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Designing micro-finishing operations with the use of diamond abrasive foils

Projektowanie operacji mikrowygładzania za pomocą diamentowych folii ściernych

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Micro-finishing with abrasive foils consists in performing several smoothing operations using abrasive foils of smaller and smaller nominal grain size in order to obtain a high smoothness of the surface being processed. The abrasive grains on the surface of the IDLF film, in particular with the grain size of 3 and 9 µm, are often arranged in the form of aggregates. This phenomenon has been described with the use of new parameters to assess the degree of surface development of aggregates. Due to the one-time use of diamond abrasive foils in the smoothing process and the associated tool costs, the principle of selecting abrasive foils for subsequent treatments was developed in such a way that the potential for reducing the unevenness height was used optimally.

KEYWORDS: diamond abrasive film, micro-smoothing, precision machining, finishing ability

Diamond abrasive films are used for very precise surface treatment [7]. Micro-smoothing is carried out by removing material in the unevenness layer formed during the pre-treatment process [8, 11]. Such films are produced in a wide range of nominal sizes of grains - most often from 0.5 to 60 µm [2.8]. Grains embedded in the binder are on a polyester tape. Characteristic for diamond abrasive films are aggregation of abrasive and free spaces around grains [10].

Micro-smoothing with the use of abrasive films is characterized by sequentiality, which means that the superfinishing process is carried out with successive films with smaller and smaller grains [3]. Considering the one-time use of a tool with an expensive diamond abrasive coating, it is extremely important to use it optimally and to investigate the speed of removing unevenness - as the factor determining the completion of the film processing with specified grain size and film replacement for a tool with a smaller abrasive grain [4].

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Analysis of aggregation of abrasive grains on the surface of diamond abrasive films

Diamond abrasive films are characterized by aggregation of abrasive grains on their surface. Assessment of the development of cross-sectional area of abrasive aggregates is an important feature describing the ability of the micro-smoothing film. To unambiguously determine the development of the surface of aggregates, an index was developed which is the ratio of the length of the aggregate L_g to the length of the rectangle describing the shape of L_p (fig. 1). The larger the ratio, the aggregate cross-section is characterized by better cutting properties due to the width of the cutting edge [1]. It should also be added that fairly large areas between aggregates contribute to effective removal of micro-smoothing products from the treatment zone, which can have a positive effect on the quality of the smoothed surface [6].

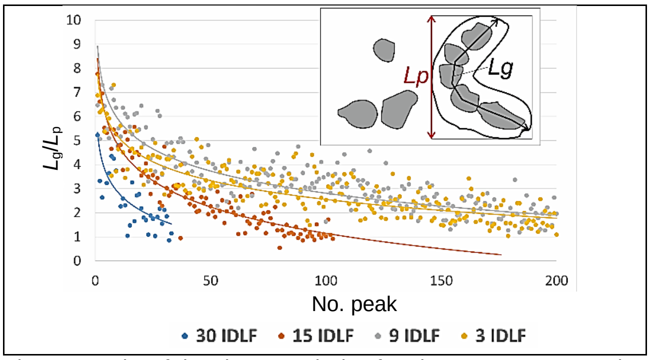

Fig. 1. Results of the shape analysis of grain aggregates occurring on the surface of diamond abrasive films (L_g – length of the ridge, L_p – length of the rectangle describing the shape of the contact field)

In [5], it was pointed out that processing products - such as chips and grains crushed from the film surface - in overflowing spaces between the grains can cause single deep scratches on the work surface.

Analyzing the features of the topography of abrasive films with grain sizes of 30, 15, 9 and 3 µm, for each aggregate on the surface of a given film, the ratio of its length to the length of the rectangle described on it was determined (fig. 1). The abrasive film with a nominal grain size of 9 µm is characterized by aggregates of the most developed shape, which can directly translate into high efficiency of removing the workpiece, as the width of the layer removed in the micro-scratching process increases [1].

Principle of selection of abrasive films in sequential micro-smoothing

The micro-smoothing was carried out with IDLF 30, 15, 9 and 3 diamond abrasive films. The surfaces of solid disks with the outer layer made of amorphous nickel and NiP phosphorus alloys were smoothed. The effects of micro-smoothing of the surface are presented in the form of their 3D images and parameters *St* and *Sa* (fig. 2).

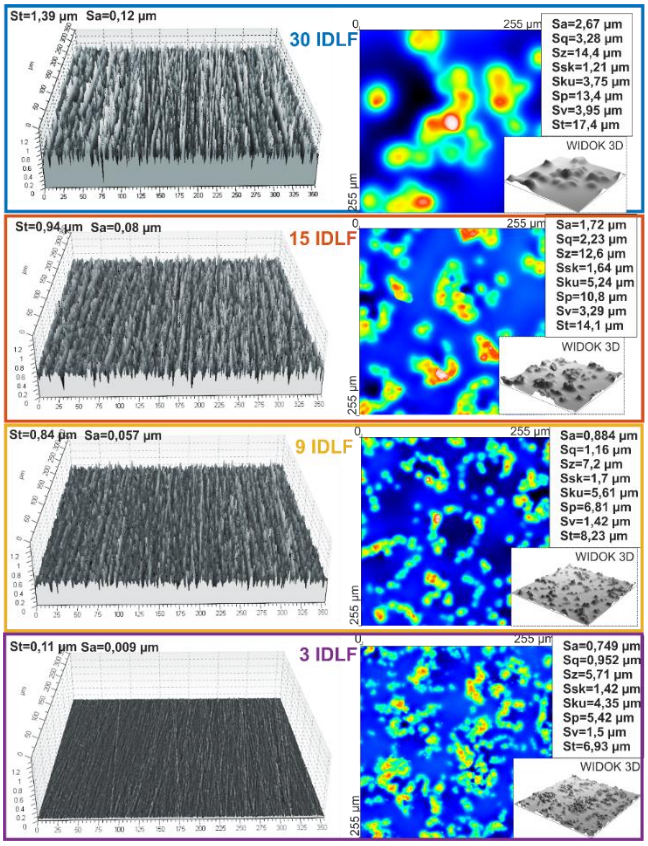

Fig. 2. Set of images of surface treatments in the smoothing process and used IDLF abrasive film surfaces with a grain size of 30, 15, 9 and 3 μm

Fig. 2 also shows images with a height map and basic parameters for the evaluation of topography of diamond surfaces of abrasive films used in the micro-smoothing process.

For the assessment of the micro-smoothing capacity of abrasive films, the developed indicator of the above-mentioned

$$w_{\mathrm{w}} = \frac{L_{\mathrm{k}} \cdot \sqrt{P_{\mathrm{k}}}}{h_{\mathrm{k}} \cdot \sigma_{\mathrm{h_k}}}$$

where: L_k - normalized number of contacts, P_k - normalized mean area of contacts, h_k - normalized mean depth of grains, σ_{hk} - normalized standard deviation of heights of active vertices for maximum depth of micro-smoothing of parameter value $0.2 \cdot St$ film.

The parameter values were normalized by determining the degree of their membership in the range <0.1>. The values of *St* and $10 \cdot Sa$ of the surface after micro-smoothing are presented in the function of the *w* index (fig. 3).

The choice of times of surface treatment smoothed with a specific abrasive film should take into account maximum utilization of the tool surface, thus maximizing the share of abrasive grit tips in the machining process and the maximum filling of the inter-grain space treatment products.

A good criterion for selecting the starting point for the next treatment using a film of smaller nominal grain size is the speed of reducing the unevenness of the work surface. An example of the procedure for the selection of working time of subsequent tools in the micro-abrasive process of abrasive films with nominal grain sizes of 30, 15, 9 and 3 μm is shown in fig. 4.

The times of subsequent micro-smoothing operations can be determined for given process conditions, taking into account specific processing parameters (such as: sanding film speed, workpiece speed and feed speed, pressure roll hardness, clamping force and oscillation frequency) and results of velocity inheritance reduction surface.

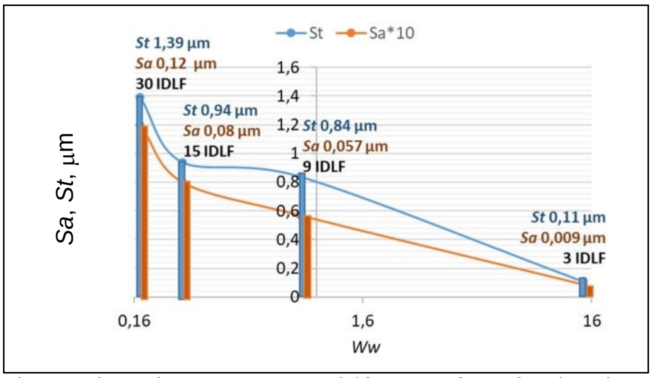

Fig. 3. Values of parameters *St* and $10 \cdot Sa$ surface after the micro-smoothing process with IDLF films with a grain size of 30, 15, 9 and 3 μm as a function of the w index (logarithmic value scale of the above)

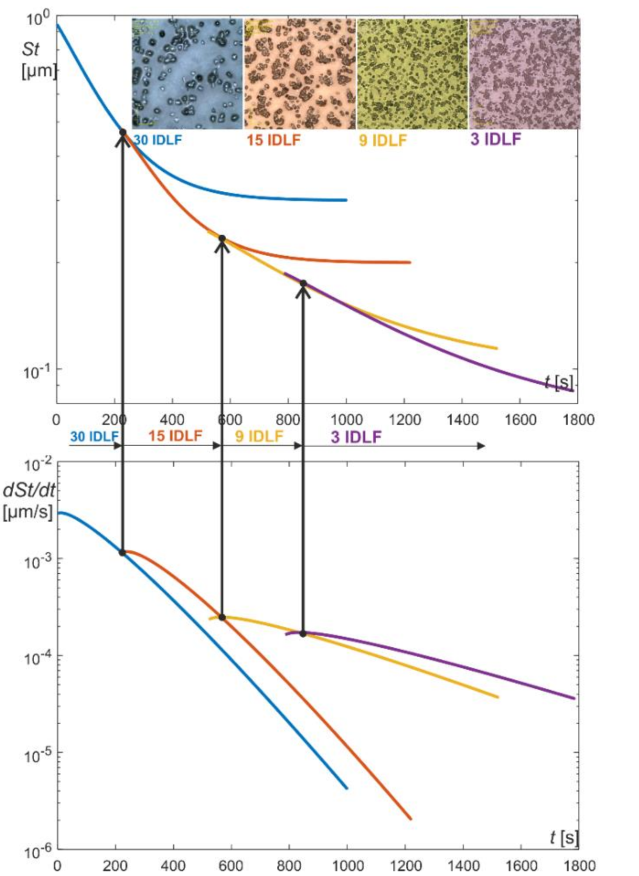

Fig. 4. Diagram of changes in the *St* parameter and dS_t/dt values (reduction in unevenness) as a criterion for ending the treatment and starting processing with another film (axis of *St* and dS_t/dt values in the logarithm scale)

Conclusions

- Diamond abrasive grains on the film surface tend to aggregate. By adopting as a criterion the developed evaluation parameter for the development of the cross-sectional area of the abrasive aggregate parallel to the surface of the substrate, being the ratio of the unit's root length to the height of the rectangle describing its shape, the highest capacity for effective material removal is shown by the abrasive film with a nominal grain size of 9 μm. The abrasive aggregates on the surface of an abrasive film with a nominal grain size of 3 μm also have a high degree of development. With this film, the surface with the lowest roughness was obtained: *St* = 0.11 μm and *Sa* = 0.009 μm.
- The least developed shapes of abrasive aggregates have a film with a nominal grain size of 30 μm (fig. 1), which is acceptable in the case of a sequential superfinishing process, when the task of this abrasive film is to pretreat the largest unevenness of the surface being worked.
- Evaluation of the shape development of abrasive aggregates can be a good parameter for assessing the ability to take processing products out of the micro-smoothing zone, while taking into account the volume between the diamond aggregates.
- Based on the roughness analysis of the treated surfaces as a function of the above-mentioned index for assessing the material removal capacity of the abrasive film taking into account the elastic pressure (fig. 3), it was found that abrasive film with a nominal grain size of 15 μm can be omitted in the sequential micro-smoothing process, when an abrasive film with a nominal grain size of 9 μm is used at the same time.
- The ratio of the *St* surface of the film to the *St* parameter of the smoothed surface can be taken as the criterion for the pre-selection of the film for the micro-smoothing process. Under the test conditions, these values are as follows: 12 for IDLF film 30 and - 15, 9 and 63 respectively for IDLF film, 9 IDLF and 3 IDLF. The value of this ratio shows that only the few abrasive grains are involved in the smoothing process. From this it follows that in the case of films with very small abrasive grains, it is extremely important to apply larger clamps of film to the workpiece in order to enlarge the field of the treatment zone. This is achieved using rollers with high compliance.
- Optimal use of diamond abrasive films is important due to the high abrasive price and the single use of the tool. An important element of the method of selecting the micro-smoothing time in a single treatment using a film with a given grain gradation is the analysis of the speed of reducing the unevenness of the treated surface (fig. 4). This is a good criterion because it allows optimal use of the technological potential of the abrasive film in the individual micro-smoothing operations.

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