Evaluation of Manufacturing Process Performance by CONWIP Hybridization of Pull Controlled Production Systems

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Abstract. The main objective of this paper is pioneering an innovative tactic for the synchronization of multi-stage, multi-line, production system. This tactic is mainly depends on the optimization policy, by means of distinct event simulation process for modeling, analysis and distinction of the execution of two alternatives of Kanban control mechanism namely SEKCS (Simultaneous Extended Kanban Control System) and IEKCS (Independent Extended Kanban Control System). At this juncture the authors putting forward the two variants of Extended Kanban control system with the hybridization of CONWIP control policy to incite HSEKCS (Hybrid Simultaneous Extended Kanban Control System) and HIEKCS (Hybrid Independent Extended Kanban Control System) to make use of pooled benefits of a representative production situation in addition to improve the outcome. Therefore in this study the comparison in between different systems of proposed HEKCS specifically are HSEKCS and HIEKCS compared with the Extended Kanban Control Systems variants SEKCS and IEKCS. Simulation studies were conducted for all the five control policies considered and modeled on a multi-line, multi-stage assembly production control system. The relative performance parameters like Throughput or Production rate, Average Waiting Time and Average Work-in-Process, were assessed by means of exponentially varying demands.

Keywords: CONWIP, Kanban, EKCS, SEKCS, IEKCS, HEKCS HSEKCS, HIEKCS.

1 Introduction

For the last few decades, global market configuration had altered largely due to hasty advancement of technology. Therefore, manufacturing industries are subjected to global antagonism, Which causes them to maintain up with new perceptions and even to practically fit into their every day manufacturing schedule persistently struggle to their insistent benefit meticulously in the hardware and automobile manufacturing sector. These

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production industries reacting to meet customer ordering through internet and e-commerce there by changing the make to order situation and re organizable manufacturing resources.

Just in time (JIT) manufacturing depends on real demand prompting the release of the job into the arrangement, and pulling of the job throughout the production system to fulfill the demand order. In such incidents, Kanban control practice has been a kind of revolution. It endeavours at sinking Work in Process (WIP) levels and manufacturing lead times in the industry. Though, the restricted applicability of Kanban control system has aggravated researchers to discover options to this strategy. Consequently new pull control mechanisms have been building up. In pull control systems optimization of manufacturing control is accomplished by functionally comprehending quite a lot of manufacturing activities into various stages after that synchronizing the discharge of parts into every stage, by the entrance of customer demands for the final manufactured goods.

W. Zhang et al. [1] (2001) suggested a mathematical model in a CONWIP production flow system to determine the best possible production quantity and suitable progression, through a precise number of Kanbans to estimate the effectiveness of a multi class generalized Kanban control system. O.S.Wormgoor [2] (2001) build up an analytical practice MVA (Mean value approximation analysis) method to find out the unidentified external arriving rate and performance parameters like WIP and lead times. DRC (Dual Resource Constrained) system conferred by Xu et al. [3] (2010) in that the during scheduling and planning additional technical tackles must be evaluated like worker flexibility, the transfer costs, workers assignment, the transport costs works dispatching. G. Liberopoulos et al. [4] (2000) evolved a unified framework in multi stage manufacturing for a pull production control production system and various features of different Kanban control systems.

Afterwards Y. Dallery et al. [5] (2002) investigated base stock versus WIP limit and make to stock production–inventory systems for the multi stage production system. Little [6] (1961) proposed Little's Law which is fundamentally queuing theory theorem having theoretical and practical importance in inventory control systems. M. L. Spearman [7] (1990) intended the concept of process CONWIP system and discussed the realistic benefits of CONWIP over pull and push systems and conversed numerous theoretical cases of CONWIP system. S H Cheraghi et al. [8] (2001) offered a reasonable effect over the ascendancy of different manufacturing control policies. Diverse input parameters and the type of factory setup influences the superiority of a manufacturing system. By implementing modeling and simulation analysis of different existing arrangements in a manufacturing system.

Yves Dallery et al. [9] (2001) discussed the formation of EKCS, which is a combination of the Base Stock and Kanban control systems and the benefits of EKCS above GKCS. The dynamics of the EKCS are explained and compared with the Kanban and Base Stock control systems. Chu. C et al. [10] (1992) presented a paper to examine how broadly and satisfactorily simulation has been used in studying Just in Time manufacturing. C. Chaouiya et al. [11] (2000) compared the two variants of EKCS namely, SEKCS) Simultaneous Extended Kanban Control System) and IEKCS (Independent Extended Kanban Control System) at what time a part is released into the assembly manufacturing section, releases its Kanban signal, consequently endorsing the production of the next part.

B. J. Berkeley [12] (1992) did an excellent survey concerning Kanban Control System and collected vast amount of literature in the relevant field. The performance of KCS deliberated by J. A. Baynatt et al. [13, 14] (2001 and 2002) in the viewpoint of the multi product manufacturing system. In addition to KCS, he has studied EKCS and GKCS. While enlarging these pull manufacturing control techniques to multiproduct system, differentiated the two diverse subjects, whether Kanbans are dedicated to a single part type or shared among various part types. O. Srikanth et al. [15] (2013) studied the performance evolution on various process parameters in hybrid Kanban control system with the conventional CONWIP system by mathematical modeling and simulation analysis.

The Hybrid mechanisms projected by the authors in which CONWIP is combined with SEKCS and IEKCS mechanisms. That is HSEKCS (Hybrid Simultaneous Extended Kanban Control System) and HIEKCS (Hybrid Independent Extended Kanban Control System) to exploit the collective benefits in addition to study their consequences in a typical production environment. By using the discrete event simulation software Process Model, the simulation studies were executed to assess the considered process performance measures like through put, average Work-in-Process and average waiting times for all the pull production control mechanisms.

2 Problem Definition

A manufacturing assembly system considered as shown in Fig. 1, having three manufacturing flow lines in which three different sub assemblies are produced for the final assembled part. Every flow line consists of three manufacturing facilities, where each line i = 1, 2, 3 and each stage j = 1, 2, 3. One cell is formed by three manufacturing facilities. At the final assembly station these three manufacturing flow lines converges.

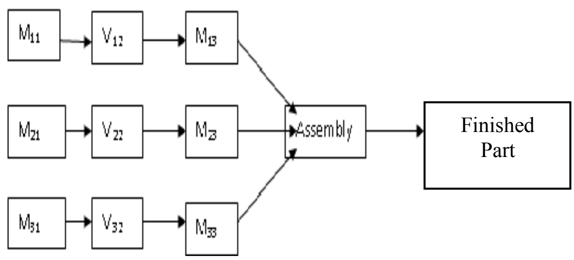

Fig. 1. A multi-line, multi-stage assembly production control system.

There is one production Kanban card for authorizing the production in every production flow line. For the both of network diagrams SEKCS and IEKCS separately the manufacturing assembly system is configured and combined also with CONWIP network. Simulation process conducted by discrete event software Process Model. Considering the processing mean times of 25, 35, 45, 55, 65, 75, 85 and 95 minutes with exponential distribution and also with the degree of imbalance of values 0.1, 0.15, 0.2, 0.25 and 0.3. With 30 duplications the complete assembly manufacturing line is simulated for 1,72,800 minutes (i.e., for 4 months with 3 shifts/day at 8hrs/shift).

For all these five pull production control policies considered explicitly CONWIP, SEKCS, IEKCS, HSEKCS and HIEKCS simulation analysis done for the multi-stage, multi-line assembly manufacturing system by using the Process Model software. The performance parameters related to Production rate or Throughput, Average Waiting Time and Average WIP were computed and comparatively assessed with each other.

3 Assumptions

- The queue lengths capacity is assumed to be of infinite length.
- Raw parts of suitably in great number are accessible that the system at any time should not descend with its deficiency.
- Between the production stages, negligible transpiration time is considered.

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- Stochastic technique is presupposed for the inter arrival time of a product demand.
- For the arrival of demands and service times at the manufacturing facilities pursue exponential distribution.
- There are two inventory points considered at every production stage, at the beginning and at the end of the stage.

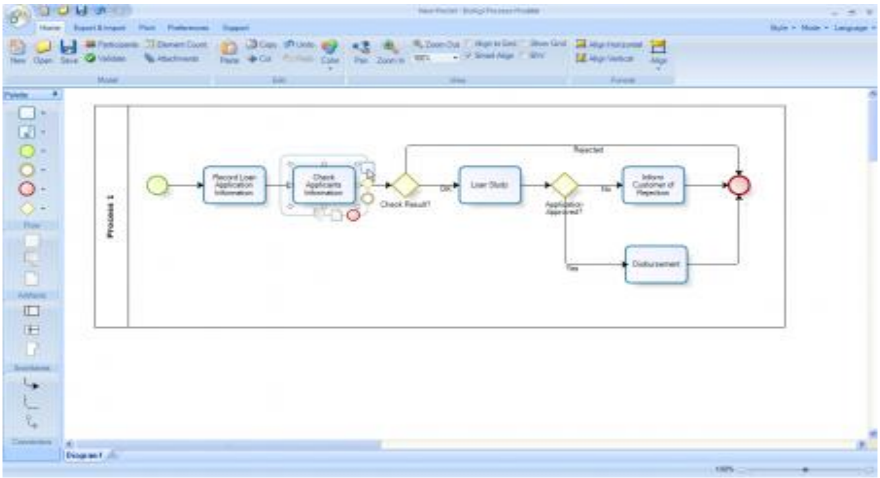

Fig. 2. Process Model Software modeling window

In the Fig. 2 discrete event simulation software Process Model software window is shown for configuring the assembly manufacturing network and for the simulation of assembly system considered.

4 Control Policies

4.1 CONWIP (Constant Work-in-Process) Control System

Constant Work-in-Process (CONWIP) is a generalized structure of Kanban control system shown in the Fig. 3. In this, cards or signals are released into the system like Kanban control system. Here in the system, the cards pass through a path in the complete production line. At the commencement of each production line a card is fastened to a standard bin of parts. Whilst the bin is employed at the ending of the production line, the card is detached and it sends back to the commencement of the line there it will wait in a cards queue and finally to be fastened to another parts container. Where ever the WIP levels can't be acknowledged earlier in a manufacturing line it is very easy to synchronize the production with the constant Work-in-Process than one.

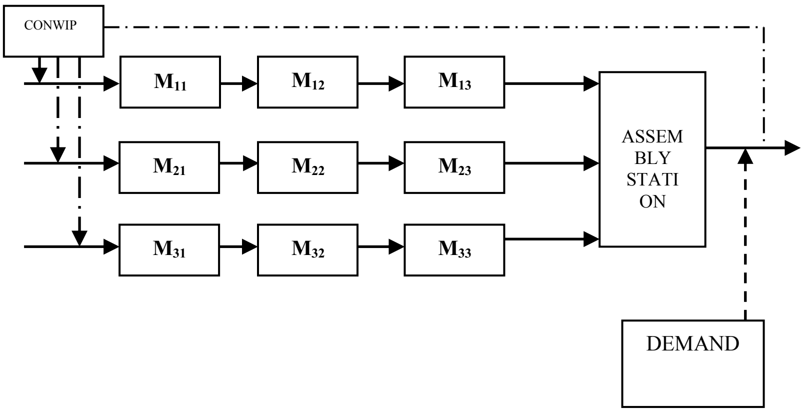

Fig. 3. CONWIP mechanism Schematic Diagram

4.2 EKCS (Extended Kanban Control System)

Whenever a demand arrives from the customer into the system it will be emphasized to all of the stages of the network in the EKCS philosophy. In this way from up stage to down stage the part is released if the production Kanban related with the corresponding stage is accessible. SEKCS and IEKCS are the two variants of Extendended Kanban Control System. The main differences in between SEKCS and IEKCS mechanism are the way the Kanban cards are transported to the production cells. In the IEKCS mechanism Kanbans are independently transported of each other while in the SEKCS mechanism all the Kanbans are transported simultaneously.

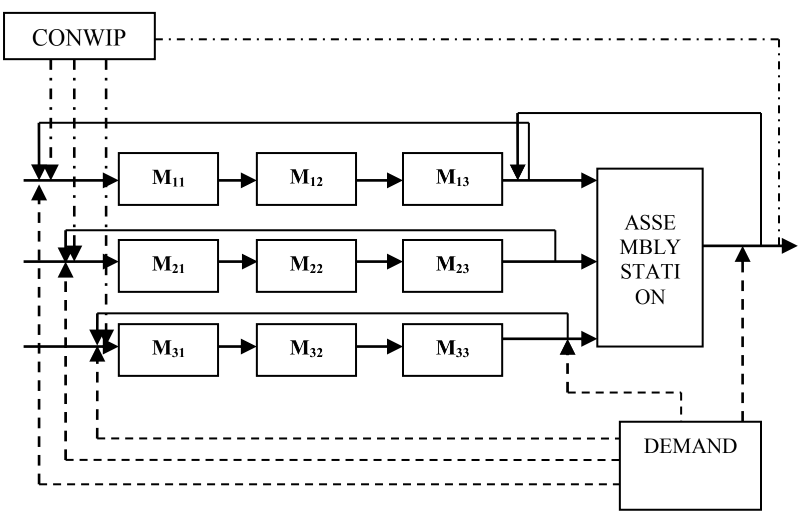

Fig. 4. HIEKCS mechanism schematic diagram.

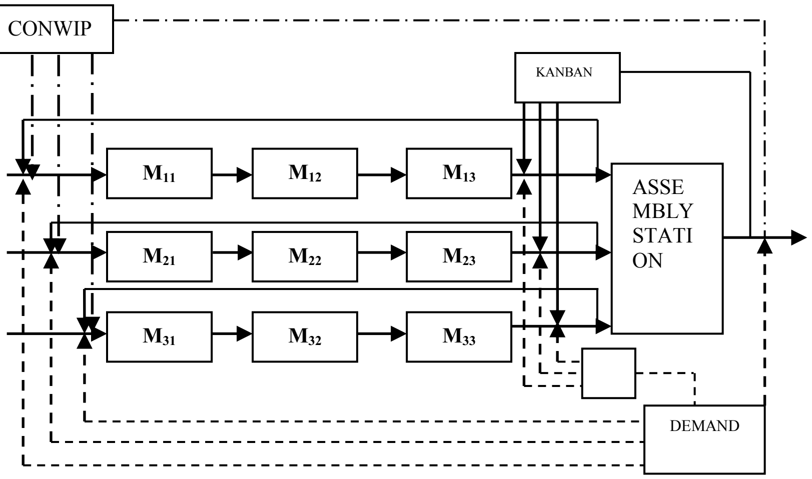

Fig. 5. HSEKCS mechanism schematic diagram

4.3 HEKCS (Hybrid Extended Kanban Control System)

Hybrid of EKCS with CONWIP gives HEKCS (Hybrid Extended Kanban Control System) pull control policy. Thus forms two variants namely HSEKCS and HIEKCS. These mechanisms in the Fig. 4 and Fig. 5 shows may have the collective benefits of EKCS and CONWIP policies.

5 Simulation Results of Various Control Policies

The Simulation results of the different policies considered are presented in the Tables 1, 2 and 3 and the respective graphs 6 to 11 plotted and presented for a mean time of 35minutes. Process Model is a discrete event simulation software which uses basic flow charting techniques when an activity time, action logic, or routing decision are considered.

Simulation studies were accomplished to evaluate the significance of EKCS, HEKCS and CONWIP in multi-line, multi-stage manufacturing system. The significance of production rate, average WIP and average waiting times for the processes CONWIP, EKCS, SEKCS, IEKCS, HSEKCS and HIEKCS are revealed in the individual figures. All the performance parameters are effected by change in the demand rate.

Out of all of the models considered, once the demand rate is rises the throughput or production rate and also increases progressively whereas average waiting times and average Work-in-Process decline when the demand rate is rises.

Production rate increases slowly and when the demand rate increases and average WIP and average waiting times decline for all the five pull control manufacturing mechanisms. It is observed that for both the variants of Hybrid Extended Kanban Control Systems even the average WIP and the average waiting time of HSKCS is nearly 50% of HIEKCS for almost the same the production rates.

Table 1. Relative Production Rate performance assessment of the Pull production control systems.

Exponential Demand	CONWIP (in units)	SEKCS (in units)	HSEKCS (in units)	IEKCS (in units)	HIEKCS (in units)
E(95)	480	388	330	360	322
E(85)	521	431	367	409	349
E(75)	566	481	395	438	377
E(65)	594	508	450	488	412
E(55)	590	550	486	540	490
E(45)	603	590	540	599	519
E(35)	594	596	583	636	572
E(25)	608	552	601	674	600

Table 2. Relative Average Waiting Time performance assessment of the Pull production control systems.

Exponential Demand	CONWIP (in min)	SEKCS (in min)	HSEKCS (in min)	IEKCS (in min)	HIEKCS (in min)
E(95)	334.1	675.6	175.8	526.98	308
E(85)	331.1	616.6	157.8	537.9	344
E(75)	328.4	552.1	142.1	496.2	344
E(65)	297.8	512.8	115.4	425.9	282
E(55)	283.9	511.6	111.3	376.18	254
E(45)	278	493.1	96.6	324.6	240
E(35)	279.2	517.2	93.1	316.19	240
E(25)	286.2	528.2	92.5	326.18	245

Table 3. Relative Average WIP performance assessment of the Pull production control systems.

Exponential Demand	CONWIP (in min)	SEKCS (in min)	HSEKCS (in min)	IEKCS (in min)	HIEKCS (in min)
E(95)	12.3	14.28	5.62	16.02	11.55
E(85)	12.45	14.57	5.88	16.02	11.74
E(75)	12.27	14.48	5.94	16.4	11.91
E(65)	12.72	14.29	5.96	16.54	12
E(55)	12.52	14.59	6	16.61	12.18
E(45)	12.63	15.3	6.35	16.83	12.49
E(35)	12.79	17.7	6.31	17.1	12.61
E(25)	12.9	18.16	6.42	16.8	12.79

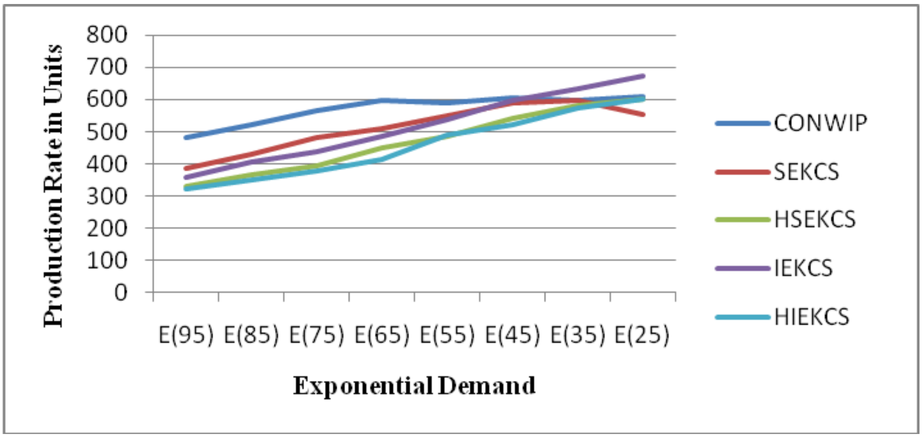

Fig. 6. Relative Production Rate performance assessment of the Pull production control systems.

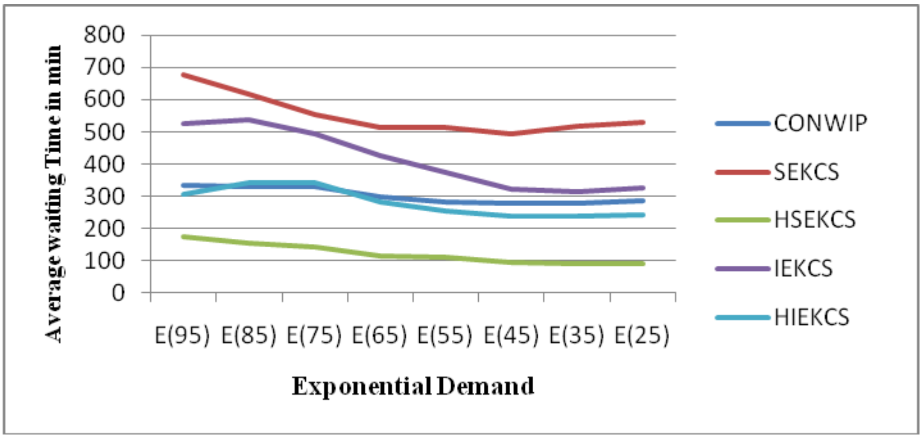

Fig. 7. Relative Average Waiting Time performance assessment of the Pull production control systems.

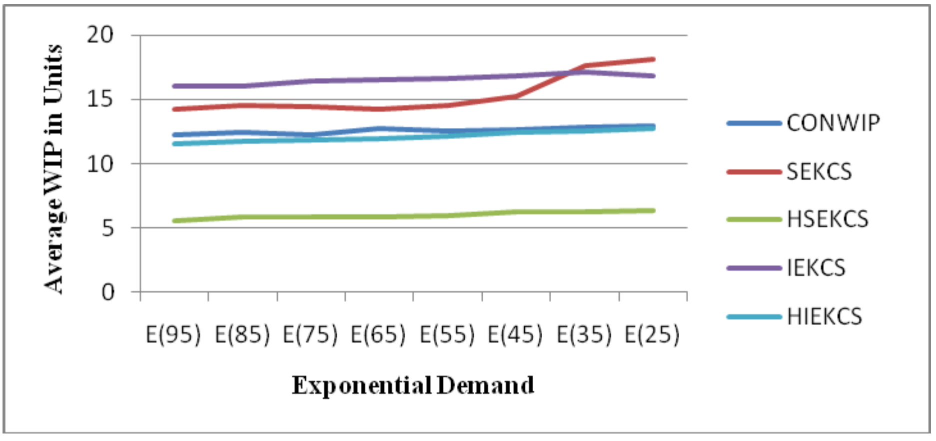

Fig. 8. Relative Average WIP performance assessment of the Pull production control systems.

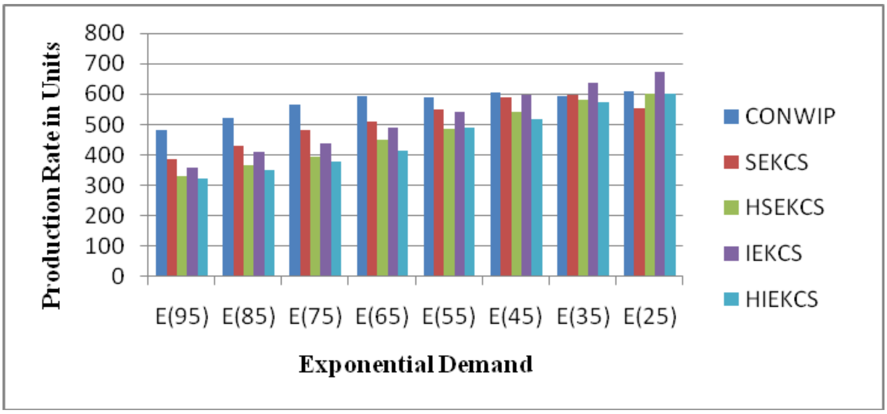

Fig. 9. Relative Production Rate performance assessment of the Pull production control systems.

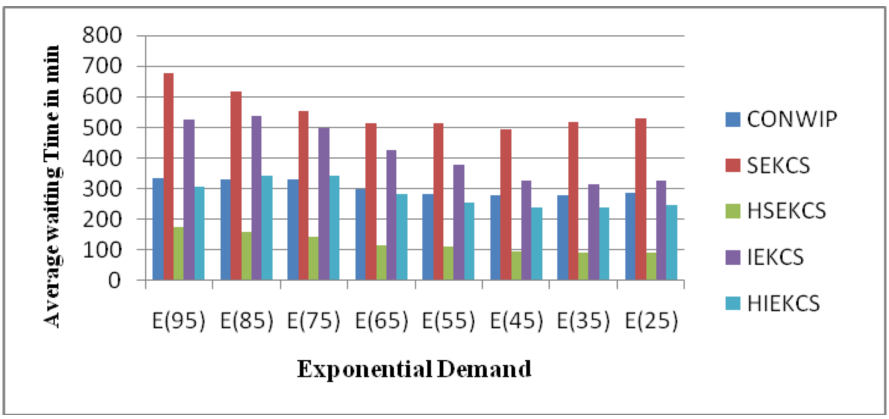

Fig. 10. Relative Average Waiting Time performance assessment of the Pull production control systems.

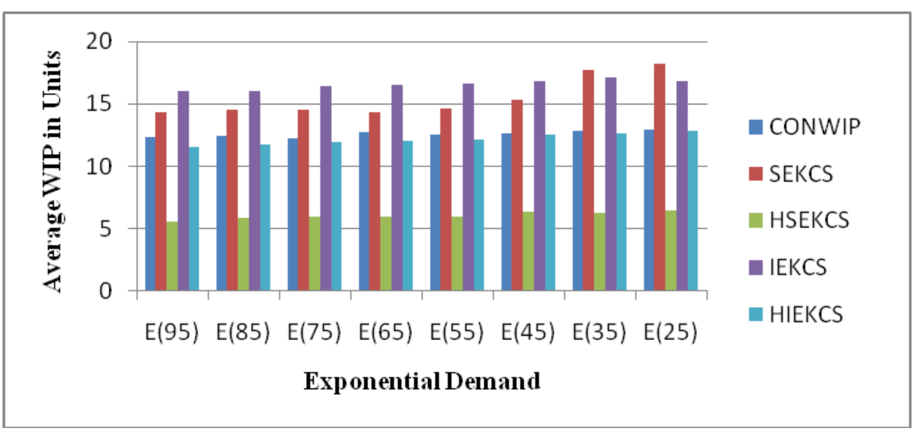

Fig. 11. Relative Average WIP performance assessment of the Pull production control systems.

6 Conclusions

The work intended here is paying awareness on the assessment of substitute policies in the planning and organizing of a pull manufacturing system. Here an effort is made to speak about some pull manufacturing control strategies for diverse arrangements of a Just-in-Time manufacturing system. The proposed hybrid production control policy may be regarded as one of the preference mechanism for a distinctive pull controlled production system.

1. It is found Extended Kanban Control Systems performs better in one instance compared to CONWIP. Proposed Hybrid Kanban Control system appears better performance with the other control policies. At the demand of E(20) it is observed for Production Rate in units for mean time of 25 min is more for IEKCS where as the average waiting time and average WIP are relatively more. For these values HIEKCS gives 40-65% reduction compared to EKCS. In case of Hybrid systems, even though the production rate is less while comparing with CONWIP, the average waiting time and average WIP are observed to be very less.
2. The effect of degree of imbalance was studied and assessed. The assembly system in each flow line harmonizes with demand at all stages of the arrangement therefore the flow lines are not independent. Consequently there is no effect of the degree of imbalance taking place the system.
3. HEKCS, the Hybrid of CONWIP and EKCS control policy has shown improved results than CONWIP and EKCS individually relating to average WIP, average waiting time and production rate. HEKCS shows good results compared to the three proposed control mechanisms (IEKCS, CONWIP and HIEKCS) evaluated. Through the observation, it is found that for all the considered five pull production mechanisms the average waiting time and average WIP are declined when demand rate increases. While related to CONWIP and HEKCS strategies, HSEKCS shows a lot of augmentation in the process parameters average WIP and average waiting time.
4. By increase in the demand rates of all of these five pull control policies, average waiting time the Work in Process increases. Relatively improved performance parameters established in the Hybrid Extended Kanban Control policies while assessing merely with CONWIP and EKCS policies. In the proposed two hybrid policies, HSEKCS shows much improved outcomes contrast to HIEKCS. Even though the average WIP and average waiting times in HIEKCS are nearly twice compared to HSEKCS, however the throughput rates are equal in both the hybrid policies.

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