PROCEEDINGS OF THE FOURTH ASIA-PACIFIC CONFERENCE ON INDUSTRIAL ENGINEERING AND MANAGEMENT SYSTEMS

December 18-20, 2002
The Grand Hotel Taipei, Taiwan R.O.C.

Editors

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Simulation Analysis of Pull Production System with Machine Breakdowns

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Abstract: *The main objective of this paper is to use simulation to study the performance of a typical multistage multiline (MSMP) pull production system having failure prone machines, we studied the effect of the following production control strategies/mechanisms namely, Independent Extended Kanban Control System (IEKCS), Simultaneous Extended Kanban Control System (SEKCS), Constant WIP (CONWIP), Hybrid IEKCS-CONWIP (HYIEKCS), and Hybrid SEKCS-CONWIP (HYSEKCS) on performance measures in such a system considered . All control policies on modeled as network diagram in Simulation Language for Alternative Modeling (SLAM). The assembly line with machine break downs is simulated for 43200 minutes and the performance factors like production rate, average WIP and average waiting time are computed from simulation runs for each control mechanisms.*

INTRODUCTION

In a pull system, the succeeding stage demands and with draws in-process units from the preceding stage only according to the rate and time the succeeding stage consumes the items. One basic objective of a pull system is to minimize in-process inventory. In the ideal pull system, inventory at each stage is one unit. However, the ideal pull system is not achievable in a real manufacturing environment where a certain amount of variation in processing times, imbalance of workloads among stages, uncertainty in demand and machine breakdowns are inevitable. Ideally the production line is perfectly balanced and most efficient when all the systems have allocated an equal amount of process times (balance). But this situation is almost impossible for all practical problems, which results the line subjected to some amount of variation in processing times (unbalance). Kanban control system (KCS) cannot be used in unpredictable fluctuations in demands. M L. Spearman et. al. [1] has introduced CONWIP which provide safety stock to reduce effect of variation and demand fluctuations in JIT environment. KCS and CONWIP are depends on number of kanbans only and customer demands cannot be transferred to all the stages immediately. So, George Liberopoulos, et. al. [2] & [3] have developed new pull production control strategies namely Extended Kanban Control System (EKCS) which combines base stock and kanban control for the production coordination. Claudine Chaouiya et. al.[4] have proposed two variants namely, Independent Extended Kanban Control System (IEKCS) and simultaneous extended kanban control (SEKCS) on the production of subassembly system and these policies were compared and found to be more productive in extending to industrial applications. G. G. Sastry et. al. [5] have studied the comparisons of SEKCS and IEKCS for multi line multi stage assembly manufacturing system through simulation using SLAM. They concluded that, IEKCS shows better than SEKCS and there is no significant effect of degree of imbalance for both IEKCS and SEKCS for MSML pull system. There is no difference between SEKCS and IEKCS when applied to single line multi stage assembly manufacturing system. N. Selvaraj et. al.[6] they combined variants of EKCS and CONWIP and proposed a hybrid control system to exploit the combined advantages. S. M. Gupta et. al.[7] have studied the impact of sudden breakdown of material handling system on the performance of traditional kanban system (TKS) and also they compared the results with flexible kanban system (FKS). They concluded that FKS superior to TKS. H. Wang et. al.[8] applied the queuing concept and then a Markov process approach to decide the number of kanban for three production configurations and discussed a method for adjusting the number of kanban for a production system in which unreliable machines exist. K.C. So et. al., [9] proposed a method of estimating the amount of safety stock need at each station of a production line take care of variations in processing times, machine breakdowns and demand fluctuations in order to meet predetermined desired level of performance.

Hence several authors have investigated the different aspects of JIT with machine breakdowns and no work has been reported to study the performance of a typical JIT system with machine breakdowns with respective to various control strategies. This paper made an attempt to analyse the MSML pull system with machine breakdowns using hybrid policies of EKCS and CONWIP using simulation.

A MODEL OF ASSEMBLY LINE

The assembly manufacturing system is assumed to have three parallel flow lines producing three different components for final assembly as shown in Figure 1. Each line to have three machines. Machines M_1, M_2, M_3 on first flow line, similarly the second flow line have three machines M_4, M_5, M_6 and third flow line have three machines M_7, M_8, M_9. Finally these three lines converge into final assembly station. Each line is considered to have one production kanban card for authorizing production. The assembly system with each of IEKCS, SEKCS, CONWIP, HYIEKCS, and HYSEKCS control policies is modeled as network diagram in Simulation Language for Alternative Modeling (SLAM). The processing times follows high-medium-low configuration and each flow line follows normal distribution with mean time of 15 minutes. The machine breakdowns assumed (i.e. mean time between failure (MTBF)) to be exponential distributed with 3000–6000 minutes and mean time to repair (MTTR) is exponential distribution of 300 minutes. The demand rate varies exponentially with mean time from 90 to 10 minutes in equal interval of time. The whole assembly line is simulated for 43200 minutes (3 months @ 8 hours per day) with 15 replications and the results are presented below.

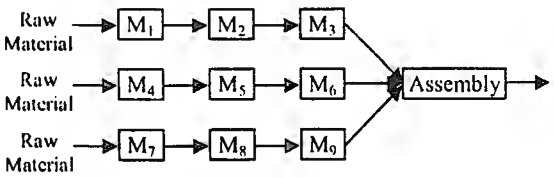

Figure-1: Diagrammatic Representation of Assembly System

RESULTS AND DISCUSSIONS

The assembly line is simulated with machine breakdowns at different MTBF and MTTR values as shown in Table 1. The performance factors like production rate, average WIP and average waiting time are computed from simulation runs for each control mechanisms. Tables 2–4 show the comparative evaluations of all five-control mechanisms and the corresponding graphs are shown in Figures 2–4. The simulation experiment 1 is conducted from the data given in Table 1 and the results and discussions are as follows. When demand rate is low, the production rate, average WIP and average waiting time are equal for all the five control mechanisms. As the demand rate increases the production rate is observed to increase till the demand rate is equal to 1.2 parts/hr. As demand rate further exceeds 1.2 parts/hr, production rate is found to be constant for IEKCS, SEKCS and CONWIP, where as incase of HYIEKCS and HYSEKCS, the production rate is gradually increases till the demand rate is equal to 3 parts/hr and further there is no significant improvement in the production rate is observed. It is also observed that, when the demand rate is increases beyond 1.2 parts/hr the average waiting time increases till the demand rate is equal to 1.5 parts/hr. Later on the average waiting time decreases up to demand rate is 2 parts/hr. for all five-control mechanisms. When the demand rate exceed 2 parts/hr, the average waiting time is almost constant for IEKCS and CONWIP where as SEKCS is varying depends upon MTBF values. But for both hybrid control mechanisms average waiting time gradually increases with the demand rate. Generally both hybrid control mechanisms performance of average waiting time always less than SEKCS. Similarly it is also observed that, the average WIP shows typical behavior like average waiting time with demand rate. For both hybrid control mechanism, average WIP is higher than other control mechanisms when the demand rate exceed 2 parts/hr. Similarly the simulation experiments 2, 3, 4, and 5 are also conducted with the different MTBF and MTTR values and the same trend is observed.

Simulation Expr. No.		M_1 M_4 M_7	M_2 M_5 M_8	M_3 M_6 M_9
1	MTBF	3000	4500	6000
	MTTR	300	300	300
2	MTBF	6000	4500	3000
	MTTR	300	300	300
3	MTBF	4500	3000	6000
	MTTR	300	300	300
4	MTBF	6000	3000	4500
	MTTR	300	300	300
5	MTBF	3000	6000	4500
	MTTR	300	300	300

Table 1: Different values of MTBF, MTTR

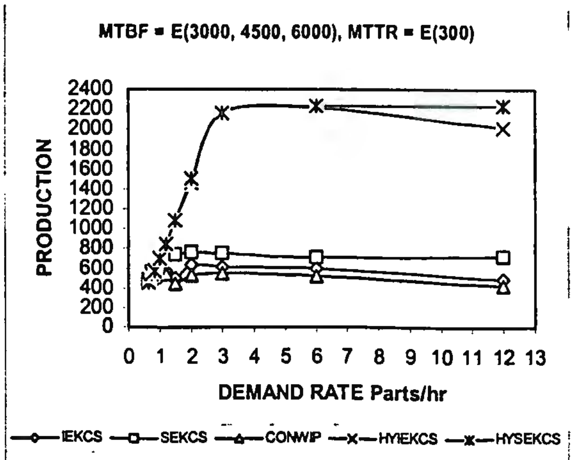

Figure 2: Effect of Production Rate

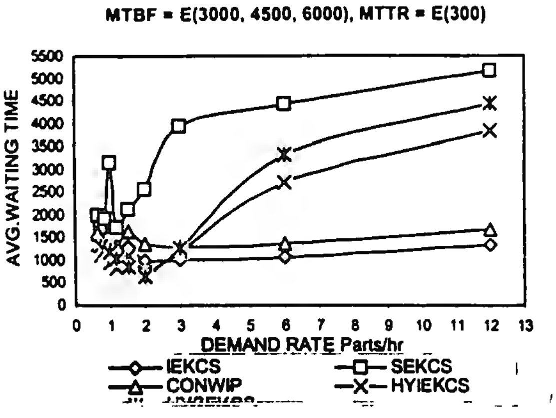

Figure 3: Effect of Avg. waiting Time

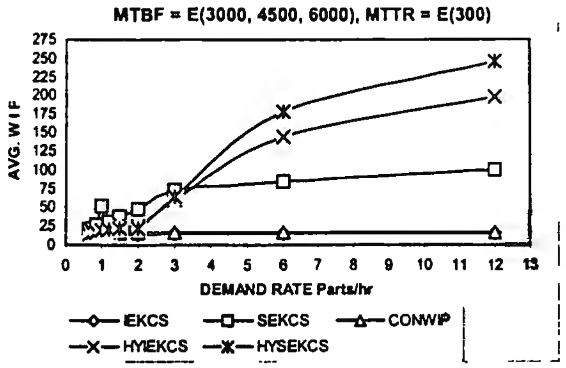

Figure 4: Effect of Avg. WIP

	IEKCS	SEKCS	CONWIP	HYIEKCS	HYSEKCS
E(90)	450	463	452	493	456
E(80)	522	567	505	550	547
E(70)	577	583	522	581	577
E(60)	643	700	586	707	701
E(50)	571	761	543	843	846
E(40)	506	744	445	1082	1087
E(30)	637	765	527	1457	1502
E(20)	619	750	554	2165	2159
E(10)	596	707	521	2216	2229
E(05)	491	718	433	2010	2236

Table 2: Effect of Production Rate

	IEKCS	SEKCS	CONWIP	HYIEKCS	HYSEKCS
E(90)	1407.58	1984.36	1618	1390.33	1351.33
E(80)	1214.68	1730.69	1430.6	1122.34	1330.69
E(70)	1113.13	1921.67	1384.51	1215.9	1239.36
E(60)	980.51	3162.88	1216.04	949.21	1183.24
E(50)	1136.32	1740.52	1323.4	833.92	1036.28
E(40)	1303.44	2140.98	1645.96	1114.91	866.46
E(30)	993.16	2576.58	1366.13	739.59	648.76
E(20)	1024.7	3950.39	1288.94	1205.35	1276.15
E(10)	1078.92	4428.42	1380.21	2722.76	3309.75
E(05)	1350.59	5174.3	1699.23	3858.13	4462.13

Table 3: Effect of Average Waiting Time

	IEKCS	SEKCS	CONWIP	HYIEKCS	HYSEKCS
E(90)	15.12	21.62	17.08	15.93	14.36
E(80)	14.8	22.79	16.85	15.54	16.98
E(70)	14.95	26.68	16.86	16.4	16.74
E(60)	14.67	51.99	16.6	15.58	19.25
E(50)	15.11	31.14	16.76	16.37	20.48
E(40)	15.4	38.31	17.14	28.32	21.83
E(30)	14.72	47.94	16.81	25.05	22.64
E(20)	14.77	72.97	16.66	60.99	64.99
E(10)	14.99	83.75	16.78	144.45	178.88
E(05)	15.46	99.66	17.2	198.05	245.6

Table 4: Effect of Average WIP

CONCLUDING REMARKS

In this paper the authors have studied the effect of machine breakdowns in a typical multiline-multistage assembly manufacturing system operated by various pull control strategies using simulation. It is concluded that, when the machines are failure prone in the production system under consideration, the hybrid control mechanisms of HYIEKCS and HYSEKCS show better performance compared to the other control mechanisms for average production output. Where as from the view point of average waiting time, hybrid control mechanisms performs better than SEKCS only. Similarly the control mechanism IEKCS, SEKCS and CONWIP operate at lower WIP compared to the hybrid control mechanisms. However this research need thorough investigations on various aspects of control strategies by various simulation models. So far no mathematical model is available to address the issues stressed in this work.

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