Design and Validation of a Pitch Tester

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Abstract

For the finish of ultrasmooth optical surfaces with average roughness values of a few parts of a nanometre and less, the use of polishing pitch is still common. One major drawback for the reliable use of natural pitch laps is the strict dependency on natural resources, e.g. wood, resin, petroleum, coal and even shellac. These raw materials show varying technical properties and thus require fast evaluation with reliable and easy-to-use measurement devices. In this paper, a high precision setup for indentation is designed and two different indenter geometries are investigated for the characterization of different pitches. It can be seen that a cone-shaped indenter tip is sufficiently sensitive but still robust enough for the derivation of several dependencies of the mechanical properties of a pitch.

1 Introduction

Several international standards for penetration tests exist for bituminous materials, for waxes and greases. The physical-chemical properties of optical pitch [1,3] and its influences on the complex process of polishing [2] have been investigated for many years now by users and in academia. Some data has been published for commercially available formulations, see e.g. [1,3,4]. Due to many short-term effects, when working with the fluid pitch, a reliable polishing operation under workshop conditions requires reliable and fast measurement methods to obtain at least one significant number. It must be possible to perform measurements on the final tool, the lap itself. Hence penetration methods with different indenter geometries are investigated in this study. A cone-shaped and a spherical tip are compared in terms of their practical use. As examples for the sensitivity of the device, an ageing effect and the influence of water absorption or rather conditioning are investigated.

2 Methods

The experimental setup is shown in figure 1. A high precision laser triangulation sensor is used for the measurement of the displacement of a mass loaded, low friction carriage, which is holding the indentor. The diameter of the spherical indenter is 6 mm and the applied normal load is 0.5 kg, similar to [4]. The conical indenter has a tip-angle of 13° and a front face of 0.7 mm in diameter. This indenter is loaded with 1 kg for 5 min. The room temperature is 22°C ± 1°C and the relative humidity is 45 % ± 5 %. The specimens are made of 20 g of pitch, filled into a glass with a diameter of approx. 50 mm to ensure a sufficient height of the medium. Typical indentation depths for polishing pitches are in a range up to approx. 2 mm. For the experiments with fluid conditioning, the glasses are filled with deionized water. At the start of an experiment, the position and time are set to zero after the contact of the tip and the specimen.

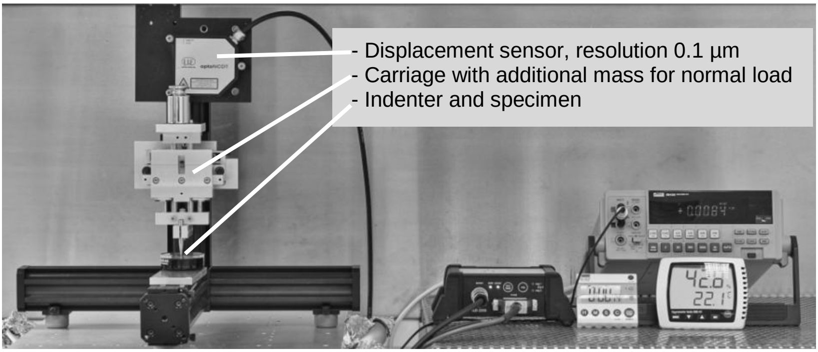

Figure 1: Experimental setup; right: amplifier, voltmeter, stop watch, thermometer

3 Results and Discussion

The spherical indenters show residue of adhering pitch. Thus the tribological situation at the contact point of the new pitch-surface and the sphere has a large influence on the measurement result. This can be demonstrated by changing the coefficient of friction, e.g. by the use of a thin grease film. The observations correlate to the results in [4], while the experimental quantities there differ significantly from results found in this study. Therefore the cone shaped indenter is chosen for further investigation. This geometry has a low influence on the freshly generated surface due to a small contact area at the front of the tip only. Low shear forces are induced there, not falsifying the results significantly.

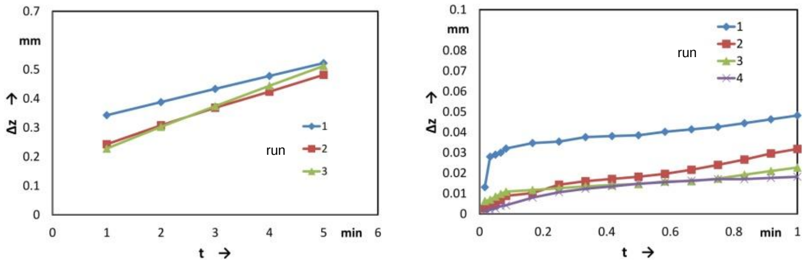

Figure 2: Experimental results: indentation depth Δz vs. time t. Left: repeatability of Gugolz HA 73, right: first minute of testing Gugolz HA 82

The repeatability of the experiments is within approx. 20% of the final indentation value for pitches with a hardness lying inside a meaningful range for practical use. There does not seem to be significantly less scatter of values for the polymer composition Acculap (Sutton Scientifics, Inc. P.O. Box 310, 246 West College St. Star, NC 27356, USA) than for the natural pitch Gugolz (Supplier: Satisloh AG, Baar, Switzerland). One reason may be the non-uniform consistency of the natural pitch in areas of less than 1 mm², which should not be taken as a disadvantage.

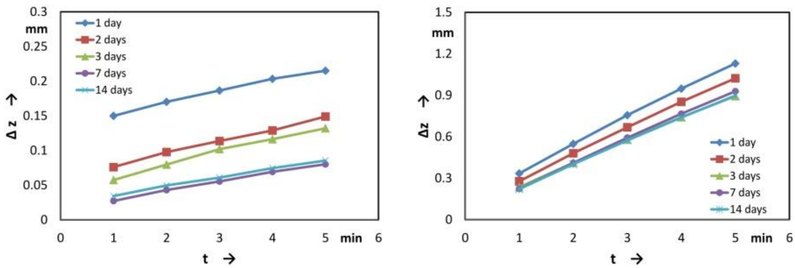

Figure 3: Ageing effect: Indentation depth Δz vs. time t. Left: Gugolz HA 82, right: Acculap HA 30, each data point is an average of 3 measurement points.

The zero point of the penetration depth is crucial, see figure 2 right. The geometrical contact is not uniform at the start of an experiment. A constant slope and quasi-steady state conditions can be seen after an indentation of several µm there. This is pointed out in figure 3 too, where ageing effects are monitored. The influence of conditioning in water is shown in figure 4. The natural Gugolz pitch exhibits a saturation period of approx. 1 day, while the Acculap pitch does not show a significant change. The offset shifts may be due to surface-near effects and the slope seems to be less affected.

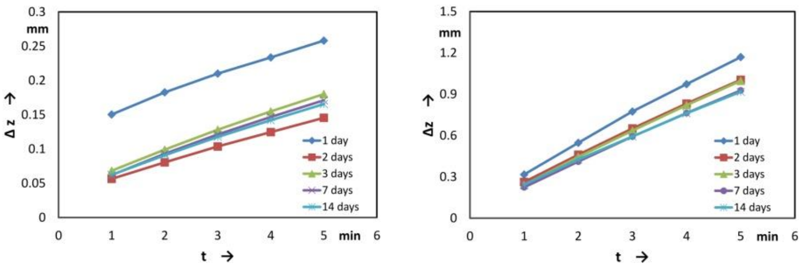

Figure 4: Conditioning effect of water. Indentation depth *Δz* vs. time *t*. Left: Gugolz HA82, right: Acculap HA30, data: average of 3 pts.

4 Conclusion and Outlook

A high precision indentation device is presented for the in-situ determination of relevant data of polishing pitches. Several specific characteristics of natural and synthetic pitches and even the influence of ageing and conditioning can be detected. Local and time dependent behaviour must be investigated in a next step for a deeper understanding of the complex mechanical properties of pitch.

References:

[1] J. E. DeGroote, S. D. Jacobs, L. L. Gregg, A. E. Marino, J. C. Hayes, Quantitative characterization of optical polishing pitch, Proc. SPIE 4451, 209–221 (2001)

[2] C. Evans, E. Paul, D. Dornfeld, D. A. Lucca, Byrne G, M. Tricard, F. Klocke, O. Dambon, B. A. Mullany, Material Removal Mechanisms in Lapping and Polishing. Annals of the CIRP 52(2):611–633 (2003)

[3] B. Mullany, S. Turner, Optical Polishing Pitches: Impact Frequency Responses and Indentation Depths. Applied Optics 49(3):442–449. (2010)

[4] B. Gillman, F. Tinker, Fun facts about pitch and the pitfalls of ignorance, Proc. SPIE 3782, 72–79 (1999)