Optimization Model for Scheduling Jobs Containing Multiple Orders on an Unrelated Parallel-Machine

Jen-Shiang Chen
Department of Business Administration
Far East University, 49 Junghua Road, Shinshri Shiang, Tainan 744, Taiwan.
Email: jschenc@ms25.hinet.net

Abstract. This article studies the unrelated machine scheduling problems with multiple orders per job (MOJ) considerations. We also consider the ready times of all orders, multiple product types within all orders, and the sequence-dependent setup times between the product types. Both lot processing machines and item processing machines are also discussed. The performance measure is the total weighted tardiness of all orders. We present two different mixed binary integer programming (BIP) formulation methods for the proposed problem, one method is based on the dichotomous restrictions and the other method adopts the concept of an assignment problem. Thus four mixed BIP models are developed to optimally solve the scheduling problems. Different formulation methods are also compared with each other for the proposed problem on the same benchmark problem data set.

Keywords: scheduling, tardiness, unrelated parallel-machine, multiple orders per job, integer programming, semiconductor manufacturing.

1. INTRODUCTION

Semiconductor manufacturing experienced rapid growth in the last couple of decades. Wafer fabrication is the most complex stage and involves multiple process flow series. Due to the increase in size, weight and economic value of the wafers, front-opening unified pods (FOUPs) are used to transport them. A FOUP is an automatic wafer transfer facility in the semiconductor manufacturing industry. To avoid contamination, wafers must be held in FOUPs with an inert nitrogen atmosphere. Semiconductor manufacturers often have the need to group orders from different customers into one FOUP. Once multiple orders are grouped into the same FOUP, these FOUPs must then be scheduled on the machine in the wafer fab, so that effective FOUP processing can reduce the work-in-process and promote on-time delivery of customer orders. Note that there are two primary decisions that must be made in this problem: (1) how to group the orders together, and (2) how to schedule the FOUPs once they are formed. In order to obtain the optimal schedule to the proposed scheduling problem, these two decisions should be made simultaneously. We refer to this problem as multiple orders per job (MOJ) scheduling problems.

There are two frequently processing machines in the semiconductor manufacturing factory, including the lot processing machine and the item processing machine. For a lot processing machine, the FOUP processing time is independent of the number of wafers in the FOUP and is equal to the time to process a single wafer on that machine. On an item processing machine, the FOUP processing time is the sum of the processing times for all wafers in all orders in the FOUP (Laub et al. 2007). To match the scheduling terminology, we call a wafer as an item and a FOUP as a job. Several items should be assembled to one order and several orders should be assembled to one job. Related MOJ scheduling literature falls into three production environments (with examples cited): (1) Single machine MOJ scheduling [Qu and Mason (2005), Erramilli and Mason (2006), Erramilli and Mason (2008), and Jampani and Mason (2008)] (2) Parallel-machine MOJ scheduling [Jampani and Mason (2008) and Jia and Mason (2009)], and (3) Two-machine flow-shop MOJ scheduling [Laub et al. (2007)].

The following terms are used to define the unrelated machines in parallel (Pinedo 2002):

Unrelated machines in parallel \((Rm)\)—There are \(m\) machines in parallel. Machine \(k\) can process product type \(l\) at speed \(v_{kl}\). The time \(p_{jk}\) that job \(j\) spends on machine \(k\) is equal to \(p_j/v_{kl}\), where \(p_j\) is the processing time of job \(j\) which does not depend on the machine. (again assuming job \(j\) receives all of its processing from machine \(k\)).

Jampani and Mason (2008) studied the identical parallel-machine MOJ scheduling problems to minimize total weighted order completion time. They presented column generation heuristics to solve the proposed problems. Jia and Mason (2009)