UDK 620.1:62-4-023.7:67.017
Original scientific article/Izvirni znanstveni članek

ISSN 1580-2949
MTAEC9, 52(1)23(2018)

MULTI-PARAMETER SURFACE-QUALITY ANALYSIS

VEČPARAMETRIČNA ANALIZA KAKOVOSTI POVRŠINE

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Prejem rokopisa – received: 2017-07-01; sprejem za objavo – accepted for publication: 2017-10-20

doi:10.17222/mit.2017.095

Recent years have been rich in the research in the field of metrology. Firstly, the research focused on contact gauges, especially on contact profilometers. Consequently, with the investigation and development of materials, it was revealed that contact profilers were not sufficient and it was necessary to focus on 3D non-contact optical profilometers and surveyors. This article describes a new method of the surface control. It is a method of surface printing using the SILOFLEX© dental silicone and the subsequent evaluation. The surface-quality control is carried out using profile geometries that are divided into two basic groups. The first group consists of contact devices and the second group consists of non-contact devices. Both of these groups can use 2D- and 3D-measurement options. Subsequently, the surface quality is assessed using the amplitude parameters specified in the standards. These parameters have to be evaluated complexly using the multi-parameter analysis. This analysis is used today by more and more companies and has become an essential part of the control. It is utilized for all the material types from the engineering industry to medicine. The article deals with a non-contact measurement method. It also shows possibilities of an evaluation using the multi-parameter analysis.

Keywords: non-contact measurement, replica, surface quality

Zadnja leta so bogata na področju metroloških raziskav. Najprej so bile raziskave osredotočene na področje kontaktnih merilnikov, še posebej na področje kontaktnih profilometrov. Posledično z raziskavami in razvojem materialov so ugotovili, da kontaktni profilometri ne zadovoljujejo vseh potreb. Zato so se raziskovalci osredotočili še na razvoj 3D-nekontaktnih optičnih profilometrov in merilnikov. V tem članku avtorji opisujejo novo metodo kontrole površine in njeno evaluacijo. To je metoda površinskega tiskanja z uporabo dentalnega silikona SILOFLEX©. Kontrola kvalitete površine se izvaja s profilnimi geometrijami, ki so razdeljene v dve osnovni skupini. Prva skupina vsebuje kontaktne in druga nekontaktne naprave. Obe skupini lahko uporabljata 2D- in 3D-merilni opciji. Naknadno so kvaliteto površine ocenili z amplitudnimi parametri, specificiranimi v standardih. Ti parametri morajo biti ovrednoteni kompleksno in jih avtorji zato imenujejo večparametrična analiza. Ta analiza se danes vse bolj uveljavlja in uporablja v podjetjih kot pomemben del kontrole. Analiza je uporabna za vse vrste inženirskih in medicinskih materialov. V tem članku avtorji opisujejo nekontaktne merilne metode. Prikazujejo pa tudi možnosti vrednotenja z uporabo večparametrične analize.

Ključne besede: brezkontaktno merjenje, replika, kakovost površine

1 INTRODUCTION

This article focuses on the research of surface replication and the identification of suitable assessment methods. Previously, Dentacryl™ was the most widely used material for the surface-replica production, which cannot be used due to its inaccuracy, surface interpretation and safety reasons.

We decided to test SILOFLEX©, which is used in dentistry, to produce replicas. In this area, we also seek expertise in the preparation and proper use of this material on surfaces. The article deals with a method of the production of replicas using the SILOFLEX© dental material, including the replicas of technological processes. Original faces and replicas are scanned using a Talysurf CLI 500 touchless 3D scanner.

2 EXPERIMENTAL PART

Evaluation of the method

Initially, 5 mm × 5 mm original surfaces were scanned using the Talysurf CLI 500 3D surface scanner with a 0.25-μm resolution on the X- and Y-axes. The Z-axis sensitivity was allowed to reach the highest possible level at 1 nm^2. After scanning individual faces in X, Y and Z, they were transferred into a three-dimensional data matrix.

Figure 1 shows 3D topography of the surfaces of the original and the replica. **Figure 2** shows photos of the real surface of the original and the replica magnified by 100×. The data was filtered using a double Gaussian robust filter to ensure the correct calculation of the surface quality of the original and the replica. To assess

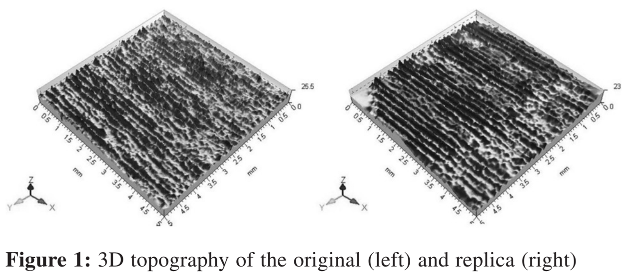

Figure 1: 3D topography of the original (left) and replica (right)

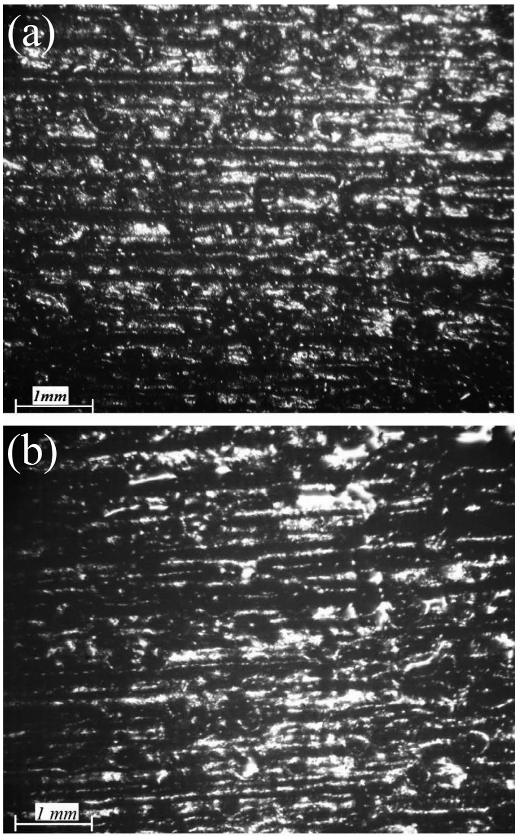

Figure 2: Photos of the surfaces magnified by 100×

whether the original and the replica were close, ISO 4287 was used.[1]

Canonical-correlation analysis

A canonical-correlation analysis examines the nature of the relationships between two sets of variables that represent the frequency parameters of the original surface and the replicated surface discussed. These relationships are further expressed with the components, which, as already mentioned, constitute a linear combination of the variables from a given set of variables.[2,3]

Components searched in the form of pairs

In a pair, one of the elements of one set of the two sets of variables always corresponds to an element from the other set. The first pair should have the greatest possible correlation. The second pair consists of independent (orthogonal) components of the first pair and has the second highest possible correlation. This is the case when both sets of variables and their relationships are described with two systems of independent components.[3]

3 RESULTS AND DISCUSSION

Canonical correlation measures the intensity of the linear dependence between two groups of linear func-

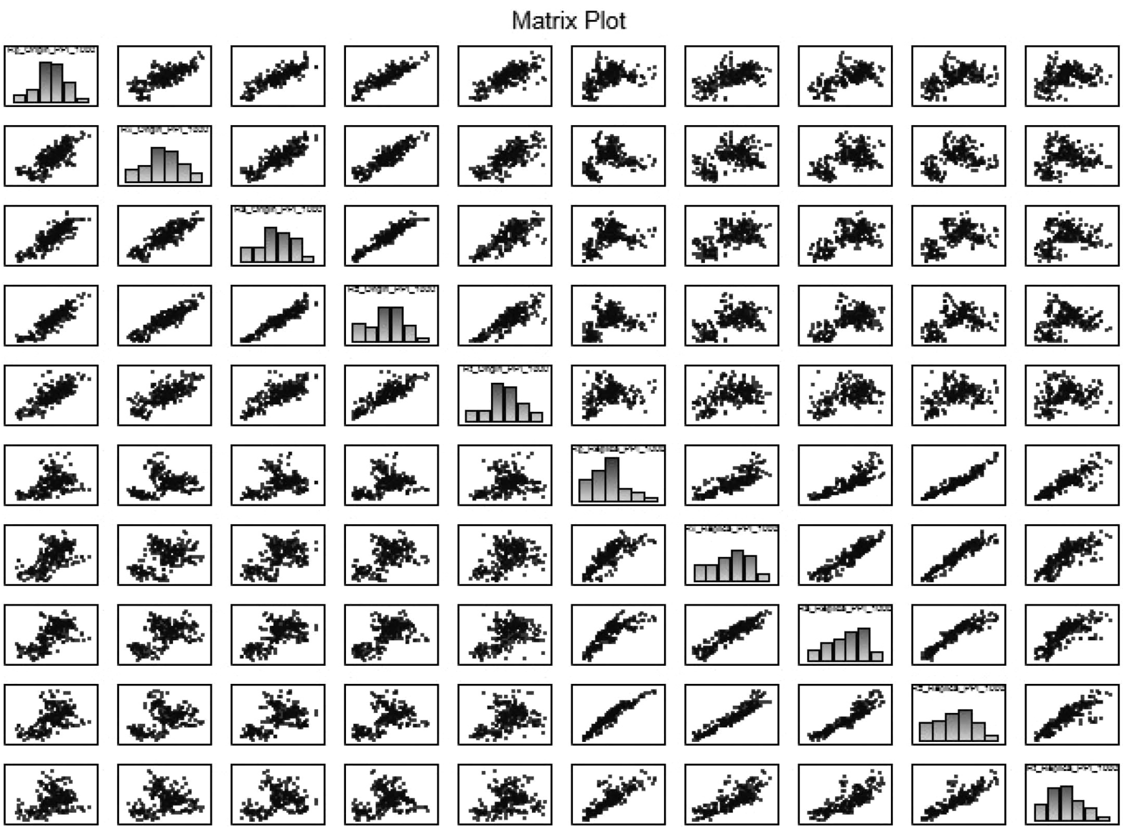

Figure 3: Calculation of matrix diagrams comprised of Pearson correlation coefficients

Canonical Analysis Summary Canonical R: 0.75999 Chi2(25)=245.91 p=0.0000		
	Left - Set	Right - Set
Variance extracted	100.00 %	100.00 %
Total redundancy	45.624 %	28.485 %

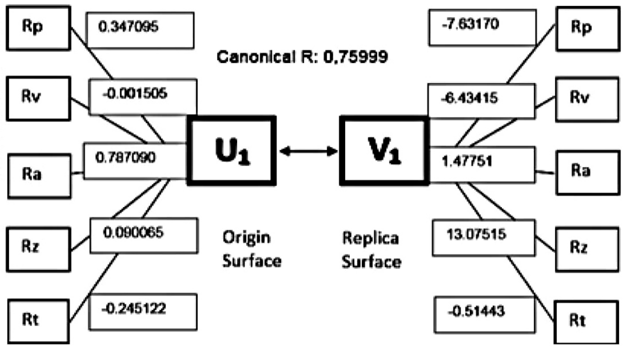

Figure 4: Summary of canonical analysis

Plot of Eigenvalues					
	Root 1	Root 2	Root 3	Root 4	Root 5
Value	0.577590	0.117433	0.015371	0.003380	0.000173

Left factor 1 versus Right factor 1:

y = - 4.5642E-14 + 0.76*x; r = 0,7600; p = 0.0000; r^2 = 0.5776

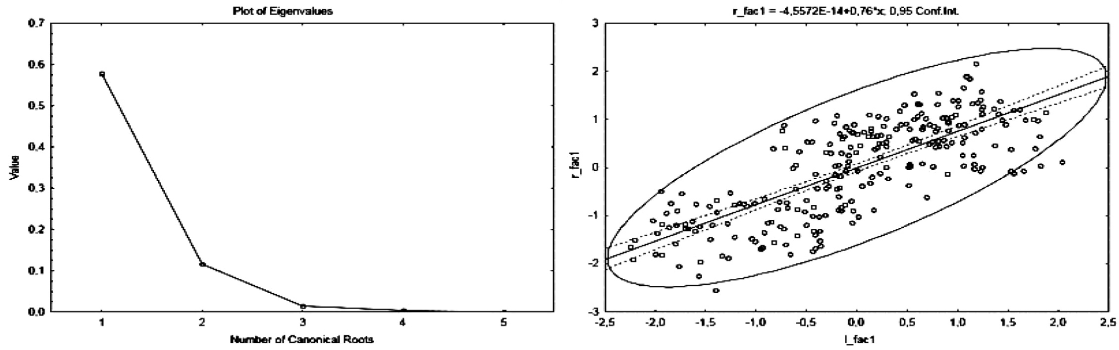

Figure 5: Plots of eigenvalues and first left factor

Left factor 2 versus Right factor 2:
y = 1.1843E-14 + 0.3427*x;
r = 0.3427; p = 0.00000; r^2 = 0.1174

Left factor 3 versus Right factor 3:
y = 1.5357E-13 + 0.124*x;
r = 0.1240; p = 0.0498; r^2 = 0.0154

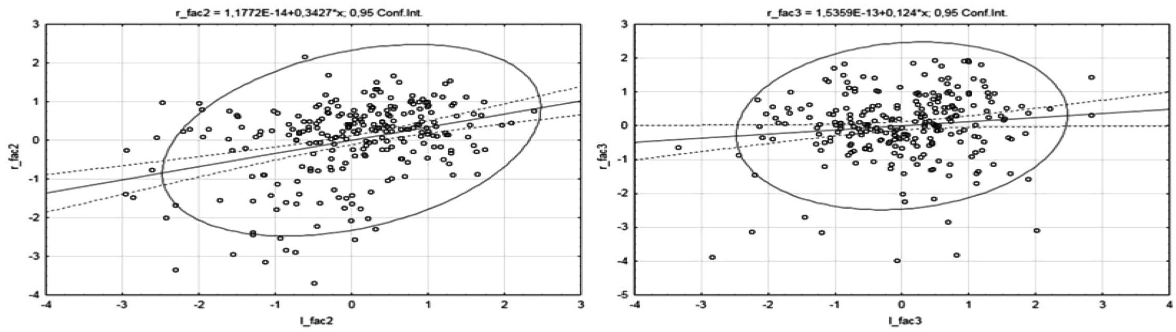

Figure 6: Plots of second and third left factors

tions of original surface vectors U (R_p, R_v, R_a, R_z, R_t) and the surfaces of the replicated V (R_p, R_v, R_a, R_z, R_t).

When evaluating the matrix diagrams (**Figure 2**) of individual parameters (either numerically or graphically), it is possible to state that there is an indication between the pairs of the characters.

It is also possible to state that the graphs exhibit homoscedasticity or heteroskedasticity and, above all, that there are no remarkable distant objects.

Thus, Pearson correlation coefficients show that most of the characters show a sufficient pair dependence and, therefore, it can be stated that measured parameters R_p, R_v, R_a, R_z and R_t for the original and replicated surface are suitable for the application of the canonical-correlation analysis.[7]

The criterion for the number of the selected major pairs is the scatter-index graph at the foot of our numbers, which, in our case, confirms that one canonical root

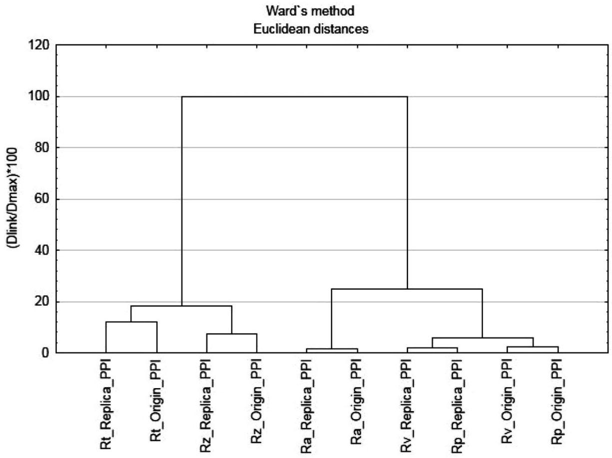

Figure 7: Tree diagram for 10 variables

will suffice to describe the amplitude parameters of the original and replicated surfaces (**Figure 3**).

The graph on **Figure 4** shows the linear dependence between the canonical score of the right set of parameters V1 (amplitude parameters of the replicated surface) and the left set U1 (amplitude parameters of the original surface).

The linear dependence is quite distinct; the Pearson correlation coefficient rises to 0.76 and its testing appears to be significant.

On the other hand, in the case of the right sets of parameters V2, V3 and left sets U2, U3, (**Figure 5**) clusters appear to be homoscedastic, linear dependence is not distinct and Pearson correlation coefficients are relatively low (0. 34 and 0.12).

Solutions obtained with cluster analysis Ward's method (**Figure 6**), using Euclidean distance, were used to create clusters.[8]

It follows from the graph that there is a high degree of similarity between the R_t and R_z parameters of the original and replicated surfaces. A similar result can be found for parameter R_a.[9]

For parameters R_p and R_v, the situation is somewhat more complex. From the clustered graph, it follows that the parameters R_a, R_p and R_v are form a separate cluster, which is determined by ISO 4287. The parameter R_a is composed of the sum of the parameters R_p and R_v. However, due to the small variability between R_p and R_v for the original and replicated surfaces, the cluster analysis fails to recognize the difference between the R_p and R_v parameters.[10]

4 CONCLUSIONS

According to the above results, following the application of the canonical correlation analysis, the first pair of correlation variables U1 and V1 sufficiently describe the dependence of the R_p, R_v, R_a, R_z and R_t characters for the original and replicated surfaces. This claim is confirmed by a high value of the canonical correlation coefficient (0.75999).

Therefore, we can assume that from the dependencies above and the relations, supported by the method of cluster analysis, it is possible to describe the parameters of the surface roughness R_a, R_z based on the interchangeability of amplitude parameters.

Acknowledgment

This work and the project were realized with the financial support of an internal grant of the TBU in Zlín, No. IGA/FT/2017/002, and grant IGA/FT/2017/010 funded from the resources for specific university research.

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