The impact of production interruptions in kitting, an analytical study

Abstract Nowadays, many manufacturing systems have to deliver customized products, leading to an increased amount of parts moving around on the shop floor. To cope with this tendency, the kitting process has been implemented. This process gathers the necessary parts for assembly into a specific container prior to arriving at an assembly unit. However, the consequences of its application on the performance of the assembly process has merely been investigated. In this article, different models of a kitting process with two parts are constructed and analyzed in a Markovian environment. Due to the multidimensionality of the state space, we chose to use sparse matrix techniques to solve our linear equations. This paper aims to study the performance of kitting operations considering realistic stochastic assumptions. In particular, the impact on kitting performance of interruptions in the production of parts is investigated. Hardly been used in the queueing theory, it discusses also the use of sparse matrix techniques.

Results show that the loss probability of a kitting process decreases when the capacity of the containers increases and the workload decreases. However, the capacity must not be too high and the workload must be high enough to ensure capacity efficiency. As a consequence, there is a need to make a trade-off in terms of cost and efficiency. The used sparse technique delivered satisfying solution speed and accuracy. Therefore, it can be applied for other queueing theoretic numerical problems.

Keywords Kitting process · Continuous Time Markov Chain · Sparse matrix · Production interruptions · GMRES

1 Introduction

Nowadays manufacturing systems are often composed of multiple in-house fabrication units (Medbo 2003). The semi-finished products stemming from these units are the input materials for other fabrication units or for assembly lines. Hence, efficient transport of materials between the different stages of the production process is key for overall production cost minimization. Kitting is a particular strategy for supplying materials to an assembly line. Instead of delivering parts in containers of equal parts, kitting collects the necessary parts for a given end-product into a specific container, referred to as kit, prior to arriving at an assembly unit (Bozer and McGinnis 1992; Som et al 1994; Bryznér and Johansson 1995; Medbo 2003; Ramachandran and Delen 2005; Ramakrishnan and Krishnamurthy 2008).

Kitting mitigates storage space requirements at the assembly station since no part inventories need to be kept there. Moreover, parts are placed in proper positions in the container such that assembly time reductions can be realized.

Additional benefits include reduced learning time of the workers at the assembly stations and increased quality of the product. Although kitting is a non-value adding activity, its application can reduce the overall materials handling time (Ramakrishnan and Krishnamurthy 2008). Indeed activities such as selecting and gripping parts are performed more efficiently. Furthermore, the whole operator walking time is drastically reduced or even eliminated since kits of components are brought as a whole to the assembly station (Johansson and Johansson 1990). The advantages mentioned above do not come for free since the kitting operation itself incurs additional costs such as the time and effort for planning the allocation of the parts into kits and the kit preparation itself. Moreover, the introduction of a kitting operation in a production process involves a major investment. Therefore it is important to analyse the performance of kitting in a production environment prior to the actual introduction of this operation. This is the subject of the present paper.

In literature, most authors consider a kitting process as a queuing system with stochastic part arrivals and kit assembly. Hopp and Simon (1989) develop a model for a kitting process with exponentially distributed processing times for kits and Poisson arrivals. They find accurate bounds for the required capacity of the buffer. Their model is limited to processes with two basic components. Som et al (1994) refine the results of Hopp and Simon by explicitly accounting for finite buffer capacities.

Of course buffers have always a finite capacity. However, if the capacity is large enough, we can have a good approximation of a process with a finite capacity on the basis of a model with unlimited capacity. This means that there is always enough space for upcoming parts which simplifies the analysis. Unfortunately, the assumption of an infinite buffer is not valid for kitting processes. If the capacity is assumed to be infinite, then the model will degrade to an unstable stochastic model. This was demonstrated by Latouche (1981) that studied waiting lines with paired customers. We can consider his analysis as an abstraction of a kitting process with two types of parts. Furthermore, in the article "Assembly-like queues", Harrison (1973) confirms that, to ensure stability in the operations of a kitting process, it is necessary to impose a restriction on the size of the buffer. Under this assumption, the probability to have a certain long-term stock position is equal and independent of the current stock position.

In this work, we focus on a kitting process modulated by a Markovian environment. The introduction of this environment allows us to study kitting under more realistic stochastic assumptions: bursty part arrivals, phase-type distributed kitting times, etc. Section 2 describes the kitting process at hand. In section 3, Chapman-Kolmogorov equations are derived and their numerical solution is discussed. In particular, the use of iterative methods for solving sparse matrix equations is examined. To illustrate our approach, section 4 considers a number of numerical examples. Finally, conclusions are presented in section 5.

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