International Conference on Economic Engineering and Manufacturing Systems
Braşov, 25 – 26 October 2007

ECONOMICAL EFFICIENCY APPRAISAL OF THE NEW MODELS REGARDING THE SURFACE QUALITY FROM THE POINT OF VIEW OF THE PRODUCTIVITY OF THE CUTTING PROCESS

Cristina GĂVRUŞ
"Transilvania" University of Brasov, Romania

Abstract. The present paper approaches some economical aspects regarding the new models of appraising the surface roughness determined by the author in some previous papers [1, 2, 3]. One of these models refers to the case of turning with a cutting tool having a nose ray r and appraises directly the roughness R_a taking into consideration the working feed, s and the nose ray of the cutting tool. This paper proposes to determine the productivity of the cutting process taking into consideration the part of the lead time that depends on the cutting parameters and to appraise the productivity through the roughness R_a of the surface of the part processed through turning. The first part of the present paper establishes the theoretical aspects regarding the productivity appraisal, determining a mathematical model and the second part of the paper presents an application of the model, in order to evaluate the productivity of the turning process from the point of view of the roughness of the processed surface. As the roughness R_a depends on the working feed, the application is based on the statistic processing of some data regarding more values of the working feed, showing the variation of the lead time and thus of the productivity of the cutting process in accordance with the working feed. Briefly, the present paper highlights the importance of the new models of quality surface appraisal because they help for a rapid evaluation of the productivity of the cutting process.

Keywords: productivity, working parameters, surface roughness, lead time

1. Introduction

The purpose of the present paper is to highlight the importance of the mathematical models described by the formula (1):

$$R_a = f(s,r,v). \tag{1}$$

Concretely, one of the new mathematical models regarding the surface roughness and demonstrated in the previous papers [1, 2, 3] is expressed through the following formula:

$$R_a = 32 \cdot \frac{s^2}{r} \cdot c_2, \tag{2}$$

where: R_a-surface roughness [μm], s-working feed [mm/rot], r-nose ray of the cutting tool [mm], c_2-correction coefficient that depends on the cutting speed and that will be further determined through an experimental research. The model from above refers to the case of turning using a nose ray cutting tool.

The present paper further proposes to appraise the productivity of the turning process through the surface roughness R_a.

One aspect regarding the importance of the mathematical model (2) refers to the fact that the model can rapidly establish the working parameters to be used in the cutting process on the basis of the surface roughness desired, eliminated in this way the drawbacks of the formulas regarding the roughness met in the specialized literature [4, 5]:

$$R_{\max} = 125 \cdot \frac{s^2}{r}. \tag{3}$$

As it can be seen, formula (3) refers to roughness R_{max} and not to roughness R_a, which is met on all the working drawings. Specialized literature [5, 6] presents a formula that makes the connection between R_{max} and R_a, but it is inexact:

$$R_{\max} = (3...6) \cdot R_a. \tag{4}$$

2. Mathematical Model of Productivity Appraisal through the Working Feed

The problem regarding the determination of the mathematical model of appraising the productivity of the turning process is solved through taking into consideration the lead time, which is an important indicator of the economical efficiency of the cutting process. The part of the lead time that depends on the cutting parameters can be expressed through the following formula

[7]:

$$\Delta N_T = t_b + t_{es}, \qquad (5)$$

where: ΔN_T - the part of the lead time that depends on the cutting regime [min], t_b - machine basic time [min], t_{es} - time of cutting tool exploitation [min].

The two terms from formula (5) are further developed. In case of a longitudinal turning using a nose ray cutting tool the basic time can be expressed through the expression:

$$t_b = \frac{L}{n \cdot s}, \qquad (6)$$

where: L - cutting tool stroke [mm], n-rotation speed [rot/min].

The time of cutting tool exploitation has the following formula:

$$t_{es} = \frac{t_b}{T} \cdot t_{sr}, \qquad (7)$$

where: T-tool life [min], t_{sr}-tool change-adjusting time [min].

Taking into consideration expressions (5) and (7) the variable part of the lead time becomes:

$$\Delta N_T = \frac{L}{n \cdot s}\left(1 + \frac{t_{sr}}{T}\right). \qquad (8)$$

Expressing the tool life in accordance with the general Taylor formula [8]:

$$T^m = \frac{C_v}{v \cdot t^{xv} \cdot s^{yv}}, \qquad (9)$$

expression (8) becomes:

$$\Delta N_T = \frac{L}{n \cdot s} \cdot \left(1 + \frac{t_{sr} \cdot v^{\frac{1}{m}} \cdot t^{\frac{x_v}{m}} \cdot s^{\frac{y_v}{m}}}{C_v^{\frac{1}{m}}}\right). \qquad (10)$$

The terms from expression (9) have the following meaning: m-tool life exponent that depends on the cutting conditions, t-cutting depth [mm], C_v, x_v, y_v - coefficient, respective exponents that depend on the type of the processed material and cutting tool and other cutting conditions (such as using some cooling-lubricating liquids).

Aiming to demonstrate the importance of the mathematical models (1) regarding the efficiency of the cutting process and knowing the great influence of the cutting feed upon the roughness R_a, for developing the necessary calculations there are used the following notations:

$$k_1 = \frac{L}{n}, k_2 = \frac{t_{sr} \cdot v^{\frac{1}{m}} \cdot t^{\frac{x_v}{m}}}{C_v^{\frac{1}{m}}}, k_3 = \frac{y_v}{m}. \qquad (11)$$

Introducing the expressions of k_1, k_2, k_3 in formula (10), it is obtained the mathematic model of productivity appraisal:

$$\Delta N_T = \frac{k_1}{s} \cdot \left(1 + k_2 \cdot s^{k_3}\right). \qquad (12)$$

3. Application

This application aims to show the impact of the mathematical models (1) upon the economical efficiency of the cutting process and thus upon the lead time, through the cutting parameters, especially through the cutting feed.

3.1. Function of Lead Time Variation in Accordance with the Cutting Feed

For making the application it is considered the case of a longitudinal turning, using a rapid steel cutting tool, having a nose ray. The following aspects are also considered:

- the processed material is cast iron;
- the cutting tool has metallic carbide plate from group K with nose ray $r = 1$ mm;
- cutting tool stroke $L = 100$ mm;
- part diameter $d = 100$ mm;
- cutting parameters: $v = 150$ m/min, $n = 478$ rot/min, $t = 1$ mm;
- tool change-adjusting time $t_{sr} = 1$ min;
- $m = 0.15$,
- $x_v = 0.22$;
- for $s \le 0.3$: $C_v = 126$, $y_v = 0.40$;
- for $s > 0.3$: $C_v = 112$, $y_v = 0.50$.

The values of the coefficient C_v and exponents m, x_v, y_v are in accordance with paper [7].

For seeing the variation ΔN_T = *f(s)*, in accordance with expression (12), there is taken into consideration a series of values for the cutting feed and for every value the function will be calculated. The results of the calculations are presented in table 1. In accordance with the data from table 1 the function ΔN_T = *f(s)* has the graphical representation from figure 1. From the graphic it results that the cutting feed has a great influence upon the lead time and thus upon the economical efficiency of the cutting process. The graphic shows that the increase of the working feed leads to the decrease of the lead time till one point (till s = 0.42 *mm/rot* mm/rot.

Table 1. Values of Function ΔN_T = *f(s)*

Crt. no.	**s [mm/rot]**	**ΔN_T**	**k_1, k_2, k_3**
1.	0.02	10.5	

2.	0.04	5.25	
3.	0.06	3.50	
6.	0.08	2.63	
5.	0.10	2.11	
6.	0.12	1.77	
7.	0.14	1.53	
8.	0.16	1.34	
9.	0.18	1.20	
10.	0.20	1.10	
11.	0.22	1.01	
12.	0.24	0.94	
13.	0.26	0.88	
16.	0.28	0.83	
15.	0.30	0.79	
16.	0.32	0.75	$k_1 = 0.21$ $k_2 = 7.01$ $k_3 = 3.33$
17.	0.34	0.74	
18.	0.36	0.72	
19.	0.38	0.707	
20.	0.40	0.699	
21.	0.42	0.695	
22.	0.44	0.695	
23.	0.46	0.698	
26.	0.48	0.704	
25.	0.50	0.713	
26.	0.52	0.725	
27.	0.54	0.74	
28.	0.56	0.76	
29.	0.58	0.78	
30.	0.60	0.80	
31.	0.62	0.82	
32.	0.64	0.85	
33.	0.66	0.88	
36.	0.68	0.90	
35.	0.70	0.94	

For greater values of the cutting feed (greater than 0.44 mm/rot) the lead time increases. This could be explained through the influence of the feed upon the tool life. The increase of the cutting feed determines the decrease of the tool life [9] and thus, the time consumed with tool exploitation increases, as formula (7) shows.

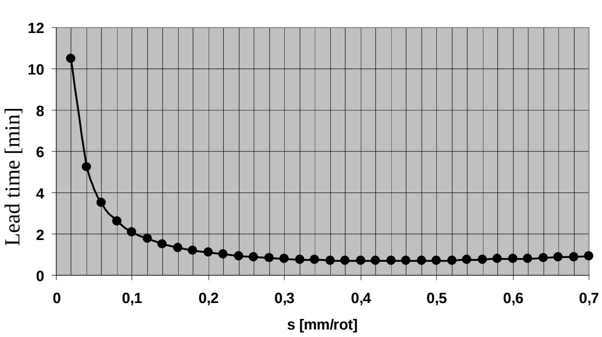

Figure 1. Variation of the Lead Time in Accordance with the Cutting Feed

To facilitate the interpretation of the influence of the cutting feed upon the lead time (especially the variable part of the lead time in accordance with the cutting parameters) it is useful that the data from table 1 to be mathematically processed with a view to obtaining a new mathematical function. In this way a software program called Modeller [9] was used. The program works in accordance with the minimum squares method and the following mathematical functions were obtained:

$$\Delta N_T = 0.237251 \cdot s^{-0.959042}, \qquad (13)$$

for $s \in [0.02\,;\,0.3]$

and

$$\Delta N_T = 3.496241 s^2 - 3.043985 s + 1.362360 \qquad (14)$$

for $s \in (0.3; 0.70]$.

3.2. Importance of the new Mathematical Model

Having in mind the aspects from above, it will be further demonstrated the importance of the mathematical model of $R_a = f(s, v, r)$ type regarding the lead time and the economical efficiency. In fact it is aimed the influence of the cutting feed upon the efficiency.

For solving this problem it should be done a comparison between the use of the mathematical models met within the specialized literature and the mathematical model from above. The model met in the specialized literature is expressed through formula (3). As on all working drawings it is met R_a roughness it is necessary to pass from R_{max} roughness to R_a roughness, through formula (4), also met within specialized literature. It results that:

$$R_a = \frac{R_{\max}}{(3-6)}. \qquad (15)$$

From formulas (3) and (15) it results that the value of the cutting feed s can vary within the following interval:

$$(0.15 \cdot \sqrt{r \cdot R_a}, \quad 0.22 \cdot \sqrt{r \cdot R_a}). \qquad (16)$$

Under circumstances, it naturally appears the question regarding the optimal value of the cutting feed, especially that it is not necessarily that if R_{max} increases or decreases, R_a follows the same way.

Using the mathematical model (2), determined and presented by the author in some previous papers, it immediately results:

$$s = 0.18 \cdot \sqrt{r \cdot R_a}. \qquad (17)$$

Formula (17) does not take into consideration the correction coefficient c_2.

Determination of this coefficient makes the object of another paper of the author. Formula (17) eliminates the situation when engineers wander about the optimal value of the cutting feed because it determines very precisely this value.

Knowing the value of the cutting feed and taking into consideration the functions (13) and (14) it can be established the part of the lead time that depends on R_a roughness:

$$\Delta N_T = 1.23 \cdot (R_a \cdot r)^{-0.48}, \qquad (18)$$

$$\text{for } 0.18 \cdot \sqrt{R_a \cdot r} \in [0.02\,;0.3]$$

and

$$\Delta N_T = 0.11 \cdot R_a \cdot r - 0.55 \cdot \sqrt{R_a \cdot r} + 1.36, \qquad (19)$$

$$\text{for } 0.18 \cdot \sqrt{R_a \cdot r} \in (0.3\,;0.7].$$

4. Conclusions

The present paper aimed to demonstrate the great utility of the appraisal models of R_a roughness from the point of view of the economical efficiency of the cutting process expressed through the lead time. The demonstration is based on the fact that the mathematical model related to R_a roughness eliminates the uncertainty regarding the establishment of the value of the cutting feed. In this way the mathematical models (12), (13) and (14) were elaborated:

$$\Delta N_T = \frac{k_1}{s} \cdot \left(1 + k_2 \cdot s^{k_3}\right),$$

$$\Delta N_T = 0.237251 \cdot s^{-0.959042},$$

$$\text{for } s \in [0.02\,;0.3]$$

and

$$\Delta N_T = 3.496241 \cdot s^2 - 3.043985 \cdot s + 1.362360,$$

$$\text{for } s \in [0.3;0.7]$$

The two limits for the cutting feed generate two other limits for the productivity of the processing expressed through the lead time (for example, for values of the cutting feed greater than 0.3 mm/rot:

$$\Delta N_{T1} = 0.079 r R_a - 0.456\sqrt{rR_a} + 1.362360, \qquad (20)$$

$$\Delta N_{T2} = 0.169 r R_a - 0.670\sqrt{rR_a} + 1.362360 \qquad (21)$$

Thus, taking into consideration these two limits it results a loss of productivity of

$$\Delta(\Delta N_T) = 0.09 r R_a - 0.214\sqrt{rR_a} \qquad (22)$$

For exemplification, it is considered the same case of a longitudinal turning with a cutting tool having a nose ray. In addition it is considered that R_a roughness is 6.3 μm. Calculating the productivity loss it is obtained $\Delta(\Delta N_T)$=0.03 min/part min/part, which represents a decrease of the productivity of 4%.

References

1. Ivan-Gavrus, C., Ivan. N.V., Ivan. M.C.: *Roughness Appraisal of Surface Processed through Turning Using Wide Cutting Tools*. Proceedings of International Conference on Manufacturing Systems, Romanian Academy Publishing House, p. 395-398, ISSN 1842-3183, Bucharest, Romania, October 2006
2. Ivan. N.V.. Ivan. C.: *More Accurate Assessments of the Roughness of the Processed Surface*. Academic Journal on Manufacturing Engineering, Vol.3. No.4, September 2005, p. 39-43, ISSN 1583-7904, Timisoara, Romania
3. Ivan-Gavrus. C: *Technical-Economical Efficiency of Using the Computer in Product Engineering.* Scientific Research Grant. Transilvania University of Brasov. October 2005 (in Romanian)
4. Picos. C.: *Machine Manufacturing Technology*. “Didactica si Pedagogica” Publishing House, Bucharest, Romania, 1974 (in Romanian).
5. Enache. S. : *Processed Surface Quality*. Dunod, Paris, France, 1972 (in French)
6. Chang. T.C.. Wisk. R.. Wang. H.P.: *Computer Aided Manufacturing*. Prentice Hall, ISBN (10) 0131429191, ISBN (13) 9780131429192, England. 2006
7. Picos. C.: *Design of Mechanical Processings by Cutting*. Vol.1. “Universitas” Publishing House, ISBN 5-362-00971-0, Chisinau, Moldavia, 1992 (in Romanian)
8. Deliu. M.. Fota. A. Chivu. C.: *Bases of Mechanical Processings*. “Transilvania Univeristy of Brasov” Publishing House, ISBN 973-635-011-8, Brasov, Romania, 2002 (in Romanian)
9. Ivan. N.: *Modeller Program Mathematical Data Processing*. “Transilvania University” of Brasov 1992 (in Romanian)