



A hybrid multi-objective artificial bee colony algorithm for burdening optimization of copper strip production

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ABSTRACT

To achieve burdening process optimization of copper strips effectively, a nonlinear constrained multi-objective model is established on the principle of the actual burdening. The problem is formulated with two objectives of minimizing the total cost of raw materials and maximizing the amount of waste material thrown into melting furnace. In this paper, a novel approach called “hybrid multi-objective artificial bee colony” (HMOABC) to solve this model is proposed. The HMOABC algorithm is new swarm intelligence based multi-objective optimization technique inspired by the intelligent foraging behavior of honey bees, summation of normalized objective values and diversified selection (SNOVDS) and nondominated sorting approach. Two test examples were studied and the performance of HMOABC is evaluated in comparison with other nature inspired techniques which includes nondominated sorting genetic algorithm II (NSGAI) and multi-objective particle swarm optimization (MOPSO). The numerical results demonstrate HMOABC approach is a powerful search and optimization technique for burdening optimization of copper strips.

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1. Introduction

With the growing world energy crisis and more intense global competition an increasing number of countries and the regions in the world pay more attention to the development and utilization of natural resources. As other non-ferrous metals industries, copper processing enterprise are also facing the critical situations of supply shortage of raw materials, rising prices of raw materials and the increasing cost of production, which makes the copper processing enterprises are facing unprecedented challenges. Copper strip is a production of high precision, great demand and high value added in copper processing enterprises. Burdening is an important process in the production line of copper strip. The process is to compute charging weight and charging time of raw materials according to charging ratio of product process, quality of raw materials and burning loss of raw materials in the smelting process. The rationality of charging ratio for various raw materials not only helps to improve the quality of copper strip and production efficiency but also is important for reducing cost of raw material and recycling waste [1].

Burdening optimization becomes one of many scholars' important researches. There has been considerable amount of work carried out on burdening optimization [2–6]. In [2], linear programming is used to optimize burdening problem. The method is very effective against the linear model which is treated, but there is a limitation for the method that it can not treat nonlinear model. Optimization procedures based on nonlinear programming, in which the objectives are

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considered one at a time, were presented in [3,4]. Burdening optimization models were established by considering some performance parameters, including product quality, cost, stocks and so on. Improve single-objective genetic algorithms were used to optimize the special burdening optimization model. The burdening optimization model was established by minimizing cost in [5]. This model was optimized by expert reasoning strategy and immune genetic algorithm. The above two optimizing methods based on the intelligent optimization algorithm are efficient and adapted to the complex nonlinear model, but they cannot obtain multiple representative optimum solutions. Three different methods for the problem of optimizing burdening optimization, linear programming, Monte Carlo algorithm and genetic algorithm, were compared in [6]. The results of the methods were analyzed through changing the constraint conditions and models parameters from the accuracy of final results, the constraint conditions, the using field, the efficiency, etc.

Burdening process of copper strip production is a complex industrial process in which interrelated factors are multiple. In addition to making the proportion of elemental composition within standard range to ensure product quality, many factors, including cost of raw materials, feeding sequence, stocks, original fused mass, burning loss of raw materials for in the smelting process and the maximizing use of waste material, have to be considered. The traditional linear model is difficult to describe the relationship between these complex factors for burdening process with above characteristics and cannot treat multiple constraints appropriately. In order to meet the actual situation of burdening process a multivariable, nonlinear and multi-objective model will be established. In this paper, a burdening optimization model with two objectives is established. One objective is minimizing the total cost of raw materials and the other is maximizing the amount of waste material thrown into melting furnace. Existing methods of burdening optimization are not suitable for solving the multi-objective model. Because a single optimal solution can not meet the need of workers in the complex shop floor of burdening and melting process and multifarious optimal solutions with the experience of workers are more valuable.

In pursuit of finding solution to the optimization problems many researchers have been drawing inspiration from the nature [7]. A lot of such biologically inspired algorithms have been developed namely genetic algorithm (GA) [8], particle swarm optimization (PSO) [9], artificial immune system (AIS) [10] and artificial bee colony (ABC) [11]. These algorithms with their stochastic means are well equipped to handle such problems. Over the past two decade, a lot of successful multi-objective algorithms based on such biologically inspired algorithms to optimize multi-objective problems were proposed in literature, such as Pareto-archived evolution strategy (PAES) [12], Pareto envelope-based selection algorithm (PESA)-II [13], nondominated sorting genetic algorithm II (NSGAI) [14], strength Pareto evolutionary algorithm (SPEA2) [15], indicator-based evolutionary algorithm (IBEA) [16], multi-objective particle swarm optimization (MOPSO) [17], multi-objective evolutionary algorithm based on Decomposition (MOEA/D) [18], two lbests multi-objective particle swarm optimization (2LB-MOPSO) [19], multi-objective differential evolution (MODE) based on summation of normalized objective values and diversified selection (SNOV-DS) [20] and so on. The primary reason for this is their ability to find multiple Pareto-optimal solutions in one single simulation run.

Artificial bee colony (ABC) algorithm is one of the most recently introduced swarm-based algorithms [11]. ABC has been found to be successful in a wide variety of optimization tasks [21]. Recently it had been extended to deal with multiple objectives, such as vector evaluated artificial bee colony (VEABC) [22], multi-objective artificial bee colony (MOABC) [23] and so on. ABC seems particularly suitable for multi-objective optimization mainly because ABC has proven to have superior computational efficiency [24] and does not use any gradient-based information. In this paper, we present a novel multi-objective approach called “hybrid multi-objective artificial bee colony” (HMOABC) to solve the burdening optimization model of copper strip production based on ABC algorithm, and its inspiration is drawn from NSGAI and SNOV-DS [14]. Pareto-optimal solutions solved by HMOABC have better global convergence local diversity and shorter running time. This algorithm has distinct advantage in burdening optimization of copper strip production which needs multiple representative optimum solutions, but the goal can not be achieved via single objective optimization algorithm. And then the priority of feasible solutions is achieved by the method of sorting Pareto solutions based on fuzzy set theory [25].

According to burdening process of copper strip production, a number of different constraints such as charging ratio, feeding amount, feeding sequence and stocks need to be satisfied considered in this model. Generally, constrained multi-objective problems are difficult to solve, as finding a feasible solution may require substantial computational resources and some additional mechanisms [26]. A self-adaptive penalty function [27] is employed to handle parts of these constraints in the burdening optimization model.

This paper is structured as follows: the notation of the burdening optimization model is presented in Section 2. The detail of the burdening optimization model and its formulation are explained in Section 3. In Section 4, basics of multi-objective problems are presented. Section 5 describes the details of the proposed HMOABC. The optimization process is presented in Section 6. After the numerical results and discussions are presented in Section 7, conclusions of this paper are given in Section 8.

2. Notation

c_i	the cost coefficients of the i th raw material
u_j, l_j	upper and lower limits for the j th element of a production
λ_j	the proportion of the j th element of the original fused mass
D_i	safety stock of the i th raw material
U_i, L_i	upper and lower limits for charging weight of the i th raw material

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