VARIATION OF AREAL PARAMETERS ON MACHINED SURFACES

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Abstract:

This paper presents study of variation of areal parameters on machined surfaces. These surfaces were measured using stylus equipment. After form removal, parameters from ISO 25178 standard were computed using TalyMap Gold software. Then these textures were divided into the smaller sub-areas, for which the parameters were calculated again. Relative deviations between parameters from measured areas and sub-areas were computed as well as the coefficients of variation of parameters, being the ratios of standard deviations to mean parameter values.

Keywords: surface topography, coefficient of variation, parameters,

1. INTRODUCTION

The assessment of surface topography was employed since the early 1930`s. The systems basically involved the use of the mechanical stylus (tactile measurement). This technique was extended into 3 dimensions.

There are a lot of factors affecting uncertainty in surface geometry measurement. They are caused by environment, measuring equipment, measured object, software and measuring method [1, 2, 3]. Parameters variations can be substantial source of the measurement uncertainty of surface topography. Variability of 2D profile parameters on typical manufactured surfaces was studied [4]. The authors of papers [5, 6] analysed variations of areal (3D) parameters. The present work is an approach to study variability of areal surface topography parameters.

2. MATERIALS AND METHODS

Several machined surface topographies with different values of texture aspect ratio Str were analysed. However 8 textures were subjected to detailed study. These surfaces were measured using Hommel Etamic T8000 stylus equipment with 2 μm tip radius. Measured areas were 2 mm x 2 mm, sampling interval was 5 μm in orthogonal directions. Measured speed was 0.5 mm/s. After form removal by polynomials, parameters from ISO 25178 standard were computed using TalyMap Gold software version 6.0. Then these textures were divided into the smaller sub-areas, for which the parameters were calculated again. Relative deviations between parameters from measured areas and sub-areas were computed as well as the coefficients of variation of parameters (in sub-areas) cv, being the ratios of standard deviations to mean values. Digital filtration was not used.

The following parameters from ISO 25178 standard were calculated:

- height parameters: Sq, Ssk, Sku, Sp, Sv, Sz and Sa.
- functional parameters: Smr, Smc and Sxp,
- spatial parameters: Sal, Str and Std,
- hybrid parameters: Sdq and Sdr,
- functional parameters (volume): Vm, Vv, Vmp, Vmc, Vvc and Vvv,
- feature parameters: Spd, Spc, S10z, S5p, S5v, Sda, Sdv, Sha and Shv.

All feature parameters were calculated after a discrimination by segmentation using a Wolfpruning of 5% of the value of the Sz parameter (maximum height). For volume parameters calculation material ratio p was 10%, q was 80%. Parameters from the Sk family (areal extension of ISO 13565-2 standard): Sk Spk, Svk, Sr1 and Sr2 were also computed.

3. RESULTS AND DISCUSSION

Table 1 presents parameters values as well as coefficients of variation cv. Fig. 1 shows contour plots of the measured surfaces.

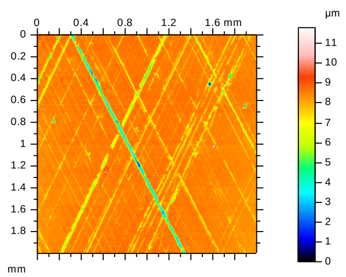
Surfaces are presented in succession corresponding to increase of texture aspect ratio Str. This parameter is used to describe the level of isotropy of surface; a ratio of 1 indicates a perfectly isotropic but of 0 anisotropic surface topography.

Surface S1 is cross-hatched stratified anisotropic cylinder texture after plateau honing. It is characterised by rather high variation of amplitude parameters. The highest coefficient of variation of maximum peak height Sp parameter (0.5) takes place. This is characteristic feature of two-process surfaces, where peak height is comparatively small but instable. It is also interesting that the cv coefficient of maximum height Sz was smaller than those of the Sa (arithmetic mean height) and Sq (root mean square height). Coefficient of variation of the Sal parameter (autocorrelation length) is comparatively small, contrary to other spatial Str parameter; in this case large relative changes are caused by its small value. Hybrid parameters are stable on the surface S1. From among functional volume parameters, the highest coefficient of variation was found for material volume Vm and peak material volume Vmp (0.573). Variations of inverse areal material ratio Smc and particularly areal material ratio Smr were large. Feature parameters (especially peak density Spd) were characterized by large variations. From among parameters from the Sk family, coefficient of variation of the Sk parameter (core height) was higher than those of Spk (reduced peak height) and Svk (reduced valley height) parameters. High relative variation of the Smr1 ratio was caused by its small value. The absolute values of relative errors were larger than 100% for the following parameters: Sp, Smc, Smr, Spc, S10z, S5p, S5v and Shv.

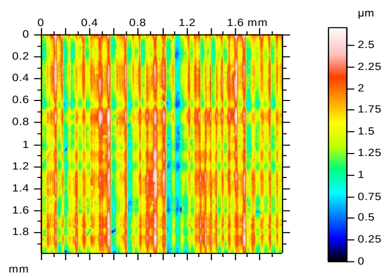
Table 1: Areal surface topography parameters and coefficient of variations cv of surfaces S1, S2, S3, S4, S5, S6, S7 and S8.

Parameters	Surfaces															
	S1		S2		S3		S4		S5		S6		S7		S8	
Height	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
Sq, µm	0.68	0.182	0.38	0.037	0.539	0.132	10.7	0.092	1.45	0.182	30.7	0.157	1.58	0.100	2.09	0.201
Ssk	-4.29	-0.142	-0.136	-1.398	-0.473	-0.140	-0.471	-0.488	-1.92	-0.118	-0.188	-2.881	-0.861	-0.200	-1.68	-1.114
Sku	26.4	0.235	2.77	0.070	3.68	0.073	1.98	0.129	11.1	0.202	1.61	0.365	4.46	0.180	18.6	0.599
Sp, µm	3.5	0.501	1.1	0.208	1.8	0.119	14.8	0.051	3.8	0.203	48.1	0.203	4.88	0.061	14.3	0.144
Sv, µm	8.3	0.117	1.6	0.146	2.65	0.185	28.5	0.101	14.1	0.191	62.2	0.200	8.98	0.134	23.4	0.249
Sz, µm	11.8	0.136	2.7	0.164	4.45	0.155	43.3	0.065	17.9	0.186	110	0.065	13.9	0.106	37.7	0.099
Sa, µm	0.365	0.170	0.307	0.034	0.423	0.133	9.39	0.088	1.03	0.167	27.7	0.189	1.22	0.106	1.25	0.224
Functional																
Smr, %	0.00732	1.997	41.2	0.539	5.49	0.458	1.69	0.321	0.239	1.072	0.00187	0.950	0.0382	0.661	0.00565	0.509
Smc, µm	3.1	0.611	0.606	0.354	1.14	0.121	2.73	0.139	2.35	0.203	11.7	0.229	3.06	0.069	12	0.158
Sxp,µm	2.29	0.255	0.783	0.090	1.19	0.124	23.6	0.180	3.84	0.156	52.7	0.279	3.94	0.125	4.28	0.364
Spatial																
Sal, mm	0.0196	0.082	0.0297	0.589	0.0577	0.804	0.137	0.099	0.063	0.484	0.343	0.115	0.0421	0.435	0.064	0.190
Str	0.0215	0.243	0.0485	0.491	0.0673	0.810	0.138	0.098	0.173	0.651	0.266	0.312	0.771	0.127	0.892	0.154
Std,^{0}	117	0.258	90	0.000	90.1	0.001	86.2	0.025	0.25	1.099	91.1	0.338	135	0.973	90	0.000
Hybrid																
Sdq	0.0877	0.121	0.0324	0.042	0.0661	0.030	0.234	0.389	0.157	0.051	0.231	0.101	0.172	0.025	0.147	0.082
Sdr, %	0.379	0.239	0.0525	0.081	0.218	0.059	1.85	0.511	1.21	0.106	2.62	0.197	1.45	0.049	1.05	0.157
Functional (volume)																
Vm, mm^3/mm^2	4.69E-06	0.573	1.51E-05	0.106	2.08E-05	0.119	9.97E-05	0.133	4.37E-05	0.276	0.000343	0.172	4.99E-05	0.042	1.08E-04	0.146
Vv, mm^3/mm^2	0.000405	0.094	0.000507	0.015	0.000674	0.124	0.0122	0.070	0.0015	0.230	0.0367	0.308	0.00187	0.088	0.00241	0.173
Vmp, mm^3/mm^2	4.69E-06	0.573	1.51E-05	0.106	2.08E-05	0.119	9.97E-05	0.133	4.37E-05	0.276	0.000343	0.172	4.99E-05	0.042	1.08E-04	0.146
Vmc, mm^3/mm^2	0.000256	0.097	0.000352	0.004	0.000478	0.128	0.0118	0.129	0.00107	0.159	0.0338	0.140	0.00136	0.115	0.000999	0.228
Vvc, mm^3/mm^2	0.000244	0.166	0.000463	0.015	0.000602	0.125	0.0111	0.089	0.00123	0.260	0.0344	0.353	0.00162	0.088	0.0021	0.183
Vvv, mm^3/mm^2	1.61E-04	0.278	4.41E-05	0.145	7.21E-05	0.130	0.00107	0.283	0.00026	0.144	0.00233	0.365	0.000245	0.109	3.07E-04	0.344
Feature																
Spd, 1/mm^2	7.01	0.608	60.4	0.208	135	0.201	1.51	0.400	110	0.544	0.25	1.277	306	0.130	16.7	0.372
Spc, 1/mm	0.0409	0.375	0.00623	0.149	0.0146	0.071	0.00444	0.171	0.0389	0.079	0.026	0.172	0.0384	0.013	0.0368	0.259
S10z, µm	6.8	0.249	1.48	0.068	2.74	0.200	22.5	**	11.5	0.127	**	**	9.64	0.105	24.1	0.129
S5p, µm	1.6	0.271	0.545	0.123	1.05	0.078	15.1	**	2.25	0.068	**	**	3.3	0.102	9.76	0.096
S5v, µm	5.2	0.322	0.936	0.185	1.69	0.369	7.37	0.094	9.28	0.172	**	**	6.35	0.133	14.3	0.271
Sda, mm^2	0.257	0.307	0.196	0.168	0.176	0.200	4.37	0.203	0.0774	0.280	11.2	0.153	0.0894	0.121	0.839	0.310
Sha, mm^2	3.31	0.488	0.269	0.111	0.185	0.277	14.4	0.156	0.183	0.610	20.1	0.295	0.0699	0.163	1.17	0.210
Sdv, mm^3	3.94E-07	0.332	2.08E-07	0.316	2.91E-07	0.581	4.08E-05	0.491	6.17E-07	0.455	0.0029	0.117	8.02E-07	0.193	8.49E-06	0.509
Shv, mm^3	1.48E-05	0.522	2.79E-07	0.252	3.73E-07	0.154	6.02E-03	0.424	7.79E-07	0.512	0.00201	1.726	5.23E-07	0.200	1.45E-05	0.248
Functional (Sk group)																
Sk, µm	0.496	0.283	1.02	0.049	1.34	0.149	19.6	0.145	2.65	0.278	69	0.513	3.64	0.106	2	0.219
Spk, µm	0.226	0.119	0.286	0.138	0.39	0.118	0.405	0.179	0.828	0.295	1.82	1.003	0.92	0.071	2.94	0.130
Svk, µm	1.56	0.115	0.385	0.188	0.692	0.159	15.2	0.435	2.74	0.223	29.4	1.272	2.45	0.132	4.29	0.402
Sr1, %	3.88	0.924	8.92	0.149	8.09	0.102	0.931	0.267	7.99	0.155	0.786	0.898	7.31	0.112	25.2	0.179
Sr2, %	78.7	0.094	90.5	0.002	88.5	0.014	66.6	0.046	83.7	0.047	72.4	0.214	86.4	0.001	88	0.035

a)



b)



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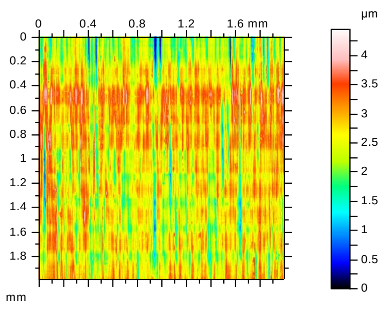
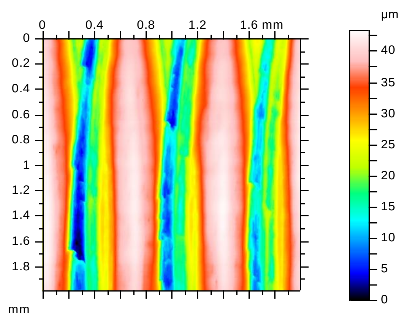


d)



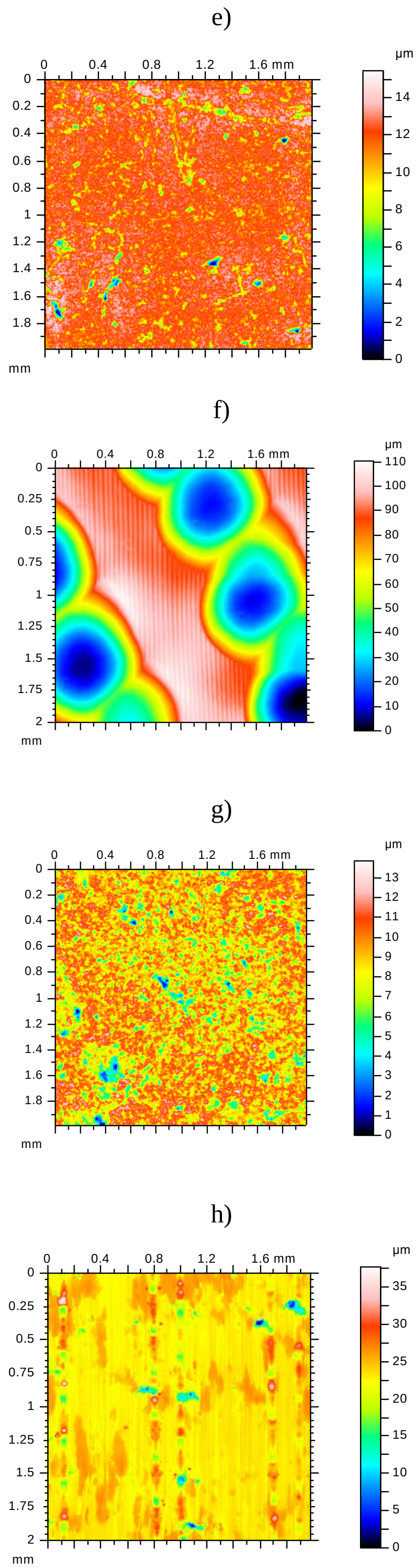


Fig. 1: Contour plots of surfaces: S1(a), S2(b), S3(c), S4(d), S5(e), S6(f), S7(g) and S8(h).

Surface S2 after flat lapping is anisotropic texture of ordinate distribution similar to Gaussian. Coefficients of variation of statistical amplitude parameters Sa and Sq were low, smaller than those of parameters Sp, Sv (maximum pit height) and Sz (total surface height). The high variability of the Ssk parameter was caused by its value similar to 0 (-0.136). The spatial parameters Sal and Str are unstable on surface S1, similarly to parameters Smc and especially Smr. Variability of hybrid parameters Sdq (rms. slope) and Sdr (developed interfacial area ratio) was small. Values of coefficient of variations of functional volume parameters were not higher than 0.15. From among feature parameters, variations of mean dale volume Sdv, mean hill volume Shv and peak density Spd were comparatively large. Differently to surface S1, coefficients of variation of the Spk and Svk parameter were much higher than that of the Sk parameter. Generally, variability of parameters of surface S2 was smaller than of surface S1, only absolute relative changes of the Ssk parameter were larger than 100%.

S3 surface after grinding is also anisotropic texture with a little symmetric ordinate distribution; skewness Ssk was equal to -0.473. Variations of parameters were similar to those of surface S2. The coefficients of variation of parameters describing maximum height were similar to average parameters Sa and Sq. Similarly to surface S2, the coefficients of variation of the Sal and Str parameters were large (about 0.8). Similarly to previously analysed surfaces, hybrid parameters were stable. The coefficient of variation of the Smr parameter was larger than those of Smc and Sxp parameters. From among feature parameters, the highest coefficient of variation was found for mean dale volume Sdv. The absolute values of relative changes of the following parameters due to different surface areas were higher than 70%: Smr, Sal, Str, S5v, Sda, Sha and Sdv.

Anisotropic surface S4 after vertical milling of a little asymmetric ordinate distribution (Ssk =-0.471) has periodic character (kurtosis Sku about 2). Periodic character causes great stability of the amplitude and spatial parameters, which was confirmed in similar investigations [7]. Unlike previously analysed random surfaces, coefficients of variations of hybrid parameters were comparatively large. Similar to other surfaces, variability of the Smr parameter was big (cv=0.32). From among functional volume parameters, variation of pit void volume Vvv was the highest. Variability of the Sk parameter was bigger than of Spk and Svk. Absolute relative differences between parameters: Ssk, Sh and Sr1 measured on area and sub-areas were higher than 100%.

Anisotropic surface S5 of stone was characterised by negative value of skewness Ssk (-1.92). Coefficients of variation of all the height parameters were similar and comparatively high. Spatial parameters were also non stable on surface, unlike hybrid parameters. Variability of the Smr parameter was higher than those of other functional parameters Smc and Sxp. Variations of volume functional parameters and of parameters from the Sk family were rather high. From among feature parameters, the highest coefficients of variation were found for Sh, Sha, Shv, Spd and Sdv parameters. Relative absolute differences of parameters Sal, Shv and Spk on smaller and larger areas were higher than 100%.

Surface S6 is turned surface with additional oil pockets created by burnishing technique. The Str parameter value is 0.266. As the results of large oil pockets sizes, the variability of majority of parameters is comparatively high. For this surface type, coefficients of variations of parameters describing maximum height Sz and Sv (unlike non-stable Sp parameter) are smaller than those characterising average amplitude Sa and Sq. It was confirmed in other research [7]. Large variation of amplitude parameters describing plateau surface part like Sp is characteristic feature of stratified textures. Variation of the Ssk parameter is large. Similar to other analysed surfaces, the coefficient of variation of the Smr parameter is higher than those of the other functional parameters Sxp and Smc. Because of surface character, it was not possible to obtain parameters S10z, S5p and S5v. High variability of the Spd parameter was caused by its value of 0 of two studied sub-areas. Variation of parameters from the Sk group: Sk, Spk and Svk was much larger than of functional volume parameters. This tendency was found for the other analysed samples. The relative changes of the following parameters were higher than 100%: Ssk, Sal, Vvc, Shv, Svk and Sk.

Surface S7 after vapour blasting has isotropic character (Str = 0.771) with a little negative distribution (Ssk = -0.861). Unlike the texture S6, surface S7 is characterised by small dispersions of parameters. Coefficients of variations of parameters characterising amplitude were similar. The Std parameter relative variation was large (0.97), which is characteristic feature for isotropic textures without stable main direction. The coefficient of variation of the Sal parameter was also large (0.43). Usually variability of the Sal parameter of isotropic surfaces is higher than on anisotropic textures. This parameter is instable because surface S7 is not homogenous. However relative variations of the hybrid parameters were comparatively small. Coefficient of variation of the Smr parameter was high (0.661). Relative changes of the following parameters were larger than 50%: Smr, Std, Sda, Sha, Sdv and Shv due to different measuring areas.

Surface S8 after laser treatment is isotropic surface (Str = 0.892) of negative skewness (Ssk = -1.68). However relative variability of skewness and kurtosis are high. Coefficient of variation of the Sz parameter is smaller comparing to Sa and Sq. Similar to other surfaces, variability of the Smr parameter was large. Non-stable character of this parameter was confirmed in the other research [7, 8]. Coefficient of variation of slope Sdq was larger than of developed interfacial area ratio Sdr, which behaviour was also found for the other surfaces [8]. Variations of feature parameters were high, particularly of Sdv and Spd. Coefficient of variation of the Svk parameter was larger comparing to functional volume parameters. Generally, the tendency was found that volume functional parameters are more stable than parameters from the Sk group. Relative absolute errors of parameters computed on smaller area in relation to bigger one were larger than 50% for the following parameters: Ssk, Sku, Sv, Smr, Vmc, Spd, S10z, S5p, S5v, Sda, Sha, Sdv, Shv and Sk.

4. CONCLUSIONS

Repeatability of areal surface topography parameters can by important source of measurement uncertainty.

Dispersions of surface topography parameters may be independent on texture character. The functional parameter Smr as well the feature parameters, particularly Sda, Sha, Sdv, Shv and Spd are also not stable on surfaces. Repeatability of parameters characterising the shape of the ordinate distribution Ssk and Sku is small.

Measured area must contain several characteristic surface features, like oil pockets. In opposite case parameters variations will be high.

Parameters variability may depend on surface character. For example the main direction Std is constant on anisotropic surfaces, contrary to isotropic textures. Usually variation of the Sal parameter on isotropic surfaces (especially non-homogeneous) is larger than on anisotropic textures. Height and spatial parameters are stable on periodic anisotropic textures. For two-process surfaces variations of height parameters describing plateau part, like Sp is larger than those characterizing valley part or the total surface amplitude.

From among hybrid parameters, Sdq is more stable on surface than Sdr. Because they are correlated, the Sdq parameter should be recommended. Volume functional parameters seem to be more stable than parameters from the Sk group.

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