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Performance Analysis of Multi-Product Systems on Conwip, KCS and Ekcs For Number of Kanbans Per Stage

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Abstract

The present manufacturing sector is more focused on high production rate, high machine utilization and low work in process. The manufacturing systems must be more systematic in its approach and effectiveness. This paper analyses the performance of pull control manufacturing systems viz., Constant Work in Process (CONWIP), Kanban Control System (KCS) and Extended Kanban Control System (EKCS), for number of kanbans per stage. These systems are modeled using technical computing software MATLAB and the simulation results are analyzed. At low demand rates, the performance of CONWIP, KCS and EKCS are same for two, three and four kanbans per stage, whereas it is low for CONWIP and high for EKCS at high demand rates. The systems shows optimal performance for minimum variability at $K_i = S_i$ and $D_i = t_i$, where K_i is number of kanbans per stage, S_i is number of manufacturing stages, D_i is demand mean time and t_i is processing mean time. Further, the performance of the pull control systems is dependent on the demand, number of kanbans per stage, number of manufacturing stages and processing mean time.

Key words: Kanban, Demand, production, average waiting time.

1. INTRODUCTION

The competitiveness in the manufacturing sector is minimization of work in process and manufacturing lead time [1]. The era of 21st century focuses on manufacturing challenges of highly integrated, complex and time sensitive products. The new approach blends with the existing methods to meet the manufacturing requirements. The era of 1970 was for push manufacturing systems and the primary objective was to improve capacity and maximize production. The pull control manufacturing system works with the movement of Kanban, a Japanese word meaning ‘card’, is a signal or authorization to produce a part replacing the work orders that are associated with conventional manufacturing system. The philosophy of pull control systems depends on demand, WIP reduction, waste elimination and producing high quality products. The blend of the manufacturing methods is a challenge to produce complex and time sensitive products. Henry Ford'sassembly line manufacturing revolution leads to the effective resources utilization with standard quality products and high volume productions.

The multi-product pull control system which handles more than one type product is analyzed to control WIP and improve customer satisfaction level using inventory review system [2]. The multi-product system operates on two types of kanban systems [3], shared and dedicated kanban [4]. The performance of KCS, Generalized Extended kanban control system (GKCS) and EKCS for multi-product is analyzed. GKCS and EKCS showed better performance as compared to KCS. Shared kanbansystem is more versatile as compared to dedicated kanban system [5]. The processing of three or more products on single workstation is analyzed for KCS [6] and is reviewed at design level and shop floor level [7]. The production rate and WIP depends on the type and number of kanbans. The hybrid and flexible manufacturing system for multi-product were analyzed for push-pull systems [8]. The throughput is high for the push system and work in process is low for the pull system. The analytical approximation method was developed and analyzed for CONWIP [9]. The rationalization of kanbans should satisfy the product variety and customer demand. The performances of multi-product systems are analyzed using Meta heuristic, integer programming, Genetic Algorithm (GA), Genetic Algorthim and simulated Annealing (GASA) [10]. GA and GASA shows optimum performance which are analyzed and compared with the results obtained from case study and simulation [11]. The artificial bee colony algorithm measures the performance parameters related to large number of parts, machines and production lines [12]. The paper outline is as follows. The brief review of the literature is presented above. Section two defines the objectives followed by the assumptions for the network model covered in section three. The discussions to tradeoff between numbers of kanbans and the performance covered in section four followed by the conclusions.

2. PROBLEM STATEMENT

The network models of CONWIP, KCS and EKCS for single flow line multi stage multi-product manufacturing systems are developed by using the technical computing software MATLAB/Simulink and the simulation results are analyzed to compare the performance viz. production, work in process, average waiting time and utilization. The multi-product systems with two types of product are analyzed on single flow line with three manufacturing stages MP_1, MP_2 and MP_3that follows exponential distribution.The processing mean time of three stages for product A are 1.5 minutes, 1.0 minutes and 1.2 minutes respectively and for product B are 1.25 minutes, 0.75 minutes and 1.1 minutes [5]. The manufacturing systems is simulated for 5760 minutes (i.e. 6 days @ 16 hours per day), which includes warm up period of 360 minutes, for two, three and four kanban's per stage. The demand mean timeis is varies from one minute to four minutes and is assumed to have dedicated type of kanban. The batch time for each product type is 480 minutes. The following are the assumptions considered for the modeling of the manufacturing systems:

i. The setup time is included in the processing mean time for each stage.
ii. The transportation time and material handling time is assumed to be negligible.
iii. The inter arrival customer demand mean time follows exponential distribution.
iv. Raw material arriving to the input buffer is infinite.

3. MODEL GENERATION

The figure 1 illustrates thenetwork diagram of single flow line pull control system with two product types' p^1 and p^2 in three manufacturing stages $MP_{i,}$ where i=1, 2, 3….

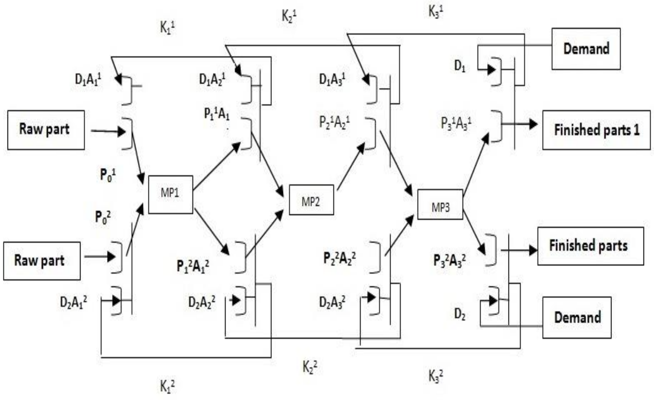

Figure 1. Network diagram for multi stage multi-product system.

The invariants and characteristics of CONWIP, KCS and EKCS for each product type are given below:

a) CONWIP

$M(D_1)\, M(P_3A_3) = 0$

$M(D_1A_1) + (MP_1 + MP_2 + MP_3) + P_3A_3 = K0 \leq D_1A_1 \leq K$

$0 \leq [(MP_1 + MP_2 + MP_3) + P_3A_3] \leq K$

b) KCS

$M(D_1A_{i+1})\, M(P_iA_i) = 0$, wherei = 1, 2, 3...

$M(D_1A_i) + M(MP_i) + M(P_iA_i) = K_i$, where i =1,2,3..

$0 \leq MP_i \leq K_i$,where i = 1,2,3...

$0 \leq (MP_i + P_iA_i) \leq K_i$, wherei = 1, 2, 3…

$0 \leq P_iA_i \leq S_i$, where i = 1, 2, 3…

c) EKCS

$M(A_{i+1})\ M(P_iA_i)\ M(D_1) = 0$ where i = 1, 2, 3,$K_i \geq S_i$

$M(A_i) + M(P_iA_i) + M(MP_i) = K_i$wherei = 1, 2, 3.

$M(A_i) = K_i - S_i$, where i = 1, 2,3, …

$0 \leq M(A_i) \leq K_i$, where i = 1, 2, 3,

$0 \leq MP_i \leq K_i$, where i = 1, 2, 3,

$0 \leq (MP_i + P_iA_i) \leq K_i$, where i = 1, 2, 3,

$M(P_iA_i) - D_1 \leq Si$, where i = 1, 2, 3,

The CONWIP, KCS and EKCS works on three dynamic elements i.e., product, demands and kanban (i.e. product authorization) for the manufacturing performance. Queue p_i^r is the output buffer of product type r, of stage i where r=1, 2 and i=1, 2, 3. The product as a raw material or semi-finished product moves from upstream to downstream stage and the demand moves from downstream to input of upstream stage. The kanban is fixed with each product type and moves with the part or demand or alone in each manufacturing stage. The finished product of each type is stored in the respective queues of the output stage.

4. RESULTS AND DISCUSSIONS

The performance viz. production, work in process, average waiting time and machine utilization;of CONWIP, KCS and EKCS for single line multi stage multi-product system for number of kanbans per stage is analyzed as under.

At low demand rates, the production is same for CONWIP, KCS and EKCS for two, three and four kanban's per stage. At high demand rates, the production in CONWIP is lowest and EKCS is highest for two, three and four kanbans per stage. With increase in number of kanbans per stage till $K_i \leq S_i$, the production increases in EKCS from 10% to 12%; in KCS from 4% to 5%; and in CONWIP from 18% to 20% as given in table 1.Further increase in kanbans beyond number of manufacturing stages i.e., $K_i > S_i$, the increase in production is approximately 5% for CONWIP, KCS and EKCS.

Table1. Simulation results of single flow line multi stage multi product for Production

Demand rate (parts per hour)	**Production**					
	CONWIP					
	2 kanbans/stage		3 kanbans/stage		4 kanbans/stage	
	A	B	A	B	A	B
15	718	716	718	717	718	717
20	950	949	951	950	951	950
30	1002	1163	1219	1410	1381	1410
60	1005	1192	1231	1433	1386	1432
	KCS					
15	718	717	718	717	718	718
20	951	950	951	950	951	950
30	1325	1388	1397	1410	1412	1411
60	1338	1381	1403	1410	1418	1411
	EKCS					
15	717	692	717	692	717	692
20	950	916	950	916	950	916
30	1411	1364	1411	1364	1411	1364
60	1513	1752	1723	1982	1810	2067

At low demand rates, the utilization is same for CONWIP, KCS and EKCS for two, three and four kanban's per stage. At high demand rates, the machine utilization is highest in EKCS and lowest in KCS as given in table 2.

Table 2. Simulation results of single flow line multi stage multi product for Machine utilization

Demand rate (parts per hour)	**Machine Utilization (in Percentage)**		
	CONWIP		
	2 kanbans/stage	3 kanbans/stage	4 kanbans/stage
15	34.6	34.65	34.75
20	46.05	46.13	46.27
30	52.34	64.07	68.28
60	52.96	64.66	73.34
	KCS		
15	29.14	29.22	29.4
20	38.72	38.89	38.89
30	56.9	57.8	58.02
60	57.26	58.04	58.29
	EKCS		

15	28.96	28.55	28.6
20	38.53	38	38.5
30	57.85	57.85	57.85
60	59	69.08	75.29

At low demand rates, the average waiting time (AWT) is 60% to 67% less in CONWIP; 95% to 97% less in EKCS; as compared to KCS. Since the part release from each stage depends upon the availability of demand.At high demand rates, the AWT in CONWIP is 8% to 10% higher than KCS; and 25% to 35% higher than EKCS, till $K_i \leq S_i$. The AWT in KCS is higher than CONWIP; and least in EKCS as given in table 3.

Table 3. Simulation results of single flow line multi stage multi product for AWT

Demand rate (parts per hour)	**Average waiting time (AWT) (Minutes)**					
	9CONWIP					
	2 kanbans/stage		3 kanbans/stage		4 kanbans/stage	
15	11.4	12.3	25.1	26.1	24.1	27.2
20	7.15	8.2	18	19.7	16.1	18.9
30	6.35	5.59	11.3	13.4	8.72	10.3
60	6.17	5.28	7.53	6.78	8.59	7.34
	KCS					
15	39.7	39.6	61.7	61.8	83.7	84
20	24.2	24.3	42.2	42.7	59.2	59.7
30	5.67	4.9	6.97	6.83	15	16
60	5.47	4.85	6.79	6.56	8.52	8.39
	EKCS					
15	1.85	2.06	1.66	1.93	1.6	1.87
20	1.44	1.34	1.16	1.15	1.07	1.08
30	1.063	1.04	0.87	0.72	0.58	0.59
60	4.91	4.19	5.72	4.94	6.58	5.7

At low demand rates, the WIP in KCS is high because the kanban and part synchronizes at each stage whereas least in EKCS due to synchronization of demand with kanban and part at each stage as given in table 4. In CONWIP, the part synchronizes with, kanban in the first stage; and demand in the last stage of the flow line. However at high demand rates, the WIP in KCS and EKCS are same but less than CONWIP.

Table4. Simulation results of single flow line multi stage multi product for WIP

Demand rate (parts per hour)	**Work in process (WIP)**		
	CONWIP		
	2 kanbans/stage	3 kanbans/stage	4 kanbans/stage
15	7	5	4
20	6	4	4
30	5	6	7
60	4	6	8
	KCS		
15	7	7	7
20	4	7	7
30	4	4	6
60	4	4	5
	EKCS		
15	1	1	1
20	2	2	2
30	2	4	5
60	4	4	5

At a demand rate of 30 parts per hour, i.e., at $K_i = S_i$ and $D_i = t_i$, where D_i is demand mean time and t_i is processing mean time, the performance of the systems shows marginal variability. The production in KCS is 2% high as compared to EKCS and 6% high as compared to CONWIP. The WIP and machine utilization are same in KCS and EKCS whereas slightly less than CONWIP. The demand rate of 30 parts per hour for three kanbans per stage is considered as optimum for the performance comparison and analysis of CONWIP, KCS and EKCS. Thus, the performance of the system depends on the demand, number of kanbans per stage and processing mean time.

5. CONCLUSIONS

The performance of the pull control systems viz., CONWIP, KCS and EKCS, has qualitative effect on number of kanbans and depends on it. The optimum performance depends upon the effective coordination of number of kanbans and demand mean time. The part movement in a flow line depends upon number of kanbans per stage, demand rate, processing mean time and its synchronizations. The allocation of the product type to each manufacturing stage depends on the batch size and buffer availability. The performance is optimum and effective, when number of kanbans per stage is less than number of manufacturing stages. However, the performance of the manufacturing system is optimal and shows minimal variation at $Di \leq t_i$ and $K_i \geq S_i$.

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