Optik 125 (2014) 4441–4445

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Compare study between smoothing efficiencies of epicyclic motion and orbital motion

Yong Shu, Xuqing Nie, Feng Shi*, Shengyi Li

College of Mechatronics and Automation, National University of Defense Technology, 47th Yanwachizheng Street, Changsha, Hunan 410073, China

ARTICLE INFO

Article history:
Received 6 August 2013
Accepted 12 February 2014

Keywords:
Epicyclic motion
Orbital motion
Smoothing efficiency

ABSTRACT

The smoothing efficiencies of epicyclic motion and orbital motion in CCOS (computer controlled optical surfacing) were compared. CCOS polishing can smooth out mid-to-high spatial frequency errors which are smaller than tool size on optical mirrors due to the rigidity of polishing tools. The smoothing efficiencies of epicyclic motion and orbital motion with pitch lap and RC lap were compared and the result proved pitch lap with epicyclic motion smoothed ~1.6 times faster than pitch lap with orbital motion while RC lap with epicyclic motion smoothed ~1.85 times faster than RC lap with orbital motion.
© 2014 Elsevier GmbH. All rights reserved.

1. Introduction

Modern optical systems such as giant telescopes [1] and inertial confinement fusion system like National Ignition Facility [2] put forward strict requirements about the magnitude of mid-to-high spatial frequency errors as these errors will affect the tails of the focal spot and the near-field modulation. When polishing mirrors using CCOS, it can smooth out mid-to-high spatial frequency errors due to the rigidity of polishing tools [3]. Nowadays smoothing is an important approach to control mid-to-high spatial frequency errors [4].

Based on Bridging model, Dae Wook Kim et al. built a parametric smoothing model and conducted experiments to verify the validity of the model and compare the smoothing efficiencies of pitch lap and RC lap [3]. Recently, they are working on analyzing the smoothing efficiencies of different tools (e.g. pitch lap, RC lap) under different polishing conditions (e.g. polishing pressure, rotation of pad) [5].

CCOS usually can be fulfilled by epicyclic motion or orbital motion and these two motions are all widely used during practical polishing processes. Their TIFs (tool influence function) have been established and their figuring abilities and figuring efficiencies have been analyzed elsewhere [6] but their smoothing efficiencies have not been studied yet. The comparison of smoothing efficiencies between these two motions is important for the practical smoothing process to improve smoothing efficiency. Based on the parametric smoothing model, the smoothing efficiencies of both pitch lap and RC lap with epicyclic motion and orbital motion are compared in this paper.

2. Theoretical background

2.1. Parametric smoothing model

The parametric smoothing model [3] can be used to analyze the smoothing efficiency for sinusoidal ripples. In this model, the ratio of $\Delta E/\Delta Z$ was defined as smoothing factor SF, where ΔE is the difference between the PV (peak-to-valley) magnitude of ripples before and after smoothing, ΔZ is the nominal removal during smoothing. The linear relationship between smoothing factor and initial surface error can be expressed as:

$$SF = k \cdot (E_{ini} - E_0) \quad (1)$$

where k is the sensitive coefficient between smoothing factor SF and initial error E_{ini} (PV value of initial ripple), E_0 is the minimum error where smoothing can happen. Smoothing capability of a polishing tool can be represented by a linear SF function of E_{ini}. The parameters k and E_0 can be fitted from experimental results.

2.2. Pitch lap and RC lap

The pitch lap is constructed with solid back plate and a layer of pitch. A high quality surface (<1 nm RMS (root-mean-square) surface roughness) can be obtained by pitch polishing. At the same time, pitch lap can smooth out mid-to-high spatial frequency errors

* Corresponding author. Tel.: +86 731 84574937; fax: +86 731 84574937.
E-mail address: letter2prec@gmail.com (F. Shi).

http://dx.doi.org/10.1016/j.ijleo.2014.02.031
0030-4026/© 2014 Elsevier GmbH. All rights reserved.

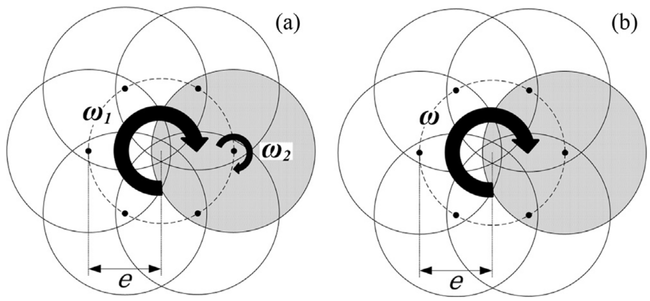

Fig. 1. Schematic picture of different motions. (a) Epicyclic motion (b) and orbital motion.

due to its rigidity. The pitch lap is widely used in optical fabrication society.

The RC lap is comprised of solid back plate, non-Newtonian fluid and polishing interface (e.g. polyurethane pad) [7]. It can automatically conform to a free-form surface and smooth out mid-to-high spatial frequency errors to some extent due to the visco-elastic behavior of non-Newtonian fluid. The RC lap has been successfully applied in the manufacturing of large mirrors [8].

2.3. Epicyclic motion and orbital motion

Fig. 1 depicts two kinds of tool motions: epicyclic motion and orbital motion. In epicyclic motion, the tool orbits around the TIF center with an orbital radius *e* at the rotation of ω_1 and rotates about the center of the tool at the rotation of ω_2; while in orbital motion, the tool orbits around the TIF center with an orbital radius *e* at the rotation of ω and does not rotate. The two rotations in epicyclic motion will complicate the structure of polishing equipment, but epicyclic motion can generate more kinds of TIFs due to its two freedoms of orbital rotation and self-rotation, that may benefit the practical polishing process [6].

3. Experiments and results

3.1. Experimental set-ups

Four sets of experiments were designed to compare the smoothing efficiencies of different tools with different motions. The four sets of experiments could be divided into two groups: first group was pitch lap vs. RC lap with both motions aiming at verifying the smoothing efficiencies of different tools, while the second group was both laps with epicyclic motion vs. both laps with orbital motion aiming at demonstrating the smoothing efficiencies of different motions. Some details of these experiments are shown in Table 1.

The smoothing efficiencies of pitch lap and RC lap with different motions were researched and the properties of these two tools used in our experiments are shown in Table 2.

Table 1
Experimental set-ups for smoothing experiments.

	1#	2#	3#	4#
Tool type	Pitch lap	Pitch lap	RC lap	RC lap
Motion type	Epicyclic motion	Orbital motion	Epicyclic motion	Orbital motion
Nominal polishing pressure (MPa)	0.15	0.15	0.15	0.15
Polishing compound	Ceria	Ceria	Ceria	Ceria
Polishing compound particle size (μm)	0.5	0.5	0.5	0.5
Smoothing time (min)	25	70	175	645

Table 2
Properties of polishing tools.

	Pitch lap	RC lap
Tool diameter	25 mm	25 mm
Stainless steel back plate thickness	4 mm	4 mm
Elastic material	64# pitch	Silly Putty
Elastic material thickness	5 mm	5 mm
Polishing interface	Pitch itself	1 mm thick KSP66A (polyurethane)

Table 3
Properties of motions.

Tool motion	Epicyclic motion	Orbital motion
Orbital radius	5 mm	5 mm
Tool orbit-motion rpm	ω_1 = 150 rpm	ω = 150 rpm
Tool self-rotation rpm	ω_2 = −155 rpm	–

The smoothing efficiencies of epicyclic motion and orbital motion were studied and the properties of these two motions used in our experiments are shown in Table 3.

3.2. Ripple generation

To be simple, the experiments were conducted on sinusoidal ripples. MRF [9] was employed to generated sinusoidal ripples on a 100 mm diameter fused silica sample.

Fig. 2 shows the different views of MRF TIF. It is not rotational symmetry like the TIFs of common CCOS methods. The TIF is symmetric along horizontal direction while distributes like a 'D' shape along vertical direction. The maximum removal of the TIF lies near one edge of the TIF and the size of the TIF is 4 mm in width and 7 mm in length here. This TIF would be employed to generate the sinusoidal ripples.

The ripples generating process was similar to the process described in [3], except that here the tool was MRF instead of ripple generating pitch tool. The MRF TIF scanned along a straight line at the velocity of *V*, and then TIF scanned at the same *V* along a subsequent line 5 mm away as shown in Fig. 3. After the MRF TIF scanned over the whole mirror, a set of sinusoidal ripples would be generated. The generating process might be repeated several times to obtain the desired magnitude.

The final ripples were measured by a Zygo GPI interferometer and the result is shown in Fig. 4. The ripples have a ∼1.0 μm PV magnitude and a ∼5 mm spatial wavelength. Then the smoothing experiments were taken on these ripples.

4. Results

During each smoothing process the polishing pad uniformly scanned the whole sample at the velocity of 800 mm/min. A uniform layer would be removed by each smoothing process and the

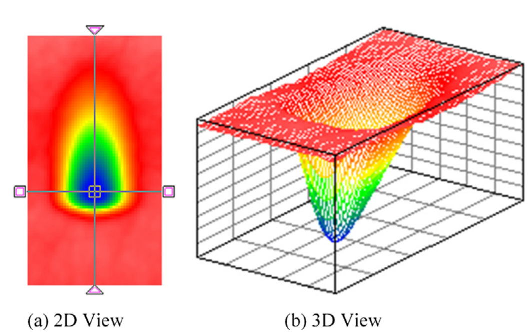

Fig. 2. Topographic structure of MRF TIF. (a) 2D view (from top) and (b) 3D view.

Download English Version:

https://daneshyari.com/en/article/848899

Download Persian Version:

https://daneshyari.com/article/848899

Daneshyari.com