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Optimizing abrasive water jet milling of alumina ceramics with RBF neural networks

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A B S T R A C T

Abrasive water jet technology is an advanced machining method that combines high-pressure water jet with solid abrasives. Owing to its unique cold-processing characteristics, high flexibility, and environmental bebefits, it has been widely applied in aerospace, medical devices, microelectronics, defense and other fields. Focusing on alumina ceramic plates, this study systematically investigates abrasive water jet (AWJ) milling through an integrated experimental and modeling approach. The research framework consists of three main phases: the development of an experimental design for abrasive water jet milling of alumina ceramics; systematic parameter optimization using single-factor and orthogonal array experiments, with material removal rate and milling depth as key performance indicators; and the application of a radial basis function (RBF) neural network model for milling depth prediction. The experimental results demonstrate that optimal parameter combinations improve machining efficiency by 38 % compared to baseline conditions. The developed RBF model achieves exceptional predictive accuracy, with maximum absolute and relative errors of 0.30 mm and 18.8 %, respectively, and a mean absolute error of 12.01 % across validation trials. This work provides a theoretical foundation for precision machining of advanced ceramics while demonstrating a viable pathway toward intelligent process optimization in AWJ technology.

A R T I C L E   I N F O

Keywords:
Abrasive water jet (AWJ);
Milling;
Alumina ceramic;
Precision machining;
Material removal rate;
Single-factor experiment;
Orthogonal array;
RBF neural network

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Izvirni znanstveni članek

Optimizacija rezkanja aluminijevega oksida z abrazivnim vodnim curkom z uporabo nevronskih mrež RBF

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POVZETEK

Tehnologija abrazivnega vodnega curka je napreden postopek obdelave, pri katerem se za odstranjevanje materiala uporablja visokotlačni vodni curek z dodanimi abrazivnimi delci. Zaradi lastnosti hladne obdelave, visoke prilagodljivosti in okoljskih prednosti se pogosto uporablja v različnih industrijskih panogah, zlasti v letalski, medicinski, mikroelektronski in obrambni industriji. Prispevek obravnava rezkanje keramičnih plošč iz aluminijevega oksida z abrazivnim vodnim curkom (AWJ) z eksperimentalnim in modelirnim pristopom. Raziskava obsega tri glavne faze. Prva faza zajema zasnovo eksperimentalnega načrta za rezkanje aluminijeve oksidne keramike z abrazivnim vodnim curkom. Druga faza vključuje sistematično optimizacijo procesnih parametrov z uporabo enofaktorskih in ortogonalnih eksperimentov, pri čemer sta kot ključna kazalnika učinkovitosti uporabljena hitrost odstranjevanja materiala in globina rezkanja. Tretja faza obsega uporabo modela nevronske mreže z radialnimi baznimi funkcijami (RBF) za napoved globine rezkanja. Rezultati eksperimentov kažejo, da optimalne kombinacije procesnih parametrov v primerjavi z izhodiščnimi pogoji povečajo učinkovitost obdelave za 38 %. Razvit model RBF dosega visoko napovedno natančnost. Največja absolutna napaka znaša 0,30 mm, največja relativna napaka 18,8 %, povprečna absolutna napaka pri validacijskih preizkusih pa 12,01 %. Prispevek predstavlja teoretično osnovo za natančno obdelavo naprednih keramik in prikazuje izvedljivo pot k inteligentni optimizaciji procesov s tehnologijo abrazivnega vodnega curka.

PODATKI O ČLANKU

Ključne besede:
Abrazivni vodni curek (AWJ);
Rezkanje;
Keramika iz aluminijevega oksida;
Natančna obdelava;
Hitrost odstranjevanja materiala;
Enofaktorski eksperiment;
Ortogonalni eksperimentalni načrt;
Nevronska mreža z radialnimi baznimi funkcijami (RBF)

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