光学 精密工程
OPTICS AND PRECISION ENGINEERING
核心期刊
主管：中国科学
主办：中国科学
中国仪器
主编：曹健林

光学精密工程 2013, 21(6) 1479-1487 ISSN: 1004-924X CN: 22-1198/TH

微纳技术与精密机械

形位不确定回转腔体内壁表面的打磨

王菲,罗忠,柳洪义

东北大学 机械工程与自动化学院

摘要： 提出一种基于逆向工程和阻抗力控制的打磨方法来实现形位、刚度不确定回转腔体内壁表面的精确打磨操作。采用准在线激光测量方对形位不确定回转腔体内壁表面进行粗、精测量，提取纵截线簇数据，处理后重构内壁曲面。联合阻抗力控制和智能控制方法，提出参考轨迹的模糊调节算法；采用激光探测内壁曲面信息计算参考轨迹，根据接触环境刚度变化，建立模糊调节规则；通过调节因子对当前控制周期的参考轨迹变化量进行调整，使机械手打磨头在回转腔体内具有柔顺控制能力，实现对形位、刚度不确定回转腔体内壁表面的精确打磨。搭建了机器人激光测量与打磨开放式试验平台，进行了力控制打磨试验研究。试验结果表明：采用准在线纵截线激光预测与测量，重构曲面模型的相对平均误差小于0.024%；采用模糊调节力控制算法对固体火箭发动机壳体绝热层内表面进行打磨，目标打磨深度为0.200 mm时，打磨正压力相对误差小于±5%，回转腔体内表面打磨深度的相对平均误差为6.5%。结果显示所提方法可实现对具有复杂回转腔体内壁表面的精确打磨

关键词： 逆向工程 阻抗力控制 打磨 模糊控制 机器人 回转腔体

Grinding control of rotary shell′s inner-surface with dynamics uncertainties

WANG Fei,LUO Zhong,LIU Hong-yi

School of Mechanical Engineering and Automation, Northeastern University

Abstract: A force control method based on reverse engineering and an impedance model was proposed for the robot grinding in a kind of rotary shell′s inner surface with dynamic uncertainties. Using quasi-online laser measuring approach, the coarse and precise measuring processes were implemented for inner surface with longitudinal curve data and the 3D model of the rotary shell′s inner-surface was reconstructed. Combining an impedance controller wi an intelligent control method, the algorithm of the reference trajectory of fuzzy adjusting was adopted. In virtue of th environmental geometry using laser measuring, the reference trajectory was accounted. According to the environmental change in stiffness, a fuzzy logic controller was used for adjusting the scale factor in sampling time. A robotic open architecture platform with force control was set up for laser measuring and grinding process. The force tracking experiments for inner-surface with dynamics uncertainties were performed. The experimental results show that the mean absolute difference rate of the model is less than 0.024% with laser measuring. The inner wall surface of a solid rocket engine was chosen for grinding experiment, and experimental results indicate that the mean absolu difference rate of force tracking is less than 5% and the difference rate of grinding depth is within 6.5% with setting depth of grinding of 0.200 m. These results prove the validity of the proposed method.

Keywords: Reverse engineering Impedance force control Grinding Fuzzy logic Robot manipulator Rotary shell

收稿日期 2012-12-25 修回日期 2013-02-05 网络版发布日期 2013-06-20

基金项目:

旋转结构件模型试验的动力学相似理论及其应用技术;转子-轴承系统模型试验的动力学相似理论与应用

通讯作者: 王菲

作者简介: 王菲(1981-)，女，山西晋中人，博士研究生，讲师， 2003年、2006年于东北大学分别获得学士、硕士学位，主要从事智能控制理论、机器人技术方面的研究。
作者Email: feiwang@mail.neu.edu.cn

参考文献：

[1]MASON M T. Compliance and force control for computer controllered manipulators[J]. IEEE Transactions on Systems Man and Cybernetics, 1981,11(6):418-432. [2]ROBERTSSON A, OLSSON T, JOHANSSON R, et al.. Implementation of industrial robot force control case study: high power stub grinding and deburring[J]. Intelligent Robots and Systems, Proceedings of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems, Beijing, 2006, 2743-2748. [3]MINAMI M, XU W W. Shape-grinding by direct position / force control with on-line constraint estimation [J]. International Conference on Intelligent Robots and Systems, 2008:943-948. [4]HAMELIN P, BIGRAS P, BEAUDRY J, et al.. Discrete-time state feedback with velocity estimation using a dual observer: application to an underwater direct-drive grinding robot[J]. IEEE/ASME Transactions on Mechatronics, 2012, 17(1):187-191. [5]LI ZH J, YANG Y P, LI J X. Adaptive motion/force control of mobile under-actuated manipulators with dynamics uncertainties by dynamic couplin and output feedback[J]. IEEE Transactions on Control Systems Technology, 2010, 18(5):1068-1079. [6]SONG Y X, LV B, YANG Z H. An adaptive modeling method for a robot belt grinding process[J]. IEEE/ASME Transactions on Mechatronics, 2012, 17(2):309-317. [7]KLINE W A, DEVOR R E, LINDBERG J R. The prediction of cutting forces in end milling with application to cornering cuts [J]. International Journal of Machine Tool Design and Research, 1982, 22(1): 22. [8]DOULGERI Z, KARAYIANNIDIS Y. Force/position regulation for a robot in compliant contact using adaptive surfac slope identification [J]. IEEE Transactions on Automatic Control, 2008, 53(9):2116-2122. [9]VANDERBORGHT B, SUGER T, LEFBER D. Adaptable compliance or variable stiffness for robotic applications [J]. IEEE Robotics & Automation Magazine, 2008: 8-9. [10]言兰, 姜峰, 融亦鸣. 基于数值仿真技术的单颗磨粒切削机理[J]. 机械工程学报, 2012, 48(11):172-182. YA

L, JIANG F, RONG Y M. Grinding mechanism based on single grain cutting simulation [J]. Journal of Mechanical Engineering, 2012, 48(11):172-182. (in Chinese) [11]KONG L Y，YAN Q SH，SONG J H. Research on uniform surface roughness in grinding of revolving curved surface[J]. Key Engineering Materials, 2009, 416:113-117. [12]MOLLEDA J, USAMENTIAGA R, GARCIA D F, et al.. Shape measurement of steel strips using a laser-based three-dimensional reconstruction technique [C]. IEEE, 2011, 47(4):1536-1544. [13]王欣, 张明明, 于晓, 等. 应用改进迭代最近点方法的点云数据配准[J]. 光学 精密工程, 2012, 20(9):2068-2077. WANG X, ZHANG M M, YU X, et al.. Point cloud registration based on improved iterative closest point method[J]. Opt. Precision Eng., 2012, 20(9):2068-2077. (in Chinese) [14]张玉香, 张兴
采用激光扫描点云拟合自由曲面的重构特性研究[J]. 激光与红外, 2011, 41(3):351-355. ZHANG Y X, ZHANG X J. Study on reconstruction property of free surface fitting for point clouds with laser scanning [J]. Laser & Infrared, 2011, 41(3):351-355. (in Chinese) [15]冯肖维, 何永义, 方明伦, 等. 应用特征估计的距离图像多尺度滤波[J]. 光学 精密工程, 2011, 19(5):1118-1125. FENG X W, HE Y Y, FANG M L, et al.. Multi-scale smoothing of noisy ranges image using feature estimation [J]. Opt. Precision Eng., 2011, 19(5):1118-1125. (in Chinese) [16]LIU H Y, WANG L, WANG F. Fuzzy force control of constrained robot manipulators based on impedance model in unknown environment [J]. Frontiers of Mechanical Engineering, China, 2007, 2(2):168-174. [17]王菲, 罗忠, 柳洪义. 一种形位不确定回转壳体内壁表面的激光测量与重构方法研究[J]. 光子学报, 2013, 42(1):59-63. WANG F, LUO ZH, LIU H Y. Laser measurement and reconstruction method research for a kind of rotary shell’s inner-surface with uncertain configuration [J]. Acta Photonica Sinica, 2013, 42(1):59-63.

本刊中的类似文章

1．王丽佳 贾松敏 王爽 李秀智.采用改进Mean Shift算法的移动机器人行人跟踪[J]. 光学精密工程, 2013,21(9): 2364-2370

2．Sergej Fatikow.纳米操纵机器人及其自动化设计[J]. 光学精密工程, 2013,21(4): 919-926

3．熊根良 陈初海 梁发云 董增文.物理性人-机器人交互研究与发展现状[J]. 光学精密工程, 2013,21(2): 356-370

4．王欣, 张明明, 于晓, 章明朝.应用改进迭代最近点方法的点云数据配准[J]. 光学精密工程, 2012,20(9): 2068-2077

5．徐逢秋, 许贤泽, 乐意, 李忠兵.基于模糊控制的快速自动安平激光扫平仪[J]. 光学精密工程, 2012,(8): 1870-1876

6．陈雯雯, 颜国正, 高鹏, 王志武.结肠诊疗微机器人控制系统的设计和实现[J]. 光学精密工程, 2012,20(6): 1296-1302

7．魏明生, 童敏明, 訾斌, 夏静, 陆阳.管道机器人无线电磁自适应定位技术[J]. 光学精密工程, 2012,20(4): 772-781

8．高鹏, 颜国正, 王志武, 姜萍萍, 刘华.肠道微机器人柔性运动系统[J]. 光学精密工程, 2012,20(3): 541-549

9．梁帆, 孟晓风, 董登峰.心脏动脉旁路手术中手术辅助机器人的模型跟随控制[J]. 光学精密工程, 2012,20(1): 131-139

10．魏振忠, 张博, 张广军.双机器人系统的快速手眼标定方法[J]. 光学精密工程, 2011,19(8): 1895-1902

11．郑继贵, 郭磊, 刘常杰, 林嘉睿, 叶声华.基于机器人的柔性电子检具测量系统[J]. 光学精密工程, 2011,19(8): 1787-1793

12．褚金奎, 陈文静, 王洪青, 戎成功.基于偏振光传感器的移动机器人导航实验[J]. 光学精密工程, 2011,19(10): 2419-2426

13．崔冰艳, 金振林.基于正交机构的机器人肩关节静力学分析与结构参数设计[J]. 光学精密工程, 2011,19(1): 77-82

14．卢科青，，王文，，陈子辰，.

点激光测头激光束方向标定

[J]. 光学精密工程, 2010,18(4): 880-886

15．聂林;陈伟;李德胜;郭书祥.等离子高分子导电薄膜的微型机器鱼图像分析[J]. 光学精密工程, 2009,17(6): 1316-1321