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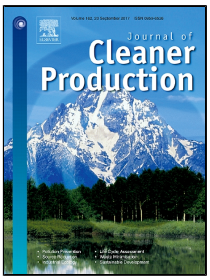

Optimization of process parameters for minimum energy consumption based on cutting specific energy consumption

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Optimization of process parameters for minimum energy consumption based on cutting specific energy consumption

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Abstract: In order to reduce the energy consumption of machine tool, the process parameters were optimized by the optimization model with the cutting specific energy consumption (CSEC) and the processing time. Based on the energy consumption characteristics of the numerical control (NC) machine tool, the energy consumption module of NC machine tool was analyzed. The power composition of machining process which was based on energy consumption module was proposed, and then CSEC was given with the cutting process parameters. The optimization model to minimum cutting specific energy consumption and minimum processing time was established with the process parameters under the actual constraint conditions in the manufacturing process. The multi-objective optimization model was transformed into the single objective optimization model by introducing the subjective and objective comprehensive weights and solved by the quantum genetic algorithm. When the optimization goal was to trade off processing time and CSEC to reduce the energy consumption, the selecting of the milling parameters should consider the complex effect if the constraints could be met with, large feed speed and large milling depth could benefit if the constrains of milling process were met with. The processing energy consumption of optimized process parameters decreased 27.21% compared with that of preferred process parameters while CSEC was reduced 32.07% and the processing time was reduced 34.11%. The proposed approach in this paper provided an efficient solution to reduce the impact of the environment caused by energy consumption and to realize the sustainable manufacturing.

Keywords: Energy consumption; CSEC; Multi-objective optimization; Subjective and objective comprehensive weight; Quantum genetic algorithm

1. Introduction

Due to the energy consumption intensity has been increasing and the impact to the environment caused by energy consumption has become increasingly prominent, the global manufacturing industry is undergoing the unprecedented pressure of energy consumption. The manufacturing consumed a large quantity of energy and resources, leading to large amounts of emissions (Du et al., 2015). Manufacturing operations accounted for as much as 19% of greenhouse gas emissions (Herzog, 2009). If the energy consumption was reduced, the environmental impact generated from power production was correspondingly diminished (Pusavec et al., 2010), so how to reduce the energy consumption has become the focus of industry and academic research field.

Machine tool was the major component in manufacturing process and was a dominant consumer of electrical energy (Li et al., 2016). It was that only 14.8% of the total energy can be actually used for material removal on machine tool (Gutowski et al., 2006). The process parameters played an important role in energy-saving in manufacturing process (Zhong et al., 2016), energy savings up to 6-40% can be realized by optimizing the cutting parameters, cutting tools and optimum tool path design (Newman et al., 2012). Thus, energy consumption module of NC machine tool was given in this paper, and the optimization model with the cutting specific energy consumption (CSEC) and the processing time was proposed for minimizing energy consumption. Experiments were conducted to demonstrate the feasibility of optimization method, and the findings were summarized in the end.

2. Literature review

In recent years, some experts and scholars have done a lot to optimize the process parameters for energy saving

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