ABSTRACT
This study emphasizes on the implementation of JIT technology using Kanban system in a mixed model assembly line of a pump manufacturing industry having demand fluctuation in the orders, which forms a trigger to the overall system. Company has adopted make-to-stock (MTS) policy. Kanban is a method for increasing productivity with emphasis on just-in-time (JIT) manufacturing system in which the movements of the materials in a process are recorded on Kanban cards. The customer demand is increasing day by day and as per the present situation, the company has introduced the use of Kanban system in their process. This system allows lead time to be minimized, as compared to the situation before implementing Kanban. Due to this system, there is no need of keeping large inventory of raw materials and work-in-process (WIP) inventory. The results of the study obtained after implementing the optimal design of the Kanban system highlights the reduction in safety stocks, increase in the material availability, improvement in the material flow in the process and reduced overproduction, as it places control at the production level.

Keywords--- JIT, Kanban, Kanban Cards, Lead Time, Safety Stock

I. INTRODUCTION
This study towards the implementation of JIT philosophy using Kanban system is to be conducted in the mixed model assembly line in the existing plant of a pump manufacturing industry. The mixed model assembly line is configured to produce several models without changeover, as pioneered by Toyota Production System (TPS). The production schedule specifies the proportion of each model required for customer demand, for example, the proportions are taken as 25%, 25% and 50%. Better material availability, reduced inventory level and strict control over the supply chain address the need for an efficient Kanban system towards the effective inventory management in the said manufacturing unit craving for sustainable business growth based on this study.

II. LITERATURE SURVEY
According to John and Kenneth, 2003, Just-In-Time (JIT) manufacturing system was developed by Taiichi Ohno which is called Japanese “Toyota production system”. JIT manufacturing system has the primary goal of continuously reducing and ultimately eliminating all forms of wastes. Based on this principle, Japanese companies are operating with very low level of inventory and realizing exceptionally high level of quality and productivity. JIT emphasizes “zero concept” which means achievement of the goals of zero defects, zero queues, zero inventories, zero breakdown and so on. It ensures the supply of right parts in right quantity in the right place and at the right time. Hence, the old system of material acquisition and, buyer and seller relationships are changed to new revolutionary concepts. Similarly, JIT becomes an inevitable system at plant level, which integrates the cellular manufacturing, flexible manufacturing, computer integrated manufacturing and Robotics.

Due to the technological advancement, the conventional method of push production system linked with Material Requirement Planning (MRP) was changed to pull type JIT production system to meet out the global competition, where work-in-process (WIP) can be managed and controlled more accurately than push-production system, as concluded by Kumar and Panneerselvam, 2007. Kanban is basically a plastic card containing all information required for production/assembly of a product at each stage and details of its path of completion. The Kanban system is a
multistage production scheduling and inventory control system where, Kanban cards are used to control production flow and inventory, as discussed by Yang, Zhang and Jiang, 2010. This system facilitates high production volume and high capacity utilization with reduced production time and work-in-process. Monden, 1983 stated a comprehensive presentation of Toyota production system. A successful Kanban system will drastically reduce the throughput time and lead time. Karmarker and Kekre, 1989 have concluded from their studies that the reduction in container size and increase in number of Kanbans will lead to better results. Many researchers were interested in finding the optimal number of Kanbans. The Toyota formula is very much effective in determining the optimal number of Kanbans.

III. METHODOLOGY

3.1 Procedure to Design an Optimal Kanban System

John and Kenneth, 2003 have proposed the various steps towards the optimal design of the Kanban system. These steps have to be executed in a mixed model assembly line of a pump manufacturing industry which are enlisted as;

Step 1: Perform the data collection to analyze the production process in order to compute the Kanban quantities in the next step

Step 2: Determine the Kanban size by estimating the Kanban container size based on current conditions, not on future plans considering the Kanban design elements - average daily consumption [ADC], total lead time [LT], vendor response time [VRT], transit time [TT], internal lead time [ILT], replenishment index [RI], lead time factor [LTF], safety stock [SS] and supply side failures / variances

a) Make the initial calculations that will utilize the production requirements, system scrap rate, process productivity rate, planned downtime and, changeover times to compute the replenishment interval

b) Compute the final Kanban container quantities that will also include a buffer for safety stock and, to account for any process cure, drying, or normalization periods, illustrated with a typical re-ordering example in the Fig.1, based on these computations:

\[ TLT = VRT + TT, \quad RI = \text{Kanban Quantity} / \text{ADC}, \quad LTF = RI + SS + TLT + ILT \text{ and, Design Control} = LTF \times ADC \]

and, this gives, the numbers of Kanban = Design Control / Kanban Quantity

**Fig.1 Re-ordering Example**

Step 3: Design the Kanban System focusing on material control, visual signals, rules for implementing Kanban, Kanban transactions, scheduling decisions, problem-solving, visual management, training required and, implementation schedule, alongwith a plan for implementation of the Kanban system including the implementation actions, action assignments and, schedule milestones

Step 4: Propose training for everyone on how the system will work and on their role in the decision-making process and, to understand the significance of Kanban signals and how to handle them

Step 5: Initiate the Kanban system - before implementing Kanban scheduling, ensure the visual management for all the pieces in place, have the signals set-up, control points marked and, the rules completed and coordinated before initiation to avoid the confusion

Step 6: Make an audit for the Kanban system to observe how the scheduling signals are handled and whether the customer stays supplied, to resolve the problems immediately by the responsible party to maintain the integrity of the Kanban design and to monitor the future requirements to make sure that Kanban quantities meet the expected demand, as if the Kanban quantities are not
adjusted to the forecasted demand, then, this will continually intervene manually in the scheduling process

Step 7: Maintain the Kanban system, as shown with an illustration in the Fig.2 - On the first day, total inventory stock is of 21 boxes with a demand of 1 box per day and delivery cycle of 7 days and, if the safety stock is 7 boxes, then, order quantity will be of 14 boxes so that the reorder point will be of 14 boxes to maintain the safety stock

Fig.2 Maintaining the Kanban System in the Mixed Model Assembly Line

Step 8: Make modifications, if necessary, to improve the Kanban system to reduce the inventory quantities with the resistance to urge to just start pulling containers that identify any quantities which are oversized, and pull the necessary containers immediately so that after this one-time adjustment, the quantities will only be reduced based on improvements made to the production process.

3.2 Daily Monitoring of the Stock

The daily monitoring of the stock is facilitated by applying the color coding with each firm having its significant color coding to the design of its Kanban system. The auditing of the Kanban system in the mixed model assembly line of the said pump manufacturing unit is conducted with a color coding to monitor the daily stock as specified;

*Specification of Color Coding to monitor the Daily Stock:*
- **Green Zone:** Operating Control Level
- **Yellow Zone:** 2/3rd of Green Zone
- **Red Zone:** 1/3rd of Green Zone
- **Blue Zone:** Excess of Inventory
- **Black Zone:** Stock out

Daily monitoring of the parts v/s vendor performance to predict the performance of various vendors has been illustrated with an example, stated in the Table 1.

Table 1 Daily Monitoring of Parts v/s Vendor Performance (stated with an example)
IV. RESULT INTERPRETATIONS

The optimal design of the Kanban system after its execution in the mixed model assembly line proves to be very beneficial. The findings of the study indicate the reduction in supply chain oscillation/ripples by over 60-70%, resulting in much strict control over the supply chain, increase in material availability factor to almost 100%, shown from monthly audit results, as stated in the Table 2 and, reduction in maximum inventory with an average of 45%, as highlighted in the Fig.3, for the different types of materials. There will be a necessity of leveling the production and monitoring weekly stock levels due to unpredictable consumption pattern. Buyers will get much more time in hand to do value added activities for analysis of the performance and improvements to the optimal design of the Kanban system in the mixed model assembly line.

Fig.3 Reduction in Inventory resulting from Optimal Design of Kanban System

Table 2 Monthly Audit Result indicating Improved Availability of Parts

<table>
<thead>
<tr>
<th>Model</th>
<th>Max&lt;sup&gt;m&lt;/sup&gt; Stock (Pre-Kanban)</th>
<th>Min&lt;sup&gt;m&lt;/sup&gt; Stock (Post-Kanban)</th>
<th>%age Inventory Reduction</th>
<th>% age Material Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN8 (40C8) Bar 25 DIA × 300 MM L</td>
<td>543</td>
<td>374</td>
<td>31</td>
<td>100</td>
</tr>
<tr>
<td>EN8 (40C8) Bar 25 DIA × 310 MM L</td>
<td>1474</td>
<td>1012</td>
<td>31</td>
<td>100</td>
</tr>
<tr>
<td>EN8 (40C8) Bar 25 DIA × 333.1 MM L</td>
<td>1065</td>
<td>831</td>
<td>22</td>
<td>100</td>
</tr>
<tr>
<td>EN8 (40C8) Bar 25 DIA × 340.5 MM L</td>
<td>341</td>
<td>309</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>EN8 (40C8) Bar 25 DIA × 347 MM L</td>
<td>2849</td>
<td>1132</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>EN8 (40C8) Bar 25 DIA × 358 MM L</td>
<td>273</td>
<td>147</td>
<td>48</td>
<td>100</td>
</tr>
<tr>
<td>EN8 (40C8) Bar 25 DIA × 367.7 MM L</td>
<td>680</td>
<td>389</td>
<td>43</td>
<td>100</td>
</tr>
</tbody>
</table>
V. CONCLUSIONS AND DISCUSSIONS

This study features a systematic approach towards the optimal design of the Kanban system and the possible benefits made through its implementation in the mixed model assembly line of a pump manufacturing industry, highlighting the improvement in the firm’s actual performance and cost reduction as well as the challenges. The optimal design of the Kanban system underlines the principle of consumption-oriented and peripheral-controlled system indicating the reduced inventory with very high material availability responding fast to demand fluctuations. Eventually, this concept of JIT manufacturing system enables the company to move towards its ultimate goal leading to sustainability and profitability, resulting in future success.

REFERENCES