Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 132 (2015) 31 – 38
Procedia Engineering
www.elsevier.com/locate/procedia

The Manufacturing Engineering Society International Conference, MESIC 2015

System machine selection in a dry grinding process: Cost and energy savings

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Abstract

The dry grinding process (DGP) could be considered as a particular complex production system. Traditionally the design of this process has been based on heuristics. We attempt to find the nearest optimal design of a DGP choosing the model and number in every stage for the machines and buffers that can minimize investment and energy cost with a reasonable service level (SL). To solve the problem, a genetic algorithm and a simulation model to evaluate the SL along the time are proposed. The viability of the approach has been tested with three real cases and encouraging results have been obtained.

Peer-review under responsibility of the Scientific Committee of MESIC 2015

Keywords: Grinding Process; Genetic Algorithm; Service Level; Simulation

1. Introduction

The grinding processes are designed to reduce raw material size in one or more stages in order to achieve a more homogeneous and useful size. This paper is focused on dry grinding process in ceramic plant (DGP) to produce bricks, tiles...

A grinding plant involves very large capital investments and the process is energy intensive. However, the design and selection of the main grinding equipment for the factory remains empirical to a significant degree and depends mainly on planner's ability. Significant waste of valuable time, high possibility of making wrong estimations

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Peer-review under responsibility of the Scientific Committee of MESIC 2015
doi:10.1016/j.proeng.2015.12.465

because of manual calculations, limited possibility of studying all the possible alternatives and the absolute dependence from "one" and "expert" person are some of the consequences of facing the problem in an empirical way.

In this paper, we consider the selection, type and quantity, of the suitable main grinding equipment for the factory [1]. It is obvious that there is a demand to develop a method that allows to find a useful solution, even more because energy cost is usually neglected. We call useful solution the one that brings the lowest investment and energy consumption cost as well as satisfies the production and granulometry needed in the process.

Moreover, it must be ensured that the material flow value (Tm/h) at the last stage of the process is equal to a value previously fixed. Therefore, it is necessary to calculate the Service Level (SL). This parameter measures the relationship between real and desired production for a long period.

For this purpose, we are going to develop a genetic algorithm (GA) to optimize the solutions to the problems proposed and also we are going to simulate these solutions in order to test their fitness.

This paper is organized as follows. Section 2 presents the literature review. Section 3 explains how the dry grinding process work and what we are going to optimize it. Section 4 develops the genetic algorithm. To demonstrate the effectiveness of the methodology, section 5 present the features of the examples serving as a test bench. In Section 6 we present the conclusions.

2. Literature review

Selecting the proper equipment can improve production process, increase the production and improve the system flexibility [2]. Moreover, miscalculate the equipment could lead to fail to achieve the required quality levels and capacity required by the client [3]. The integration of the plant scheduling in the early stage of the plant design is essential to improve the economic goals. Therefore, the design of new processes or plants must take into consideration the interplay between the planning and scheduling aspects of the production. This trend motivated the formulation of even more complex optimization problems in an attempt to determine simultaneously the optimal plant sizing and scheduling. Several approaches have been reported in the literature to model and solve this class of problems. See for instance the reviews [4], [5], [6] proposed a two stage approach for the design of single product batch/semicontinuous plants. The design problem is divided in two parts: the plant network synthesis subproblem and the sizing subproblem. These problems are solved adopting an evolutionary strategy, and using an approximate method.

These plants operate with a single product in a semi-continuous way and the goal is to size the machines that fix the manufacture-scheduled program. Works related with these items can be found in [7], [8], [9] and [10].

The sizing problem consists of selecting the type and number of machines and the buffer size in each stage. The selection is based on the commercial model existing in the market and others production variables, especially the theoretical production. The typical sizing problem is replaced by a function that considers both, the process cost (equipment and energy consumption) and the production performance expressed as a Service Level.

To calculate the Service Level, it is necessary to simulate the process. Therefore, we need a discrete time representation. [11] shows and justifies models that discretize the time and variable to control states at each moment. However, discrete-time formulations may require a large number of time slots to represent accurately a problem. This in turn requires a large number of binary variables associated to each discrete-time interval, leading to problems of higher dimensionality, and often with elevated computational times.

Highest energy consumption occurs in the grinding itself. The three laws of comminution [12] are applied to calculate the energy consumption. A small but not insignificant percentage is consumed in transporting the material by conveyor belts.

This kind of problems is NP-hard, so we are going to use a genetic algorithm in order to optimize the search. Genetic algorithms carry out searches using the simulation processes, natural selection and genetic recombination. They are based on the genetic processes of living organisms: through generations populations evolve in nature according to the principles of natural selection and the survival of the strongest. This algorithm principles where introduced by [13] and have been well described by [14], [15], [16] y [17]. The use of genetic algorithms in similar problems can be found in [18]. Uses of the GA with multiobjetive in similar problems of equipment selections can