WITHDRAWN: Model of Dependence Between the Parameters of Surface Roughness and the Parameters of Form and Location During the Machining by Drills with the use of Artificial Neural Networks

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The full text of this preprint has been withdrawn by the authors while they make corrections to the work. Therefore, the authors do not wish this work to be cited as a reference. Questions should be directed to the corresponding author.

Abstract

This paper presents a model of dependence between the parameters of surface roughness and the parameters of cylindricity and eccentricity in drilling operation for the enhancing steel EN 42CrMo4, hardness 28 HRC, with twist drills DIN 338 made of high-speed steel EN HS6-5-2, with normal blade. The quality of machining, besides the accuracy of measures, completely determined with the values of the parameters of the surface roughness and the parameters of form and location, hence this paper is oriented to the creating models between parameters of the quality of a machined surface and parameters of deviations from form and position. By the developing models based on artificial neural networks and using experimental results, it is possible to analyse the quality of machining on the basis of parameters of a surface roughness.

1. Introduction

In making products, regarding the aspect of the quality of machining, a special attention is devoted to their dimensional accuracy and the quality of machined surfaces, hence the measurement of both roughness parameters and accuracy parameters is especially important. The accuracy of machining comprises a precision of measures, accuracy of shapes of surfaces and accuracy of mutual relationships of two or more surfaces, while the quality of a machined surface is most often determined through a surface roughness. Since the quality of machining, besides the accuracy of measures, is completely determined by the values of parameters of the quality of a surface roughness and the parameters of form and location, this paper is oriented to the establishment of a model between parameters of quality of machined surface and parameters of form and position deviations. By the development of models based on neural networks by using experimental results, it is possible to analyse the quality of machining on the basis of the parameters of a surface roughness.

Krivokapić, Z., et al [1], give the application of a multiple regression and artificial neural networks (ANNs), and this paper describes the development of models for the predicting a surface roughness, linking an arithmetic mean deviation of a surface roughness to a torque as an input variable, in the process of drilling.

Paper Vučurević, R., et al [2] presents the models for prediction of an arithmetic mean deviation of a surface roughness using artificial neural networks, developed on the basis of parameters of drilling process and an axial force obtained for different values of blunting twist drills, based on the experimental results by using Taguchi design of experiment.

Peper Vučurević, R., et al [3] presents a comparative analysis of the models for the predicting a surface roughness developed by the application of a multiple regression and artificial neural networks. These models were developed using experimental data for an arithmetical mean deviation of a surface roughness and the axial cutting force obtained by implementing the Taguchi design of experiment.

Paper by Spaić, O., at al [4] presents the prediction of a tool condition by applying a family of artificial neural networks.

The book [5] and papers [6-12] aims at presenting the various methodologies and practices that are being employed for the prediction of surface roughness.

Çiçek, A., Kivak, T. and Samtaş, G. [13], by the application of Taguchi design of experiment, have found an optimal combination of the process parameters from the aspect of a surface roughness, while drilling an austenite stainless AISI 316 by twist drills of high-speed steel (HSS), in conventionally and cryogenically processes, varying a feed f [mm/o] and a cutting speed v [m/min] on two levels.

Raghunandan, B.V., Bhandarkar, S.L. and Pankaj, K.S. [14] also used a regression analysis to obtain a surface roughness model, while machining EN-19 material by turning with cemented carbide inserts.

Kumar, P.J. and Packiaraj, P. [15] used Tacuchi design of experiment, regression analysis and the analysis of a variance for the purposes of the researching the impact of drilling parameters such as a cutting speed v [m/min], feed f [mm/o] and a diameter of a twist drill d [mm], on a surface roughness and deviation of a hole diameter from rated values for drilling OHNS material, tool steel that is widely used in the production of tools, by twist drills made of high-speed steel (HSS).

Xu, Y., et al [16] present a very interesting paper related to the application of a back propagation wavelet neural network based prediction of a drill wear from thrust force and cutting torque signals.

2. Processing Quality Parameters

Mechanical machining yields micro-geometrical deviations of a machined surfaces in comparison to an ideal surface. These micro-geometric deviations, which characterise the quality of a machined surface, are called a surface roughness that have big impacts on the functional characteristics of machine parts [17]. Surface roughness, whose basic terms are prescribed by ISO 4287 standard [18], can be traced through several amplitude parameters of a roughness profile such as maximum profile height R_p, maximum profile valley depth R_v, maximum height of the profile R_z, arithmetical mean deviation of assessed profile R_a (Figure 1).

Based on standard ISO 4287, a maximum profile height R_p is the largest profile peak height within on the sampling length l_r, while a maximum profile valley depth R_v is largest profile valley depth within on the same length. A maximal height of the profile is the sum of height of the largest profile peak height and the largest profile valley depth within a sampling length l_r. According to this standard, an arithmetical mean deviation of the assessed profile R_a is arithmetic mean of the absolute ordinate values Z(x) within a sampling length l_r:

$$R_a = \frac{1}{l_r} \int_0^{l_r} |Z(x)| dx \cdot \qquad \ldots (1)$$

An arithmetical mean deviation of the profile is the most often used of all the standardized parameters for the measuring a surface roughness R_a [19].

When making holes during the machining by drilling, the deviations of form and sizes of holes occur and it represents a geometrical difference between a hole given on the drawing and a real hole during the very development [20]. The most common parameters of form and location which are applied during making openings, holes and parts of a circular cross-section are roundness, cylindricity, and concentricity, and, besides the mentioned parameters, a tilting of a hole axis in relation to an ideal axis given by the drawing (eccentricity) can be traced as an additional parameter.

For the roundness, a tolerated circumferential line must lie into a round ring of a given tolerated width, while for cylindricity the tolerated cylindrical surface must lie between two coaxial cylinders, given the tolerated radial distance. For concentricity, an axis of tolerated part must lie inside a cylinder of given tolerated diameter whose axis coincides with the axis of a referent element [21].

3. Experimental Results

The experimental results were obtained by measuring values of an arithmetical mean deviation of the profile, as parameters of the surface roughness and the parameters of form and location conducting the experiment by a Taguchi orthogonal experimental plan, with varying factors of experiment (d – diameter of twist drill, n – speed, f - feed, ε – angle of installation of the workpiece) on three levels.

In this paper, the Taguchi orthogonal experiment plan L_9 [22], given in Table 1, with nine combinations of machining process parameters, was used.

Table 1. Orthogonal matrix L_9

Com. No.	Factors			
	X_1	X_2	X_3	X_4
1.	1	1	1	1
2.	1	2	2	2
3.	1	3	3	3
4.	2	1	2	3
5.	2	2	3	1
6.	2	3	1	2
7.	3	1	3	2
8.	3	2	1	3
9.	3	3	2	1

The experiment was carried out by drilling holes with a depth of l=3d in a test tube made of enhancement steel , hardness 28 HRC, using twist drills DIN 338 of high speed steel EN HS6-5-2 with normal blade.

The measurement of a surface roughness was done by measuring an arithmetical mean deviation (R_a) in a characteristic moments by rotating test tube for an angle of 90^o and measuring roughness at four characteristic positins, where a mean value of the measured values was taken as valid.

Before the start of the measurement, a validation of measuring device SURTRONIC 25 was carried out using a reference panel type 112/1534, with a value of arithmetical mean deviation of a surface roughness R_a = 6 μm. Figure 2 presents the results of validation.

The measurement of form and location deviation, cylindricity (c) and eccentricity (e), was carried out in characteristic moments during drilling by twist drills, with normal blade in a test tube whose hardness is 28 HRC.

Before the start of the measurement, a qualification of the stylus for measurement three-coordinate measurement device CONTURA G2 AKTIV manufactured by CARL ZEISS, measurement range 700x700x600 mm, with a CALYPSO measurement software, using a reference sphere and stylus for the qualification was executed. Figure 3 gives the results of the qualification.

The overview of the results of the measurement of an arithmetical mean deviation of profile (R_a), cylindricity (c) and eccentricity (e), for different wear values on back surface of a twist drill (VB), is presented in Table 2.

Table 2. The result of the measurement of a surface roughness and form and location deviation

No.	d [mm]	n [rev/min]	f [mm/rev]	ε [º]	VB=0 mm R_a [μm]	c [mm]	e [º]	VB=0,02d R_a [μm]	c [mm]	e [º]	VB=0,04d R_a [μm]	c [mm]	e [º]
1.	3	300	0,03	0	0,306	0,0249	0,3361	0,675	0,0159	0,6212	0,960	0,0502	0,9539
2.	3	500	0,05	3	0,411	0,0126	0,7156	1,23	0,0113	0,0703	1,41	0,0119	0,0393
3.	3	800	0,10	5	2,61	0,0119	0,1202	3,25	0,0226	0,0132	3,71	0,0105	0,0483
4.	5	300	0,05	5	0,702	0,1587	0,5406	0,825	0,1566	0,5333	1,53	0,1337	0,3892
5.	5	500	0,10	0	2,58	0,0254	0,1353	2,88	0,0161	0,3060	3,25	0,0078	0,2697
6.	5	800	0,03	3	1,54	0,0278	0,0302	1,81	0,0116	0,0129	2,07	0,0137	0,1157
7.	8	300	0,10	3	3,08	0,0212	0,6480	3,24	0,0191	0,5850	3,85	0,0194	1,1545
8.	8	500	0,03	5	1,88	0,0214	0,0547	2,99	0,0369	0,1080	4,00	0,0252	0,6861
9.	8	800	0,05	0	2,86	0,0197	0,1329	3,29	0,0238	0,1872	4,46	0,0443	0,1271

4. Correlational Interdependences

With the goal to determine the existence of a correlational interdependence between an arithmetical mean deviation of the profile and a cylindricity and eccentricity as parameters of form and location of a hole, the application of a scatter diagram on the data obtained for drilling by twist drills with normal blade in test tube with hardness of 28 HRC was carried out. The scatter diagram of roughness - cylindricity (Figure 4), was created by using data for arithmetical mean deviation of the profile (R_a) and cylindricity (c) measured in characteristic moments, at the beginning of the process (VB=0 mm), at the moment a mean bluntness of the tool (VB=0,02 d) as well as at the moment of a bluntness of the tool (VB=0,04 d).

Based on the same principle, by using data both for arithmetical mean deviation of the profile (R_a) and eccentricity (e), measured in characteristic moments, a scatter diagram of roughness - eccentricity was created (Figure 5).

Based on the comparative analysis of given scatter diagrams with characteristic scatter diagrams [23], it can be noticed that there is no correlational interdependence between an arithmetical mean deviation of the profile and a cylindricity and eccentricity, as the form and location parameters.

5. Artificial Neaural Networks (ANN) design

When a correlational interdependence cannot be established, then using of artificial neural networks (ANN) is recommended [24]. The creation of the model based on artificial neural networks for the wear values on back surfaces of twist drills VB=0 mm and VB=0,04d was carried out Using MATLAB software package, based on the experimental results.

The creation of the model with several inputs and one output was done using Backpropagation artificial neural network with two hidden layers with a sigmoidal transfer function and a linear transfer function in the output layer. The least errors in training, validation and testing were achieved by a neuron network of 15 neurons in the first hidden layer, 10 neurons in the second hidden layer, and the learning function LEARNGDM.

The input data, used for training of the ANN for the prediction of cylindricity, were; diameter of twist drill, speed, feed, angle of installation of the workpiece and an arithmetical mean deviation of surface roughness, while a cylindricity was used as an output. Figure 6 presents the artificial neural network architecture which yielded a cylindricity as the output through two hidden layers with five inputs. The data used for training were the data obtained by the experiment for VB=0 mm and VB=0,04d and calculated for VB=0,01d and VB=0,03d.

The network for the predicting eccentricity cannot be established by previous analogy, hence an approach from paper [4] was used in this paper. Therefore, a cylindricity was introduced as the sixth input what provided an acceptable convergence of the network and only then it yielded the results. Figure 7 presents the architecture of artificial neural network which yielded an eccentricity as the output through two hidden layers with six inputs.

The simulation of both networks was carried out for data obtained by the experiment for h=0,02d, and the results are given on Figure 8a for cylindricity and on 8b for eccentricity.

Based on the comparative analysis of the results obtained in the experiment and the result of artificial neural networks, it is possible to prove that a mean error for cylindricity is 15,29%, while it is 13,57% for eccentricity.

6. Conclusions

Based on the experimental results, it can be seen that the value of an arithmetical mean deviation of the profile as a parameter of surface roughness rises with tool wear, while the parameters of form and location, cylindricity and eccentricity have no such a trend. The check of a correlational interdependence between an arithmetical mean deviation, as well as the parameters of the surface roughness, and cylindricity and eccentricity, as the parameters of form and location, leads to the conclusion that the parameters of the surface roughness are not in a correlational interdependence with the parameters of form and location.

Therefore, this paper is oriented to the establishing a model between the parameters of the surface roughness and form and location parameters. By developing models based on artificial neural networks and using experimental data it is possible to estimate the quality of machining on the basis of surface roughness parameters.

Based on the comparative analysis of the results obtained by the experiment and simulation of neural networks, it can be established that a mean error for cylindricity is 15,29%, while it is 13,57% for eccentricity.

Declarations

Author Contributions: Z. Krivokapić and R. Vučurević — research, methodology and analysis, P. Dašić — methodology and analysis, and P. Ivanković — formal analysis.

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References

1. Krivokapić Z, Vučurević R, Kramar D, Šaković Jovanović J (2020) Modelling surface roughness in the function of torque when drilling. Metals 10 (3): 337
2. Vučurević R, Krivokapić Z, Brđanin R (2018) Comparative analysis of surface quality prediction models. International Journal of Engineering and Technology (IJET) 10 (2): 441–449
3. Vučurević R, Krivokapić Z, Brđanin R (2018) Surface quality prediction using artificial neural networks. Annals of the University of Oradea: Fascicle of Management and Technological Engineering 17: 174–177
4. Spaić O, Soković M, Krivokapić Z (2013) Prediction of tool condition by applying family of artificial neural networks. Metalurgia International 18 (6): 87–93
5. Dašić P (2019) Response surface methodology: Selected scientific-professional papers (in Serbian). SaTCIP Publisher Ltd., Vrnjačka Banja, Serbia

6. Abouelatta OB, Mádl J (2001) Surface roughness prediction based on cutting parameters and tool vibrations in turning operations. Journal of Materials Processing Technology 118(1-3): 269–277
7. Asiltürk İ, Neşeli S (2012) Multi response optimisation of CNC turning parameters via Taguchi method-based response surface analysis. Measurement 45(4): 785–794
8. Benardos PG, Vosniakos GC (2003) Predicting surface roughness in machining: A review. International Journal of Machine Tools & Manufacture 43(8): 833–844
9. Bouacha K, Yallese MA, Mabrouki T, Rigal J-F (2010) Statistical analysis of surface roughness and cutting forces using response surface methodology in hard turning of AISI 52100 bearing steel with CBN tool. International Journal of Refractory Metals and Hard Materials 28(3): 349–361
10. Dašić P (2013) Comparative analysis of different regression models of the surface roughness in finishing turning of hardened steel with mixed ceramic cutting tools. Journal of Research and Development in Mechanical Industry 5(2): 101–180
11. Rizvi SA, Ali W (2016) A review on machinability of different materials by turning process. Journal of Mechanical and Mechanics Engineering 2(3): 28–58
12. Shirpurkar PP, Bobde SR, Patil VV, Kale BN (2012) Optimization of turning process parameters by using tool inserts – A review. International Journal of Engineering and Innovative Technology (IJEIT) 2(6): 216–223
13. Çiçek A, Kivak T, Samtaş G (2012) Application of Taguchi method for surface roughness and roundness error in drilling of AISI 316 stainless steel. Strojniški vestnik - Journal of Mechanical Engineering 58(3): 165–174
14. Raghunandan BV, Bhandarkar SL, Pankaj KS (2013) An experimental mathematical modelling of surface roughness in turning opertion of EN19 with carbide tool. International Journal of Mechanical Engineering and Research 3(5): 495–502
15. Kumar PJ, Packiaraj P (2012) Effect of drilling parameters on surface roughness, tool wear, material removal rate and hole diameter error in drilling of OHNS. International Journal of Advanced Engineering Research and Studies 1(3): 150–154
16. Xu Y, Hiroyuki K, Wei Z (2009) Back propagation wavelet neural network based prediction of drill wear from thrust force and cutting torque signals. Computer and Information Science 2(3): 75–86
17. Spaić O (2016) Cutting theory (in Bosnian). Faculty of Production and Management, Trebinje, Bosnia and Herzegovina
18. ISO 4287:1997 (1997) Geometrical Product Specifications (GPS) – Surface texture: Profile method -- Terms, definitions and surface texture parameters. International Organization for Standardization (ISO), Geneva, Switzerland
19. Chi T, Ballinger T, Olds R, Zecchino M (2004) Surface texture analysis using dektak stylus profilers. Veeco Instruments Inc., Tucson, USA
20. Astakhov VP (2014) Drills: Science and technology of advanced operations. CRC Press Inc., Boca Raton, Florida, USA
21. Meadows JD (1998) Measurement of geometric tolerances in manufacturing. Marcel Dekker Inc., New York, USA
22. Cavazzuti M (2013) Optimization methods: From theory to design. Springer-Verlag, Berlin-Heidelberg, Germany
23. Soković M, Jovanović J, Krivokapić Z, Vujović A (2009) Basic quality tools in continuous improvement process. Strojniški vestnik - Journal of Mechanical Engieering 55(5): 333–341
24. Hagan MT, Demuth HB, Beale MH, De Jesús O (2014) Neural network design. 2nd Edition, Independent author's edition

Figures

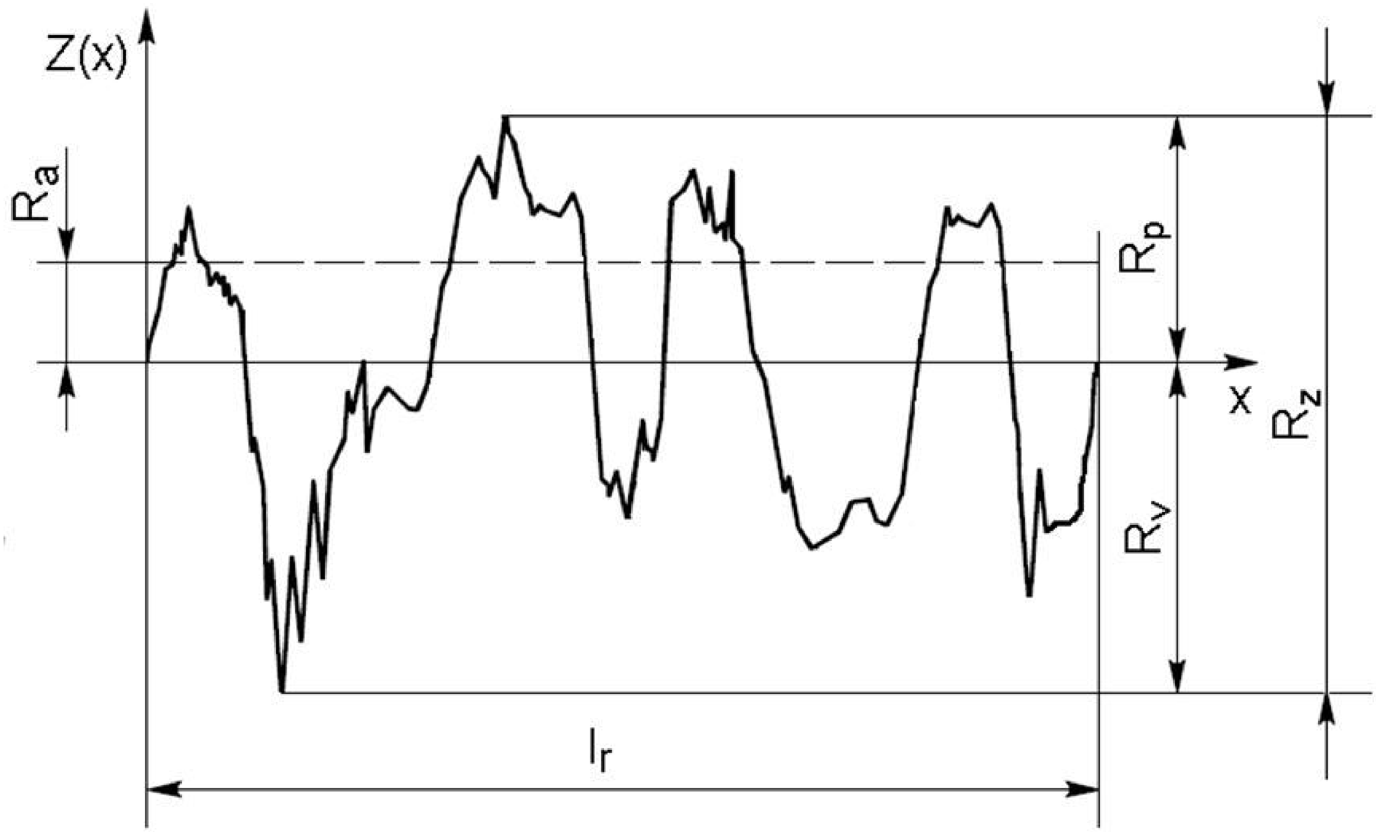


Figure 1

The surface roughness with amplitude parameters

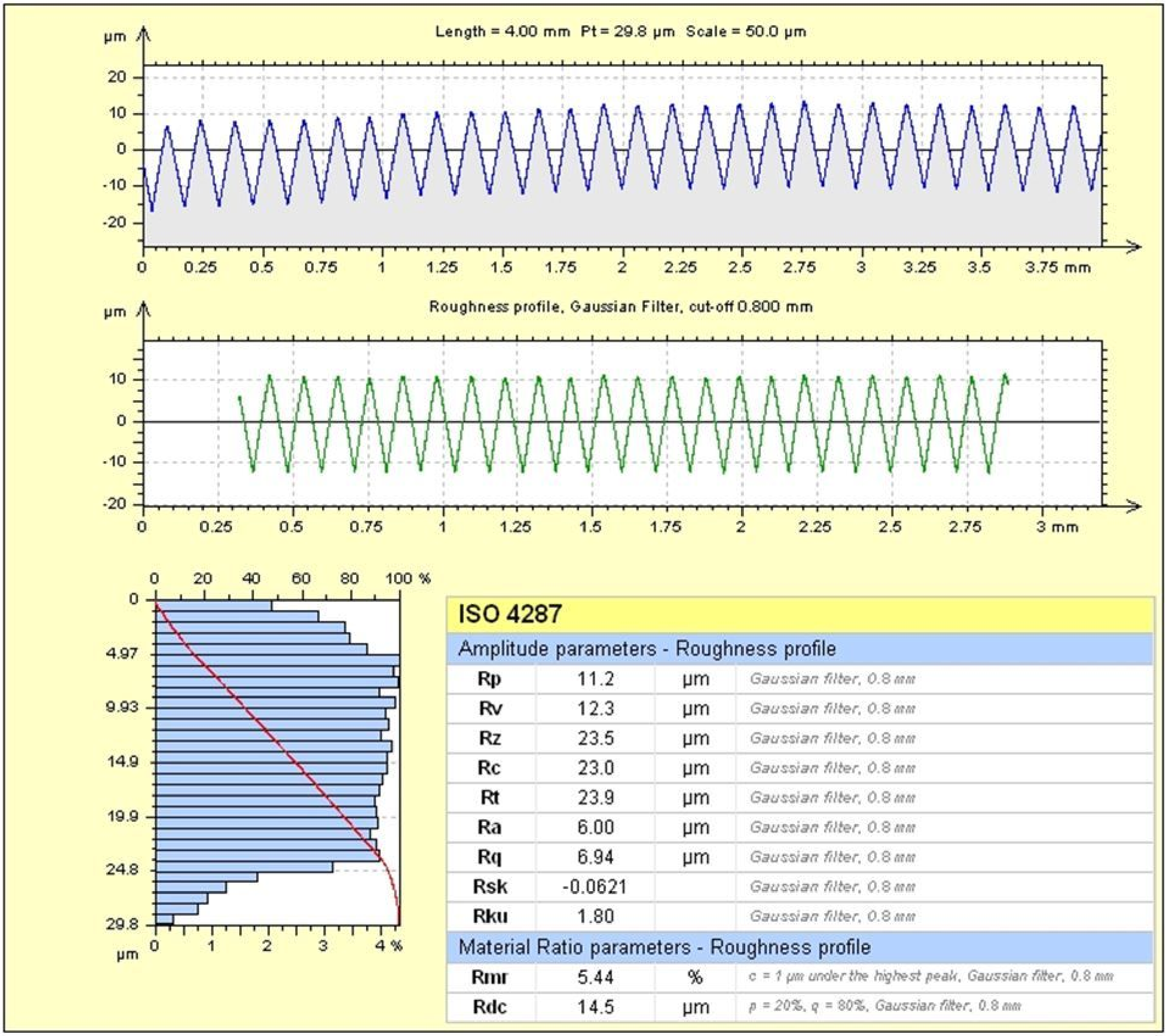


Figure 2

The results of validation of measuring device SURTRONIC 25

Figure 3

The results of the qualification of stylus for measurement

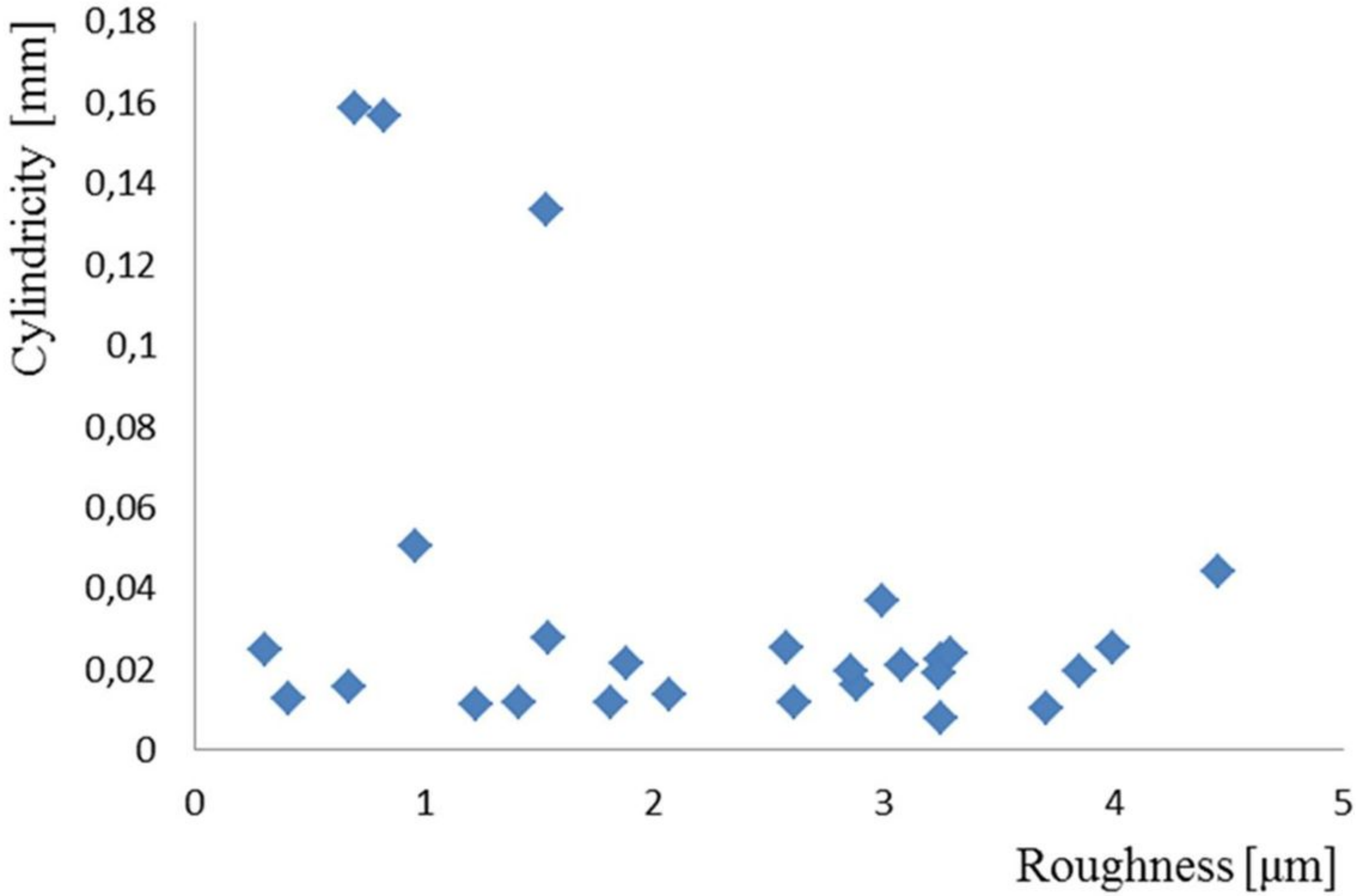


Figure 4

The scatter diagram of roughness - cylindricity

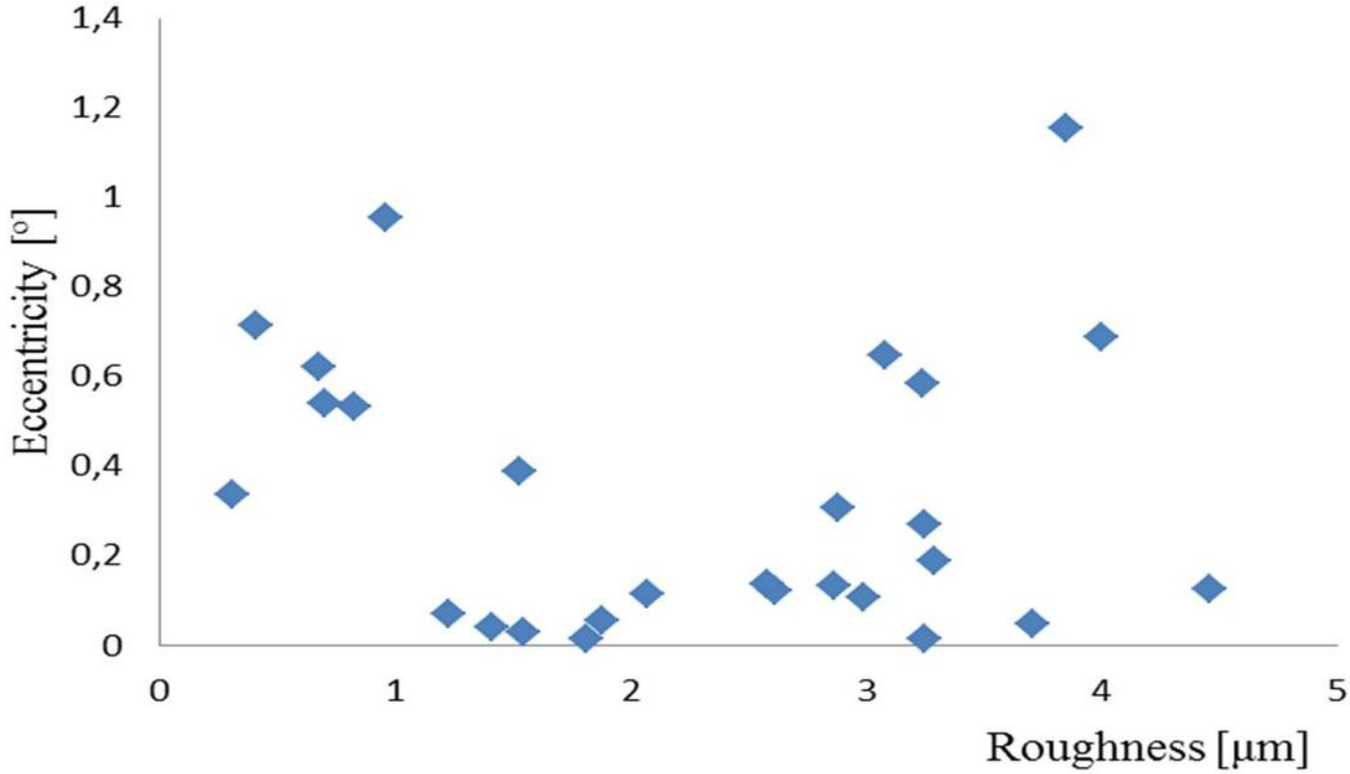


Figure 5

The scatter diagram of roughness – eccentricity

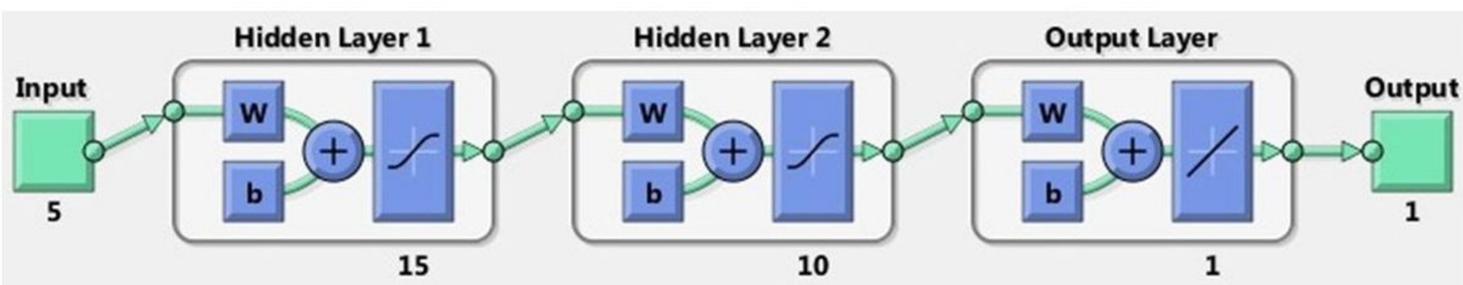


Figure 6

The architecture of the artificial neural network for cylindricity

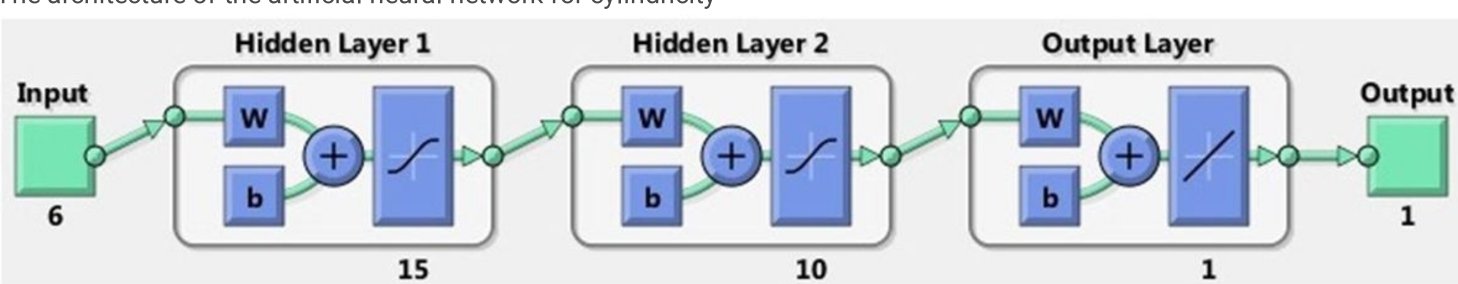
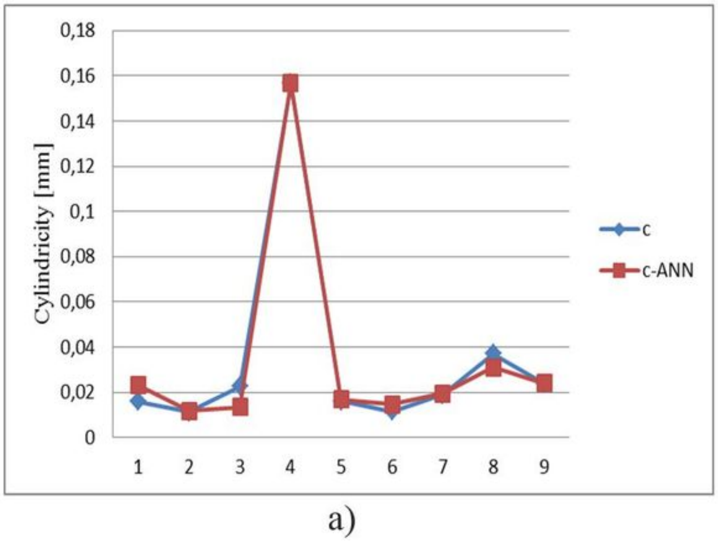


Figure 7

The architecture of the artificial neural network for eccentricity



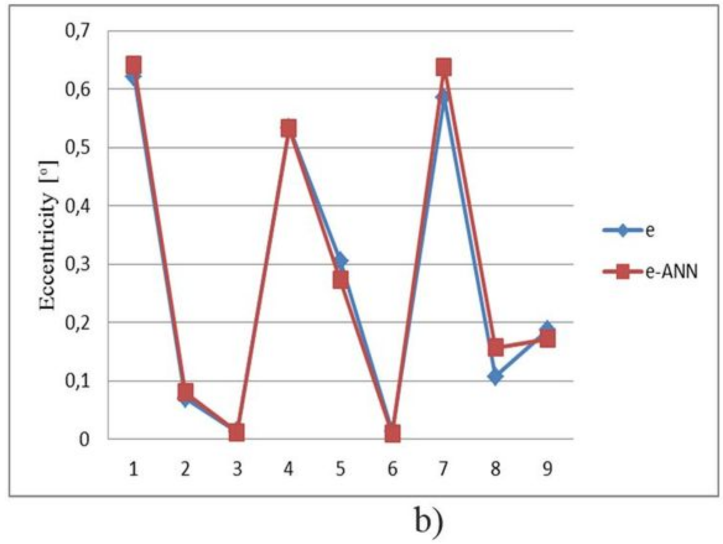


Figure 8

The comparative analysis for the experiment (blue) and artificial neural network (red)