Implementation of Lean Manufacturing concepts for Common Rail Pump assembly at Bosch limited, Bangalore

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Abstract - *In manufacturing industries, the current trend is to adopt lean manufacturing which is about reducing the wastes in all aspects of production. There are various lean tools and techniques that can be adopted to serve this purpose. Implementing a **'pull production system' to the manufacturing setup reduces** inventory levels, costs and thereby provides a greater control of the production system to the management. In case of a pull system, the incoming customer order triggers production process and thereby reduces the stock levels in the industry/warehouse. Hence for the concerned product family (components of common rail pump), pull system is to be implemented to its value stream. Kanban cards are used to link the pull system and thereby forming a closed loop. Firstly, the current state of material and information flows was mapped. This represents the connections between processes. It is known as value stream mapping (VSM). Then in the VSM, the critical zones to be improved were identified which is followed by preparing the proposed future state map. This was followed by designing the closed loop and kanban calculations. The kanban linked pull system reduced/defined inventory levels in the loop and reduced the overall lead time of production. On implementing the proposed pull system, the lead times for the three main components of common rail pump were reduced- For cylinder head- from 3.5days to 2.9days, for eccentric shaft- from 23.4days to 18.7days, for housing- from 1.98days to 1day. Also, the Work-In-Process (WIP) in the value stream was reduced- For cylinder head- from 11,680Nos to 6,110Nos, for eccentric shaft- from 40,635Nos to 29,165Nos, for housing- from 295Nos to 85Nos. This in turn increased the time saved for cylinder head, eccentric shaft and housing by 20.6%, 25.1% and 98% respectively. Also, due to reduced WIP, floor apace on the shop floor was freed.*

Key Words: Kanban, Lean Manufacturing, Pull System, Value Stream Mapping(VSM)

1. INTRODUCTION

The project was carried out at Bosch Limited. Robert Bosch GmbH, or Bosch, is a German multinational engineering and electronics company headquartered in Gerlingen, near Stuttgart, Germany. It is one of the world's largest supplier of automotive components. The company was founded by Robert Bosch in Stuttgart in 1886.

Bosch's core products are automotive components (including high pressure pumps, brakes, controls, electrical drives, electronics, fuel systems, generators, starter motors and steering systems), industrial products (including drives and controls, packaging technology and consumer goods) and building products (including household appliances, power tools, security systems and thermo-technology).

1.1 BOSCH in India

Bosch stepped into India in 1922, when the Illies Company setup a sales office at Calcutta. In India, Bosch set up its manufacturing operation in 1953, which has grown over the years to include 10 manufacturing sites and 7 development and application centers.

2. Product details

The core product of Bosch ltd- The Common Rail Pump (CRP) is manufactured at plant Number-3 of Bosch ltd at Bangalore. The high-pressure pump compresses the fuel and supplies it in the required quantity. It constantly feeds fuel to the high-pressure reservoir (rail), thereby maintaining the system pressure. The required pressure is available even at low engine speeds, as pressure generation is not linked to the engine speed. Most common rail systems are equipped with radial piston pumps. Compact cars also use systems with individual pumps which operate at a low system pressure.

There are mainly two kinds of CRPs that is being produced at the plant, namely-

1) CP1 pump (output- 180 units per day)

2) CP1H pump (output- 1050 units per day)- The three major components of CP1H pump are-

a) Eccentric shaft

b) Cylinder head

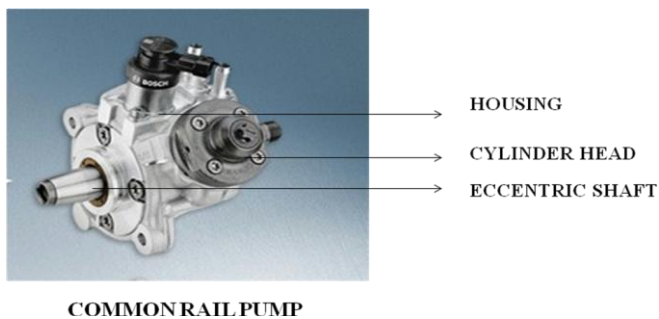c) Housing

These components are shown in Figure- 2.1.

Fig -2.1: Components of CRP

The process details of all three major components of CP1H pump i.e, Cylinder head, Eccentric shaft and Housing were studied.

The main problem observed for all the three components i.e, cylinder head, eccentric shaft and housing is that the lead times and WIP were on the higher side. Also, the **current production system is of 'push' type. Hence, a** closed loop control pull production system is to be implemented in value stream of all the three components.

3. LITERATURE REVIEW
3.1 Origin of Lean Manufacturing
After the world war-II Japanese were using the scraps and built new usable things. They built many types of machines to fulfill their other requirement. Japanese were facing financial problems too. So they tried to minimize the cost of manufacturing the new product. They focused on the unnecessary things and their elimination. So the lean concept came in focus.

After success of LEAN in Japan, the term LEAN was defined as a system that produced the same output with less input. Lean is to manufacture only what is needed, when it is needed and what quantities ordered. For the reduction in the cost, the information system played main role. Kanban

is used as the form of information. In the industry, information goes from the customer to retailer, retailer to manufacturer and manufacturer to supplier and the product goes from supplier to manufacturer, manufacturer to retailer and in the last retailer to customer. Here we can reduce the time of transportation to save the delivery time. But in the manufacturing unit the waste is not like only transportation but other wastes are also there like over production, over processing, unnecessary motion, waiting, transportation and inventory. [1]

LEAN PRODUCTION
It means-
- Only produce what the customer requires.
- Increase efficiency and standardization by continuous improvements (CIP).
- A philosophy that leads to low-waste processes in a company.
- Focus on quality and cost reduction

3.2 Value Stream Mapping (VSM)-
The value stream map is a tool which draws the current state map and future state map. The current state mapping is one of the parts of the value steam mapping. From this mapping the wastes are identified easily. This mapping makes all the processes visual. Here the inventory is the main cause of waste. The inventory creates non value added time. It means lead time may be viewed as two related issues. The large amount of inventory waits for long time in queue for the process i.e. creates large lead time. Large amount of inventory is the main cause of increase in cost i.e. holding cost and maintenance cost. All the demands order by the customer from EDI (Electronic Data Interchange). Data collection for the material flow starts at the internal customer (assembly department) and worked backward all the way to the supplier, gathering snapshot data such as inventory levels before each process, process cycle times (CTs) etc. The procedure is given below.

a) Draw a Visual Representation of every process as the material and information Flows / Passes through (Current State).
b) Examine & Evaluate Flow of Value Stream, to eliminate Muda (Waste) or NVAs.
c) Draw a **"Future State" map of how Value should** flow in Stream.

3.3 Production control
Production control mechanisms can be divided into two categories:
a) Push system
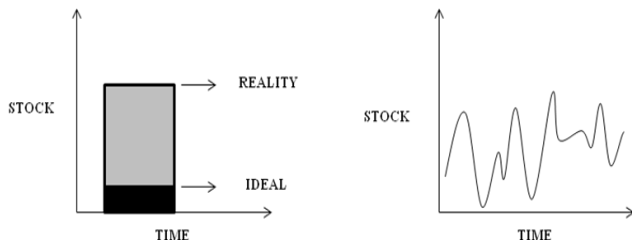b) Pull system.

a) Push system-

Fig -3.1: Stock levels in push system

- In the push system, production is initiated when demand is scheduled to individual workstations and parts are available for processing.
- Production is carried out irrespective of the customer demand.
- The Work-In-Process (WIP) and finished goods quantity is huge due to compensation for lapses in co-ordination. Figure-3.1 shows the stock levels in case of a push system. The stock levels are well beyond the ideal limit and the variation in stock levels with respect o time is also high. [8]

b) Pull system: Synchronous production (flow line production)
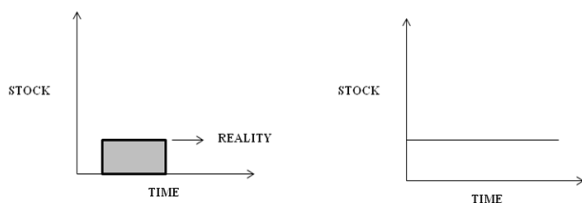

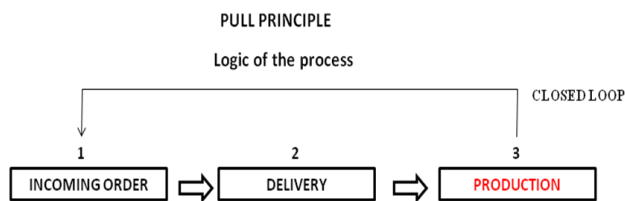Fig -3.2: Stock levels in pull system

Fig -3.3: Pull principle

- In the pull system, production is initiated when finished goods/WIP inventory are withdrawn and parts are available for replenishment.

- With JIS (just in sequence), the right quantity is delivered in the right sequence and at the right time.
- A small buffer in the form of a FIFO line is possible for decoupling.
- Material "flows" directly to the point of use.
- The pull system is based on the kanban where the product will be pulled from the upstream processes.
- The stock levels are far less when compared to push system as shown in Figure-3.2.
- The operating sequence of pull system is shown in Figure-3.3. It also has a closed loop control system to initiate production. [4]

3.4 Kanban

It is a method for maintaining an orderly flow of material. Kanban cards are used to indicate material order points, how much material is needed, from where the material is ordered, and to where it should be delivered.

Kanban System- The Kanban system can be viewed as an information system that controls Just-In-Time (JIT) production. Kanban is the inventory replenishment system developed by Toyota to accomplished JIT production. In Kanban production system, the production processes for **various products are controlled as per the customer's** order. Generally speaking, each item consumed, determines a replenishment signal: a production card (Kanban) is collected in a special Kanban board that displays items consumption and then used to start production or order placing according to the sequencing rules of the upstream section. There are two types of Kanbans: withdrawal kanban and production kanban. Withdrawal Kanban specifies the kind and quantity of product to be withdrawn from the subsequent process. While the production Kanban specifies the kind and quantity of product to be produced. The withdrawal Kanban is used as an inter-process signal to move physical units from one process to another process that takes place at a different location, whereas the Production Kanban is an intra-process signal to issue production orders in a particular process. As a result of this dual chain of Kanbans, the rate of production of the succeeding process is transmitted to the preceding and every process receives the necessary units at necessary time in necessary quantities.

4. METHODOLOGY

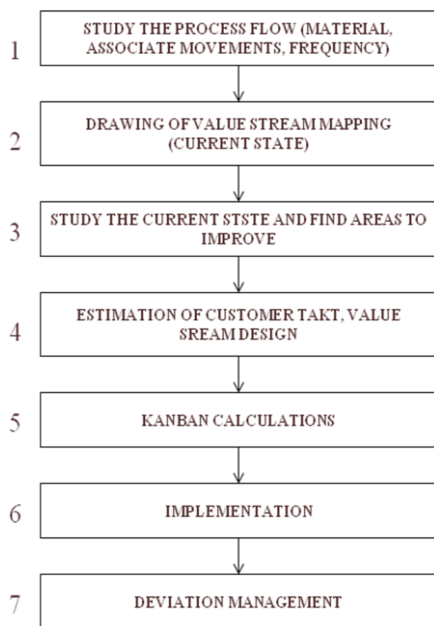The methodology adopted is shown in Figure- 4.1.

Fig- 4.1: Methodology

5. VALUE STREAM MAPPING (VSM)

VSM is prepared for the three components of CP1H Common Rail Pump-

5.1 Present value stream map- Cylinder head

The current state value stream mapping represents the present way by which the information and material flows are being carried out. It is mapped from the supplier end to the customer end. For cylinder head, the current state value stream map is shown in Figure-5.1.
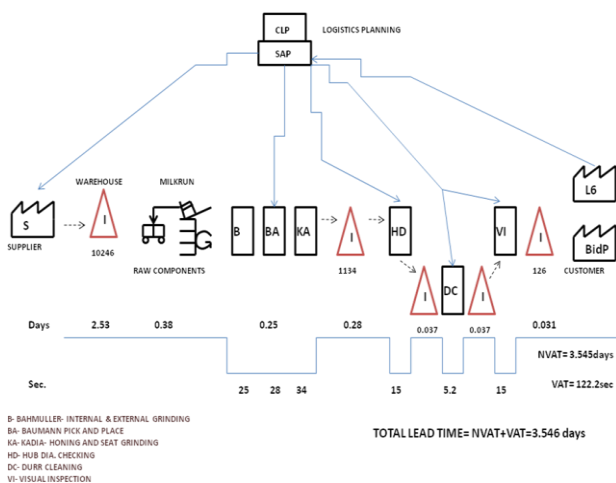

Fig -5.1: Present value stream map- cylinder head

Description-

The customer gives the demand to logistics planning via electronic information system. Production is initiated by logistics planning (CLP) department. CLP has to convey the requirement information to all the work stations as shown in the map.

The raw cylinder head components to the first station i.e, **'Baumann' machine is delivered from the warehouse via** milk run. External and internal grinding operations are carried out at Bahmuller, followed by honing and seat **grinding at 'Kadia'. Baumann is a robotic** pick and place machine to both Bahmuller and Kadia. There are two modules of Bahmuller, Baumann and Kadia i.e, there are two machines for all the three mentioned. The three **machines together is called as 'kadia module'. Baumann is** where the loading of raw materials and unloading of materials is carried out. Then, hub diameter of the cylinder head is checked manually which is followed by Durr cleaning and visual/endoscopic inspection. The WIP between work stations have no defined limits in the current state value stream. Also, the information about production requirements to the operators are carried out manually.

The total lead time is as given below-

The total Non Value Adding Time (NVAT) = 3.545days

The total Value Adding Time (VAT) = 122.2sec= 0.00141days

Therefore the total lead time= NVAT + VAT

= 3.546days

5.2 Proposed value stream map- cylinder head

In case of the proposed 'future state' value stream, the WIP are replaced by FIFO. FIFO acts as a control element between preceding and following operation to minimize the WIP. In this case, the FIFO between work stations is fixed based on machine capacity which is also the lot size. The lot size is 400pcs. Hence FIFO is 800pcs (there are two modules) between Kadia module and hub diameter checking. It also ensures the component which was first-in is also the component that is first to be fed to the following operations. The proposed VSM also has a closed loop with production kanban (PK). This makes the information about production requirement automatic to the operators in the form of kanban cards. This can be identified by observing the reduced number of information flow lines from CLP to the work stations in case of the proposed value stream map which is given in Figure-5.2.
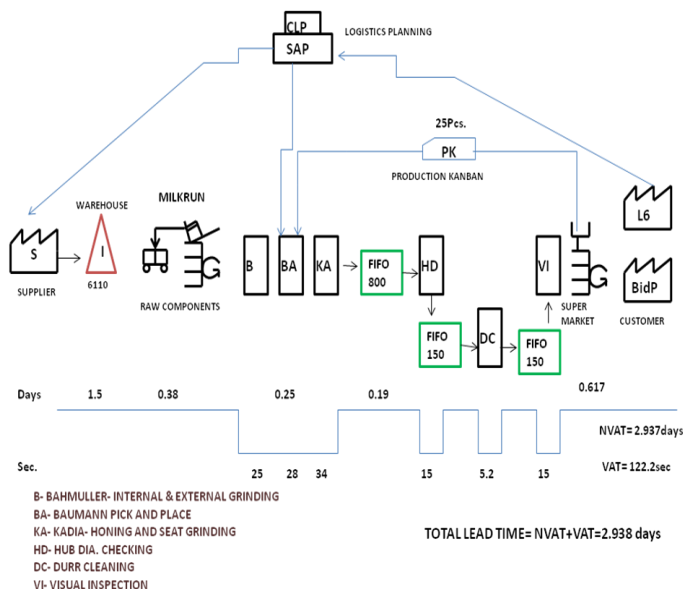
Fig -5.2: Proposed value stream map- cylinder head

The total Non Value Adding Time (NVAT) = 2.937days
The total Value Adding Time (VAT) = 122.2sec= 0.00141days
Therefore the total lead time= NVAT + VAT
                              = 2.938days

Similarly, current state value stream maps for Eccentric shaft and Housing were prepared and proposed versions were designed to reduce the WIP and lead times. The following tables give the comparison in lead times and WIP between current state and future state maps-

Table -5.1: WIP comparison

Component	Work-In-Process (WIP) (present)	Work-In-Process (WIP) (proposed)	Reduced by
Cylinder head	11680 pcs.	6110 pcs.	5570 pcs.
Eccentric shaft	40635 pcs.	29165 pcs.	11470pcs.
Housing	295 pcs.	85 pcs.	210 pcs.

Table -5.2: Lead times comparison

Component	Lead time (present)	Lead time (proposed)	Reduced by
Cylinder head	3.54days	2.93days	0.61days
Eccentric shaft	23.4days	18.71days	4.69days
Housing	1.98days	1day	0.98days

6. KANBAN CALCULATIONS

Prior to kanban, capacity calculations were carried out to ensure availability of capacity for meeting the customer requirement (based on takt time). Also, it was be used to determine the time available for changeover, which in turn helped to find out the lot size for that particular component.

Introduction- Kanban is a control element that limits the quantity of circulating goods. The rules of kanban system are as follows-
- Production is triggered by consumption at the customer.
- Production only takes place if there is a kanban card and then in the quantity and order of sequence stipulated on kanban cards.
- Delivery is made only with a kanban card.

Kanban formula-
Total number of kanban cards in the loop-
   K = RE + LO + WI+ SA [ref. BPS manual]
   Where,
- RE = Replenishment time coverage (covering the replenishment lead time and the average consumption amount).
- LO = Lot size coverage (covering the production lot size).
- WI = Withdrawal peak coverage (covering the withdrawal peaks).
- SA = Safety time coverage.

On accumulating the required data for kanban calculation, the Number of kanban cards and finished goods level (in supermarket) for all the three components were determined-

   a) Cylinder head-
The total number of Kanban cards in the loop, K= RE+LO+WI+SA= 171cards.
Finished goods supermarket calculations-
-Minimum size= SA= 54*25= 1350pcs.
-Maximum size= 0.8*K*25= 3420pcs.

-From the calculations, the total number of kanban cards to be in the loop is determined= 171 cards.

-The maximum and minimum quantity of components in the supermarket is defined, which keeps the inventory level in check considering customer fluctuations.

b) Eccentric shaft- Similarly, the number of kanban cards in the loop and the supermarket limits are determined using the same formula.

Table -6.1: Kanban table- Eccentric shaft

PART NO.	K	TOTAL QTY. [K*NPK]	MIN QTY. [SA*NPK] (pcs.)	MAX QTY. [0.8K*NPK] (pcs.)
F01M101808	180	1800	210	1440
F01M101285	288	2880	470	2304
F01M101765	150	1500	140	1200

c) Housing-

Table -6.2: Kanban table- Housing

PART NO.	K	TOTAL QTY. [K*NPK]	MIN QTY. [SA*NPK] (pcs.)	MAX QTY. [0.8K*NPK] (pcs.)
F01M101857	9	270	150	216
F01M101562	19	570	240	456
F01M100423	9	270	90	216

7. CONCLUSION

a) On implementation of the proposed closed loop control pull production system with kanban to the value stream, the total lead times for the components of CRP i.e, (cylinder head, eccentric shaft and housing) were reduced by a considerable margin.

b) The Work-In-Process levels were reduced after introducing FIFO in between work stations.

c) Introduction of kanban system facilitates the automatic functioning of the loop i.e, the operators need not be told how much to produce and which product type to produce. This is because, all the information will be available in the kanban cards and hence no manual intervention is required for this purpose.

d) The maximum and minimum quantity of components in the supermarket (finished goods section) is defined, which keeps the inventory level in check.

e) Due to reduction in lead times, the percentage time saved for cylinder head, eccentric shaft and housing is 20.6%, 25.1% and 98% respectively.

f) The reduction in WIP levels saved floor space on the shop floor.

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