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| Abstract | <p>The analysis of manufacturing defects of functional surfaces showed that traditional technologies do not provide a sufficient level of quality required for their manufacture through reduced wear resistance in general. Much more opportunities in the technology of quality management of surface layers appear in the application of methods, based on superficial plastic deformation, through the emergence of an enabling technological factor. The experimental research of the process of strengthening- smoothing treatment after turning operation has been carried out. Smoothing indenters of thermally stable polycrystalline diamond type were used. For roughened steel test specimen C45 type various roughing strength values were used to study roughness. Structural surface curves have been constructed and microphotographs of the surface layer have been made. The comparative analysis of the obtained profilograms has been carried out. After comparing the micrograph of obtained samples, it was found that at the same roughness the surface has a better shape of the reference curve. Practical conclusions and recommendations are made.</p> |                                                                                         |
| Keywords | Microgeometry - Roughness - Diamond smoothing - Smoothing force                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                         |



# Influence of Diamond Smoothing Treatment Power Parameters on Microgeometry of Working Surfaces of Conjugated Parts

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**Abstract.** The analysis of manufacturing defects of functional surfaces showed that traditional technologies do not provide a sufficient level of quality required for their manufacture through reduced wear resistance in general. Much more opportunities in the technology of quality management of surface layers appear in the application of methods, based on superficial plastic deformation, through the emergence of an enabling technological factor. The experimental research of the process of strengthening- smoothing treatment after turning operation has been carried out. Smoothing indenters of thermally stable polycrystalline diamond type were used. For roughened steel test specimen C45 type various roughing strength values were used to study roughness. Structural surface curves have been constructed and microphotographs of the surface layer have been made. The comparative analysis of the obtained profilograms has been carried out. After comparing the micrograph of obtained samples, it was found that at the same roughness the surface has a better shape of the reference curve. Practical conclusions and recommendations are made.

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**Keywords:** Microgeometry · Roughness · Diamond smoothing · Smoothing force

## 1 Introduction

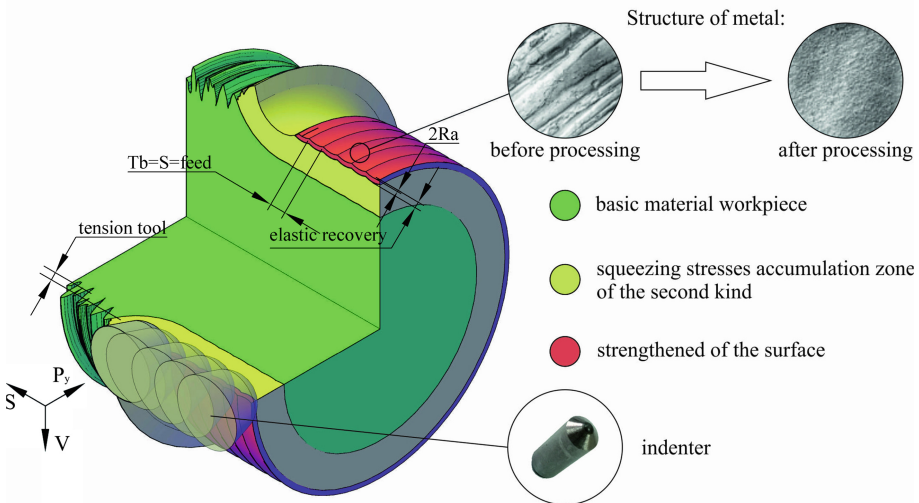
The reasons for the failure of conjugate steaming are their static and fatigue destruction, contact damage, wearing etc. [1–3]. During the contact each element of the rolling surface takes variable voltage. Moving the contact area on the parts surface causes cyclic changes in the voltage in all microcircuits near the contact trajectory. This causes the formation of microscopic cracks on the surfaces, which are places of stresses concentration. Fatigue cracks appear on the working surfaces of parts in the zone of maximum cyclic contact stresses. In bearings they appear on the central part of rolling tracks, and are placed across the track, that is, across the action of stretching stresses on the edges of rolling contact. Along with the cracks that appear on the working surfaces under the action of sliding and normal tensile stresses microness of the treated surface play a role similar to microcracks. The wear of conjugate twains as a result of contact fatigue occurs due to the gradual violation of intracrystalline bonds, local displacements of the crystal

lattice in the surface layers of the working surfaces of the parts under the influence of a large number of cycles of re-variable contact stresses [4–6].

Therefore, the reliability and durability of the work of constituent mechanisms depend on the qualitative state of the surface layer of its parts. The parameters of surface layer have influence on the operational properties such as resistance to fatigue, wear resistance, corrosion resistance, contact resistance fatigue, etc.

To obtain the necessary working capacity of machines and mechanisms, it is necessary to ensure the technological quality of the working surfaces of the conjugated parts. Characteristics of the surface layer quality have a direct connection with the operational properties of the parts. Therefore, the optimum surface should be sufficiently solid, have residual compressive stresses, fine-dispersed structure, smoothed form of micronivores with a large area of the supporting surface. The area of the supporting surface is characterized by the reference surface ability, that is, the actual surface area in the depth of the profile obtained.

By grinding the necessary shape of the parts is created with the given accuracy, but the required microgeometry of the surface layer is often not provided. One of the ways to obtain the required microgeometry of the working surface is strengthening-smoothing treatment [7–9]. During the strengthening-smoothing process the chips are not formed, but there can be noticed a thin superficial plastic deformation (SPD) of the surface layer (Fig. 1).



**Fig. 1.** Scheme of strengthening-smoothing treatment.

The choice of tool and processing modes is of great relevance for this processing technology. The tool must have physical and chemical properties higher than the material being processed [8, 10]. The quality of the surface layer after processing depends on the cutting conditions.

## 2 Literature Review

Having made a critical analysis of literary sources, it has been established that wear resistance of friction surfaces depends essentially on the height of the inequalities and the direction of finishing strokes [11]. In the initial period the friction contact surface occurs at the tops of the inequalities. The actual contact surface is only 5-10% of the calculated one. On the contact areas there are large vents, the magnitude of which in some cases exceeds the boundary of material fluidity. At the points of contact there is plastic deformation, abrasion and cut of inequalities. This results in an intense initial triggering of the tangent parts surfaces and in the clearance increase between the contact surfaces. The increase of instantaneous temperatures at local contact points and the breakdown of the oxide foam that covers the metals create favorable conditions for the molecular bonding of the contacting surfaces with the formation of adhesion seizure knots and intensive wearing.

Researches made by Matalin A. [12] showed that the shape of the irregularities at the same height  $R_z$  affects the operation of the friction parts. Experiments [13] showed that during the initial operation, which occurs during the period of grinding, there is a change in the size and shape of the microgeometry inequalities. The height of the irregularities decreases or increases in some cases, approaching some specific optimal height.

The increase in the height of the microniveness, in comparison with the optimal, enlarges the trigger owing to the growth of clamping, cutting and crushing of the protruding surface irregularities. Reducing the height of roughness, compared with the optimal, leads to abrupt triggering. This is owing to the emergence of molecular grip and jamming of tightly tangent surfaces of increased smoothness [14].

## 3 Research Methodology

Materials for the working part of the smoothing tools should have higher physical and mechanical properties than the workpieces materials. They should have the following basic properties: high hardness; resistance to abrasion; high compression strength; low coefficient of friction on metal; high thermal conductivity and heat capacity; the ability to abrade the surface to obtain a minimum roughness [10, 12, 15].

The purpose of the work is to: (1) justify the choice of working part of the smoothing tool. (2) investigate the formation of microgeometry of working surfaces of machine parts and devices on strengthening-smoothing operations.

Tasks of work are to: (1) choose a working part of a smoothing tool for strengthening- smoothing operations. (2) study microgeometric parameters of working surfaces of machine parts and mechanisms during reinforcement smoothing treatment using the chosen tool. (3) establish the supporting curves of the studied surfaces and draw conclusions and recommendations on the use of strengthening operations for the parts processing of turning operation.

## 4 Results

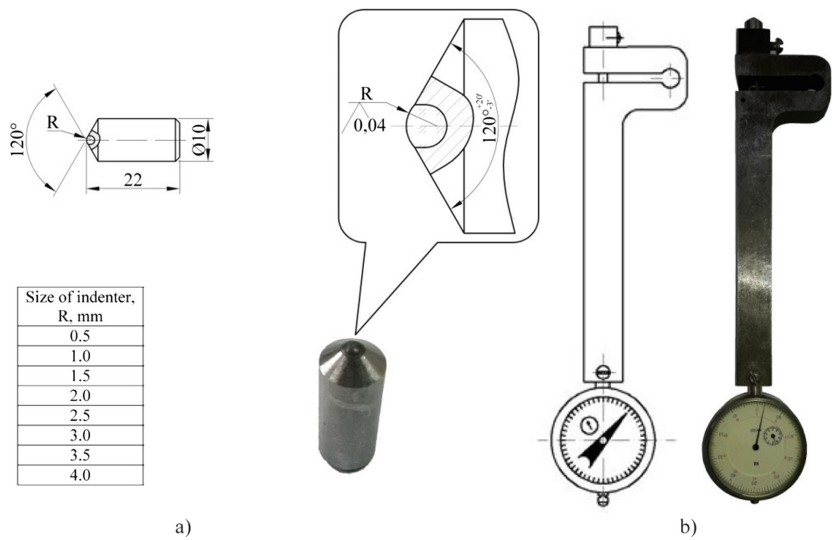
Hard alloys and synthetic diamonds that meet the above mentioned requirements (Table 1) are mainly used for smoothing out processes. One of the promising types of synthetic diamonds to be used in working parts of indentation smoothing agents is the type of thermally stable polycrystalline diamond (TSP diamond). Its hardness, compressive strength, modulus of elasticity, thermal conductivity and thermal stability characteristics are better in comparison with analogues (ASB and ASPK types), therefore, cutting conditions for smoothing can be intensified to improve processing performance.

**Table 1.** Physical and mechanical characteristics of diamond properties and toll materials.

| Material                        | Density, g/cm <sup>3</sup> | Mohs scratch-hardness test | Modulus of elasticity, GPa | Thermal resistance, K | Compression hardness limit, GPa |
|---------------------------------|----------------------------|----------------------------|----------------------------|-----------------------|---------------------------------|
| TSP diamond                     | 3.45                       | 10                         | 970                        | ~ 1500                | 3.1                             |
| Diamond                         | 3.49...3.54                | 10                         | 900                        | ~ 1000                | 2                               |
| Silicon carbide                 | 3.2                        | 9                          | 365                        | ~ 1300                | 2.3                             |
| Solid alloy BK10-KC type        | 14.4...15.0                | –                          | 520                        | ~ 1200                | 4.2...4.5                       |
| Steel HS 18-0-1 type (tempered) | 8.5...8.7                  | –                          | 220                        | ~ 700                 | 3.6                             |

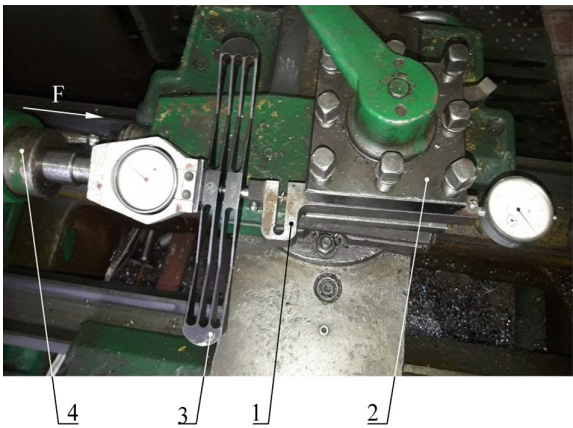
The reinforcement strength depends on the workpiece material. So according to Konovalov E. and Sidorenko V. [11, 12], the hardness of the surface layer, depending on the metal sensitivity to the reinforcement increases by 30...80%, while processing parts from silumin – by 50%, steel C25 – by 45%, cast iron – by 30...60%, brass – by 60% The depth of over-peening for soft materials is 0.8...3 mm, and for materials of average hardness is about 0.3...8 mm.

An elastic belt (Fig. 2b) is used for conducting experimental diamond stroke studies, a stainless steel synthetic diamond tip from the TSP diamond (Fig. 2a) is used as a working tool.



**Fig. 2.** Materials and tools for diamond smoothing: (a) physical configuration and standard sizes of synthetic diamond type flip-off tips of the TSP diamond; (b) physical configuration of an elastic pad for smoothing.

As part of the study, cylindrical steel test specimen of C45 type, previously subjected to turning, was used. After the turning operation, the smoothing treatment was used, and the pressure of stroke P (smoothing force) varied in different areas. The changes in strength were monitored on a clock-type indicator that was calibrated by loading (Fig. 3).

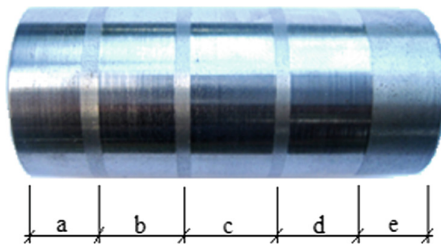


**Fig. 3.** Scheme of sleeper stretcher holder: 1 – holder with a clock type indicator; 2 – lathe cutter; 3 – exemplary mechanical DOSM-3-0,05 compression dynamometer; 4 – rear grinder of the lathe.

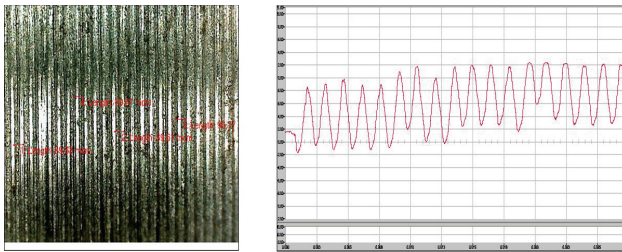
The change of force interval was 100 N, 200 N, 300 N, 400 N. The feed  $s$  and the smoothing rate  $V$  were selected according to the recommendations [9] at maximum values. Technological regeneration modes are:  $S = 0.1$  mm/rev.,  $V = 20$  m/min.

After processing the test specimen was subjected to roughness measurements on the profilometer 201 equipped with ADC and micro-images were made on a Smart-Eye photomicroscope.

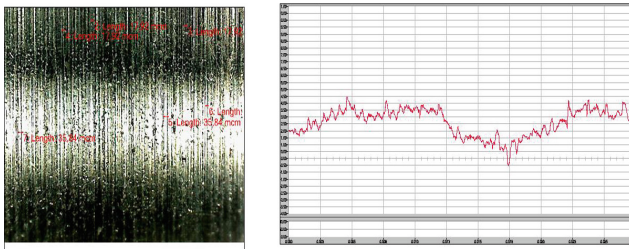
As a result, a digital data packet used for the further analysis of the experiment was obtained. In order to compare the results of the smoothing, the most characteristic profilographs of sharpened and smoothed surfaces were constructed (Figs. 4, 5, 6, 7, 8 and 9).



**Fig. 4.** Test specimen after turning (e) and diamond smoothing (a, b, c, d) operations.

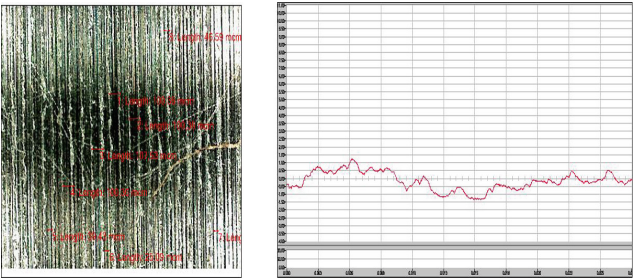


**Fig. 5.** Test specimen after turning (Fig. 4, zone “e”).

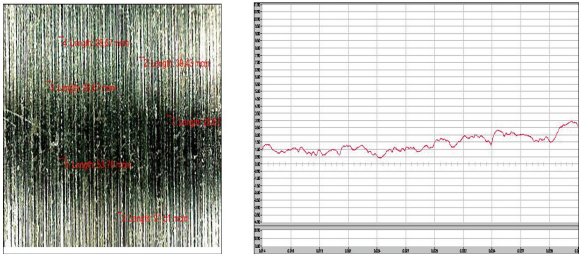


**Fig. 6.** Micro-picture and profile graph after smoothing,  $P = 100$  N (Fig. 4, zone “a”).

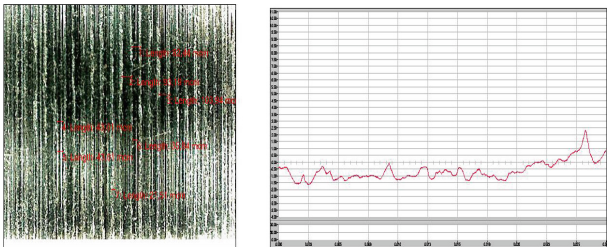




**Fig. 7.** Micro-picture and surface profile after smoothing,  $P = 200$  N (Fig. 4, zone “b”).



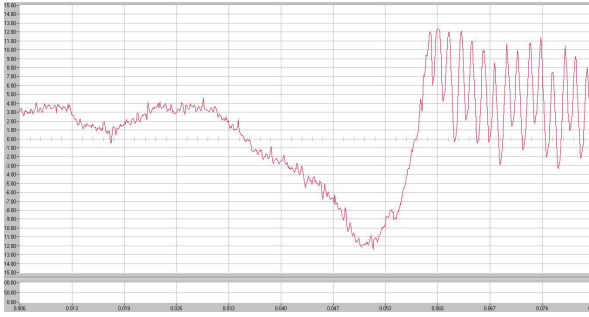
**Fig. 8.** Micro-picture and surface profile after smoothing,  $P = 300$  N (Fig. 4, zone “c”).



**Fig. 9.** Micro-picture and surface profile after smoothing,  $P = 400$  N (Fig. 4, zone “d”).

When designing the technology of processing parts using diamond smoothing, it is necessary to take into account the features of this operation. While choosing a tool for the working surface a transition work mode is observed. That means that at the initial period of time when the necessary smoothing force is established on the surface, a transition zone with a small influx on the surface is formed, a similar pattern is observed at the end of the smoothing (Fig. 10).

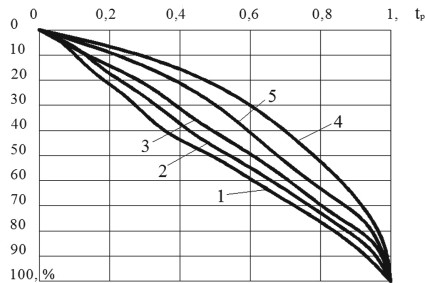
For the analysis the reference surface curve is constructed. As a result of comparing the microtopography of the obtained test specimen, it has been stated that having the same roughness value the smoothed surface has more optimal shape of the reference curve than the polished one.



**Fig. 10.** Switch from turning to smoothing.

Wear resistance is an important parameter for contacting surfaces, which depends on microgeometric characteristics of the surface layer. The actual contact area is affected by both the height and the forms of microroughnesses. This dependence is satisfactorily described by the curves of the reference lengths of the profiles, by means of which the supporting profile curve is constructed. It characterizes the distribution of material in a rough layer and plays a very important role in calculations of contact interaction of rough surfaces [14]. For comparison, the support curves for the above profilograms were constructed (Fig. 11).

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**Fig. 11.** Supporting surface curves: 1 – turning processing; 2 – smoothing treatment ( $P = 100$  N); 3 – smoothing treatment ( $P = 200$  N); 4 – smoothing treatment ( $P = 300$  N); 5 – smoothing treatment ( $P = 400$  N);  $t_p$  – relative reference length of profile at level  $p$ .

## 5 Conclusions

As a result of the analysis of profilograms and reference curves of the treated surfaces, the following conclusions were made: (1) the use of the TSP diamond surface smoothing after the turning process reduces the initial roughness by 6 times; (2) rational power of smoothing at  $S = 0,1$  mm/rev.,  $V = 20$  m/min, equals to 300 N; (3) the application of the proposed tools and materials allows to extend the upper limits of the indenter and the speed of smoothing; (4) the more favorable form of the reference curve

has a surface that is treated with a smoothing force of 300 N, a force of 400 N although gives almost the same reduction of roughness, however, does not satisfy the requirements to the microroughnesses form.

Owing to the larger support area compared to other types of processing, the smoothed surface in the interaction of the conjugate surfaces of the parts provides more complete contact of the surfaces that interact with each other. The resultant reduction of the contact pressure on the individual working surfaces leads to an increase in the multiplicity of the surface deformation, thereby contributing to wear reduction.

When smoothing, favorable conditions are created to increase wear resistance of parts. The most significant increase is achieved mainly due to deformation strengthening of the smoothed round form of microroughnesses and orientation of inequalities.

It should be noted that after diamond smoothing there is a “bleeding” of the ways penetration of corrosive medium into the metal due to defects in the surface. This reduces corrosion and increases the fatigue strength of the parts.

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Please use the proof correction marks shown below for all alterations and corrections. If you wish to return your proof by fax you should ensure that all amendments are written clearly in dark ink and are made well within the page margins.

| <i>Instruction to printer</i>                                  | <i>Textual mark</i>                                                                           | <i>Marginal mark</i>                           |
|----------------------------------------------------------------|-----------------------------------------------------------------------------------------------|------------------------------------------------|
| Leave unchanged                                                | ... under matter to remain                                                                    | Ⓟ                                              |
| Insert in text the matter indicated in the margin              | ⏞                                                                                             | New matter followed by<br>⏞ or ⏞ <sup>22</sup> |
| Delete                                                         | / through single character, rule or underline<br>or<br>⏞ through all characters to be deleted | Ⓞ or Ⓞ <sup>22</sup>                           |
| Substitute character or substitute part of one or more word(s) | / through letter or<br>⏞ through characters                                                   | new character / or<br>new characters /         |
| Change to italics                                              | — under matter to be changed                                                                  | ↙                                              |
| Change to capitals                                             | ≡ under matter to be changed                                                                  | ≡                                              |
| Change to small capitals                                       | ≡ under matter to be changed                                                                  | ≡                                              |
| Change to bold type                                            | ~ under matter to be changed                                                                  | ~                                              |
| Change to bold italic                                          | ≈ under matter to be changed                                                                  | ≈                                              |
| Change to lower case                                           | Encircle matter to be changed                                                                 | ≡                                              |
| Change italic to upright type                                  | (As above)                                                                                    | ⏞                                              |
| Change bold to non-bold type                                   | (As above)                                                                                    | ⏞                                              |
| Insert 'superior' character                                    | / through character or<br>⏞ where required                                                    | Y or Y<br>under character<br>e.g. Y or Y       |
| Insert 'inferior' character                                    | (As above)                                                                                    | ⏞<br>over character<br>e.g. ⏞                  |
| Insert full stop                                               | (As above)                                                                                    | ⊙                                              |
| Insert comma                                                   | (As above)                                                                                    | ,                                              |
| Insert single quotation marks                                  | (As above)                                                                                    | Y or Y and/or<br>Y or Y                        |
| Insert double quotation marks                                  | (As above)                                                                                    | Y or Y and/or<br>Y or Y                        |
| Insert hyphen                                                  | (As above)                                                                                    | ⏞                                              |
| Start new paragraph                                            | ⏞                                                                                             | ⏞                                              |
| No new paragraph                                               | ⏞                                                                                             | ⏞                                              |
| Transpose                                                      | ⏞                                                                                             | ⏞                                              |
| Close up                                                       | linking ⏞ characters                                                                          | ⏞                                              |
| Insert or substitute space between characters or words         | / through character or<br>⏞ where required                                                    | Y                                              |
| Reduce space between characters or words                       | <br>between characters or words affected                                                      | ↑                                              |