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INFLUENCE OF LAPPING PLATE TEMPERATURE ON ROUGHNESS PARAMETERS OF SPECIMENS

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Abstract

Lapping is used in the production of components of the highest quality in terms of form finish accuracy and surface integrity. A number of precision manufacturing applications use lapping process as a critical technology to achieve thickness tolerance and surface quality specification. Because of required parts accuracy tool flatness is the key to the successful machining. To avoid its excessive thermal expansion, plate temperature research was taken. This article goal was to check the influence of lapping wheel temperature on workpiece roughness after lapping process. In earlier work, authors investigated the dependence between time and the temperature of executory system elements. Tests showed that after five hours of machine working temperature stabilizes and slightly fluctuated around a certain value. Thus, this work concerns lapping results in this elevated temperature. Research was proceed during Al_2O_3 elements lapping. It was realised with use of ABRALAP 380 lapping machine. The lapping machine executory system consisted of three working conditioning rings. Executory system elements temperature was measured remotely by infrared camera Thermo Gear G100. Elements machining was started after 10, 140, and 270 minutes of machine working time. Studies showed that machine executory system elements temperature affected only the $\Delta Ra_{\ parameter}$, which is higher for surfaces, which were processed starting from 270th minute of machine working time.

Keywords: *lapping, infrared measurement, lapping plate temperature, lapped surface quality*

1. Introduction

Commonly used as a finishing operation, lapping has been used for achieving ultra-high finishes and close tolerances between mating pieces. The most extensively used type of lapping process is flat lapping. Its goal is to achieve extremely high flatness of the workpiece and/or close parallelism of double-lapped faces. The other applications include removal of damaged surface and sub-surface layers and, enhancement of the surface finish on workpieces.

Lapping process is carried out by applying loose abrasive grains between work and lap surfaces, and causing a relative motion between them resulting in a finish of multi-directional lay (Fig. 1). In this process, abrasives such as diamond, silicon carbide, boron carbide, and aluminum oxide are used. They are usually mixed with a liquid to form a slurry [1, 3-5].

The grains are cutting tools during lapping. They are responsible for material removal and for surface formation, but it is not the only effect of abrasive grains working in the gap. There is also a certain amount of heat generated that causes the temperature rise of the executory system elements, including lapping plate. Earlier lapped elements observations suggested that temperature rise was small during lapping, they showed little evidence of structural changes commonly associated with localized high temperatures as found in grinding, phase transformation or burns. Despite plate temperature rise is quite low, it is uneven heating over the surface can cause flatness deviation. The wheel flatness is the key to the operation of free-abrasive machining as lapped parts takes a mirror image of it [2, 6-9].

As the friction heat from the long run lapping in particular deforms the lapping plate and degrades its flatness, it is essential to cool the plate down during the lapping in order to keep the plate to a certain temperature. Cooling the lapping plate prevents its shape accuracy from deterioration to be caused by the heat deformation of the lapping plate during the lapping. Most of today produced lapping machines have devices to carry away the heat generated during the process or to control lap plate temperature. It could be water-cooled system built in the plate (Fig. 2) or temperature control system or both [1, 4-10].

a) b)

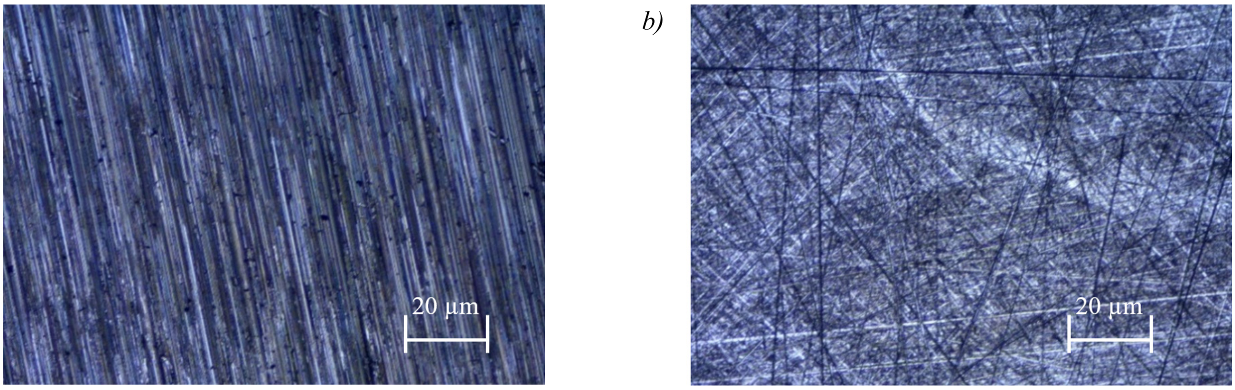

Fig. 1. Workpiece surface of steel C45: a) after grinding, b) after lapping with SiC-F400, p = 0.04 MPa, v = 49 m/min

a) b)

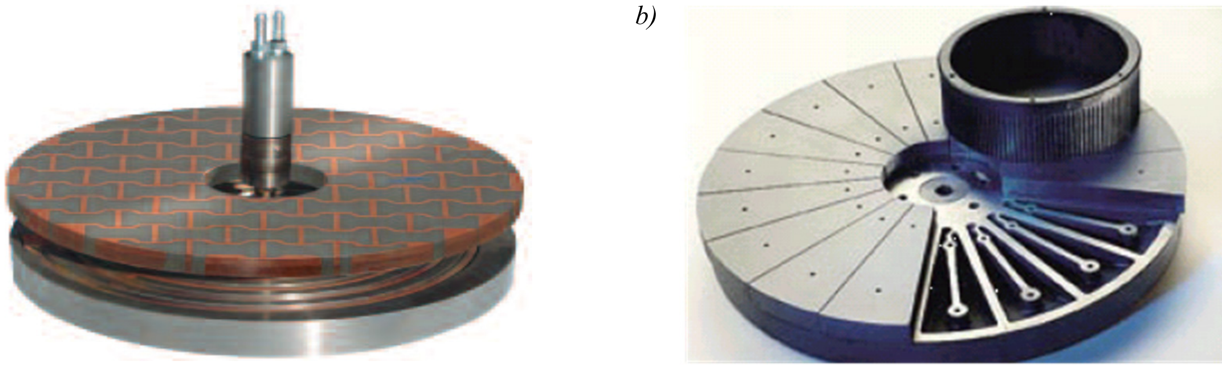

Fig. 2. Water-cooled wheels: a) manufactured by LAMPLAN, b) manufactured by PETER WOLTERS [7, 8]

Despite the technical solutions exist, the problem was not widely analysed by researchers. There are only few works in the published literature about lapping temperature. In previous tests, researchers usually neglected the influence of temperature rise on lapping results and assumed that lapping is low temperature process. Meanwhile problem of executory system elements heating is important because of high demands for lapped elements accuracy and because of enabling their wider automated dimension control during mass production. While machining workpieces heating up to temperature of executory system elements and therefore need cooling to normal temperature before measurements, what extending machining time.

Uneven plate temperature is not the only reason of its flatness deviation. The other one is material removal process. As the workpieces, the tool is also formed during the process. Abrasive grains are held by the facing workpieces; and simultaneously scratch the plate surface as a reciprocal behaviour. This causes profile wear of lap plate. With the increase of the lapping time surface flatness of the lapping plate deteriorates, requires reconditioning. Reconditioning is normally done by removing the lapping plate from the machine, whose surface is then ground or lapped, or by placing a conditioning ring on the lapping plate to recondition the plate (Fig. 3). In order to recondition the plate that is dented (Fig. 3a); conditioning rings are placed slightly toward the edge of the plate and run while lapping slurry is being supplied onto the plate. When the lapping plate has become convex (Fig. 3b), the conditioning rings should be placed slightly toward the centre. Next to lapping machines producers recommendations about it, there are also mathematical models in the published literature [1, 7, 8, 10].

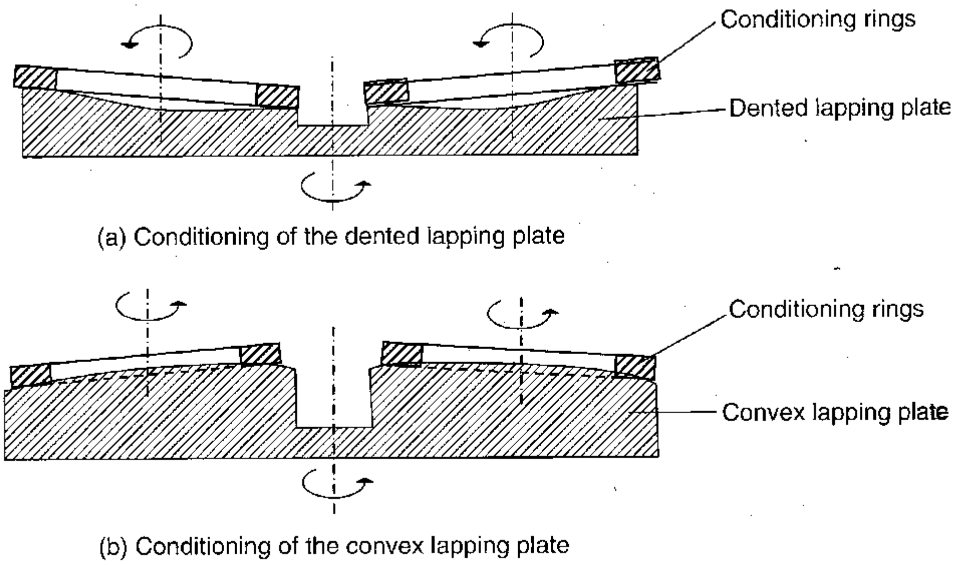

Fig. 3. Conditioning methods of the lapping plate with a conditioning rings [10]

Hence, to reduce workpieces flatness deviations, constant wear and temperature of the wheel should be provided.

Workpieces flatness after lapping were inspected by others researchers. Here other lapping process results like surface roughness parameters ΔRa and Rk were analysed.

2. Experimental setup

The workpieces were valve sealing parts (Fig. 4) made of oxide ceramic Al_2O_3 (95%), one of the hardest materials known. Its high hardness makes it one of the most commonly used ceramic materials. It is used for machining tools, mechanical sealing elements, bearings, as abrasive material or electrical and thermal insulator [10].

a)

b)

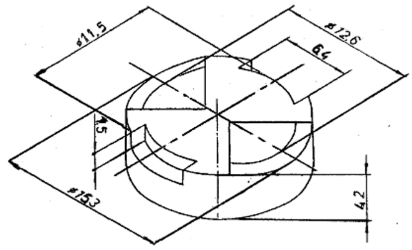

Fig. 4. Valve sealing lapped during the tests

The experiments were carried out on a plate-lapping machine ABRALAP 380 (Fig. 5a) with a grooved cast-iron lapping plate and three conditioning rings (Fig. 5b). The machine kinematics allows adjusting directly the wheel velocity in range up to 65 rev/min. It is also equipped with a four-channel tachometer built with optical reflectance sensors SCOO-1002P, and a programmable tachometer 7760 Trumeter Company, which enables to read the value of rings and plate rotational speed. Elements were settled in rings with used of separators, as depicted in Fig. 5c.

Temperature was measured by infrared camera Thermo Gear G100 produced by NEC Avio Infrared Technologies Co., Ltd (Fig. 5a). The camera serves for contact-less, remote temperature measurement and visualization of its distribution. As a result of a measurement, it is obtained a data set that is presented in a form of a colour map: a thermogram. The thermogram consists of 76800 measuring points (320 points in 240 lines). Two measuring ranges are defined: –40-+120°C and 0-500°C. The measurement accuracy is ±2°C or 2% of reading, whichever is greater. The camera employs a gun grip design with a rotatable monitor similar to that of video cameras, which enables one-hand operation. The image capture support functions of a 2-megapixel visible camera.

a) b) c)

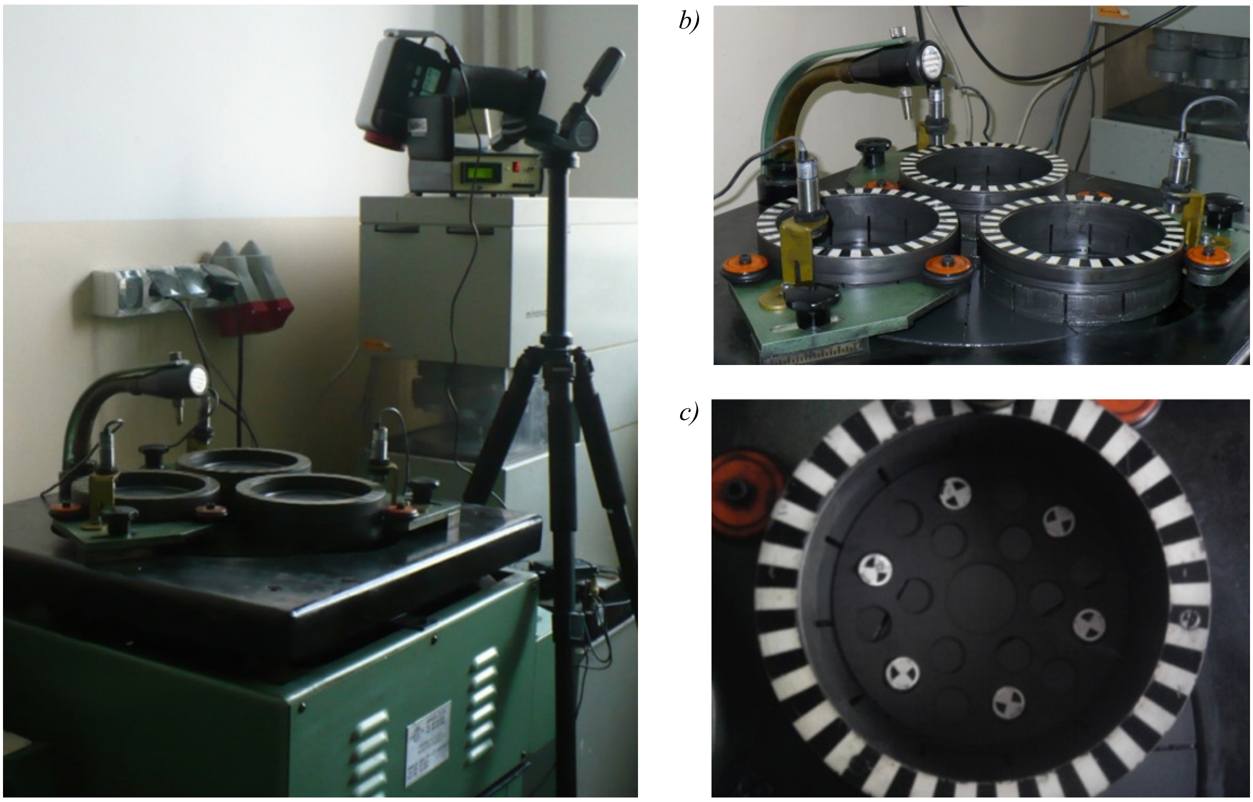

Fig. 5. Experimental setup: a) general view, b) executory system, c) samples condition in conditioning rings

3. Test procedure and results

For analysing the influence of tool temperature on workpiece roughness, lapping process was started to execute in three different moments of machine working time. Specimens machining was started after 10, 140, and 270 minutes of machine working (t_p). Different samples were being lapped during 15 and 20 minutes. Before lapping they were grinded to Ra = 0.79 µm – mean value determined after statistical analysis of measurements results of 92 samples.

For Al_2O_3 lapping researchers generally use slurry composed of diamond grains mixed with liquid or paste carrier. Due to diamond price, this is an expensive solution, especially when considering continuous supplying. Hence, the abrasive mixture in this research was boron carbide powder; grain number F400/17, mixed with kerosene and machine oil with grain concentration equal 0.25. There were executed two sets of lapping parameters:

1. lapping pressure p = 0.051 MPa, and lapping speed v = 27 m/min;
2. lapping pressure p = 0.03 MPa, and lapping speed v = 38 m/min.

The surface quality characteristics of ΔRa and Rk specimens are studied in the light of used described lapping parameters. A Hommeltester T8000-R60 profilometer with a resolution of 0.01 µm was used to determine the surface roughness before and after lapping. The radius of the stylus used was 2 µm. There were executed three measurements in different directions for each workpiece.

Percentage Ra improvement was determined using [4]:

$$\Delta \mathrm{Ra} = \frac{(\text{Average initial Ra} - \text{Average final Ra}) \times 100}{\text{Average initial Ra}}, \qquad (1)$$

The temperature of the lapping plate T was determine as mean in the limited area shown in Fig. 6a. The emissivity determined in previous authors' works [11, 12] was 0.95. It is quite high value but during lapping surface of the wheel is very dark due to charging and covering the waste slurry, as is shown in Fig. 6b. Tab. 1 presents obtained results.

a) *b)*

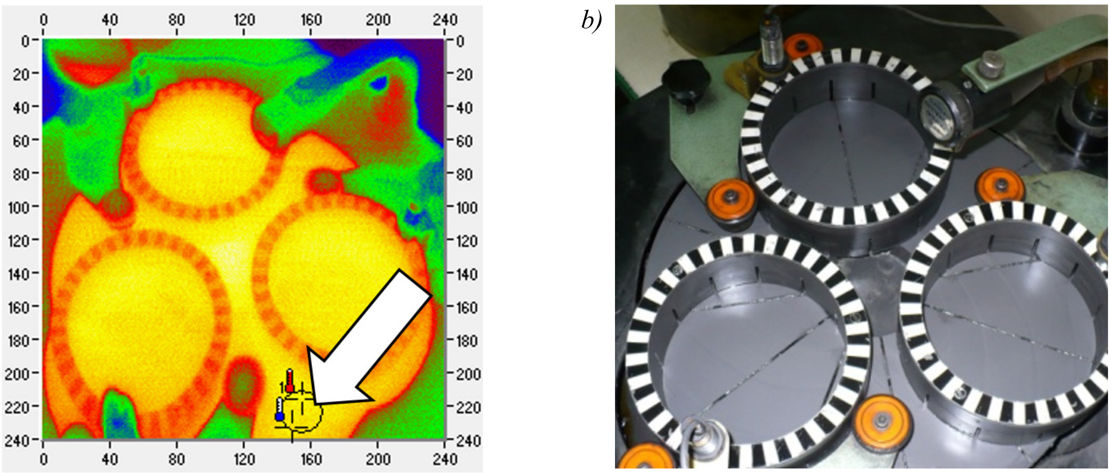

Fig. 6. ABRALAP 380 executory system: a) the thermographic camera view, b) photo camera view

Tab. 1. Test results of ΔRa, and Rk obtained for Al_2O_3 elements (BC-F400/17)

t_p [min]	T [°C]	ΔRa [%]		Rk [μm]	
		t = 15 min	t = 20 min	t = 15 min	t = 20 min
1. F400, p = 0.051 MPa, v = 27 m/min					
10	24.13	5	8	2.29	2.04
140	33.37	4	6	2.09	2.29
270	37.63	1	4	2.24	2.33
2. F400, p = 0.03 MPa, v = 38 m/min					
10	25.03	4	5	2.45	2.04
140	34.07	1	5	2.54	2.21
270	38.27	0	4	2.18	2.06

6. Conclusions

The present article goal was to check if there is dependence between lapping wheel temperature lapped surfaces roughness. Studies showed that plate temperature affected the ΔRa parameter, which is lower for surfaces processed in higher temperature. There was observed only slight drop of ΔRa parameter values. It can be caused by the change in material removal process conditions due to different properties of grains carrier in higher temperature. Its viscosity decreases with increasing temperature, which implies direct interactions between plate and workpiece surface. Normally those two surfaces interact indirectly via abrasive grains. In case of the Rk parameter, can be observed any trend showing influence of plate temperature. Values obtained in different temperatures were almost the same.

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