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Production planning in the molded pulp packaging industry

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ABSTRACT

Production planning in molded pulp packaging companies involves decisions about setting up appropriately the production process to meet the demands of different products. This production process comprises stages such as blending, molding and drying, and the major challenges for the production planning occur in the molding stage, where the mix of products manufactured simultaneously depends on the combination of molds attached to the molding machine, called molding pattern. Thus, the problem lies in deciding which molding patterns should be used, how long each pattern should be used and the production sequence that they should be scheduled. In this study we propose a novel optimization approach to deal with this problem by considering some possible settings for the molding machine based on specific technological constraints. These preset settings are included into a mixed integer programming model to define the molding patterns and to deal with the production lot sizing and scheduling decisions. Since the molding patterns are defined by the approach, three types of production setup times and costs (some of then are sequence-dependent) must be also calculated and taken into account in the planning decisions. Computational tests with real data from a Brazilian molded pulp plant show that the production plans generated by this approach are suitable in practical settings, as well as define molding patterns different from those commonly used and simultaneously reduce setup times and costs, when compared to the production plans of the company.

1. Introduction

Environmental, social and economic concerns result in constant search for more sustainable products and industrial processes. Molded pulp consists of an environmentally friendly material for packaging solutions, made of waste papers and water, so it is 100% biodegradable. Both fiber and water are recycled and reused in the manufacturing process, resulting in almost zero waste (EMFA, 2015; IMFA, 2015). The process implies the recovery of discarded materials, specially products made of paper fibers as cardboards, books, newspapers, magazines and others; which increases the recovery rate of post-consumed paper. On a global basis, countries such as South Korea, Germany, Japan, United Kingdom and Spain present the highest recovery rates of apparent consumption of paper, which are between 73.8% and 91.6%. Brazil registers a recovery rate of only 45.5% of its apparent paper consumption, being at the twelfth position in the world, and encouraging the development of industrial processes that use scraps of paper as raw materials. In this context, the molded pulp packaging industry is relevant and has great perspective of growth in Brazil, as well as in many others countries (BRACELPA, 2015).

The molded pulp production process involves several steps: blending, molding, drying and sometimes, pressing, printing, among others. One of the particular aspects of this process is related to the molding equipment, in which is attached a set of custom design tools called "molding patterns". From a single molding pattern, different products can be manufactured simultaneously in the molding equipment, and each specific product can be manufactured by alternative molding patterns. In this industry, the amount produced of each product depends on the molding patterns, how long they are used and also on the speed of the molding machine. That is, the production planning focuses on planning and scheduling molding patterns to meet the demand, reducing setup times and production costs.

Before choosing the molding patterns for production, it is necessary to define them, and generally, companies make this based only on planners expertise, usually considering a sub-set of all the possible molding patterns. In this study we propose a novel optimization approach to define the molding patterns via preset settings of the molding equipment, considering sequence-dependent setup and changeover times. Production and

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decision-making processes are characterized by a case study of a Brazilian industrial plant that produces packaging for eggs and fruits, which often fails to define production plans that meet the demand for all products, and spends long times doing setup operations. Although this work was motivated by a case study, the company studied is typical in this sector and it is part of a group that comprises a vast portfolio of companies, including an equipment manufacturer for molded pulp industry. So, we believe that the approach developed here can be easily adapted to deal with the production planning in other molded pulp production systems.

To the best of our knowledge, there are few works in the literature that combine production planning and process selection problems. Thus, the contribution of this study is threefold: (i) characterizing the production planning in molded pulp packaging industry, identifying the most relevant features of the manufacturing process and the major challenges; (ii) approaching decisions about defining molding patterns and planning the production of the manufacturing process, simultaneously; and (iii) including different types of setups separately, which can facilitate the study of techniques to reduce changeover times, for example, SMED (Single Minute Exchange of Die) very common in Lean Production. Three setup types considered in this industry are: stopping/starting the production line, attaching/detaching molds to the molding machine and setting up other components of the production line.

This paper is organized as follows: the next section presents a brief literature review of production planning problems, mainly extensions of lot sizing and scheduling problems in industrial contexts; Section 3 describes the manufacturing process of molded pulp packaging companies; Section 4 presents an optimization approach proposed to deal with the production planning in the studied industry; Section 5 reports the computational tests performed with this approach; and finally Section 6 gives some concluding remarks and future research directions.

2. Review of related works

2.1. Production planning problems

Production planning problems generally comprises decisions about lot sizing and scheduling, which involves to determine what to produce, when to produce and how much to produce, as well as to manage inventory levels, minimizing the total costs involved in the production process (Hax & Candea, 1984; Johnson & Montgomery, 1974; Karimi, Fatemi Ghomi, & Wilson, 2003). Several studies present mathematical models for lot sizing and scheduling problems considering different features. Some of the classical formulations for this problem are the Discrete Lot Sizing and Scheduling Problem – DLSP (Fleischmann, 1990; Gicquel, Wolsey, & Minoux, 2012; Gicquel, Minoux, & Dallery, 2009), the Continuous Setup Lot Sizing Problem – CSLP (Drexl & Kimms, 1997), the Proportional Lot Sizing and Scheduling Problem – PLSP (Drexl & Haase, 1995), the Capacitated Lot Sizing Problem – CLSP (Karimi et al., 2003) and the General Lot Sizing and Scheduling Problem – GLSP (Fleischmann & Meyr, 1997).

Production planning problems have been studied and applied to different industrial settings, like in dairy and yogurt industry (Marinelli, Nenni, & Sforza, 2007), brewery industry (Baldo, Santos, Almada-Lobo, & Morabito, 2014; Guimares, Klabjan, & Almada-Lobo, 2012), non-alcoholic and soft drinks industry (Ferreira, Morabito, & Rangel, 2009; Ferreira, Clark, Almada-Lobo, & Morabito, 2012; Toledo, Oliveira, Pereira, França, & Morabito, 2014), tobacco industry (Pattloch, Schmidt, & Kovalyov, 2001), glass industry (Almada-Lobo, Oliveira, & Carravilla, 2008; Toledo, da Silva Arantes, de Oliveira, & Almada-Lobo, 2013), foundries (Araujo, Arenales, & Clark, 2007; Araujo, Arenales, & Clark, 2008; Hans & Velde, 2011), chemical industry (Transchel, Kallrath, Minner, Lohndorf, & Ulrich, 2011), pulp and paper industry (Figueira, Oliveira Santos, & Almada-Lobo, 2013; Furlan, Almada-Lobo, Santos, & Morabito, 2015; Santos & Almada-Lobo, 2012), animal nutrition (Clark, Morabito, & Toso, 2010; Toso, Morabito, & Clark, 2009), tire industry (Jans & Degraeve, 2004) and many others. Such studies described the production planning and processes involved, and proposed different mathematical models usually based on those classical formulations mentioned above. These approaches involve different features, such as multiple products and stages, multi-period planning horizon, parallel machines, sequence-dependent setup times and costs, and other peculiarities based on each production process. Solutions strategies and methods were also proposed, based on mathematical programming techniques, heuristics and metaheuristics proceedings.

2.2. Production planning and process selection problems

Most of the studies mentioned above deals with lot sizing and scheduling problems focusing on products. However, these problems can also be related to the decisions of which production processes should be used, considering that in some processes different products can be obtained simultaneously (also known as Process Selection Problems; Johnson & Montgomery, 1974). So production planning decides how many times or how long each process should be used, and how the processes should be scheduled. In this case, the amount produced, the capacity consumption, and the setup times and costs are related to the processes, not products. An example is the integrated lot sizing and cutting stock problem (Gramani & França, 2006), where the production depends on the choice and use of cutting patterns to produce different items.

Some studies approach the planning and scheduling of production processes in industrial contexts. Luche, Morabito, and Pureza (2009), for example, studied the production planning in the electrofused grain industry, in which the mix and the quantities of products depends on which set of shaking sieves are used in the process. Each combination of shaking sieves with different dimensions is viewed as a different process, by which electrofused grains of different sizes can be obtained simultaneously. The main decisions are about which set of sieves to use in each period of the planning horizon, considering demands, capacities, non-depending setup times, minimizing product demand shortages and overproduction.

Another example appears in the lumber industry, in which each product is defined as a combination of length and quality grade, and they are produced based on the way both the drying and finishing processes are carried out. The finishing stage is related to planing, sorting and trimming (Gaudreault, Frayret, Rousseau, & D Amours, 2011). So, quantities of products to be produced depends on the combination of the drying program (times for air and kiln drying), and finishing processes (sawmills setup). These combinations are called "kiln loading patterns". The objective is to plan these activities on parallel machines, so that the production backorders are minimized.

In oil refineries, quantities of diesel, gasoline and other kinds of products depends on the operation modes (alternative processes) set up in the production units. These production units usually involve atmospheric distillation units (ATM), vacuum distillation units (VDU), hydrogen desulfurization units (HDS), etherification units (ETH), hydrorefining (HTU), catalytic reformers (RF), and others. The production decisions involve to choose the operation mode for each production unit along the planning horizon, so that the production, inventory and start up costs are minimized (Göthe-Lundgren, Lundgren, & Persson, 2002; Shi, Jiang, Wang, & Huang, 2014).