WOOD RESEARCH
62 (6): 2017
895-904

THE EFFECT OF THE POSITION OF 2D ROUGHNESS MEASUREMENT ON THE ROUGHNESS PARAMETERS BY NATURAL WOOD MATERIAL

Zsolt Molnár, Gábor Németh, Sándor Héjja
University of Sopron, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts
Institute of Wood Machinery
Sopron, Hungary

Endre Magoss, Sándor Tatai
University of Sopron, Simonyi Karoly Faculty of Engineering
Wood Sciences and Applied Arts, Institute of Wood Machinery
Sopron, Hungary

(Received March 2017)

ABSTRACT

There are notable differences between the 2-D standardized surface roughness parameters depending on the position of the profil of the surface roughness eavluation of natural wood. Therefore it is fundamental to determine which parameters are the least dependent on the position of the measured profil.

The dependence of the standardized roughness parameters on the different measuring positions varies. We observed the smallest average dependence at the arithmetic average roughness (P_a) parameter of the P-premary profile, and at the Mr_1 (threshold as the minimal Asperities' height distribution AHD)and Mr_2 (threshold as the maximal AHD) parameters and "reduced" height peak amplitude (P_{pk}) was more dependent.

The greatest deviation occurs in the mean roughness depth (P_z), maximum height of the profile (P_t), and the maximum roughness depth (P_{max}) values. These three parameters whoed the highest differences in function of the measuring positiions.

KEYWORDS: Tactile roughness, 2-D roughness parameters, finished surface, premary profile.

INTRODUCTION

Both the contact styles and laser techniques have the advantage that they provide data points. However, stylus tracing remains the most accurate measuring technique despite its limitations and the slow speed of the method compared to the laser technique is only usable in off-line measurements (Gurau and Irle 2017).

In order to determine the surface roughness of natural wood material, 2-D stylus tracing method is used on knotless areas. In most cases 10 st ilustraces are concluded and – irrespectively of machining technology – the following parameters are obtained: R_a/P_a arithmetic average roughness, R_z/P_z mean roughness depth, R_{max}/P_{max} maximum roughness depth and seldom the parameters of the Abbot-curve.

The main goal of this research is to determine the dependency of the surface parameters on the random position of the 2-D stylus tracing system.

The *R*-profile is most commonly used for the determination of surface roughness of natural wood material which is produced with the help of the Gaussian filter. The improper determination of the cut length of the Gaussian filter results in artificial protrusion in the profile in some wood species, especially ring-porous wood species (Fujiwara et al. 2001, 2003). In order to avoid the problem with wood species having large wood vessels, the use of robust Gaussian filter (Fujiwara et al 2003.), profile filter (Gurau et al. 2005, Henderto et al. 2006) or the remove of the vessels from the profile (Fujiwara et al 2003, Henderto et al. 2006) is advised. The choice of the line of measurement in species with large vessels influences the values of the roughness parameters which are observed (Csiha 2004).

In order to minimise the surface inequality, the machining was done with a Marunaka Royal FX super surfacer. The resulting smooth surface made profile filtering unnecessary (Sander 1993), so it was possible to work with the primary P-profile properties.

MATERIALS AND METHODS

Our research was conducted on a wide variety of wood materials, with different anatomical structures. Scotch pine (*Pinus sylvestris*), larch (*Larix deciduas*), oak (*Quercus robur*), beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), aspen (*Populus alba*), walnut (*Juglans regia*), balsa (*Ochroma lagopus*), etimoe (*Copaifera mildbraedii*), kotibe (*Nesogordonia paverifera*), sipo (*Entandrophragma utile*), sapell (*Entandrophragma cylindricum*), okume (*Aucomea klaineana*), zebrano (*Microberlinia brazzavillensis*). Altogether the evaluation used 14 different species.

For the base of test samples we took laths of each species with a dimension of 1 meter in length, 5 centimetres in width and 2.5 centimetres in height. The sides of these laths were prepared on each side by a thickness planer in order to achieve parallel surfaces. After that, the finishing of the surfaces of the samples was done by the Royal FX type planer (Fig. 1). This machine has a standing knife arrangement where the knife remains stationary and the material is pushed along by a rubber belt place on top, thus removing a thin layer of material from the surface. This method effectively filters out the cycloid curve caused by the rotating too (Csanády and Magoss 2013).

Fig.1: Royal Fx planer.

Fig. 2: Test sample.

The measurement was performed using a Mahr S2 type perthometer. This particular instrument is equipped with a table capable of moving bi-directionally. The table can be moved manually by micrometre screws. The neasurements were conducted perpendicular to the grain. The length of evaluationis 17.5 mm.

After finishing, the samples were cut to the dimension of 5 x 5 x 2.5 centimetres (Fig. 2).

We conducted 175 measurements on each sample, making ten measurements for each 1 mm. In reality the machine divides this 17.5 mm region into 7 even sub-regions (resulting in a regional size of 2.5 mm). However, the first and last of these smaller sub-regions are not stored, so the measurement data for each set of measurements is only available for the central 12.5 mm region. The instrument collects 8000 point coordinates lying within this 12.5 mm region which are available later for visualization and post-processing.

The surface roughness parameter is classified according to its primary profile (*P*), roughness profile (*R*), and waviness profile (*W*) in order to evaluate different aspects of the profile (ISO 4287:1998). When the wavelengths of the waviness and primary profile components are compared, the surface roughness component is the one which has the caparatively shorter wavelength. Because the filter process offen cause artifical peaks (Fujiwara et al 2003), and the processing method produced produced a relatively smoth surface we chose the primary profile.

The processing was done using Curve Cutter software (Alpár et al. 2004). The software is capable of calculating the material volume graph before (original P profile) and after manually cutting the large vessels from the measured profile. All of the measured and calculated values can be stored afterwards.

RESULTS

Using the Curve Cutter software we evaluated 9 standardized roughness parameters (P_z, P_a, P_t, P_{max}, P_k, P_{pk}, P_{vk}, Mr_1, Mr_2) (Fig. 3). The visualization of different parameters was done in the order of measurement, displayed on individual graphs by species in order to show the changing trend of each parameter depending on the current place of the measuring profile.

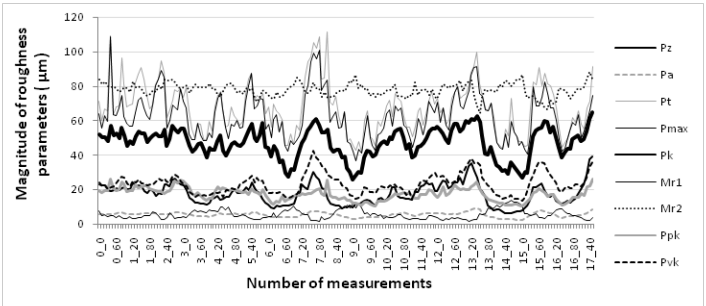

Fig. 3: Roughness parameter levels of beech.

In the following step we conducted statistical analyses in order to obtain the mean values, deviations and relative deviations of the parameters. The summary of these analyses is shown in Tab. 1.

Tab. 1: Statistical evaluation of roughness parameters.

	Balsa			Beech			Walnut			Scotch pine			Etimoe			Kotibe			Ash		
	Ochroma lagopus			*Fagus sylvatica*			*Juglans regia*			*Pinus sylvestris*			*Copaifera mildbraedii*			*Nesogordonia papaverifera*			*Fraxinus excelsior*		
	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)
Pz: (µm)	74.49	23.38	31.38	46.86	8.58	18.32	47.30	6.86	14.51	45.64	3.91	8.56	54.23	7.78	14.35	47.78	3.88	8.12	71.20	14.77	20.74
Pa: (µm)	5.86	1.16	19.85	5.24	1.32	25.20	3.83	0.64	16.67	4.25	0.36	8.52	4.45	0.53	11.99	4.32	0.58	13.35	4.56	0.81	17.81
Pt: (µm)	128.61	45.97	35.74	67.78	14.54	21.46	70.85	11.50	16.24	68.59	9.62	14.02	84.05	12.28	14.61	68.28	7.93	11.62	119.37	21.39	17.92
Pmax: (µm)	120.01	43.69	36.40	62.57	13.29	21.24	65.43	9.77	14.93	60.87	9.64	15.84	80.97	11.81	14.59	61.15	7.50	12.26	107.99	19.15	17.74
Pk: (µm)	17.98	1.31	7.29	17.36	6.25	36.01	11.75	2.17	18.51	16.27	1.24	7.62	13.60	2.17	15.95	15.95	2.35	14.74	13.62	2.14	15.73
Mr1: (%)	7.28	1.09	14.97	5.60	2.75	49.07	6.13	1.26	20.49	8.02	1.22	15.26	6.68	1.57	23.50	14.88	2.41	16.20	12.93	2.16	16.72
Mr2: (%)	84.09	1.88	2.24	77.67	3.88	5.00	78.70	2.16	2.75	81.51	1.97	2.42	79.54	2.15	2.70	86.81	3.16	3.65	87.23	2.38	2.73
Ppk: (µm)	21.03	4.25	20.19	17.48	3.73	21.32	12.80	2.14	16.72	16.11	1.76	10.90	13.99	1.58	11.28	17.48	1.82	10.40	14.17	2.52	17.77
Pvk: (µm)	34.37	14.67	42.69	23.26	5.92	25.44	19.14	3.86	20.15	23.17	3.12	13.47	22.09	3.44	15.58	24.75	4.14	16.73	44.94	9.71	21.61

	Aspen			Sipo			Sapelli			Okume			Oak			Larch			Zebrano		
	Populus alba			*Entandrophragma utile*			*Entandrophragma cylindricum*			*Aucomea klaineama*			*Quercus robur*			*Larix decidua*			*Microberlinia brazzavillensis*		
	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)	Mean value (µm)	Deviation (µm)	Rel. deviation (%)
Pz: (µm)	48.84	2.61	5.34	73.08	11.40	15.60	79.24	7.00	8.84	70.35	9.34	13.27	69.88	12.64	18.09	41.52	3.24	7.80	85.71	14.27	16.65
Pa: (µm)	3.84	0.32	8.27	4.59	0.50	10.96	7.72	0.83	10.73	5.34	1.12	20.99	5.00	0.92	18.37	3.38	0.33	9.75	7.98	1.03	12.87
Pt: (µm)	58.28	4.58	7.87	112.67	18.10	16.06	105.25	10.06	9.56	112.19	20.18	17.98	118.07	20.04	16.97	55.16	6.13	11.11	132.32	27.35	20.67
Pmax: (µm)	55.19	4.44	8.04	101.93	16.26	15.95	99.72	9.01	9.04	98.69	15.68	15.89	108.73	19.71	18.13	49.90	6.03	12.08	121.40	26.36	21.72
Pk: (µm)	8.42	0.71	8.47	16.29	1.97	12.11	17.50	2.97	16.96	13.39	7.03	52.45	10.84	1.09	10.09	15.39	1.99	12.97	35.53	4.04	11.37
Mr1: (%)	7.56	1.02	13.57	12.42	2.98	24.00	6.97	1.68	24.12	10.15	1.92	18.88	12.54	1.88	14.99	10.38	1.52	14.66	5.57	2.44	43.74
Mr2: (%)	74.82	1.55	2.07	89.03	2.15	2.42	78.04	2.54	3.25	79.67	3.82	4.80	85.59	1.72	2.01	87.44	1.32	1.51	86.29	2.87	3.32
Ppk: (µm)	9.36	0.81	8.65	18.89	3.28	17.35	21.95	2.60	11.84	18.69	6.23	33.35	16.63	1.51	9.08	16.25	1.96	12.05	30.22	7.26	24.03
Pvk: (µm)	25.91	1.47	5.69	39.00	7.90	20.25	36.66	4.17	11.37	34.32	6.58	19.16	38.93	10.50	26.97	15.91	1.25	7.88	48.57	9.59	19.75

A few roughness parameters tend to maintain a near constant level by species, having little to almost no deviation in their trends. One of these parameters is the P_a average roughness parameter over the P profile. This parameter held the most constant level in all species. Judging by this behaviour it is safe to assume that the value of the parameter does not depend greatly on the place of measurement.

The biggest difference among the parameter values occurs for beech and balsa, whilst the smallest difference occurs for aspen, Scotch pine and larch. These trends are summarized in Tab. 1.

The following roughness parameters are Mr_1 and Mr_2 which show the lowest and highest material volume (the porosity of the sliced surface). The values of the Mr_1 parameter are low everywhere because it represents the lower part of the material volume. The higher this value, the smoother the surface is. On the other hand, the values of the Mr_2 parameter are high in all cases because it represents the higher part of the material volume. This means that the higher this value, the smoother the surface is.

The ruggedness of a surface is considered low if the Mr_1 and Mr_2 parameters reach high values. These observations on the matter are clearly shown on the next two material volume curves. These curves were obtained by tracing back the measurement lines of the lowest Mr_1 and the highest Mr_2 values.

The values depend very little on the point of measurement. This observation regarding the dependence of the values on the point of measurement can be considered low.

The next parameter for evaluation is the peak height of the core profile (P_k) shown in Tab. 1 above. The magnitude of deviation is considerably higher for this parameter, with a notable difference depending on point of measurement. The deviation is especially high in beech, okume and zebrano, while it is negligible for Scotch pine, aspen and oak.

If the magnitude of the core profile (R_k) height shows a high deviation, it means that for those species there were lines along which we did not find deep vessels, but there were also lines where we did encounter such vessels during the measurement. This results in a change of the Abbot curve from flat to straight and the reverse.

The shallower material volume curve means we did not encounter deep vessels along the measurement making the surface considerably more even. On the other hand, when many deep vessels were included along the measuring line, the magnitude of roughness is higher. This phenomenon explains the great differences between different measurements. Zebrano generally has many small but deep vessels. This particular material property led to the frequent experience of not encountering any vessels along a measuring line. However, along the profiles which contained a few of these vessels, the roughness values were considerably different. Again, this phenomenon is the key behind the difference among the values. In general, beech does not have large vessels on its surface given that it belongs to a diffuse-porous species. The reason for these differences may be the lower surface roughness of the speckles of the rays compared to the roughness of the material itself. Wherever we encountered speckles alone the line, the roughness was lower than where there were none.

Aspen and Scotch pine do not have many large wholes on their surfaces, producing a considerably more homogeneous structure. Therefore the values we measured show only small deviations.

While the same homogeneity does not apply to oak and balsa, we did not notice any large difference between the values. The explanation is that it does not matter if they have large vessels. When these vessels are distributed evenily on the surface, the differences will not be large with only small deviations.

The next two roughness parameters are the reduced depth of valleys (P_{vk}) and the reduced height of peaks (P_{pk}). The tendency of the P_{vk} parameter values shows greater differences than that of the P_{pk}. This difference is clearly observable in the deviation of the P_{vk} parameter, which is considerably higher than the deviation of the P_{pk} parameter for all species. This observation is logical since the magnitude of the peak height strongly depends on whether the line of measurement includes deep vessels or not.

The smallest difference always occurs in the P_{vk} parameter of aspen and larch. The software used for evaluation always cut off the same amount of roughness profile for each species. This happened because these two species have relatively constant roughness profiles, lacking large vessels on the surface.

The greatest difference occurs between surfaces of zebrano, oak, ash and balsa. It is well known from their anatomy that these species have the largest vessels among the species chosen for evaluation. Along the lines where the stylus hit these deep vessels, the value of the P_{vk} parameter was higher than along those where it did not. This relative difference lead to a higher than along those where it did not. This relative difference led to higher deviation afterwards.

Aspen and oak have the smallest difference of the values of P_{vk} parameter and the largest is between okume and zebrano. the highest deviation of the reduced peak height developed for species which hadmost of the fibre fragments ripped away but not torn off by machining. Since the downforce of a modern measuring stylus is as low as about 0.7 – 0.8 mN, the stylus does not push these fragments in front of itself but simply jumps over them. The high deviation observed for zebrano, okume and balsa led us to the conclusion that the machining process produced many ripped fibres on these surfaces. The conclusion was later confirmed by microscopic examination.

Earlier we saw that in oak there is no large difference between P_k and P_{pk} but that is not true for the P_{vk} parameter. We retraced the profiles on the highest and lowest values and generated their Abbot curves in hope of understanding what was behind the profiles.

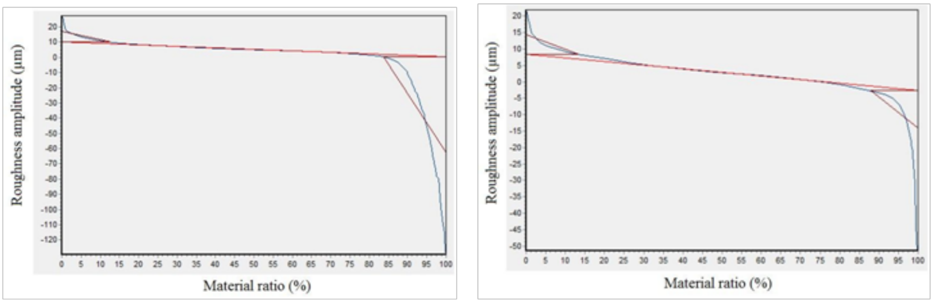

Fig. 4: Abbot curves for oak contains deep vessels and without deep vessels.

Fig. 4 shows the differences in the Abbot curves caused where the stylus encountered deep vessels along its path in the first case and where it did not find large differences in the P_k values and the P_{vk} in the second, while we do find differences between the values of the P_{vk}. These two graphs show the values of the P_{pk} and P_k do not change significantly; only the P_{vk} changes. The first graph shows a deep valley (vessel) of 120 µm while it is only 50µm deep on the second.

In balsa there are small differences in the P_k values while the P_{vk} and P_{pk} vary considerably. This means that the core profile is constant, but the peak height and valley depth vary heavily depending on where the measurement was done.

The highest average mean values of P_k, P_{vk} and P_{pk} occur with zebrano, while the lowest average occurs with aspen, although there are species with lower P_{vk} values.

The next three roughness parameters discussed are P_z, P_t and P_{max}.

We obtained these 3 roughness parameters out of 9 showing the greatest reliance on the point of measurement, regardless of species. The parameters themselves mean the distance in height between the deepest valley and the highest peak over different evaluation lengths. The values of the parameters vary greatly along every line of measurement depending on the depth of the vessels. Deep vessels lead to higher values, whilst the lack of them leads to lower values.

The deviation in these three parameters was enormous for balsa and zebrano. This means the values of these parameters show huge differences depending on which line we take for measurement. Aspen produced the smallest deviation among all the species (Tab. 1).These graphs were made by retracing the lines of measurement of the minimum and maximum values of the P_t parameter. The illustration of the roughness profiles for these lines shows the differences between them. As stated above, aspen showed the smallest differences. It is safe to say that the distance between the minimum and maximum values is indeed very small (Fig. 5).

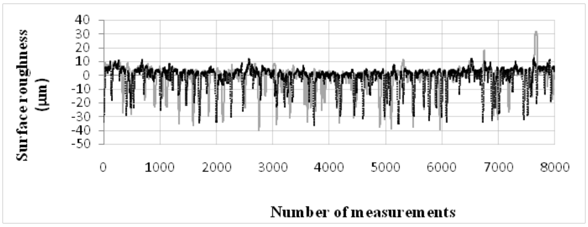

Fig. 5: Surface roughness of aspen along two lines, (minimum value-dotted line; maximum value-continuous line).

The highest value of the P_t parameter occurs along the continuous curve which belongs to an unexpected peak. This peak probably represents a torn fibre on the surface. By neglecting this peak the difference between the minimum and maximum values of P_t would be even smaller (Fig. 6).

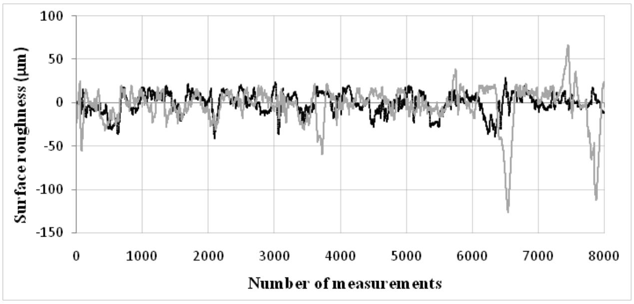

Fig .6: Surface roughness of zebrano along two lines (minimum value-dotted line; maximum value-continuous line).

Zebrano produced the highest differences in these three roughness parameters. The reason behind this phenomenon is clearly stated on the graph above. While there are neither deep valleys nor high peaks along the dotted curve, the continuous curve includes both of them. The two deep valleys supposedly represent two large vessels, whilst the high peak may be caused by a torn fibre fragment. The vertical distance between the deepest valley and the peak is much higher than anything we see along the dotted line curve for instance.

Wood has unique characteristics that complicate its surface texture measurement and analysis such as the need to separate distinct causes of error of form, waviness, and roughness as well as to correlate visual grades of processing standards with 2-dimensional 2-D, and 3-D measurements. Some researchers discussed the performance characteristics of the 3-D optical imaging system for wood roughness measurement and compares them to those of the stylus tracing system.

The abilities of both approaches to capture the types of roughness information required in wood manufacturing processes are discussed as well as the functionality of 2-D, and 3-D roughness descriptors (Funck et al. 1993, Deleanu et al. 2012).

CONCLUSIONS

In conclusion, some of the 2-D parameters depend heavily on the point of measurement while other parameters rely less on it. $P_a$and P_k require less, while P_z, P_{max} and P_t parameters show a greater dependence on the point of measurement. Within the same wood species, there can be decided differences. There were low deviations within Scoth pine, larch, and Kotibe. Aspen had the lowest deviation for almost every parameter. The species with the highest deviations are balsa and zebrano where the surface roughness measurements are greatly affected by the placement of the line of measurement. Tab. 1 shows large vessels produced the largest deviation in every parameter. The key factors could be the number, size and location of the line of measurement. It is not practical to take into account the number of cut vessels as an independent variable.

The characterisation of a wood surface always requires more surface roughness parameters. The measuring conditions must be carefully defined, especially the location of the measurement, the number of profiles, and the correct filter method.

ACKNOWLEDGEMENT

This article was made in frame of the „EFOP-3.6.1-16-2016-00018 – Improving the role of research+development+innovation in higher education through institutional developments assisting intelligent specialization in Sopron and Szombathely”.

REFERENCES

1. Alpár, T., Csiha, Cs., Magoss, E., 2004: Surface roughness profile filtering (Curve Cutter). COST E35 2nd WORKSHOP, Cluny, France.
2. Csanády, E., Magoss, E., 2013: Mechanics of wood machining. Springer Verlag, Berlin Pp 55-61.
3. Csiha, Cs., 2004: Study of wood surface roughness on *P* and *R* profile focused on big poroused species. PhD Theses University of West Hungary, Sopron.
4. Deleanu,L., Georgescu, C., Suciu, C., 2012: A comparison between 2D and 3D surface parameters for evaluating the quality of surface, The Annals of “DUNĂREA DE JOS” University of Galati Fascicle V, Technologies in Machine Building Pp 5-12.
5. Fujiwara, Y., Fujii, Y., Okumura, S., 2003: Effect of removal of deep valleys on the evaluation of machined surfaces of wood, Forest Product Journal 53(2): 58-62.
6. Fujiwara, Y., Fujii, Y., Okumura, S., 2003: Robust Gaussian filter and three-dimensional parameters to evaluate wood surface roughness as related to tactile roughness. Proceedings of 16th IWMS Vol. 1, Pp 359-365.
7. Fujiwara, Y., Fujii, Y., Okumura, S., 2001: Development of a parameter to reflect to roughness of wood surface that corresponds to tactile roughness, Holz als Roh- und Werkstoff 59: 351-355.
8. Funck, J.W., Forrer, J.B.,. Butler, D.A., Brunner, Ch. C., Maristany, A.G., 1993: Measuring surface roughness on wood: a comparison of laser-scatter and stylus-tracing approaches. Proc. SPIE 1821, Industrial Applications of Optical Inspection, Metrology, and Sensing 173 (May 28, 1993).

9. Gurau, L., Irle, M., 2017: Surface roughness evaluation methods for wood products: a Review, Curr Forestry Rep 3:119–131.
10. Gurau, L., Mansfield-Williams, H., Irle, M., 2005: Processing roughness of sanded wood surfaces. Holz als Roh- und Werkstoff 63(1): 43-52
11. Hendarto, B., Shayan, E., Ozarska, B.; Carr, R., 2006: Analysis of roughness of a sanded wood surface, The International Journal of Advanced Manufacturing Technology 28(7-8): 775-780.
12. Magoss, E., 2008: General regularities of wood surface roughness. Acta Silvatica nd Lignaria Hungarica 4: 81-93.
13. Sander, M., 1993: Oberflächenmesstechnik für den Praktiker, Feinprüf Perthen GmbH, Göttingen Pp 26-31.
14. MSZ EN ISO 4287, 1998: Geometrical product specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters.
15. MSZ EN ISO 3274, 1996: Geometrical product specifications (GPS) – Surface texture: Profile method – Nominal characteristics of contact (stylus) instruments.
16. ISO 13565-3, 1998: Geometrical product specifications (GPS) – Surface texture: Profile method; Surfaces having stratified functional properties.
17. ISO 13565-2, 1996: Geometrical product specifications (GPS) – Surface texture: Profile method; Surfaces having stratified functional properties.
18. ISO 11562, 1996: Geometrical product specifications (GPS) – Surface texture: Profile method – Metrological characteristics of phase correct filters.

Zsolt Molnár, Gábor Németh, Sándor Héjja
University of Sopron
Simonyi Karoly Faculty of Engineering, Wood Sciences
and Applied Arts
Institute of Wood Machinery
Bajcsy Zs. U. 4
H-9400 Sopron
Hungary

*Endre Magoss, Sándor Tatai
University of Sopron
Simonyi Karoly Faculty of Engineering
Wood Sciences and Applied Arts
Institute of Wood Machinery
Bajcsy Zs. U. 4
H-9400 Sopron
Hungary
Corresponding author: magoss.endre@uni-sopron.hu