INFLUENCE OF THE MICROTOPOGRAPHY OF REAL SURFACES UPON DRY TECHNICAL CIRCULAR CONTACT IN ELASTO-PLASTIC DOMAIN

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Abstract: *The paper presents a numerical approach with respect to the influence of the surfaces microtopography upon the dry technical circular contact in elasto-plastic domain, in the case of no-linear hardening. A Φ = 6,35 ball with three different finishing stages (grinding, rough-polishing, smooth-polishing) was considered. The geometry and the microtopography of each ball was measured with the "UBM 14" optical profilometer of the Department of Mechanical Engineering – University of Suceava and was represented both three-dimensional and bi-dimensional (axial section profile). The numerical simulation software developed to this end was able to determine the pressure distribution and the plastic deformations of the contact (.depth and diameter of the plastic imprint) for 6 levels of the load which would determine in a contact of perfectly smooth surfaces maxim hertzian pressures of: 3; 3,5; 4; 4,5; 5; 5,5 and 6 Gpa. The results hereby obtained revealed important characteristics and peculiarities of the stress and strain state.*

Keywords: *microtopography, stress, elasto-plastic, pressure distribution*

1 Introduction

The undulation's parameters (amplitude and wavelength), as well as their pattern (periodical or random) influence the pressure distribution, stress and strain state of mechanical contacts in elasto-plastic domain.

A Φ = 6,35 mm ball with three different finishing stages (grinding, rough-polishing, smooth-polishing) was considered.

The actual surface was measured with the UBM optical profilometer of the Department of Mechanical Engineering – University of Suceava. Through the conversion of the data into ASCII format and using the FORTRAN 100 software it was possible to run numerical calculus programmes developed to this purpose, [1].

The pressure and the stress distribution as well as the permanent deformation for a number of 9 circular contacts was obtained. For each of the contacts a number of 6 simulation tests corresponding to 6 maximum contact hertzian pressures calculated in the hypothesis of a ideal flat surface (3.5 Gpa, 4 Gpa, 4.5 Gpa, 5 Gpa, 5.5 Gpa, and 6 Gpa) were carried out.

In order to be able to make a comparison with the stress distribution in a case of a ideal contact between a perfectly smooth ball in contact with a ideal flat surface , a simulation test in these conditions was also carried out.

The numerical software programs used in order to perform the simulation tests considered a discretisation of the contact area of 39x51=1989

2 Influence of real surfaces microtopography

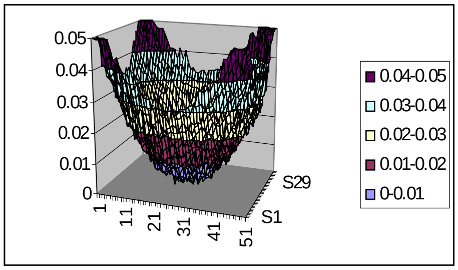
For the Φ = 6,35 mm ball, three different finishing stages were considered :

a) grinding;
b) rough-polishing;
c) smooth-polishing.

The three-dimensional initial contact between these real spherical surfaces is presented in figure 1 and the axial profile of the initial contact is presented in figure 2 (values on abscissa in mm).

Using the ordinates of the these actual surfaces as input data in the numerical simulation software developed, the pressure distribution as well as the stress state and the permanent deformation on the direction of the loading force were calculated, [2].

Figure 3 is a spatial representation of the pressure field induced by the contact of these surfaces, corresponding to maximum hertzian pressures between perfectly smooth surfaces in the range: 3.5 – 6 Gpa (values on abscissa in Mpa).



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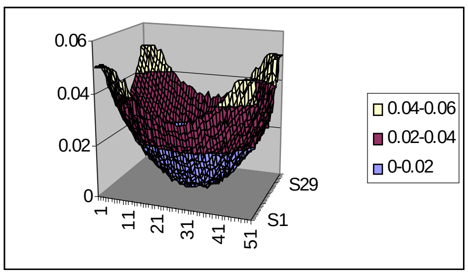

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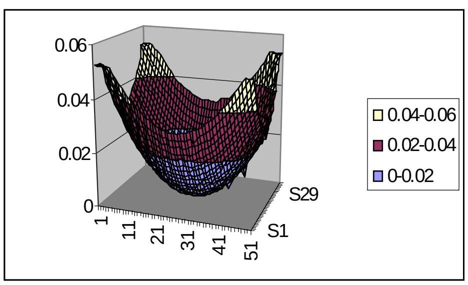

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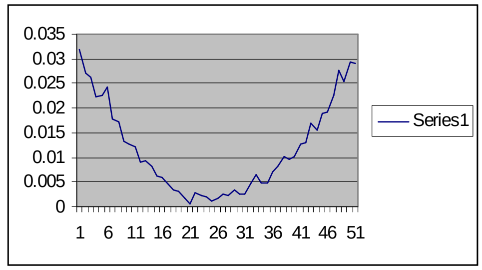
Figure 1 *The three-dimensional initial contact*



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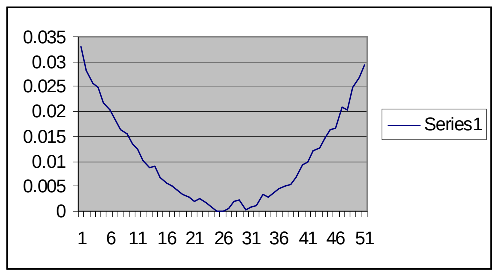

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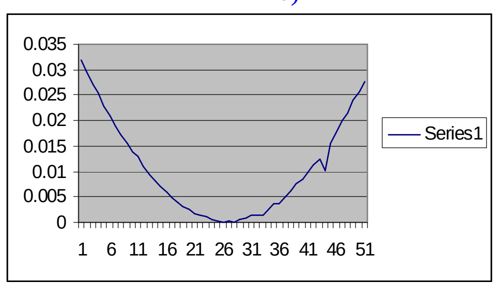

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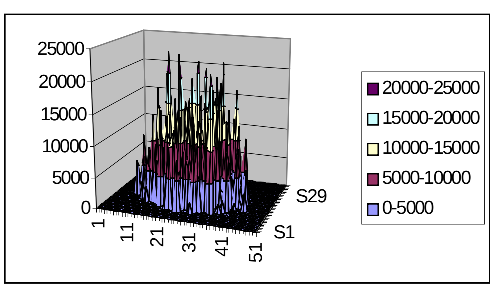
Figure 2 *The axial profile of the initial contact*



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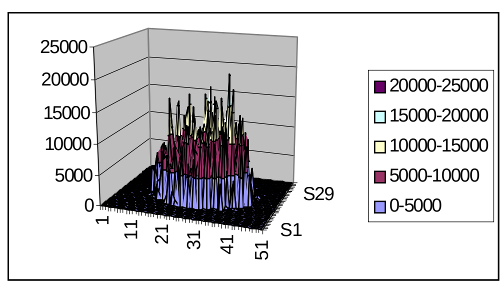

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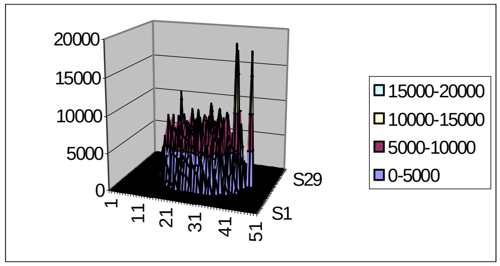

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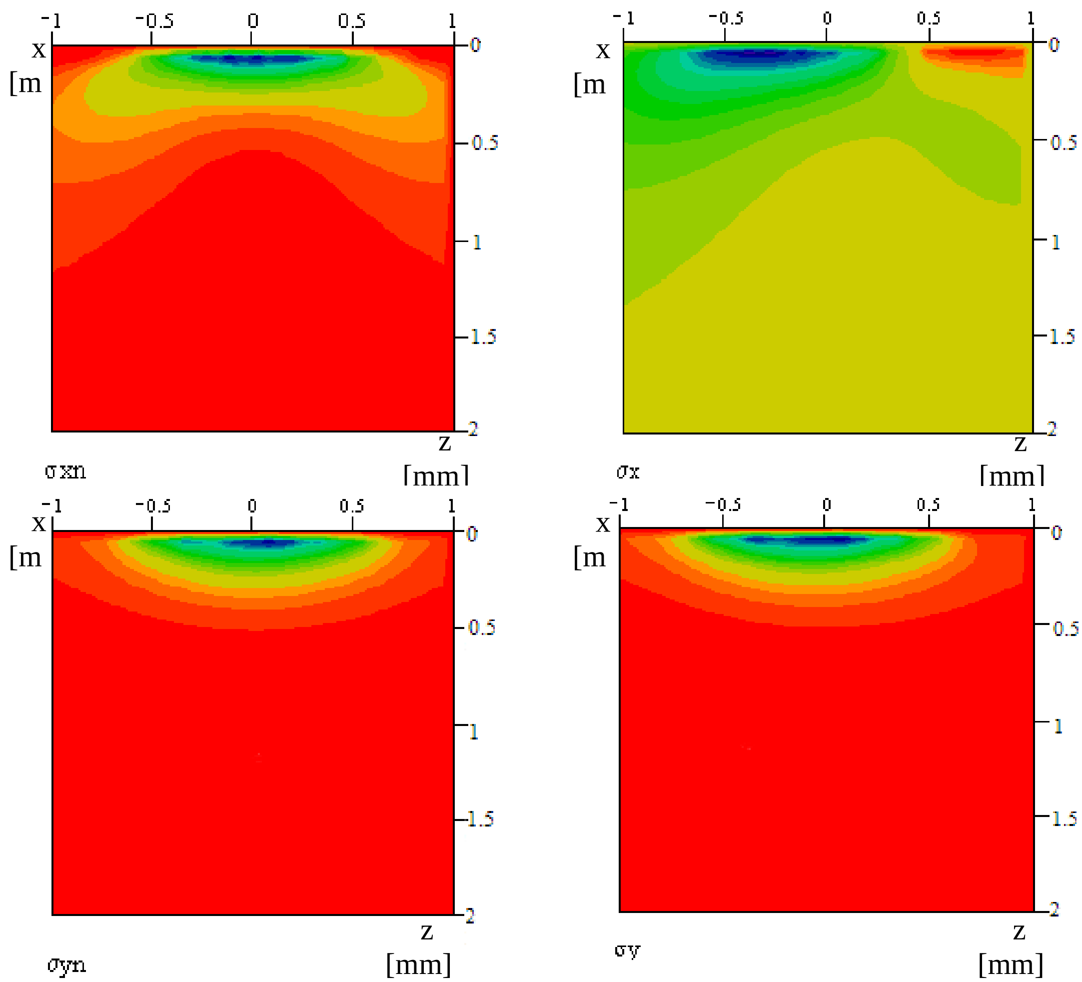
Figure 3 *Influence of the finishing degree upon spatial pressure distribution ; PHmax=6 GPa.*

The constant level curves in figure 4 represent normal subsuperficial stresses $\sigma xn, \sigma yn, \sigma zn$ for normal load and the subsuperficial stresses $\sigma x, \sigma y, \sigma z$ for a normal load combined with a friction coefficient f=0.5. Stresses concentration in the close proximity of the contact area as well as a noticeable perturbation of the stresses field induced by the presence of friction is remarked, [3].



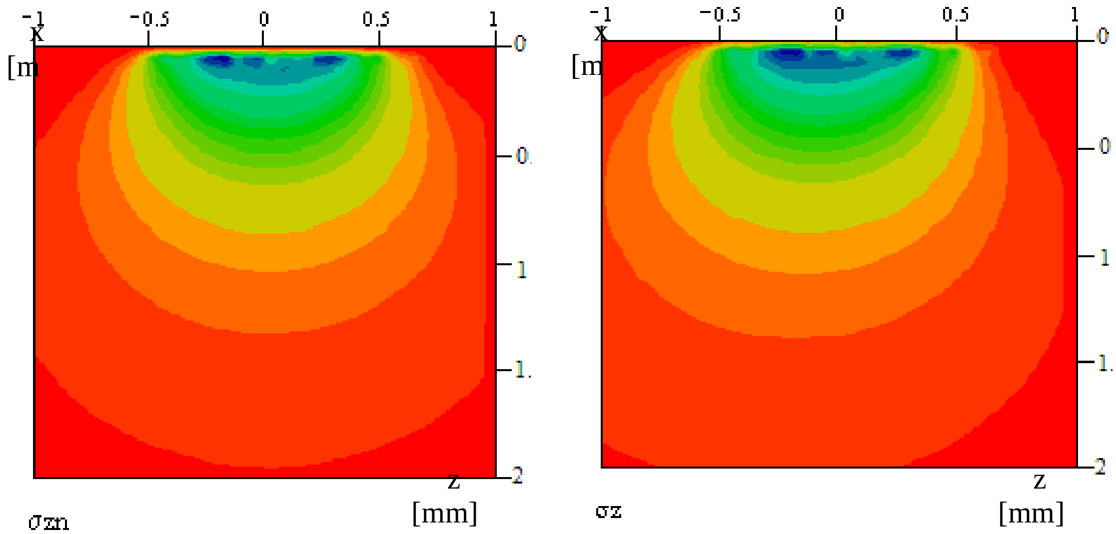


Figure 4 *Subsuperficial normal stresses, represented through constant level curves*

The constant level curves in figure 5 represent subsuperficial orthogonal tangential stresses τxzn for normal load and subsuperficial orthogonal tangential stresses for a normal load combined with friction (friction coefficient f=0.5). Stresses concentration in the close proximity of the contact area as well as a noticeable perturbation of the stresses field induced by the presence of friction is remarked

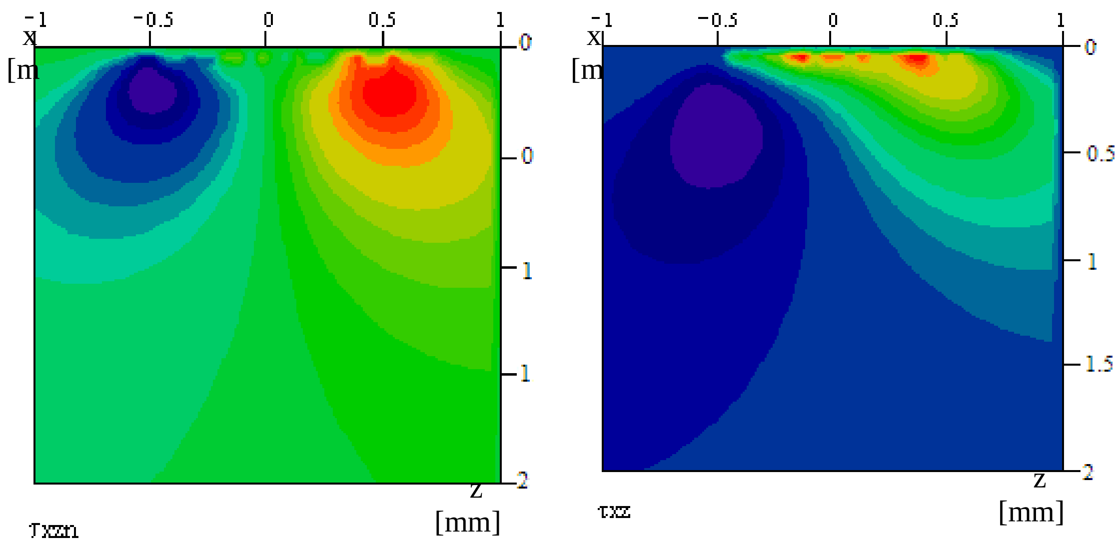
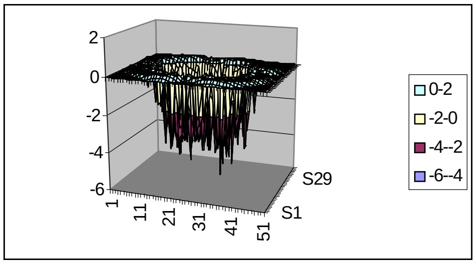


Figure 5 Subsuperficial tangential stresses, represented through constant level curves

The plastic deformations of the flat surface , hardness 56HRC, evaluated for the contact with the actual surfaces are three-dimensionally presented in Figure 6.



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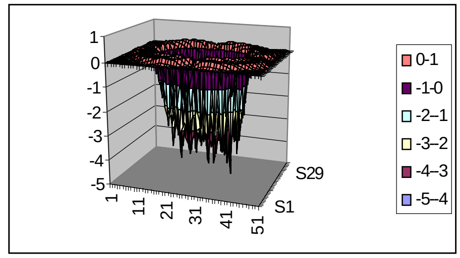

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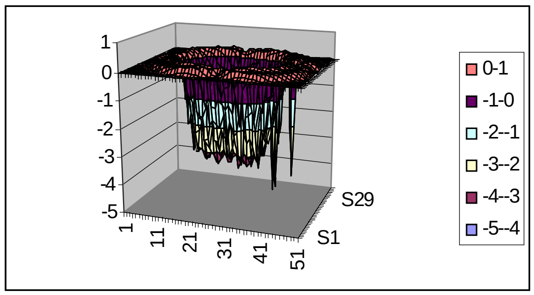

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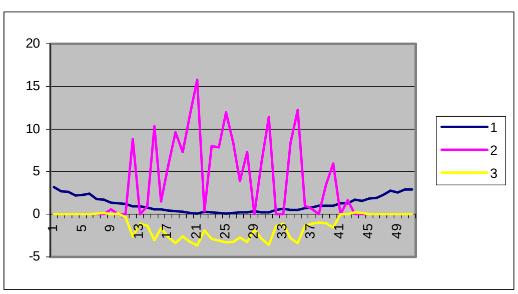
Figure 6 *Influence of the finishing degree upon the deformation of the flat surface : PHmax=6 GPa*.

The evolution of the pressure distribution as well as of the plastic deformation depending on the finishing stage of the spherical surface, for a 6 GPa load is presented in figure 7. Moreover, figure 7 c reveals, in addition, a peak in the pressure distribution 2 and a pit in the plastic deformation 3, induced by a slight defect of the smooth polishing process of the surface (cross-section) 1.

The values of the maximum pressure in the centre of the contact and of the plastic deformations in the centre of the contact or in the close proximity of the centre, as well as the values of the average diameter of the contact imprint and the diameter of the hertzian contact area are presented in table 1, for the 6 loading steps.



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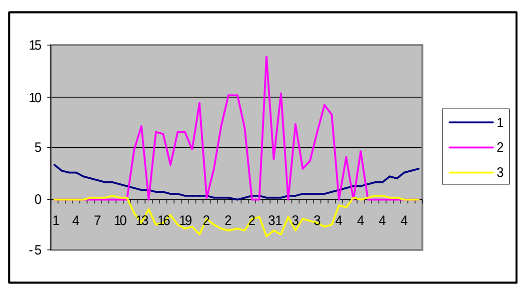

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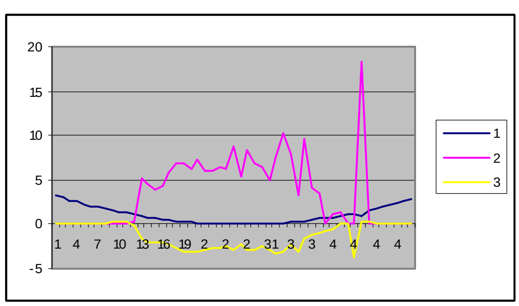

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Figure 7 *Evolution of the pressure distribution (2) as well as of the plastic deformation (3) depending on the finishing stage of the spherical surface (1) , for Phmax=6 GPa*

The variations of the maximum pressures for the three different finishing stages (grinding, rough-polishing, smooth-polishing) of the Φ = 6,35 ball, compared with the case of a ideally sphere and for the 6 loading steps (maximum contact hertzian pressures 3.5 Gpa, 4 Gpa, 4.5 Gpa, 5 Gpa, 5.5 Gpa, and 6 Gpa) are presented in figure 8. The maximum pressure decreases with the finishing degree of the surface, yet remains noticeably bigger than for perfectly smooth surfaces.

Table 1 Elements of the rough contact for the Φ = 6,35 ball

HERTZ			RUGOS ϕ 6,35 mm											
W [N]	PHmax [GPa]	2a [mm]	P max [GPa]			2a med [mm]			δ pl centre [μm]			δ pl max [μm]		
			a	b	c	a	b	c	a	b	c	a	b	c
166	3,5	0,30	16,7	13,3	7,6	0,27	0,23	0,24	0,60	0,65	0,64	1,87	1,68	1,20
276	4,0	0,36	19,2	16,7	9,3	0,32	0,29	0,28	1,15	1,09	1,06	2,54	2,11	1,59
386	4,5	0,40	20,6	18,1	13,4	0,37	0,31	0,31	1,66	1,52	1,44	3,06	2,62	2,01
500	5,0	0,44	21,5	18,9	16,1	0,42	0,38	0,37	2,08	1,89	1,77	3,57	3,14	2,56
667	5,5	0,48	22,8	19,7	18,2	0,44	0,42	0,42	2,62	2,36	2,26	4,49	3,83	3,53
843	6,0	0,52	23,7	20,3	19,1	0,47	0,47	0,45	3,22	2,94	2.66	5,25	4,59	4,31

The depths of the pits are presented in figure 9, while the diameters of the contact plastic deformations for the Φ = 6,35 ball are showed in figure 10. For theoretical pressures under 5 Gpa, the plastic deformation in the centre of the perfectly smooth contact is bigger than for the rough contacts, whereas over the pressure of 5 Gpa, this situation is reversed

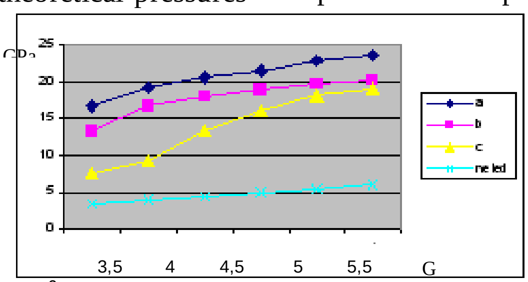
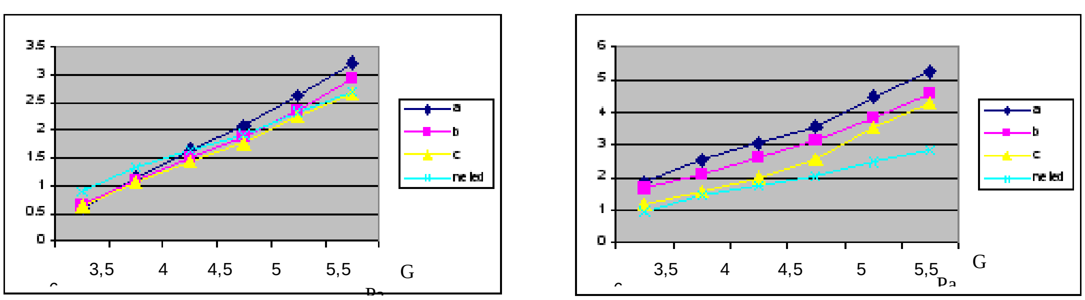


Figure 8 *Influence of the finishing degree upon the maximum contact pressure*



1) **2)**

Figure 9 *Influence of the finishing degree upon the depth of the plastic deformation*
1) in the centre of the contact ; 2) maximum depth

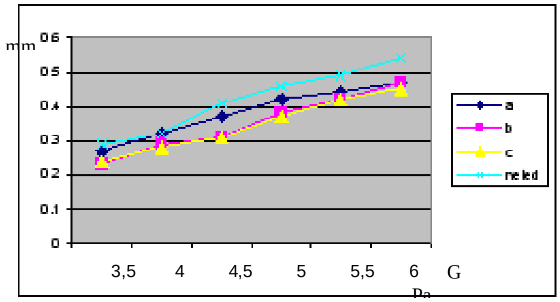


Figure 10 *Influence of the finishing degree upon the diameter of the plastic deformation*

The diameter of the contact plastic imprint is smaller in the case of a perfectly smooth surface than for the real rough surfaces

The paper presents a numerical approach with respect to the influence of the surfaces microtopography upon the dry technical circular contact in elasto-plastic domain, in the case of no-linear hardening.

A Φ = 6,35 mm ball with three different finishing stages (grinding, rough-polishing, smooth-polishing) was considered in this approach.

The geometry and the microtopography of each ball was measured with the "UBM 14" optical profilometer of the Department of Mechanical Engineering – University of Suceava and was represented both three-dimensional and bi-dimensional (axial section profile).

The numerical simulation software developed to this end was able to determine the pressure distribution and the plastic deformations of the contact (.depth and diameter of the plastic imprint) for 6 levels of the load which would determine in a contact of perfectly smooth surfaces maxim hertzian pressures of: 3; 3,5; 4; 4,5; 5; 5,5 and 6 Gpa. These results were represented both three-dimensional and bi-dimensional (axial section profile). Through a numerical simulation of the stress state it was possible to calculate and, consequently, to represent through "constant level curves" and other graphic representations, the normal as well as the subsuperficial and superficial stresses, either without friction, either in the presence of a tangential force corresponding to f=0.5 friction coefficient (for the ϕ=6,35 mm ball; finishing stage – grinding; hertzian pressure – 6 Gpa).

Maximum contact pressure decreases with the finishing degree, yet remains well above the values of contact pressures for perfectly smooth surfaces. The presence of microgeometical defects in contact area can perturb this behaviour. The bigger the load the smaller the influence of these defects which almost disappears over certain loads. Moreover, for higher degree of the finishing of the surface, that is of its smoothness, the shape and configuration of the pressure distribution is almost identical with the hertzian case.

The results hereby obtained revealed the next characteristics and peculiarities of the stress state which can be highlighted :

- the constant level curves representing the stresses have, under the contact surface, a peculiar shape with concentrations in the proximity of the microasperities ;
- the presence of the friction (friction coefficient f=0.5) has a significant influence on the stress state under the contact surface ;
- the variation of the orthogonal stresses shows that at a certain depth they become null ;
- on the contact surface only normal stresses have significant values, whereas tangential stresses have null or insignificant values;
- the equivalent stress Huber-Mises-Hencky has two peaks on the contact surface and in its close proximity ; for a f=0.5 friction coefficient the modification of the stress field shape

and the increase of its maximum value is noticed.

Using the value of the maximum hertzian pressure PH_{max} in order to obtain no-dimensional results, the maximum values of no-dimensional orthogonal stresses were calculated and presented in table 2

Table 2 Maximum values of no-dimensional orthogonal stresses

$\sigma_x n / PH_{max}$	$\sigma_y n / PH_{max}$	$\sigma_z n / PH_{max}$	$\tau_{xz} n / PH_{max}$
-0,705	-0,743	-1,394	-0,192
σ_x / PH_{max}	σ_y / PH_{max}	σ_z / PH_{max}	τ_{xz} / PH_{max}
-0,936	-0,723	-1,367	-0,507

Only $\sigma_x, \sigma_y, \sigma_z, \tau_{xz}$ stresses have been included in table 2 as they have a significant influence upon the strength of the materials in contact, all the other stresses are negligible.

The depth of the plastic deformation in the centre of the contact decreases with the finishing degree of the surface. The presence of microgeometical defects in central contact area can perturb this behaviour.

The depth of the maximum plastic deformation decreases with the finishing degree of the surface. This behaviour is more obvious for bigger loads.

The variation of the diameter of the plastic deformation with the finishing degree of the surfaces is negligible, even when compared with the case of perfectly smooth surfaces.

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