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Optimization of cutting parameters in multi-pass turning using artificial bee colony-based approach

Ali R. Yildiz

Bursa Technical University, Department of Mechanical Engineering, Bursa, Turkey

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ABSTRACT

Selection of cutting parameters in machining operations is an essential task to reduce cost of the products and increase quality. This paper presents an optimization approach based on artificial bee colony algorithm for optimal selection of cutting parameters in multi-pass turning operations. The objective is to find the optimized cutting parameters in the turning operations. A comparison of evolutionary-based optimization techniques to solve multi-pass turning optimization problems is presented. The results of the proposed approach for the case studies are compared with previously published results by using other optimization techniques in the literature.

1. Introduction

Turning is one of the conventional and widely used machining methods for material removal in manufacturing industry. Optimization of cutting parameters in machining processes is very important to produce high quality products and reduce the product costs.

The literature survey shows that several research works [1–15] have been made for optimization of cutting parameters in turning operations. Population-based optimization techniques such as cuckoo search algorithm, differential evolution algorithm (DE), particle swarm optimization algorithm (PSO) and genetic algorithm (GA) are becoming more popular in design and manufacturing tasks because of the availability and affordability of high-speed computers [15–36]. Recently, a comparison of population-based optimization techniques for solving multi-pass turning optimization problems is presented by Yildiz [15]. Although some improvements regarding optimization of cutting parameters in multi-pass turning operations have been achieved, due to the complexity of machine parameters with conflicting objective and constraints, it still presents a matter of investigation.

In this research, a hybrid optimization approach entitled hybrid artificial bee colony algorithm (HABC) based on the ABC and Taguchi method is introduced and applied to the two case studies to optimize cutting parameters in multi-pass turning operations. It is inferred from the results that HABC is better than the previous works in terms of accuracy and precision. The number of generations for HABC is very much less compared with the previous works making it faster. The selection of cutting parameters for the two case studies has been carried out by using the HABC.

The rest of the paper is organized as follows: the Section 2 describes a detailed formulation of the objective and constraints in multi-pass turning. The standard ABC and Taguchi method are presented in Section 3. In Section 4 two case studies are solved. The results and discussions for case studies are given in Section 4. The paper is concluded in Section 5.

E-mail address: aliriza.yildiz@btu.edu.tr

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2. Metal cutting optimization model

In multi-pass turning operations, the aim is to minimize unit production cost (C_U). The unit production cost is the sum of the cutting cost (C_M), machine idle cost (C_I), tool replacement cost (C_R) and tool cost (C_T), respectively. A photo of a turning process is shown in Fig. 1.

In Fig. 2a, a schematic illustration of a turning operation is given and the forces acting on a cutting tool in turning are shown in Fig. 2b.

The developed hybrid optimization approach is applied to optimize multi-pass turning operation for the determination of cutting parameters considering minimum production cost under a set of machining constraints which are presented and adopted in the references of Shin and Joo [5], Chen and Tsai [8], and Chen [30].

2.1. The cost function

$$C_U = C_M + C_I + C_R + C_T \tag{1}$$

$$C_U = k_0\left[\frac{\pi DL}{1000V_r f_r}\left(\frac{d_t - d_s}{d_r}\right) + \frac{\pi DL}{1000V_s f_s}\right] + k_0\left[t_c + (h_1 L + h_2)\left(\frac{d_t - d_s}{d_r} + 1\right)\right] + k_0 \times \frac{t_e}{T_p}\left[\frac{\pi DL}{1000V_r f_r}\left(\frac{d_t - d_s}{d_r}\right) + \frac{\pi DL}{1000V_s f_s}\right] + \frac{k_t}{T_p}\left[\frac{\pi DL}{1000V_r f_r}\left(\frac{d_t - d_s}{d_r}\right) + \frac{\pi DL}{1000V_s f_s}\right] \tag{2}$$

2.2. Parameter bounds and cutting condition constraints

In multi-pass turning operations, the unit production cost (C_U) is imposed by different constraints which are (i) parameter bounds cover depth of cut, cutting speed and feed; (ii) tool-life constraint; (iii) cutting force constraint; (iv) power constraint; (v) stable cutting region constraint; (vi) chip–tool interface temperature constraint; (vii) surface finish constraint (only for finish machining); and (viii) parameter relations. These constraints are as follow [5]:

2.2.1. Rough machining

Depth of cut

$$d_{rL} \leqslant d_r \leqslant d_{rU} \tag{3}$$

Feed

$$f_{rL} \leqslant f_r \leqslant f_{rU} \tag{4}$$

Cutting speed

$$V_{rL} \leqslant V_r \leqslant V_{rU} \tag{5}$$

Tool-life constraint

$$T_L \leqslant t_r \leqslant T_U \tag{6}$$

Fig. 1. Turning operation [37].