Fuzzy work-in-process inventory control of unreliable manufacturing systems

N.C. Tsourveloudis *, E. Dretoulakis, S. Ioannidis

Department of Production Engineering and Management, Technical University of Crete, University Campus, 73100 Chania, Greece

Abstract

We consider single and multiple part type production lines and networks with finite buffers and unreliable machines. Three fuzzy control modules, namely, *line*, *assembly*, and *disassembly* controller, are developed. The objective is to keep the work-in-process (WIP) inventory and cycle time at low levels, along with high machine utilization and throughput. This is achieved by adjusting the processing rate of each production stage so that workflow is balanced and the extreme events of machine starving or blocking are reduced. The approach is extensively tested via simulation. After a series of simulation runs, it has been observed that the proposed approach outranks other control policies in keeping the WIP inventory low. © 2000 Elsevier Science Inc. All rights reserved.

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1. Introduction

The continuing changes in the production environment create new challenges, which companies have to face in order to stay in business. One of the essential surviving requirements is the ability of a firm to adapt its production structure according to the fast changing global market needs. Modern production technologies such as, for example, *flexible/agile* and *just-in-time* manufacturing, recognize that speedy and punctual response to market changes is associated with short cycle times and low in-process inventories. As a result,

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* Corresponding author. Fax: +30-821-69410.

E-mail addresses: nikost@dpem.tuc.gr (N.C. Tsourveloudis), manos@dpem.tuc.gr (E. Dretoulakis), dervish@dpem.tuc.gr (S. Ioannidis).

control policies that tend to keep *work-in-process* (WIP) in low levels have drawn a great deal of attention from researchers and practitioners. WIP inventory is measured by the number of items in each buffer and should stay small because of various reasons [5,9]:

- Capital invested to inventories as long as they remain in the factory or the warehouse provides no profit.
- High in-process inventories increase cycle times and decreases responsiveness to customers.
- High in-process inventories require more space and expensive material handling equipment increasing the invested capital.
- Inventory quality decreases as the unfinished items remain to the factory because they are vulnerable to damage.

Many researchers have studied the problem of WIP management in unreliable production systems [1–3,5,9,12,13]. Conway et al. [5] examined the effects of in-process inventory in production lines. Bai and Gershwin introduced a WIP control algorithm for scheduling single [4] and multiple part-type [3] production lines. In almost all works, WIP inventories are associated with built-in parameters of the system, as for example, the number of wokstations/machines, their processing rate, the interstation buffer capacity and assumptions concerning failure and repair rate of each machine. It is also a common belief that the large size of real production systems along with the effects of failures occurring in such systems, do not allow for an analytic treatment of WIP minimization [9]. Since analytical solutions are not attainable, heuristic policies are suggested to control job flow within production systems [2–4] sometimes supported by fuzzy set theory [6,7].

In this paper, we develop a distributed fuzzy control methodology for single and multiple part-type production lines and networks. The overall control objective is to keep the WIP and cycle time as low as possible, and at the same time to maintain high machine utilization and throughput. In contrast to the traditional produce-at-capacity approach, according to which the system always operates at its maximum capacity, we control the production rate in each production stage in a way that eliminates extreme events of idle periods due to machine starving or blocking. The next section describes the three production modules and the proposed architecture of the distributed fuzzy logic control system that is used. There, we also present a fuzzy logic formulation of the WIP control problem. In Section 3, simulation results are drawn along with comparisons, and in Section 4, the contribution of this work is summarized and further work is outlined.

2. The production control modules

A production system is usually viewed as a network of machines/workstations and buffers. Items receive an operation at each machine and wait for the