Aggregate Modelling and Wafer Cycle-Time Estimation using Novel Queuing Approach

Mehrdad Mohammadi, Stéphane Dauzère-Pérès, Claude Yugma

[1] Department of Manufacturing Sciences and Logistics, Center of Microelectronics in Provence
École des Mines de Saint-Étienne, CNRS laboratory LIMOS
Gardanne, France
{mehrdad.mohammadi, dauzere-peres, yugma}@emse.fr

Mots-clés *: Aggregate modelling, Cycle time estimation, Analytical queue system.*

1 Introduction

Despite of traditional competition among semiconductor manufacturers regarding product design and cost, recently, short delivery times have also become an important differentiator among these firms. Short deliveries have highlighted the importance of manufacturing cycle time as a critical performance measure. Accurate cycle-time estimation is necessary to provide more stable production environment and shorter cycle-time may lead to a higher quality product, and better responsiveness to the customer needs [1,2]. Leachman [3] pointed that "there is considerable evidence that yields are inversely related to manufacturing cycle times."

The importance of cycle-time to semiconductor manufacturing industry has been highlighted through numerous researches particularly the International Roadmap for Semiconductors 2006 Update [4]. This roadmap obliges to improve the cycle-time for preventing the slow growth of the industry, while cycle-time reduction leads to remarkable financial benefits. All these given importance to cycle time as a performance metric in the semiconductor manufacturing industry motivate the need for a time-efficient and accurate approach to estimating it.

Quick and accurate estimation of the cycle-time can be achieved through an efficient aggregate model that accurately represents the function of the original workstation/equipment. The parameters of the aggregate model as well as its performance are directly estimated from the parameters of the original system.

Two well-known approaches to model and estimate the performance of the production systems are discrete-event simulation models and analytical queueing models. Although simulation models incorporate various shop floor details, but they are computationally expensive to achieve reliable results. An additional drawback is an impossibility of gathering all the shop floor details in practice. Analytical queueing models are an attractive counterpart to simulation models. Classic analytical models cannot estimate the performance metrics as accurate as simulation models; however, they are less computationally expensive.

In this paper, we aim at developing an improved analytical queuing-based approach for aggregate (QAG) modeling that enables accurate and even exact cycle-time estimation of multi-step parallel-series production operations (Figure 1). The number of parameters in the proposed QAG model is much smaller than in simulation models, feeding the model with appropriate data is then not trivial. Additionally, the proposed QAG model does not require multiple runs to obtain reliable results, and it is remarkably timely-efficient comparing to simulation-based models.

This paper first aggregates a multi-step production system (Figure 2) into an aggregated single-step one (Figure 3) by proposing closed approximation formulation to estimate the cycle-time.

Finally, corresponding formulations are provided to estimate the cycle-time of the original parallel-series multi-step production system. A prominent novelty of the QAG modelling approach is developing a dynamic formulation for cycle time estimation. The proposed approach has been employed on real/simulation data from one of the leading semiconductor manufacturing in France and its performance is benchmarked with the most well-known approach in the literature called EPT algorithm [5] (Figure 4).

In summary, the main contribution of this paper is developing new queue-based aggregate modelling of multi-step production system through accurate and timely efficient dynamic formulation.

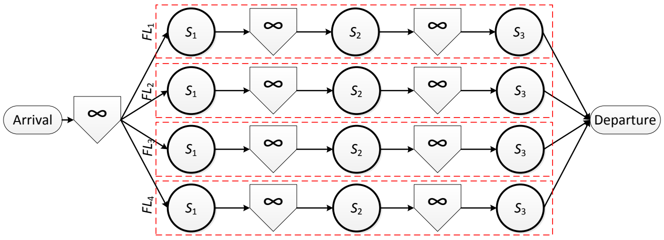

Figure 1. Multi-step parallel-series production system

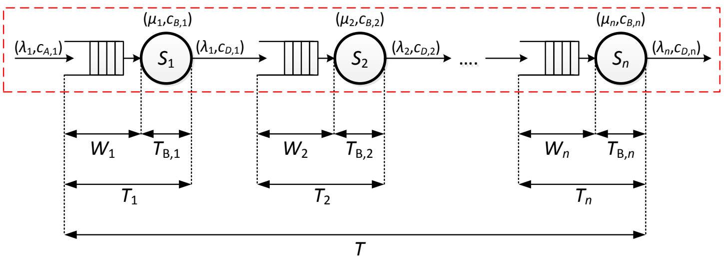

Figure 2. Modelling series production line using queuing systems

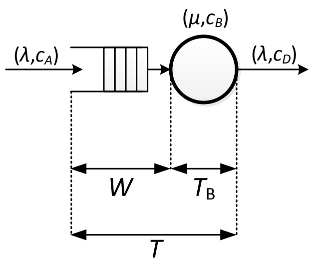

Figure 3. Aggregate modelling of series production line

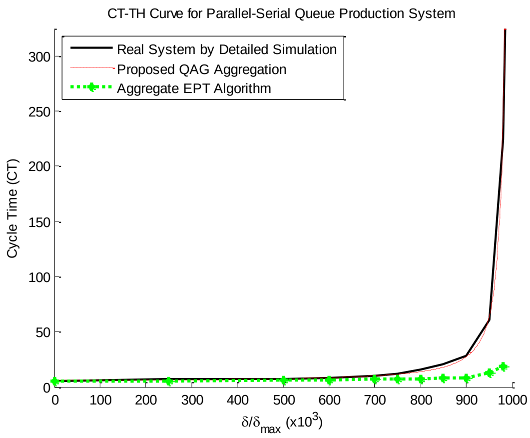

Figure 4. Comparison between proposed QAG approach with EPT aggregation

REFERENCES

[1] S.H. Chung and C.M. Lai, "Job releasing and throughput planning for wafer fabrication under demand fluctuating make-to-stock environment", International Journal of Advanced Manufacturing Technology 31, 316–327, 2006.

[2] W.J. Hopp and M.L. Spearman, "Factory physics", Irwin McGraw-Hill, Boston, 2002.

[3] R.C. Leachman, "Competitive semiconductor manufacturing study: final report on findings from benchmarking eight-inch, sub-350nm wafer fabrication lines", University of California, Berkeley, 2002.

[4] Semiconductor Industry Association. 2006. International Technology Roadmap for Semiconductors 2006 update, <http://www.itrs.net/Links/2006Update/FinalToPost/10_Factory_2006Update.pdf>. [Accessed January 2007].

[5] A.A.A. Kock, L.F.P. Etman, and J.E. Rooda, "Effective process times for multi-server flowlines with finite buffers", IIE Transactions, 40(3), 177-186, 2008.