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Single machine group scheduling with resource dependent setup and processing times

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Abstract

A single machine scheduling problem is studied. There is a partition of the set of n jobs into g groups on the basis of group technology. Jobs of the same group are processed contiguously. A sequence independent setup time precedes the processing of each group. Two external renewable resources can be used to linearly compress setup and job processing times. The setup times are jointly compressible by one resource, the job processing times are jointly compressible by another resource and the level of the resource is the same for all setups and all jobs. Polynomial time algorithms are presented to find an optimal job sequence and resource values such that the total weighted resource consumption is minimum, subject to meeting job deadlines. The algorithms are based on solving linear programming problems with two variables by geometric techniques.

Keywords: Scheduling; Single machine; Group technology; Resource allocation; Linear programming

1. Motivation and literature review

We study a single machine scheduling problem with resource dependent setup and processing times under group technology (GT) constraints.

GT is an approach to manufacturing and engineering management that seeks to achieve the efficiency of high-volume production by exploiting similarities of different products and activities in their production/execution. With respect to part manufacturing, the main idea of GT is to identify similar parts and classify them into groups to take advantage of their similarities. After the parts are classified into groups, cells of machines are configured and are dedicated to the production of specific groups of parts.

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In many applications, a major setup of the machine is needed for switching between the groups and a minor setup is needed for its switching between the jobs of the same group. When setup times are sequence independent, the time requirement for a minor setup can be included in the processing time of the corresponding job.

Studies of GT were originated by Mitrofanov [25] and Opitz [26]. Numerous manufacturing companies have taken advantage of GT to improve productivity and competitiveness, see, for example, Ham et al. [14], Wemmerlv and Hyer [35], Tatikonda and Wemmerlv [33], Hadjinicola and Ravi Kumar [13], and Gunasekaran et al. [12].

The first publications on scheduling in group technology environments are due to Petrov [27], and Yoshida et al. [34]. Results on group scheduling problems are reviewed by Potts and Van Wassenhove [29] and Liaee and Emmons [23]. Results not included in these reviews can be found in papers of Kovalyov and Tuzikov [21], Janiak and Kovalyov [17], Janiak et al. [19], Liu and Yu [24].

Note that GT approach does not allow group splittings. In a more general batching approach, each group can be partitioned into two or more batches processed separately, see Potts and Kovalyov [28].

There are publications on scheduling problems without group technology constraints but with resource dependent job processing times or release dates. Among them are papers by Janiak [15,16], Cheng and Janiak [6], Janiak and Portmann [20], Chen et al. [9], Janiak and Kovalyov [18], Li et al. [22], Cheng et al. [5], Cheng et al. [10], Biskup and Jahnke [2]. Some models of this type are discussed in the monograph of Blazewicz et al. [3].

It is natural to study the situations where group scheduling and resource allocation decisions are combined.

A single machine batch scheduling problem with resource dependent parameters has been studied by Cheng and Kovalyov [7] and Cheng et al. [8]. In this problem, there is a single group that can be partitioned into batches and jobs of the same batch complete together when the latest job of this batch has finished its processing. The processing of each batch is preceded by a common setup time. The former paper contains complexity results, dynamic programming algorithms and approximation for the case when only the job processing times are resource dependent. The latter paper assumes that the setup time is also resource dependent and presents polynomial time algorithms for this case. To the best of our knowledge, there are no other results available in the literature for group or batch scheduling problems with resource dependent setup and/or processing times.

2. Problem formulation

We study the following problem.

There are n independent, non-preemptive and simultaneously available jobs to be scheduled for processing on a single machine. A partition of the set of jobs into g groups is given. Jobs of the same group are processed contiguously and cannot be split into subgroups processed separately. Each group G_f includes q_f jobs, $\sum_{f=1}^{g} q_f = n$. A sequence independent machine setup time S_f precedes the processing of the first job of group G_f, $f = 1, \dots, g$. Each job J_j has a processing time p_j and a deadline d_j, $j = 1, \dots, n$.

The setup times are variables depending on an equal amount x of a renewable continuously divisible or discrete resource used for their performing: $s_f = a_f - b_f x$, where a_f is the value of s_f for $x = 0$ and b_f is the value of the setup time reduction per unit of the resource, $f = 1, \dots, g$. It is assumed that $x \in [0, x_{\max}]$ and $a_f - b_f x_{\max} > 0$, $f = 1, \dots, g$.

Similarly, the job processing times depend on an amount y of the same or another renewable resource: $p_j = r_j - t_j y, y \in [0, y_{\max}]$, $r_j - t_j y_{\max} > 0$, $j = 1, \dots, n$. It is assumed that both resources are either continuous or discrete.