Chapter 23

Dantzig-Wolfe Decomposition and Lagrangean Relaxation-Based Heuristics for an Integrated Production and Maintenance Planning with Time Windows

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ABSTRACT

In this chapter, two approaches are developed to solve the integrated production planning and maintenance problem. Moreover, Some Propositions and mathematical properties were suggested and applied in the proposed heuristics to solve the problem. The first heuristic developed is based on Dantzig-Wolfe decomposition. The Dantzig-Wolfe Decomposition principle reformulates the original model and Column generation is then used to deal with the huge number of variables of the reformulated model. A simple rounding heuristic and a smoothing procedure are finally carried out in order to obtain integer solutions. The second heuristic is based on Lagrangean relaxation of the capacity constraints and sub-gradient optimization. At every step of sub-gradient method, feasibility and improvement procedures are applied to the solution of the Lagrangean problem. Computational experiments are carried out to show the results obtained by our approaches and compared to those of commercial solver.

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I. INTRODUCTION

Maintenance is a task closely related to production scheduling in industrial settings. It is the operations or techniques that allow maintaining or restoring equipment to a specific state and guaranteeing a given service. Both activities conflict since, as it is known, maintenance is generally a secondary process in companies that have production as their core business. Indeed, production management often views maintenance in the context of hours or days out of service and fails to realize the strategic importance of incorporating maintenance in the manufacturing planning. On the other hand, management for the maintenance function attempts to impose constraints on production that it deems necessary to achieve complete equipment reliability. As we can see, the production planning and maintenance are dealt separately in the literature and also in the industry. Therefore, maintenance planning should be an integral part of the overall business strategy and should be coordinated and scheduled with manufacturing activities. So, we should consider maintenance as integral parts of the production plan rather than as interruptions to that plan. Any violation of the maintenance schedule is treated as a violation of the production plan integrity.

As a remedy to this problem, we develop an integrated model of production and maintenance planning at the tactical level. In the core of production planning, we find the single stage multi item capacitated lot sizing problem with demand shortages in which the schedules and lot sizes are planned for the production of multiple items that share capacity constrained resource. We deal with problems with tight capacities, and when we are in lack of capacity to produce the total demand, we try to spread the capacity among the items by minimizing the total amount of demand shortages. Maintenance planning problem is to determine the dates of preventive maintenance in time windows according to reliability of production equipment. When preventive maintenance actions are carried out the production line is restored to an 'as-good-as-new *(AGAN)*' status, and when a production line fails, a minimal repair is performed to restore it to an 'as-bad-as-old *(ABAO)*' status. The resulting problem is modelled as a linear mixed-integer program to minimize production, inventory, setup, demand shortage, preventive and corrective maintenance costs.

We develop two approaches to solve the integrated production planning and maintenance problem. The first heuristic is based on Dantzig-Wolfe decomposition (Dantzig and wolfe, 1960). The Dantzig-Wolfe Decomposition principle reformulates the original model. Column generation is then used to deal with the huge number of variables of the reformulated model. Finally, we apply a simple rounding heuristic and smoothing procedure in order to obtain integer solutions. The second heuristic is based on Lagrangean relaxation (Ficher, 1981) of the capacity constraints and sub-gradient optimization. At every step of sub-gradient method, feasibility and improvement procedures are applied to the solution of the Lagrangean problem.

To our knowledge, there are only few works dealing with this issue. (Weinstein and Chung, 1999) presented a three part-model to resolve the conflicting objectives of system reliability and profit maximization. An aggregate production plan is first generated, and then a master production schedules is developed to minimize the weighted deviations from the specified aggregate production goals. Finally, work-center loading requirements, determined through rough cut capacity planning, are used to simulate equipment failures during the aggregate planning horizon. (Aghezzaf et al. 2007) studied a production system that subjects to random failures. They assume that any maintenance action carried out on the system, in a period, reduces the system's available production capacity during that period. The objective is to find an integrated lot-sizing and preventive maintenance strategy of the system that satisfies the demand for all items over the entire horizon without backlogging, and which minimizes the expected sum of produc-