BALKANTRIB'O5
5^{th} INTERNATIONAL CONFERENCE ON TRIBOLOGY
JUNE.15-18. 2005
Kragujevac, Serbia and Montenegro

HEAT LOAD OF THE WORKPIECE SURFACE-LAYER IN GRINDING PROCESS

Assoc. Prof. Marin Gostimirovic, Ph.D.; Prof. Dragoje Milikic, Ph.D.
University of Novi Sad, Faculty of Technical Sciences, Institute for Production Engineering,
Trg D. Obradovica 6, 21000 Novi Sad, Yugoslavia, E-mail: maring@uns.ns.ac.yu

Abstract

This paper points the development of high heat load in the workpiece surface layer, special during productivity grinding. In order to identify the influence of grinding heat on the workpiece surface layer were determined the temperature fields in the workpiece under different machining conditions. Beside this, the state of the workpiece surface layer was identified through examination of microstructure, microhardness, microcracks and appearance of burned surface layers. Thus obtained experimental research results made possible a complete identification of thermal state of the workpiece surface layer in grinding.

***Key words**: Grinding, Temperature, Surface layer, Thermal load*

1. INTRODUCTION

The recent period, marked by a rapid development of the grinding techniques, has led not only to improvements in the conventional multipass grinding used for finishing, but also to improvements in the high productivity grinding technique [1,4]. This technique significantly increases the relatively low material-removal rate, which has long since been the major disadvantage of the conventional grinding.

The intensive heat energy increase and the difficulties of its distribution are generating high interface temperatures which cause extreme thermal loads on the work as well as the tool. This heat load which primarily affects the work surface-layer presents a major impediment to further development of the grinding techniques [2,3,5].

For that reason, a special attention has to be paid to the problem of thermal phenomena in grinding and to explanations for all the phenomena taking place in the machined surface-layer of the workpiece.

2. DESCRIPTION OF EXPERIMENTAL RESEARCH

Measuring temperatures in the grinding wheel and workpiece contact zone is carried out by means of thermocouples built in the workpiece. Using this method makes it possible to determine the temperature field distribution in the workpiece surface-layer, namely maximal temperature of contact that develops in the cutting zone [1].

Measuring, analysis and control of the temperature during the process of machining with grinding was performed with the help of a modern, highly accurate computerized measuring system. The acquisition of data is performed by means of an advanced integrated software package, which makes possible direct measuring of temperatures with standard thermocouples, presenting the measurement results in graphic form and memorizing data.

Components of the identification of the workpiece surface layer state after grinding are: metallografic examination of changes in microstructure; measuring microhardness; exploring burned surfaces and microcracks. Metallografic examination of changes in microstructure and measuring microhardness in depth of the surface layer of the workpiece material has been performed with an optic microscope.

3.TEST RESULTS

3.1 Grinding temperatures in the cutting zone

To determine temperature field distribution in the workpiece surface-layer; temperatures in the workpiece were measured for various distances from the measuring point to the contact surface of the workpiece and the grinding wheel. A characteristic graphic review of temperature changes in time in the cutting zone, obtained through gradually drawing the grindstone closer to thermocouple's hot junction, is shown in Fig. 1.

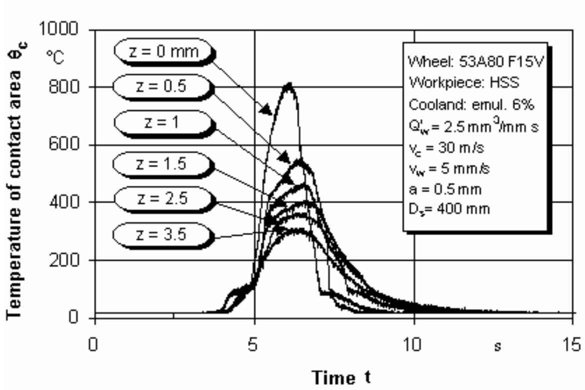

Fig.1: *Temperature change in time for different distance of measuring point to the workpiece surface-layer*

From the diagram shown on Fig. 1 we can conclude that the intensity of thermal source is decreasing, and the time of its influence is increasing as the point of view is further from the contact surface. Beside this, in the deeper layer maximal temperature was reached just after passing of the grinding wheel above the measuring point, concerning the time needed for heat conduction from the cutting zone. When increasing the distance from contact surface, the differences between maximal temperatures are significantly decreasing.

If taking into account the moment when grinding wheel enters the cut, dimensions and the workpiece's feed speed, it is possible to form the cutting zone temperature range through the temperature change in time. An example of a formed temperature range which gives a review of the temperatures rising up in particular places in workpiece's material surface-layer, determined on the basis of Fig. 1., is shown in Fig. 2.

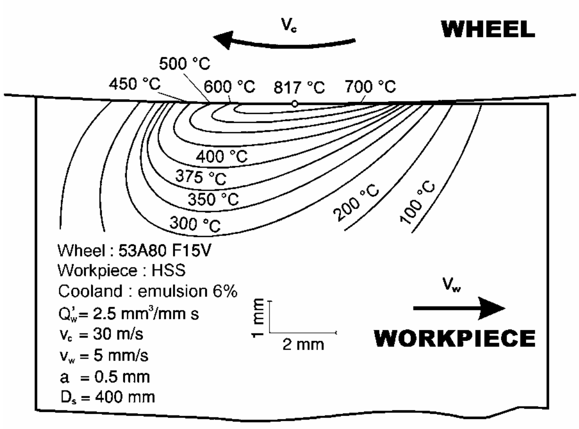

Fig.2: *Temperature field distribution formed on the basic of the results*

In order to determine the disposition of temperatures in the dept of the workpiece material's surface-layer, we used the maximal temperatures measured during every pass of the grindstone while it was successively approaching the hot junction of the thermocouple. Fig. 3. shows a change of temperatures in depths of the workpiece material's surface-layer in different condition machining.

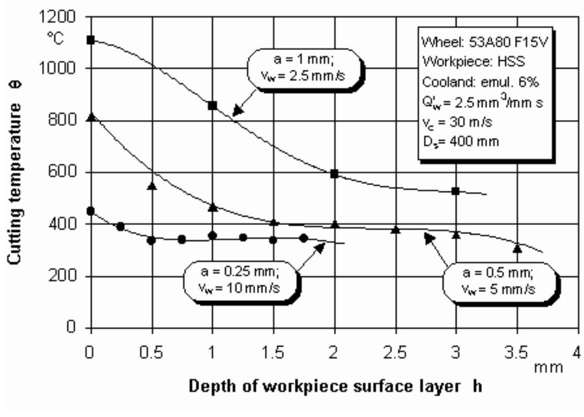

Fig.3: *Temperature change by the depth of workpiece surface-layer in case different condition machining*

From Fig. 3. it is obvious that higher values of contact temperature are reached for higher values of depth of cut and lower values of cutting speed. This fact is confirming thesis that in creep-feed grinding are reached higher values of cutting temperatures, because of simultaneous increase of power of heat source and time of its duration.

3.2 The workpiece material surface layer condition

Metallografic examination of changes in microstructure of the workpiece surface layer show that secondary changes appeared in each case when the measured maximal grinding contact temperature was higher than the temperature of previous remission, which is 550°C for the steel that was used in testing. Characteristic metalograph picture of workpiece material surface layer's microstructure, showing the microstructure generated by grinding, is presented in Fig. 4

Secondary hardened layer, seen through microscope as a white surface, contains martenzit, remaining austenit with strongly outstanding grains, and cementit. The interlayer is characterized by a black zone, with more or less explicit lighter reticular zone, and is made of martenzit-austenit net and cementit, where the content of austenit decreases with increasing the distance from the secondary hardened layer. The microstructure of the secondary remissioned layer is remissioned martenzit and cementit, which are gradually becoming the basic microstructure of material made of martenzit with fine arranged globular cementit.

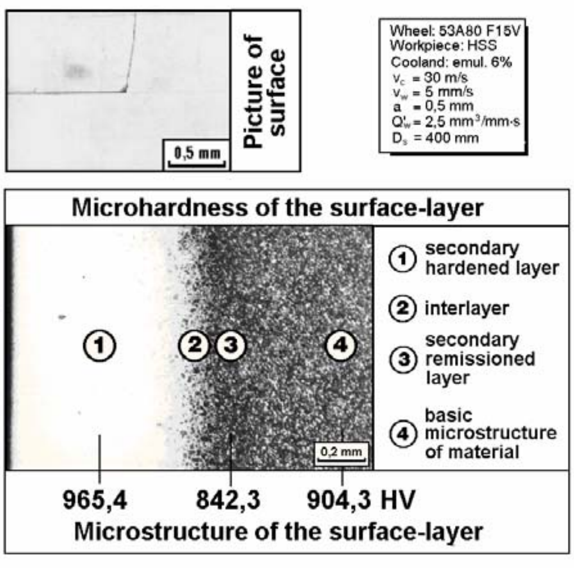

Fig.4: *Picture, microstructure and microhardnes of the workpiece surface-layer*

The depth of the secondary changed layer was in the limits from several tenths of a millimeter to a couple of millimeters, and in direct proportion with grinding contact temperature and the previous remission characteristic temperature keeping time. The change of the secondary changed workpiece surface layer depth in the function of grinding's temperature of contact area is shown in figure 5.

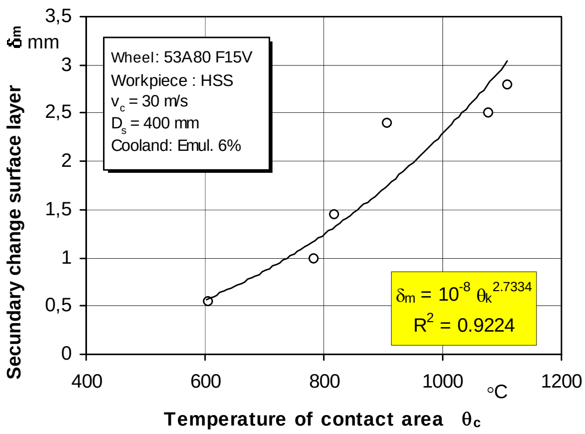

Fig.5: *Changes of secondary changed microstructure of the workpiece material surface layer, in elation to the contact area grinding temperature*

The measured microhardness, shown in Fig. 4, indicates that the microhardness of the secondary hardened layer is a little higher than the microhardness of the basic material. The smallest measured value of microhardness found in the secondary remissioned layer.

The increased microhardness of the secondary hardened layer is a result of remaining transformation of austenit into martenzit. The decrease of microhardness, that starts in the interlayer and has its minimal value in the secondary remissioned layer, appears in the martenzit-austenit net around the parts where high remission appeared.

During the further identification of the workpiece material surface layer condition not one sample was found with microcracks in it. On the other hand, burned surfaces were noticed in all samples where the measured grinding contact temperature was above the temperature of the previous remission.

4. TEST RESULTS ANALYSIS

On the basis of experimental investigations it can be concluded that in creep-feed grinding, due to simultaneous increase of the heat source power and time of activity, really high grinding temperatures are developed.

Unfavorable heat charge of the workpiece material surface layer developed in creep-feed grinding initiates intensive changes in the workpiece surface layer. Figure 6 shows the function of the depth of the secondary changed workpiece material surface layer from the machining conditions for the constant specific material removal rate. The same figure also shows the time in which the remission temperature is being held at 550°C in the cutting zone.

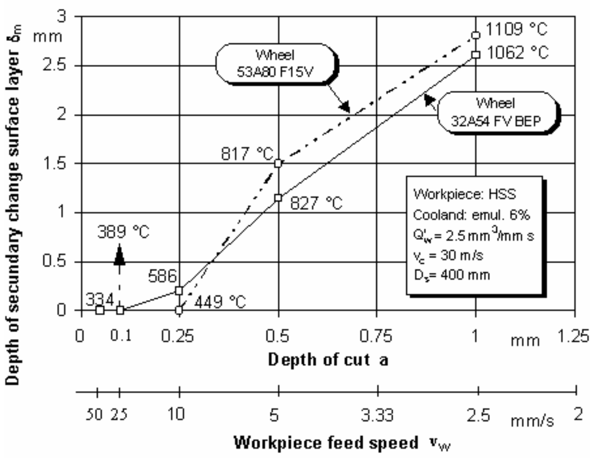

Fig.6: *Secondary changed workpiece material surface layer in relation to machining conditions for constant specific material removal rate*

Through a complete analysis of tested metalographic samples it can be concluded that the secondary changes in the workpiece surface layer can be found in every case where the contact grinding temperature is higher than the remission temperature. At the same time, if the contact grinding temperature does not go beyond austenit-to-ferit phase transformation temperature, which is 723°C for steel containing more than 0,8% carbon, just the remissioned layer is registred. In the opposite case, if the temperature goes beyond, all three characteristic changed layers are registered: the hardened layer, the interlayer, and the remissioned layer.

5. CONCLUSIONS

On the basis of experimental investigations done and analyses performed and shown in this paper, the following conclusions can be reached:

- The installed the method and computerized measuring systems for data acquisition maximal temperature in the cutting zone can be measured, the changes of contact area temperature in time function can be followed, and the temperature field in the workpiece's material surface-layer can be determined;
- On the basis of the contact area grinding temperature it is possible to determine with certainty particular conditions of the grinding process, or to compare the influence of different parameters on the grinding process;
- Secondary metalographic changes are present in all cases of machining when the measured maximal contact grinding temperature was higher than the temperature of workpiece material's previous remission and is direct proportion with the height of the contact grinding temperature and the time it is held above the temperature of previous remission;
- Microhardness of the secondary hardened layer is a little higher, and of the secondary remissioned layer a little lower from the microhardness of the basic material;

6. LITERATURE

[1] Gostimirovic M.: An Investigation into the Influence of the Tool-Work Interface Temperature on the State of the Surface-Layer in Creep-Feed Grinding (in Serbia), Ph.D. thesis, Faculty of Technical Sciences, Novi Sad, Yugoslavia, 1997.

[2] Gostimirović, M., Milikić, D., Sekulić, M., Uzelac, S.: Temperature field distribution of the workpiece surface-layer in creep-feed grinding, Second international congress mechanical engineering tehnologies, Sofia, 1999., pp. 16-17.

[3] Gostimirović M., Milikic D.: Control of the thermal effects in the grinding process (in Serbia), Monograph, Faculty of Engineering, Novi Sad, Yugoslavia, 2002.

[4] Guo S., Malkin S.: Analytical and Experimental Investigation of Burnout in Creep-Feed Grinding. Annals of the CIRP, Vol. 43/1/1994, pp. 283-286.

[5] Rowe W.B. and sec.: Experimental Investigation of Heat Transfer in Grinding. Annals of the CIRP Vol. 44/1/1995, pp. 329-332.