OPTOELECTRONICS AND ADVANCED MATERIALS – RAPID COMMUNICATIONS Vol. 7, No. 1-2, January - February 2013, p. 125 - 128

Advanced chrome coatings with hemispherical surface structure

ŞERBAN RADU
Transilvania University of Brasov, Department of Mechanics, 29 Eroilor Blvd, 500036 Brasov, Romania

Using basic surface values, a method to appreciate the properties of the chrome coating bearing with hemispherical surface structure was developed. Due to the manufacturing process of tailored chrome coatings which enables adjustable surface topography, an effective surface evaluation tool seemed to be necessary. Four main types of chrome coatings were used for this study. By using a scanning electron microscope, the materials underwent first an optical investigation. The bearing area diagrams were obtained from the roughness profiles, measured for each type of chrome coating. By using the multidimensional vector method, an effective value of the bearing area was calculated. This enables a direct comparison between the four types of coating

(Received August 3, 2012; accepted February 20, 2013)

Keywords: Chrome coatings, Surface bearing area, Surface roughness, Multidimensional vector method

1. Introduction

High performance coatings have nowadays a widespread field of applications, providing superior properties to parts manufactured from common materials [7]. They could represent a viable solution for an era dominated by environmental friendly product design and cost efficient manufacturing [1],[8].

The manufacturing technology for coatings has had a tremendous development, so that producers could offer basically an unlimited number of solutions to their customers. For chrome coatings which have a hemispherical surface structure, the manufacturing process enables an adjustable surface topography: the density of hemispheres per mm can be controlled as well as their height, resulting virtually unlimited variants of coating types [3]. Thus, the development of an efficient and simple method to characterize and evaluate such a large amount of coating types seems to be necessary.

2. Chrome coatings with hemispherical surface structure

Chrome coatings are mainly used for metallic parts subjected usually to high cyclic mechanical stresses. Between the base material and the coating, an intermediate Cu or Ni layer is inserted. As pictured in Fig. 1, the surface structure can be open (A, B, C) or closed (D), with high (A, D) or low (B, C) density of hemispheres. The roughness profile height can be high (B, C) or low (A, D). The profiled surface of these coatings has two major advantages: it provides better grip when brought in contact with a softer surface and generates less wear and friction when brought in contact with a harder surface [3, 5].

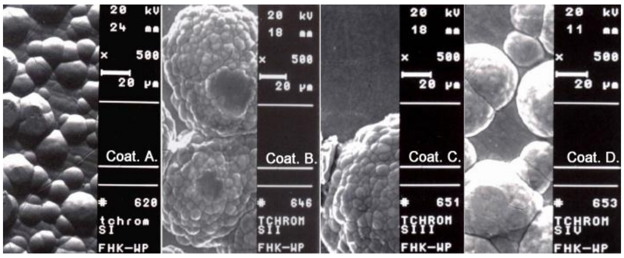

Fig. 1. SEM view of the four types of chrome coatings investigated (500x magnification).

For this study, four main types of chrome coatings with hemispherical surface structure were chosen. Their main mechanical properties are presented in Table 1.

Table 1. Mechanical properties of the four types of chrome coatings investigated.

	Coating A	Coating B	Coating C	Coating D
Structure type	Open	Open	Open	Closed
Maximum roughness profile height R_t [μm]	9,51	36,47	79,45	19,25
Density of hemispheres [hem./cm]	227	87	57	132
Hardness HV0,1	1000	1000	1000	1000
Coating thickness [μm]	20	70	140	70

2. Determining the surface bearing area

The engineering term known as the bearing area, refers to the properties of the contact area between two surfaces [4]. It is usually defined as:

$$B_A = A_r / A_n \tag{1}$$

The real contact area A_r is defined as the sum of micro contact areas between two surfaces, whereas the nominal contact area (geometric contact area) A_n is obtained by projecting the smaller surface on the larger one. Determining these two parameters is difficult, so another method for calculating B_A had to be developed.
Measuring the roughness profile of a surface is a common laboratory procedure and it enables the representation of the Abbott-Firestone diagram, shown in Fig. 2.

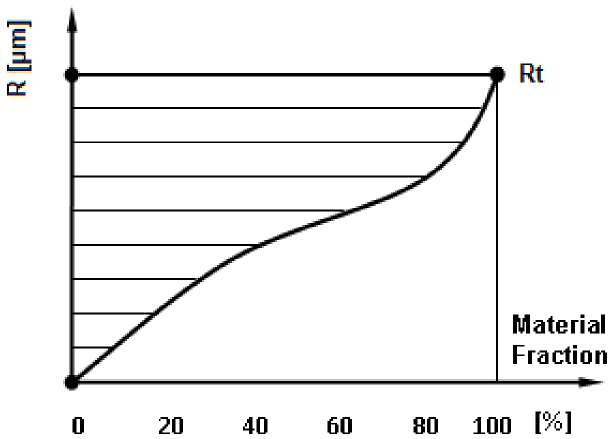

Fig. 2. The Abbott-Firestone diagram

This diagram is obtained by intersecting the measured roughness profile with a minimum of 10 parallel, equidistant lines (perpendicular to the profile). The resulting segments, representing the material fraction of the corresponding intersection line, are then represented on the diagram in percentage. The dashed horizontal line corresponds to the total profile height R_t, of the roughness profile. The resulting area above the curve (delimited by R_t) is proportional to the material fraction included in the roughness profile. The roughness profile of the four types of chrome coatings are shown in Fig. 3 and Fig. 4. [4].

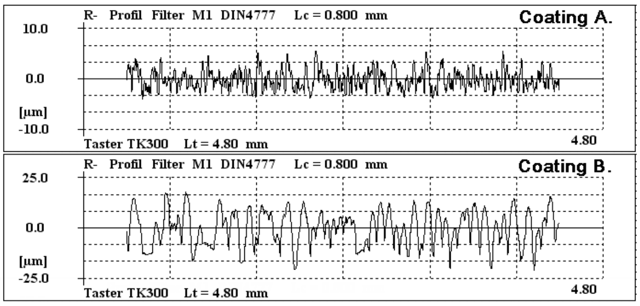

Fig. 3. The roughness profile measured for coatings A and B

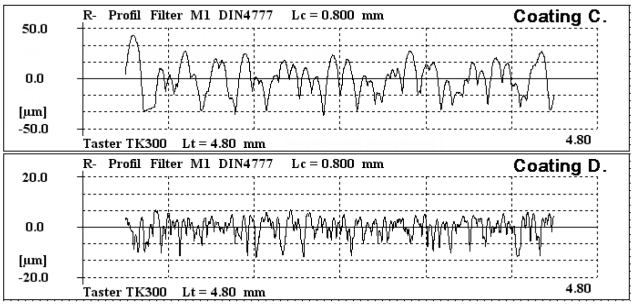

Fig. 4. The roughness profile measured for coatings C and D.

The Abbott-Firestone diagrams for the four coating types are shown in Fig. 5 and Fig. 6 [4].

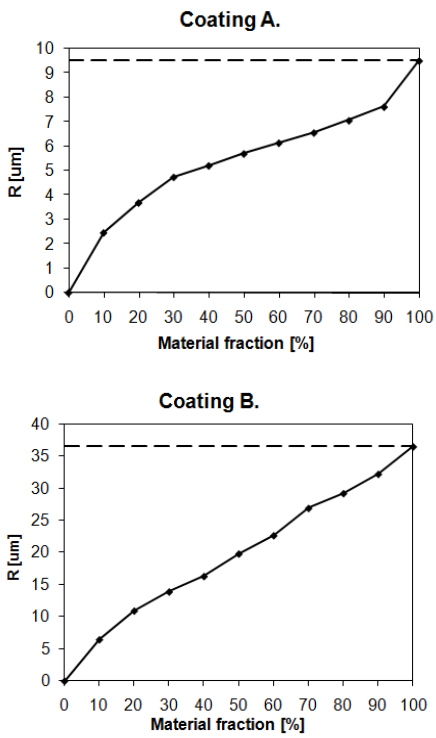

Fig. 5. The Abbott-Firestone diagram for coatings A and B.

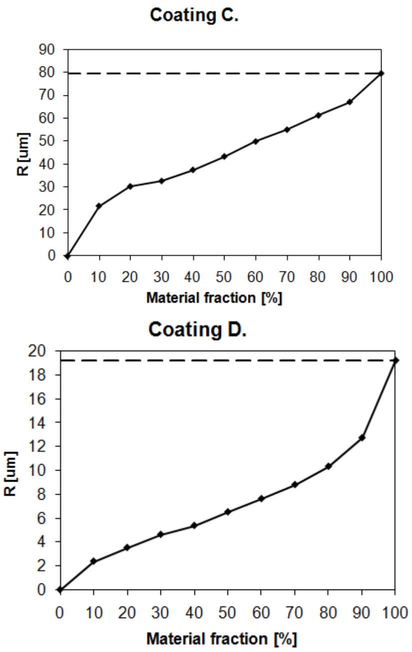

Fig. 6. The Abbott-Firestone diagram for coatings C and D.

3. Theoretical aspects of the multidimensional vector method

This method allows estimating relative or absolute distance between two or more data series having the same amount of "n" elements. The series can be analytical defined curves or sequences of discrete data measured experimentally. For example, for two given curves A (a=a(x)) and B (b=b(x)), as shown in Fig. 7, by using the multidimensional vector method, the absolute or relative distance between the two curves can be calculated [2].

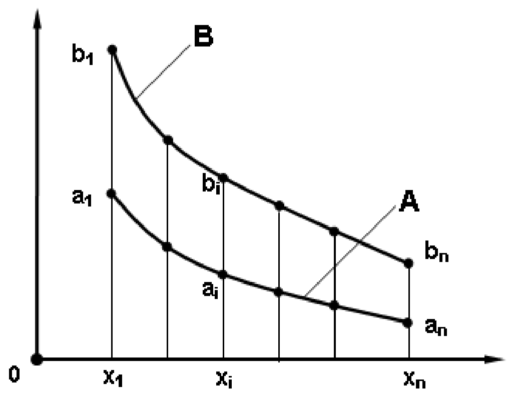

Fig. 7. Determining a distance between two curves.

By intersecting the two curves with "n" parallel lines, two data series are obtained:

$$a = (a_1, a_2, ..., a_n) \quad (2)$$

$$b = (b_1, b_2, ..., b_n) \quad (3)$$

The absolute distance between the two curves is given by the following equation:

$$d_{p_a}(a,b) = \left[|a_1 - b_1|^n + |a_2 - b_2|^n + ... + |a_n - b_n|^n \right]^{1/n} [\mu m] \quad (4)$$

The relative distance between the two curves is given by the following equation:

$$d_{p_r}(a,b) = 100\left[|1 - b_1/a_1|^n + |1 - b_2/a_2|^n + ... + |1 - b_n/a_n|^n \right]^{1/n} [\%] \quad (5)$$

4. Determining the bearing area using the multidimensional vector method

The method described above will be used to estimate the bearing area from the Abbott-Firestone diagrams (see Fig. 5 and Fig. 6). This is done by calculating the distance between the curve and the line corresponding to the total profile height R_t. The calculated values for the four types of coating are shown in Table 2.

Table 2. Calculated values for the absolute and relative distance between the curves.

	d_{pa} (a,b) [μm]	d_{pr} (a,b) [%]
Coating A	9,545964	100,3781
Coating B	36,919618	101,2328
Coating C	79,722308	100,3427
Coating D	18,891464	103,3322

For evaluating the coatings, only the relative distance is being considered. It can be assumed that for a high value of d_{pr}, more material is included in the roughness profile. Thus, the contact area between two parts becomes higher, determining a decrease of contact pressure and wear.

According the results shown in Table 2, Coating type D. has the best surface properties with a d_{pr} of 103,332%. This was somehow expected because of its closed structure and low roughness profile.

5. Conclusions

A method for characterizing the bearing area of chrome coatings with hemispherical surface structure was developed. The method is based on the multidimensional vector principle [6] which enables the estimation of the distance between two curves. For verifying this method, four types of chrome coatings with different surface profiles were chosen. The value of the bearing area was estimated by calculating d_{pr}, which represents the relative distance between the bearing area curve and the maximum profile height, R_t. The best value for d_{pr} was calculated for coating type D, which has a closed surface structure and a relative low profile roughness.

The purpose for developing this calculation method was to create a simple tool for manufacturers and product developers, which enables a fast and effective evaluation of coatings.

Acknowledgements

This paper is supported by the Sectorial Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/89/1.5/S/59323.

References

[1] S. Bahadur, Effect of Surface Coatings and Treatments on Wear, ASTM STP 1278, ISBN 0-8031-2036-2, 1996.

[2] S. Bobancu, V. Cioc, Inovare inginereasca in design, Editura Infomarket, Brasov, 2002.

[3] T. Bogatzky, P. Gümpel, Die Anpassung von Hochleistungsschichten an Komponenten von Verbrennungsmotoren, HTWG Forum, ISSN 1619-9812, Konstanz, 2007, pp. 33-38.

[4] S. Radu, S. Vlase, An Analytical Evaluation of Hard Coatings for Engine Components Based on Surface Quality Analysis, Recent Researches in Computational Techniques, ISBN 978-1-61804-011-4, 2011, pp. 313-317.

[5] S. Radu, The Use of High Performance Coatings at Components of Internal Combustion Engines, 2004 CONAT Conference, No. 20045019,. Web. Jan. 2012 <http://www.conat.ro/conat2004/e/index.html>

[6] H. Teodorescu-Drăghicescu, S. Vlase, Homogenization and Averaging Methods to Predict Elastic Properties of Pre-Impregnated Composite Materials, Computational Materials Science, 50, 4, Feb. (2011).

[7] H. Teodorescu-Drăghicescu, A. Stanciu, S. Vlase, L. Scutaru, M. R. Calin, L. Serbina, Optoelectron. Adv. Mater. – Rapid Commun. **5**(7), (2011).

[8] S. Vlase, H. Teodorescu-Drăghicescu, D.L. Motoc, M. L. Scutaru, L. Serbina, M. R. Calin, Optoelectron. Adv. Mater. – Rapid Commun. **5**, 4, April (2011).

*Corresponding author: serban.radu@unitbv.ro