THEORETICAL CONSIDERATIONS OF SURFACES HAVING STRATIFIED FUNCTIONAL PROPERTIES

Jerzy Jabłoński, Paweł Pawlus
Rzeszów University of Technology
35-959 Rzeszów, ul. W. Pola 2, Poland
fax: +48 17 8543112
email: jjablons@prz.rzeszow.pl

Abstract
The paper is devoted to the analysis of stratified functional surfaces. The profiles after two processes were computer generated using the special procedure. The parameters of the resulting profile were studied as the function of input parameters.

1. Introduction

Most of the surfaces are manufactured by more than one process. The resulting texture is combination of the textures due to the two processes. Sintered materials and plateau honed cylinder structure are the examples. Whitehouse in papers [1,2] analysed the effect of filtration on distortion of plateau honed cylinder surface. He also proposed other fitted curves and suggested method of describing the material ratio curve. It is based on analysing the cumulative distribution plot on normal probability graph. This approach is similar to the transitional processes pointed out in [3]. This method was detailed described in [4]. It is possible to obtain three parameters. They are directly related to the honing process through the selection of honing stones and process parameters. The understanding of two-process textures comes from an understanding of the independent components of the texture. The effect of time of plateau honing (change of the depth of plateauing or the placement of the plateau roughness within the valley roughness), plateau stone variation and base texture stone variation on the proposed parameters are reported in [5]. The similar effect of plateau honing time was shown in [6]. This method was also proposed by Zipin [7]. t is included in ISO standard [8]. Other procedure of parameters computation was proposed in [6]. Recently, surfaces having stratified functional properties received a lot of attention. Standard [9] described filtering method of these surfaces topographies. This approach suppresses the valley influence on the reference line. In standard [10] Rk roughness parameters described the material ratio curve are suggested. Two last standards are based on German standard DIN 4776 (1990) [11].

2. The scope of the investigation

Multi-process texture was analysed. The creation of this texture based on the imposition of two Gaussian profiles of known parameters. The additional input value is the distance between mean lines of the profiles (sometimes called plateau depth). The fundamental aim of this work is to obtain relation between parameters of two profiles of normal ordinate distribution creating the resulting profile, plateau depth and the same parameters of the resulting profile. The profiles were computer generated.

3. Subject and methods

The methods of generating Gaussian 3-D surface of known auto correlation function and height parameter were described in [12, 13]. They were a little modified in order to obtain profiles of linear and exponential shape of auto correlation function. All Gaussian profiles are described mainly by standard deviation R_q (R_{qp} –fine or plateau, R_{qv} - base or valley) and correlation lengths CL (CL_p and CL_v). Correlation length is a distance, at which the auto

correlation function decays to 0.1 [14]. Other parameters (which are functions of the presented) were also analysed.
The procedure of creation of profile after two-processes is based on the probability method of describing stratified profile [2-8] – see Fig. 1.

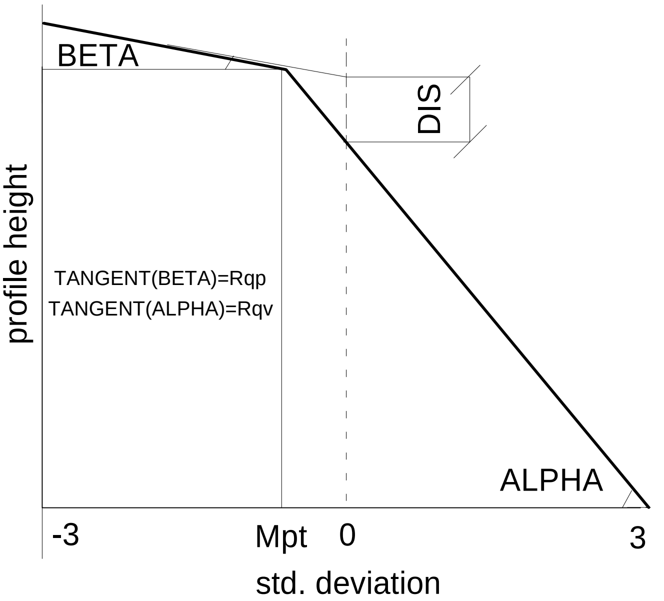

Fig. 1. Graphical interpretation of the probability parameters

From Fig. 1 one can see that third parameter can be the addition to R_{qp} and R_{qv}. It can be M_{pr} (the abscissa) or DIS (distance or plateau depth). Third parameter describes placement of the plateau roughness within the valley roughness. There is equation connecting two of them:

$$ODL = M_{pt}(P_{qp} - P_{qv})$$

The following procedure was done in order to simulate two-process profile:
1. Creation of two Gaussian profiles PP (plateau or fine) and PV (valley or base) with adequate auto correlation distances and variances.
2. The choice of the distance (DIS) between the mean lines of the profiles (the centers of the normal distributions).
3. For all the points of two distributions: If PV(i) > PP(i) then TP (i) (profile after two processes) = PP (i), else TP (i) = PV (i).

We have information about parameters of two profiles of normal ordinate distribution and about the final profile. Parameters R_{qp}, R_{qv} and M_{pr} (or DIS) are known a priori. The following parameters were analysed: amplitude R_q, horizontal: S_m, β^*(only for profiles of exponential shape, 2.3 β^* is correlation length [14]) and SP parameters equal to 1(2f) being the maximum (best) sampling interval for 3-D cylinder measurement [15]. In addition average (Δa_2, Δa_7) and rms. slopes (Δq_2, Δq_7) were calculated based on 2- point equation [11] an 7-point Lagrangian difference formulae [16]. Other parameters were connected with peaks. They were: peak curvature based on 3-point and 7-Lagrangian formulae sc_3, sc_7 [17]. Peak of curvature sc_3 was recognised when its ordinate was bigger than 2 neighbouring points (sc_7 – 6 neighbouring points), but peak of curvature $sc_{3/7}$ was recognised when the ordinate was bigger than 2 points, but curvature was calculated according to 7-point formula.

4. Results

60 profiles were analysed. M_{pt} parameter in linear scale was between 50 and 90 % bur R_{qv}/R_{pt} ratios were between 6 and 17. It is interesting if one can predict parameters P_T of profile after two processes when parameters characterising Gaussian profiles creating final profile P_p and P_v are known, From the assumption the resulted profile parameter should be:

$$P_T = P_p M_{pt} + P_v (1 - M_{pt})$$

M_{pt} should be in linear scale. It was found that errors of obtaining average slopes (Δa_2, Δa_7) were very small (average errors about 3.5%). The errors of parameters Δq_2, Δq_7 were bigger and amounted (mean values) to, respectively, 23.9, and 20.8 %. The last results were possible to predict, rms. slopes are sensitive on valley existence [18]. Rather small average errors were found during analysing the curvature sc_3 (4.8%), bigger $sc_{3/7}$ (8.5%) and the biggest sc_7 (18%). Average relative errors of prediction of R_q were 5.5 %. It was difficult to forecast spacing parameters of the final profile. The predicted values were similar to the parameters of the final profile only when spacing parameters of the base (valley) region were bigger than of fine (plateau) region. In this case the average error of SP was 13 % S_m 20 %, and β^* 40 %.
Because rather good results were obtained during analysing average slope, it was decided to use it in order to calculate (predict) spacing parameters. The dependence between spacing parameters and average slopes for profiles of normal ordinate distribution was studied. As the example, the relation between SP and Δa_7 is shown in Fig.2. This relation is valid for profiles of linear and exponential shapes.

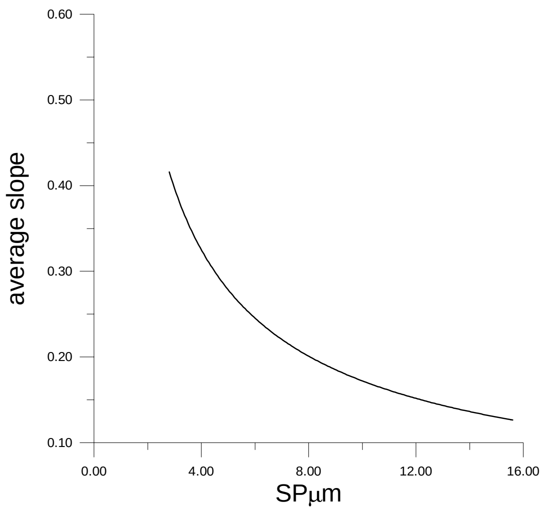

Fig.2. Dependence between SP and Δa_7 for profiles of Gaussian ordinate distribution (sampling interval was 1 μm, R_q was 1 μm)

Average slope of the resulted profile was normalised (divided by R_q) and from figures (similar to Fig.2) or equations describing them spacing parameters were calculated. The average errors of predicting S_m was 10 %, SP 11%, but β^* 25 %. Bearing into mind that these parameters were calculated indirectly, based on parameters computed with some errors, results of computing SP and S_m parameters are rather good.

5. Conclusions

From the analysis of computer generated profiles the cost and time of experimental investigation could be smaller. It was found that it is possible to predict with very good accuracy average slope parameters of the profiles after two processes. Comparatively good results were obtained in predicting the peak curvature calculated using three-point equation and amplitude parameter R_{qv}. The results of spatial parameters forecasting are not so good using the normal procedure, but other method based on predicted values of slope and amplitude parameter improved the results. The next steps should be the analysis of parameters in three dimensions and study of real surfaces.

References:

1. D.J. Whitehouse: Some theoretical aspects of a practical measurement problem in plateau honing. Int. J. Prod. Res., 1983, 21 (2), 215-221
2. D.J. Whitehouse: Assessment of surface finish profiles produced by multi-process manufacture. Proc. Instn Mech. Engrs vol. 199, No B4, 263-270
3. J.B.P. Williamson. Microtopography of surfaces. Proc. Instn Mech. Engrs, 1967/68, 192, part 3K, 21
4. M.C. Malburg, J. Raja: Characterization of surface texture generated by plateau honing process. CIRP Annals 1993, 42/1, 637-640
5. M.C. Malburg, M.B. Grant: The characterisation of two-process surface texture using the cumulative Gaussian probability distribution. ISO Paper, 1993, 93/701187, 13-31
6. H. Sanna Reddy, J. Raja, K. Chen: Characterisation of surface texture created by multi-process manufacture. Transactions of the 7th International Conference on Metrology and Properties of Engineering Surfaces, 111-118
7. R.B. Zipin: Analysis of the Rk surface roughness parameters proposals. Precision Engineering, 12, 1990, 106-108
8. ISO 13565-3: Surface texture (profile method) – characterisation of surfaces having stratified functional properties - part 3: Height characterisation using the material probability curve
9. ISO 13565-1: 1996: Surface texture (profile method) – characterisation of surfaces having stratified functional properties - part 1: Filtering and general measurement conditions.
10. ISO 13565-2: 1996: Surface texture (profile method) – characterisation of surfaces having stratified functional properties - part 2: Height characterisation using the linear material ratio curve
11. L. Mummery: Surface texture analysis. The handbook. Hommelwerke GmbH, 1990
12. Y.Z. Hu, K. Tonder: Simulation of 3-D random rough surface by 2-D digital filter and Fourier analysis. Int. J. Mach. Tools Manufact. 1992, 32, (1-2), 83-90
13. N. Patir: A numerical procedure for random generation of rough surfaces. Wear. 1977, 45, 263-277
14. D.J. Whitehouse, J.F. Archard: The properties of random surfaces of significance in their contact. Proc. Roy. Soc. London 1970, 316A, 97-121
15. P. Pawlus, D. G. Chetwynd: Efficient characterisation of surface topography in engine bores. Precision Engineering, 1996, 19, 164-174
16. D.G. Chetwynd : Slope measurement in surface texture analysis. J. Mech. Engng Sc. 1978, 20/3, 115-119
17. D.J. Whitehouse: The digital measurement of peak parameters on surface profiles. J. Mech. Engng Sc., IMech. 1978, 20, 221-227
18. P. Pawlus: Slope calculation of Gaussian and stratified surface topographies. X International Colloquium on Surfaces, Chemnitz 2000, 426-433