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Dynamic performance of a hybrid inventory system with a Kanban policy in remanufacturing process

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Abstract

In this paper we study a hybrid system with both manufacturing and remanufacturing. The inventory control strategy we use in the manufacturing loop is an automatic pipeline, inventory and order based production control system (APIOBPCS). In the remanufacturing loop we employ a Kanban policy to represent a typical pull system. The methodology adopted uses control theory and simulation. The aim of the research is to analyse the dynamic (as distinct from the static) performance of the specified hybrid system. Dynamics have implications on total costs in terms of inventory holding, capacity utilisation and customer service failures. We analyse the parameter settings to find preferred "nominal", "fast" and "slow" values in terms of system dynamics performance criteria such as rise time, settling time and overshoot. Based on these parameter settings, we investigate the robustness of the system to changes in return yield and the manufacturing/remanufacturing lead time. Our results clearly show that the system is robust with respect to the system dynamics performance and the remanufacturing process can help to improve system dynamics performance. Thus, the perceived benefits of remanufacturing of products, both environmentally and economically, as quoted in the literature are found not to be detrimental to system dynamics performance when a Kanban policy is used to control the remanufacturing process.

Keywords: Hybrid system; Combined manufacturing and remanufacturing; Dynamic performance

1. Introduction

With the growing concern for environmental protection from the customers' perspective and stricter environment legislations issued by the governments, more and more world leading companies have begun to pay attention to the strategy of product take back. From a production viewpoint, this strategy covers aspects of environmental production, such as

- green manufacturing,
- use of natural resources,
- recycling,
- material re-use,
- remanufacturing.

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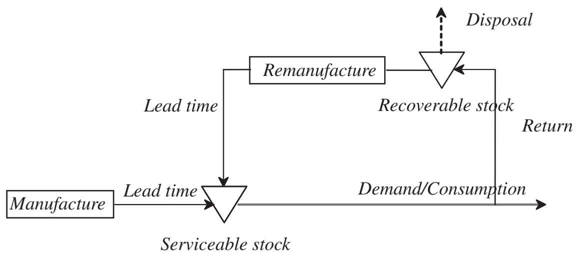

Fig. 1. The material flow in a simple open—loop manufacturing/remanufacturing system.

In a number of recent papers, many issues regarding reverse logistics have been addressed, such as how to design a product so that it is easy to be disassembled and reused [1], how to make reselling, recovery and/or disposal decisions on product recovery [2]. Moreover, managing such a reverse supply chain involves coping with uncertainties, especially those concerned with the quantity, quality and timing of the returned products [3].

In this paper, we focus on the dynamic analysis of a hybrid inventory system with joint remanufacturing of old products and manufacturing of new products. "Old products" are any products, either end-of-life or end-of-lease, that have been returned from the market place and require remanufacturing to be remanufactured to be "as good as new". As shown in Fig. 1, the products come back to the system after having been used by the customer. Parts of returned products then enter the remanufacture process whilst the rest go to land-fill. Customer demand is satisfied from the service stock, which is replenished from manufacturing and remanufacturing processes. Since the remanufactured products are "as good as new", we cannot distinguish them from the manufactured ones as soon as they have been pooled into the serviceable stock site. We will investigate the dynamic performance consequences of integrating the remanufacturing process with the traditional pipeline concerned with the production of new products. The traditional pipeline is modelled using the automatic pipeline, inventory and order based production control system (APIOBPCS), representative of industry practice [4–6] and the dynamic characteristics of which are well known [5,7]. Thus, the APIOBPCS is a well established benchmark by which to judge the impact of new information and material flow structures.

We consider the scenario where a Kanban policy is employed in the remanufacturing process. In our Kanban policy, the remanufacturing process is triggered by a remanufacturing inventory level, which releases a Kanban batch, or container quantity. We have observed such a hybrid inventory system in practice, in a Swedish manufacturing company producing aluminium profiles. The basic material for profiles is alloyed aluminium billets. These are warmed up in an induction furnace to a temperature of 450–500 °C and then forced through a die and the finished profile runs out. In this extruding process, depending on the shape of the die, the aluminium scrap is highly variable but can be up to 30%. It is still a valuable source of re-usable raw material. The manager thus needs to decide how to handle the scrap. It could be collected at a recoverable stock point and afterwards it is re-melted, and subsequently remanufactured, and enters the serviceable stock, along with the newly manufactured billets to form the serviceable billet inventory (cf. Fig. 1).

In this case, a PUSH/PULL policy is needed to determine the relative timing and quantity of the manufacturing and remanufacturing orders. Alternatively, the aluminium scrap is collected immediately after the extruding process and after a certain (small) target amount is reached, it enters again into the furnace with the new billets for the extruding process. In this latter case, the management of the return scrap process is analogous to a Kanban policy.

Another case exists in the (re)manufacturer of photocopiers [8] where used photocopiers first enter the disassembly process to conduct a number of operations including inspection, cleaning and disassembly itself. Disassembled products go through a remanufacturing process such as repair, upgrading, and testing operations. Finally, in the assembly line, new and remanufactured modules are assembled to form serviceable inventory. Even though both PUSH and PULL strategies can be adopted in this situation, the PULL policy was found to be more cost effective.

We highlight how adding a Kanban policy in the remanufacturing process affects traditional pipelines, i.e. orders placed and serviceable inventory level. In particular we consider the impact of the remanufacturing process on APIOBPCS parameter selection and test the robustness of the new hybrid system to uncertainties in return yield rate and remanufacturing/manufacturing lead-times.

Our approach is in contrast to much of recent operation research work on remanufacturing and reverse logistics as we aim to study the dynamic behaviour of the hybrid system. As Towill [9] has highlighted, an efficient production control system can only be designed and operated if the dynamic behaviour of the constituent parts is properly understood. Table 1 summarises our control theory approach which we adopt, as have John et al. [7], Evans et al. [5] in analysing a traditional APIOBPCS. In this paper we focus on the time domain and the impact of shock stimuli. In particular we develop transfer functions in the "s" domain and use the classic step input as it helps to develop a "rich picture" of dynamic behaviour [11].