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ON THE "SURFACE LAYER" THICKNESS OF PLANE GRINDED WORKPIECES

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Abstract

This paper is a study on the structure of the surface layer of a grinded plane workpiece. It establishes the time variation of the surface layer temperature field, the workpiece layer where the melting temperature is attained. It is possible, in this way, to know the maximum width of the layer where the fast austenite/martensite transformations are changing the material properties. The study also establishes the variation of the surface layer width as a function of time, feed velocity and grinding tool thickness.

Keywords: *grinding, surface layer, temperature field, hardened layer.*

1. Introduction

The studies of the thermal phenomena that occur during materials processes are a very important part of the research activity that is developed continuously. Particularly, the grinding process is one of the mechanical processes that has been studied previously; the aspects regarding the heat fluxes occuring in the process [1] where completed by studies on the temperature fields in the disc-tool and the workpiece [2 ÷ 4].

This paper is trying to complete the image we have on the grinding process by taking into consideration the thermal loads of the workpiece surface layer. It is a layer of material whose temperature goes beyond the melting point during the grinding process. This layer will suffer fast austenite / martensite transformations of its structure and, consequently, modification of the physical and mechanical properties of the workpiece.

The method by which the temperature field is calculated in the workpiece was established elsewhere [3]. In essence, the method is considering that in every moment of the grinding process, the grinding tool is acting on the workpiece with an array of instantaneous point sources (Fig. 1). Integrating in time and space the instantaneous thermal loads, it is possible to have the map of the temperature field of the grinding process.

The paper presents the temperature variation as a function of height, for different moments, in a certain point (Fig. 2) of the workpiece as well as the time variation of the temperature in different layers (Fig. 2, Fig. 3). The influence of the cooling conditions on the temperature field profile is presented by figures 5 and 6. The paper is defining the surface layer thickness (SLT) as the maximum thickness of the layer where the temperature attains, at a certain moment in time, a value of 1500 K. The SLT variations as a function of grinding disc thickness and feed velocity are also presented (Figs. 7 ÷ 10).

2. Modeling results

In every moment of the grinding process, the thermal load of a grinded plane workpiece is the summ of the heat point sources acting on the workpiece all along the grinding tool width (Fig. 1). Integrating in time all these successive influences, an estimation of the workpiece temperature can be obtained [3, 4]. A further step is taken by this study. The material properties and the default working conditions are presented in Table 1 and Table 2.

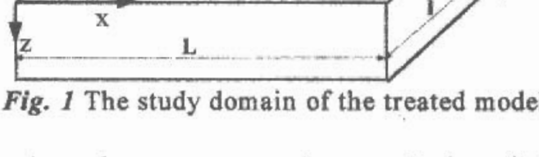

Fig. 1 The study domain of the treated model.

In order to express the complexity of the temperature field during the grinding process, Fig. 2 and Fig. 3 present its variation as a function of height for the surface point (0,5L;0,5l).

Table 1

Default working parameters during grinding process

Power	P	3 kW
Tool velocity	V	20 m/s
Workpiece velocity	V_l	10 m/min
Tool diameter	2a	0.3 m
Tool width	B	0.03 m
Depth of cut	-	0,05 mm
Cross feed	V_s	V_s=sB=B
Workpiece length	L	0.2 m
Workpiece width	l	0.1 m
Workpiece height	H	0.01 m
Grain dimension	lg	110 µm
Grain/piece area	A	0.01
Heat transfer coefficient	h	2000 $W/m^2/k$

Table 2 **Material properties**

	H_2O	NCB	Steel
Thermal conductivity k [W/m/k]	0,65	1300	10,5
Density ρ [kg/m^3]	1000	3450	7865
Specific heat c_p [J/kg/k]	4180	506	460

The maximum value is shifted, in time, towards higher depths. Now, we can notice that the moment domain for which the temperature is higher than a certain value (1500K, for example) depends on the position of the point considered.

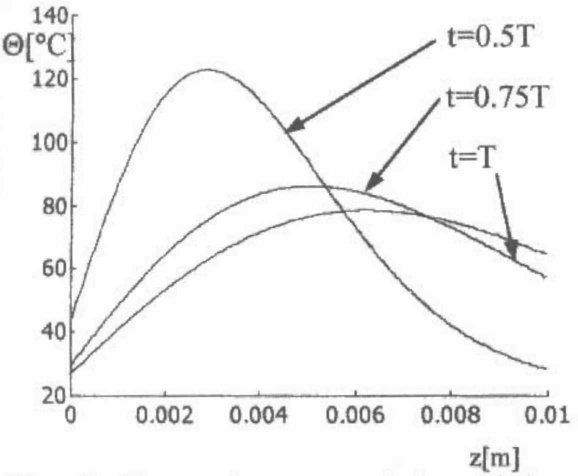

Fig. *2* Temperature - workpiece height dependence for different moments of time (T is the total working time); B = 3 cm, s=V_s/B= 1.0.

Figures 3 and 4 are comparing the time variation of the temperature field for two surface points (0,5 L;0,5 l) and (0,25 L;0,25 l). Due to the small differences between the shapes and levels of the two temperature fields, we proceed the study using the values of the temperature field in the points (0,5L;0,5l,z), accepting the small errors implied by this assumption.

The temperature field is affected by the cooling conditions through the Biot number (Bi=hH/k). Figure 5 is emphasizing this dependence using the time variation of the temperature field in the point positioned at z=10^{-5}m in the workpiece, for three different values of Bi parameter and the same energy input on the surface unit. A Bi number of order one is the indication of a good thermal contact between the workpiece and the environment. A high Biot number is inducing a lower temperature field level.

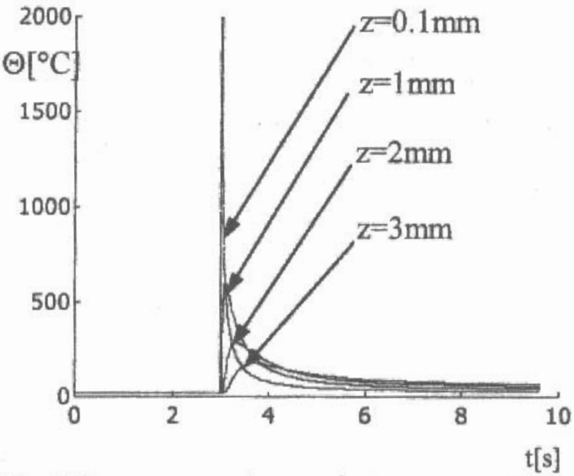

Fig. 3 Temperature-time variation for the (0.5L, 0.5l) surface point and different workpiece height; B = 3 cm, s = V_s/B = 1.0.

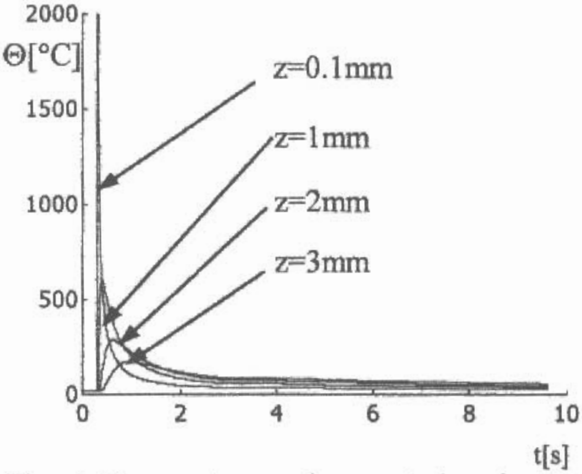

Fig. 4 Temperature - time variation for the (0.25L, 0.25 l) surface point and different workpiece height; B = 3 cm, s = V_s/B = 1.0.

Fig. 6 presents the influence of the Bi number on the temperature distribution on the height of the workpiece. The same influence of the Biot number on the temperature field level can be noticed.

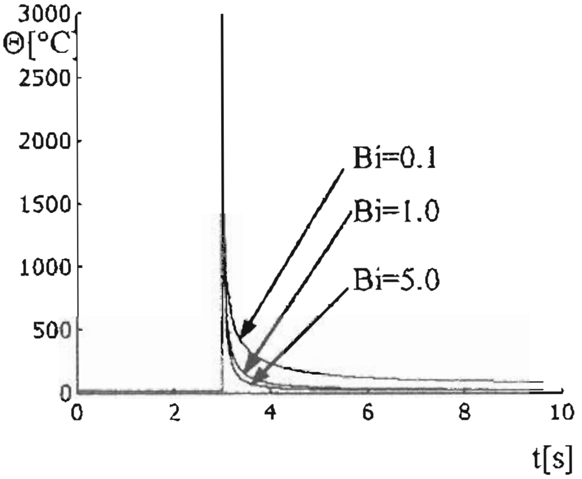

Fig. 5 Temperature-time variation for the point (0.5, 0.5, 1.0 e-5), for Biot numbers 0.1; 1.0 and 5.0; B=3 cm, s= V_s/B= 1.0.

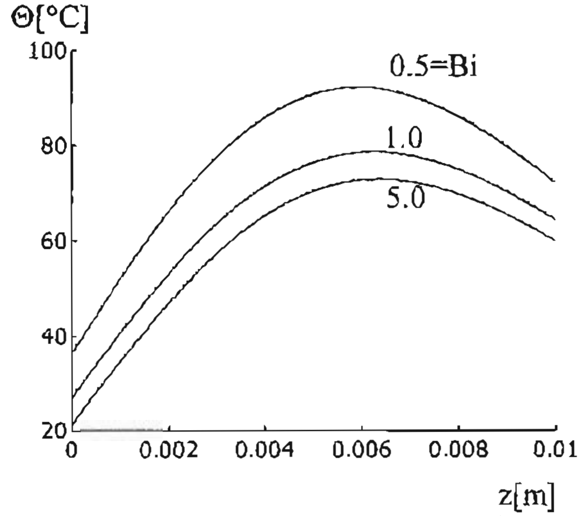

Fig. 6. Temperature-height variation for the point (0.5, 0.5, 1.0e-5), for Biot numbers 0.5; 0.1; 1.0 and 5.0; the time t is the working time; B=3 cm, s=V_s/B=1.0.

The feed velocity is another parameter that is influencing the grinding process and the temperature field of the workpiece. Figure 7 is presenting the SLT variation as a function of time for three different feed velocities (B=3 cm). Smaller values of SLT can be obtained for higher values of the feed velocity. We can also notice the time domain when the surface layer occurs; this domain is larger for smaller feed velocities.

Figure 7 is also defining the maximum value of the surface layer thickness (SLT_max) as the maximum thickness of the layer where, during the grinding process, the temperature becomes greater than 1500K.

Using the definition for SLT_max presented in figure 7, its variation as a function of feed velocity is presented by Fig. 8. Smaller values of SLT_max are implying higher feed velocities, the feed velocities s = 1.0 being the best choice.

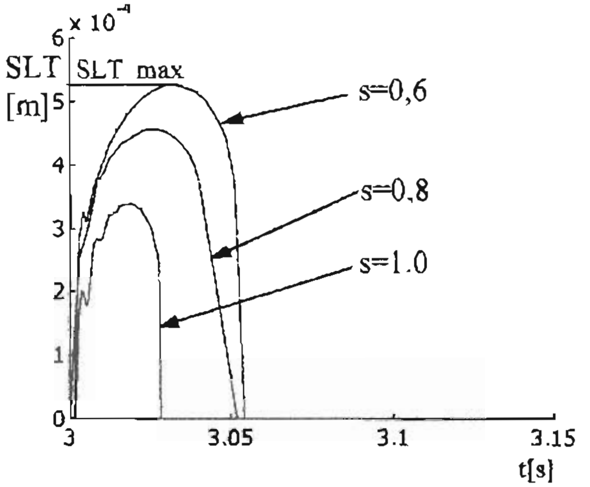

Fig. 7 SLT thickness variation as a function of time for three different values of feed velocity(s=V_l/B); B=3 cm.

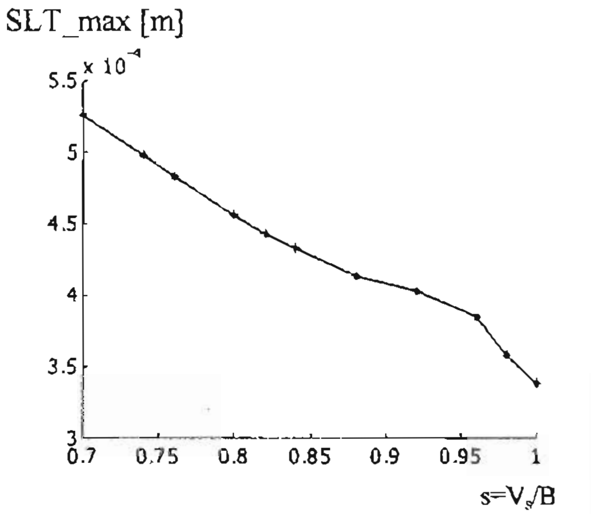

Fig. 8 SLT_max variation as a function of feed velocity; B=3 cm.

Figure 9 is presenting the surface layer thickness variation as a function of time for three different values of the grinding disc thickness. A closer look at this variation is shown in Fig. 10. There, the maximum values of the layer thickness, the SLT_max, is presented as a function of the grinding disc thickness for the same ratio s=V_s/B=1.0. A minimum value occurs, for the point (0.5L, 0.5l,z), around B=3,3 cm.

The lack of experimental data obliged us to approximate the power input in the grinding process. Based on the experience, a power input of 3kW was accepted throught the paper. The influence of the power input value on the results is big as the temperature field is proportional to the power input. In order to emphasize the influence of the power input on the order of magnitude of the surface layer thickness, its variation is presented, for three values P=3; 2,5 and 2,3 kW, in Fig.11. There were considered B=3 cm and s=1.0.

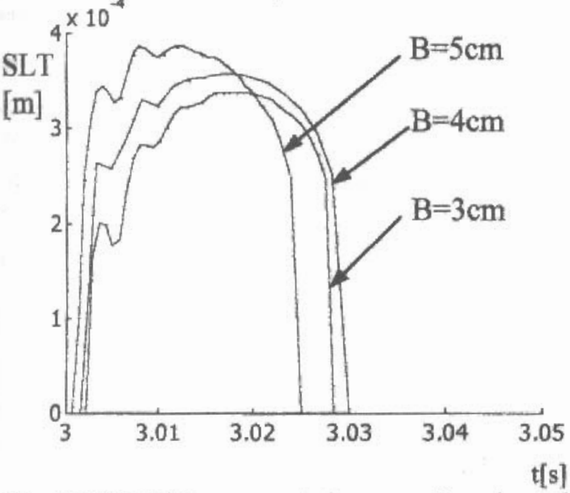

Fig. 9 SLT thickness variation as a function of time for three different values of grinding disc thickness; s=1.0

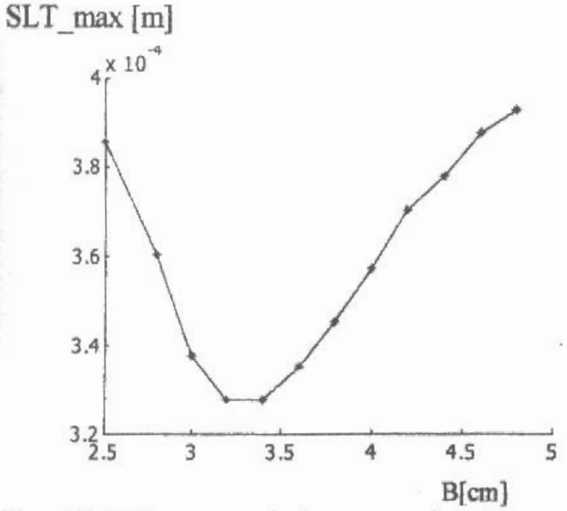

Fig. 10 SLT_max variation as a function of grinding-disc thickness, B; s=1.0.

As we can notice the surface layer thickness decrease from 100 % to 76 % and, respectively, 65 % as the power input decreases from 3 kW, to 2,5 kW and, further, to 2,3 kW.

The points belonging to the surface layer are cooling very fast. For example, for a feed velocity V_s=B, and a tool thickness of B=3 cm, the point situated at the width $z=3.37\times10^{-4}$m is cooling from 1500 K to 300 K in less than 1 minute.

Due to the fast cooling process, the final structure will be a martensitic one (with a residual austenite), so the structure will have a high hardness, low plasticity, and it will be very brittle.

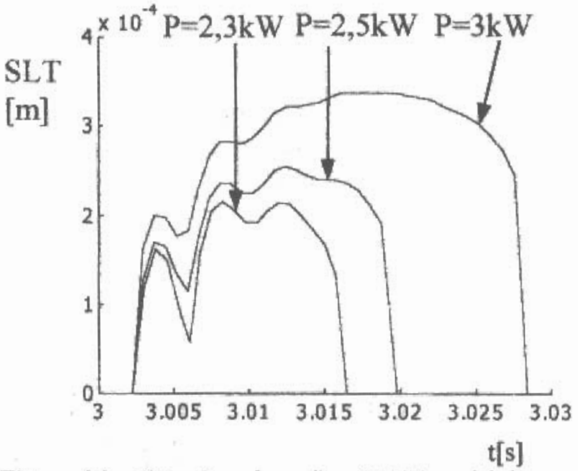

Fig. 11 "Surface-layer" (SLT) thickness variation as a function of time for three different power inputs; B=3 cm, s=1.0.

3. Conclusions

1. The surface layer structure has a very high inhomogeneity regarding its structure; the material temperature goes beyond the melting point and is maintained there for different moments of time depending on the depth of the point considered and its position on the workpiece surface. Consequently, the structure will have martensitic grains of different sizes, in different layers, as well as along the workpiece length, in different points.
2. The absence of the experimental points imposed us to choose the value of the power in the process. As the temperature field level depends on the power in a proportional manner, the values presented here have a qualitative value; the temperature and, consequently, the surface layer thickness are slightly overestimated.
3. The time and space variation of the surface layer depends also on the feed velocities (Fig.7) and the grinding disc thickness (Fig.9).
4. Naming surface layer thickness (SLT) as the maximum thickness of the layer where the temperature goes beyond 1500K, its variation is presented as a function of the cutting feed velocity (Fig. 8) and grinding tool thickness (Fig. 10).
5. The conclusion is that a high feed velocity assures a low surface layer thickness. There is an optimum value for the grinding tool thickness, value for which the surface layer thickness is minimum.

6. The problem treated in this study is actually a very general one. It cannot be applied only to grinding process, but also to any machining process of plane surfaces that imply the input of a uniformly distributed heat flux.

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STRUCTURA "STRATULUI SUPERFICIAL" AL PIESELOR PLANE RECTIFICATE

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Rezumat

Această lucrare este un studiu a stratului superficial al pieselor plane rectifcate. Se prezintă aici modelarea variaţiei în timp a stratuluisuperficial, acolo unde temperatura materialului depăşeşte temperatura de topire. Este, astfel, posibil de aflat grosimea maximă a stratului unde are loc tranformari austenită/martensită foarte rapide care schimbă proprietăţile mecanice ale materialului. Studiul prezintă variaţia grosimii maxime a stratului superficial ca o funcţie de timp, viteza de avans a piesei şi grosimea discului abraziv.

STRUCTURE "DE COUCHE EXTÉRIEURE" DES OBJETS PLATS DE RECTIFIÉ

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Résumé

Cet article est une étude de la structure de la couche extérieure d'un objet rectifié. Il établit la variation de temps de la couche isotherme où la température de fonte est atteinte. Il est possible, de cette façon, de savoir la largeur maximum de la couche où la transformation d'austenitic / martensitique se produit et les propriétés de matériel s'attend. L'étude établit également la variation de la largeur de couche de surface en fonction du temps, vitesse d'avans de l'objet et l'épaisseur d'outil.