Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 45 (2016) 183 – 186
www.elsevier.com/locate/procedia

3rd CIRP Conference on Surface Integrity (CIRP CSI)

Optical Polishing Using Fiber Based Tools

Hossein Shahinian[a], Brigid Mullany[a,]*

[a]Department of Mechanical Engineering and Engineering Science,University of North Carolina at Charlotte, 9201 University City Blvd, Charlotte, North Carolina 28223, USA

* Brigid Mullany. Tel.: +001-704-687-8343 ; fax: +001-704-687-8356. *E-mail address:* bamullan@uncc.edu

Abstract

Novel, polymer based fiber tools were utilized to polish BK7 glass. Initial tests with these tools investigated the factors affecting the material removal rates. Fiber type and count, polishing pressure and tool rotational speed were all found to affect the removal rates. Abrasive particle size affects the effective contact length whereby smaller particles resulted in narrower tool processing widths. On a sample with an imparted sinusoidal pattern (amplitude = 100 nm, wavelength = 2 mm), it was found that the surface roughness on the higher regions were higher than the lower regions thus emphasizing the importance of the fiber-abrasive interaction.

Peer-review under responsibility of the scientific committee of the 3rd CIRP Conference on Surface Integrity (CIRP CSI)
"Keywords:Optical; Polishing; Fibers"

1. Introduction

Felt, polymer and pitch based polishing pads are synonymous with optical glass polishing. While the final finishes and removal rates obtainable will vary depending on the material chosen for the polishing tool, tool construction is common to all types in that the polishing pad material is adhered to a rigid substrate. The rigid underlying substrate can limit the tools to applications where the surface being polished has zero to low radius of curvature variations, i.e. planar, spherical, or mildly aspherical surfaces. The addition of a compliant intermediate layer between the polishing pad and the metal substrate can accommodate increased radius of curvature variations, but there are limits to this approach.

In this paper a completely different polishing tool structure is considered and its material removal mechanisms explored. The core tool material is not a typical pad, but instead several polymeric fibers are arranged circumferentially, and parallel to the polishing tool shaft, similar in configuration to a flat ended painting brush, see figure 1. The rationale for using fibers in this configuration is to enable them to conform to workpiece curvature variations while still maintaining contact with the surface and thus removing material. Should this tooling configuration be successful it will open up new possibilities in polishing of aspherical and freeform surfaces, a rapidly growing area of optical fabrication.

2. Fiber selection and tool design

While fiber based tools are commercially available, i.e. for painting and deburring applications, individual fibers were sourced and tools were fabricated specifically for this work. The reason for this approach is to fabricate tools with comparable configurations to facilitate a systematic analysis of how fiber type and tool construction affects the material removal and resulting surface finish. Figure 1(a) depicts a schematic of a typical tool, while figure 1(b) illustrates how it engages with the workpiece surface.

2.1 Fiber requirements

Table 1 details the range of polymeric fibers selected for initial tool fabrication. Fibers were selected that fulfill the following requirements; 1) sufficiently stiff to apply a load when engaged with the workpiece surface, 2) sufficiently compliant to bend and contact the workpiece over a length of approximately 5 mm, and 3) be sufficiently large (min. fiber diameter > 500 microns) to facilitate manual tool fabrication.

Peer-review under responsibility of the scientific committee of the 3rd CIRP Conference on Surface Integrity (CIRP CSI)
doi:10.1016/j.procir.2016.02.166

The requirements were chosen as material removal rates in conventional polishing depend on both contact and polishing pressure [1]. A separate test bed, where the fiber was brought into contact with an Ohaus Adventurer Pro scale with 0.1 mg resolution was utilized to ensure that the first requirement was met by any given fiber. During the same procedure the length of fiber contacting the scale was also visually estimated, this provided information for the second requirement.

Table 1. Fibers selected for initial tools.

	Material	Geometry	Fiber length (mm)	Fibers / tool
T1	Copolymer	∅1.4 mm	37	15
T2	Copolymer	∅1.4 mm	37	8
T3	Nylon 6/6	∅1.6 mm	37	13
T4	Nylon 6/6	∅1.6 mm	37	12
T5	Polypropylene	Δ, 1.2mm /side	30	12
T6	Copolymer	∅ 0.5 mm	37	58
T7	Composite	▬,1mm ×0.1mm	37	12
T8	Silicon	∅1.3 mm	30	12

2.2 Tool design

In the initial tools the fibers were glued to the tool as indicated in figure 1(a). The last column in table 1 details the number of fibers attached to each tool. The low density of fibers was selected to avoid fibers potentially tangling and interfering with each other during polishing operations. When in contact with the workpiece, the fibers contact the workpiece in an annular region, figure 1(b), and material is only removed from this region.

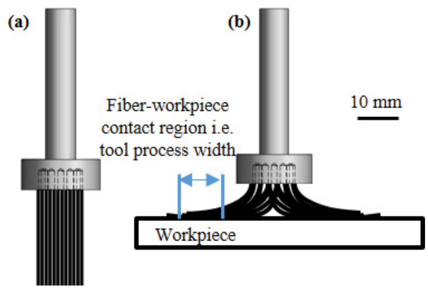

Fig. 1. Fiber tool design; (a) disengaged (b) engaged with workpiece

3. Testing set up and sample preparation

The ability of the fiber based tools to remove material from BK7 glass, was evaluated on a Bridgeport milling machine. The workpiece is submerged in a slurry bath, whereby the latter is fixed to a mass scale located on the machine table, see figure 2. The Ohaus Navigator XT scale has a resolution of 0.5g and records the load (mass × 9.81 m/s^2) applied by the fiber based tool on the workpiece during polishing at a sampling rate of 10 Hz. Details of the samples and testing conditions are supplied below.

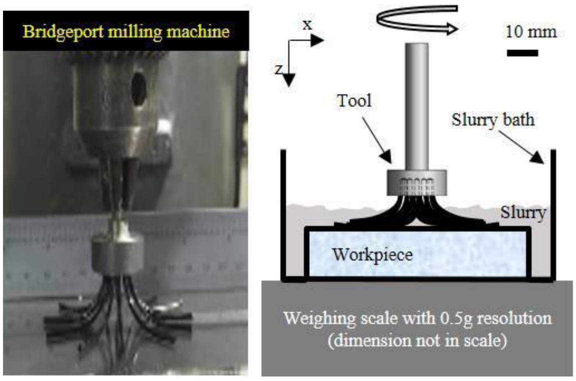

Fig. 2. Polishing test platform

3.1 Sample generation

Two types of Ø75 mm BK7 samples were used to evaluate the performance of the fiber based tools; 1) planar (λ/4, λ = 633 nm) samples, and 2) the same planar samples with an additional concentric repeating sinewave feature (wavelength = 2 mm, PV ≈ 100 nm) imparted on the workpiece surface. The sinewave features were fabricated on a QED magnetorheological finishing (MRF) Q-22 XE.

The planar samples were used to determine the material removal rates obtainable with fiber based tools and the factors affecting. The sinewave samples were used to provide a better understanding of the fiber-particle-workpiece interaction, whereby the post polishing surface finish on the higher and lower regions were measured and considered with respect to slurry particles size and fiber – abrasive interactions.

3.2 Supporting Metrology

The BK7 samples were measured interferometrically via a Zygo Verifire AT 1000 laser Fizeau interferometer. The workpiece ‘pre polishing’ interferogram was then subtracted from the ‘post polishing’ interferogram to calculate the process outputs such as processing widths, i.e. contact length between the fiber and workpiece, and the volume of material removed. For the calculation of either parameters, the average circular profile was calculated from the interferogram. The volume of the removed material can be obtained by calculating the area of the removal region on the 2-D averaged profile, and then the rotation of such region 360° around the center of the polished annulus. The Zygo NewView 4000 Scanning white light interferometer (SWLI) was utilized to measure the surface roughness of the peaks and valleys on the sinewave samples. The 10× Mirau objective was used providing a field of view of 0.83 mm × 0.83 mm and a nesting index of 0.4 mm.

3.3 Testing details and conditions

Fourteen different tests were conducted using the eight different tools detailed in table 1. Table 2 details the main