



A novel machining parameter driven modeling method for 3D rough surface on vibrating finishing

Hao Zhang¹ · Wen Shao¹ · Jinyuan Tang¹ · Xin Li¹ · Jiling Chen¹

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Abstract

Accurate modeling of submicron-scale rough surfaces based on machining parameters represents the forefront of precision manufacturing. Currently, there is limited research on precisely modeling the three-dimensional topography resulting from vibration finishing processes. This study explores a novel method for modeling rough surfaces in vibration finishing, focusing on a roller as the subject of investigation. The approach considers the elastic and plastic deformation principles of discrete random abrasive particles impacting the workpiece surface. By knowing the normal and tangential velocities of the abrasive particles relative to the workpiece, along with material parameters of both the abrasive particle and workpiece, quantitative formulas are derived. These formulas estimate the depth of permanent deformation caused by individual abrasive particle impacts and calculate the number of particles involved within a specified machining time. The cumulative effect of all particle impacts yields the final three-dimensional surface morphology. Experimental validation is conducted using a roller post-shot peening, comparing its surface morphology before and after processing. The study finds a mere 8.65% average error between the predictive model and experimental results, affirming the model's efficacy. Furthermore, the influence of abrasive particle diameter and workpiece surface hardness on roughness is analyzed. The three-dimensional topography prediction model proposed in this paper can effectively improve the control ability of vibration finishing process, which has positive guiding significance for production practice.

Keywords Roller · Vibration finishing · Elastic–plastic deformation · Surface topography · Predictive modeling

Nomenclatures

m	Mass of abrasive particles (kg)	E_1	Elastic modulus of particle material
ρ	Density of the particles (kg/m ³)	E_2	Elastic modulus of workpiece material
R	Radius of the particles (mm)	v_{y0}	Initial normal velocity of the particles when it hits the workpiece (m/s)
$v_{y-crit-pla}$	Critical normal velocity at which the abrasive particles impact the surface of the workpiece to produce permanent plastic deformation (m/s)	λ_{max-el}	Maximum crater depth during the elastic deformation phase (mm)
$\lambda_{crit-pla}$	Critical impact crater depth at which plastic deformation occurs (mm)	$P(r)$	Pressure distribution in the vertical direction (MPa)
F_{ela}	Normal contact force between abrasive grain and workpiece during elastic deformation stage (N)	σ	Radius of impact crater (mm)
ν_1	Poisson's ratio of particle material	P_0	Maximum pressure between abrasive grains and workpiece (MPa)
ν_2	Poisson's ratio of the workpiece material	λ_{ela}	Maximum crater depth during the elastic deformation phase (mm)
		σ_y	Yield limit of the workpiece material (MPa)
		$\lambda_{crit-pla}$	Critical crater depths in the elastic and plastic deformation stages (mm)
		$v_{y-crit-pla}$	Critical normal impact velocity of abrasive particles impacting the workpiece when plastic deformation occurs (m/s)

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