)]

Daily Production requirement for JC 8037 Outer Ring = 4000 components

According to monthly plan

If safety factor α = 1,

Inventory level for

JC 8037 Outer Ring = *DR* * (1 + α)

= 4000 * (1 + 1) = 8000.

This inventory or safety stock keeping in between the process that is just before the TG and ODG operation.

Here it is to recognize that reverse process of maintaining inventory as safety stock level between intermediate departments. Tomorrows' stock requirements only will be prepared today and today's requirement is only prepared yesterday. Here that is major principle of material flow on shop floor.

- Inventory Level = [Daily Production Requirement * Replenishment time * (1 + α)]
- Daily Production requirement for JC 8037 = (57000/27) $\approx$ 2000
- Daily req. for JC 8037=2000

If safety factor α = 1,

Inventory level for

JC 8037(*RT* = 7 days, lot size = 2000, batch size = 6000)

= DR * RT* (1 + α)

= 2000 * 7 * (1 + 1)

= 28000

α = 1, means safety stock for one day

IMPLEMENTATION PHASE

Action Plan

In this section action plan has been discussed.

To Decide Kanban Methodology

After study of the existing process it was found that maximum inventory and lack of utilization of available resources is with production process. In the process of production WIP inventory was increasing more so to avoid this it was decided to implement Toyota Production System KANBAN Methodology.

Monitoring Phase

Having implemented Toyota Methodology the next most important step is to monitor the flow of materials. This step is important so as to know whether an Just In Time, Toyota implementation is successfully running or not. This step is started from January 2009 onwards.

Steps at Monitoring Phase

- Daily production fulfillments according to Monthly plan
- Attend daily Production Meeting
- Update Current status of Notice Board
- Attend breakdown and know the root cause
- Calculation of WIP inventory at starting of every month.

Present Proposed Method to Management and Decide Further Action

Above results were presented to the management for taking further steps. To get proposed method green signal present it to them those will get affected by this improved method. Take every problem for discussion with team and after answering it design the solution on paper and gather necessary tools to implement these solution. Getting proposal from top management is major thing it depend on understanding solution designed and how that can solve the problem associated with the existing process.

RESULTS

After implementation of in Toyota Production system TPS, the process was monitored rigorously and the following results are achieved.

Reduction of WIP Inventory with Same Output

After implementation of Toyota Production system TPS, WIP Inventory reduced by

- 15% for the component of the JC 8037 Outer Ring,
- 12% for the component of the JC 8037 Inner Ring,
- 15% for the JC 8038/33 B family of cylindrical bearings.

Following Table 5 shows the month wise WIP inventory level for the Cylindrical bearings family members.

Following Table 6 shows the comparison of average of six months WIP inventory before implementation and average of three months WIP inventory after implementation of the

Following Figure 12 shows how the variation has taken in WIP inventory level for the cylindrical Bearings JC 8038/33 B

Utilization of Available Resources

After implementation of integrated Toyota KANBAN methodology the better utilization of number of days, effective utilization manpower has been obtained.

Table 5: Monthly-Wise WIP Inventory Level for the Selected Components

Component	August	September	October	November	December	January	February	March	April
JC 8037 Outer	38495	38001	37506	40595	37810	38562	27811	28698	27999
JC 8037 Inner	36007	36789	35156	35965	36785	37009	29895	31445	30201
JC 8038/33 B	10903	10562	9945	10023	10562	9345	8226	8562	8884

Figure 11: WIP Inventory for the JC 8037 Inner Ring

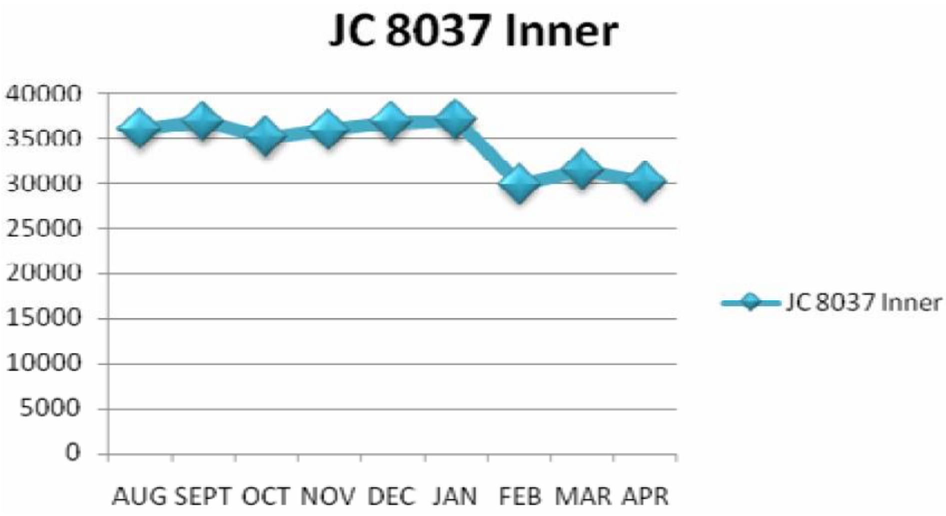
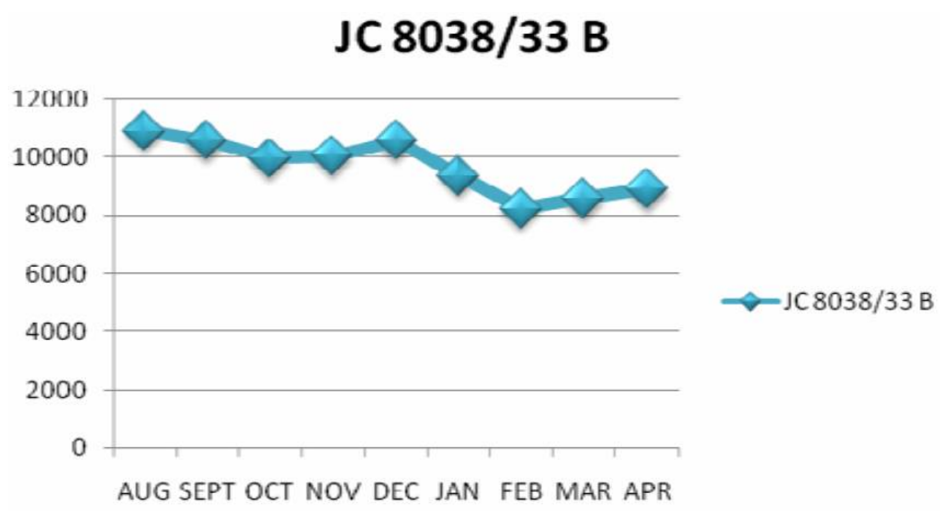


Figure 12: JC 8038/33 WIP Levels



- 5.35% for the component of the JC 8037 Outer Ring,
- 6.6% for the component of the JC 8037 Inner Ring,
- 5.58% for the component of the JC 8038/33 B Cylindrical bearing.

Following "Table 6" shows the month wise M/c idle hours because of no material condition in percentage for the selected components.

Following Figure 13 shows the M/c idle hours variation for the BEND212316 in percentage Above graphs are showing the loss of M/c utilization. After implementation of Toyota Production system TPS, machines do not remain idle. So at that place resources utilization is maximum. That means loss of resource of man, machine utilization is almost zero percent because of no material condition.

Figure 13: Improved Inventory Control for JC 8038/33

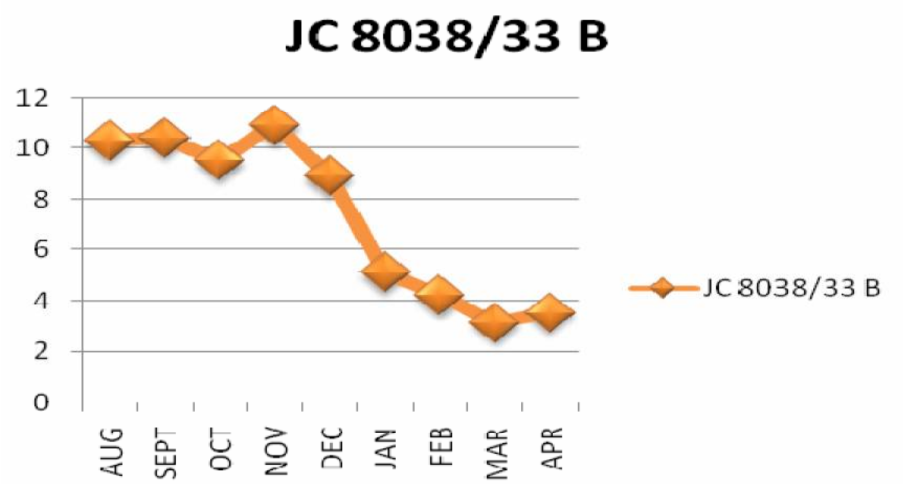
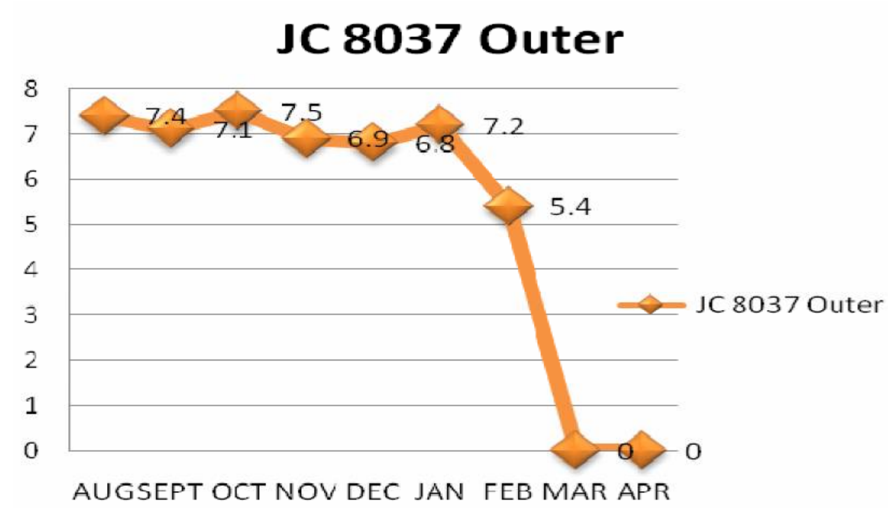


Figure 14: Improved Inventory for JC 8037 Outer Ring



CONCLUSION

- Mathematical model generates schedule for today considering yesterday's production, no excessive inventory is generated.
- Simple and effective, easy to recognize the material flow on shop floor First in First Out (FIFO) terminology has been proved best for Finished Goods inventory reduction.

- WIP inventory reduced by 15% for the JC 8037 Outer Ring of Cylindrical variety.
  - 12% for the JC 8037 Inner Ring of Cylindrical variety,
  - 32% for the JC 8038/33B variety of Bearings.
- Loss of resources man, machine utilization reduced by:
  - 7.1% for the JC 8037 Outer Ring of Cylindrical variety,
  - 6.5% for the JC 8037 Inner Ring of Cylindrical variety,
  - 6.7% for the JC 8038/33B variety of bearings.
- Process flow has resulted in drastic reduction in inventory levels and has facilitated a smooth flow of operations due to its online supply chain and shop floor execution communication capability.
- In summary, time-advantaged companies enjoy one or more of the following benefits, relative to their peers: increased productivity; pricing flexibility; reduced risks; reduced costs and increased response capability.

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