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Correlation between contact surface and friction during the optical glass polishing

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ABSTRACT

This study aims to determine the correlation between the contact surface, the polishing pressure and the friction coefficient during the optical glass polishing. For this purpose, BK7 optical glass samples were polished and the mentioned parameters were measured to find a correlation between them. Several methods of characterization have been used; the mechanical profilometer, the AFM, and in addition setups for measuring forces and the contact surface have been developed and adapted to the polishing machine. The found results have shown the existence of a close relationship between the three parameters and the influence of each other. This have allowed to deduce that during the polishing process it is very important to control the contact pressure and the polisher form according to the pressure distribution in order to guarantee a very high quality of the polished surface.

1. Introduction

The reproducibility of optical surfaces with high accuracy is a major aim of the optical industry development. The free abrasives polishing process consists of a frictional contact between the sample and the rotating polishing pad. In polishing, slurry of abrasive grain sizes below 1 μm is supplied on a soft polisher generally used in this operation. The fine abrasive particles are retained on the pad surface resiliently and plastically, and the work surfaces are scratched microscopically. Polishing actions are by far smaller if compared with lapping, contributing to the successful applications to the brittle materials [1].

Several hypotheses were proposed to describe the material removal in the polishing process [1–5], but the most used is the combined hypothesis of two actions; a mechanical action generated by the abrasive grains and a chemical one produced by the reaction between the suspension liquid and the polished material.

During the polishing process, material removal is highly influenced by the local pressure and the relative speed between the tool and the workpiece. For a constant tool pressure, the shape change can be easily found. However, this is not possible in several cases because of the tool and the workpiece shapes that are not generally the same, the roughness (overlap between the polisher and the sample asperities), the presence of the forces and the accelerations simultaneously activating on the surface to be polished [6–11]. The material removal model proposed by Savio et al. [2] shows a satisfactory estimation of the material removal as a function of the process parameters.

The polishing process can produced highly mirror surface. Material is removed at a very low rate. Consequently, the geometry of the surface needs to be very close to the correct shape before polishing.

The polishing pressure is applied on the abrasive through the comfortable polishing pad. This allows the abrasive to follow the contours of the workpiece surface and limits the penetration of individual grains into the surface. The use of fine abrasive grains involves a moderate abrasive action between the grains and the workpiece. The polishing operation principal consists to the contact between the sample and the polishing pad with the presence of the abrasive grains. During the process, the friction of the sample surface on the polisher allows the abrasive grains to remove the hydrated layer formed on the surface of the sample by the chemical reaction. It was reported that the effect due to friction is proportional to the compressive force [12]. The polishing rate is assumed to be proportional to the friction between the substrate and the pad [13]. In polishing, the removal material on the surface is closely related to the variation of the friction coefficient [14].

Bowden and Tabor [15] have stated that the true area of contact is a very small percentage of the apparent contact area. The true contact area is formed by asperities. When the normal force increases, more asperities come into contact and the average area of each asperity contact grows. The frictional force is dependent on

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Table 1
Characteristics and chemical composition of the BK7 optical glass.

Characteristics					
Refractive index	Abbe number	Young's modulus [GPa]	Poisson's coefficient	Density [g/cm^3]	Knoop hardness [MPa]
1.509	64.17	82	0.206	2.51	610
Chemical composition (% mass)					
SiO_2	B_2O_3	Na_2O	K_2O	BaO	As_2O_3
68.9	10.1	8.8	8.4	2.8	1

the true contact area. Several studies have proved that friction plays a significant role during the polishing [16–21], the authors show results on the variation of the efficiency and quality of the process according to the friction coefficient consequently they affirm that it has a role because it can influences the results. Indeed, the friction can influence the most important parameters in the optical glass polishing operation which are the quality and the efficiency of the process characterized by the obtained surface quality and the material removal rate. These latter are closely related to the tool quality (abrasive grains wear), the polishing time, the relative speed, etc.

In order to highlight what parameters, friction or contact surface or the contact pressure, is the most influential on the obtained surface quality we performed this work to study the pressure influence on the contact surface and thus the effect of the friction phenomenon in the polishing process. This study based on the direct measurement of the pressure distribution in the contact area, the real contact surface between the sample and the polisher and the friction coefficient variation was carried out.

2. Experimental study

In this study, a measurement setup during polishing was developed. The setup consists of an adaptation of a pressure sensor (Tekscan type) on the polishing machine, where it was placed under the polisher then connected to a computer. The position of the sensor is the unique possibility in our installation to obtain reliable results, but, to minimize the effect of the thickness we have taken the smaller thicknesses possible to eliminate the effect of the polisher elasticity which can especially affect the results of the pressure. During the polishing operation, the variation of the pressure and the contact area between the polishing pad and the optical glass sample during the process are measured directly and saved using appropriate software. The measurements are recorded at each time step during polishing, where one hundred values are registered and their mean value is calculated. Moreover, the friction coefficient was calculated on the basis of the tangential force (friction force) values measured using a special force sensor (Kistler type) adapted to the polishing machine (see Fig. 1).

The polished samples were BK7 Schott optical glass having the characteristics given in Table 1. In our work, five flat samples of 40 mm diameter were used and each one must undergo lapping with alumina abrasive grain fractions successively 40, 20 and 9 before polishing. The polishing operation was performed by employing a soft polyurethane GR35 polisher (supplier Brandt & Pieplow GmbH) fixed on a cast iron support and a cerium oxide abrasive grains slurry whose industrial name is CERI3000G (supplier Brandt & Pieplow GmbH) and its temperature was the ambient temperature. The characteristics of the polisher and the polishing abrasive grains are given in Tables 2 and 3, respectively. During the process, the polishing solution was continuously supplied while the workpiece and the tool rotation velocities was about 100 and 40 rpm, respectively, and the normal polishing force was fixed to 30 N.

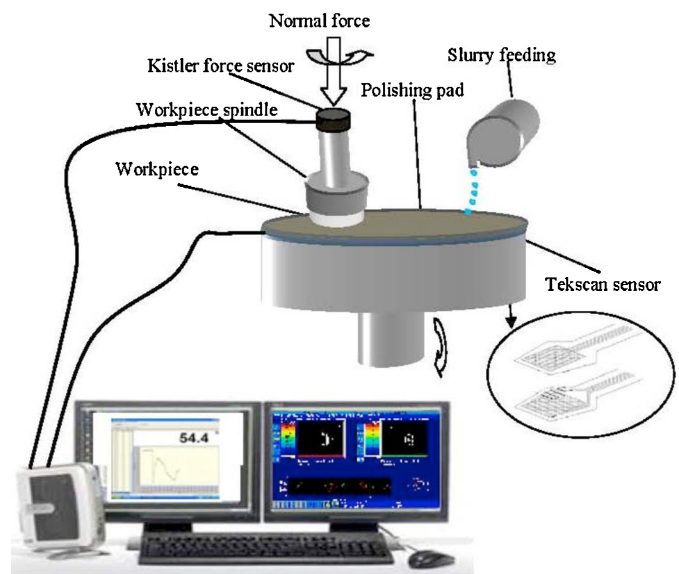

Fig. 1. Measuring setup of the pressure, the contact area and the friction force.

Table 2
Characteristics of the polishing pad GR35.

TYPE	Thickness [mm]	Shore hardness *D*	Density [g/cm^3]	Porosity
GR35	0.51	37	0.56–0.67	50%

Characterization of the sample surface was performed by the mechanical profilometer (Form Talysurf serie 2). However, the values of the pressure and the contact surface have been measured by the Tekscan sensor; the results were saved using specific software sensor.

The frictional force variation was measured by the kistler force sensor and sampled continuously during the polishing process via the software "Labview®". Furthermore, the friction coefficient was calculated by the ratio of the tangential and normal forces.

3. Results

3.1. Pressure distribution

Fig. 2 shows the pressure variation according to the polishing time.

The results in Fig. 2 show that the pressure increases during the first minutes before stabilizing and then tends to decrease from 15 min of polishing. This may be related to changes in the surface