**The impact of production interruptions in kitting, an analytical study**

**Abstract**

This paper discusses the performance of *kitting operations* in a production environment. Specially models considering temporal interruptions in the production of the subparts are investigated. Therefore, these parts arrive at part inventories according to an *Interrupted Poisson Process* instead of a *Poisson Process*. In this article, Kitting is analyzed as a queue model where two independent input streams feed into a stochastic assembly system. Unlike previous studies, we use *sparse matrix techniques* to solve linear equations. Results show that this technique is a valuable queuing theoretic numerical approach in terms of solution speed and accuracy to estimate the performance of the kitting process. The research gives also some insights on the performance of the Kitting process depending on factors. (Out of the research, we conclude that the size of the capacity and the arrival intensities are important features of the Kitting process when dealing with production interruptions.)

1. **Introduction**

Nowadays customers put a lot of pressure on the market to afford customized products. This result in the handling of a large number of components in the production systems. The problem of keeping many and varied components is met by applying *kitting*.

of

Nowadays manufacturing systems are often composed of multiple in-house fabrication units [8]. 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 a key issue for overall production cost minimization. Therefore the *Kitting* method was introduced.

Kitting is a particular strategy for supplying materials to an assembly line. Instead of delivering parts at the assembly line in containers of equal parts, in kitting prior to arriving at an assembly unit the necessary parts are collected into a specific container, referred to as “kit” [1,2,8,11-13]. This contrasts with the more traditional line stocking where the parts are delivered at the assembly line in containers of equal parts [1].

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 [11]. The advantages above do not come for free since the kitting operation itself also incurs additional costs. There are mostly the time and effort for the additional planning of the parts allocation into kits and the kit preparation itself. A storage space will also be essential to store the already prepared kits.

Although kitting is a non-value adding activity, its application can reduce the overall materials handling time [Ramakrishnan and Krishnamurthy, 2008]. However, the introduction of a kitting operation in a production process involves a major investment. Therefore it is important to analyze the performance of kitting in a production environment prior to the actual introduction of this operation. The goal of this paper is to better understand the kitting process in a production environment, taking possible production inefficiencies of the subparts into account. Special attention is put on queuing models and queuing analysis techniques.

1. **Kitting as a Markov proces**

The concept of uncertainty being central in queuing theory, a queuing theoretic approach will be used in order to assess the performance of a kitting process under uncertainty of inventory replenishments and/or product demand. Often, neither the product demand nor the inventory replenishment can be fully controlled such that Kitting processes are preferably modeled as stochastic processes.

This paper models the kitting process as a Continuous Time Markov Chain

1. **The Models description**

Three mathematical queuing models are constructed and analyzed to assess the impact of production interruptions on the performance of kitting.

1. **Methodology**

We describe the kitting process as a Continuous Time Markov Chain.

Queuing models for kitting processes are rather complicated. Since two queues are involved (one for each part in the kit) and the process can be whether in a productive or unproductive state, the *state space* of the associated Markov chain is inherently *multidimensional*. The state of the Markov chain roughly corresponding to the number of distinct parts in the different inventories, the state space includes all possible part inventory levels. Multidimensionality leads to huge state spaces; this is the state space explosion problem. A second complication is more intricate. Obviously, inventories always have a finite capacity. However, if this capacity is sufficiently large, one may assume that the capacity is infinite. This means that there is always room for arriving parts, which simplifies the analysis. Unfortunately, the *infinite-buffer-capacity* *assumption is not applicable* for kitting processes. If the capacity is assumed infinite, the model degrades to an instable stochastic model in which some or all of the queues have an unlimited number of parts available all the time with a positive probability. This was already showed in [6] which studies queues with paired customers, an abstraction of a kitting process with two types of parts.

Having established these complications, it is clear that not every queuing model of a kitting operation is mathematically tractable.

Intricate performance models are developed taking realistic assumptions into account.

Efficient numerical algorithms are developed which generate the performance measures of interest fast.

* 1. *Sparse matrix method*

1. **Numerical examples**
   1. *Input parameters*
   2. *Performance measures*

A good queuing model can accurately predict the performance measures of a real system in terms of this system’s parameters. For the kitting operation, the queuing analysis focuses on performance measures such as the throughput of the kits as well as the mean and variance of the kit buffers. The stock-out probability, the probability that one of the part inventories is empty such that the kitting operation is disrupted is another important measure.

[8] L. MEDBO, Assembly work execution and materials kit functionality in parallel flow assembly systems, International Journal of Industrial Ergonomics, 2003, vol. 31:263-281.

[1] Y.A. BOZER, L.F. MCGINNIS, Kitting versus line stocking: A conceptual framework and a descriptive model, International Journal of Production Economics, 1992, vol. 28:1-19.