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Modeling of Surface Topography After Burnishing Processing

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Abstract: In this paper the way to numerical modeling of surface details after finishing is examined. Feature of the presented model is a sequence in the simulation results: at the beginning surface is modeled after processing by grinding and only then topography is modeled after burnishing. Simulation of a burnishing tool on close to real surface but not on the perfect surface allows considering the effect of technological heredity, which is important for the engineering manufacture.

Introduction

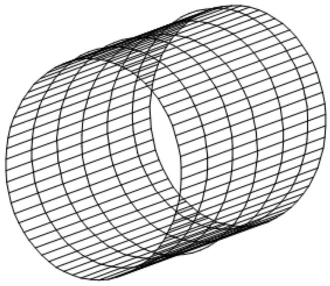
Machined surfaces microgeometry parameters determine the functional properties of the entire unit [1]. For example, surface treatment of the cylinder block defines efficiency of the internal combustion engine. During the last century, the trend of constant increase of the requirements for quantitative values of microgeometry parameters (e.g., reduction of the parameter Ra) was replaced by a rational regulation of complex parameters (Ra, Rz, Rmax, Rvk, Rpk, Rk, tp), which is possible only with the use of a number of processing technologies such as honing or surface plastic deformation or another advanced technology technique [2].

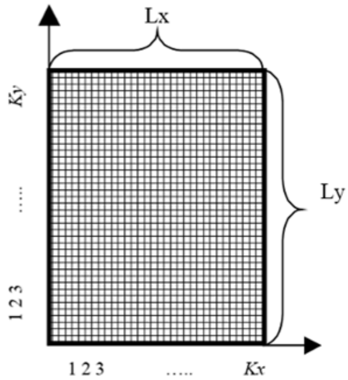
Experimental study of the effects arising from the burnishing only allows to establish a causal link between the input and output parameters of the experiment, which does not give adequate assessment of processes taking place during processing and possibility of projecting specific results on the fundamental provisions of the processing in general and does not reveal interference of each factor. Moreover, quite a number of factors for variations destabilize purely experimentally obtained models, which demonstrates their usefulness in each case, but leads to a need for the recycle experiments changing the input parameters. Thus experimental methods for studying the effects of the interaction of the tool with the work piece due to difficulties as purely technical and fundamental character, and have a fairly limited capacity. Perspective approach is based on creating a model that adequately describes the process of machining. In the presence of such model based on a numerical experiment can get detailed information about the features of the formation process in the vicinity of the contact zone with the tool surface to be treated and to reveal the reasons arising from the effects of the work piece.

In this model, the authors sought to take into account dynamic effects, and sufficiently developed near the elastoplastic deformation contact zone. Dynamic problems of elastoplastic interaction of bodies explored relatively weak, which is determined by the complexity of their performances and lack of mathematical methods of model solutions of boundary value problems of continuum mechanics. The greatest progress in this area is due to the intensive development of direct numerical methods for solving complex schemes and physically nonlinear problems. Long time drawbacks of these methods were their complexity and fundamental limitations of practical opportunities associated with the level of use of computer technology. The current level of development of computer technology allows to simulate reliably the surface of machine parts including after a few cycles.

Structure of model

In constructing the model was used the following approach to solve this problem:
- Treated neck of a shaft that is a cylindrical surface partitioned into K_x points along X axis, and *Ky* dots around the circumference part (Fig. 1);
– Further, the scanning cylindrical surface is produced as shown in (Fig. 1a) to simplify calculation.





a b

Fig. 1 - Interpolation of processed surface
a) the model processed surface; b) sweep

To obtain a processed surface microtopography is necessary to calculate coordinates of each point of the model shown in (Fig. 1b). For more evident interpretation the results of the calculation should be presented as a result of the matrix size Kx×Ky, where each element of the matrix is numerically express the coordinates of the point of the height of the surface obtained in the forming machining process.

The processed surface forming viewed as working surface geometry transformation of the tool to the work piece of original surface (Fig. 2). In the mathematical simulation must be given an equation describing the image of the surface during machining.

At burnishing forming is a sphere, then the equations of the forming curve takes the form:

$$\sqrt{(x-x_0)^2+(y-y_0)^2}=R^2 \tag{1}$$

where R – burnisher tool radius, mm; x0, y0 – burnisher functional surface point (it is recessed into the surface of maximum work piece), mm; x, y – calculated coordinates of surface point, mm.

Burnisher coordinates of position (x0, y0, z0) can be calculated from production performance

$$\begin{cases} x_0 = \dfrac{S\cdot t\cdot n}{60} \\ z_0 = \dfrac{\pi d\cdot t\cdot n}{60} \\ y_0 = h \end{cases} , \tag{2}$$

where n – workpiece rotational speed, rev/min; t – processing time, c; S – feed, mm/rev; d – workpiece diameter, mm; h – indenterpenetration depth, mm.

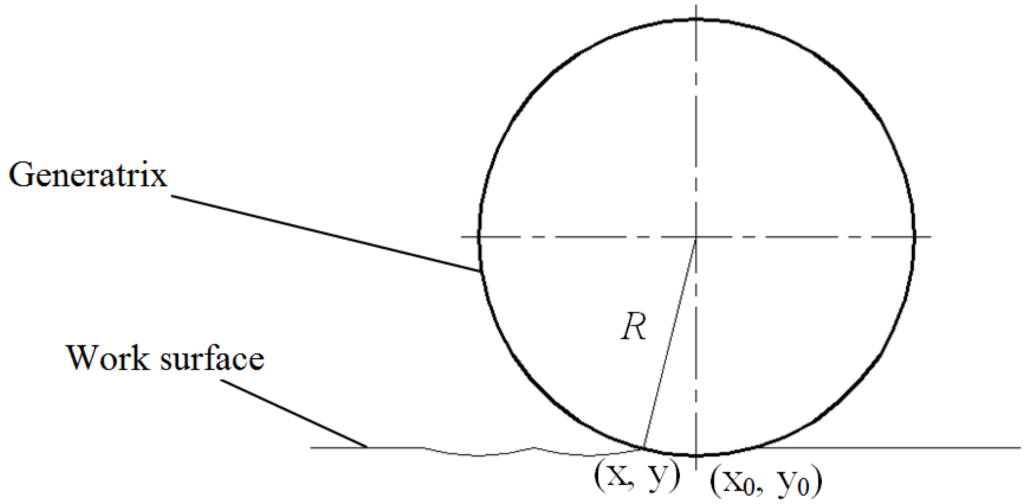


Fig. 2 - Generation of geometry process

In this issue of technological heredity in the formation of the treated surface microrelief is extremely important, as the presence of abrasive tool "feed marks" is beneficial to work in conditions of friction parts as serve as reservoirs for lubricants. Thus, the burnishing process including applying the relief to deform (rounds) apex of surface pattern, while leaving a micro-relief valleys of the preceding abrading for retaining lubricant.

Proceeding from the aforesaid, the model should be considered microrelief from the previous operation. In a majority of papers in the work piece original surface simulation are encouraged to use the algorithm modeling surface roughness with the specified parameters. However, the proposed algorithms also does not adequately simulate the surface after machining with abrasive tools. In mathematical modeling of the original surface forming process appropriately addressed as a stochastic impact of abrasive grains on a surface of the workpiece [3].

Burnishing process is kinematically similar to the turning operation. Forming process can be considered as the motion of the sphere (burnisher active face) along a helical surface with a displacement amplitude equal to the tool advance (S, mm/rev). A mathematical model of the burnishing process considering technological heredity from the previous operation can be generally represented by the following block diagram (Fig. 3). This model will allow selecting the processing parameters based on the working surface tribological requirements. (Fig. 4) shows an example of a model obtained surface which treated with burnishing process based on heredity with different processing parameters. Area with increased surface finishheights not yet processed by burnishing.

For comparative assessment of the developed mathematical model simulation results and pictures of the surface were analyzed for convergence. The photos were taken by a scanning electron microscope, high-resolution Supra 50 VP LEO with microanalysis system INCA x-sight + Oxford.

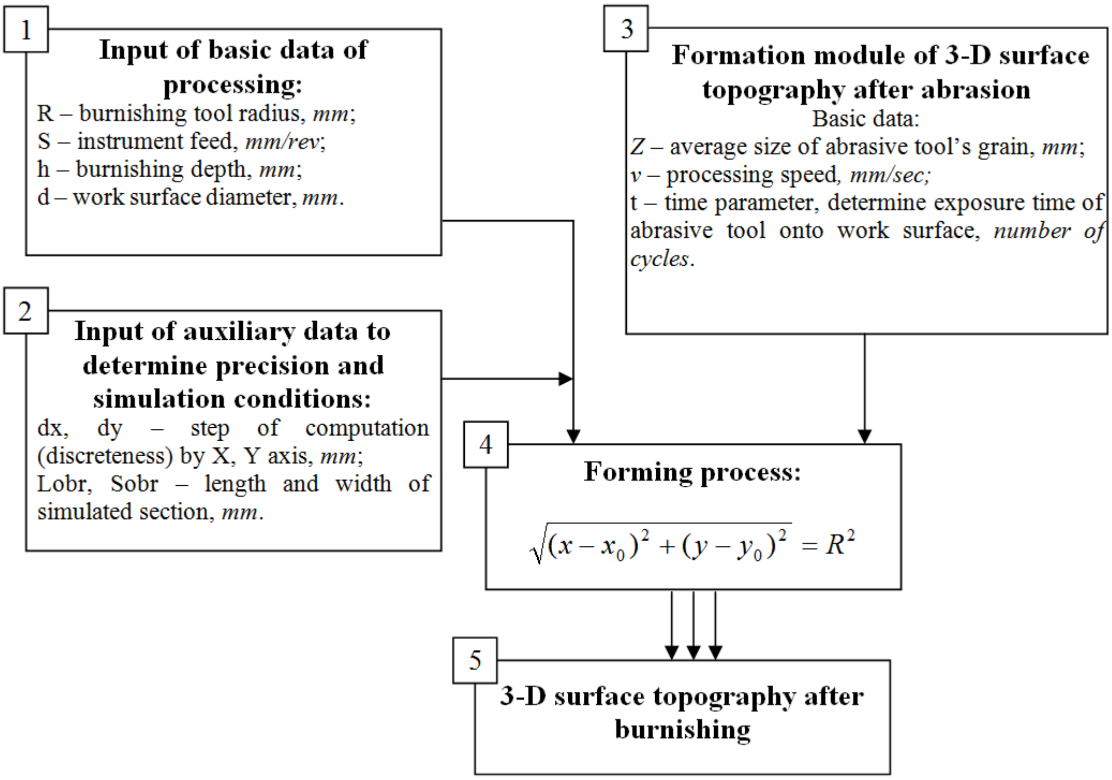


Fig. 3 - Burnishing process block schematic diagram

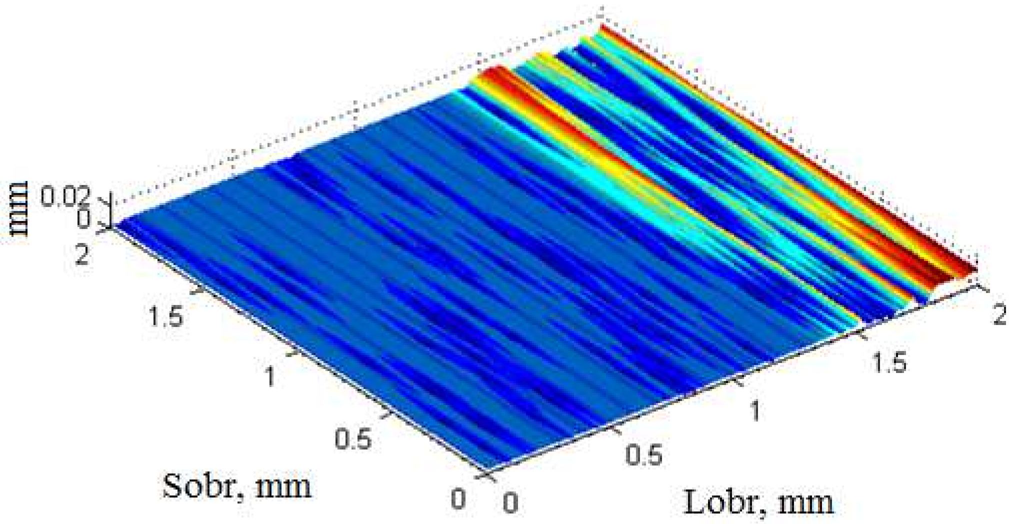


Fig. 4 - Model of burnished surface

Contention computer-simulated surface and photography shows high convergence (Fig 5).

Results and Discussion

(Fig. 5) clearly shows how changing the topography across the border between polished and burnished segmental surfaces. Surface pattern on the burnished segment smoother and lower in height, without sharp apex, but deepest depressions in the microrelief obtained during abrasive machining are remained on burnished surface because of heredity. Thus in both cases were the same processing parameters: R = 3 mm – burnisher tool radius; S = 0.3 mm/rev, h=0.01 mm – indenter projected range (upon receipt of this parameter in the industrial conditions was used the methodology proposed in [4]).

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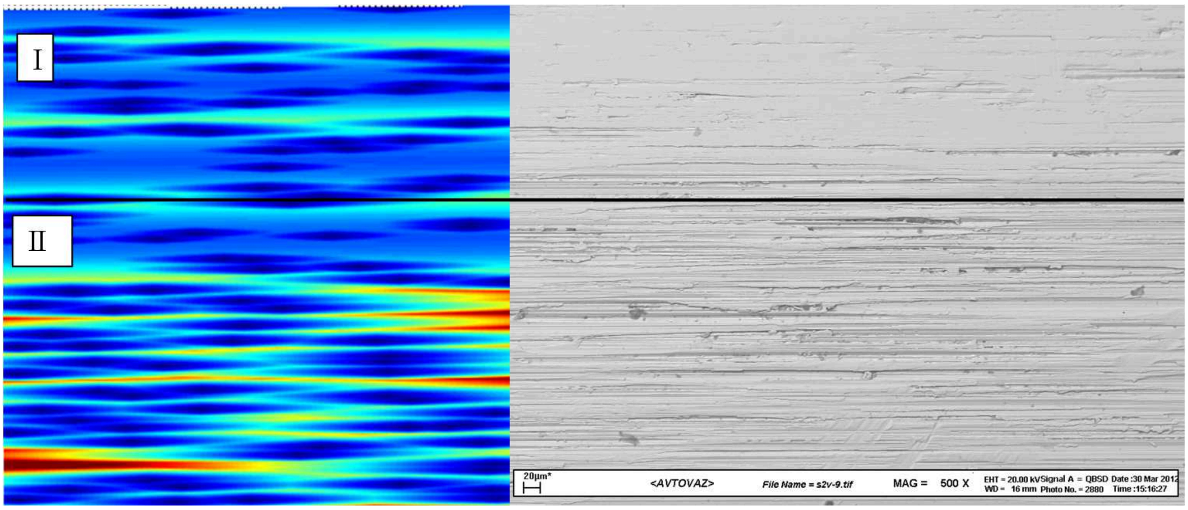

Fig. 5 – Contention of surfaces (plane view), achieved from electron microscope (right) and computer-simulated (left). Roman figure I – burnished surface patch, II – grounded surface patch

Conclusion

1. Direct numerical methods for modeling surfaces of machine parts after processing are bulky and limited by use of computer technology, but allows sufficient accuracy to perform the simulation. Analytical methods are easy to use and visually. Combining of analytical and numerical methods allows to present the simulation results more fully, and this was done in the developed model.
2. The model contains a group of parameters (R, S, h, d, Z, v, t) and allows to reliably simulate abrasive machining process and the subsequent processing of burnishing, which is confirmed by the results of the pilot study.
3. Presented model needs futher development that will add possibility of assignment of controlled formation of the topography, which will simulate the regular microrelief with required functional properties taking into account the application of modern types of coatings [5].

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