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Authors: Wojciech Kacalak, Katarzyna Tandecka, Filip Szafraniec, Łukasz Rypina, Thomas G. Mathia
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Analysis of the discontinuities of the micro-finishing process, taking into account the form and characteristics of the micro-chips structure

Analiza nieciągłości procesu mikrowygładzania z uwzględnieniem postaci i cech budowy mikrowiórów

WOJCIECH KACALAK
KATARZYNA TANDECKA
FILIP SZAFRANIEC
ŁUKASZ RYPINA
THOMAS G. MATHIA*

Micro-finishing with abrasive foils is characterized by a single use of the tool, which makes it necessary to optimally fill the space between the grains of the processing products. Microscopy research with the use of scanning electron microscopy enables a more complete evaluation of the machining process. Based on the structure of micro-chips, the phenomena occurring in the micro-finishing zone with foils with electrocorunded abrasive grains with a nominal size of 15 μm have been described. It has been shown that the analysis of micro-chips, the bottoms of machining marks and the size of micro-chips with segmentation construction allows to estimate the frequency of process discontinuities. Different types of spherical chips, created as a result of very high temperatures, are also presented as a phenomenon unfavorable for the process.
KEYWORDS: abrasive foil, micro-finishing, precision machining, micro-chips, spherical chips

Analysis of the surface of the film after the smoothing process

The micro-smoothing process with abrasive films ensures obtaining surfaces with a very low roughness [8]. The treatment consists in sequentially smoothing the surface with smaller and smaller grains.

* Prof. dr hab. inż. Wojciech Kacalak (wojciech.kacalak@tu.koszalin.pl), dr inż. Katarzyna Tandecka (katarzyna.tandecka@tu.koszalin.pl), mgr inż. Filip Szafraniec (filip.szafraniec@tu.koszalin.pl), dr inż. Łukasz Rypina (lukasz.rypina@tu.koszalin.pl) – Wydział Mechaniczny Politechniki Koszalińskiej; Emeritus Research Director, dr hab. inż. Thomas G. Mathia (thomas.mathia@ec-lyon.fr) – Centre National de la Recherche Scientifique, (CNRS) Laboratoire de Tribologie et Dynamique des Systèmes (LTDS), École Centrale de Lyon, France

There are two types of abrasive foils: higher machinability films, with abrasive grains embedded in the binder in the electrostatic field, which ensures optimal grain orientation with respect to the work surface, and foils with abrasive grains embedded under a thin layer of binder. The films produced in the electrostatic field include IMFF films (imperial micro-finishing film), most often used to prepare surfaces for further processing with abrasive grains embedded under a thin layer of adhesive – type ILF (imperial lapping film).

Regardless of the type of abrasive film, the tools are disposable [11, 12]. This means that for economic reasons the machining parameters should be selected so as to optimally use the film's processing potential. At the same time, it must be added that the machining products are removed from the micro-scratch zone in the spaces between the grains, which also determines the choice of processing parameters, especially the film speed, to optimally fill these spaces (fig. 1).

a) *b*)

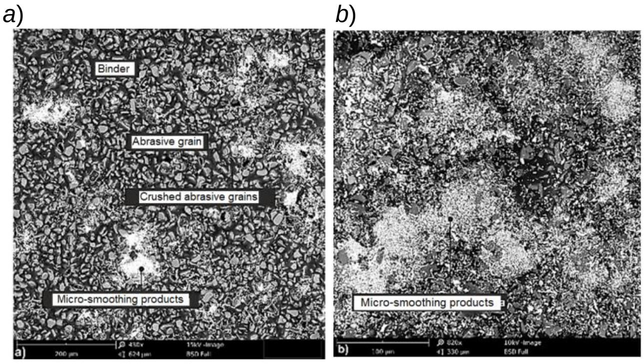

Fig. 1. SEM abrasive film IMFF images after a micro-smoothing process: *a*) with incomplete use of the tool's potential, *b*) with the optimal filling of the inter-grains between the grains

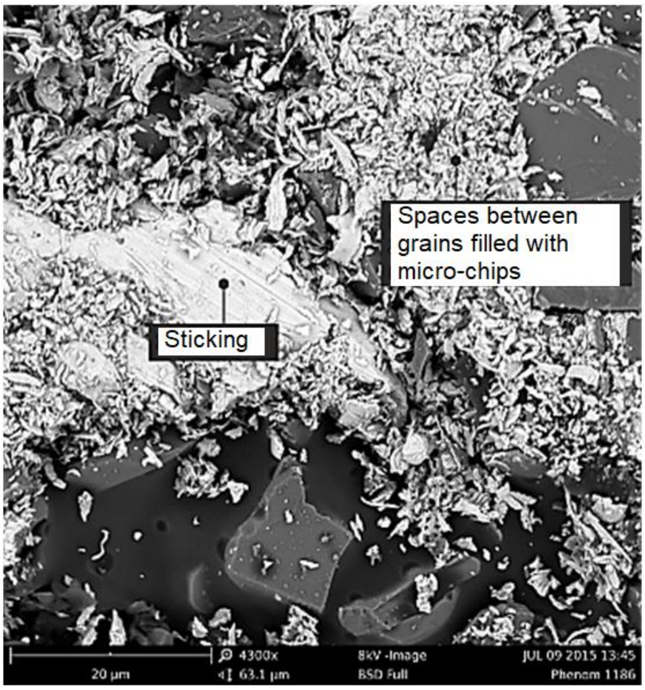

Fig. 2. SEM image of IMFF abrasive foil 15 after a micro-smoothing process with visible adhesion and microbial spaces filled with grains

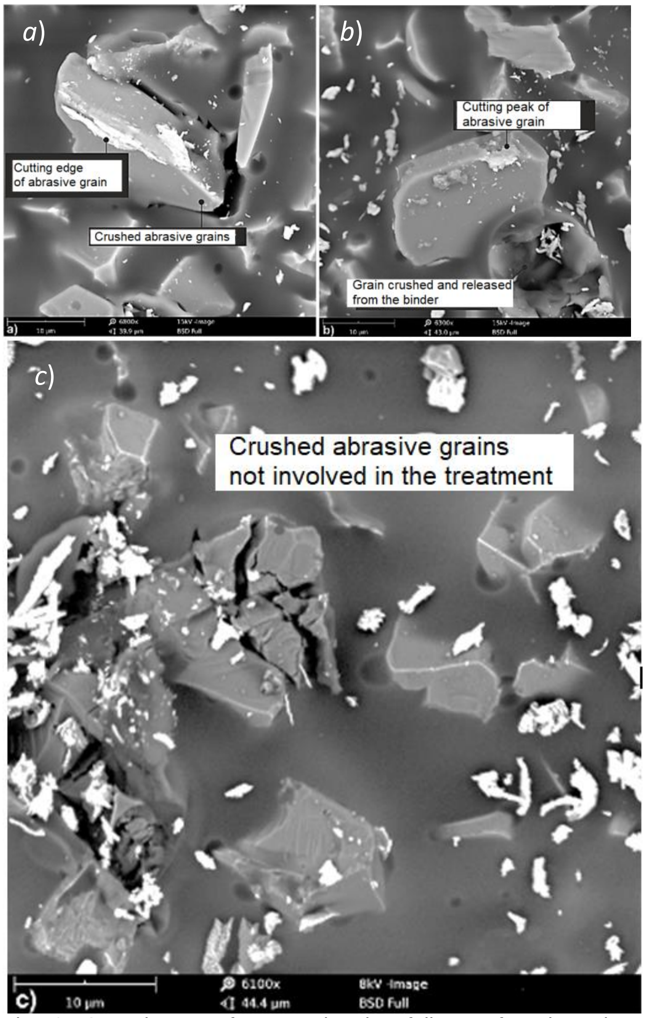

Fig. 3. SEM image of IMFF abrasive foil 15 after the micro-smoothing process: *a*) with visible broken grain after micro-screening, *b*) with grain crushed and released from the binder, *c*) with crushed grain

Too slow displacement of the film from the micro-smoothing zone may cause the space between the grains to overflow and, as a result of high temperature, the formation of stresses on the tool surface (fig. 2) [7]. The formation of plug-in is a disadvantageous phenomenon, because it prevents the removal of material by neighboring abrasive grains and makes it much more difficult to smooth the micro-machinability of the surface [10].

The abrasive film is pressed by the pressure roller against the workpiece. Number of active abrasive grains by choosing the pressure and hardness of the roll can be maximized. Excessive unit pressure, however, causes crushing of abrasive grains (fig. 3), which is not recommended, because the loose abrasive in the machining zone contributes to the formation of deep scratches [5, 6]. As a result of the influence of very high temperature in the treatment zone, the appearance of spherical chips can be observed – their characteristic shape is the result of material melting and its rapid crystallization (fig. 4) [4, 9].

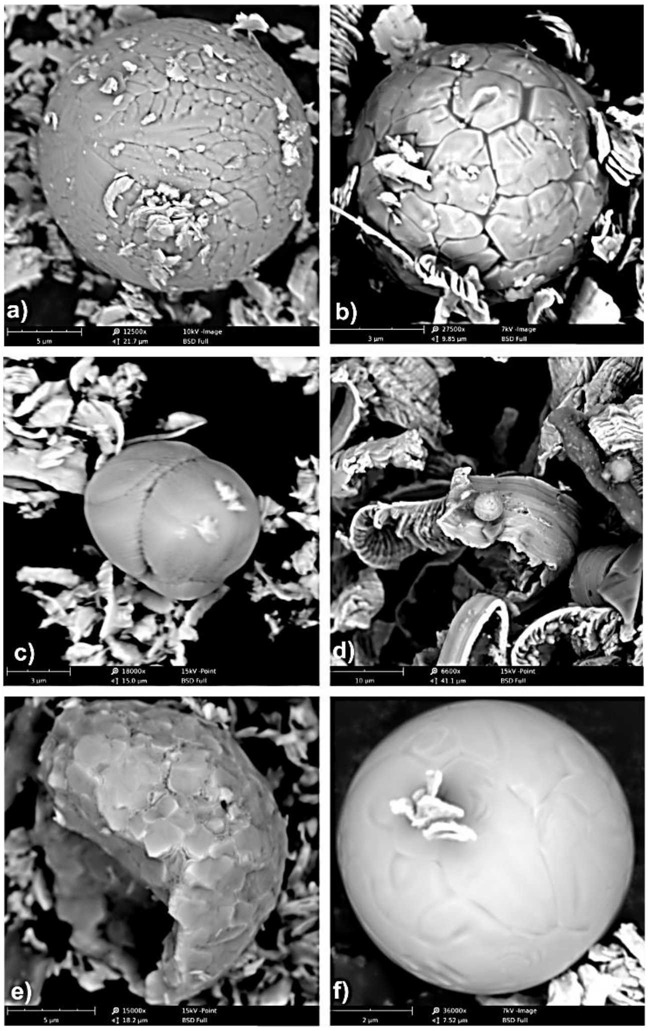

Fig. 4. SEM images of spherical microspheres after the micro-smoothing process: *a*) with visible very complex surface structure, *b*) with a surface made of large, geometric elements, *c*) with a shape deviating from the sphere, *d*) with a characteristic stepped structure, glued to the surface *e*) made up of small elements that make up a fragment of the sphere, *f*) with a very smooth surface

Analysis of microcirculation process discontinuities

The surface of the solid disk with very low roughness, amorphous nickel and phosphorus (NiP) alloy was used to study the micro-cutting process with a single grain. Workpiece speed $v_p = 14.86 \cdot 10^2$ mm/s.

It was observed that the points of the largest depressions do not lie on the straight line contained in the longitudinal section of the microscope trace. The range of deviations of these points from the bottom profile of the trace does not exceed – in the direction perpendicular to the plane of the

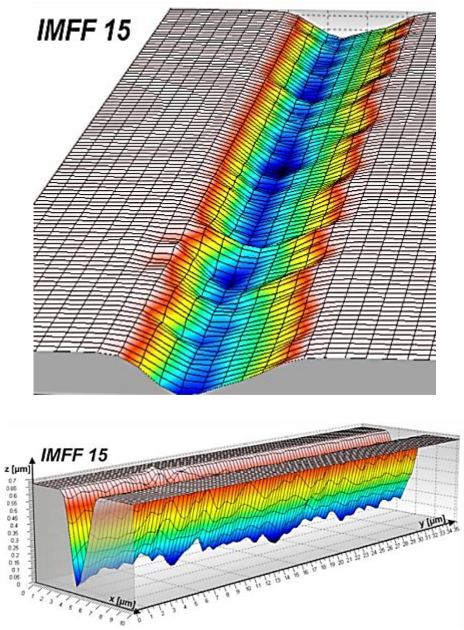

Fig. 5. Fragment of the micro-cutting trace with visible unevenness of the bottom of the crack and with the grain of an electrocorund attached to the surface of the abrasive film 15 IMFF

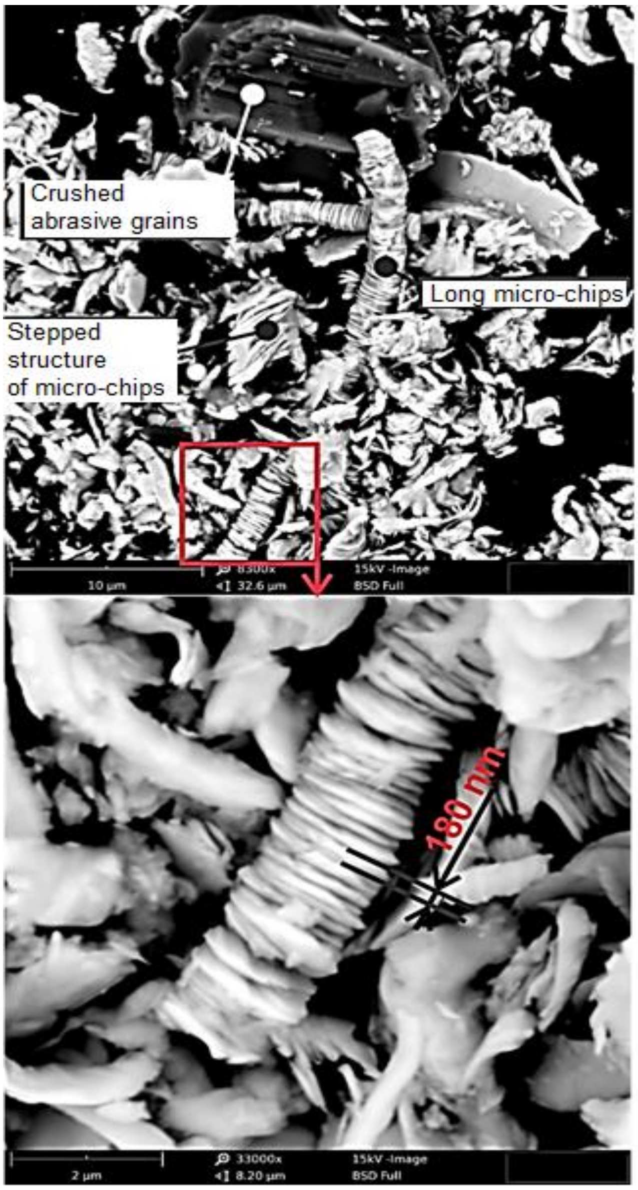

Fig. 6. SEM images of microflora resulting from the micro-smoothing process of 40H steel with stepped construction and plate thickness of 180 nm

cross-section – 0.25 of the crack width (fig. 5). The frequency of micro-integrity in the material separation process, determined by the crack bottom analysis for a given micro-cut speed v_p, results from the width of the micro-stop zone S_{m15} = 0.00289 mm as the distance between the maximum depths of the cutting edge in subsequent sub-volumes of material removed, and amounts to 0.514 MHz.

Investigations of the discontinuity phenomenon were also carried out for another process, in which 15 IMFF abrasive foils were smoothed 40H steel shafts with a hardness of 60 HRC. The peripheral speed of the roller was 35 m/min, and the speed of the film was 160 mm/min. The foil was pressed against the workpiece with a pressure roller with a force of 60 N.

The transformation of the workpiece into a chip is accompanied by plastic deformations [1, 13], affecting the thickness of the chip-forming chipboards (fig. 6) [2, 3]. It was found that the thickness of g_p plates in the studied chips is about 180 nm, which allows, taking into account the coefficient of upsetting w_{sp} = 10, to determine the frequency of process micro-continuity based on chip construction.

$$f_{p15} = \frac{v_f}{S_{m15}} = 0{,}514 MHz \quad f_w = \frac{v_p}{g_p w_{sp}} = 0{,}32 MHz$$

where:
- f_p – frequency of micro-disruptions in the material separation process, determined by the scratch test method,
- f_w – frequency of micro-integrity in the material separation process, determined by the method of testing the chip structure,
- S_m – width of the micro-non-continuity zone,
- v_p – speed of the workpiece,
- g_p – thickness of the chip board with stepped structure,
- w_{sp} – upset coefficient.

Conclusions

Improper selection of micro-smoothing parameters may result in film coatings, formation of spherical microspheres (as a result of too high temperatures), crushing of abrasive grains on the surface of the film and release of abrasive to the micro-smoothing zone, removal of grains from the binder and uneconomical use of the abrasive film, which the effect is worsened by the quality of the smoothed surface.

During micro-smoothing, a discontinuity of the process can be observed, which can be determined on the basis of the examination of the bottom of the scratch, as well as on the basis of the stepped structure of the microbe. The discontinuity of the process depends very much on the speed of smoothing. The use of the cracks test method resulted in a higher material separation frequency of f_{p15} = 0.514 MHz, but this method is easier to use because it does not require an estimation of chip swelling ratio and microscopic examination.

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