光学精密工程 OPTICS AND PRECISION ENGINEERING
Ei 核心期刊
主管：中国科学院
主办：中国科学院长春光学精密机械与物理研究所
中国仪器仪表学会
主编：曹健林

光学精密工程 2013, 21(3) 680-686 ISSN: 1004-924X CN: 22-1198/TH

微纳技术与精密机械

光学材料磨削亚表面损伤预测

吕东喜[1],王洪祥[1,2],黄燕华[2,3]

1. 哈尔滨工业大学 机电工程学院
2.
3. 中国工程物理研究院 激光聚变研究中心

摘要： 基于压痕断裂力学理论，建立了工件表面粗糙度与亚表层损伤深度的理论关系模型，用于预测磨削加工脆性光学材料引起的亚表层损伤深度。利用磁流变角度抛光技术检测了不同磨削加工工艺条件下亚表层的损伤深度，验证了理论模型的正确性。分析了加工工艺参数对工件表面粗糙度及亚表层损伤深度的影响规律，提出了提高材料去除率的磨削加工工艺方案。分析结果表明：脆性材料工件的亚表层损伤深度与工件的表面粗糙度呈非线性单调递增关系。工件亚表层损伤深度及工件表面粗糙度均随着切削深度和进给速度的增加而增加，随着主轴转速的增加而减小。对比实验结果与理论模型预测结果表明，提出的模型可以准确、无损伤地的预测磨削加工引起的工件亚表层损伤深度。

关键词： 脆性材料 磨削 压痕 磁流变抛光 表面粗糙度 亚表层损伤

Prediction of grinding induced subsurface damage of optical materials

LV Dong-xi[1],WANG Hong-xiang[1,2],HUANG Yan-hua[2,3]

1. School of Mechanical and Electrical Engineering, Harbin Institute of Technology
2.
3. Research Center of Laser Fusion, China Academy of Engineering Physics

Abstract: On the basis of indentation fracture mechanics, a theoretical model was developed to evaluate the relationship between surface roughnesses (SRs) and Subsurface Damage Depths (SSDs) of brittle optical materials and to predict their grinding induced SSDs. For validating the feasibility of this method, the SSDs generated with various process parameters were measured by Magnetorheological Finishing (MRF) wedge technique. The influences of processing parameters on the SRs and SSDs were investigated, and a process strategy was also proposed to improve the material removal rate. The prediction results of this theoretical model show that the SSDs are nonlinear monotone increasing with the square of SR values during grinding processes. The SSDs and SRs increase with the increasing of cutting depth and feed rate, while reduce with the increasing of spindle speed. The measurement results of SSDs are consistent with the prediction values of the model, which demonstrates the feasibility of utilizing this model to accurately and non-destructively predict the SSDs.

Keywords: brittle optical material grinding indentation magnetorheological finishing (MRF) surface roughness subsurface damage

收稿日期 2012-07-19 修回日期 2012-09-14 网络版发布日期 2013-03-20

基金项目:

通讯作者: 吕东喜

作者简介: 吕东喜(1983-)，男，河北沧州人，博士研究生，2007年于燕山大学获得学士学位, 2009年于哈尔滨工业大学获得硕士学位，主要从事精密磨削及超声加工方面的研究。
作者Email: dongxi_lv@yahoo.com

参考文献:

[1]LI S, WANG Z, WU Y. Relationship between subsurface damage and surface roughness of optical materials in grinding and lapping processes [J]. Journal of Materials Processing Technology，2008, 205: 34-41. [2]LI Y, ZHENG N, LI H, et al.. Morphology and distribution of subsurface damage in optical fused silica parts: Bound-abrasive grinding [J]. Applied Surface Science，2011, 257: 2066-2073. [3]王卓, 吴宇列, 戴一帆,等. 光学材料研磨亚表面损伤的快速检测及其影响规律[J]. 光学 精密工程，2008，16(1): 16-21. WANG ZH, WU Y L, DAI Y F, et al.. Rapid detection of subsurface damage of optical materials in lapping process and its influence regularity [J]. Opt. Precision Eng.，2008, 16(1): 16-21. (in Chinese) [4] WANG J, LI Y, HAN J, et al.. Evaluating subsurface damage in optical glasses [J]. Journal of the European Optical Society-Rapid Publications，2011, 6:1-16. [5]NEAUPORT J, AMBARD C, CORMONT P, et al.. Subsurface damage measurement of ground fused silica parts by HF etching techniques [J]. Optical Express，2009, 17: 20448-20456. [6] MALKLN S, HWANG T W, Grinding mechanisms for ceramics [J]. Annals of the CIRP，1996, 45(1):569-580. [7]LIU D F, CONG W L, PEI Z J, et al.. A cutting force model for rotary ultrasonic machining of brittle materials [J]. Journal of Machine Tools & Manufacture，2012, 52: 77-84. [8]GU W, YAO Z. Evaluation of surface cracking in micron and sub-micron scale scratch tests for optical glass BK7 [J]. Journal of Mechanical Science and Technology，2011, 25(5): 1167-1174. [9] LAWN B R, SWAIN M V. Microfracture beneath point indentations in brittle solids [J]. Journal of Materials Science，1975, 10(1): 113-122. [10]LAWN B R, EVANS A G, MARSHALL D B. Elastic/plastic indentation damage in ceramics: the median/radial crack system [J]. Journal of the American Ceramic Society，1982, 63(9-10): 574-581. [11] LAMBROPOULOS J C, JACOBS S D, RUCKMAN J. Material removal mechanisms from grinding to polishing [J]. Journal of American Ceramic Society，1999, 102: 113-128. [12]MAHMOUD T, TAMAKI J, YAN J. Three-dimensional shape modeling of diamond abrasive grains measured by a scanning laser microscope [J]. Key Engineering Materials，2003, 238/239: 131-136.

本刊中的类似文章

1. 张海峰 刘晓为 李海 陈楠.电极表面粗糙度对检测电容的影响[J]. 光学精密工程, 2013,21(9): 2266-2271
2. 荆君涛 刘运凤 李占杰 饶小双.旋转超声磨削加工中影响磨具寿命的结构参数优化[J]. 光学精密工程, 2013,21(4): 972-979
3. 吴耀军 王群书 叶锡生 唐传祥 林新伟 吴丽雄.周期和随机分量叠加而成粗糙表面的激光散射[J]. 光学精密工程, 2013,21(3): 546-553
4. 孟艳丽 李达 陈波.光学表面X射线异常散射现象[J]. 光学精密工程, 2013,21(2): 253-259
5. 刘运凤, 荆君涛, 李占杰.旋转超声磨削加工中刀具结合剂类型与加工性能的关系[J]. 光学精密工程, 2012,20(9): 2021-2028
6. 宋洪侠, 赵苏苏, 娄志峰, 王立鼎.降低齿轮齿距累积偏差的方法[J]. 光学精密工程, 2012,(8): 1796-1801
7. 戴欣平, 赵萍, 文东辉.单晶蓝宝石的延性研磨加工[J]. 光学精密工程, 2012,20(6): 1316-1324
8. 林滨, 张彦斌, 陈善功.基于非负矩阵分解算法的工程陶瓷磨削表面损伤检测[J]. 光学精密工程, 2012,20(11): 2459-2464
9. 陈晓苹, 谢京江, 宋淑梅.提高玻璃表面强度的材料去除模式[J]. 光学精密工程, 2011,19(6): 1256-1264
10. 寇淑清, 王金伟, 郑祺峰, 杨慎华.曲轴轴承座/连杆激光加工裂解槽的组织与胀断性能[J]. 光学精密工程, 2011,19(4): 768-774
11. 杨林, 郑贤良, 陈波.基于反射镜表面粗糙度计算极紫外望远镜分辨率[J]. 光学精密工程, 2011,19(11): 2565-2572
12. 宋 辞, 戴一帆, 彭小强, 石 峰.光学镜面磁流变抛光的后置处理[J]. 光学精密工程, 2010,18(8): 1715-1721
13. 仇中军, 周立波, 房丰洲, 椎名刚志, 江田弘.石英玻璃的化学机械磨削加工[J]. 光学精密工程, 2010,18(7): 1554-1561
14. 凌四营,王立鼎,马勇,王晓东,娄志峰.大平面砂轮磨削面锥形误差对齿轮螺旋线偏差的影响[J]. 光学精密工程, 2010,18(3): 630-637
15. 杜立群.UV-LIGA和微细电火花加工技术组合制作三维金属微结构的研究[J]. 光学精密工程, 2010,18(2): 363-368