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# RESULTS OF LAPPING PROCESS EXECUTED IN ELEVATED TEMPERATURE

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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 paper goal was to check the influence of temperature of executory system elements on lapping process results. 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 $R_a$ parameter, which is higher for surfaces, which were processed starting from 270th minute of machine working time.*

***Keywords:*** *lapping, infrared measurement, lapping plate temperature, lapping results*

## 1. Introduction

Modern-day products are characterised by high-precision components. A wide range of materials, including metals and their alloys, ceramics, glasses and semiconductors, are finished to a given geometry, finish, accuracy and surface integrity to meet the service requirements. To satisfy those high requirements several machining techniques can be applied, among them is lapping.

Lapping process is used in a wide range of applications and industries. Typical examples of the processed components are pump parts, transmission equipment, cutting tools, hydraulic and pneumatic, aerospace parts, inspections equipment, stamping and forging. This type of machining is capable of providing high finish and accuracy of form without complex setup. It is carried out by applying loose abrasive grains between two surfaces and causing a relative motion between them resulting in a finish of multi-directional lay. In general, one of the two surfaces is the surface to be machined, which is called the work surface or workpiece, and the other is the lap or plate surface.

The grains, workpiece, and lap are the three materials that take part in abrasion process, which occurs as a result of the relatively motion of the affecting partners. Among all grains supplied to the working gap, only a particular part is active (can roll or slide), which means it takes part in material removal process [2, 3-8, 9].

Since the parts will take a mirror image of the wheel surface, the key to the operation of free-abrasive machining, like lapping, is the flatness of the wheel. It is the most influential and deciding factor to the processing accuracy of the workpieces. Undesirable deviation of lapping tool flatness can be caused by its uneven wear or heating.

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. 1). In order to recondition the plate that is dented (Fig. 1a), 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. 1b), 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, 5, 6, 9].

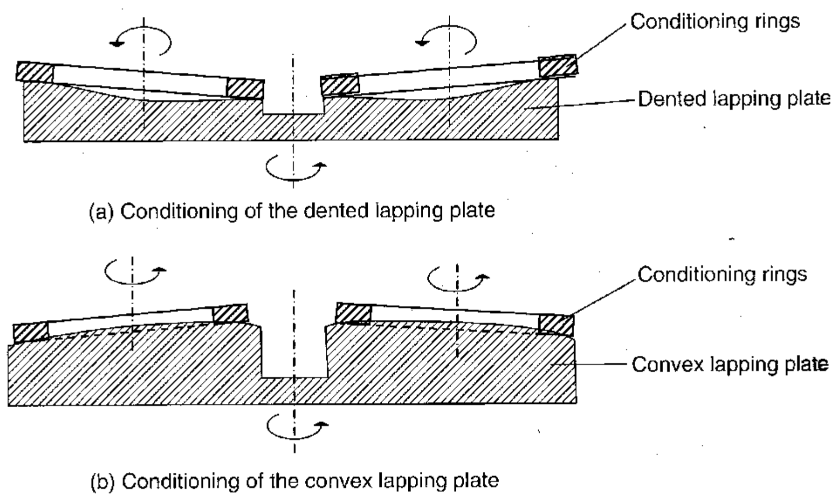


*Fig. 1. Conditioning methods of the lapping plate with a conditioning rings [9]*

Hence, to reduce workpieces flatness deviations, constant wear and temperature of the wheel should be provided. Temperature change caused by the friction heat generated during the lapping and environmental temperatures also affects the shape accuracy of the lapping plate. 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, 2, 3-8, 9].

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.

Despite the temperature rise is quite low during lapping (always under 200 °C), it influences on plate flatness due to uneven heating over its surface and thus non-uniform thermal expansion. Since lapped parts will take a mirror image of the wheel surface, the flatness of free-abrasive machining wheel is the key to the operation of FAM and therefore a temperature-resistant tool is an essential requirement.

Workpieces flatness after lapping were inspected by others researchers. Here other lapping process results like material removal rate in [g] and [mm], and surface roughness parameter $R_a$ were analysed.

a) b)

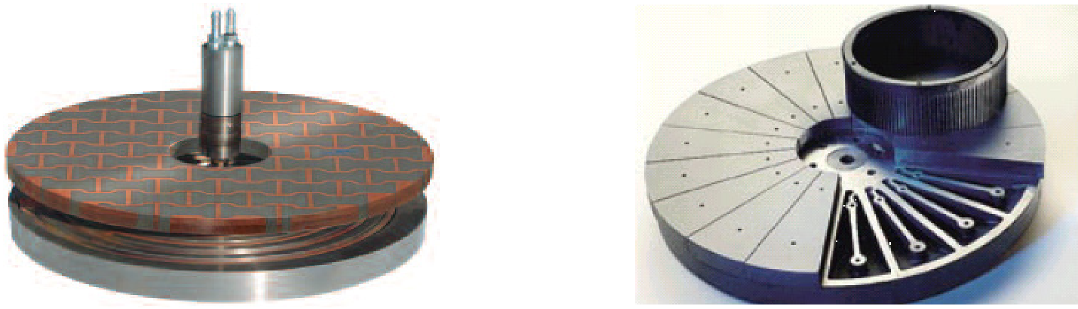

*Fig. 2. Water cooled wheels: a) manufactured by LAMPLAN, b) manufactured by PETER WOLTERS [5,6]*

## 2. Experimental setup

Fig. 3a) shows tests setup. The experiments were carried out on a plate-lapping machine ABRALAP 380 with a grooved cast-iron lapping plate and three conditioning rings (Fig. 3b). The machine kinematics allows adjusting directly the wheel velocity in range up to 64 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 (Fig. 3c).

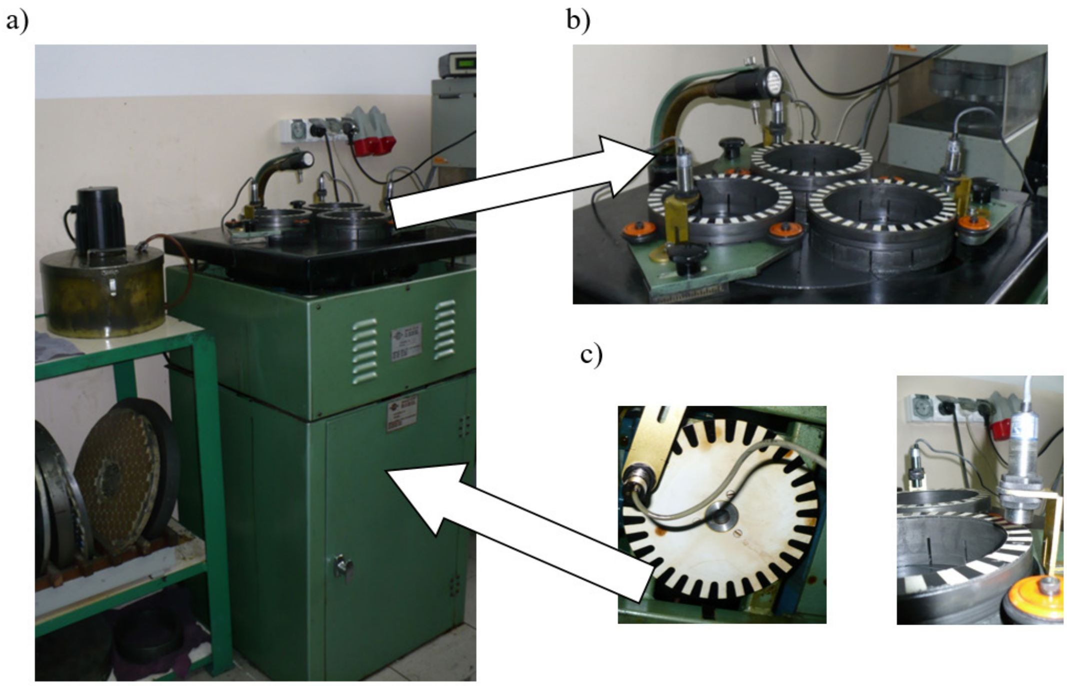


*Fig. 3. Experimental setup*

The workpieces were ceramic $Al_2O_3$ (95%) valve sealing parts (Fig. 4a). Aluminium oxide is one of the hardest materials known. Its high hardness promotes a series of applications in marine engineering, such as bearings and seals.

Samples positions in conditioning rings were as depicted in Fig. 4b.

## 3. Test procedure and results

For analysing the results of lapping processes, it was executed in different temperature of the plate. After grinding, the specimens were being lapped during 15 and 20 minutes. Machining was started after 10, 140, and 270 minutes of machine working time ($t_p$).

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 these researches 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:

a)


b)

*Fig. 4. Valve sealing lapped during the tests*

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 amount of removed material in [mm] (Δh) and in [g] (Δm) and specimens surface characteristics ($R_a$) are studied in the light of used described lapping parameters. Each workpiece was weighed before and after lapping using a precision weighing scale precise to within $1\times10^{-4}$ g to determine ΔW. In addition, the initial thickness of each sample was determined with a digital micrometer precise to within $1\times10^{-3}$ mm. The difference between the initial thickness and final thickness was used to obtain the amount of removed material.

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.

Tests results are presented in Fig. 5 – 7.

## 6. Conclusions

The present paper goal was to check the dependence between lapping machine executory system elements temperature rise and lapping process results. Studies showed that machine executory system elements temperature affected only the $R_a$ parameter, which is higher for surfaces, processed starting from 270$^{th}$ minute of machine working time. There was observed only slight increase of $R_a$ 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. Others tested lapping results were independent of lapping machine executory system elements temperature. Values obtained in different temperatures were almost the same.

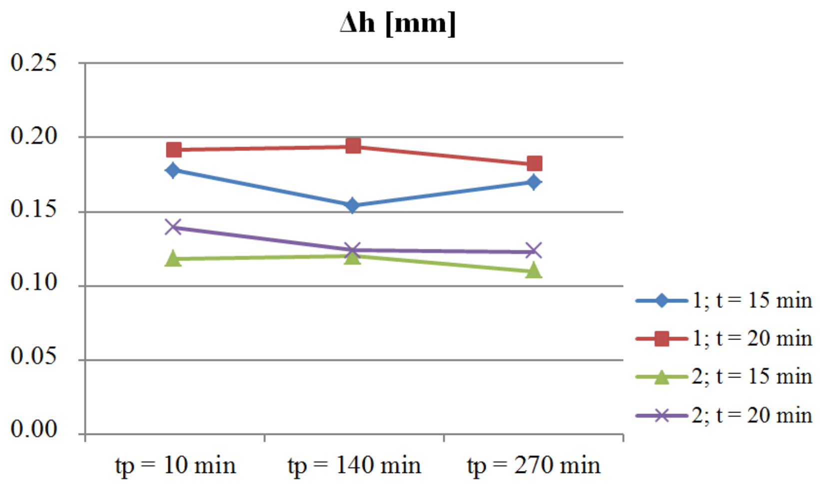


*Fig. 5. Dependence between Δh and tp, and t for BC-F400: 1 – v =27 m/min, p = 0.051 MPa; 2 – v = 38 m/min, p = 0.03 MPa*

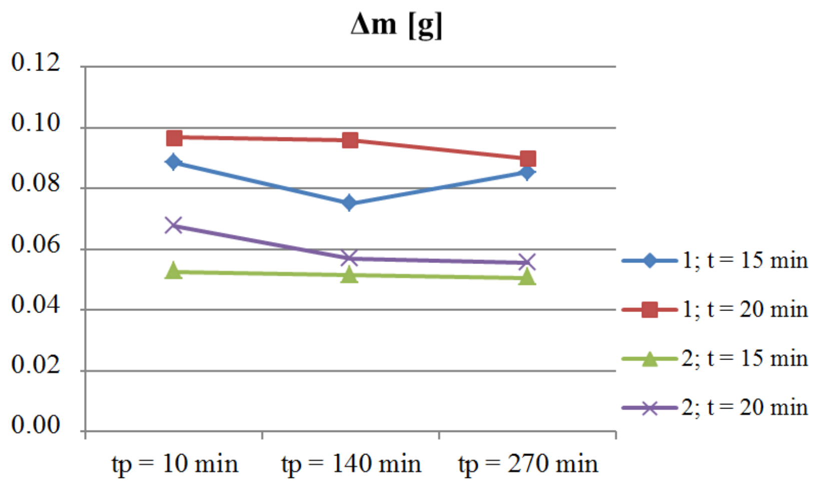


*Fig. 6. Dependence between Δm and tp, and t for BC-F400: 1 – v =27 m/min, p = 0.051 MPa; 2 – v = 38 m/min, p = 0.03 MPa*

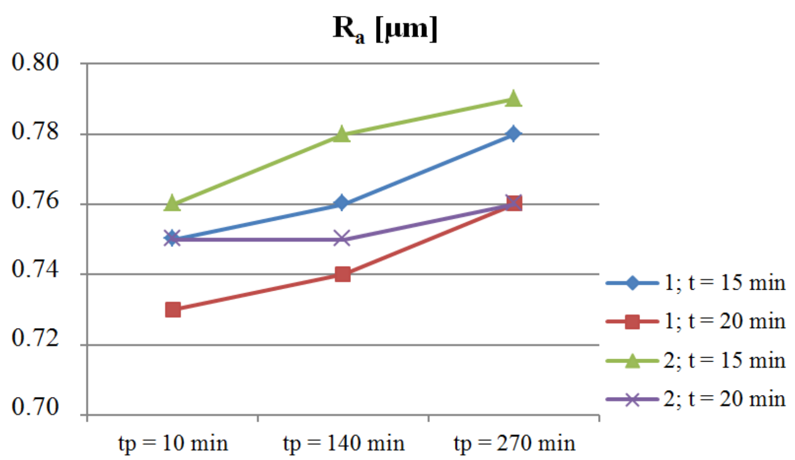


*Fig. 7. Dependence between $R_a$ and tp, and t for BC-F400: 1 – v =27 m/min, p = 0.051 MPa; 2 – v = 38 m/min, p = 0.03 MPa*

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