Scheduling Cellular Manufacturing Systems Using ACO and GA

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ABSTRACT

In this paper, cellular manufacturing scheduling problems are studied. The objective is to minimize makespan (C_{max}) considering part family in the manufacturing cell flow line where the setup times are sequence dependent. Minimizing C_{max} will result in the increment of output rate and the speed of manufacturing systems which is the main goal of such systems. This problem is solved using Ant Colony Optimization (ACO), Genetic Algorithm (GA) operators, and local search technique. To show the validity of proposed approach, it is compared with a tailor-made heuristic algorithm, called SVS. The obtained results indicate that the proposed method is quite fast and efficient.

Keywords: Ant Colony Optimization (ACO), Cellular Manufacturing System, Genetic Algorithm (GA), Local Search, Scheduling, Sequence-Dependent Setup Times

1. INTRODUCTION

Cellular Manufacturing System (CMS) is an efficient approach to manufacture part families economically. In this system, a number of machines with different capabilities form a cell called machine cell. Each machine cell is responsible for manufacturing parts which are similar and belong to a group or family. Defining machine cells and part families is one of the main challenges of designing manufacturing cells.

The main advantages of CMS are the reduction of setup times, work in process, transportation cost, improvement of quality, production control, increasing operational capabilities, and flexibility (Hendizadeh, Faramarzi, Mansoi,

Gupta, & El-Mekkawy, 2008). In manufacturing systems, part and part families scheduling are the main and effective factors toward the success of such systems (Wemmerlov & Hyer, 1989).

When assigning parts to a family based on the tool requirements, setup times decreases drastically and hence, setup times can be included in the processing time. However, when a part belongs to another family a relatively large setup time is often needed and for this reason it is better to consider sequence-family dependent setup times (Schaller, Gupta, & Vakharia, 2000). In group scheduling, it is assumed that each part family can be processed within one cell (Logendran, Mai, & Talkington, 1995) while considering real world constraints such as budget and manufacturing space this is very hard to be achieved (Lin, Lu, Shyu, &

Tsai, 2008). Hence, we have considered sequence dependent setup times. CMS scheduling problems are categorized as NP-Hard (Schaller, Gupta, & Vakharia, 2000) and due to the good performance of meta-heuristic algorithms in finding good solutions for this kind of problems, ant colony optimization (ACO) approach with genetic operators have been used.

2. LITERATURE REVIEW AND BACKGROUND

Most of group scheduling algorithms in the literature contain two phases. They first define part sequence in each group and then identify group sequence. Hitomi and Ham (1976) identified a lower bound for optimal maximum completion time and used branch-and-bound algorithm to reach optimal parts and group sequence. Yoshida and Hitomi (1979) then presented an algorithm to solve job shop scheduling of a two-machine problem with setup times optimally. Sekiguchi (1983) and Baker (1990) continued Yoshida and Hitomi's work on scheduling of two machines where each group has its own setup times. Logendran and Nudtasomboon (1991) presented a heuristic algorithm, named LN, to solve group scheduling to minimize maximum completion time which was similar to NEH algorithm presented by Navaz et al. (1983). The only difference between NEH and LN is that in NEH, jobs are arranged with decreasing order of total processing time while in LN they are arranged with declining order of average processing times.

Wemmerlov and Vakharia (1991) compared the performance of scheduling algorithms considering eight families and reported that family-based scheduling algorithms were mainly used to minimize flow time and lateness. Mahmoodi and Dooley (1991) evaluated a job shop cell including part families with sequence dependent setup times. Sridhar and Rajendran (1993) formulated a new heuristic algorithm to minimize total production time inflow shop cells and solved it using Simulated Annealing (SA) method.

Skorin-Kapov and Vakharia (1993) compared two cellular manufacturing flow shop scheduling approaches considering independent setup times. They proposed a Tabu Search (TS) based technique and solved them by SA. Sridhar and Rajendran (1994) proposed a genetic algorithm to solve parts and families scheduling in a flow shop manufacturing cell. Later on, Chien (1997) suggested a two-phase algorithm for scheduling flow shop CMS problems considering intercellular parts routing.

A performance comparison between Petrov(PT), Logendran and Nudtasomboon (LN), and Campbell-Dudek-Smith (CDS) methods was investigated by Logendran et al. (1995). They showed that LN-PT, which uses LN for first and PT for the second phase of the algorithm, has better performance than PT-LN, PT-CDS and CDS-PT. PT and CDS are one and multi-phase algorithms, respectively that transforms a flow shop scheduling problem with m machines and n jobs to a 2-machine and n-job problem solved by Johnson algorithm.

A group scheduling problem with two cells considering intercellular transportation was analyzed and solved by branch-and-bound and a heuristic algorithm by Yang and Liao (1996). Ponnambalam, Aravindan, and Reddy (1999) presented a new heuristic algorithm for group scheduling and compared it with previous algorithms for a seven-machine cell in a job shop setting.

Rajendran and Ziegler (1999) worked on scheduling job shop cell manufacturing to minimize weighted total flow time and weighted lateness. Schaller (2000) presented a new approach to schedule job shop CMS with sequence independent setup times to minimize maximum completion time and compared it with Wemmerlov and Vakharia (1991), Skorin-Kapov and Vakharia (1993), and Sridhar and Rajendran (1993).

Then, Schaller et al. (2000) presented a two-stage method called CMD to solve flow line manufacturing cell scheduling problems with sequence dependent setup times. CMD algorithm contains 3 algorithms: C, M and D. Algorithm C, constructed based on CDS,

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