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The replication method to analyze roughness of shaft, tool, and grinding wheel microgeometry

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Abstract ***This article presents the possibility of using the replication method to measure selected parameters of the surface geometry. The results of the tests obtained while measuring the replica and surface of the tested object are presented. The obtained results indicate the suitability of using RepliSet F5 to measure the roughness parameters (Ra and Rz), microgeometry tool, and grinding wheel. It has been proven that the replication method using the RepliSet F5 is suitable for chosen parameters of roughness and tool microgeometry measurements. However, it is not suitable for measuring the porosity of a grinding wheel.***

Keywords *replica, geometric structure of surface, replication method, RepliSet F5*

1. Introduction

There are a number of concerns with regard to the use of the replication method in broadly understood production processes. This method is used in many areas, from archeology to medicine and engineering. In the field of engineering, replicas are used primarily as material for nondestructive testing, that is, where the surface of the tested object is not damaged and they allow to assess the condition of the top layer.

The use of the replication method in medicine and archeology is primarily to map the surface of tooth crowns and in histological examinations, which require high accuracy in mapping the tooth surface and material durability [1–3].

The use of this method shortens the time needed to dismantle parts from the machine tool, performs tests without damaging or destroying the surface of the tested objects, and quickly and efficiently inspects the surface of the workpiece.

For decades, replicas have been used to assess material cracks. They identify the cracks in the top layer, monitor their initiation and growth, allow their location to be identified, and provide information on the type of damage (whether it is a crack, scratch, etc.) [4].

The use of the replication method for testing hard-to-reach jet engine parts allows assessing the condition of the surface geometry of the part without the need to disassemble the part or destroy it [5].

The replication method allows tool wear without removing it from the chuck as well as a quick and simple diagnosis of the morphology of the tool surface in hard-to-reach places [6]. Such application shortens the time of testing the tool required for the entire process of tool disassembly. It also allows the examination of each selected surface of the tool, as opposed to the use of direct techniques for observing morphological changes, which is not always effective due to the shape and dimensions of the tool [7, 8].

The replication method is also used in all kinds of surface geometry tests, that is, from the assessment of cavitation damage [9], assessment of the surface condition after honing, to the assessment of the surface microstructure [10].

So far, replicas have been limited to their use as the material of choice for conducting research, but it has not been determined what type of material is used in the method to measure selected features of the surface geometry.

Therefore, the aim of this article is the testing product RepliSet F5, for use in the chosen measurement parameters of roughness (*Ra* and *Rz*), microgeometry of the FSW tool, and porosity of the grinding wheel.

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2. Experiment

Tests were carried out according to the following procedure. First, the selected parameters were measured on the real surface – the exception is the process of measuring the porosity of the grinding wheel, where, due to the large dimensions of the tool, this step was omitted. Next, the test surface was prepared for the application of the replication material. The area to be examined was cleaned and degreased with cotton and solvent (acetone). Before application the solvent was evaporated completely. The next stage was putting replica mass on the surface and waiting for an appropriate time – here 18 min – to solidify the mass. After this time, the hardened material was removed and the replica was measured by a microscope.

2.1. Apparatus

The material used to conduct the tests was the Struers RepliSet F5 system. The measurement of these replicas was carried out using the Alicona Infinite Focus G4 focal variation microscope. To measure the shaft roughness parameters, the Mahr Marsurf M400 profilographometer was used.

2.2. Research on the porosity of the grinding wheel

To measure the porosity of the grinding wheel, Strato Ultra ceramic bond grinding wheel, SU33A602II10VB1, was used. The marking indicates the particle size, which is in the range from 250 to 300 μm. It has a very open structure and belongs to the soft grinding wheels. Three fields on the grinding wheel were measured. The chosen porosity was measured, because it is a characteristic property of this tool.

2.3. Shaft roughness tests

In order to test the roughness parameters, four shafts were made of steel for thermal improvement and quenching, designated as 40HM. The steel was treated as delivered

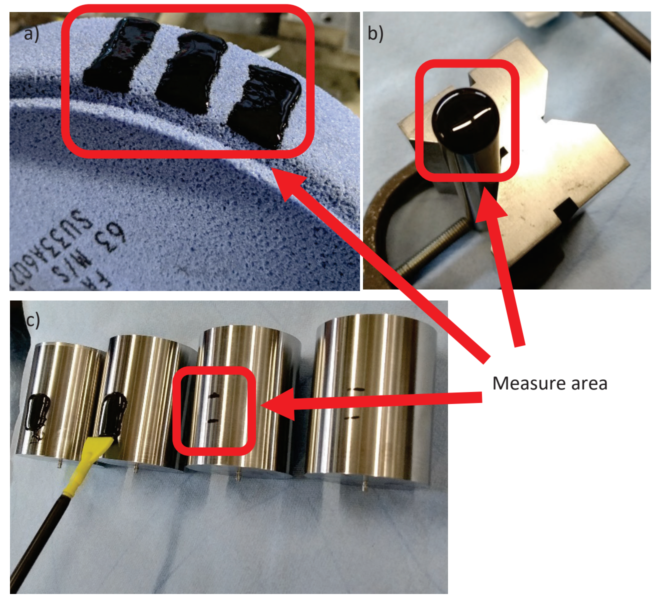

Figure 1. Measure items: a) grinding wheel b) FSW tool c) shafts

and was not heat treated. In the tests, two parameters of roughness – *Ra* and *Rz* – were also measured. Each shaft was made with different parameters to get different value parameters of *Ra* and *Rz*. The four fields measured in each shaft are shown in Figure 1c. The roughness parameters were chosen, in this case, because they described the shaft properties after touring.

2.4. Friction stir welding tool measurement

The friction stir welding tool was used for the test performed for the usefulness of RepliSet F5 in profile mapping. This tool is considered a 6-turn oval tool. The tool geometry is made of cemented carbide with the use of laser technology. Two properties of the microgeometry were measured: the height from the grove to the top of the tool and the height from the working surface to the top of the tool. These properties were chosen because they are characteristic values of this tool and it is difficult to measure it with any other method.

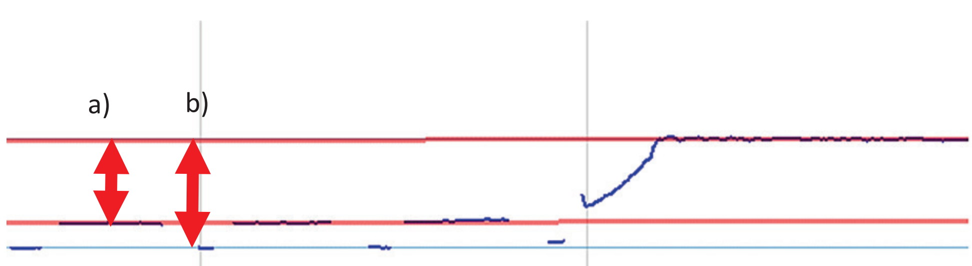

Figure 2. Measured microgeometry: a) height from working surface to top of tool b) height from grove to top of tool

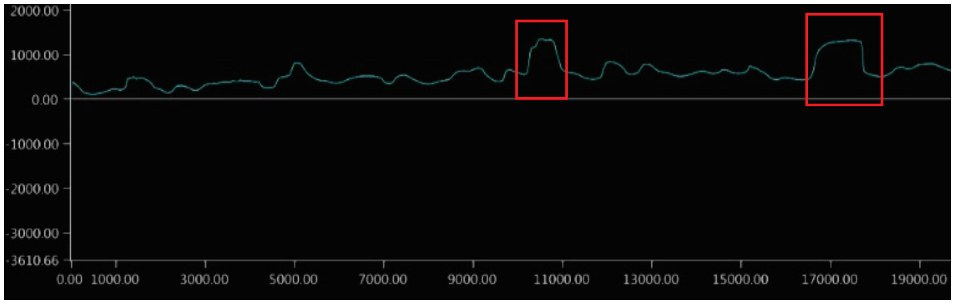

Figure 3. Measurement carried out on a replica of the grinding wheel

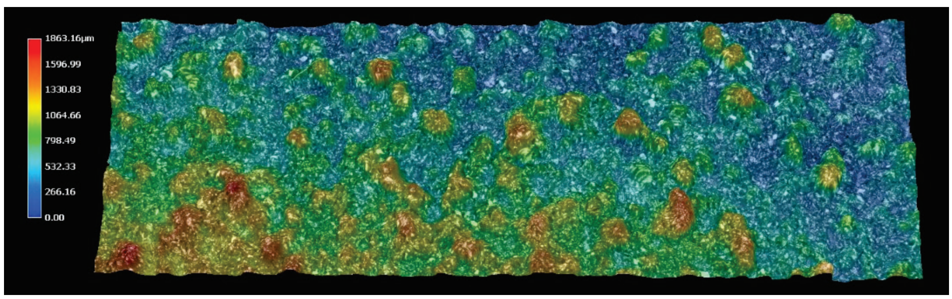

Figure 4. Surfaces obtained from replicas of the grinding wheel

3. Results and Discussion

3.1. Research on the porosity of the grinding wheel

The selected wheel porosity tests indicate that the RepliSet F5 system is not suitable for use in this type of grinding wheel. Due to its high viscosity and fluidity, it penetrates too deep into the pores and distorts the results. A different type of grinding wheel used would have made it possible to measure, as was done in the research conducted by Kacalak [7]. The mapping of the obtained structure in Figure 1 shows that this is not suitable for porosity testing. As the replica plunges into the pores of the grinding wheel, the measurement cannot be created. These places are marked in red in Figure 3.

3.2. Shaft roughness tests

The average values of the measured parameters differ from each other. These differences may result from several factors, including error of the measuring person, from damage to the test surface, and so on.

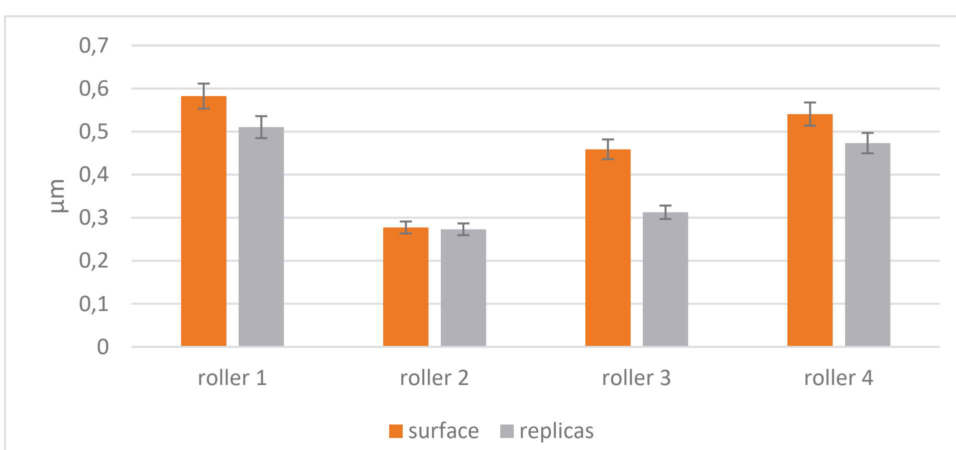

Figure 5. Average values of the Ra parameter

Tabel 1. Averaged measurement results of selected roughness parameters

Number of shaft	Profilographometer		Microscope		Replica	
	Ra	*Rz*	*Ra*	*Rz*	*Ra*	*Rz*
1	0.555667	3.477	0.582433	3.487867	0.5104	3.409867
2	0.297667	2.022333	0.277333	1.849133	0.2731	1.9946
3	0.351333	2.136333	0.458933	2.6193	0.3126	2.078433
4	0.538	2.910667	0.540667	2.823567	0.473333	2.579067

As can be seen in Figures 5 and 6, the greatest differences in measurement can be seen in the mean values of the measured parameters in shaft No. 3. This may result from a wrong selection of the test surface. This proves that the silicone supplied by Struers is suitable for this application. A comparison of the results of measuring the original surface – using profilographometer and microscope – and the surface from the replica is shown in Table 1.

3.3. Measuring the geometry of the FSW tool

Comparisons of the obtained results of the measurement of the tool height measured from the groove and the tool height measured from the working surface of the tool are presented in Figures 7 and 8.
The differences between the heights in replica and the original faces are very small, at less than 10 μm. The values may be different due to an incorrectly made tool – different depths of the grooves made.

4. Conclusions

The conducted research draws the following conclusions:

- To measure the porosity of ceramic grinding wheels, other replication systems should be used, because the experimental system using this has not proved successful; however, it can be suitable for testing CBN or diamond grinding wheels due to their construction.
- Differences in the values of roughness parameters may result from the deposition of impurities on the replica.
- The results obtained during the examination of the roughness parameters indicate the correctness of using the replication method for this type of examination. The chosen parameters, *Ra* and *Rz,* can be measured by the replicated method.
- The results obtained when examining the tool geometry show that the replication method can be used to map the geometry. Tool height can be measured by the replicated method.
- The values obtained may have been distorted by operator error, surface damage, insufficient cleaning of the test surface, or lack of repeatability of the measured area.

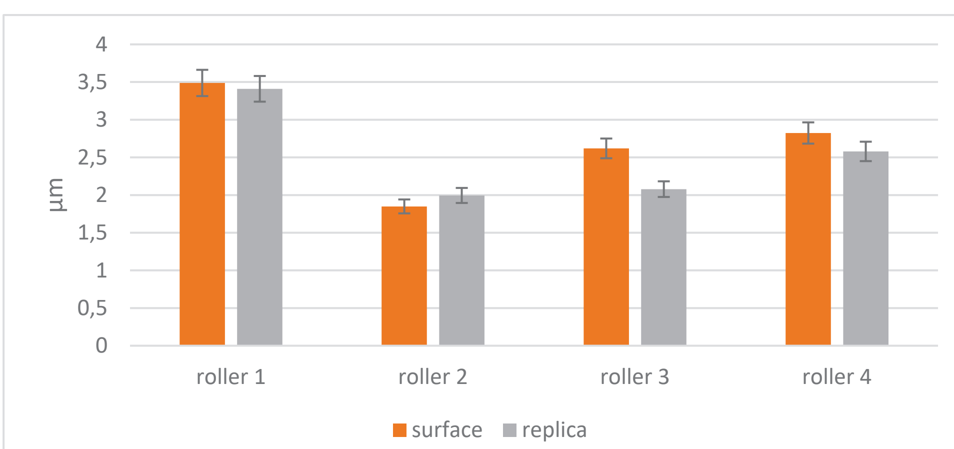

Figure 6. Average values of the Rz parameter

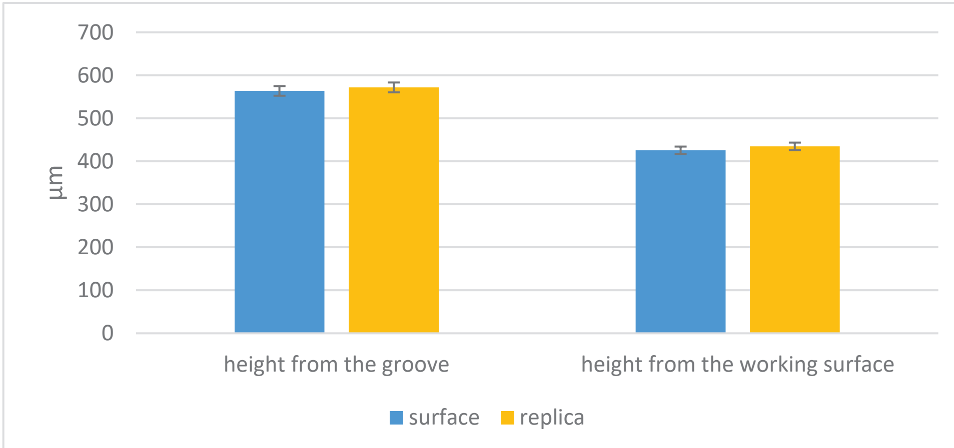

Figure 7. Differences in the obtained values – height from the groove and height from the working surface

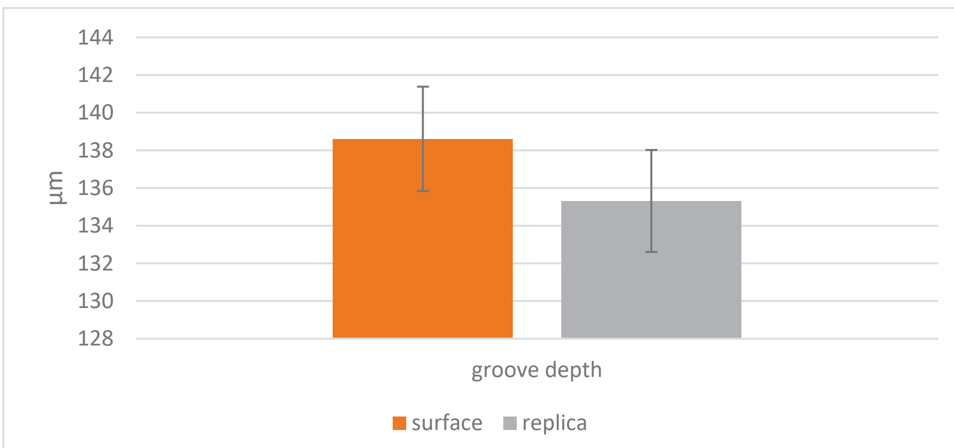

Figure 8. Differences in the obtained values – groove depth

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