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Effect of Tool Rotation Erroron the Topography of Flank Machined Surface

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Abstract

In the flank milling process, processed metal surface is formed by the edge of the cutting tool and affected by errors of it in the manufacturing process. Among those errors, the error of tool rotation movement has the most significant effect on machined surface. This article focuses on the machining process influenced by cutting tool rotation errors in the NC machining process. In this paper, a mathematical model of machining process is built. The effect of tool offset error and tool tilt error on tool deflection error is studied. A method of detecting tool rotation errors through machined surface topography is presented in the paper.

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Keywords: flank milling; tool rotation error; surface topography, error detection

1. Introduction

In order to reduce the error of the machined surface, many researchers optimize tool path to avoid over cut and under cut.[11-12]

In order to reduce the deformation error of the machining process, many researchers study the machining force and error compensation strategy. [13-15]

In recent years, more and more researchers began to study how tool rotation errors affect machined surface errors. Liang Yu et al. studied the machined surface formed by specially designed cutting edge under cutter offset error. [16] Can Liu et al. proposed a new idea of identifying tool eccentricity and wear with force [17].P． franco et al. modeled Final part surface roughness from tool offsets and height deviations that affect the surface marks provoked by back cutting.[18] Miguel Arizmendi et al. studied a new model to predict the effects of tool parallel axis offset error and cutter axis tilt on the topography of machined surface in flank milling process.[19-21] Dong Yang and Zhanqiang Liu proposed a corresponding surface generation model to predict the generated surface topography.[22] Eduardo Diez et al. studied a methodology to evaluate tool offset in peripheral milling by using a piezoactuator-based system. [23]

The author studied the influence of cutting tool offset error and tilts error on cutting force and machined surface. In section 2, a machining process model was built. In section 3, the cutting force and the tool deflection model influenced by tool rotation errors are researched. Section 4 is the simulation result and discussion of the milling process model. section 5 is a way to measure tool rotation errors through machined surface topography.

2. Trajectory of tool edge influenced by tool rotation errors

Tool rotation errors are the errors in the tool rotation movement in machining processes. Tool rotation errors may have multiple sources; all these sources cause two errors of tool rotating movement: offset error and tilt error.

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Fig. 1, shows how the tool rotation errors affect tool rotating motion. The offset of tool causes the tool to rotate around the revolving axle instead of its own axle, which causes the difference of tool tip trajectory compared with the ideal one.

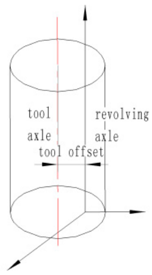

Fig. 1. Tool offset error

The influence of tool tilt on tooth tip trajectory is decided by two parameters. The first parameter is the tilt angle θ, which is the magnitude of tool tilt error. Another parameter is the angle ε that shows the position of tool tilt error. Fig. 2shows the rotating axis, tool axis, tool offset and tilt error.

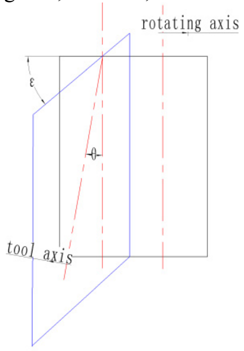

Fig. 2. Tool offset and tilt error

Fig. 3. shows the real radius of the first tool tip influenced by both tool offset error and tilt error.

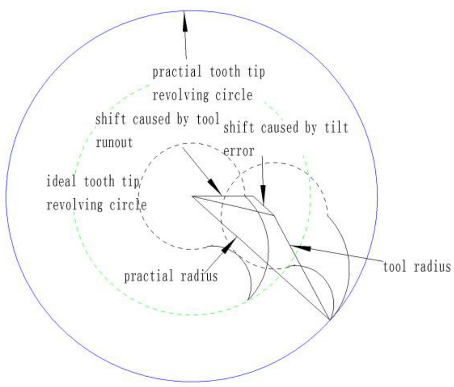

Fig. 3. Tool offset and tilt error

$$R_{r,i,z}=\left\{d_z^{\,2}+r^2+2d_z r\cos[a_{i,z}+\frac{z\times\tan\beta}{r}+2\pi(i-1)/n]\right\}^{1/2} \tag{1}$$

$$d_z=\sqrt{d^2+[(h-z)\tan\theta]^2+2d[(h-z)\tan\theta]\cos\varepsilon} \tag{2}$$

$$a_{i,z}=[a-\Delta a+\frac{z\times\tan\beta}{r}+2\pi(i-1)/n] \tag{3}$$

$$\Delta a=\frac{\tan^{-1}\{(h-z)\tan\theta]sin\varepsilon}{[(h-z)\tan\theta]cos\varepsilon+d]} \tag{4}$$

Where d is the total offset error at height 0, r is tool radius, a is the total offset angle at height 0; h is the length of tool, ω is tool Angular velocity, θ is tool helix angle, $x_{i,z,t}$ and $y_{i,z,t}$ is the coordinate of ith tooth tip at height z and time t; $a_{i,z}$ is the practical offset direction angle at height z.

3. Cutting force and tool deflection influenced by tool rotation errors

To calculate the tool deflection error $\delta_x(z)$and $\delta_y(z)$, the cutting force must be calculated first.

Previous study shows the cutting force of tool's infinitesimal element at height z can be calculate through chip thickness.[24] To, calculate chip thickness h, cutting Cutting start angle $\varphi_{imin}(z)$ and maximum chip thickness angle $\varphi_{hmin}(z)$ are needed.

$$h_i(\varphi_i(z))=R_{r,i,z}-\sqrt{[S_1+S_2]^2+S_3} \tag{5}$$

$$S_1=R_{r,j,z}\sin(\varphi-\frac{(i-j)f_n cos\varphi}{\left(R_{r,j,z}+\frac{Nf_n}{2\pi}\cos\varphi\right)}+\sigma_i) \tag{6}$$

$$S_2=v\times\left(-\frac{2(i-j)\pi}{N\omega}-\frac{(i-j)f_n cos\varphi}{\omega\left(R_{r,j,z}+\frac{Nf_n}{2\pi}\cos\varphi\right)}\right) \tag{7}$$

$$S_3=\left[R_{r,j,z}\cos\left(\varphi-\frac{(i-j)f_n cos\varphi}{\left(R_{r,j,z}+\frac{Nf_n}{2\pi}\cos\varphi\right)}+\sigma_i\right)\right]^2 \tag{8}$$

Where σ_i is the starting phase angle of the ith cutter tooth tip.