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THE FAST ESTIMATION OF THE CUTTING FORCES AT TURNING AND DRILLING

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Abstract: *The paper presents a fast experimental method to estimate the cutting forces at turning and drilling, method that is based on the electric current at cutting. The method can be used at the cutting processes of metal with edges that are good conductors of electricity. In the first part the paper presents in detail the fast estimation of the cutting force at turning steel OL37 with a cutting tool that has the edge made of P20 metallic carbide and in the second part it is shown the possibility of estimation of the axial force at drilling steel OLC45 with a drill from fast steel Rp3.*
Keywords: *electric current at cutting, cutting forces, turning, drilling*

1. INTRODUCTION

It is known the fact that the measuring of the cutting forces, for any processing method, has a great practical importance because besides the dimensioning and checking that are done with their help, these can be also used to diagnose the cutting process.

The new systems for measuring the cutting forces are based on piezoelectric transducers and are reasonable accurate, but they are modifying the stiffness characteristics of the technological system. So, in the tables 1 and 2 are presented the types of piezoelectric dynamometers and their characteristics, that can be used at turning, milling and drilling, produced by the company „Kestler”. The cost of these measuring systems is reasonable high (more than 20000$) and in consequence there are few that can afford these systems.

Table 1. Piezoelectric dynamometers for turning and milling produced by the company „Kistler”

Crt. No.	Type	F_x, F_y		F_z	
		Domain	Work Freq.	Domain	Work Freq.
1	9255A - milling -	± 20 KN Er.<0,01 N	1,5 KHz	-10÷40 KN Er.<0,01 N	1,5 KHz
2	9257A milling/turning	± 5 KN Er.<0,01 N	4 KHz	± 5 KN Er.<0,01 N	4 KHz
3	9265A1 - turning -	± 15 KN Er.<0,01 N	1,5 KHz	0÷30 KN Er.<0,01 N	2 KHz
4	9265A2 - milling -	± 15 KN Er.<0,01 N	1,5 KHz	-10÷30 KN Er.<0,01 N	2 KHz
5	9281B22 - milling -	± 20 KN Er.<0,01 N	0,6 KHz	-20÷40 KN Er.<0,01 N	0,6 KHz
6	9281B23 - milling (different plate) -	± 20 KN Er.<0,01 N	0,6 KHz	-20÷40 KN Er.<0,01 N	0,6 KHz

From the tables can be observed that the produced systems are accurate but they modify the stiffness of the technological system and in consequence there must be searched other solutions to avoid this fact but also to avoid the high aquisition cost. In the next rows it is proposed a method to diagnose the cutting forces, method that mostly eliminates the negative facts previous presented.

Table 2. Piezoelectric dynamometers for drilling produced by the company „Kistler”

Crt. No.	Type	F_x, F_y		F_z		M_z	
		Domain	Work Freq.	Domain	Work Freq.	Domain	Work Freq.
1	9271A drilling	-	-	-5÷20 KN Er.<0,02 N	3 KHz	± 100 Nm Er.<0,02 Ncm	3 KHz
2	9273 drilling	± 5 KN Er.<0,02 N	1,5 KHz	-5÷20 KN Er.<0,02 N	3 KHz	± 100 Nm Er.<0,02 Ncm	3 KHz
3	9291 drilling	-	-	-100÷200 KN Er.<0,02 N	5 KHz	± 2000 Nm Er.<0,05 Ncm	2,5KHz
4	9293 drilling	± 20 KN Er.<0,01 N	4,5 KHz	-100÷200 KN Er.<0,02 N	5 KHz	± 2000 Nm Er.<0,05 Ncm	2,5KHz

2. THE FAST ESTIMATION OF THE CUTTING FORCES AT TURNING

2.1. The strategy of the fast estimation of the cutting forces

At turning of the metallic materials with edges that are good electricity conductors appears an electric current, in consequence, mainly, of the heat in the cutting process. As the heat in the cutting process depends on the cutting forces, results that we have data about the cutting electric current and we can appreciate the value of the cutting forces.

The measuring of the cutting electric current is more simple and more accurate than the measuring of the forces with rezistive systems or even with piezoelectric systems, and, in addition, it doesn’t modify the stiffness of the technological system of processing.

In order to use the value of the cutting electric current tension at the appreciation of the cutting forces it must be determinated the relation between force and electric current. This can be done using two methods.

The first method consists in the determination of the relation that gives the value of the electric current depending on the cutting parameters, and based on the data from the specialty literature it can be determinated the relation that gives the value of the cutting force depending on the value of the cutting parameters, and finally, through the cutting parameters results the relation between the cutting force and the measured cutting electric current tension. The method is simple, it is necessary minimum of equipment, so it is also cheap, but the weak point it is represented by the data from the specialty literature.

The second approach, more accurate, consists in simultaneous using of a system to measure the tension of the electric current with another system to measure the cutting forces, the data being collected by an acquisition card and saved in the memory of a computer, and then it will be determinated the relation between the force and the tension of the electric current. This method is the best but it also needs an accurate system to measure the cutting forces, fact that is not available for anyone.

From economical reasons it will be used the first approach.

2.2. The elaboration of the methodology and experimental data

To determinate the cutting force is used the relation (1).

$$F_z = C_{Fz}.t^{xFz}.s^{yFz}.(HB)^{nz}.K_{Fz} \quad [daN] \qquad (1)$$

The experiments were done at turning OL37 steel with a P20 metallic carbide plate, that has the next geometry: $\alpha = 8^0$; $\gamma = 10^0$; $\lambda = 0^0$; K= 45^0; r = 0,5 mm. According [4], OL37 steel, having HB = 164, the next data are found:

$C_{Fz} = 27,9$; $x_{Fz} = 1$; $y_{Fz} = 0,75$; $n_z = 0,35$; $K_{Fz} = 0,33$.

Introducing the below data in the relation (1) it results:

$$F_z = 54,87 \,.\, t \,.\, s^{0,75} \quad [daN] \qquad (2)$$

To determinate the relation for the tension of the electric current depending on the cutting parameters it is used the installation presented in papers [1,2,3]. The obtained experimental data are centralized in table 3.

The processing of the experimental data has led to relation (3).

$$U = 1,615 \,.\, v^{0,506} .\, s^{0,323} .\, t^{0,129} \quad [mV] \qquad (3)$$

Table 3. Experimental data, for tension of the electric current at cutting, obtained at turning OL37 steel with CMP20 plate.

Exp. No.	n [rot/min]	d [mm]	v [m/min]	s [mm/rot]	t [mm]	U [mV]
1	200	49,7	31,22	0,106	0,5	4,13
2	250	49,7	39,03	0,106	0,5	4,65
3	315	49,7	49,18	0,106	0,5	5,05
4	400	49,7	62,45	0,106	0,5	5,7
5	500	49,7	78,06	0,106	0,5	6,65
6	630	49,7	98,36	0,106	0,5	7,36
7	400	49,2	61,82	0,053	0,5	4,18
8	400	49,2	61,82	0,106	0,5	5,66
9	400	49,2	61,82	0,151	0,5	6,40
10	400	49,2	61,82	0,208	0,5	6,90
11	400	49,2	61,82	0,25	0,5	7,12
12	400	49,2	61,82	0,302	0,5	7,33
13	400	49,5	62,2	0,106	1,5	6,93
14	400	49,5	62,2	0,106	1,25	6,71
15	400	49,5	62,2	0,106	1,00	6,56
16	400	49,5	62,2	0,106	0,75	6,28
17	400	49,5	62,2	0,106	0,5	6,00

Relation (2) can be written:

$$F_z = 54,87 \cdot t \cdot s^{0,75} \cdot U(v,s,t)/U(v,s,t) \quad [daN] \tag{4}$$

Using also the relation (3) is obtained the connection relation between the force and the tension of the electric current:

$$F_z = 33,98 \cdot v^{-0,506} \cdot s^{0,427} \cdot t^{0,871} \cdot U \quad [daN] \tag{5}$$

The verifying of the relation (5) it is done for the next example: having v = 62,2 m/min; s = 0,106 mm/rot; t = 1,5 mm experimental resulting U = 6,9 mV, with relation (2) is obtained F_z = 15,29 daN and with relation (5) is obtained F_z = 15,83 daN.

3. THE FAST ESTIMATION OF CUTTING FORCES AT DRILLING

To estimate the cutting forces at drilling it is used the same method as for turning. In addition, it will approach the cutting moment.
In order to determinate the force and the cutting moment at drilling OLC45 steel, with a drill made from Rp3 fast steel, that has the next geometry, $\alpha = 8^0$; $\gamma = 25^0$; $2K = 118^0$, there are used the relations (6) and (7).

$$F = C_F \cdot t^{xF} \cdot s^{yF} \cdot K_F \quad [daN] \tag{6}$$
$$M = C_M \cdot t^{xM} \cdot s^{yM} \cdot K_{FzM} \; [daN.cm] \tag{7}$$

According to [4] results the next practical relations:

$$F = 78,75 \cdot d^{1,07} \cdot s^{0,72} \quad [daN] \tag{8}$$
$$M = 7,705 \cdot d^{1,71} \cdot s^{0,84} \quad [daN] \tag{9}$$

To determinate the relation that gives the tension of the thermocurrent depending on the cutting parameters it is used the installation presented in the papers [1,2]. The obtained experimental data are centralized in table 4.
The processing of the experimental data has led to relation (10).

$$U = 0,222 \cdot v^{0,723} \cdot s^{0,462} \cdot d^{0,396} \quad [mV] \tag{10}$$

The relation (8) can be written:

$F = 78{,}75 \cdot d^{1{,}07} \cdot s^{0{,}72} . U(v,s,t)/U(v,s,t)$ [daN] (11)

Table 4. Experimental data, for the tension of the cutting thermocurrent, obtained at drilling the OLC45 steel with drills with edges from Rp3 fast steel.

Exp. No.	n [rot/min]	d [mm]	v [m/min]	s [mm/rot]	U [mV]
1	160	9	4,52	0,13	0,63
2	315	9	8,90	0,13	0,93
3	450	9	12,72	0,13	1,30
4	630	9	17,81	0,13	1,80
5	900	9	25,44	0,13	2,06
6	630	9	98,36	0,10	1,4
7	630	9	61,82	0,13	1,7
8	630	9	61,82	0,19	2,0
9	630	9	61,82	0,27	2,4
10	630	9	61,82	0,38	2,6
11	1250	6	23,56	0,13	1,6
12	900	7	19,79	0,13	1,6
13	630	9	17,81	0,13	1,7
14	630	11	21,77	0,13	1,9
15	630	12	23,75	0,13	2,2

Using also the relation (10) is obtained the connection relation between the axial force and the tension of the electric current at cutting:

$F = 354{,}73 \cdot v^{-0{,}723} \cdot s^{0{,}258} \cdot d^{0{,}684} \cdot U(v,s,t)$ [daN] (12)

In a similar way is obtained the relation (13).

$M = 34{,}71 \cdot v^{-0{,}723} \cdot s^{0{,}378} \cdot d^{1{,}324} \cdot U(v,s,t)$ [daN] (13)

4. CONCLUSION

The estimation method of the cutting forces at turning and drilling, presented in this paper, is using the connection relation between the tension of the electric current at cutting and the force and/or the cutting moment. The main advantage of this method consists in it's simplicity and it's accuracy and shows that using few technical equipment, very good results can be obtained. Also, the estimation it is done in a short time, processing by cutting almost 20 seconds and measuring the tension of the resulted electric current. The tension of the resulted electric current is measured by milivolts fact that means that it can easily be measured with the actual technical equipment. Comparing turning with drilling it can be observed that the tension of the electric current at turning is greater than the tension of the electric current at drilling, the differences resulted because of the processed material, because of the different geometry of the tools, because of the used cutting parameters and most of all because of the material of the cutting edge.

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