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EXPERIMENTAL AND FEM STUDY OF THE INFLUENCE OF THE GRINDING STONE ON THE TEMPERATURE FIELD DURING SUPERFICIAL GRINDING

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Summary. *Grinding is a mechanical process that involves a great amount of energy per unit volume of removed material [1]. This energy is almost all converted into heat, causing a significant rise of the temperature, mainly on the surface of the workpiece.*

In this work an experimental process to determine the influence of the grinding stone on the temperature field of the workpiece is described.

The finite element model used is based on Jaeger's model [2]. A comparison between the numerical results obtained with the proposed model and the experimental measurements is made.

1 INTRODUCTION

Grinding is a mechanical process that involves a great amount of energy per unit volume of removed material [1]. This energy is almost all converted into heat, causing a significant rise of the temperature. Therefore, locally, the surface of the entire workpiece or parts of it will experience rapid thermal cycles, while the rest of the part remains at lower temperatures.

The action of the abrasive grains of a grindstone on the workpiece depends of their physical form [3] and on the operational variables [4]. The abrasive grains have variable forms and only a small amount of them has, in each moment, the adequate morphology to remove material in the form of chips [5]. When the material is being removed, the interaction between the grain and the workpiece produces heat that spreads in the chip, in the active grain and in the workpiece [1]. Other grains only scratch the workpiece, and although they can contribute to a posterior removal of material, its immediate effect is the production of heat, which goes to the workpiece and grain. Others still, just slide through the workpiece without practically scratching it, producing only heat, which spreads in a way identical to the previous situation.

The presence of lubrifying/cooling liquids on superficial grinding acts more in the sense of globally cooling the workpiece than to prevent very high temperatures locally [1].

An important aspect of a grinding operation is that the energy that comes from the grindstone is almost all converted into heat.

In this work, the procedure to determine the experimental temperatures in superficial grinding is described. In the experiments, two materials and tree different grinding stones were used. The obtained results were then compared with the ones obtained by numerical simulation, obtained using the commercial code ABAQUS.

2 EXPERIMENTAL WORK

The experiments were conducted using two different materials for the workpiece, in agreement with Table 1.

Ref.	Material	Observation
ST	H13 – AISI	0.45% C annealed steel, alloyed with Cr, Mo and V
ADI	Austempered Ductile Iron grade 1 – ASTM 897-90	Used in automotive parts (crankshafts)

Table 1 : Workpiece materials used in the experiments

The samples are placed over a piezoelectric dynamometer, which is then placed on the plate of the grinding machine [6]. A thermocouple is placed in a hole with 0.5 mm of diameter, at a distance of 1 mm below the surface. The sample, has the form of a block, with an incision were the hole to place the thermocouple is drilled. A signal conditioner and a data acquisition board attached to a PC allow the simultaneous obtaining of the forces and temperatures acting on the workpiece.

The different grinding wheels have a diameter of 350 mm and their speed of cut is 26.4 m/s. Their characteristics are presented on Table 2.

Ref.	Wheel	Greet	Bond
Al 60	A-60-I-6-V	Alumina	Vitrified
SiC	C-60-J-8-V	Silicon carbide	Vitrified
CBN	B-60- N-50-M	Cubic boron nititride	Metallic

Table 2 : Grinding wheels used in the experiments

The velocity of the plate of the grinding machine was 300 mm/s. The cooling liquid was water with 2% of soluble oil. The grinding was performed in alternate directions, until the thermocouple is cut, which will append when the thermocouple is at the surface. The different depths of cut used were 0.00625, 0.0125 and 0.01875 mm.

2.1 Experimental results

The temperature data of each experience can be arranged in a three-dimensional graph as shown in Figure 1 and 2. This can only be made if we measure the forces simultaneously with the temperatures and therefore knowing exactly the instance when the grinding stone start contacting with the workpiece in every passage.

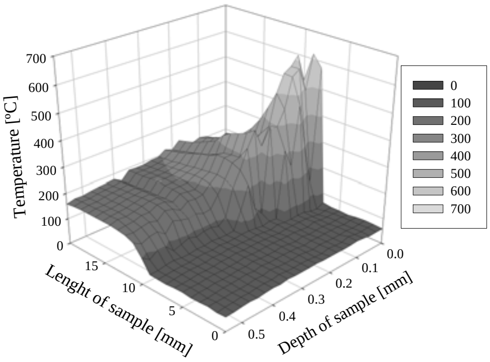

Figure 1: Measured temperatures for a ST workpiece material, grinded with the Al60 grinding stone and with a depth of cut of 0.0125 mm.

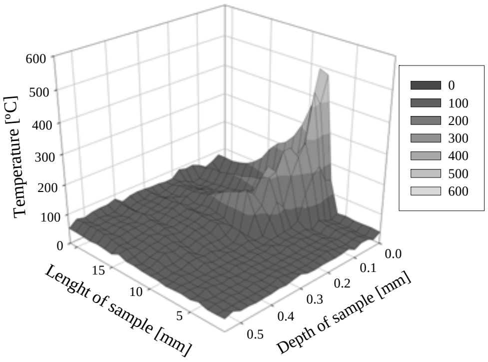

Figure 2: Measured temperatures for a ST workpiece material, grinded with the CBN grinding stone and with a depth of cut of 0.0125 mm.

3 NUMERICAL SIMULATION

The simulation was carried out using the commercial software ABAQUS. The finite element model used [6] is based on Jaeger’s model [2], taking also in account the effect of the cooling liquid. The 2D model has a length of 20 mm and a height of 4 mm, which is sufficient to the temperature field to fully develop. The used mesh consists of 200x64 DC2D4 elements and the grinding wheel is considered a moving heat source that moves with the speed of the plate of the grinding machine. The cooling effect from the grinding fluid is simulated by means of convective boundary conditions. Heat exchanges only happen on the top surface of the workpiece, all other surfaces are considered to be adiabatic.

This kind of model is only suitable for a grinding process with a very small depth of cut, since there is no modelling of the chip. In this kind of process, of precision or ultraprecision grinding, the chips are very small and so they can be neglected.

The heat flux and the convection coefficient are chosen by trial and error, until we get a good agreement between the experimental results and the numerical ones. The convection coefficient is taken to be equal to 0.1 W/mm^2 in all simulations. The heat flux used in the simulations has to be smaller then the power spent by the grinding stone, which we can determine using the tangential force and the peripheral speed of the grinding stone. The power spent by the grinding stone is not entirely converted into heat, and the generated heat distributes itself to the workpiece, the cooling liquid, the removed material, and the grinding stone.

On Figure 3 the temperature field on the model are presented, for a ST workpiece material, grinded with the Al60 grinding stone and with a depth of cut of 0.0125 mm.

Once the value used in the flux and convection coefficient is well chosen, the numerical results and the experimental ones become very close.

Results indicate that CBN wheels introduce less heat in the sample than other wheels. As a result, reached temperatures are lower for these wheels.

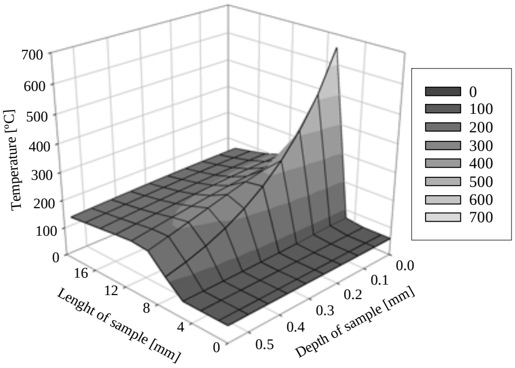

Figure 3: 3D representation of the simulated temperatures.

4 CONCLUSIONS

The grinding process has been studied using an experimental method and recurring to numerical simulations with the commercial implicit finite element code ABAQUS. The following conclusions can be drawn:

- The CBN grinding wheel introduces on the workpiece a smaller percentage of the spent energy on the grinding operation and as a consequence, the maximum temperatures obtained are lower.
- The amount of heat that enters into the workpiece depends more on the material and grinding wheel and less on the depth of cut used.
- The maximum temperature depends of the depth of cut, the workpiece material and the grinding wheel. In all the situations the CBN grinding wheel produced lower temperatures.

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