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University POLITEHNICA of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania

EXPERIMENTAL RESEARCH ON CUTTING TEMPERATURE DURING ALUMINIUM ALLOYS MANUFACTURING

Dănuț OPREA, Ioan TĂNASE, Sorin Mihai CROITORU

Abstract: *There are few studies regarding experimental research on cutting temperature during the manufacturing of aluminium alloys with Romanian drills having the active part made of metal carbides. This paper presents the experimental measurement stand, the obtained results and their interpretation. The use of these considerations is the fact that cutting temperature is directly influencing the wear of the drill, its durability and the shape of the chips. Also, the cutting temperature is a criterion to evaluate the cutting machinability of the manufactured materials.*

Key words: *cutting temperature, experimental research, deep drilling, aluminium alloys.*

1. CUTTING TEMPERATURE EXPERIMENTAL MEASUREMENT STAND

The experimental research was conducted on an original stand assembled on the milling machine for cutting tools TOS CELAKOWICE - Czechoslovakia.

In principle, the measurement of cutting temperature was made using the natural thermo-couple method [5 - 11].

The scheme of the measuring stand in case of deep holes drilling is presented in Fig. 1.

Figure 1 presents the following elements of the experimental stand: 1 - drill; 2 - workpiece; 3 - natural thermo-couple TN made of the drill and workpiece; 4 - rotational contact with mercury (mercury tank); 5 - digital electronic multi-meter TESLA BM 518.

In case of using this method to measure the cutting temperature there must be solved two problems: electric insulation of the cutting tool and workpiece from the rest of the technological system and micro-electrical-currents caption from elements which are rotating.

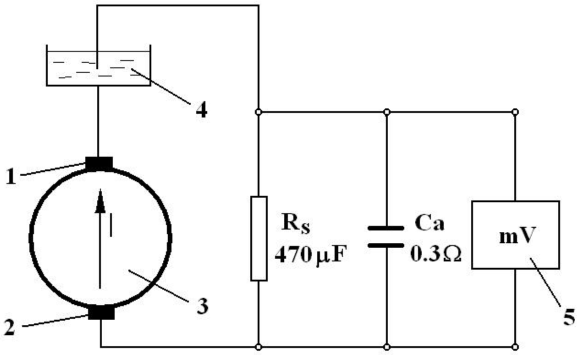

Fig. 1. Experimental stand for cutting temperature measurement.

The first problem was solved by electrical insulation of the workpiece and the drill from the rest of the technological system. Thus, the workpiece was isolated from its holding device by means of plastic sheets. The same insulation was made for the drill from the spindle of the milling machine.

The second problem is micro-electrical-currents caption because the drill is rotating during the machining. This is the reason the mercury rotational contact is used (pos. 4 in Fig. 1).

This rotational contact, which has an original construction, was assembled at the top of the spindle of the milling machine.

Reading the voltage of the thermo-electrical currents was made by means of a digital multi-meter TESLA BM 518 (pos. 5 in Fig. 1).

It must be mentioned the experiments on cutting temperature were done for two aluminium alloys: ATSi12CuMgNi (hardness 135 HV), named material 1 and ATSi9Cu3Mg (hardness 125 HV), named material 3. It also must be mentioned the experimental research was complex, not only on cutting temperature, and it were studied several materials.

For both studied materials when the cutting temperature was measured no coolant was used. For any measurement experimental stand, no matter the measured physical parameter, the reference values regulation is a real problem.

In this case, to regulate the reference values of the thermal-electrical currents, which appear during the cutting process, an original installation was used. Its principle scheme is presented in Fig. 2.

In principle, the regulation of the reference values of the cutting temperature measurement stand was done by simultaneous measurement of the voltage generated by the natural thermo-couple drill-workpiece and the voltage generated by an etalon thermo-couple Copper-Constantan, fixed in the workpiece, made of each studied aluminium alloy.

In Fig. 2 the following elements are presented: 1 - drill; 2 - workpiece; 3 - natural thermo-couple TN drill-workpiece; 4 - rotational contact with mercury; 5 - digital multi-meter TESLA BM 518; 6 - etalon thermo-couple Copper-Constantan; 7 - heating device; 8 - holding device; 9 - insulators; 10 - electronic milivoltmeter.

A bar made of workpiece material (studied aluminium alloy) was heated with an electrical resistor plugged to a regulated electrical autotransformer.

Temperature of the hot end of the bar was measured by means of a Copper-Constantan thermo-couple and an electrical milivoltmeter.

During the regulation process, by means of the experimental stand the voltage of the natural thermo-couple TN was measured for different temperatures of the heated workpiece with the electrical resistor. These temperatures of the workpiece were measured by means of the etalon thermo-couple Copper-Constantan.

Regulation operations were made separately for each couple drill-workpiece, which represents the natural thermo-couple. Each regulation operation had the following steps: using the heating device 7 the workpiece bar 2 was progressively heated, being registrated the voltages generated by both thermo-couples: workpiece-drill and Copper-Constantan.

The workpiece bar was heated in the range 60 … 230˚C, being measured 6…8 values, which represent the points through which the reference curve is draw.

It must be mentioned that based on these measurements for regulation of the stand, considering the relationship between the temperatures and voltages there were determined formulae to transform the voltages in temperatures for each couple of drill (P20 metal carbides sort) and workpiece (studied aluminium alloys).

Without details, the following formulae were determined:

a) Couple: material 1 ATSi12CuMgNi (135HV), drill *d* = 10 mm:

Θ = 189 Utn + 47 [˚C],

b) Couple: material 1 ATSi12CuMgNi (135HV), drill *d* =1 2 mm:

Θ = 97 Utn + 51 [˚C],

c) Couple: material 3 ATSi9Cu3Mg (125HV), drill *d* = 10 mm:

Θ = 101 Utn + 34.6 [˚C],

d) Couple: material 3 ATSi9Cu3Mg (125HV), drill *d* = 12 mm:

Θ = 77 Utn + 37.8 [˚C].

2. EXPERIMENTAL RESULTS AND THEIR INTERPRETATION

The results of the experimental measurements are presented in Tables 1 and 2, in order to determine the influence of the cutting regime parameters upon the cutting temperature.

Data in the two presented tables was used to draw some graphics to show the influence of cutting speed and feed upon the cutting temperature.

Even if in current practice they have small applicability, based on the data presented in Tables 1 and 2 and variation diagrams of cutting temperature vs. cutting regime parameters, exponential relationships to determine cutting temperature when deep drilling aluminium alloys were determined.

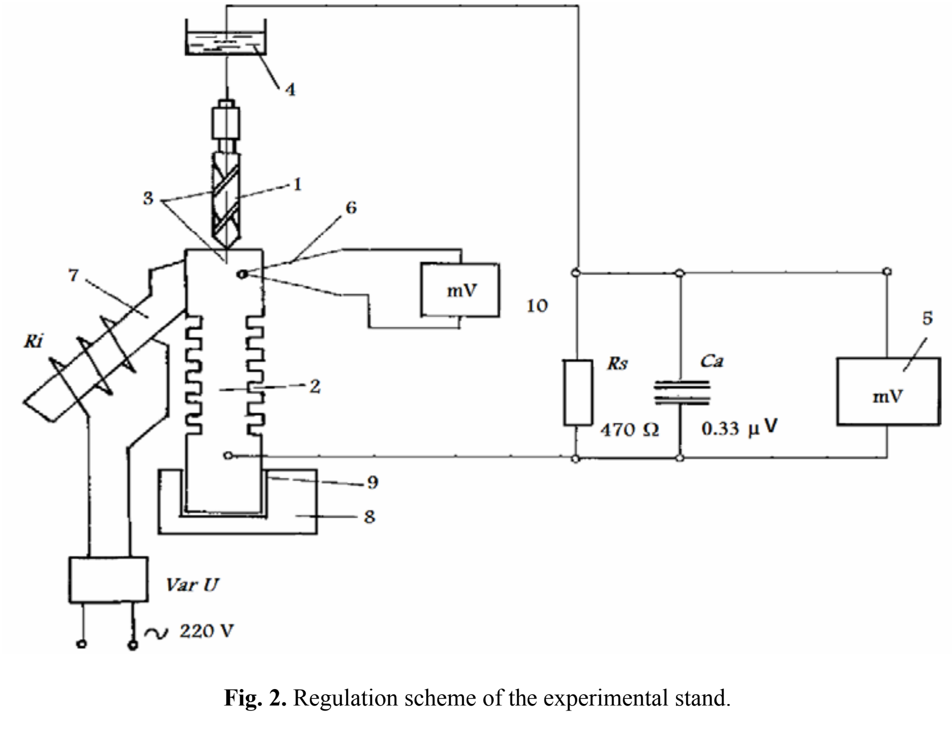

Fig. 2. Regulation scheme of the experimental stand.

Table 1

Cutting temperature for deep drilling of material 1 ATSi12CuMgNi (135HV)

n_c, rpm	f_v, mm/min	f, mm/rot	d = 10 mm		d = 12 mm	
			v_c, m/min	Θ, ˚C	v_c, m/min	Θ, ˚C
1000	20	0.02	31.42	69.65	37.7	62.64
	40	0.04		88.6		78.2
	80	0.08		107.4		89.8
1600	20	0.0125	50.3	66	60.3	61
	40	0.025		92.3		81.1
	80	0.05		103.64		95.6
2000	20	0.01	63	66	75.4	62.64
	40	0.02		88.6		82
	80	0.04		103.64		99.5
Relationship			Θ = 189 Utn + 47		Θ = 97 Utn + 51	

Table 2

Cutting temperature for deep drilling of material 3 ATSi9Cu3Mg (125HV)

n_c, rpm	f_v, mm/min	f, mm/rot	d = 10 mm		d= 12 mm	
			v_c, m/min	Θ, ˚C	v_c, m/min	Θ, ˚C
1000	20	0.02	31.42	56.82	37.7	72.5
	40	0.04		59		75
	80	0.08		61		80
1600	20	0.0125	50.3	45	60.3	49
	40	0.025		59		60
	80	0.05		65		64.2
2000	20	0.01	63	47	75.4	52
	40	0.02		71		60
	80	0.04		81		62
Relationship			Θ = 101Utn + 34.6		Θ = 77 Utn + 37.8	

Without details, the exponential relationships to determine cutting temperature for deep drilling of the two studied aluminium alloys with drills having the diameters d_A = 10 mm and d_B = 132 mm are the following:

- for material 1 ATSi12CuMgNi (135 HV), v_c = const,
  a) drill d = 10 mm:
  $v_c = 31.42$ m/min, $\theta = 237 f^{0.31}$,
  $v_c = 50.3$ m/min, $\theta = 330 f^{0.37}$,
  $v_c = 63$ m/min, $\theta = 301 f^{0.33}$.
  b) drill d = 12 mm:
  $v_c = 37.7$ m/min, $\theta = 173.5 f^{0.26}$,
  $v_c = 60.3$ m/min, $\theta = 306 f^{0.37}$,
  $v_c = 75.4$ m/min, $\theta = 288 f^{0.33}$.
- for material 3 ATSi9Cu3Mg (125 HV), v_c = const,
  a) drill d = 10 mm:
  $v_c = 31.42$ m/min, $\theta = 69.3 f^{0.05}$,
  $v_c = 50.3$ m/min, $\theta = 167 f^{0.3}$,
  $v_c = 63$ m/min, $\theta = 295 f^{0.4}$.
  b) drill d = 12 mm:
  $v_c = 37.7$ m/min, $\theta = 96 f^{0.07}$,
  $v_c = 60.3$ m/min, $\theta = 129 f^{0.22}$,
  $v_c = 75.4$ m/min, $\theta = 95 f^{0.13}$.
- for material 1 ATSi12CuMgNi (135 HV), f = const,
  a) drill d = 10 mm:
  $f = 0.02$ mm/rot, $\theta = 21.6\, v_c^{0.34}$,
  $f = 0.04$ mm/rot, $\theta = 40\, v_c^{0.23}$.
  b) drill d = 12 mm:
  $f = 0.02$ mm/rot, $\theta = 15.7\, v_c^{0.38}$,
  $f = 0.04$ mm/rot, $\theta = 22\, v_c^{0.35}$.
- for material 3 ATSi9Cu3Mg (125 HV), f = const,
  a) drill d = 10 mm:
  $f = 0.02$ mm/rot, $\theta = 19\, v_c^{0.32}$,
  $f = 0.04$ mm/rot, $\theta = 12.6\, v_c^{0.45}$.
  b) drill d = 12 mm:
  $f = 0.02$ mm/rot, $\theta = 166\, v_c^{-0,23}$,
  $f = 0.04$ mm/rot, $\theta = 197\, v_c^{-0.27}$.

3. CONCLUSIONS

Based on the obtained experimental results, some conclusions can be underlined, as following:

- for the chosen cutting regimes, the cutting temperature varied between 300˚C and 600˚C;

- there is an important rise of the cutting temperature with the increase of the cutting regime parameters as feed and cutting speed;

- cutting temperature rise, both for cutting speed and feed variation, is approximately linear. This can be seen in the cutting temperature variation graphics;

- the reason to measure the cutting temperature is because this dramatically influences wear and durability of the cutting tools. The cutting temperature variation laws are the same as the cutting tool durability variation laws;

- as expected, the cutting temperature is more influenced by the cutting speed than the feed. This results also from the values of the exponents in the relationships of the cutting temperature vs. cutting regime parameters.

As a consequence, from the cutting temperature point of view and, of course, from the cutting tool wear and durability point of view, it is better to increase the cutting operation productivity by means of feed increase (extensive cutting regimes) and less by means of cutting speed increase (intensive cutting regimes).

However, the increase of feed must be precautious because of the increase of cutting efforts, roughness of the machined surfaces, rise of the cutting temperature, occurring of high deposit edges etc.

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Authors:

Eng., Dănuţ OPREA, PhD Student, University Politehnica of Bucharest, Machine and Production Systems Dept,
PhD, Ioan TĂNASE, Professor, University Politehnica of Bucharest, Machine and Production Systems Dept,
E-mail: `tanase@imst.msp.pub.ro`
PhD, Sorin Mihai CROITORU, Assoc. Prof., University Politehnica of Bucharest, Machine and Production Systems Dept,
E-mail: `croitoru@artelecom.net`