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THE NUMERICAL DETERMINATION OF CONTACT ZONE TOOL AND WORK-PIECES IN BURNISHING ROLLING PROCESS

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Abstract

This work concerns burnishing rolling the shafts with elastic pressing of burnishing elements. One of the most important problems during designing this process is calculate value of technological parameters: principal force of burnishing (F3), feed (fn) and velocity (vn). The principal force of burnishing was calculated by integration the elementary contact pressure over contact zone. It is possible to determinate as product of means the contact pressures and contact zone. It requires to determinate the both distributions it contact pressures and calculate of mean value and contact zone. The unacquaintance of the contact zone or contact pressures distributions leads to incorrect calculations of principal burnishing force and this can bring to destruction of work-pieces surface layer. In this work the numerical way of contact zone determinate between burnishing elements and work pieces was shown. The cases with the option when the roughness of surface after previous process were analyzed.

Key words: burnishing rolling, contact zone, Finite Elements Method (FEM)

1. INTRODUCTION

This work concerns burnishing rolling the shafts with elastic pressing of burnishing elements.

One of the most important problems during designing this process is calculate value of technological parameters: principal force of burnishing (F_3), feed (f_n) and velocity (v_n). The principal force of burnishing was calculated by integration the elementary contact pressure over contact zone [1,2,5,6,7,8]. It is possible to determinate as product of means contact pressures and contact zone. It requires to determinate the both distributions it contact pressures and calculate of mean value and contact zone. The unacquaintance of the contact zone or contact pressures distributions leads to incorrect calculations of principal burnishing force and this can bring to destruction of work-pieces surface layer (figure 1). In the thermodynamics opinion of continuum medium the burnishing process is triple (geometrical, physical and thermal) non-linear boundary and initial condition problem, with unknown boundary conditions in contact zone of the tool and work-pieces. The basic problem is to know the mechanism of material plastic deformation and definition of displacement states, strains and stresses that occur in surface layer of processing work-pieces in the force or depth function in burnishing process. These states have significant influence on the phenomena occurring in the burnishing rolling process, which decide about properties of formed work-pieces surface layer. In this work the numerical way of contact zone determinate between burnishing elements and work pieces was shown. The cases with the option

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when the roughness of surface after previous process were analyzed. The modeling was conducted with use of updated Lagrange'a description and Finite Elements Method. The tool was modeling as a rigid and object as elasto – visco/plastic (*E/VP*) body. In aim to variational formulation of the contact problem for the bodies the variational functional was selected. There is only one independent field – displacements increment field. Moreover, compatibility equations and initial and boundary conditions were fulfilled. Such foundations lead to obtain the pattern, formulated in displacements increments, model problem for geometrical and physical non-linear dynamics. The movement equations solution was execute with explicit method, in applauded the differential approximation of displacement partial derivatives. Worked out mathematical models of process were applied in the author's application in programme Ansys/Ls - Dyna which makes possible the contact automatic detection and calculation the contact zone, and also they calculations the states of deformation and stresses for different material models with regard the influence of elastic strain, friction, strain rate and temperature. The results of simulation are basis to technological operation designing – the burnishing rolling. The exemplary results of the contact zone calculations were presented.

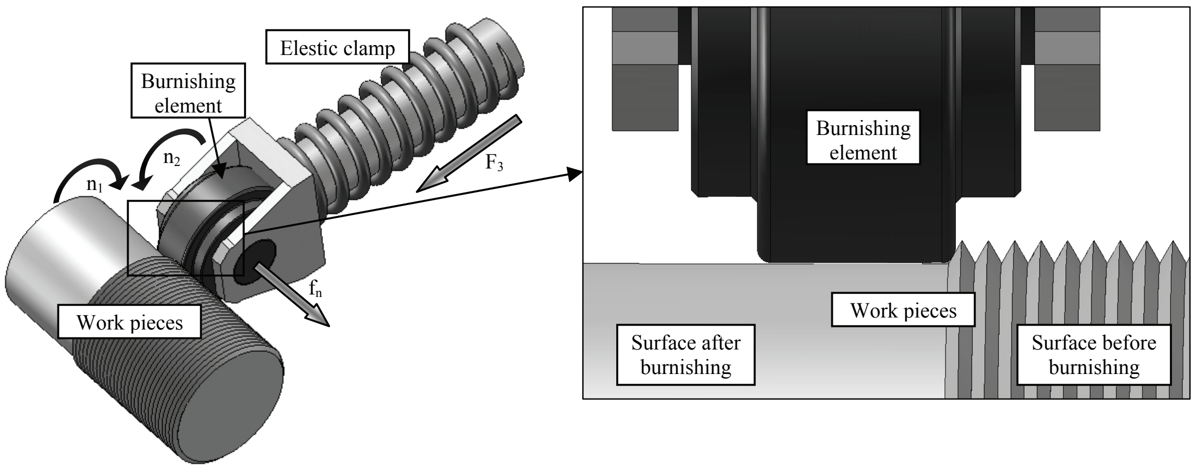

Fig. 1. The schema of burnishing process of rough surface with elastic clamp.

2 SHAPE AND FIELD OF CONTACT AREA OF THE TOOL AND SURFACE

The shape and field of contact area of the tool and surface of the work-pieces depends from geometrical structure of surface prepared for burnishing, geometry of burnishing element, its initial setting in relation to unevenness, feed and depth of burnishing [8]. The contact zone Σ_k of burnishing element with individual unevenness are active surface part of tool limited: outline of burnishing element in axial section and penetration lines $S_{k,l=1}$ i $S_{k,l=2}$ (general $S_{k,l}$) other surface of flash unevenness material with active surface of tool (figure 2).

Field of contact area Σ_k determinate the formula:

$$S_{\Sigma_k} = \int_{\Sigma_k} \mathbf{A}_k \mathbf{N}_k = \iint_{\Omega_{3k}} \frac{dx_1 dx_2}{\cos(\mathbf{N}_k, x_3)}, \qquad (1)$$

where: $\boldsymbol{A}_k$ it is a leader vector of point lying on active surface of burnishing element, $\boldsymbol{N}_k$ it is a elementary normal vector in this point. Formula (1) result from, that one should, in aim of field calculations of area Σ_k , count hereinafter suitable integral area or after area Ω_{3k}, which is the projection of zone Σ_k on plane x_1x_2. Shape of zone Ω_{3k}, for practical changeability of parameters in burnishing process, four curves of second degree limit $f_4^{(k,l)}(x_1)$, and its area was possible to calculate with formula:

$$S_{\Omega_{3k}} = \int_0^s [f_4^{(k;l=2)}(x_1) - f_4^{(k;l=1)}(x_1)]dx_1 =$$

$$= (0{,}19w + 1{,}136a)s\,, \qquad (2)$$

Where: a is the half of length of basis contact zone, s is its height, w inclination of contact zone defines.

Depends (2) is a general formulation for zone of area Ω_k. Special formulas were received by substitution value: w, a, and s, with determinate conditions of previous machining and burnishing. Height s of the contact zone of burnishing element with k unevenness it is distance of intersection point A_k (figure 2) of active surface of burnishing element with

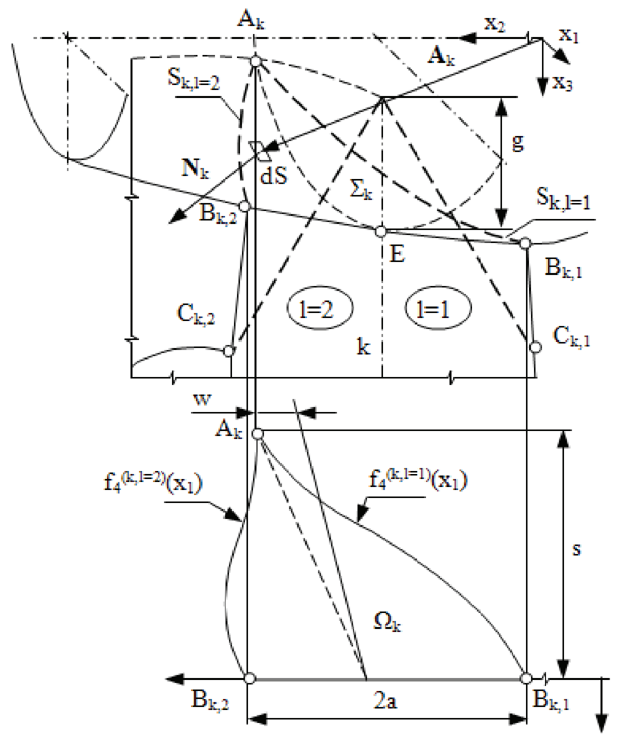

***Fig. 2.** Area Σ_k of contact of burnishing element with unevenness and projection Ω_{3k} of this domain on the plane x_1x_2.*

crest line of unevenness. For example for cylindrical burnishing element and flat part distance *s* has formula:

$$s = \sqrt{g(D-g)}\,, \qquad (3)$$

however in case of burnishing of rolls:

$$s = \sqrt{H^2D^2 - [H^2 + 0{,}25(D^2 - d^2)]^2}\,/\,2H\,, \qquad (4)$$

where: $H = 0{,}5(D+d) - g$ it is distance axis of work-pieces from axis of tool, D is diameter of tool, d diameter of work-pieces, g depth of burnishing.

The inclination w of contact zone depends from feed f in previous processing and the type of part (figure 2) and has value: $w = 0$, for flat part and $w = (f/360)\arcsin(2s/d)$, for rotatory part. The length of basis $2a$ of contact zone depends from received mechanism of material deformation, its mechanical properties, vertical angle of unevenness 2θ, outline of active surface burnishing element and the depth of burnishing g.

During the burnishing rolling process can be put forward three ranges of depth and two limited depths: $0 < g < g_I$, $g = g_I$, $g_I < g < g_{II}$, $g = g_{II}$, $g > g_{II}$, where g_I and g_{II} is properly first and second limited depth. Burnishing with depths $0 < g < g_{II}$ causes, that on burnishing surface, in even spaces feed in previous processing, cracks stay (secondary valley). For $g = g_I$ neighbouring walleyes are in contact. However near $g = g_{II}$ follows total fulfilment of walleys after previous processing.

3. NUMERICAL DETERMINATION OF CONTACT FIELD

Numerical determination of contact field was conducted with using Finite Element Method in Ansys/Ls-Dyna program [2, 3, 4]. Burnishing element into the machining article was squeezed. Computer model of the process was elaborated using axial symmetry of geometrical model. In the figure 3 schema of burnishing rolling process and its discrete model is presented. The tool posses diameter D_n = *50 [mm]*, machining article d = *45 [mm]*. It was accepted, that vertex angle of surface asperities (roughness after previous treatment) equels $\vartheta = 70°$, and feed equals f_n = *1,5 [mm/obr]*.

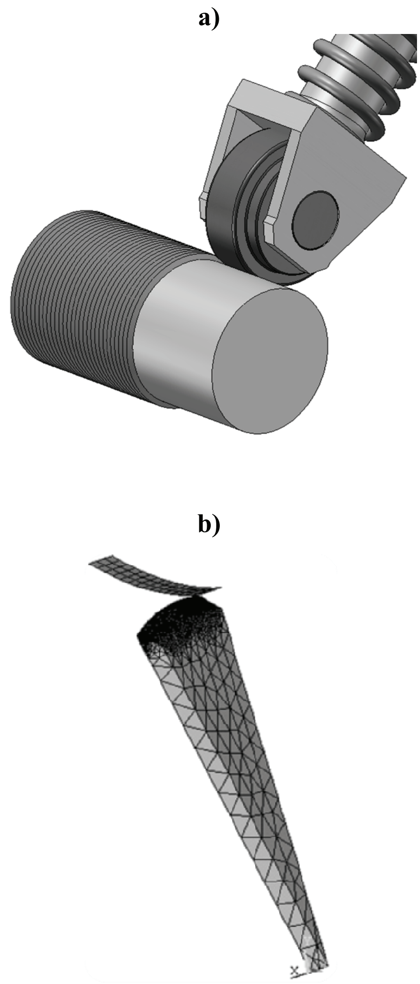

***Fig. 3.** Schema of burnishing rolling process: (a) general view, (b) model simplification.*

Burnishing element was modeling as a rigid body ($E \to \infty$), the object as elasto – visco/plastic

(*E/VP*) body. The tool was discretized with the Shell elements, the work pieces was discretized with the Solid elements. Into burnishing element was apply a force F_3 with induced of burnishing depth even $h = 0,535$ *[mm]*.

4. RESULTS OF NUMERICAL ANALYSIS

The numerical analysis concern of surface unevenness burnishing of work pieces roll about twotoroidal – cylindrical outline. In the figure 4 results of calculations of dislocations in contact zone and length of semi – axe of ellipse are presented.

5. EXPERIMENTAL RESEARCHES

The experimental researches in aim of verification numerical results were conducted. In researches steel *C55* in normalized state was accepted. The burnishing process on universal heigh- speed turning lathe *TUB 32* type was realized, which poses burnishing element about twotoroidal – cylindrical outline (figure 5). The static test of pressing the burnishing element on depth $h = 0,535$ *[mm]* was conducted.

In presented research position the cold work of regular, triangular unevenness about vertical angle $\vartheta = 70°$, and height unevenness $R_z = 1,07$ *[mm]* and feed $l = 1,5$ *[mm]* was made. The view of burnishing element impression on the worked material is presented in the figure 6. The obtained trace with results of numerical analysis was compared.

6. SUMMARY

The quality of burnishing work pieces fundamentally depends of determinate precision of technological parameters, mainly forces and/ or depth of

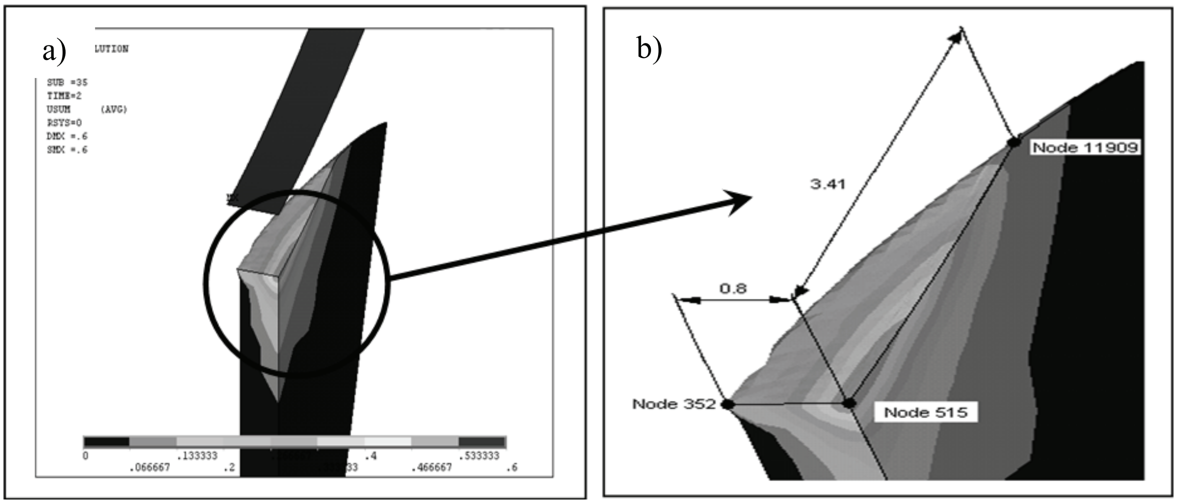

Fig. 4. *Results of simulation: a) view of contact zone, b) length of semi-axe of ellipse.*

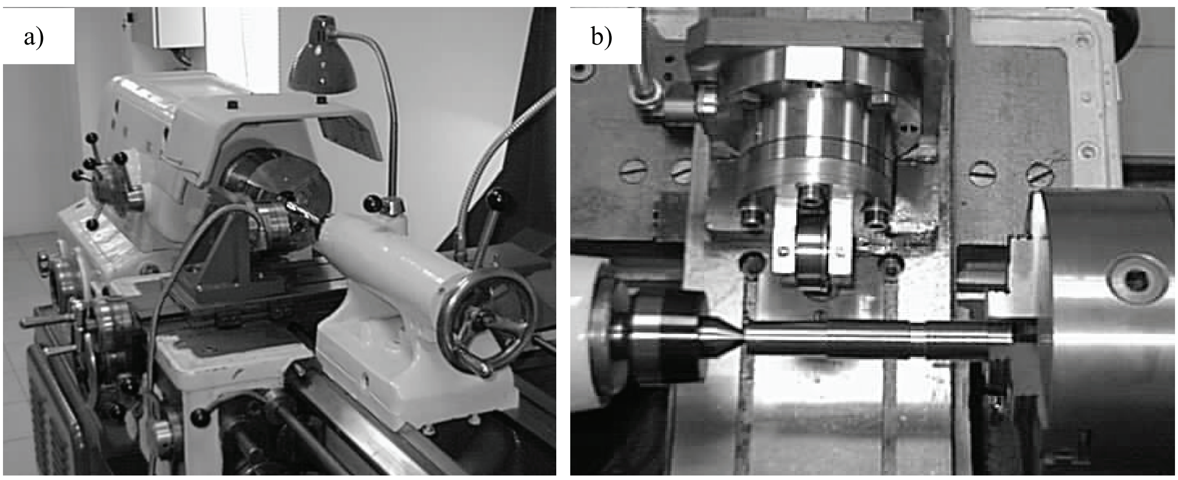

Fig. 5. *Position to experimental researches: a) general view, b) detail view.*

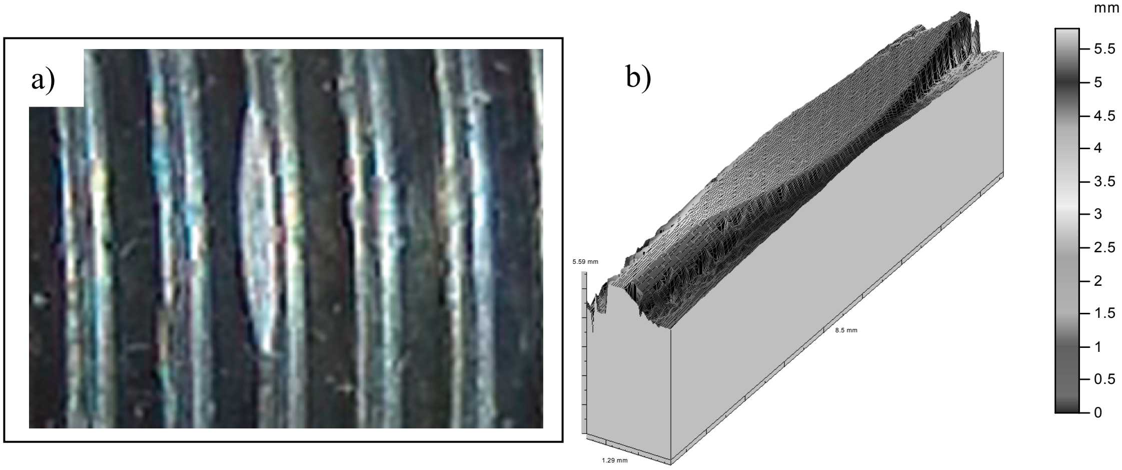

Fig. 6. *The view of roller impression, a) picture, b) view of measurement.*

burnishing. The shape and field of contact zone of burnishing element with work pieces indirectly in fluence. The formulas given in literature do not con cern roughness of the surfaces. The application in system Ansys/Ls - Dyna can be used to determinate the shape and contact zone of burnishing element with taking into account roughness of surface. The received results of computer simulation with results of experimental researches were compared. Received results did not differ indeed apart. The worked methodology of researches can be useful to design technological process with using the burnishing process.

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NUMERYCZNE OKREŚLANIE POLA KONTAKTU NARZĘDZIA Z PRZEDMIOTEM W PROCESIE NAGNIATANIA TOCZNEGO

Streszczenie

Praca dotyczy nagniatania tocznego wałków z elastycznym dociskiem elementów nagniatających. Jednym z najważniejszych problemów w projektowaniu procesu jest obliczenie wartości parametrów technologicznych takich jak główna siła nagniatania, posuw i prędkość. Główną siłę nagniatania oblicza się całkując jednostkowe siły nacisku po obszarze styku. Można tą siłę również wyznaczyć jako iloczyn średnich nacisków jednostkowych i pola styku. Wymaga to określenia zarówno rozkładu nacisków jak i obliczenia wartości średniej oraz pola styku. Nieznajomość jednej z tych wielkości prowadzi do nieprawidłowego obliczania siły nagniatania, a poprzez to przy praktycznym zastosowaniu modelu może doprowadzić do zniszczenia warstwy wierzchniej wyrobu. W pracy przedstawiono sposób numerycznego określania pola styku elementu nagniatającego z przedmiotem obrabianym. Analizowano przypadki, dla których uwzględniono chropowatość powierzchni po obróbkach poprzedzających.

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