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EMISSIVITY OF THE ONE-PLATE LAPPING MACHINE TOOL

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Abstract

A number of precision manufacturing applications use lapping process as a critical technology to achieve thickness tolerance and surface quality specification. Typical examples of the processed components are pump parts, transmission equipments, cutting tools, hydraulic and pneumatics, aerospace parts, inspections equipment, stamping and forging. Lapping leads to a surface with low roughness and high precision. It is carried out by applying loose abrasive grains between work and lap surfaces, and causing a relative motion between them resulting in material removal. The grains activities in the working gap cause also temperature rise of the executory system elements, including lap plate.

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.

Temperature is the most often measured physical quantity, second only to time. All advantages of infrared technology have led it to become frequently used technique for temperature measurement. It was also used by authors for lapping process observation. To assure accurate noncontact infrared temperature measurement there is a need to keep in mind several factors, including determining appropriate value of emissivity. Incorrectly, designated emissivity results in bigger measuring error.

This work presents a method for determining wheel emissivity and its value obtained by presented way. To find emissivity of the lapping plate infrared camera V-20 II produced by VIGO System S.A. and contact thermometer TES1312 Dual K-Type were used. The experiments were carried out on a plate-lapping machine ABRALAP 380 with a grooved cast-iron lapping plate and three conditioning rings. The determined emissivity was equal 0.95 and was bigger than value from the table, as was expected. During lapping wheel surface is in fact very dark due to charging and covering the waste slurry. Obtained value will be used in future measurements.

Keywords: *lapping, infrared measurement, lapping plate temperature, lapping parameters, emissivity*

1. Introduction

Temperature is the most frequently measured physical quantity, second only to time. Temperature plays an important role as an indicator of the condition of a product or piece of machinery, both in manufacturing and in quality control. Accurate temperature monitoring improves product quality and increases productivity. Downtimes are decreased, since the manufacturing processes can proceed without interruption and under optimal conditions.

Infrared technology is not a new phenomenon - it has been utilized successfully in industrial and research settings for decades - but innovations have reduced costs, increased reliability, and resulted in noncontact infrared sensors offering smaller units of measurement [5, 12].

The advantages offered by noncontact temperature measurement are:

1. it is fast (in the ms range) - time is saved, allowing for more measurements and accumulation of data (determination of temperature field),
2. it facilitates measurement of moving targets (conveyor processes),
3. measurements can be taken of hazardous or physically inaccessible objects (high-voltage parts, great measurement distance),
4. measurements of high temperatures (greater than 1300°C) present no problems. In similar cases, contact thermometers cannot be used, or have a limited life,
5. there is no interference - no energy is lost from the target. For example, in the case of a poor heat conductor such as plastic or wood, measurements are extremely accurate with no distortion of measured values, as compared to measurements with contact thermometers,
6. there is no risk of contamination and no mechanical effect on the surface of the object; thus wear-free. Lacquered surfaces, for example, are not scratched and soft surfaces can also be measured.

All of these factors have led infrared technology to become an area of interest for new kinds of applications and users, including lapping process observations [5, 12].

2. Material removal mechanism in flat lapping

Lapping is a precision manufacturing process in which grains are suspended in a fluid or paste, forming the slurry. The removal of the material is due to the relative movement between the workpieces and the lapping plate. The process is applied in order to produce elements with high shape accuracy, excellent surface finish and isotropic surface topographies.

The grains are the cutting tools during lapping. They are responsible for the material removal and for the surface formation. There are two models to explain the predominant mechanism for material removal (Fig. 1). In the first one, the grains roll in the working gap. The workpiece material is elastically and plastically deformed by the indentation of corner points until small particles break off due to material fatigue. In the second mechanism, lapping grains are embedded in the lapping plate and material is removed by chip formation [2, 4, 7].

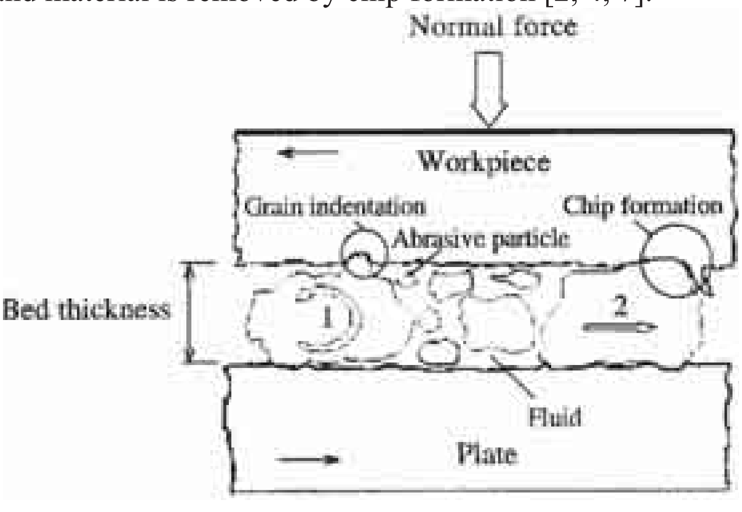

Fig. 1. Material removing by lapping: 1 – grain rolling, 2 – grain is embedded into the lapping plate

Depending on the process strategy, the slurry may be supplied continually in order to increase the material removal rate or without replenishment when high surface finish must be achieved. In both cases, the slurry is applied to the lapping plate and a one-layer film of grains is formed. To achieve the penetration of the grains into the surface, the workpieces are pressed against the lapping plate. Part of the pressure generated at the interface between workpiece and lapping plate is experienced by the active grains and the other part by the fluid phase of the slurry. During the lapping process with non-replenished slurry, the grains fracture into smaller pieces due to the normal load on them, but they remain sharp and continue removing material [2, 3].

3. Lapping plate temperature

Material removal process 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. Observations of lapped elements structures showed little evidence of structural changes commonly associated with localized high temperatures as found in grinding, phase transformation or burns. These observations suggest that the temperature rise is small during lapping [1, 3, 6].

Due to that nature of the lapping process, there are very few works in the published literature pertaining to lapping temperature. 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. presents the lapping machines producers offer of those systems, which are available as optional equipment.

Tab. 1. Lapping machines producers offer about control and decreasing lap plate temperature [8-13]

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	
Engines 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							

Systems maintaining an even temperature across the entire plate minimize plate distortion caused by heat, improving uniform flatness and maintaining stock removal rate. The wheel flatness is the key to the operation of free-abrasive machining as lapped parts takes a mirror image of it. Older machines, still operated, have not such equipment, so there is a need to find other solution to the problem of uneven and excessive plate thermal expansion [6, 7].

4. Noncontact temperature measurement

To control thermal deformation of the lapping plate, the influence of basic lapping parameters on wheel temperature should be known. For measuring the temperature, infrared camera V-20 II produced by VIGO System S.A. was used. The camera serves for remote temperature measurement and visualization of its distribution. It cooperates with three types of computers, traditional PC, laptop or PALMTOP. The camera has two measuring ranges 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). The camera view is presented in Fig. 4.

To assure accurate noncontact infrared temperature measurement there is a need to keep in mind several factors, including determining appropriate value of emissivity. The last can be done in various ways.

First, emissivity of many frequently used materials can be found in a table. Particularly in the case of metals, the values in such tables should only be used for orientation purposes since the condition of the surface (e.g. polished, oxidized or scaled) can influence emissivity more than the various materials themselves. The emissivity of a particular material can be determined during experiment by different methods.

5. Determining the emissivity of lapping plate

To find emissivity of the lapping plate, next to the camera, a contact thermometer TES1312 Dual K-Type was used. The experiments were carried out on a plate-lapping machine ABRALAP 380 with a grooved cast-iron lapping plate and three conditioning rings (Fig. 3). The machine kinematics allows for direct adjusting wheel velocity in range up to 64 rpm. 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. 3. One-plate lapping machine ABRALAP 380

Measurements were taken during machine working with all three rings and without lapping material. A constant supply of the slurry was maintained using the abrasive feed mechanism to provide a fresh supply of abrasive grains into the work zone. The supply of the slurry was maintained at $19 \cdot 10^{-8}$ m^3/s. It was composed of silicon carbide grains F400/17 mixed with kerosene and machine oil in the ratio of one part of abrasive to six part of fluid (53% kerosene and 47% oil) by weight. The wheel velocity had maximum value i.e. 64 rpm.

According to table, cast iron emissivity in temperature 50ºC is about 0.81. To determine the exact value of lapping plate emissivity one of the available methods was used. Method chosen by authors involved heating up the wheel to a known temperature, measured with high accuracy with use of contact thermometer and then measuring the target temperature with the infrared camera. The next step was changing the emissivity until the temperature corresponds to that of the contact thermometer. Emissivity value determined this way would be use for all future measurements.

To minimize defining errors, the temperature only of the limited area shown in Fig. 4. was taken into account.

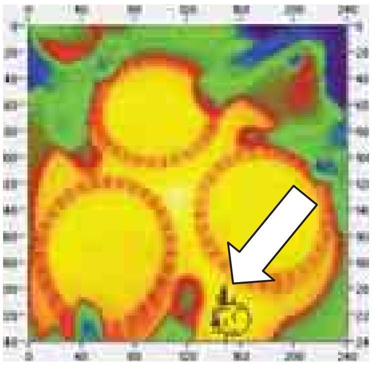

Fig. 4. The lapping plate surface area limited in order to determine plate emissivity

The determined emissivity was equal 0.95 and was bigger than value from the table, as was expected. During lapping wheel surface is very dark due to charging and covering the waste slurry, as is shown in Fig. 5.

Fig. 5. The lapping plate surface charged and covered by waste slurry

6. Conclusions

This and earlier authors works focus on determining the conditions for subsequent research of lapping plate temperature rise. For measuring wheel temperature, a noncontact infrared method was used. In the published literature, authors have found barely few works about temperature in mechanical lapping and about applying infrared measurements to observe lapping process.

The most important thing about taking temperature measurements by infrared camera is to know the investigated element emissivity. There are emissivity tables of many frequently used materials but particularly in the case of metals, the values in such tables should only be used for orientation purposes since the condition of the surface can influence emissivity more than the various materials themselves. The emissivity of a particular material can be determined during experiment. Lapping plate emissivity obtained during experiment was 0.95 and was different, bigger than value form table (0.81). Designated value will be used in future research.

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