國立交通大學
機械工程學系
碩士論文

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Abstract

Micro drilling tool plays an extremely important role in many processes such as the printed circuit board (PCB) manufacturing process, machining of plastics and ceramics. The improvement of cutting performance in tool life, productivity and hole quality is always required in micro drilling.

In this research, a dynamic model of micro-drill tool is optimized by the interior-point method. To achieve the main purpose, the finite element method (FEM) is utilized to analyze the coupled lateral and torsional micro-drilling spindle system with the gyroscopic effect. The Timoshenko beam finite element with five degrees of freedom at each node is applied to perform dynamic analysis and to improve the accuracy of the system containing cylinder, conical and flute elements. Moreover, the model also includes the effects of continuous eccentricity, the thrust, torque and rotational inertia during machining. The Hamilton's equations of the system involving both symmetric and asymmetric elements were progressed. The lateral and torsional responses of drill point were figured out by Newmark's method.

The aim of the optimum design is to find some optimum parameters, such as the diameters and lengths of drill segments to minimize the lateral amplitude response of the drill point. Nonlinear constraints are the constant mass and mass center and harmonic response of the drill. The FEM code and optimization environment are implemented in MATLAB to solve the optimum problem.

Keywords: Finite element analysis, Nonlinear constrained optimization, Micro-drill spindle, Gyroscopic effect

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Nomenclature

E,G	Young's modulus, Shear modulus
C_{ij}, C_{φ}	Damping coefficient and torsional damping of bearing; i, j= x, y
I_{av}, Δ	Mean and deviatoric moment of area of system element
I_p	Polar moment of area of system element
I_u, I_v	Second moments of area about principle axes U and V of system element
k_s	Transverse shear form factor
K_{ij}, K_{φ}	Stiffness coefficient and torsional stiffness of bearing; i, j= x, y
L, A, ρ	Length, are and density of system element element
F_z, T_q	Thrust force and torque
N_t, N_r, N_s	Shape functions of translating, rotational and shear deformation displacements, respectively
z	Axial distance along system element element
T, P, W	Kinetic, potential energy and work
q	DOF vector od fixed coordinates
(u, v)	Components of the displacement in U and V axis coincident with principal axes of system element
(x,y)	Components of the displacement in X and Y in fixed coordinates
γ_u, γ_v	Shear deformation angles about U and V axes, respectively
γ_x, γ_y	Shear deformation angles about X and Y axes, respectively
e_u, e_v	Mass eccentricity components of system element in U and V axes
θ_u, θ_v	Angular displacements about U and V axes, respectively
θ_x, θ_y	Angular displacements about U and V axes, respectively
Φ	Spin angle between basis axis and X about Z axis
ϕ, θ, ψ	Euler's angles with rotating order in rank
Ω	Operating speed
φ	Torsional deformation

Subscript and Superscript

{.}, {'}	To be referred to as derivatives of time and coordinate
s, c, f	Superscript for cylinder, conical, flute element
t	Superscript for transpose matrix

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