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A flexible service rule for the dynamic make-to-stock/make-to-order hybrid production system

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Abstract

A dynamic MTS/MTO hybrid system combines make-to-stock (MTS) and make-to-order (MTO) operations with MTS dedicated machines and hybrid machines which can be switched between both operations flexibly. The two classes, priority and ordinary demands, and the demand increases by discounting the price of MTS product are assumed. For the dynamic MTS/MTO hybrid system, a flexible service rule with demand prioritization and pricing rules is proposed. The operating cost and the MTO queue length are evaluated by Markov analysis. The results of analysis showed that the system performance could be improved by the proposed rule.

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*Keywords:*Make-to-stock; Make-to-order; Hybrid system; Two demand classes; Pricing rule

1. Introduction

In general, production systems can be categorized into two types: make-to-stock (MTS) and make-to-order (MTO) system [1]. The MTS/MTO hybrid systems, which consist of MTS and MTO operations in common facility, are analyzed and used in many fields: e.g. apparel and confection companies, also semiconductor factory. Then, the MTS/MTO hybrid systems are analyzed by some researchers. Chang et al. [2] and Wu et al. [3] investigated integrated devices and semiconductors manufacturing system as hybrid MTS/MTO production systems, where product scheduling and production control are considered. Peña-Perez and Zipkin [4] and Veatch and Véricourt [5]

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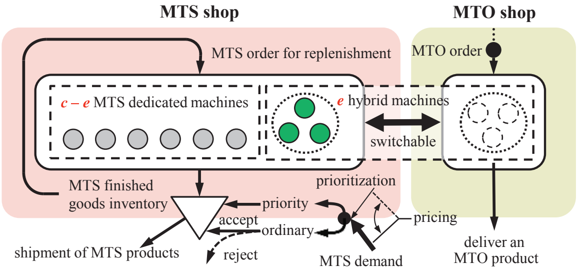

Fig. 1. A dynamic MTS/MTO hybrid production system.

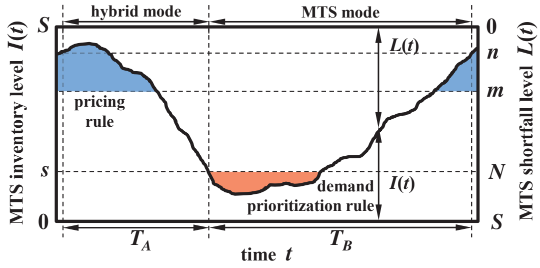

Fig. 2. Time variation of the MTS inventory and shortfall.

investigated a multiproduct system with a single machine that can be switched between productions for each product as a two-class queue; i.e. multiclass single-server queue. Chang and Lu [6] analyzed a hybrid MTS/MTO system as a queuing model, in which demands arrive at a single-station production system that determines which system to follow (MTS or MTO). Zhang et al. [7] analyzed a dynamic MTS/MTO hybrid system as a multi-queueing model. In this system, there are two types of machines: MTS dedicated machine and hybrid machine which can be switched between MTS and MTO operations flexibly. This model, however, sometimes has the problems: such as increasing system operating cost and waiting customers at the MTO shop.

To solve such problems, we utilize the flexible service rule proposed by Liu et al. [8]. Moreover, in general, because the demand from customers varies dependent of a price of the products, we also develop discount model that the price is discounted if the inventory level is high. Then, it is expected to reduce excess inventory and suppress the stock-out. Thus, we propose a flexible service rule introduced both demand prioritization and pricing rules, and show the effectiveness of the system performance for the dynamic MTS/MTO hybrid production system.

2. Modeling a dynamic MTS/MTO hybrid system

In the dynamic MTS/MTO hybrid system has two virtual shops: MTS and MTO shops. There are c machines in the system: $c-e$ MTS dedicated machines, and e hybrid machines which can be switched between MTS and MTO operations depending on the situation. The framework of this system and time variations of MTS inventory and shortfall are shown in Fig. 1 and Fig. 2, respectively. We describe some assumptions for this system as follows:

- MTS and MTO demands arrive depending on i.i.d. Poisson process with demand rates λ_s and λ_o, respectively. Moreover, MTS demand is classified into two classes [8]: priority demand with demand rate λ_s^p, and ordinary demand with demand rate λ_s^o. The ordinary demand is only served with priority rate η. In addition, as MTS demand depends on the price of MTS product, we assume iso-elastic model $\lambda = ap^{-b}$ ($a > 0$, $b > 0$ are constant values and p is a price of product) [9, 10]. Therefore, the MTS demand λ_s can be expressed by $\lambda_s = (\lambda_s^p + \eta\lambda_s^o)\,\zeta^{-\gamma}$. Then, note that ζ is a discount rate, not a price.
- Production times of each machine at MTS and MTO shops are exponential distributed with production rate μ_{s} and μ_{o}, respectively. In the steady state, $c-e$ dedicated machines are not enough to satisfy the MTS demand, i.e. we assume the condition $(c-e)\mu_{\mathrm{s}} < \lambda_s < c\mu_{\mathrm{s}}$.
- We define order-up-to level S, safety stock level s, $N = S - s$, and $n = c - e$ (refer to Fig. 2). At time t, if MTS inventory level $I(t) = S$, i.e. MTS shortfall level $L(t) = 0$, MTS production is stopped. The system operates both hybrid and MTS modes; hybrid mode is switched and switchovered to/from MTS mode if $L(t) = N$ and if $L(t) = n$. In MTS mode, all machines are available for MTS shop. In contrast, in hybrid mode, $c-e$ machines are utilized for MTS shop and others are for MTO shop.
- We assume the service constraint such that backorders for MTS product are accepted although MTS stock-out probability should be less than small enough value ε; that is, Pr(stock-out) $\leq \varepsilon$.

For the dynamic MTS/MTO hybrid system, we propose a flexible service rule which consists of demand prioritization rule (DPR) and pricing rule (PR). In the DPR, MTS ordinary demand served with priority rate η as