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Multi-objective optimization of the turning process using a Gravitational Search Algorithm (GSA) and NSGA-II approach

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ABSTRACT

In this paper, we proposed a Gravitational Search Algorithm (GSA) and an NSGA-II approach for multi-objective optimization of the CNC turning process. The GSA is a swarm intelligence method exploiting the Newtonian laws on elementary mass objects interaction in the search space. The NSGA-II is an evolutionary algorithm based on non-dominated sorting. On the basis of varying values of the three independent input machining parameters (i.e., cutting speed, depth of cut, and feed rate), the values of the three dependent output variables were measured (i.e., surface roughness, cutting forces, and tool life). The obtained data set was divided further into two subsets, for the training data and the testing data. In the first step of the proposed approach, the GSA and the training data set were applied to modelling a suitable model for each output variable. Then the accuracies of the models were checked by the testing data set. In the second step, the obtained models were used as the objective functions for a multi-objective optimization of the turning process by the NSGA-II. The optimization constraints relating to intervals of dependent and independent variables were set on the theoretical calculations and confirmed with experimental measurements. The goal of the multi-objective optimization was to achieve optimal surface roughness, cutting forces, and increasing of the tool life, which reduces production costs. The research has shown that the proposed integrated GSA and NSGA-II approach can be implemented successfully, not only for modelling and optimization of the CNC turning process, but also for many other manufacturing processes.

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POVZETEK

V članku smo predlagali gravitacijski iskalni algoritem (angl. GSA) in metodo NSGA-II za večkriterijsko optimiranje postopka CNC struženja. GSA je metoda roja delcev, ki izkorišča Newtonske gravitacijske zakone oziroma interakcije med elementarnimi masnimi delci v iskalnem prostoru. Metoda NSGA-II je evolucijski algoritem, ki temelji na nedominiranem razvrščanju. Na osnovi spreminjanja vrednosti treh neodvisnih vhodnih spremenljivk (obdelovalne hitrosti, globine reza in podajanja) smo dobili vrednosti treh odvisnih izhodnih spremenljivk (hrapavosti površine, odrezovalne sile in življenske dobe orodja). Dobljene podatke smo razdelili v dve skupini, in sicer v skupino za učenje in skupino za testiranje. V prvem koraku predlaganega pristopa smo uporabili metodo GSA in podatke za učenje; tako smo dobili ustrezen model za vsako izhodno spremenljivko. Nato smo s pomočjo podatkov za testiranje preverili uspešnost učenja. V drugem koraku smo doblejne modele uporabili kot kriterijske funkcije za večkriterijsko optimizacijo postopka struženja z algoritmom NSGA-II. Omejitve, ki se nanašajo na intervale odvisnih in neodvisnih spremenljivk smo dobili na osnovi teoretičnih izračunov, ki smo jih potrdili tudi z meritvami. Namen večkriterijske optimizacije je bil doseči optimalne površinsko hrapavost in odrezovalne sile, a hkrati povečati življensko dobo orodja ter tako zmanjšati izdelovalne stroške. Raziskava je pokazala, da predlagan povezan GSA in NSGA-II pristop ne omogoča le uspešnega modeliranja in optimiranja postopka CNC struženja, ampak tudi mnogih preostalih obdelovalnih postopkov.

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Ključne besede:
Struženje
Večkriterijska optimizacija
Evolucijski algoritmi
Roj delcev
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