Performance Evaluation of Pull Production Control Mechanisms by Mathematical Modeling and Simulation Analysis on EKCS and HEKCS Policies

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Abstract – Predictive simulation is an advanced analytical technology that is used to support complex decision making within business and organizations. This paper introduces a new mechanism for the co-ordination of machines and other facilities in multi stage manufacturing system. The methodology is mainly to control and optimize the resources in the intelligent manufacturing environment, using discrete event simulation to model, evaluate and compare the performance of Extended Kanban Control System (EKCS), and the projected Hybrid Extended Kanban Control System (HEKCS). Here we are proposing the Hybrid Extended Kanban Control System (HEKCS), hybridization of Conwip system to aggravate Hybrid Extended Kanban Control System (HEKCS) to develop the combined advantages and also to study their effect in a typical manufacturing environment. A typical multi stage assembly manufacturing system is considered and the system with each hybrid control mechanism is modeled and Simulation studies were performed for 2880 hrs to evaluate the performance parameters like Average Work-in-Process, Production rate and Average Waiting Time for all the control mechanisms with exponentially anecdotal demands.

Keywords – CONWIP, Extended Kanban Control System (EKCS), Hybrid Extended Kanban Control System (HEKCS), Performance parameters.

I. INTRODUCTION

Essentially due to rapid development of technology in the past three decades, comprehensive market structure has changed significantly. As a result, local markets have become accessible to foreign investors, who are not only able to perform well in their newly established territory, but who are even able to excel because of advanced technology. Manufacturing companies are facing worldwide antagonism, forcing them to keep up with new concepts and even to proactively slot in into their daily production routine continually strive to their competitive advantage particularly in automotive, electronics and computer industries. These industries are responding to the brazen out of e-commerce and customer ordering through Internet by shifting to re-configurable manufacturing equipment and a make-to-order environment. Just-in-time production relies on actual demand triggering the release of work into the system, and pulling the work through the system to fill the demand order. The kanban technique has been a kind of revolution in these circumstances. It aims at reducing lead times and Work-in-Process (WIP) levels in the factory. However, the limited applicability of Kanban has aggravated researchers to find alternatives to this control strategy.

Therefore, new pull strategies have been developed. Predictive simulation allows production analysts to go beyond simple patterns, trends and basic data models, adding awareness of process complexities, interactivity and variability. Through process modeling, analysts are able to fully understand the effect that process change has on business performance. Identifying threats and opportunities in the data is only the first step, process simulation enables solutions to be tried, tested and optimized before decisions are made and action is taken.
Optimization of production control in pull control systems is achieved by functionally aggregating several production actions into different production stages and then coordinating the release of parts into each stage, with the arrival of customer demands for final products.

Spearman ML, Woodruff B L & Hoop WJ et al proposed CONWIP policy which provides safety stock to reduce effect of variation and demand fluctuations in JIT environment. George L & Yves D et al The two variants of Extended Kanban Control System have been found more productive in extending to manufacturing industrial applications. They developed the Extended Kanban Control System (EKCS) pull production control mechanism which consists of base stock and kanban control system. They found that, these policies are more useful in assembly manufacturing system.

The authors have proposed Hybrid mechanisms where Extended Kanban Control system (EKCS) is combined with CONWIP; i.e, Hybrid Extended Kanban Control System (HEKCS) to exploit the combined advantages and also to study their effect in a typical manufacturing environment. Simulation studies were performed using Process Model software to evaluate the performance measures like production rate, average waiting time and average Work in Process for all the control mechanisms.

II. PROBLEM DEFINITION

A production system consists of three manufacturing facilities in series producing three different operations on components sequentially as shown in fig-1 is considered. The line has three machines, Where i=1, 2, 3. The three machines from one cell. Finally a part from all three operations, sent into final shipping station.

The flow line had one production kanban card for authorizing the production for the initial position. The assembly system is modeled as network diagrams EKCS individually and also combined with CONWIP named as Hybrid Extended Kanban Control System,HEKCS.

In this work, we extended the decomposition – based method of Di mascolo et. to analyze the Extended Kanban Control System (EKCS) and Hybrid control system, and the synchronization station with three feeding queues. The finished parts of a stage are synchronized first with the external demands, which arrive according to a Poissons process; the aggregate arrivals are then synchronized with the kanbans of the next stage.

The same problem is modeled analytically by using basic Queing Theory, Queuing networks and Continuous Time Markov Chains and using Jackson’s algorithm, Buzen’s algorithm and Gordon andNewell theorem and other standard stochastic mathematical methods.

The Process Model simulation time is 160000 sec, which includes a warmup period of 20000 sec. The processing times of the manufacturing systems follow exponential distribution and equal to 15 min. The service times of manufacturing follow Exponential distribution and the demand follows exponential distribution with the required parts/hr are 0.75, 0.875, 1, 1.2, 1.5, 2, and 3. The entire assembly line is simulated for 1, 72,800 min. (4 months @ 3shifts/day 8hrs/shift) with 15 replications.

III. CONTROL POLICIES

EXTENDED KANBAN CONTROL SYSTEM (EKCS):

Extended Kanban Control System(EKCS) was proposed as a general approach to pull production control combining the Base stock and Kanban Control System. The EKCS philosophy is that when a customer demand arrives to the system; it is highlighted to all the stages in the system. Thus the part is released from up stage to down stage, if the production kanban associated with that stage is available.

Fig.1 : Diagrammatic Representation of EKCS System

Fig.2 : Diagrammatic Representation of HEKCS System
HYBRID EXTENDED KANBAN CONTROL SYSTEM (HEKCS):

This new control mechanism proposed by the authors, in this system combines the control concepts of both EKCS & CONWIP thus proving tight control on the WIP in the system. This system also responds to customers demands quickly due to the inherent EKCS mechanism.

Mathematical modeling and Simulation analysis of multi-stage manufacturing system for both of the control mechanisms namely EKCS and HEKCS is done and the performance measures like Average Work-in-Process, Production rate and Average Waiting Time were computed and relatively evaluated for each other.

IV. PERFORMANCE MODELLING TOOLS

Performance evaluation methods for Production systems fall into two classes: Performance measurement and performance modeling.

Performance measurement is carried out on obtainable, operational systems and is generally used for monitoring of key variables, detection of failures and for probable reconfiguration. Data collection and analysis are customarily done in factories as a part of Management Information Systems reporting.

Performance modeling of Production systems can be either simulation modeling or analytical modeling. Conventionally, discrete event simulation has been widely accepted and employed in factory environments for study of issue in design and operation. Analytical modeling tools such as those based on Markov chains, Queing theory and Stochastic Petrinets are now becoming increasingly popular and have emerged as an alternative to simulation.

Simulation Models:

Discrete event simulation modeling offers the scope for building and analyzing detailed models of manufacturing systems. The performance estimates will be very precise if the number of simulation runs is made large. Simulation is quite popular because of its simplicity and power. Here we conducted the simulation process by Process Model software. Object-oriented simulation have become popular, powerful graphical animation features also support many of these languages.

Analytical Models:

Analytical models can be solved either in closed form or by using numerical techniques. Once a tractable analytical model has been formulated, the model and its solution can be fully validated. Typically, such models can be analyzed in a short time and quick feedback about system performance is possible. Often, analytical models can be used to validate simulation models and vice versa.

Process Parameters

Production rate: Which is the rate at which jobs leaves the station with respect to the demand.

Mean Work in Process: Average number of semi finished products waiting in between stations and number of finished products waiting for dispatch. This number depends on the arrival rate of demands.

Mean waiting Time: For a part to be released from the system, the average time waited in the queue at all the processing stations.

V. ASSUMPTIONS

- The inter arrival time of product demand is Stochastic Process.
- Each production facility has two inventory points, one at the beginning and the other at the end of the stage.
- There is a transportation stage between two adjacent production stages. However, the transportation time is considered to be negligible as the transportation times between production stages is always much shorter than production time.
- The production system for assembly consists of three stages. The entire system is pull type system in which the processing time of each stage follows exponential distribution.
- The manufacturing system processes only a single part type and raw parts are always available.
- Each node in the network is FIFO queue with infinite queue capacity.

Fig.3: WITNESS Software Modeling window
VI. RESULTS & GRAPHS

<table>
<thead>
<tr>
<th>λ (Parts/Hour)</th>
<th>IEKCS Simulation</th>
<th>IEKCS Analytical</th>
<th>HIEKCS Simulation</th>
<th>HIEKCS Analytical</th>
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<td>1855.82</td>
<td>1900.43</td>
<td>2244.84</td>
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Table 1: Production rate for 4 months in units.

<table>
<thead>
<tr>
<th>λ (Parts/Hour)</th>
<th>IEKCS Simulation</th>
<th>IEKCS Analytical</th>
<th>HIEKCS Simulation</th>
<th>HIEKCS Analytical</th>
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Table 2: Mean Work in Process for 4 months in units.

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<th>λ (Parts/Hour)</th>
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<th>IEKCS Analytical</th>
<th>HIEKCS Simulation</th>
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Table 3: Mean Waiting Time for 4 months in min.

Mathematical and simulation analysis were conducted and the results were tabulated. The graphs show the relative performance of the two processes Extended Kanban Control System (EKCS) and Hybrid Extended Kanban Control System (HEKCS).
showing optimum performance in all the three process parameters; Higher Production rate, Lower Average Work in Process and Lower Average Waiting Time that is lesser average queue length than Extended Kanban Control Systems (EKCS).

Finally, it was noticed that there is no significance and effect of degree of imbalance in the system.

VIII. REFERENCES


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