Simulation Modelling Practice and Theory 84 (2018) 83–105

Contents lists available at ScienceDirect

Simulation Modelling Practice and Theory

journal homepage: www.elsevier.com/locate/simpat

Development and evaluation of a Basestock-CONWIP pull production control strategy in balanced assembly systems

Tarek Al-Hawari*, Ahmed Gailan Qasem, Hazem Smadi

Industrial Engineering Department, Jordan University of Science and Technology, Irbid 22110, Jordan

ARTICLE INFO

Article history:
Received 3 October 2017
Revised 1 January 2018
Accepted 23 January 2018

Keywords:
Kanban
CONWIP
Basestock
Assembly line balancing
Pull production control strategy
Genetic algorithms

ABSTRACT

In this study, a new pull production control strategy called Basestock-Constant Work-in-Process (B-CONWIP) is proposed. It is used to control the flow of materials and information in balanced assembly production systems. This proposed control strategy uses one type of authorization cards called CONWIP card that limits the work-in-process (WIP) in the whole system. It has been applied in a single-product and a mixed-product assembly system balanced by two efficient Genetic algorithms introduced in literature. The performance of this control strategy is compared with another pull production control strategy called Basestock Kanban CONWIP (BK-CONWIP), which is a very promising production control strategy found in literature. The proposed strategy has two control parameters, CONWIP authorization cards and basestock levels while BK-CONWIP has three control parameters Kanban authorization cards, CONWIP authorization cards and basestock levels. The comparison is based on three performance measures average system WIP, percentage of satisfied customer demand (service level) and WIP variation between workstations. The performance of the proposed strategy B-CONWIP and BK-CONWIP is mainly similar in both types of assembly systems when mean demand rates are low with respect to mean service rates with the proposed strategy being easier to control and optimize. On the other hand, when mean demand rates are high with respect to mean service rates; B-CONWIP is preferable if service level is more important, while BK-CONWIP is preferable if WIP level is more important. Regarding WIP variation, it mainly depends on the efficiency of the balancing approach. The more efficient the balancing approach, the less WIP variation. Treating demand as lost instead of backordered results in decreased average system WIP and does not affect service levels in both PCSs. It is also shown that S-KDP is more flexible in dealing with situations of variable product mixes than D-KDP because control parameters can be used by any product which minimizes the effect of the unbalanced systems.

1. Introduction and literature review

In serial production systems the manufacturing of parts passes through several stages. Each stage has a workstation to perform a manufacturing process and a buffer space for inventory. During the passage of a part from upstream stages to downstream stages, raw material is converted to finished products. Production systems can be classified according to the flow of parts, information and release of orders into push, pull and hybrid systems. The difference between pull and

* Corresponding author.
E-mail addresses: tarek321@just.edu.jo (T. Al-Hawari), hjsmadi@just.edu.jo (H. Smadi).

https://doi.org/10.1016/j.simpat.2018.01.008
1569-190X/

push systems is in the mechanism used to control the flow of materials and information through the production system. A push production system releases parts based on forecasted demand and raw materials availability. In contrast, a pull system releases parts based on actual demand and the availability of the raw materials and production authorization cards which give permission to workstations to start production. Hybrid systems integrate merits of different pull systems, or different push systems, or both [9].

Pull production systems which are referred to as just-in-time (JIT), use authorization cards (Kanban or CONWIP) to authorize the release of parts into a system. Several mechanisms called production control strategies (PCS) are used to regulate and control the flow of materials and information in pull systems; such as, Kanban Control Strategy (KCS) [26], Base Stock Control Strategy (BSCS) [13], Constant Work-In-Process Control Strategy (CONWIP) [25], Hybrid Kanban CONWIP Control Strategy (HK-CONWIP) [3]. These strategies limit the WIP in the system using a specific number of authorization cards in order to achieve specific goals such as improving customer satisfaction level or minimizing WIP. The advantages of these pull PCS lie in their ability to eliminate waste, reduce WIP and improve customer service levels [13].

According to previous studies on PCS that were performed in single product systems [7,8,14,24]; it is shown that pull control strategies (KCS, BSCS, CONWIP and HK-CONWIP), achieved high service levels and low WIP levels which led to a reduction in production cost, inventory, lead time and an increase productivity and fill rate.

In multi-product systems, pull PCS can be operated by two different policies called Kanban Distribution Policies (KDP); Shared Kanban Distribution Policy (S-KDP) or Dedicated Kanban Distribution Policy (D-KDP) (Bayant et al. [2], Faccio et al. [6] and Lolli et al. [16]). In D-KDP, an authorization card is used for a specific product type and cannot be used to authorize other product types so the part cannot be released into a system when that specific authorization card for that part is not available. On the other hand, in S-KDP presented by Bayant et al. [2], an authorization card can be shared among product-types, and can be used to release any available part type, depending only on the availability of demand information and raw material. Sharing of authorization cards among product types leads to quick response to any change in demand volume or product mix and reduces WIP in multi-product systems.

Unfortunately, the results of Bayant et al. [2] showed that pull PCS, such as KCS, BSCS, CONWIP and HK-CONWIP, can be operated only with D-KDP and cannot be operated with S-KDP as a result of the coupling between authorization cards, demand information and parts. This coupling means that the authorization card is attached to a specific product type from the beginning and cannot be shared among different products which prevents the usage of S-KDP [19]. Therefore, a large number of authorization cards for every product are required which leads to an increase in WIP in each stage for every product type in the system. This also leads to long lead times, poor service levels and high waste and production cost [27]. This is not compatible with the concept and objectives of pull production systems. In addition, these control strategies have drawbacks such as, long delays, high response times to high demand volume and product mix variation [17,28].

These drawbacks of pull PCS in multi-product systems led researchers to develop new pull PCS, which can separate demand information from authorization cards to operate S-KDP in addition to D-KDP, with the objective of minimizing WIP and improving service levels. Several pull PCS which have the ability to operate S-KDP were developed such as, Extended Kanban control strategies (EKCS) [5], Generalized Kanban Control Strategy (GKCS) [4], Basestock Kanban CONWIP Control Strategy (BK-CONWIP) [19], Modified Hybrid Kanban CONWIP Control Strategy (MHK-CONWIP) [20]. In these strategies, the authorization cards are not coupled to demand information which allows for the implementation of both S-KDP and D-KDP policies.

The results of Baynat et al., [2] proved that, S-KDP outperformed D-KDP when using the same pull PCS, in terms of WIP and service levels. In another study performed by Olaitan and Geraghty [18], S-KDP and D-KDP were applied in multi-product systems with several pull PCS (BSCS, CONWIP, GKCS, EKCS, KCS). The study found that, PCS that can apply both S-KDP and D-KDP (EKCS, GKCS) perform better with S-KDP. It also found that control strategies that can only apply D-KDP (BSCS, CONWIP, KCS) are found to perform poorly with respect to strategies that can apply both. Piplani and Ang [22] made a comparison between KCS, BSCS and EKCS (both D-KDP and S-KDP) that control multi-product systems in terms of a total cost measure. It was proved that the both types of EKCS perform better than the other two control strategies. On the other hand, there was no a big difference in the performance of dedicated and shared EKCS.

Onyeocha et al. [20,21] studied the performance of BK-CONWIP strategy with S-KDP and D-KDP in a multi-product system. The performance of this strategy was checked and compared with other strategies (EKCS, GKCS, HK-CONWIP) under several factors; erratic demand, product mix variation, significant setup time and demand volume variation. The performance of BK-CONWIP combined with S-KDP was found to be the best for all the examined production conditions when WIP level is the priority for selection, but when customer satisfaction (service level) is the priority; BK-CONWIP combined with D-KDP was found to be the best strategy for all examined production conditions.

In this study, a new pull PCS called Basestock-Constant Work-in-Process (B-CONWIP) is presented. This strategy is a hybrid of BSCS and CONWIP. It has been applied in a single-product and a mixed-product assembly system balanced by two efficient Genetic algorithms (GA). The two (GAs) are the Priority-based Genetic Algorithm (PriGA) presented by Hwang et al. [10], and the Multiple Assignment Genetic Algorithm (MA-GA) presented by Al-Hawari et al. [1], which are used to assign tasks to workstations and perform assembly line balancing. The performance of this control strategy is compared with BK-CONWIP [19], which outperformed other pull PCS. The proposed strategy uses two of the three control parameters used by BK-CONWIP namely; Basestock and CONWIP cards and excludes Kanban cards. The basestock level is the minimum inventory for a stage that is needed to satisfy any unanticipated demand. CONWIP card is similar to a Kanban card, it is used to limit WIP in the whole system while a Kanban card is used to limit WIP only in one stage in the system.