THE INFLUENCE OF THE RATIO CUTTING DEPTH/NOSE RADIUS OF TNMG160408-P30 PLATE ONTHE CUTTING THERMOCURRENT AT CUTTING OLC45 STEEL

Valentin DIŢU
Transilvania University of Brasov, Romania

Abstract. At metals cutting with metallic edges it appears an electrical current due mainly to the temperature in the cutting zone. Because the temperature in the cutting zone shows how the cutting process develops and the resulted electrical current estimates precisely the temperature, results that the electrical current at cutting is a simple diagnose method due to the possibility to be measured with accuracy. The paper shows the influence of the ratio between the cutting depth and nose radius of TNMG160408-P30 metallic carbide plate at turning OLC45 steel. It was chosen the influence of the ratio between cutting depth and nose radius of the plate because the phenomenon during the cutting process are developing differently in the nose radius zone than in the rectilinear part of the edge. The paper shows this aspect.

Keywords: cutting, turning, electrical current (thermocurrent), diagnose

1. Introduction

The research in the field of cutting metals with metallic edges has shown the fact that it appears an electrical current that has as primary cause the temperature in the cutting zone [1, 2, 3, 4]. The resulted electrical current is based on the Seebeck effect, Thomson effect and on the phenomenon of emission in metals [2]. The first practical application of the electrical current at cutting was (and it is) the appreciation of the temperature in the cutting zone. The later research done in different countries, between them being Romania, identified also the next applications of the thermocurrent:

- efficiency appreciation of using cutting fluids;
- efficiency appreciation of additional sharpening at cutting tools;
- appreciation of the cutting force without dynamometer;
- appreciation of the cutting edge wear;
- appreciation of the cutting edge quality;
- fast appreciation of the cutting edge breakage;
- constructive optimization of cutting tools;

The cutting process is identified as a system with degenerative feedback loop [2], the feedback loop being the wear. As consequence, the temperature in the cutting zone and implicitly the electrical current at cutting, are influenced by all the parameters entry elements in process. The parameters of the entry elements can be identified as:

- constructive parameters;
- geometrical parameters;
- dynamical parameters (cutting parameters);
- state parameters (temperature, aggregation state, rigidity, etc.)
- mechanical parameters;
- chemical parameters;
- electrical parameters.

Other than the entry elements with their parameters, in the system “Cutting Process – CP” enter also perturbation factors (noise) (ex. vibration chamber of a forge hammer). The electrical current at cutting is influenced by all the identified elements that can be independent between them or dependent between them fact that complicates even more their study. As more influence factors are analyzed the more practical applications can be identified.

In this paper is being analyzed the influence of the ratio t/r_z (cutting depth/nose radius of the cutting plate) over the electric current at cutting. It was chosen this ratio and not the cutting depth to show the different development of the cutting process in the nose radius zone of the edge than in the situation when at cutting participates the rectilinear part too.

2. Experimental determination and results processing

To experimentally analyze the influence of the ratio t/r_z, that will be written as “t_{rz}”, there were made parts with the diameter of ø50 and L = 200 mm, from OLC45 steel on which was removed the initial layer because it could have been a noise factor. The material was analyzed both in terms of chemical and hardness resulting the next:

- hardness = 224 HB;

- chemical composition: C-0.46%, Mn-0.7%, Si-0.27%, P-0.013%, S-0.025%, the rest Fe;
- normal and homogenous structure.

The installation of collecting and measuring the cutting thermocurrent is shown in Figure 1, where:
1 – lathe SNB 400×1000;
2 – part from OLC45;
3 – metallic carbide plate P30 and support plate P20;
4 – thermocurrent collector;
5 – precise digital multimeter.

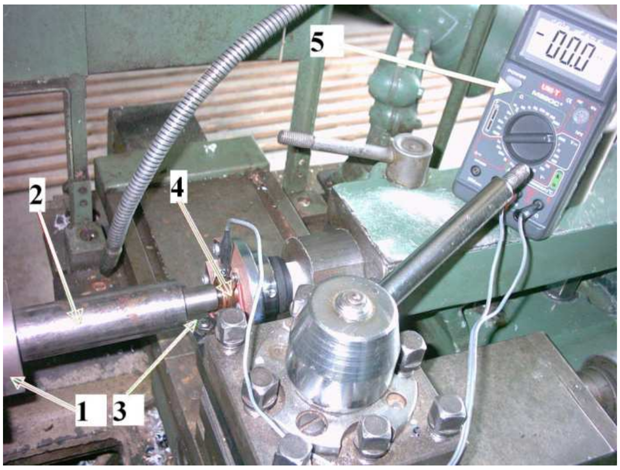

Figure 1. The installation used to measure the cutting thermocurrent at turning

The metallic carbide plate is type TNMG 160408 - P30 with α = 5º; γ = – 5º; λ = – 6º; χ = 90º, *r* = 0.8 mm, triangular shape with side of 16 mm, depth 4 mm, nose radius "r_z" of 0.8 mm, with threshold for chip breaking and with central hole. The support plate is metallic carbide type P20.

The collector "4" for collecting the current is type copper / copper to eliminate the parasite currents that would have appeared as consequence of frictions.

The part, the collector and the cutting tool were electrical insulated from the machine tool to avoid forming another electrical circuit.

To see how the cutting speed and feed influence the tension of the thermocurrent when the cutting develops in the nose radius zone the first tries were done with variable cutting speed and then with variable feed. The results of the tries are shown in Tables 1 and 2.

Processing the data from Table 1 with CurveExpert 1.4 software it can be seen that the function that can be used is "Shifted Power Fit" and has the expression (1):

$$U = 2.8008 \cdot (v - 5.7370)^{0.2373} \quad [\text{mV}] \qquad (1)$$

where *U* – tension of electric current, standard error (*s*) = 0.049, and correlation coefficient (*r*) = 0.999.

Table 1. Influence of cutting speed

Crt. no.	*v* [m/min]	*s* [mm/rev]	*t* [mm]	U_V [mV]
1	25.72	0.106	0.5 (t_{rz} = 0.625)	5.7
2	41.15	0.106	0.5 (t_{rz} = 0.625)	6.5
3	51.44	0.106	0.5 (t_{rz} = 0.625)	7.0
4	78.57	0.106	0.5 (t_{rz} = 0.625)	7.7
5	102.88	0.106	0.5 (t_{rz} = 0.625)	8.3
6	129.63	0.106	0.5 (t_{rz} = 0.625)	8.8

OLC45; TNMG 160408-P30; α = 5º; γ = – 5º; λ = – 6º; χ = 90º, *r* = 0.8 mm; *s* = 0.106 mm/rev; t/r_z = 0.625; without cooling

Table 2. Influence of cutting feed

Crt. no.	*v* [m/min]	*s* [mm/rev]	*t* [mm]	U_V [mV]
1	102.88	0.106	0.5 (t_{rz} = 0.625)	8.3
2	102.88	0.151	0.5 (t_{rz} = 0.625)	8.5
3	102.88	0.208	0.5 (t_{rz} = 0.625)	8.8
4	102.88	0.250	0.5 (t_{rz} = 0.625)	8.9
5	102.88	0.302	0.5 (t_{rz} = 0.625)	9.0
6	102.88	0.416	0.5 (t_{rz} = 0.625)	9.4

OLC45; TNMG 160408-P30; α = 5º; γ = – 5º; λ = – 6º; χ = 90º, *r* = 0.8 mm; *v* = 102.88 m/min; t/r_z = 0.625; without cooling

The graphical representation of relation (1) it can be seen in Figure 2.

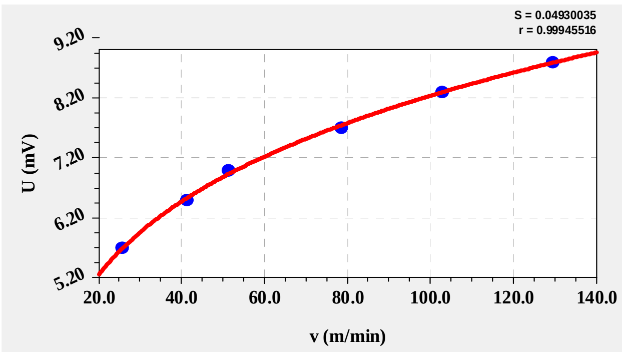

Figure 2. Thermocurrent variation with cutting speed

Data from Table 2, processed, give the regression curve (2):

$$U = 10.2362 \cdot (s + 0.1405)^{0.1493} \quad [\text{mV}] \qquad (2)$$

where U – tension of electric current, standard error (*s*) = 0.050 and correlation coefficient (*r*) = 0.994.

Graphical representation of relation (2) is shown in Figure 3.

The next experiments show the influence of ratio "t_{rz}" over the cutting thermocurrent tension. In order to see this influence the experiments were developed with variable cutting depth (Table 3).

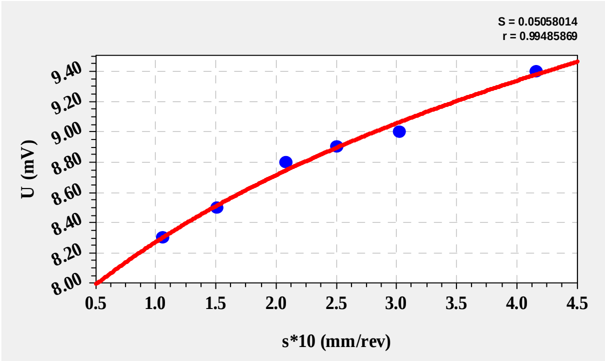

Figure 3. Thermocurrent variation with feed

Table 3. Influence of ratio t_{rz}

Crt. no.	v [m/min]	s [mm/rev]	t_{rz} [mm]	U_V [mV]
1	102.88	0.106	0.625 (t = 0.5)	8.3
2	102.88	0.106	0.937 (t = 0.75)	8.3
3	102.88	0.106	1.25 (t = 1.00)	8.4
4	102.88	0.106	1.875 (t = 1.5)	8.6
5	102.88	0.106	2.5 (t = 2.00)	8.7

OLC45; TNMG 160408-P30; α = 5º; γ = – 5º; λ = – 6º; χ = 90º, r = 0.8 mm; v = 102.88 m/min; s = 0.106 mm/rev; without cooling

The expression that can be easily used, given by the CurveExpert 1.4, is the function “Polynomial Fit” of grade 3 and has the expression (3):

$$U = 8.568127 - 0.855576 \cdot t_{rz} + 0.776129 \cdot t_{rz}^2 - 0.165167 \cdot t_{rz}^3 \quad [\text{mV}] \qquad (3)$$

Graphical representation of function (3) is shown in Figure 4.

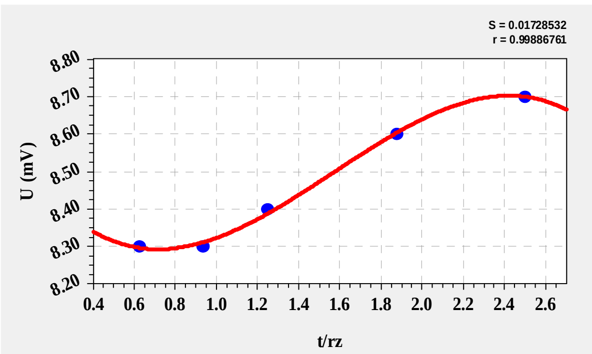

Figure 4. Thermocurrent variation with ratio “t/r_z”

It can be seen the fact that the function presents an inflexion point that can be found out cancelling the 2nd order derivative (equation (4)):

$$0.776129 - 3 \cdot 0.165167 \cdot t_{rz} = 0 . \qquad (4)$$

Solving the equation leads to the coordinates of the inflexion point as: t_{rz} = 1.566 and U = 8.5 mV.

Using the last three points from Table 3 results the graphic from Figure 5 and the function “Shifted Power Fit” (5):

$$U = 8.600166 \cdot \left(t_{rz} - 0.883138\right)^{0.236583} \quad [\text{mV}] \qquad (5)$$

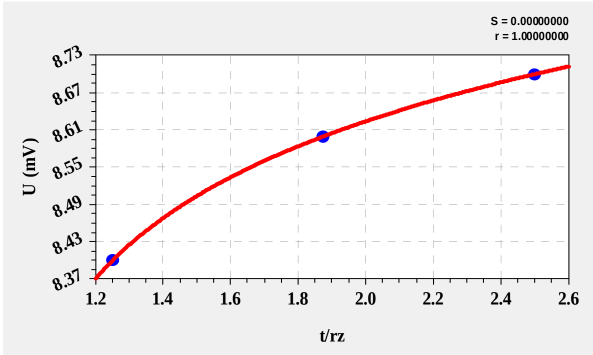

Figure 5. Variation of thermocurrent with ratio “t/r_z”, when $t_{rz} \geq 1.566$

Using the first three points from Table 3 results the graphic from Figure 6 and the function “Quadratic Fit” (6):

$$U = 8.599361 - 0.798466 \cdot t_{rz} + 0.511182 \cdot t_{rz}^2 \quad [\text{mV}] \qquad (6)$$

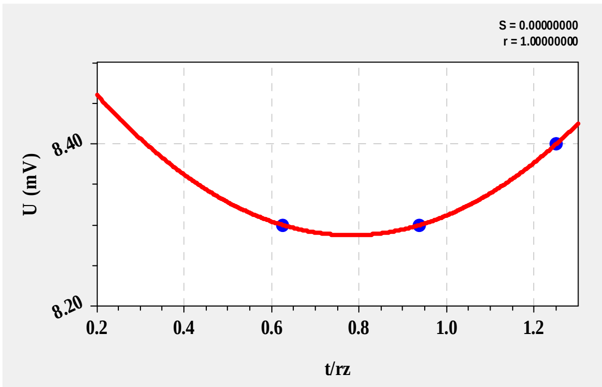

Figure 6. Variation of thermocurrent with ratio “t/r_z”, when t_{rz} < 1.566

Relation (6) presents a minimum in the point of coordinates t_{rz} = 0.781 and U = 8.29 mV.

3. Conclusions

Processing the experimental data leads to the next conclusions:

- when ratio $t/r_z \geq 1.566$ its influence over the electrical current at cutting (and implicitly over the temperature in the cutting zone) is similar to the influence of the cutting speed and feed; the resulted regression function from processing the experimental data is “Shifted Power Fit” and not the function “Power Fit” presented in the specialty literature;
- when ratio t/r_z < 1.566 the regression function is “Quadratic Fit” that presents a minimum when the cutting depth is equal with the nose

radius of the cutting plate, fact that totally correspond to the development of the cutting process;

- when the cutting develops at a cutting depth lower than the nose radius, the cutting process, because of the variable lead angle, develops differently than in the situation when the cutting depth is higher than the nose radius of the cutting edge, fact shown by the relation (6);
- when ratio $t/r_z \geq 1.566$ the degree of influence of the cutting depth over the electrical current at cutting is greater than the degree of influence of the feed because between the exponents from relations (2) and (5) is the connection, $0.1493 < 0.236583$; this observation contradicts what it was known until now, that the influence of cutting depth over the average temperature at cutting (the electric current at cutting reflects precisely the temperature in the cutting zone) is greater than the influence of the cutting depth;
- if it is compared the degree of influence of the cutting speed (relation 1) and the one of the ratio t/r_z, when this last one is greater than 1.566 (relation 5), it is observed that these are very closed ($0.2373 > 0.236583$), fact that contradicts the data from the specialty literature, that the influence of the cutting depth over the temperature in the cutting zone is very low, almost insignificant; for more information regarding to the connection between the ratio t/r_z and the exponent of the cutting speed from relation (1) the experimental research must be continued;
- the using of the electrical current to diagnose the cutting process represents an innovative technique because it combines information from two fields, mechanics and electrics;
- the electrical current resulted at cutting, known in the specialty literature as the thermocurrent, represents a simple and precise method to analyze different influences in the cutting process.

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