



Research Paper

Study of the pressure distribution during the optical glass polishing

Étude de la distribution de la pression lors du polissage du verre optique

Hasna MOUNIR^a, Amine HAMDJ^{a,b}, Toufik ALIOUANE^{a*}, Djamel BOUZID^a

^aLaboratory of Applied Optics, Institute of Optics and Mechanics of Precision, Ferhat Abbas University, Setif 1, 19000, Algeria.

^bTissemsilt University Center.

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ABSTRACT

The reproduction of very high quality surfaces during the optical glass polishing is the main objective. To come closer this objective, it is necessary to take in consideration all polishing parameters while more especially interesting to the change of the surface polished shape determined by the intermediate of the distribution pressure measure and the surface contact.

In this paper, one determines of the pressure distribution and the surface contact between the pad polishing LP35 and the glass BK7 during the polishing, while using the sensor of pressure. Results show that the change of the glass surface shape is in large part to the variation of the contact surface during the polishing.

RÉSUMÉ

La reproduction de surfaces de très haute qualité pendant le polissage du verre optique est l'objectif principal escompté. Pour se rapprocher de cet objectif, il faut tenir compte de tous les paramètres de polissage, bien que particulièrement intéressant pour le changement de la forme de surface polie déterminée par l'intermédiaire de la mesure de distribution de pression et la surface de contact.

Dans cet article, on détermine la distribution de la pression et la surface de contact entre le polissoir LP35 et le verre BK7 pendant le polissage, tout en utilisant le capteur de pression. Les résultats montrent que le changement de la forme de la surface du verre est en grande partie due à la variation de la surface de contact pendant le polissage.

1 Introduction

The reproducibility of the optical surfaces with a polishing process is the main objective pursued by the scientists and industrialists who are interested in the field of optical manufacturing.

Several studies [1, 2, 3, 4] have shown that obtaining better optical surface is intimately related to technological parameters of polishing. It was highlighted that the most influential parameters are the pressure and the relative speed between the polisher and the optical glass [5, 6].

* Corresponding author. Tel.: +213 (0) 662146974.

E-mail address: aliouane.toufik@gmail.com; aliouanetoufik@univ-setif.dz

The polishing process can produce high precision surfaces. Material is removed at a very low rate. Therefore, the geometry of the surface must be very close to the correct shape before polishing pressure is applied to the abrasive through the soft polisher. This allows the abrasive to follow the contours of the workpiece surface and limits the penetration of the individual grains in the surface. The use of fine abrasive grains involves moderate abrasive action between the grains and the glass piece. The main operation consists of polishing the contact between the sample and the polisher with the presence of abrasive grains. During the process, the friction of the sample on the surface of the polisher allows abrasive grains to remove the hydrated layer formed on the surface of I sample by chemical reaction. It has been reported that the effect due to the friction is proportional to the compressive force [7]. The polishing rate is assumed to be proportional to the friction between the substrate and the polisher [8]. In polishing, the material removed from the surface is closely related to the variation of the friction coefficient [9].

The permanent change in the shape of the glass surface during the polishing process is the result of the modification of the contact surface between the polishing pad and the glass surface [10].

This change can be attributed to the variation in the local pressure. We measured the local pressure in real time, by using the pressure sensor.

2 Experimental study

One used the pressures transmitters of Tekscan, and assembled them on the polishing machine «Naikotec» as shows it in the fig.1.

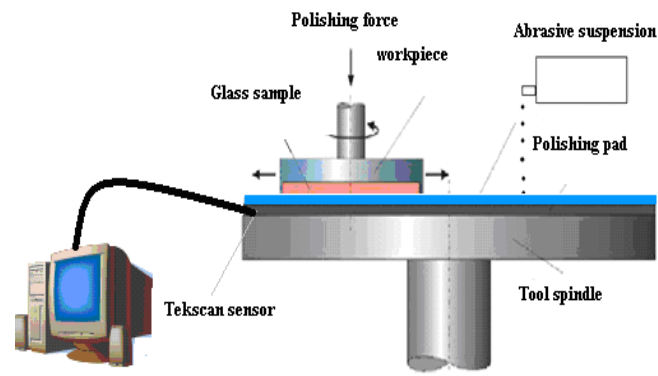
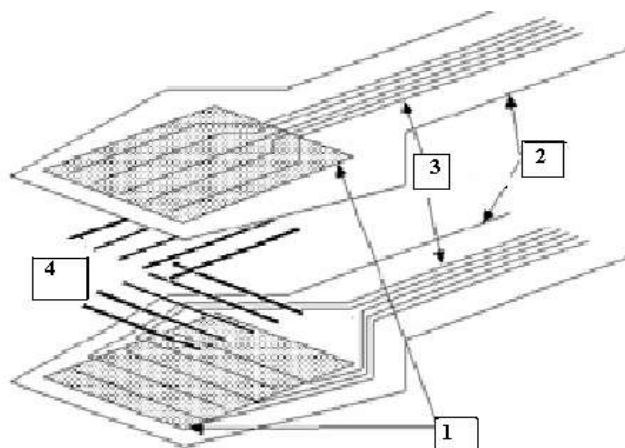


Fig. 1 – Experimental setup.

The Tekscan pressure sensor is placed under the polishing pad and is joined directly to a computer that permits to give in real time the pressure and the surface of contact between the polishing tool and the optical glass during all the process.



- 1- Surface sensible,
- 2- Polyester sheet,
- 3- Conductors pistes,
- 4- Over-sensitive material to the pressure.

Fig. 2 – Example simplified of sensor.

The sensor is composed of two thin polyester sheets that have, electrically, of electrodes set down drivers in the variable models. In an example simplified fig.2 below, the interior surface of a sheet forms a model of row while the interior surface of the other uses a model of column. The spacing between rows and the columns change according to the application of the probe and can be as small as 0,5 millimeter.

In this figure, a conductor thin coat (ink) is applied like intermediate layer between the electric contacts (of rows and columns). This ink provides the electric change of resistance to each of the points of intersection. When the two polyester sheets are placed one on the other, a model of grid is formed, creating a feeling place to every intersection [11].

While measuring changes of the current flowing to every point of intersection, the applied model of distribution can be measured by force and displayed on the screen of the computer. With this system, measures can be made by force statically or dynamically and information can be seen in 2-D or the instructive graphic displays 3-D.

Systems matrixes provide a sensible cellular choice by forces that permit you to measure the distribution of pressure between the two surfaces. The 2-D and displays 3-D show the place and the experienced force importance on the surface of the sensor to every feeling place. The changes by force and pressure can be observed, measured, recorded, and analyzed in the entire test, providing a powerful technological tool.

The aim of this experience is to determine the pressure distribution on the whole of the glass surface and especially the evolution of the contact surface according to the polishing time for the three glass samples with convex shape, concave shape and flat shape.

For this need, one used the glass BK7 of Schott of diameter 40mm whose characteristics is given in the table 1 and whose composition is given by the table 2, a polyurethane polishing pad LP35 whose characteristics are represented in the table 3 and the slurry Ceri 3000G whose characteristics are represented in the table 4, the feeding of the polishing agent makes himself of a continuous way during all the period of polishing. The oscillation frequency of the piece is 100 rpm. The pressure force is 30 N.

The I-scan software of Tekscan gives data in real time of the pressure values, force and the contact surface in all points of the workpiece.

Table 1 - Bk7 glass characteristics.

Refraction index	ABBE number	Young Modulus [GPa]	Poisson Coefficient	Density	Knoop Hardness [MPa]
1.509	64.17	82	0.206	2.51	610

Table 2 - Chemical composition of bk7 glass (weight %).

SiO ₂	B ₂ O ₃	Na ₂ O	K ₂ O	BaO	As ₂ O ₃
68.9	10.1	8.8	8.4	2.8	1

Table 3 - Polishing pad characteristics.

TYPE	Thickness [mm]	Diameter [mm]	Shore Hardness A	Porosity
LP35	0.563	11.02	82.14	50%

Table 4 - Chemical composition of slurry ceri 3000g (weight %).

	SiO ₂	CeO ₂	Cs ₂ O	PF	La ₂ O ₃	MgO
Ceri 3000G	2.38	55.09	1.54	1.20	35.88	0.52

3 Results and discussion

The fig.3 shows a window of the I-Scan software indicating information concerning a polished flat surface for 2 min and 20 min.

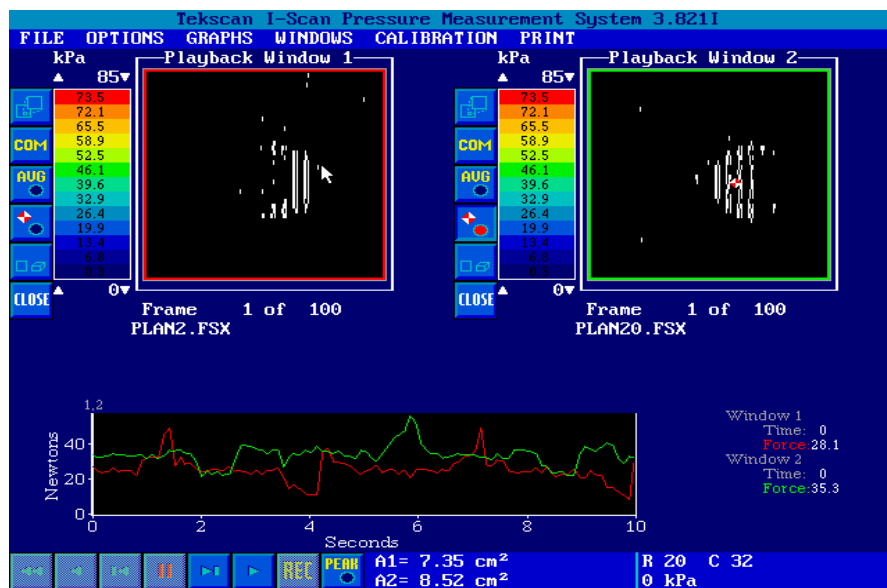


Fig. 3 – Outline of information of a polished flat surface.

3.1 Pressure distribution

The figures 4, 5 and 6 shows the variation of pressure distribution respectively according with the polishing time for surfaces flat, convex and concave.

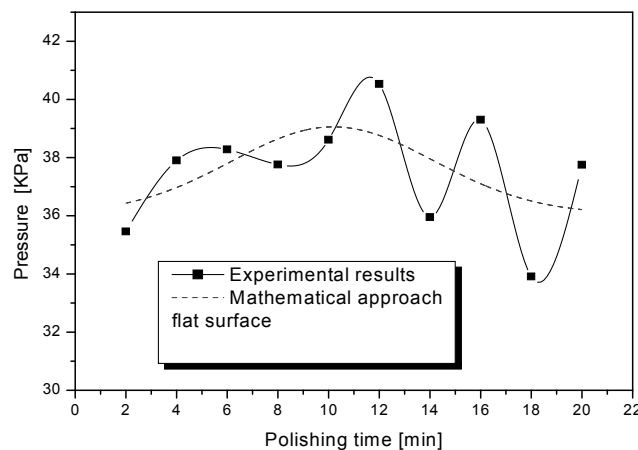


Fig. 4 – Variation of pressure according the polishing time for a flat surface.

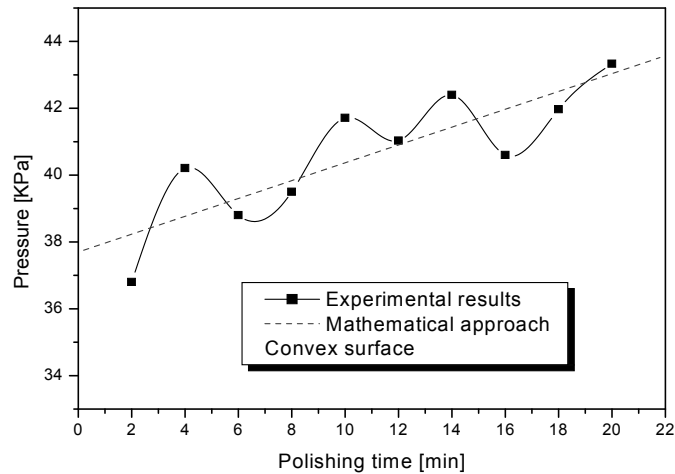


Fig. 5 – Variation of pressure according the polishing time for a convex surface.

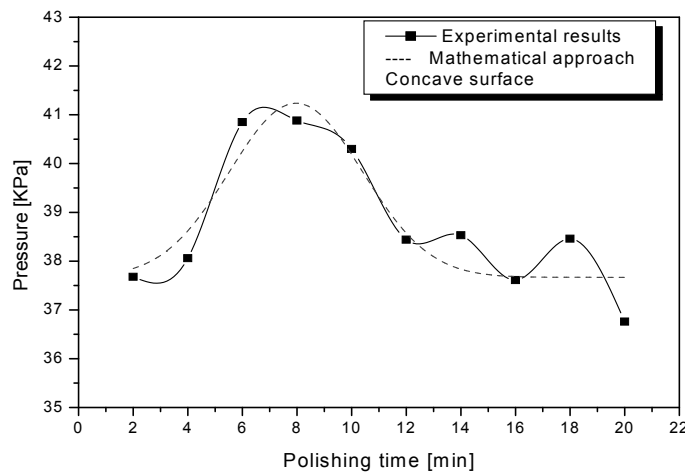


Fig. 6 – Variation of pressure according the polishing time for a concave surface.

From the figures 4, 5, 6, one notices that the pressure distribution is not uniform and not constant during all the polishing process.

For the flat surface, the pressure varies between a maximal value of 41 KPa and a minimal value of 33 KPa. The pressure on the concave surface increases, then until $t_p = 8$ min and decreases the remainder of the process. On the other hand, for a convex surface: the pace of the curve is increasing. According to fig.6, one notices that the pressure is not constant along the polishing time, it increases until $t_p = 12$ min then it starts to decrease that gradually can be to explain by the change in shape of the glass surface.

3.2 Contact surface

The figures 7, 8 and 9 show the contact surface variation between the polishing tool and the workpiece according with the polishing time for the flat surface, convex surface and concave surface [12].

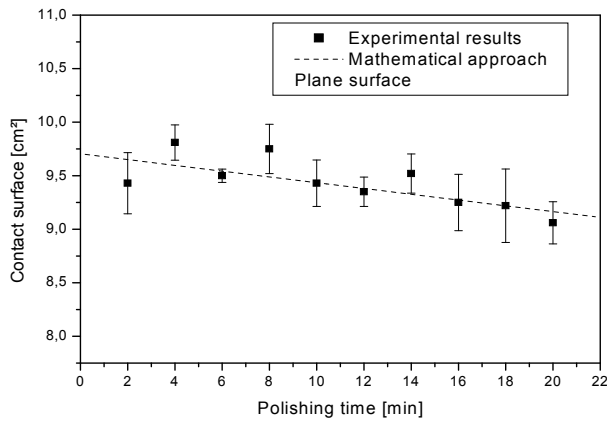


Fig. 7 – Contact surface according with the polishing time for a flat surface.

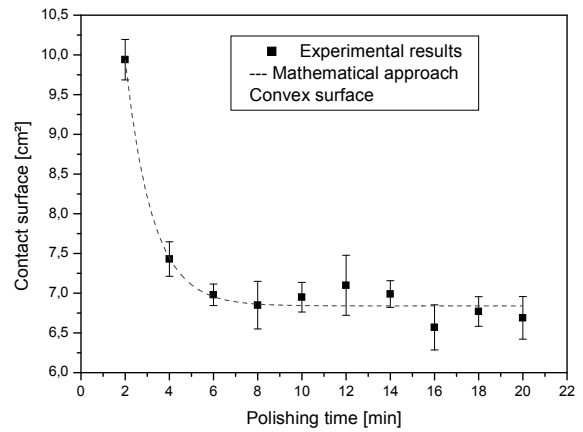


Fig. 8 – Contact surface according with the polishing time for a convex surface.

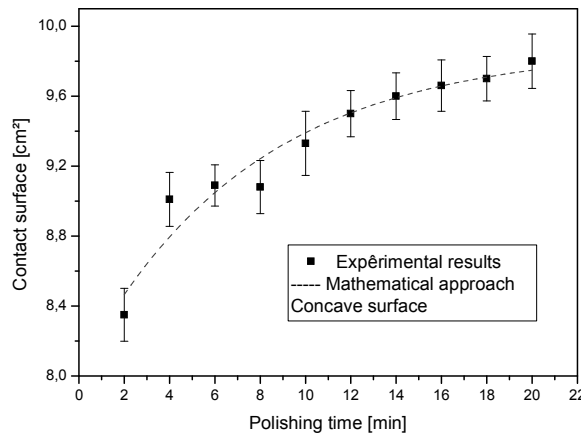


Fig. 9 – Contact surface according with the polishing time for a concave surface.

From the figures 7, 8, 9, one notices that the contact surface between the polishing tool and the work piece is not constant during the process for the three shapes that one used.

- For the flat surface and in the most favorable conditions the contact surface reached 75.46% max, 69.69% min and a middle value of 72.55% of the total surface of the glass sample.

The mathematical approach of the contact surface is:

$$Y = A + B.X \tag{1}$$

Where: $A = 9.70$, $B = - 0.0268$ and the correlation coefficient is 0.75.

- For the convex surface: the curve tendency is decreasing, the contact surface can take the maximal value of 76.46%, the minimal value of 50.54% and a middle value 55.59% during all the polishing time.

The mathematical approach of this contact surface is:

$$Y = Y_0 + A_1.exp(-X/t_1) \tag{2}$$

Where: $Y_0 = 6.84$, $A_1 = 16.02$, $t_1 = 1.21$ and the correlation coefficient is 0.976.

- For a concave surface: the contact surface increases progressively according to the polishing time, its maximal value is 75.38%, its minimal value is 64.23% and a middle value of 71.70% during all the polishing process.

The mathematical approach of this contact surface is:

$$Y = Y_0 + A_1.exp(-X/t_1) \tag{3}$$

Or: $Y_0 = 9.87$, $A_1 = -1.87$, $t_1 = 7.48$ and the correlation coefficient is 0.95.

3.3 Comparison of results

The table 5 represents the middle values of the pressure distribution and the contact surface between the polishing pad LP35 and the BK7 glass.

Table 5 - Average values of the pressure and the contact surface.

	Pressure [KPa]	Contact surface [%]
Flat surface	37,545	72.55
Convex surface	40,635	55.59
Concave surface	38,757	71.70

Fig.10 shows the contact surface variation between polishing pad and the part according the polishing time.

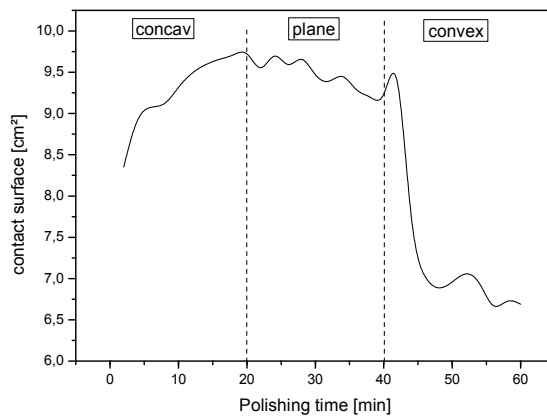


Fig. 10 – Evolution of the contact surface during the bk7 glass polishing.

Fig.10 illustrates the evolution of the contact surface during 20min of polishing for every sample. In the case of the concave sample, the contact surface increases but the flat and convex samples, the surface of contact decreases when the polishing time increases.

On the other hand the relationship between the pressure and the contact surface is satisfied for the convex form case, but not for the other two cases; which confirms that after the polishing, the shape of the piece tends always to become convex. This form change could be explained as follows:

- The optical glass polishing is considered as a dynamic regime for which all the parameters can vary, even the local pressure force vary with the polishing time between 20 and 60N with regard to the nominal value.
- The pad surface is adapted to the functional glass surface. The variation of the Pad surface shape under the effect of the polishing pressure; the large abrasive grains incrust at the edges and the small ones to the centre of the pad; which leads to a surface slightly concave that will take the piece surface.

4 Conclusion

Measuring pressure distribution in the polishing process is a key to the various technological problems. Their results are exploited to complete knowledge by the way of complications of the process. So, with the help of the simulation

technique, it will be possible to anticipate the shape to polish more precisely especially for aspheric surfaces while generalizing the method for other materials as the crystal and semiconductors.

REFERENCES

- [1] D. Bouzid, S. Bouzid, M. Bouafia, U. Jungstand, and V. Herold, Comparative investigations on the polishing performance of various polishers. *Journal of Glass Technology* 38 (1) (1997) pp.18-21.
- [2] N. J. Brown, Some speculations on the mechanisms of abrasive grinding and polishing. *Journal of precision engineering* 9 (1987) pp.129-138.
- [3] L. M. Cook, Chemical processes in glass polishing. *Journal of Non crystallin* 120 (1990) pp.152-171.
- [4] T. Izumitani, Polishing, Lapping and Diamond Grinding of Optical Glasses", in "Treatise on Material Science and Technology. Ed. By M. Tomozawa and R. Doremus, Academic Press, New York. 1979.
- [5] V. Herold, O. Schmelzer and R. Pechmann, In-process measurement of pressure in the polishing of optical glasses, 9th International Precision Engineering Seminar Braunschweig, 1997, pp. 636-639.
- [6] T. Aliouane, D. Bouzid, N. Belkhir and S. Bouzid, Determination of friction coefficient during optical glass polishing with polyurethane pad. 3rd International Conference of the African materials research society, Marrakech, Morocco, 2005.
- [7] H. Liang and D. Craven, Tribology in Chemical-Mechanical Planarization, CRC Press/Taylor & Francis Group, London, 2005.
- [8] S. Ki, A low cost and residue-free abrasive-free copper CMP process with low dishing erosion and oxide loss, in: Proceedings of the IEEE International ITC, 2001.
- [9] A. Kelm, R. Boerret and S. Sinzinger, Improving the polishing accuracy by determining the variance of the friction coefficient. *J. Eur. Opt. Soc. Rap. Public.* 7 12049 (2012).
- [10] V. Herold, Joint International IMEKO TC1+TC7 Symposium Ilmenau Germany, 2005.
- [11] Tekscan Pressure Mapping. Catalog of Tekscan sensor (2006). Retrieved from <http://www.tekscan.com>
- [12] N. Belkhir, T. Aliouane and D. Bouzid, Correlation between contact surface and friction during the optical glass polishing. *Journal of Applied Surface Science* 288 (2014) pp. 208-214.