Proceedings of the 16th International Conference on Manufacturing Systems – ICMaS
ISSN 1842-3183
University POLITEHNICA of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania

INFLUENCE OF THE CUTTING CONDITIONS ON SOME LESS KNOWN PARAMETERS FOR CHARACTERIZING THE SURFACE ROUNGHNESS

Laurențiu SLĂTINEANU, Margareta COTEAȚĂ, Adrian IOSUB, Adriana MUNTEANU

Abstract: *The surface roughness can be evaluated by means of many parameters. At present, the most used surface roughness parameters are the roughness average R_a and the average maximum height R_z of the profile. Some researches concerning the influence exerted by different factors characterizing the cutting conditions (the work feed f, the cutting speed v and the tool noise radius r_ε) on some less used surface roughness parameters (namely the root mean square roughness R_q and the maximum height R_y of the profile are presented in this paper. The researches proved the similitude of the empirical mathematical models in the case of the parameters R_a and R_q.*

Key words: *cutting, surface roughness parameters, empirical models.*

1. INTRODUCTION

In machine building, *the surface state* should be defined both by the characteristics referring to the surface geometrical state and by aspects characterizing the physical - chemical state of the examined surface. As parameters concerning the geometrical state of the machined surface, we could mention the so-called *geometrical deviations of first degree* (shape deviations), *of second degree* (waviness), *of third degree* (periodical asperities, due essentially to feed motion of the tool and respectively *of fourth degree*, which are generated by the inhomogeneities existing in the workpiece material [1]. In principle, the deviations of third and fourth degree constitute *the surface roughness*.

Some time ago, to evaluate the surface roughness, two categories of parameters were used [1]:

a) Physical parameters; here, the maximum roughness depth R_{max}, the average maximum height R_z of the profile, the mean spacing S_m of the profile irregularities etc. were included;

b) Statistical parameters; this group was including the maximum profile peak height R_p, the roughness average R_a, the profile bearing length ratio t_p etc.

In Romania, to characterize the roughness of the surfaces obtained by cutting, on the mechanical drawings, in the majority of the situations, only the roughness average R_a is used; this parameter is defined as the mean size of the absolute sizes of the machined surface profile in comparison with the mean line, between the limits of the base length. In relatively few situations, we can meat mechanical drawings in which the so-called parameter R_z is used; this parameter is sometimes defined and named as *the height of the profile irregularities in ten points.*

Taking into consideration the necessity to completely characterize the roughness of the surfaces belonging to a piece, the specialists consider that the characterizing the surface quality by means of the roughness average in not enough [10]; of course, some specialists emphasize the necessity to have an image concerning the entire workpiece surface, established eventually by the using of scanners.

We can also specify that the modern apparata for surface roughness measuring have usually the possibili-

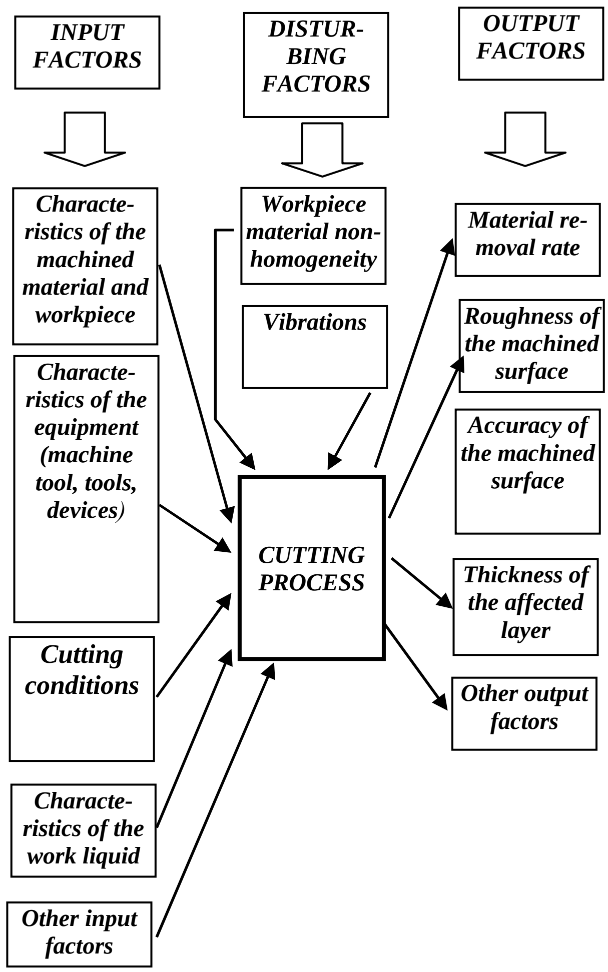

Fig. 1. The cutting process as system.

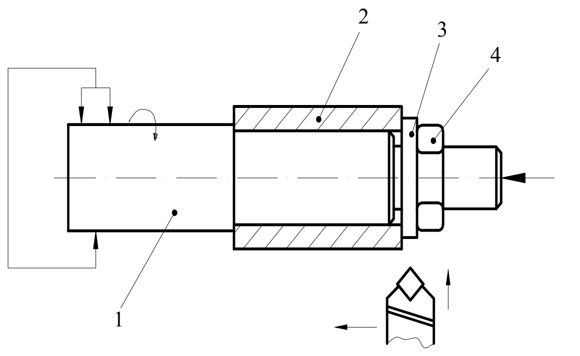

Fig. 2. Machining schema used to study the influence exerted by some factors on the surface roughness parameters.

ties to measure not only the sizes of the parameters R_a and R_z, but the evaluation of other different parameters could be made.

There are different empirical and theoretical mathematical models used to emphasize the influence exerted by the work conditions on the sizes of the surface roughness parameters [1, 2, 3, 4]; one of these mathematical models [6] is the following:

$$R_a = 0.000032 \frac{f^2}{r_\varepsilon}, \qquad (1)$$

where f is the work feed (mm/rev) and r_ε is the tool corner radius (in mm).

In the Machine Manufacturing Technology Department of the Technical University "Gh. Asachi" of Iaşi, there are some equipment for surface roughness measurement; thus, we was interested to know how different work conditions exert influence on the parameters R_q (the root mean square roughness), R_y (the maximum height of the profile) and, eventually, to compare the influences exerted on the surface roughness parameters by the work conditions.

In Romania, some monographs presenting different aspects about the roughness of the surfaces machined by cutting were elaborated by the professor *Ştefănuţă Eache*, from University Politehnica of Bucharest [3, 4, 5]; professor *Eugen Străjescu* (also from University Politehnica of Bucharest) elaborated a monograph concerning the surface roughness of the active zones belonging to the cutting tools [8].

2. CHARACTERIZING THE SURFACE ROUGHNESS BY MEANS OF THE PARAMETR R_q

As we above have mentioned, one of the parameters able to be used to characterize the surface geometrical state is *the root-mean-square roughness*; the parameter is defined as the square mean size of the profile deviations, between the limits of the base length:

$$R_a = \sqrt{\frac{1}{l}\int_0^l y^2(x)dx}, \qquad (2)$$

where l is the base length, namely the length of the reference line used to separate the irregularities which constitute the surface roughness, and y is the profile deviation, namely the distance from a point of the profile to the reference line, in the measuring direction.

The maximum height R_y *of the profile* is the distance from the line of the profile prominences and the line of the profile gaps, between the limits of the base length.

We must mention that the both surface roughness parameters (the root-mean-square roughness R_q and the maximum height R_y of the profile) were specified in an older Romanian standard (STAS 5730/1-85 – *The surfaces state. The surface roughness. Terminology*); at present, the two surface roughness parameters are included in many national and international standards.

Of course, generally speaking, many factors exert influence on the surface roughness: the work parameters (the feed, the cutting speed, the depth of cut), the geometrical parameters of the tool active part (the back-rake angle γ, the side relief angle α, the entering angle κ, the end cutting edge angle κ_1, the tool corner radius r_ε etc.), the presence and the nature of the work liquid, the nature and the metallographic structure of the workpiece material, the rigidity of the system machine - tool - tool - device - workpiece, the presence of the eventual vibrations, etc.

We can see a presenting of the cutting process as a system in Fig. 1.

At the machining by turning, the specialists appreciate that the most important factors able to be modified if we want to change the surface roughness are the feed f, the cutting speed v and the tool corner radius r_ε.

In order to experimentally determine the influence exerted by the above mentioned factors (f, v and r_ε.) on the surface roughness parameters R_a, R_q, R_y, we used the machining schema presented in Fig. 2. Thus, 8 sleeves *2* made of a steel containing 0.45 % carbon were before prepared. Each of the sleeves was placed on an arbor *1*, forming a fit with small radial clearance.

The sleeve *2* was fixed on the arbor *1* by means of a washer *3* and a nut *4*. At its turn, the arbor *1* was placed in a universal chuck and at the other end in the back center. We used sleeves as samples proofs trying to maintain the same rigidity of the technological system for each experiment; if we were using a proof sample type arbor with distinct zones machined in different work conditions, this means that for each zone another rigidity was valid and the rigidity variation along the arbor could exert influence on the surface roughness parameter.

For the three factors taken into consideration, we designed an experimental plan in accordance with the rules of the factorial experiment at two levels. Thus, we established for each factor two levels: $f_{\min}$ = 0.15 mm/rev and $f_{\max}$ = 0.5 mm/rev, $v_{\min}$ = 60.28 m/min and $v_{\max}$= 188.4 m/min, r_ε = 0.4 mm and r_ε = 1.2 mm.

To establish the size of the feed, we took into consideration the common sizes of the work feed and the machine tool possibilities.

The cutting speed sizes were established so that the small size to be placed in the zone where we expect to appear the so-called *built-up edge*; on the other hand, the big size of the cutting speed (v_{max}=188.4 m/min) was so established to be out of the zone specific to the forming of the built-up edge.

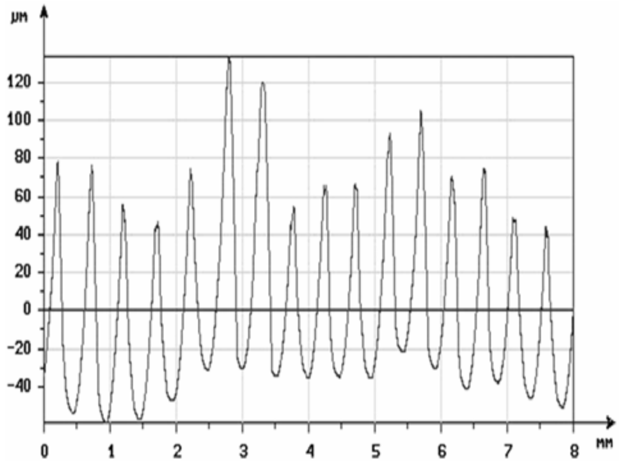

Fig. 3. Example of surface profile ($f = 0.5$ mm/rev, $v = 188.4$ m/min, $r_\varepsilon = 0.4$ mm).

For the tool corner radius, we used the sizes existing on the carbide tips mechanically fixed on the tool body. We want to specify also that the selection of the work feeds was so made to avoid the participation of the recti-linear zone of the cutting edge to the forming of the so-called profile of the remained section; thus, we could consider that the resulted profile is the consequence only of the action developed by the curvilinear zone of the cutting edge.

The sizes of the surface roughness parameters R_a, R_q and R_y were measured by means of a surface roughness measuring instrument Talyrond-Talysurf.

We can see a graphic representation of the profile in Fig. 3.

For each experiment, the concrete sizes of the work feed, the cutting speed and the tool corner radius are presented in Table 1; we included also in the table the sizes of the parameters R_a, R_q and R_y, determined as average size of three measurements.

The experimental results were processed by means of adequate software [2], to determine the so-called *regression functions*: this software is based on the using of the method of the smallest squares.

Thus, in the case of the roughness average R_a, by means of the above mentioned software, we established that the most adequate function is the following:

Table 1

Experimental conditions and results

Exp no.	Feed f [mm/rev]	Cut-ting speed, v, [m/min]	Nose ra-dius, r_ε [mm]	Sur-face rough-ness para-meter, R_a, [µm]	Sur-face rough-ness para-meter R_q, [µm]	Maxi-mum height of the pro-file, R_y, [µm]
1	0.15	60.28	0.4	1.90	2.30	12.00
2	0.15	60.28	1.2	3.83	4.68	25.03
3	0.15	188.4	0.4	2.23	2.70	12.98
4	0.15	188.4	1.2	0.665	0.89	4.97
5	0.5	60.28	0.4	25.87	30.26	109.94
6	0.5	60.28	1.2	7.74	8.9	32.16
7	0.5	188.4	0.4	25.43	29.78	115.38
8	0.5	188.4	1.2	7.79	8.74	32.82

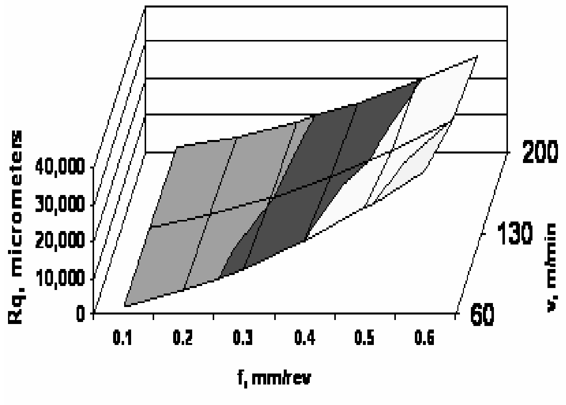

Fig. 4. Influence exerted by the work feed and cutting speed on the surface roughness parameter R_q ($r_\varepsilon = 0.4$ mm).

$$R_a = 2.28 \cdot 352.1^f 0.996^v 0.404^{r_\varepsilon} . \quad (3)$$

For such a regression function (exponential function), the Gauss sum (used to appreciate the adequacy of the function to the experimental data) was $S_G = 17.4115$.

But we consider that more suggestive and useful to compare two or more regression functions, the power function is; by means of the same software, we established the function:

$$R_a = 186.210 f^{1.704} v^{-0.351} r_\varepsilon^{-0.659} , \quad (4)$$

for which the Gauss sum is $S_G = 17.4115$.

A regression function type power was also determined in the case of the roughness average:

$$R_q = 192.48 f^{1.64} v^{-0.336} r_\varepsilon^{-0.648} , \quad (5)$$

for which the Gauss sum is $S_G = 25.29$.

The regression function for the maximum height R_y (in µm) of the profile is the following:

$$R_y = 556.84 f^{1.357} v^{-0.322} r_\varepsilon^{-0.616} , \quad (6)$$

the Gauss sum being $S_G = 458.1129$.

A first remark established by the examination of the regression functions (type power) determined for the surface roughness parameters R_a and R_q concerns the relative similitude of the mathematical relations: the sizes of the exponents are relatively close for the both relations

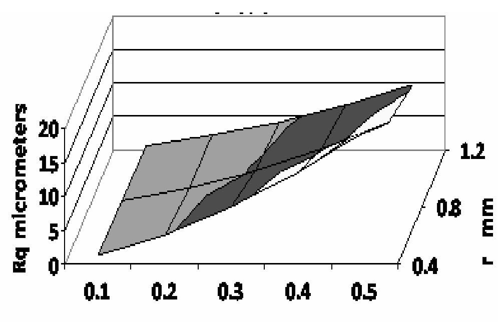

Fig. 5. Influence exerted by the work feed f and corner radius r_ε. on the surface roughness parameter R_q ($v = 180$ m/min).

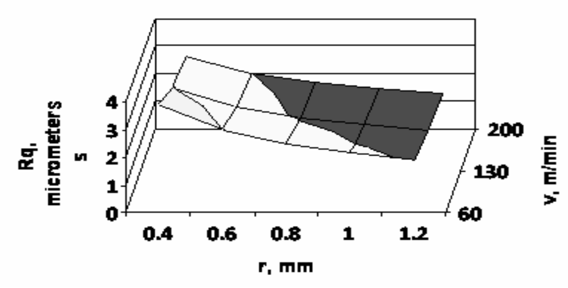

Fig. 6. Influence exerted by the cutting speed f and tool corner radius r_ε on the surface roughness parameter R_q ($f = 0.5$ mm/rev).

(for example, for the feed f, we obtained the exponents 1.704 for the surface roughness parameter R_a and 1.64 for the surface roughness parameter R_q, but the sizes of the exponents are also close for the exponents specific to the cutting tool v and the corner radius r_ε).

We could remark yet that taking into consideration the absolute sizes of the exponents belonging to different factors, we can put in order these factors on the base of their importance; thus, we can affirm that the most important influence is exerted by the work feed f, followed by the tool corner radius r_ε and by the cutting speed v (for the root mean square roughness R_q, the absolute sizes of their exponents being $1.64 > 0.648 > 0.336$, while for the maximum height R_y of the profile, the absolute sizes of the exponents being $1.357 > 0.616 > 0.322$).

The influence of the work feed f is bigger in the case of root mean square R_q than the influence exerted by the same factor in the case of the maximum height R_y of the profile.

Some graphical spatial representations corresponding to the empirical models (5) and (6) are presented in Fig. 4, 5, 6 and 7.

3. CONCLUSIONS

In Romania and probably in other countries, the most used surface roughness parameters are the roughness average R_a and the average maximum height R_z of the profile, but the specialists recommend to be used many other surface profile parameters.

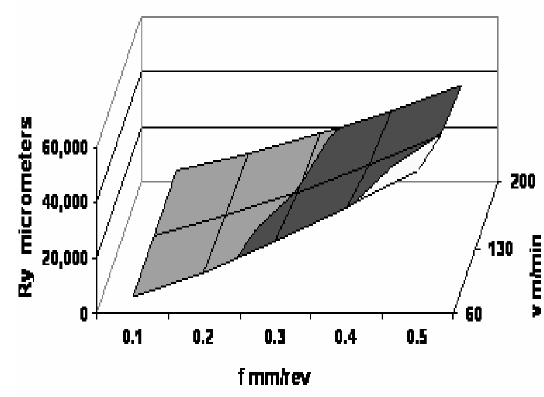

Fig. 7. Influence exerted by the feed f and the cutting speed v on the surface roughness parameter R_y ($r_\varepsilon = 1.2$ mm).

Within the Machine Manufacturing Department of the Technical University "Gh. Asachi" of Iasi, we tried to study two other surface roughness parameters, namely the root means square roughness R_q and the maximum height R_y of the profile.

We used the roughness average R_a as comparison parameter. As a first remark, we could specify that the empirical models for the parameters R_q and R_a are very similar.

REFERENCES

[1] Bohosievici, C. (1981). *Tehnologia de fabricație a mașinilor termice* (*Thermal machines manufacturing technology*). Institutul Politehnic Iași (in Romanian).

[2] Crețu, Gh. (1992). *Bazele cercetării experimentale. Ghid pentru activități de laborator* (*Fundamentals of the experimental research. Handbook for laboratory activities*. Institutul Politehnic Iași (in Romanian).

[3] Enache Șt. (1994). *La qualité des surfaces métallliques* (*Quality of the machined surfaces*). Edit. Tehnică, Bucharest.

[4] Enache, St. (1972). *La qualité des surfaces usinée*s (*Quality of the machined surfaces*). Dunod, Paris.

[5] Enache, St. (1966). *Calitatea suprafețelor prelucrate prin așchiere* (*Quality of the machined surfaces*). Edit. Tehnică, Bucharest (in Romanian).

[6] Groover, M.P. (1997). *Fundamentos de manufactura moderna* (translation of English language). Prentice Hall Hispanoamericana, S.A., ISBN 968-880-846-6, México.

[7] *** (1985). *STAS 5730/1-85. Starea suprafețelor. Rugozitatea suprafețelor. Standard de stat. Terminologie* (*The surfaces state. The Surface roughness. State Standard. Terminology*) (in Romanian).

[8] Străjescu, E. (2004). *Rugozitatea suprafețelor sculelor așchietoare* (*The surface roughness of the cutting tools*). Edit. Bren, ISBN 973-648-366-5, Bucharest (in Romanian).

[9] *** (2001). *Surface profile parameters*, available at `http://www.exact-address-of-site.` Accessed: 2005-04-10.

[10] Zecchino, M. (2006). *Characterizing surface quality: why average roughness is not enough*, available at `http://www.veeco.com/pdfs.php/246.` Accessed: 2007-06-10.

Authors:

Ph.D., Eng. Laurențiu SLĂTINEANU, Professor, Technical University "Gh. Asachi" of Iași, Department of Machine Manufacturing Technology,

E-mail: slati@tcm.tuiasi.ro

Ph. D. student, Eng. Margareta COTEAȚĂ, junior assistant, Technical University "Gh. Asachi" of Iași, Department of Machine Manufacturing Technology.

E-mail: mcoteata@tcm.tuiasi.ro

Eng. Adrian IOSUB, junior assistant, Technical University "Gh. Asachi" of Iași, Department of Machine Manufacturing Technology,

E-mail: adrian.iosub@gmail.com

Ph.D. student, Eng. Adriana MUNTEANU, junior assistant, Technical University "Gh. Asachi" of Iași, Department of Machines Tools,

E-mail: adycypmunteanu@yahoo.com