Наведено результати експериментальних досліджень температури в первинній, вторинній і третинній зонах різання та їх порівняння з розрахунковими даними моделювання процесу різання методом скінченних елементів за допомогою програми "DEFORM". Одержані результати можуть бути використані як при дослідженні процесів різання, так і для проектування різальних інструментів

Ключові слова: визначення температури, зони різання, метод скінченних елементів, програма "DEFORM"

Приведены результаты экспериментальных исследований температуры в первичной, вторичной и третичной зонах резания и их сравнение с расчетными данными моделирования процесса резания методом конечных элементов посредством программы "DEFORM". Полученные результаты могут быть использованы как при исследовании процессов резания, так и для проектирования режущих инструментов

Ключевые слова: определение температуры, зоны резания, метод конечных элементов, программа "DEFORM"

This paper presents the results of experimental analyses of the cutting temperature in primary, secondary and tertiary cutting zones. The experimental data are compared with the simulation results gained by means of the FE-method with the programme „DEFORM". The results can be used both for the analysis of cutting processes and for the designing of cutting tools

Key words: determination of temperature, cutting zones, the finite-element-method, programme „DEFORM"

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DETERMINATION OF TEMPERATURE IN THE CUTTING ZONES

U. Heisel
Dr.-Ing.

M. Storchak
Dr. Sc. tech., Stuttgart, Germany

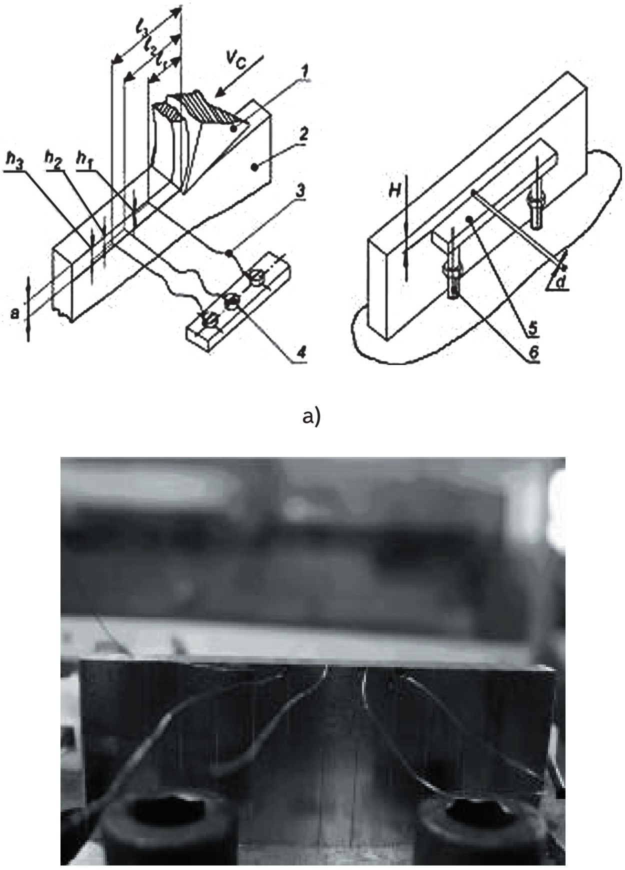
M. Korotkih
Dr. Sc. tech. St.-Petersburg, Russland

1.Introduction

Among the most important characteristics of cutting processes are cutting forces and temperatures, which are often used as integral values in order to evaluate a process. Both the theoretical and the experimental determination of cutting temperatures cause considerable difficulties. In this paper the results of the experimental analysis of temperatures in the cutting zones are presented and compared with the data gained by means of the FE-method.

2. Test procedure

The experimental analyses for the determination of the temperatures in the primary, secondary and tertiary cutting zones were conducted by means of semi-artificial thermocouples, which are based on the Seebeck effect [1], [2] and [3]. Two analysing methods have been used. With the first method the temperature distribution inside the workpiece and chip can be analysed. One arm of the thermocouple consisted of constantan wire and the other of the material that was to be machined. Hence, a thermocouple of the type "J" was generated. Before the actual measurements were conducted, constantan wires of different diameters from 0.02 mm to 0.1 mm were tested for suitability. Wires with a diameter of 0.03 mm showed the best results with regard to resolution and stability and were eventually used for the analyses. The basic schematic drawing of the first method is illustrated in Fig. 1, a). The workpiece with welded constantan wires (arms) is shown in Fig. 1, b).



a)

b)

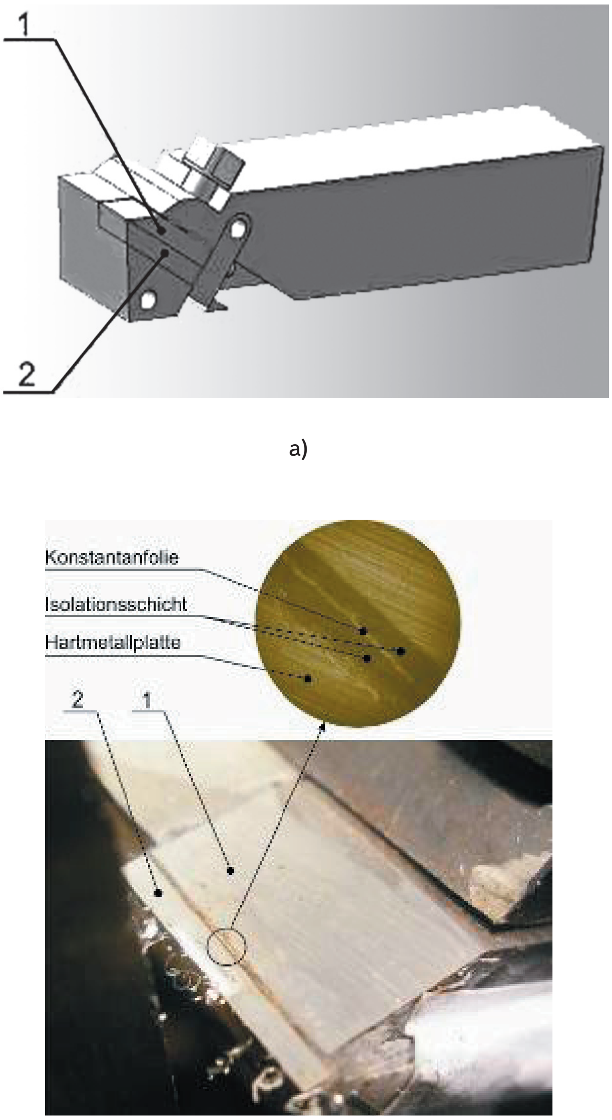
Fig. 1. Schematic drawing of the temperature measurement setup (a) and workpiece with welded thermocouples (b)

According to the schematic drawing in Fig. 1, a) the wires are welded with the sample or the workpiece by means of a condenser welding apparatus, in which each constantan arm is set to a previously determined height hi and length relative to the boundary of the sample. If the exact starting point of the measurement, which is determined by a trigger, and the cutting speed are known, the distances li can be calculated. Hence, the exact position of the individual constantan arms, relative to the wedge, and the exact position of the point to be measured can be calculated, correspondingly.

With the second method the temperature distribution at the boundary between wedge and chip can be analysed. In this case the arm of the thermocouple consists of a constantan foil, which is fixed between two carbide plates 1 and 2, see Fig. 2, a). The workpiece is used as the second arm. The constantan foil and the entire workpiece are isolated by the upper and lower cutting plates, see Fig. 2, b). Depending on the relative position of the upper and lower cutting plates to each other, and depending on the type of tool bevel, the position of the foil relative to the wedge point can be changed. Thus, the contact temperatures can be measured at different points, which are mainly in the secondary cutting zone. The thermocouple is of the type “J”, as it was in the first method.

The recording and processing of the signals was carried out by means of a measuring map of the type “PCI-6133” of the company National Instruments with 32 simultaneous measuring channels, which is built into a measuring computer.

The software recording and processing as well as the control and analysis of the signals were conducted using the programme LabVIEW 7.1.



a)

b)

Fig. 2. Model of the cutter (a) and image of the tool used (b)

3. Experimental Results

The FEM model, which was extended by thermal effects, has been verified by a comparison of experimental and simulated values. The temperatures in the primary, secondary and tertiary cutting zones and in the base material are taken as reference values. C 45 was used as test material and the standard carbide plates P20 of the company Walter were used as cutting plates.

The chip angle was chosen to be 5° and the clearance angle 8°. Characteristic signals in the primary cutting zone and in the chip are depicted in Figure 3. When the starting point of the cutting process and the cutting speed are known, the temperature signal can be identified with regard to the sensor position in the material to be machined. Hence, the temperature in the cutting zones and in the base material can be determined. During cutting, the signal shape and the amplitude correspond to the position of the temperature sensor or the constantan arm in the different layers of the material (see Fig. 4).

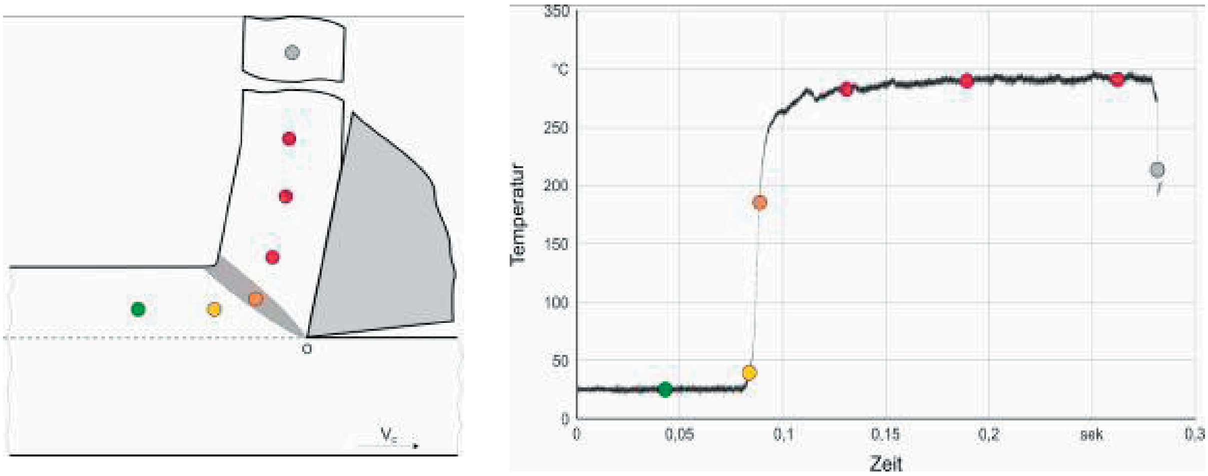


Fig. 3. Characteristic signal shape in the primary cutting zone and the chip

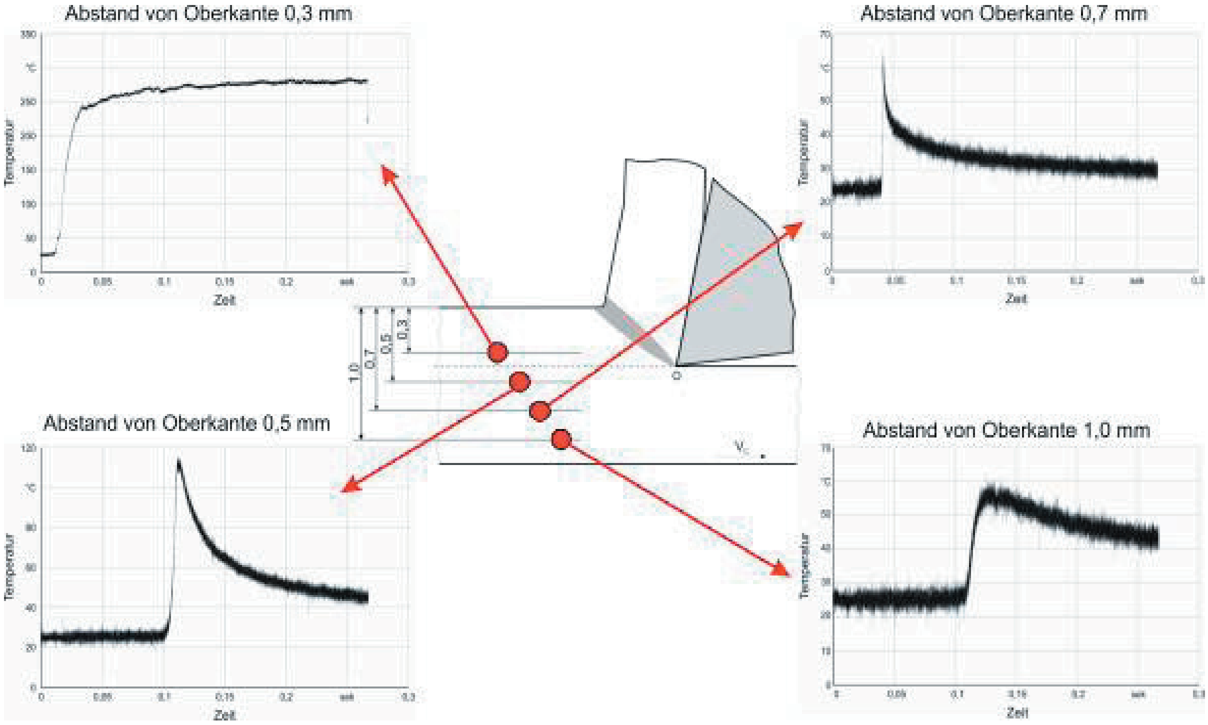


Fig. 4. Characteristic signal shape in the material layers to be cut

The method with the welded constantan wire, see Fig. 1, can only be used in practice in comparatively great cutting depths so as to achieve a proper resolution and to be able to reliably determine the position of the constantan arm. Therefore, this method should be applied in the experimental analysis of temperatures in the primary and secondary cutting zone as well as in the base material.

The method with the constantan foil, which is fixed between two cutting plates, see Fig. 2, does not exhibit such a restriction and was hence used as the basic method for recording the cutting temperature.

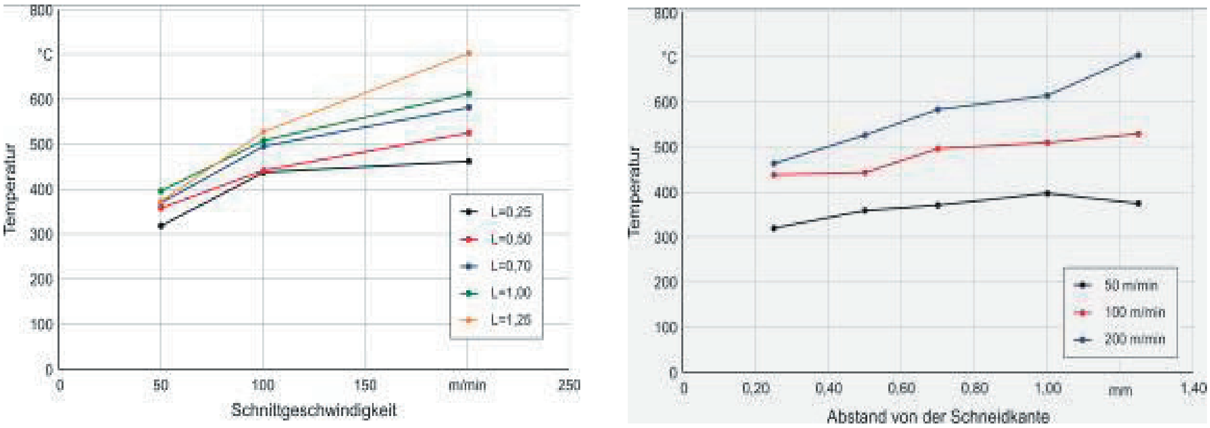


Fig. 5. Temperature change in the secondary cutting zone

Figure 5 shows the change in temperature in the secondary cutting zone and in the chip, respectively. The change is dependent on the cutting speed and on the distance of the measuring point and on the position of the constantan foil relative to the cutting edge of the tool plate, respectively. It can be noticed that the change in temperature at a cutting speed of 50 m/min is extreme. The maximum is reached at a distance of 1mm between measuring point and cutting edge. This corresponds to the known temperature distribution in the secondary cutting zone. With cutting speeds of 100 m/min and 200 m/min the temperature maximum is only reached when the distances to the cutting edge are greater.

Figure 6 presents the results of the verification of the FEM cutting model at a distance of 0.25 mm to the cutting edge. The maximum difference between the simulated and experimentally recorded results is 13.8 %, which can be regarded as an acceptable error.

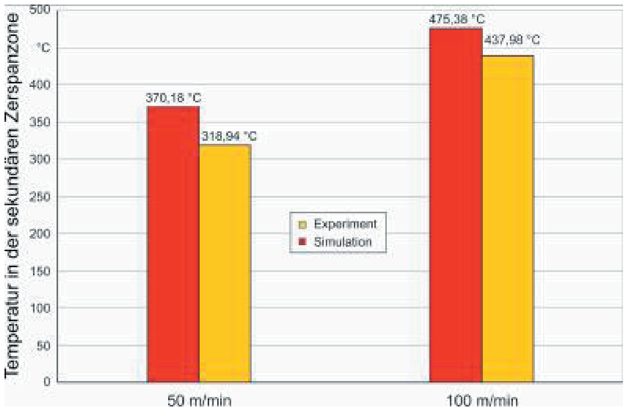


Fig. 6. Simulated and experimentally recorded temperatures in the secondary cutting zone

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