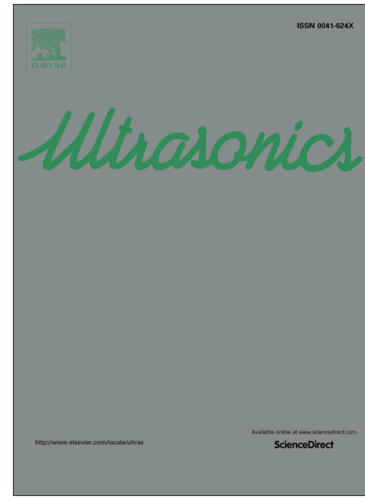
Accepted Manuscript



A Novel Ultrasonic Surface Machining Tool Utilizing Elastic Traveling Waves

Ruinan Ji, Jiamei Jin, Liang Wang, Jianhui Zhang

PII: S0041-624X(17)30117-8
DOI: http://dx.doi.org/10.1016/j.ultras.2017.05.001
Reference: ULTRAS 5531

To appear in: *Ultrasonics*

Received Date: 7 February 2017
Revised Date: 25 April 2017
Accepted Date: 2 May 2017

Please cite this article as: R. Ji, J. Jin, L. Wang, J. Zhang, A Novel Ultrasonic Surface Machining Tool Utilizing Elastic Traveling Waves, *Ultrasonics* (2017), doi: http://dx.doi.org/10.1016/j.ultras.2017.05.001

A Novel Ultrasonic Surface Machining Tool Utilizing Elastic Traveling Waves

Ruinan Ji[a], Jiamei Jin[a,*], Liang Wang[a], Jianhui Zhang[a,b]

[a]State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics, 29 Yudao St., Nanjing, 210016, China

[b]School of Mechanical and Electrical Engineering, Guangzhou University, Guangzhou, 510006, China

*Corresponding author, E-mail: jrn@nuaa.edu.cn; Tel:+86-159-5204-6717.

Abstract

With the rapid development of modern industrial technology and high performance technology products, ultra-precision machining technology becomes increasingly important. However, joint clearance of kinematic pairs, lack of feeding accuracy and overlarge contact stress still limit the further improvement of ultra-precision machining technology. In this study, a novel surface machining method utilizing structural elastic waves was proposed, and a machining tool using the piezoelectric actuating principle was presented for verifying the proposed method. Two vibration modes with a phase shift of π/2 in both space and time domains are exited simultaneously in the elliptical motion of points on the structural surface. By means of adjusting driving signal parameters, such as frequency, voltage amplitude and phase shift, different machining performances could be achieved. The configuration and working vibration modes of the proposed machining tool were firstly calculated by the finite element method, and then the optimal working frequency of the machining tool prototype was determined by vibration characteristic experiments. At last, machining characteristic experiments were conducted to validate the proposed machining method. Experimental results showed that the minimum working contact force between the machining tool and workpiece was 1 N, and the chipped depth of 1.93 μm was achieved at the same contact force after machining for 5 minutes. And at the conditions of the contact force of 6 N, two driving voltages of 400 V_{pp} with a phase shift of π/2, and machining time of 5 minutes, the prototype could achieve to machine the workpiece most efficiently and the roughness of the machined workpiece surface could be reached approximating 0.20 μm. In conclusion, this proposed machining method could achieve a good quality machined surface with low residual stress and little damage by applying low contact force. Furthermore, it also had the advantage of no joint clearance error due to no kinematic pair in the structure, which improves the machining precision.

Keywords: Ultrasonic; Surface machining method; Elliptical motion; Ultra-procision; Elastic traveling waves.

1. Introduction

With the rapid development of high density storage, ultra-precision optical engineering and new energy industry, the demand of full-spectrum and nano-precision for heterogeneous surface manufacturing has drastically increased. From large astronomical telescope lens to micro mechanical components, the requirements on manufacturing precision have approximated to nano-scale[1]. As a common manufacturing technology in high-tech industries, ultra-precision machining is capable of obtaining nanometric roughness surface[2]. In fact, ultra-precision machining is a growing technology based on conventional machining methods, which is also an important symbol of science, technology, and national strength of a country[3-6].

Ultra-precision machining technology has the machining accuracy of less than 0.2 μm, and the surface roughness can reach 10 nm[2]. In the early 1960s, Lawrence Livermore National Laboratory (LLNL) in USA first proposed Single Point Diamond Turning technology (SPDT) for manufacturing high precision military products[7]. Not until the 1980s, the large optics diamond turning machine was developed by the same laboratory, which is still the classic representative of ultra-precision machining. It had been used to machine optical elements of 1.4 meters in diameter, and the surface accuracy could reach 0.025 μm with surface roughness R_a of less than 5 nm[8]. During this period, the ultra-precision machine technology began to make its way into civilian areas. Owing to the development of