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Modeling and multi-objective optimization of cutting parameters using response surface method for milling of medium carbon steel (EN8)

N. L. Bhirud[1] · A. S. Dube[1] · Amit S. Patil[2] · K. S. Bhole[2]

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Abstract
Continuous growth of the manufacturing sector is resulting in to higher energy demand due to which the manufacturing costs and greenhouse gas emissions are also increasing. Beside reduction in energy consumption; improvement in energy efficiency, power factor and reduction in cutting temperatures are also vital to ensure better sustainability of the machining sector. This work evaluates the trade-offs between energy, heat generation and cutting quality during milling of medium carbon steel (EN8) alloy steel. The effects of input process parameters viz. spindle speed, feed rate, axial depth of cut, radial depth of cut and tool helix angle has been studied on the energy consumption, energy efficiency, power factor, cutting temperatures, surface roughness response parameters. The inclusion of helix angle as an input factor and, using energy efficiency and power factor as output parameters are the major highlights of this work. The machining experiments were conducted using response surface methodology for design of experiments. The multi objective optimization was carried out by using desirability approach, for three different groups of response variables considering the different importance of energy consumption, cutting temperatures and surface roughness, under different manufacturing circumstances. The predictability of the multiple regression approach was found to be more than 90% for all the responses which highlights model significance. The direct and interaction effect were studied and discussed in details for all the responses. The values of the composite desirability achieved in all the three types of optimization problems were on higher side (0.813, 1 and 0.794). The results of the optimization were confirmed by conducting the experiments the optimized settings. The percentage error between experimental and RSM predicted result was found to be within acceptable limits. This study can be helpful for reducing the energy consumption and cutting temperature without compromising on surface roughness, in the machining of medium carbon steel.

Keywords End milling · Energy consumption · Energy efficiency · Power factor · Cutting temperature · Predictive modelling · Multi-objective optimization

Abbreviations

ANOVA	Analysis of variance
CE	Cutting energy
CCD	Central composite design
CCRD	Central composite rotatable design
DoE	Design of experiment
EE	Energy efficiency
F	Feed rate
GA	Genetic algorithm
H	Helix angle
MRR	Material removal rate
N	Spindle speed
NSGA-II	Non-dominated sorting genetic algorithm-II
PF	Power factor

✉ N. L. Bhirud
niteenbhirud@gmail.com

A. S. Dube
anildube100@gmail.com

Amit S. Patil
amitpatil36@hotmail.com

K. S. Bhole
kiran_bhole@spce.ac.in

1 Department of Mechanical Engineering, Sandip Institute of Engineering and Management, Nashik, affiliated to Savitribai Phule University of Pune, Pune, Maharashtra, India

2 Department of Mechanical Engineering, Sardar Patel College of Engineering, Andheri, Mumbai 400058, India

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