THE INFLUENCE OF ABRASIVE MACHINE ON TEMPERATURE DURING ONE SIDE LAPPING

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Abstract

Lapping process is characterized by its low speed, low pressure, and low material removal. It's 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.

The grains activities in the working gap cause temperature rise of lap plate. In their work Bulsara and others studied the heat generated during lapping and polishing. They developed a moving heat source model to estimate the maximum and average temperature rise of abrasive-workpiece contacts. The heat generated at this contact was taken as a product of the friction force and the relative sliding velocity between abrasive and work surface.

The model verification showed that real lap plate temperature rise was different from calculated.

This work presents the results of lapping plate temperature rise research. The investigation has been conducted to check the influence of lapping machine on temperature rise. It was made during flat lapping with use of ABRALAP 380 lapping machine and thermographic camera V-20 II produced by VIGO System SA. The lapping machine executory system consists of three conditioning rings. Lapping plate temperature was measured during machine's work without, with one, two and three rings. Results of the measurements showed that even when lapping machine was working without load i.e. without rings, there was observed lap plate temperature rise. This wasn't taken into consideration in mentioned model and there is necessity to develop more comprehensive one.

Keywords: *one side lapping, temperature rise model, executory system temperature, thermal imaging measurements, lapping parameters, lapping machine executory system*

1. Introduction

The high demands required today by manufacturing engineers for machine parts and tools necessitate very precise machining. The finishing processes are an important perspective to be considered today to meet the goals like parallelism, tolerances, flatness, and smooth surface. These processes are high-precision abrasive processes used to generate surfaces of desired characteristic such as geometry, form, tolerances, surface integrity, and roughness characteristics. A leading importance in this perspective has the lapping process. It leads to a surface with low roughness and high precision. The topographical structure resulting from lapping is very advantageous in sliding joints, because of the high ability of lubricant retention, as well as in nonsliding joints because of the high load-carrying ability [2, 4, 5].

Many materials can be lapped including glass, ceramic, plastic, metals and their alloys, sintered materials, satellite, ferrite, copper, cast iron, steel, etc.

Lapping process is used in a wide range of applications and industries. Typical examples of the processed components are pump parts, transmission equipments, cutting tools, hydraulic and pneumatics, aerospace parts, inspections equipment, stamping and forging [4, 6, 7].

2. Lapping temperature

Many observations pertaining to the mechanical state of lapped surfaces have shown that the temperature rise at the interface between an abrasive particle and the work surface is small during lapping. Due to that nature of the lapping process there are very few works in the published literature about lapping temperature. In some of them [1, 2] authors developed models to estimate the maximum and average temperature rise of the work surface in lapping [1] and polishing [2]. They assume that the heat source during mechanical lapping is abrasive particles actions in the working gap.

Heat generated at each abrasive - workpiece contact is taken to be the product of the friction force and the relative sliding velocity. This heat is distributed over a contact area which is obtained from indentation hardness considerations. A calculation of the temperature rise produced during lapping is then made by treating each of the abrasive particles as a moving heat source applied to the work surface, and using the theory of moving sources of heat and heat partition developed by Jaeger and Blok respectively [1, 2].

The maximum contact temperature (T_{max}) rise is calculated for the contact involving the largest particle in the gap, i.e. for the particle whose size $x_i = X_{max}$:

$$T_{\max} = \frac{1.22 \mu v H_p tg\Theta(X_{\max} - X)}{(1 + \sqrt{H_p / H_d})} \cdot \frac{1}{\lambda_p \sqrt{\Pi(0.6575 + P_e)} + \frac{3.66\Pi\lambda_s}{8}}, \tag{1}$$

where:
μ - ratio of friction force to normal force on an abrasive particle,
υ - sliding velocity of an abrasive particle,
H_p - Knoop hardness of workpiece material,
Θ - semi-apical (cone) angle of a sharp abrasive particle,
X_{max} - diameter of the largest abrasive particle in slurry,
X - separation between the lapping plate and workpiece,
H_d - Knoop hardness of lapping wheel material,
λ_d, λ_p - thermal conductivity respectively plate and workpiece material,
P_e - Peclet number for the workpiece.

The average contact temperature rise (T_{sr}) of an active particle is a weighted average of the contact temperature rises over the individual contacts and can be estimated as:

$$T_{śr} = \frac{\int_X^{X_{\max}} T\Phi(x)dx}{\int_X^{X_{\max}} \Phi(x)dx} = \frac{1.22\mu R v\sqrt{H_p}}{\Pi\lambda_p} \cdot \frac{\int_X^{X_{\max}} \frac{\sqrt{P}}{\sqrt{(0.6575 + P_e)}} \Phi(x)dx}{\int_X^{X_{\max}} \Phi(x)dx}, \tag{2}$$

where:
R - fraction of heat flux that flows into the workpiece,
P - normal force on an abrasive particle,
Φ(x) - probability density function of abrasive particle diameters [1, 2].

As indicates previous authors' work [5] the model is not precise enough so its use for real process describing is aimless. It has two basic defects. Firstly the model allow to estimate constant values of temperature rise whereas experiments show that temperature of executory system elements is time dependent [5]. Secondly, important factor which is not taken into consideration is lapping machine warming up during working. This paper goal is to analyze the influence of lapping machine executory system on temperature rise.

3. Executory system

In case of single disc lapping machines executory system can consist of 3 or 4 conditioning rings. The number depends on the lap plate size. These rings are placed on the flat rotating wheel and serve a dual purpose; they are used primarily for retaining parts during processing and at the same time maintain lap plate flatness. The flatness of free-abrasive machining wheel is the key to the operation of FAM. Parts will take a mirror image of the wheel surface. Thermal expansion due to heat can cause an out of flatness condition and therefore a temperature-resistant wheel is an essential requirement. However, modern production machines have devices to carry away the heat generated during the process or to control lap plate temperature. It could be water-cooled system build in the plate or temperature control system or both. Tab. 1. present the lapping machines producers offer of those systems which are available as optional equipment [4, 9].

Tab. 1. Lapping machines producers offer about control and decreasing lap plate temperature [6-10]

Kemet International Limited							
d_D [mm]	508 (20”)	610 (24”)	915 (36”)	1219 (48”)	1422 (56”)	1829 (72”)	2132 (84”)
Options	-	TCS	TCS	WCLP	WCLP	WCLP	WCLP
Lapmaster International LLC							
d_D [mm]	508 (20”)	610 (24”)	915 (36”)	1219 (48”)	1422 (56”)	1829 (72”)	2132 (84”)
Options	WCLP	WCLP	WCLP	WCLP	WCLP	WCLP	WCLP
Peter Wolters GmbH							
d_D [mm]	-	600	800	1200	1600	-	
Options	-	WCLP	WCLP	WCLP	WCLP	-	
STAHLI Group							
d_D [mm]	500	550	750	1000	1250	1500	
Options	WCLP	WCLP	WCLP	WCLP	WCLP	WCLP	
Engis Corporation							
d_D [mm]	381 (15”)	610 (24”)	711 (28”)	915 (36”)	1067 (42”)	1219 (48”)	
Options	WCLP TCS	WCLP TCS	WCLP TCS	WCLP TCS	WCLP TCS	WCLP TCS	
d_D - lapping wheel diameter, TCS - temperature control system, WCLP - water cooled lapping plate.							

4. Experimental setup

Figure 1a) 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. 1b). 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.

Temperature was measured by thermographic camera V-20 II produced by VIGO System S.A. The camera serves for contact-less, remote temperature measurement and visualization of its distribution. It cooperates with three types of computers, traditional PC, laptop or PALMTOP. In the camera, two measuring ranges are defined: 10-80 and 10-350ºC. 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 57600 measuring points (240 points in 240 lines).

a) b)

Fig. 1. Experimental setup; a) general view, b) executory system

5. Test procedure and results

This research focuses on investigating the influence of the rings number on lapping plate temperature rise. The camera view is presented in Fig. 2a). To minimize measurement errors, during the results analysis, this view was limited to the area shown in Fig. 2c).

a) b) c)

Fig. 2. ABRALAP 380 executory system: a) the thermographic camera view, b) camera view, c) limited area to lapping wheel temperature analysis

In order to attain the research objective four tests were carried out. First, when there was no ring loaded on the lap plate, second with one ring, third with two and finally fourth with three rings. When the rings were loaded, slurry was applied. It was composed of black silicon carbide grains F400/17 mixed with machine oil. The lapping slurry was supplied automatically during the process with efficiency $19 \cdot 10^{-8}$ m^3/s.

The wheel velocity had maximum value i.e. 64 rev/min for every test.

The results are presented in the graph (Fig. 3).

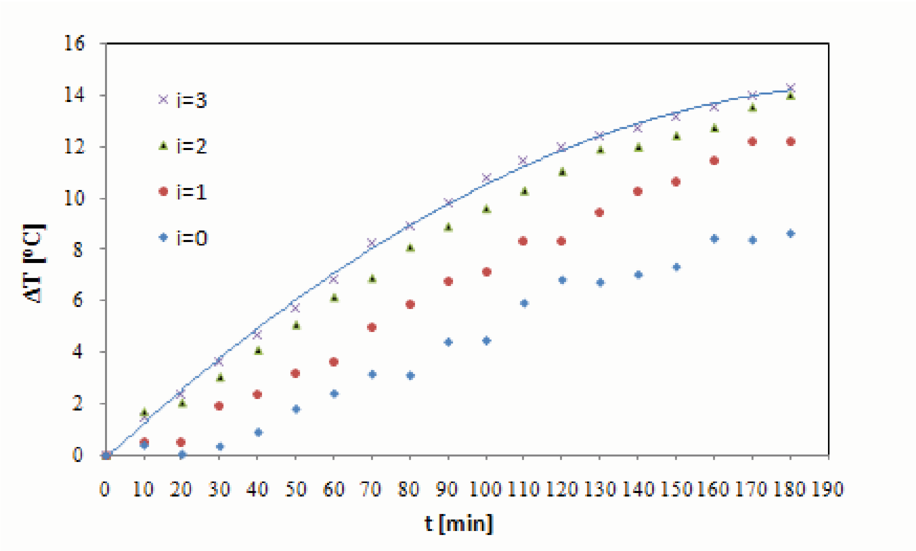

Fig. 3. Dependence of lapping plate temperature rise on conditioning rings number

Shape of the curve which is an approximation of test results is similar to curves shapes received from other, earlier experiments [5]. This one shows how lap plate getting warm during machine working with all three rings.

It can be seen from the chart that the wheel temperature increases even when there is no machining process, moreover it raises even when there is no conditioning rings loaded on the plate surface (i = 0).

In the next step the statistical analysis was conducted. It was verified if the plate temperature is influenced by the number of working rings. It was done with hypotheses testing use and with help of F-test [3]. Tab. 2 presents its results. They were calculated for temperature values measured after 180 minutes of machine working.

Tab. 2. Statistical analysis results

Numerator degrees of freedom	υ_1	3
Denominator degrees of freedom	$\upsilon 2$	8
Significance level	α	0.05
Upper critical value of the F distribution	$F_{,05(\upsilon1,\upsilon2)}$	4.07
Test statistic	F	96.98

6. Conclusions

This paper goal was to confirm the dependence of lapping plate temperature rise on conditioning rings number. It was realised during ABRALAP 380 machine working. Four experiments were conducted with different number of rings (i = 0, 1, 2, 3). For each test lap wheel temperature was measured with help of thermographical camera. Then the results were statistically analyzed. The analysis showed that the number of rings had significantly impact on plate temperature. Therefore model which doesn’t include that factor can’t successfully describe real process. This is consistent with earlier author’s work [5].

Although the existence of models developed in [1, 2], there is still a need of more particular research on that issue.

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