Performance Analysis of Single Flow line Manufacturing –A Modeling Simulation approach

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ABSTRACT

The flow line manufacturing with pull production control mechanisms in multi stage manufacturing systems has received much attention in the past decade. These systems are derived using the concept of just in time (JIT) manufacturing whose objective is that material should be produced in right quantity at right time at right place. The paper focuses on the performance of Extended Kanban control system (EKCS), Constant work in process (CONWIP) and kanban Control system (KCS) for a single flow line by considering three manufacturing stages. The above systems are modeled as a network diagram using technical computing software MATLAB SIMULINK. The simulation studies are analysed to evaluate the performance parameters like production rate, average waiting time, total work in process(WIP) and machine utilization. The demand is considered with exponential distribution mean time varying from 50min to 10min. The processing time at each manufacturing stage follows exponential distribution mean time of 15min. The flow line was simulated for 57600 minutes. At optimal demand rates, the pull control system with tighter coordination is EKCS with reference to production rate, total work in process (WIP) and average waiting time.

Keywords: EKCS, KCS, CONWIP, Performance, kanban

"1. Introduction "

Just in time (JIT) manufacturing, application of kanban control system (KCS), used in Toyota production systems in mid seventies, is the best known pull type production control system. The word kanban is the production authorization card used to control and limit the release of parts into each stage of production system. The advantage of the system is less work in process (WIP) limited to number of kanbans. The disadvantage of the system is slow to react during variation of demand.

In the recent years, with the growing needs of industries, the traditional business model is not adaptable due to rise in competition and demands. There is a need to fill the gap to compensate the changes by creative and qualitative approaches. Thus, the pull control production system needs to maintain a minimum inventory to operate. For any pull control system to work and for a part to be released from output buffer of stage i -1 to the input buffer of stage i the following conditions need to satisfy.

1).There should be at least one finished part in output buffer i-1.
2) There should be one demand to release new part into stage i.
3) There should be at least one kanban to release new part into stage i from i-1.

There are many contributions regarding the pull control systems and their performance with reference to different configurations. Some of the contributions are as follows.
[1] discussed the unified framework of pull production control mechanism in multi stage manufacturing systems. The mechanism coordinates the release of parts into each stage upon arrival of the customer demand. They have presented four mechanisms based on coordination, Base stock control system (BSCS), Kanban Control system (KCS), Generalized kanban control system (GKCS) and Extended Kanban Control system (EKCS). [2] Introduced new mechanism called EKCS, combination of BSCS and KCS. The charactertics are exhaustively discussed and concluded that EKCS

is more effective than BSCS. [3] Discussed about the comparison between pull control mechanisms using simulation considering the real application of machining and concluded that the mechanism BSCS was considered the best with respect to work in process (WIP). [4] Presented the review of production control system based on four categories viz., order control, hybrid, stock control and schedule of flow and has discussed for repetitive and flow shop manufacturing. It was concluded that hybrid system is more promising compared to individual pull systems. [5] Presented the performance using simulation for multistage single line production system analyzed for Kanban, CONWIP and hybrid. [6] Presented the review and extensively discussed the strong emphasis of design in manufacturing knowledge domain and Manufacturing knowledge management analysis. [7] Emphasized on the performance of KCS over CONWIP. The KCS is flexible and outperforms the CONWIP, if number of kanbans is optimally set. Further, [8] discussed about optimum number of kanbans with varying demand and concluded that the number of kanbans has influence and effect on throughput, work in process (WIP) and machine utilization. But, [9] suggested Meta heuristics techniques like simulation annealing, genetic algorithm to find solution to determine number of kanbans and other measures.[10] Discussed the review of theoretical concepts and presented the maximization of pull control benefits with the development of new hybrid systems combining existing pull control strategies.

"2. Problem Formulation"

The aim of Pull production control system is minimum waiting time and minimum work in process. The material is pulled by downstream station, rather pushed by upstream station, by kanban coordination. The kanban is 'Japanese word' a tag or card to coordinate with material of upstream station and demand from downstream station. A single flow line system with three manufacturing stages is considered for the performance analysis. Each manufacturing stage consists of single machine or family of machines for the machining operation. The mean processing time of each manufacturing stage is 15 minutes and follows exponential distribution. The Customer demand follows exponential distribution; mean time varies from 50 minutes to 10 minutes in the time interval of 5 minutes. The model for KCS, CONWIP and EKCS is formulated as a network diagram using the technical computing software MATLAB-SIMULINK. The manufacturing flow line with the above configuration is simulated for the time period of 57600 minutes with the following assumptions.

a). Setting time at each manufacturing stage is included in the respective processing times
b). Transportation time/Material Handling time between manufacturing stages is negligible.
c). The failure rate is assumed to be zero.
d). The processing time follows stochastic distribution.

The aim of the paper is to study, compare and analyze the parameters like production rate, total work in process (WIP), average waiting time and server utilization.

"3. Results and Discussions"

"3.1 Queuing Network Model"

The figure1 represents the queuing network model for three stage kanban control system (KCS). The network model has three manufacturing stages in series, with kanbans K_i where i =1, 2, 3. FP_i represents the output buffer of stage i and contains stage i finished parts. Queue D_4 contain customer demands. Queue P_0 represents the pair of raw parts. Queue I_i represents the input buffer of each stage. When an external demand arrives at stage 3, i.e. D_4 , it is immediately satisfies, if there is at least one finished part in output buffer of stage 3 i.e. FP_3. If demand cannot be satisfied at some stage i and the finished part is not available in $FP_{i,}$ no kanban is transferred upstream, it is then backordered, until the finished part is available. The KCS with three stages is modeled as network diagram in MATLAB SIMULINK and simulated. The performance results are discussed. Similarly, CONWIP and EKCS are also modeled, as shown in figure 2 and figure 3, and the simulation results are also discussed.

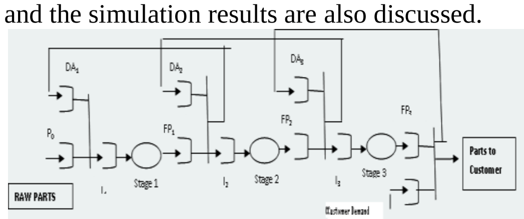


Figure 1 Queuing Network Model of KCS

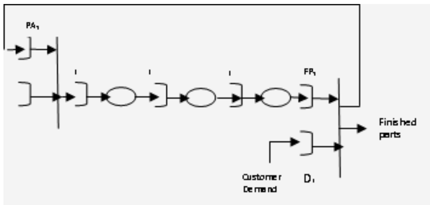


Figure 2 Queuing Network Model of CONWIP

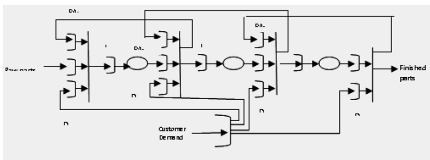


Figure 3 Queuing Network Model of EKCS

"3.2 Simulation of single manufacturing flow line for CONWIP, KCS and EKCS"

A single flow line with three manufacturing stages in series is modeled as network diagram in MATLAB SIMULINK. The network diagrams are shown in figure 4 for CONWIP, figure 5 for KCS and figure 6 for EKCS

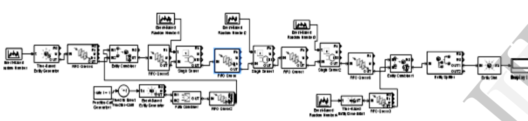


Figure 4 Network Diagram of CONWIP

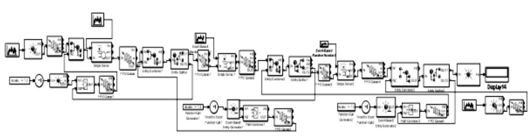


Figure 5 Network Diagram of KCS

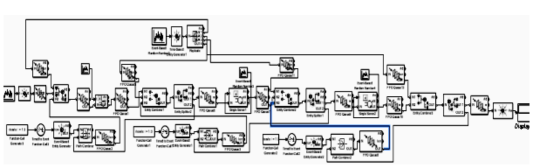
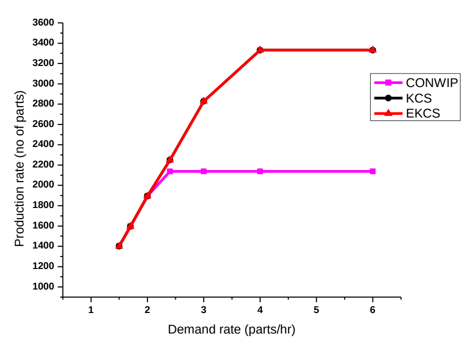


Figure 6 Network Diagram of EKCS

The figure 7(a) and Figure 7(b) indicates that the production rate and server utilization are same for all the three mechanisms till the demand rate is 2 parts per hour. At high demand rates, the production rate and server utilization remains constant for CONWIP, since there is only one kanban and one synchronization station for all the three manufacturing stages. Therefore, the demand has to wait till the processing of component is completed. But for KCS and EKCS it increases linearly and becomes constant beyond 4 parts per hour. Because there is one kanban and one synchronization station for each manufacturing stage, the semi finished component is released to next stage as soon as the kanban and demand are available for synchronization.

At low demand rates, the average waiting time for CONWIP is high compared to KCS and EKCS as shown in figure 7(c). The average waiting time becomes constant for CONWIP at demand rate higher than 2 parts per hour, whereas for KCS and EKCS it increases linearly till 4 parts per hour and then becomes constant.

The total work in process (WIP) for CONWIP is constant for any demand rate and its value is equal to the number of manufacturing stages as shown in figure 7(d). The average waiting time is same for all the mechanisms at an optimum demand rate of 2.4 parts per hour as analyzed in figure 7(c). At the same demand rate, the total work in process of EKCS is nearly 60% lesser than KCS. Further, at high demand rates, CONWIP shows lesser server utilization compared to EKCS and KCS as shown in figure 7(b). However, at higher demand rates, the response of EKCS and KCS are same with respect to total work in process, average waiting time and production rate.



(a)

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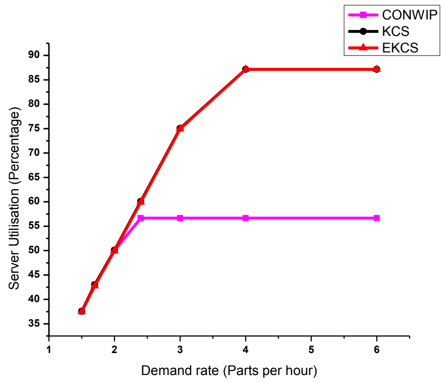
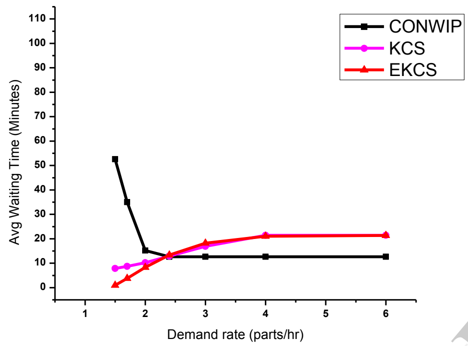
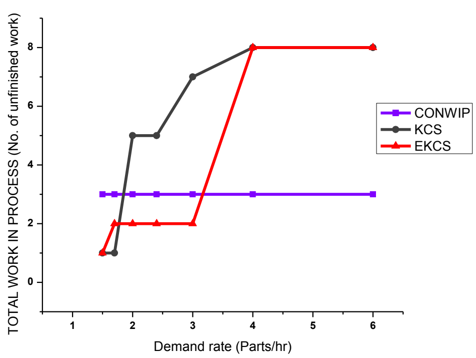


(b)



(c)



(d)

Figure 7 Effect of performance (a) Production (b) Server Utilization (c) Average Waiting Time (d) Total Work in process

"4. Conclusions"

The simulation results obtained for the pull production control mechanisms, Extended kanban control system (EKCS), Kanban Control system system (KCS) and Constant work in process (CONWIP) are compared for the performance parameters viz., production rate, average waiting time, total work in process and server utilization. At low demand rates, the server utilization and production rate for KCS, CONWIP and EKCS are same. At high demand rates, the production rate, server utilization and work in process of EKCS and KCS are high and similar compared to CONWIP which is low. For all the mechanisms, the average waiting time is same for the optimum demand rate of 2.4 parts per hour. At that demand rate, the total work in process of EKCS is nearly 60% less than KCS and 33% less than CONWIP. Thus, EKCS shows more superior performance and tighter coordination of demand and kanban compared to KCS. At high demand rates, the response of KCS and EKCS are same.

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