The impact of production interruptions on kitting, an analytical study

E. De Cuypere and D. Fiems

University of Ghent, Department of TELIN,
{eline.decuypere,dieter.fiems}@telin.ugent.be

Abstract

Nowadays, customers request more variation in a company's product assortment leading to an increased amount of parts moving around on the shop floor. To cope with this tendency, a kitting process can be implemented. As it gathers the necessary parts into a container prior to assembly, kitting enables a more cost-efficient and qualitative production. However, the performance of this preparation technique in an assembly process has merely been investigated. Therefore, we study a kitting process with two parts as a continuous-time Markovian queueing model. In particular, our study assess the impact of production interruptions on kitting.

Keywords: Kitting process, continuous-time Markov Chain, Sparse matrix

Introduction

Nowadays, many manufacturing systems have to deliver customized products. This trend leads to an increased amount of parts moving around on the shop floor [1]. 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 the assembly unit [1, 2].

Although kitting is a non-value adding activity, its application can reduce the overall materials handling time [2]. 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. However, 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 and the effect on efficiency are uncertain. Therefore, it is important to analyse the performance of kitting in a production environment prior to its actual introduction.

In this work, we propose to model the kitting process as a continuous-time Markovian queueing model. Parts arrive in accordance with a (possibly interrupted) Poisson process and wait in their buffer until they are collected into a kit. We focus on a kitting process with two types of parts and the kitting times adhere an exponential distribution. Note that the kitting process significantly differs from standard Markovian queueing networks: service in the buffers is tightly coupled. Upon service completion, a part leaves in each buffer and kitting blocks when one of the buffers is empty.

Methodology and analytical results

The modelled kitting process has a multidimensional state space which describes all possible inventory levels. While the state space of the chain is large, the number of possible state transitions from any specific state is limited. This means that most of the entries in the generator matrix are zero, i.e. this matrix is sparse. Techniques to define and solve sparse matrices (in particular the generalized minimal residual method) are applied and yield performance measures – like mean buffer content, blocking probability of the kitting process, etc. – of the kitting process at hand fast. By numerical examples, we can quantify expected buffer behaviour - e.g. more production yields higher queue content, higher buffer capacity mitigates blocking of the production, etc. In addition, some non-trivial results were obtained. For example, interruptions in the production of a part more negatively affect buffer performance of the other part. Indeed, the buffer of the other part will be full and empty more often.

Conclusion

In this paper, we investigate kitting buffers in a Markovian setting. As our numerical results show, the interplay between the different queues leads to complex performance behaviour. The current numerical methodology does not impose any restrictions on the various involved intensities and hence allow for many extensions. Some future work includes phase type kitting times, arrival processes adapted to the queue size, etc.

References

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