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指狀銑刀安裝偏差對真空泵螺桿轉子加工精度影響之研究

A Study on Influence of Finger-Shaped Milling Tool Offsets on Machining Accuracy of Vacuum Pump Screw Rotors

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摘 要

螺桿轉子之加工精度對雙螺桿真空泵之內部流體洩漏及工作性能有極大影響，在實務中，利用指形銑刀進行螺桿轉子之成形銑削是常用的加工方法之一，然而，如何利用加工機台上刀具偏移的方式，降低及控制因刀具磨耗所造成之轉子線形加工誤差，使符合精度要求，至今甚少文獻進行研究及探討。故本文基於具間隙之轉子線形離散點資料創生指形銑刀廓形並建立數學模型，透過建立傳統數控銑床上刀具與被加工轉子間之相對運動關係，進行加工模擬並研究指形銑刀偏移後之轉子線形加工偏差，其中，包括三個線性及兩個角度之刀具偏移量。此外，本研究亦應用敏感度矩陣(Sensitivity Matrix)法結合奇異值分解(SVD)求解可行的刀具偏移組合，以達到所需之轉子線形加工精度。由數值案例之結果，可證實本文所提方法可以有效降低轉子線形之加工誤差。

關鍵詞：成形銑削、刀具偏移、敏感度矩陣、SVD、真空泵、加工精度

Abstract

Manufacturing accuracy of a pair of screw rotors greatly affects the performance of a twin-screw vacuum pump. In the practical application, form milling with the finger-shaped cutting tools is one of the commonly used ways to manufacture the screw rotors. Nevertheless, how to reduce and control the rotor profile error, caused by the tool abrasion, by means of the adjustment of cutting tool offsets on the CNC milling machine has not been studied by now. Therefore, the mathematical model is presented to generate the finger-shaped cutting tool profile based on the discrete rotor profile points with clearance. Next, the relative motion relationship between the cutting tool and the screw rotor on a traditional milling machine with the tool offsets is established to pursue the cutting simulation and study the manufactured rotor profile deviation with respect to different milling tool offsets, including three linear and two angular offsets. In addition, the sensitivity matrix method combined with the singular value decomposition (SVD) is applied to obtain a feasible combination of tool offsets to achieve the desired rotor profile accuracy. As the results shown in the numerical examples, it has been validated that the manufacturing accuracy of rotor profile can be reduced by applying the proposed method.

Keywords: form milling, tool offset, sensitivity matrix, SVD, vacuum pump, manufacturing accuracy

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Thi-Xuyen Bui

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Table of Contents

List of Figures

List of Tables

Nomenclature

Symbols	Explanations	Units
2D	two-dimensional	-
3D	three-dimensional	-
β_p	pitch helix angle of rotor	degree
Δx	tangential tool offset	mm
Δy	radial tool offset	mm
Δz	axial tool offset	mm
E_t	center distance between tool and rotor	mm
γ_w	tilt angle	rad
HPMS	Holroyd profile management system	-
φ_r	rotational angle of rotor	degree
L_d	screw lead	mm
L_t	axial movement of rotor	mm
r_d	inner radius of rotor	mm
r_p	pitch radius of rotor	mm
R_c	transverse radius of tool	mm
$S_i(x_i, y_i, z_i)$	coordinate system of i	-

Symbols	Explanations	Units
SVD	singular value decomposition	-
ξ	approach angle	rad
ψ	wrap angle of rotor	degree