Binary method of grinding wheel surface descriptions

J Jablonski
University of Rzeszow Institute of Technology, Poland
E-mail: jjablons@univ.rzeszow.pl

S Pawlowski
Rzeszow University of Technology, Poland
E-mail: spawlo@prz.rzeszow.pl

Abstract. The paper presents series theory usefulness for binary description of porous surfaces. Grinding wheel surface is here practical representative. In the work the following probability distribution was implemented: $P(Ta = r \cdot Dt)$, where: $Dt$ – hypothetical interval, $Ta$ - distance between abrasive grains, $r = 1,2,3$...

1. Introduction
The dependence between grinding wheel surface topography and workpiece surface topography is very important in the grinding process. However, this dependence is very complex. Therefore, the topography of grinding wheel and the workpiece is performed and described independently. The researchers analysed [1,2,3] or modelled grinding wheel surface topography [4,5,6]. These measurements provide necessary data for a phenomenological notation of the dependence $P_{sw} = f(P_t)$; where $P_{sw}$ - parameters of the worked surface, $P_t$ - parameters of the grinding process. A significant methodological convenience is the fact that the grinding wheel topography may be treated as a random stationary and ergodic field. In such cases, an adequately long 2D cross section of such field is its sufficient representative.

2. An idea of binary descriptions of grinding wheel elementary profile
The value of distance between abrasive grains with the $P(Ta)$ function of probability distribution in particular, may be assumed as wear criterion of the grinding wheel. Where the wear time is represented by variable level of severance $u$ (Figure1) calculated from the highest peak of the 2D profile. These levels, (2D profile cross sections cutting planes parallel to cutting planes of the grinding wheel), are numbered into the depth of the grinding wheel material. Thus, the linear wear of the grinding wheel may be estimated. On each level the number of linear wear intersection with 2D profile cross cuts is counted. This profile is sampled with a $dt \equiv dl$ sampling interval. Values of the profile ordinates, which exceed the $u$ level, are marked “1”; those below the $u$ level are marked “0”. As a result on each $u$ level a series of “1”s and “0”s is obtained. The following marking has been
introduced. The probability of “1” existence is marked by symbol B, and (1-B) in case of “0” existence.

Figure 1. Idea of binary description of elementary grinding wheel profile.

Figure 2. Model of worn elementary profile:
- Ta – distance between neighbouring of worn profile,
- b – length of worn grain,
- a – distance between grains.

The estimated probability is of a frequency type. It equals respectively: for B the ratio of “1”s on a given u level to the general number of Ndt intervals on the entire measured length. The notion of series is introduced as a binary portion consisting of only “1”s or only “0”s. Alternation of 1 → 0 or 0 → 1 limits the series. The further factors are:

a) coefficient of series: \( MI = \frac{n}{N} \); where n- number of the series (on given “u” level).

b) variable theoretical interval \( Dt \) defined as [1]:

\[
Dt = \frac{2 \cdot B(1-B)dt}{MI}
\]  

(1)

Probability of obtaining a \( rDt \) series for this interval equals to:

\[
P\{r \cdot Dt\} = (1-B) \cdot B^{r-1}
\]  

where \( r = 1, 2, 3... \)  

(2)

The average size of the “1”s series is equal to \( \frac{Dt}{1-B} \) whereas the average square deviation of the series size is equal to:

\[
\sigma(r \cdot Dt) = \frac{B^2Dt}{1-B}
\]  

(3)

During its wear, the grinding wheel profile takes the form of (see Figure 2). From the geometrical point of view such profile corresponds to a genuine one i.e. not worn out, which has been cut off by the u line. The distance between adjacent, worn fields equals to \( Ta \). With such formulation, the function of distance probability distribution between “worn” grains \( P\{Ta\} \) forms:

\[
P\{Ta = r \cdot Dt\} = \left\{ \begin{array}{ll}
\left[ \frac{B(1-B)}{1-2B} \right]^{r-1} \cdot B^{-1} & \text{where } -B \neq \frac{1}{2} \\
\left[ \frac{r-1}{2^r} \right] & \text{where } -B = \frac{1}{2}
\end{array} \right.
\]  

(4)
3. Example of description of elementary wheel profile
The mentioned above theory was used for description of grinding wheel of hard binder. For that binder type model of truncated grains is actual. Figure 3 presents function \( P[Ta] \) before (a) and after wear of grinding particles (b).

The following calculation sequence has been implemented:
1. Scanning of a grinding wheel surface sector size 2.0 x 2.0 mm (Talysurf150 – Taylor Hobson) with quantization interval of \( dt = 5 \) micrometers. The surface was approximated by a third degree multinomial.
   The average value of Sz parameter (ISO 4287-2000) equalled respectively:
   \( Sz-A = 27.9 \mu m \); \( Sz-B = 20.1 \mu m \); where: \( Sz-A \) – initial value, \( Sz-B \) – wear value.
2. Transformation (conversion) of the scanned surface into a continuous 2D profile (the route – profilogram- meander type characteristic for Talysurf 150 T.H.)
3. Selection of measuring length.
4. Drawing the function of the grain distance distribution \( TaP \).

![Figure 3. Functions of probability distribution: \( P[Ta=rDt] \); a) grinding wheel after wear, b) grinding wheel before wear.](image)

![Figure 4. Functions of probability distribution: \( P[Ta]=f(u,r) \) parameterised by integer numbers \( r = 1,2,3,... \)](image)

4. Discussion
In our opinion from practical point of view it is necessary only to analyse for \( r = 1 \) – see formula 4. It means one should analyse only outer curves function \( P[Ta=rDt] \). For unworn wheel, this curve has quasi-symmetric character of quasi-triangular distribution with maximum in distance 13.5 \( \mu m \) from the highest curve peak (level \( u = 1 \)). It could be interpreted as forecast of achieving criticality value \( Ta \) on 13.5 \( \mu m \) depth. (The question, which of combination of parameters \( (B, MI, r) \) is proper from operating reasons is separate problem not analysed here). For worn grinding wheel, the probability distribution \( P[Ta=Dr] \) is asymmetric and has changed character. Only 4.5 \( \mu m \) distance was in order to obtain the mentioned above maximum. Interesting is the result of parametrization of distribution \( P[Ta]=f(u,r) \) using \( r \). Namely: with increase of \( r \) value a probability distribution decreases quickly (see Figure 4). It depend by \( u \) level. This result is logical from the mathematical point of view (see formula 4). Practical interpretation would be very interesting but the additional investigation is here necessary.
5. Conclusions
That can say, that described method exemplifies of mathematical tool (model) which is useful even so
simplifies reality (i.e. separate points of profile – after sampling – are not precisely independence).

\[ P\{b = Ta - a\} \] (where \( b - \) see Figure 2) formula maybe applied while describing and estimating the
length of worn grain on the \( u \) level. It corresponds to notion of linear wear curve (ISO 4287-2000).

Maximum value of function of probability distribution \( P\{Ta = rDt\} \) can be a criterion of cutting
grains properties. The fact that it is possible to estimate depth, on which the arbitrary chosen average
value \( Ta \), exists (the distance among worn-truncated grains) is additional advantage.

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References
[1] Mc ADAMS G 1964 *Topography of grinding wheel – abrasive properties*, MIR, Vol. 1, pp. 44-56, (in russian).
[2] BLUNT L, EBDON S 1996 *The application of three-dimensional surface measurement techniques to characterizing grinding wheel topography*, International Journal of Machine Tools and Manufacture, Vol. 36/11, pp. 207-226.
[3] CHEN X, ROWE B 1996 *Analysis and simulation of the grinding process. Part I: generation of the grinding wheel surface*, International Journal of Machine Tools and Manufacture, Vol. 36/8, pp. 871-892.
[4] NGUYEN T, ZHANG L C 2005 *Modelling of the mist formation in a segmented grinding wheel system*, International Journal of Machine Tools and Manufacture, Vol. 45/11, pp. 21-28.
[5] WANG Y, MOON K S 1997 *A methodology for the multi-resolution simulation of grinding wheel surface*, Wear 211, pp. 218-225.
[6] SALISBURY E J, DOMALA K V, MOON K S, MILLER M H, SUTHERLAND D W 2001 *A three-dimensional model for the surface texture in surface grinding. Part II. Grinding wheel surface texture model*, ASME Journal of Manufacturing Science and Engineering, Vol.123, pp. 582-590.