



## How to cite this article:

Authors: Ireneusz Zagórski, Monika Kulisz, Tomasz Warda  
 Title of article: „Wpływ parametrów technologicznych na chropowatość powierzchni po toczeniu oraz predykcja chropowatości z użyciem sztucznych sieci neuronowych: (“The influence of technological parameters on surface roughness during turning and roughness prediction using artificial neural networks”)  
*Mechanik*, Vol. 91, No. 10 (2018): pages 898 - 900  
 DOI: <https://doi.org/10.17814/mechanik.2018.10.157>

# The influence of technological parameters on surface roughness during turning and roughness prediction using artificial neural networks

## Wpływ parametrów technologicznych na chropowatość powierzchni po toczeniu oraz predykcja chropowatości z użyciem sztucznych sieci neuronowych

IRENEUSZ ZAGÓRSKI  
 MONIKA KULISZ  
 TOMASZ WARDA \*

The purpose of this investigation was to determine whether and to what extent the technological parameters of turning (feed, cutting speed) affect selected surface roughness parameters of aluminum alloy EN-AW 7075 (AlZn5.5MgCu). The principal findings indicate a significant impact of feed and show on the surface roughness and simultaneously show that cutting speed has no effect on the value of surface roughness parameters under investigation. An artificial neural network was employed to evaluate the prediction of surface roughness parameter  $R_z$  in turning.

**KEYWORDS:** aluminum alloys, turning, 2D surface roughness, simulations, artificial neural networks

Light alloys (aluminum and magnesium) are widely used in various industrial areas as a modern construction material (due to its favorable strength properties and low density). The machinability of aluminum alloys can be influenced by such physical properties as: high expansion and thermal conductivity as well as a small modulus of elasticity. On the other hand, surface roughness can be influenced by: tool material, workmanship quality and tool nose geometry, material properties (e.g.  $R_m$ ,  $H_B$ ) and technological parameters.

The machinability of aluminum alloys depends mainly on their chemical composition (about 10% Si constitutes a significant machinability limit, above which an increased wear of the tool blades may occur) and the structure of the alloy shaped during the heat treatment [8, 15, 16]. In a certain generalization, the machinability of light alloys (e.g. aluminum

and magnesium alloys) can be similar in the case of comparable strength characteristics and the absence of particles (e.g. Si) resulting in increased abrasive wear.

During turning of the AZ31 alloy, the roughness decreases with the increase of the cutting speed (up to  $v_c$  approx. 160 m/min), and increases with increasing depth and feed. The change in the  $R_a$  parameter is in the range of about  $1 \mu\text{m}$  ( $R_a = 1.1 \div 2.2 \mu\text{m}$ ) [9]. Similar relationships were observed when processing the AZ61 alloy ( $v_c$  to 200 m/min). The  $R_a$  parameter in experimental studies was  $R_a \approx 0.1 \div 2.8 \mu\text{m}$  [1].

When rolling aluminum alloys, apart from the right geometry ( $\gamma$  to  $30^\circ$ ,  $\alpha$  to  $10^\circ$ ), it is important to control the breaking or rolling of the chip. As stated in [12], Ceratizit introduced a compressed air cooling system integrated in the tool (the ability to process dry aluminum alloys).

Often when roughing light alloys with carbide tools (up to  $v_c$  approx. 400 m/min), machining surface roughness  $R_a < 10 \mu\text{m}$ . Also the change in the angle of attack (increase in  $\gamma$ ) may positively affect the improvement of the quality of the final surface [16].

AlMg1Si alloy is difficult to cut (malleable, hard, reinforced by forging). The use of a tool with a PCD blade, with a laser shaped chip winder and a chamfer with the so-called the negative rake angle  $\gamma$  can increase the efficiency of the process (chip breaking at small intervals and easy discharge from the cutting zone) [11].

A similar relationship can occur when treating the surface of pistons made of foundry eutectic or non-toxic aluminum alloys. In this case, optimum cutting data values for  $v_c = 610$  m/min and  $a_p \leq 1$  mm [14] were obtained.

Positive influence on machinability indexes and cutting properties of tools, and even on a significant increase in durability of tools, has rounding of the cutting edge (better adhesion of the coating to the substrate and reduced tendency to peeling on the edges of the blades) [2]. It can significantly improve the operational properties of tools, for example in the abrasive machining process.

\* Dr inż. Ireneusz Zagórski (i.zagorski@pollub.pl), mgr inż. Tomasz Warda (t.warda@pollub.pl) – Katedra Podstaw Inżynierii Produkcji, Wydział Mechaniczny Politechniki Lubelskiej; dr inż. Monika Kulisz (m.kulisz@pollub.pl) – Wydział Zarządzania, Katedra Organizacji Przedsiębiorstwa, Wydział Zarządzania Politechniki Lubelskiej

This favorable phenomenon is explained, among others obtaining significantly lower roughness of the blade's working surfaces and thus less friction on the tool contact surfaces with the workpiece and limiting abrasive wear and adhesive blade [2, 6]. The radius of the cutting edge curvature can also be used to determine the minimum thickness of the cutting layer, where  $h_{\min}$  is the product of the friction coefficient between the cutting edge and the material being machined and the radius of the cutting blade's curvature [10]. It is logical to say that the role of  $r_\epsilon$  grows during the finishing of the finishing work. For the  $\beta_n$  ( $50 \div 70^\circ$ ) angle, the radius of the cutting edge rounding  $r_n \approx 6 \div 11 \mu\text{m}$  is obtained - expected for the new hard sintered edge. In practice, the values are greater - around  $15 \mu\text{m}$ . They grow along with the progressive wear of the tool tip [13]. On the roughness of the surface after turning, the conditions of mapping the cutting edge on the machined surface can also influence [3].

As reported in [5, 12, 16] and in the recommendations of tool manufacturers [17], popular aluminum alloys can be processed with  $v_c \geq 2500 \text{ m/min}$ . However, for reasons related to the construction of technological machines, these parameters may be limited under certain conditions. It seems therefore important and purposeful to carry out machinability tests in the area of increased machining parameters in order to increase the efficiency and effectiveness of light alloys processing.

However, the increase in production efficiency may contribute to the increase of requirements for cutting tools. One of the basic criteria for assessing the suitability of a machining tool can be assured to ensure an adequate surface quality [7, 15, 16]. It has also been proven many times that there are close relationships between surface topography and functional properties of machine parts. So there are practical possibilities to improve the technological and usable quality of parts, including in finishing operations [4].

## Methodology and purpose of research

The main stages of the research included machining at high cutting speeds ( $v_c$  up to  $1700 \text{ m/min}$ ), 2D surface roughness parameters analysis and prediction of the selected surface roughness parameter ( $Rz$ ) using artificial neural networks.

The treatment was carried out on a DMG MORI CTX450 turning center with the Sinumerik 840D control system. The tool used was a folding knife with the symbol SDJCL 25x25M11 CORO Turn 107. For turning, a DCGT 11T304-FN-ALUH210T carbide insert (Ceratizit) with a corner radius of  $r_\epsilon = 4 \text{ mm}$  and a radius of rounding of the cutting edge of approx.  $11 \mu\text{m}$  were selected. A constant cutting depth  $a_p = 1 \text{ mm}$  and a variable range of other technological parameters were assumed:  $f = 0.05 \div 0.15 \text{ mm/rev}$ ,  $v_c = 1000 \div 1700 \text{ m/min}$ .

The EN-AW 7075 (AlZn5.5MgCu) alloy was used in the T6 state (supersaturated, artificially aged). A machining emulsion was used during machining. The length of the turning path was  $L = 20 \text{ mm}$ . The Hommel Tester T1000 profilographometer was used for surface roughness measurements. Roughness measurements were repeated five times on each surface. The value of the elementary segment was  $l = 0.8 \text{ mm}$ , and the measurement section  $h_n = 4.8 \text{ mm}$ .

The results of experimental tests (average values of roughness parameters) were the input element in simulations of the  $Rz$  roughness parameter using artificial neural networks, which were carried out in the Statistica software. The simulations used MLP networks (multi-layered perceptron) with activation functions: linear, exponential, logistic, tanh and sine. The indicators of the correct selection of the network were: the quality of teaching, the quality of validation, as well as the learning error determined by the least squares method.

To make the network construction as simple as possible, they have one layer hidden with the number of neurons in the  $1 \div 10$  range (experimentally selected), the input layer with two neurons (cutting speed  $v_c$ , feed  $f$ ) and the output layer with one neuron ( $Rz$  parameter roughness). BFGS gradient method (Broyden-Fletcher-Goldfarb-Shanno) was used to teach the network. Statistica Automatic Neuron Networks enables the use of two fast learning algorithms: the conjugate gradient algorithm and the BFGS algorithm. The BFGS algorithm provided better results when simulating this process. When teaching the network, 75% of the measurement results were a learning group and 25% were validated. Due to the small number of data sets, the test group was dropped [15, 18].

## Results of tests and simulations and their analysis

After taking into account the corner radius  $r_\epsilon$  and the feed value  $f$ , one can calculate the theoretical surface roughness -  $Rz_t$  parameter. For the analyzed range of  $Rz_t$  parameters it was respectively:  $4.5 \mu\text{m}$  - in case of change in  $v_c$ ,  $0.8 \div 7.0 \mu\text{m}$  - in case of change  $f$ .

The graphs (fig. 1 and fig. 2) show the change of 2D surface roughness parameters ( $Ra$ ,  $Rz$ ,  $Rv$ ,  $Rp$ ) depending on the change in the cutting speed  $v_c$  and the feed rate  $f$ . Additionally, the numeric values of the  $RS_m$  parameter are given.

Fig. 1 shows roughness parameters  $Ra$ ,  $Rv$ ,  $Rp$ ,  $Rz$  for different cutting speeds  $v_c$ . The values of the  $Ra$  parameter are approx.  $1.0 \mu\text{m}$ . The values of the parameter  $Rp$  are in the range of  $2.7 \div 3.1 \mu\text{m}$ . The value of the parameter  $Rz$  is approx.  $4.5 \mu\text{m}$ , while  $Rv$  - approx.  $2 \mu\text{m}$ . For the entire  $v_c$  range, the numerical value of the  $RS_m$  parameter was approx.  $118 \mu\text{m}$ .

It can therefore be seen that the cutting speed  $v_c$  does not significantly affect the surface roughness. It follows an important conclusion that machining with high  $v_c$  values is possible without deterioration of the treated surface quality. This is an important statement in the context of efficiency and efficiency of machining processes.

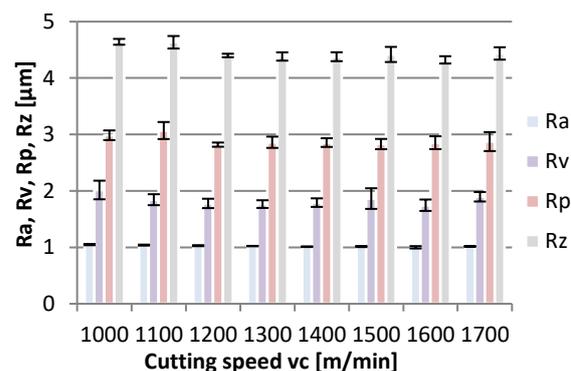


Fig. 1. Influence of cutting speed  $v_c$  on parameters  $Ra$ ,  $Rv$ ,  $Rp$ ,  $Rz$  ( $f = 0.12 \text{ mm/rev}$ ,  $a_p = 1 \text{ mm}$ )

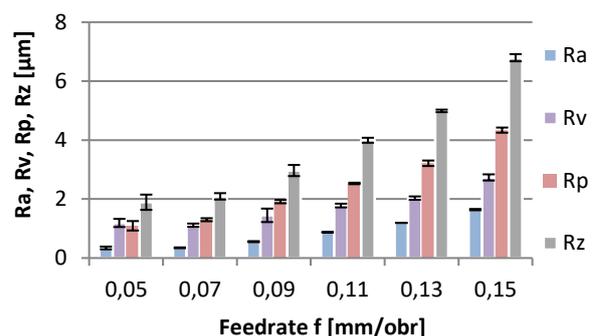


Fig. 2. Influence of feed  $f$  on parameters  $Ra$ ,  $Rv$ ,  $Rp$ ,  $Rz$  ( $v_c = 1400 \text{ m/min}$ ,  $a_p = 1 \text{ mm}$ )

Fig. 2 presents roughness parameters  $Ra$ ,  $Rv$ ,  $Rp$ ,  $Rz$ . The  $Rz$  parameter is in the range of about  $2\div 7\ \mu\text{m}$ , while  $Rv$  - about  $1\div 3\ \mu\text{m}$ . The  $Ra$  parameter values increase with increasing feed - up to approx.  $2\ \mu\text{m}$ . The values of the parameter  $Rp$  are in the range of approx.  $1\div 4\ \mu\text{m}$ . For the entire feed range  $f$ , the numeric value of the  $R_{sm}$  parameter was within  $85\div 147\ \mu\text{m}$ . It can therefore be seen that the feed affects the value of surface roughness parameters quite significantly.

As a result of experimental research, it was possible to predict the selected roughness parameter -  $Rz$  - using artificial neural networks. During the simulation of each parameter, 100 networks were designated, of which the best three were selected based on the above mentioned indicators. Their characteristics are presented in the table.

Based on the analysis of the obtained neural networks, it can be concluded that the best results have been achieved for MLP 2-3-1 networks. The simulation results for this network are shown in fig. 3.

**TABLE. Network parameters for simulating the roughness parameter  $Rz$**

The largest height of the profile $Rz$			
No. of network	1	2	3
Network name	MLP 2-7-1	MLP 2-6-1	MLP 2-3-1
Quality (of learning), %	99,54	99,66	99,74
Quality (of validation)%	99,96	99,99	99,98
Error (of leaing/vali-dation)	0,025/0,228	0,016/0,068	0,012/0,017

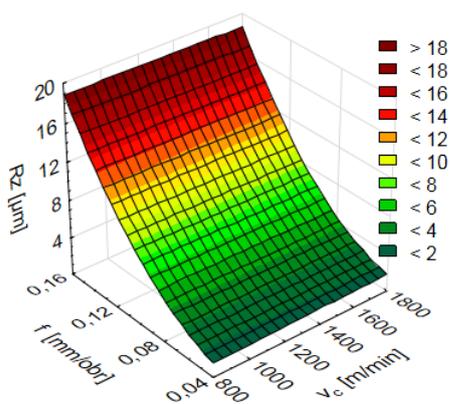


Fig. 3. Simulation results of the  $Rz$  parameter depending on the cutting speed  $v_c$  and feed  $f$  for MLP 2-3-1 networks

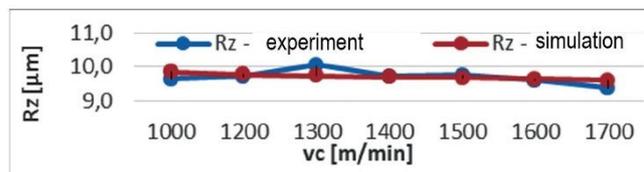


Fig. 4. Comparison of results of  $Rz$  parameter simulation for MLP networks 2-3-1 with actual values for feed  $f = 0.12\ \text{mm/rev}$  and variable parameter  $v_c$

Based on the simulations carried out, one can (by entering the values of  $v_c$  and  $f$  parameters in Statistica) get the value of the  $Rz$  parameter roughness. In order to verify the simulated model, the actual values were compared with the predicted values (fig. 4). The error in determining the parameter values did not exceed 8%. Thus, it can be concluded that the results of the simulation are characterized by an acceptable level of error and can be a tool to determine

the processing parameters in order to obtain the assumed roughness.

## Conclusions

The analysis shows the importance of the correct selection of technological cutting parameters. Measurements and analysis of results allow to formulate more important general conclusions:

- cutting speed does not significantly affect the surface roughness parameters after turning ( $Ra$  value was approx.  $1\ \mu\text{m}$ ,  $Rz$  - approx.  $4.5\ \mu\text{m}$ ),
- a significant effect on the surface roughness has a feed rate, this effect is approximately proportional to the feed rate; this is due to m.in. increase in cross-section of the cutting layer,
- it is possible to use high cutting speeds (up to  $v_c$  1700 m/min) without worrying about the roughness of the treated surface (increase in the efficiency of the process),
- it is possible to model the roughness parameters depending on the cutting speed and feed using artificial neural networks (the error between the actual values and obtained from the model for the  $Rz$  parameter does not exceed 8%),
- models obtained as a result of the simulation enable determination of a set of machining parameters allowing to obtain the assumed surface roughness after machining.

Further analysis of 2D and 3D roughness parameters can be an important prerequisite for engineers designing turning technology for aluminum alloys.

## REFERENCES

1. Alharthi N.H., Bingol S., Abbas A.T., Ragab A.E., Aly M.F., Alharbi H.F. „Prediction of cutting conditions in turning AZ61 and parameters optimization using regression analysis and artificial neural network”. *Advances in Materials Science and Engineering*. ID 1825291 (2018): pp. 1–10.
2. Cichosz P., Kuzinovski M., Tomov M., Urych A. „Zaokrąglenie krawędzi skrawających ostrzy z węglików spiekanych”. *Mechanik*. 7 (2018): pp. 458–462.
3. Chwalczuk T., Rybicki M., Korzeniewski D., Przystacki D. „Chropowatość po toczeniu materiałów stosowanych w konstrukcjach lotniczych”. *Mechanik*. 10 (2016): pp. 1312–1313.
4. Grzesik W. „Wpływ topografii powierzchni na właściwości eksploatacyjne części maszyn”. *Mechanik*. 8–9 (2015): pp. 587–593.
5. Horvath R., Palasti-Kovacs B., Sipos S. „Optimal tool selection for enviromental-friendly turning operation of Al”. *Hungarian Journal of Industrial Chemistry Veszperem*. 39, 2 (2011): pp. 257–263.
6. Kalisz J. „Właściwości tribologiczne warstwy wierzchniej po obróbkach wykończeniowych stopu aluminium”. *Mechanik*. 7 (2018): pp. 492–495.
7. Kamieńska-Krzowska B., Kłonica M. „Rola strategii pomiarów topografii powierzchni w ocenie wybranych parametrów chropowatości”. *Mechanik*. 8–9 (2014): pp. 138–145.
8. Kuczmaszewski J., Pieško P. „Wear of milling cutters resulting from high silicon aluminium alloy cast AlSi21CuNi machining”. *Eksploatacja i Niezawodność – Maintenance and Reliability*. 16, 1 (2014): pp. 37–41.
9. Lu L., Hu S., Liu L., Yin Z. „High speed cutting of AZ31 magnesium alloy”. *Journal of Magnesium and Alloys*. 4, 2 (2016): pp. 128–134.
10. Nowakowski Ł., Skrzyniarz M., Miko E. „Porównanie sposobu wyznaczania wartości minimalnej grubości warstwy skrawanej dla toczenia i frezowania”. *Mechanik*. 8–9 (2015): pp. 733–741.
11. Oczko K.E. „Doskonalenie procesów kształtowania ubytkowego stopów aluminium”. *Mechanik*. 3–4 (2009): pp. 153–163, 249–256.
12. Oczko K.E., Kawalec A. „Kształtowanie metali lekkich”. Warszawa: Wyd. Naukowe PWN, 2012.
13. Storch B. „Podstawy obróbki skrawaniem”. Koszalin: Wyd. Politechniki Koszalińskiej, 2001.

14. Wojciechowski S., Lisiak P., Twardowski P. „Optimization of cutting parameters for the longitudinal turning of combustion engines' pistons”. *Mechanik*. 8–9 (2016): pp. 1022–1023.
15. Zagórski I., Kulisz M., Semeniuk A., Malec A. „Artificial neural network modelling of vibration in the milling of AZ91D alloy”. *Advances in Science and Technology Research Journal*. 3 (2017): pp. 261–269.
16. Zagórski I., Warda T., Włodarczyk M. „Wpływ parametrów technologicznych obróbki toczeniem na wybrane parametry chropowatości powierzchni stopu aluminium 7075”. *Mechanik*. 8–9 (2016): pp. 1060–1061.
17. <http://www.sandvik.coromant.com/pl> (dostęp: 7.05.2018 r.).
18. <http://www.statsoft.pl/Portals/0/Downloads/Sieci%20neuronowe.pdf> (dostęp: 11.07.2018 r.). ■

---

Translation of scientific articles, their computer composition and publishing them on the website [www.mechanik.media.pl](http://www.mechanik.media.pl) by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.



Ministry of Science  
and Higher Education

Republic of Poland