COMPARATIVE STUDY ON COLD PLASTIC DEFORMATION OF THE RACEWAY OF THE BEARING RINGS

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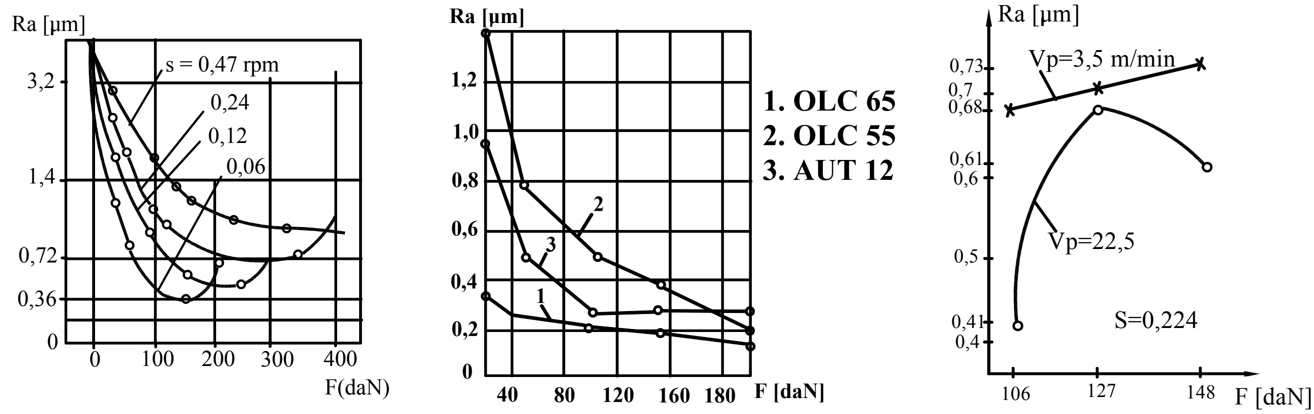
Abstract: This paper presents comparative results from cold plastic deformation on outer ring raceway of the two types of bearings: 6211 and 6309. The experimentation conditions, the variation diagrams of the shape deviation (ovality and circularity) and of the roughness of the raceway of the outer rings depending on deformation force, deformation feed and rotation speed of the roller. After the mathematic modeling of the experimental results, the comparative analysis and the conditions concerning the optimum processing conditions are presented.
Key words: plastic deformation, ovality, circularity, roughness, mathematic modeling.

1. INTRODUCTION

The cold plastic deformation processing has become widely used in the machine manufacturing industry for the manufacturing of motor vehicles, aircrafts, agricultural machines, etc. In comparison with chipping, forging, casting processes, the cold plastic deformation is characterized by high precision in terms of dimension and shape, superior quality of the processed surfaces, roughness and superficial layer, metal economy, increased productivity etc [Braha et al, 2003].

In literature there are works [Pruteanu et al, 2009; Leonte et al, 2010] which present the influence of some technological factors on the quality parameters of the processed surface. [Lupescu, 1999] presents calculation relations established by various researchers depending on the considered criterion: geometry of the tool and of the piece [Maier, Schneider], the rugosity of the run surface [Herold], the work parameters [Bokoiavlenscki] etc. One presented variation charts of the roughness of the surfaces depending on the deformation force for various levels of working feed figure 1-a, for various materials figure 1-b, for various speed rates figure 1-c. There are also variation charts of the roughness depending on the working feed for various materials figure 2-a, and for various speed rates figure 2-b.



a. b. c.

Fig.1. Influence of the deformation force on roughness for various: a. feed rates; b. materials; c. speed rates.

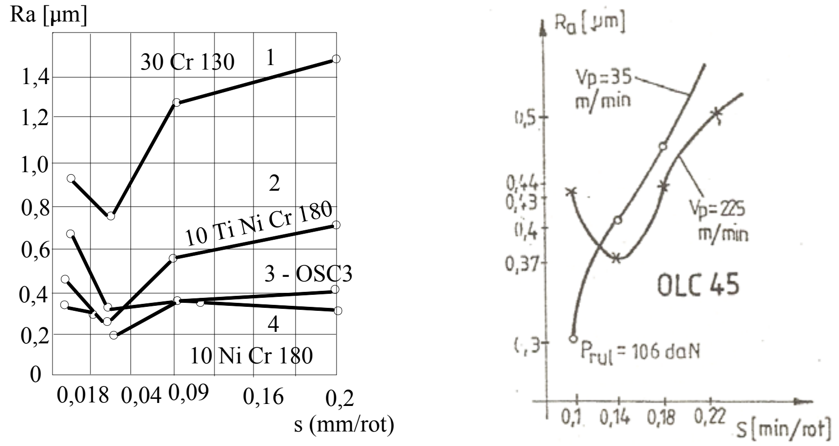
2. EXPERIMENTAL CONDITIONS

Experimental research was realized at SC Rulmenți SA Bârlad in the following conditions:

- *material*: 100Cr6 – specific to bearing manufacture,
- *unfinished goods*: warm forged and laminated outer rings for the types of bearings 6211 and 6203,
- *machine: special for the cold plastic deformation of the bearings, type CRF-120 OR, with the work parameters presented in table 1,*
- *tools*: specific to the machine and to the type of

bearing – mandrel and deformation roller,

- *measurement devices:* Taylor Hobson Formtalysurf.



a. b.

Fig.2. Influence of the feed rate on roughness for various: a. materials, b. speed rates

Table 1. Work parameters of the machine CRF-120 OR

Parameters	Range	Experimental values
Deformation force F [daN]	12100 - 17600	12100; 13200; 14300; 15400; 16500; 17600
Feed rate, s [mm/min]	30 – 50	30; 35; 40; 45; 50
Rotation speed of the s roller, n [rpm]	85 – 125	85; 90; 95; 100; 110; 120

3. EXPERIMENTAL FINDINGS

Experimental research was conducted on the two types of outer rings from bearings 6211 and 6309 by variation of one parameter at the values mentioned in table 1 and the maintaining of the other two parameters constant. The results are presented in table 2.

Table 2. Experimental results

Independent parameter	**6211-10**			**6309-10**		
	Ovality µm	Circularity µm	Roughness µm	Ovality µm	Circularity µm	Roughness µm
Force F [daN]	Variation of the deformation force, F [daN] / **constant** : n = [90 rpm] : s = 40 [mm/min]					
12100	13	130	0.28	15	150	0.24
13200	55	310	0.35	42	260	0.32
14300	30	180	0.33	27	240	0.34
15400	52	275	0.29	39	310	0.27
16500	48	300	0.28	31	290	0.30
17600	26	160	0.30	28	180	0.32
Feed rate s [mm/min]	Variation of the feed rate, s [mm/min] **constant** P= 15400[daN], n= 90 [rpm]					
30	42	255	0.085	34	170	0.10
35	32	195	0.10	28	185	0.12
40	36	180	0.15	30	210	0.22
45	39	210	0.12	33	205	0.14
50	44	220	0.18	37	200	0.19
Rotation speed of the roller n [rpm]	Variation of the rotation speed of the roller n [rpm] **constant** P = 15400[daN], s = 40[mm/ min]					
85	25	180	0.10	35	210	0.14
90	38	290	0.12	44	240	0.19
95	36	190	0.22	51	200	0.26
100	44	220	0.18	48	220	0.22
110	49	240	0.14	54	245	0.24
120	52	210	0.15	56	250	0.28

The figures 3-5 present the variation of the quality parameters (roughness, ovality and circularity) depending on the work parameters (deformation force, feed rate, rotation speed of the roller).

4. MATHEMATICAL MODELLING OF THE EXPERIMENT RESULTS

For the deduction of the relations of work parameters influences on quality parameters, the TableCurve 2D v5.01 is used.

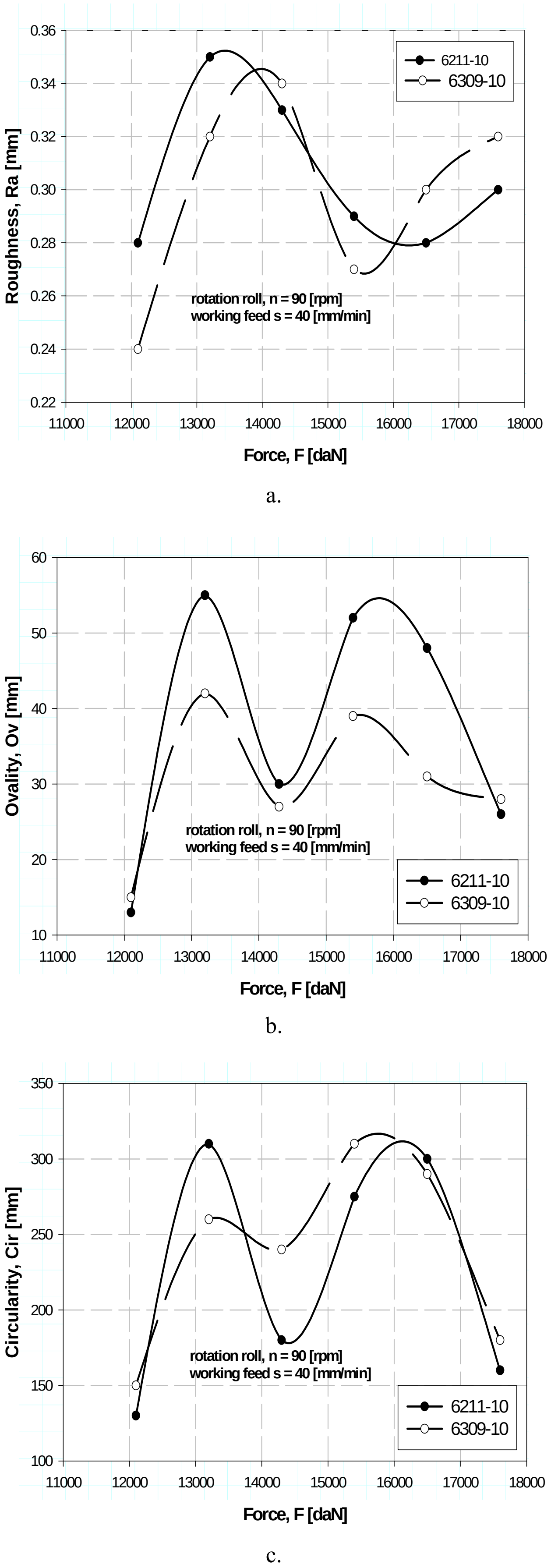


Fig. 3. Variation of the roughness (a.), ovality (b.) and circularity (c.) with the deformation force, F

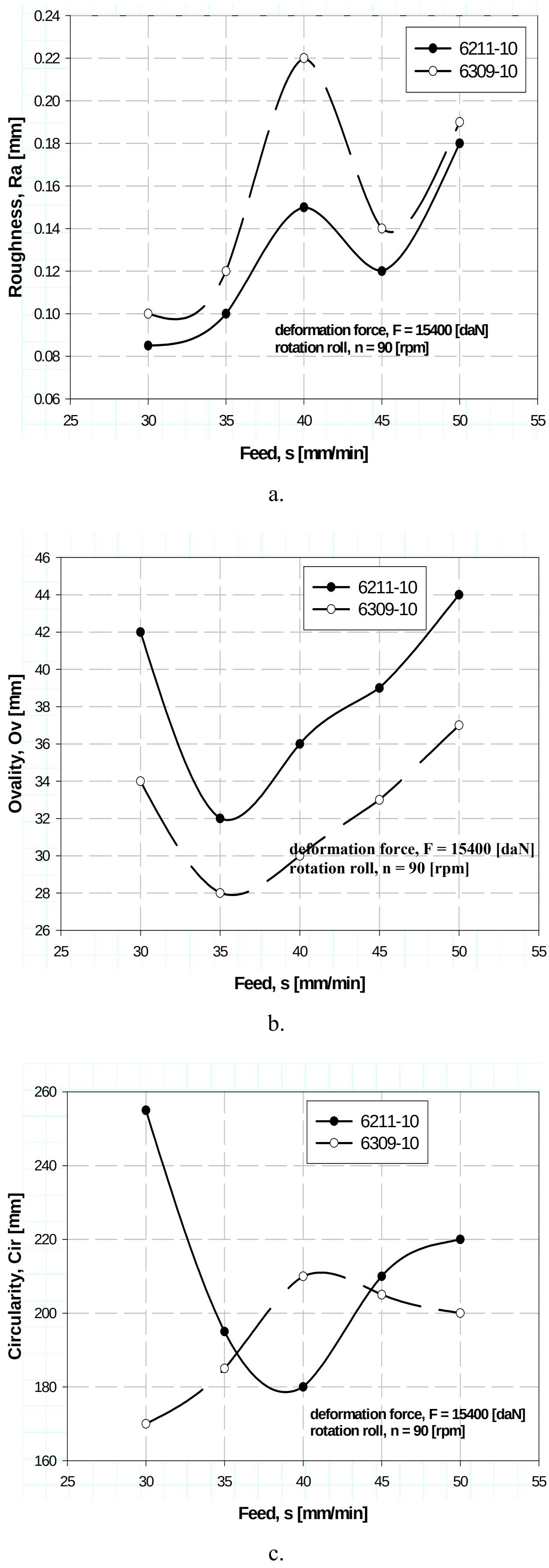
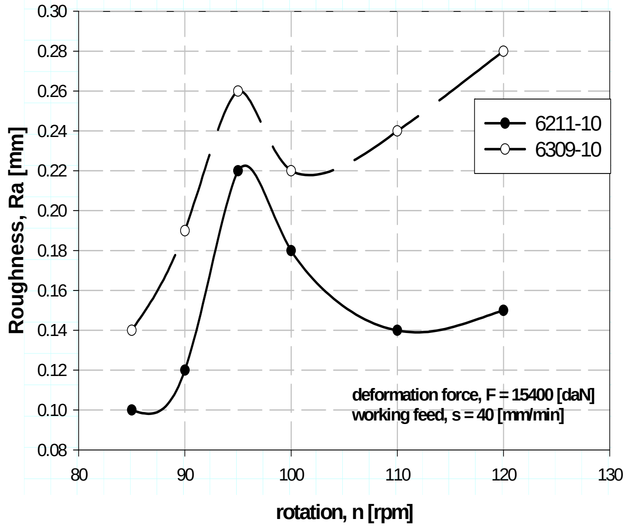
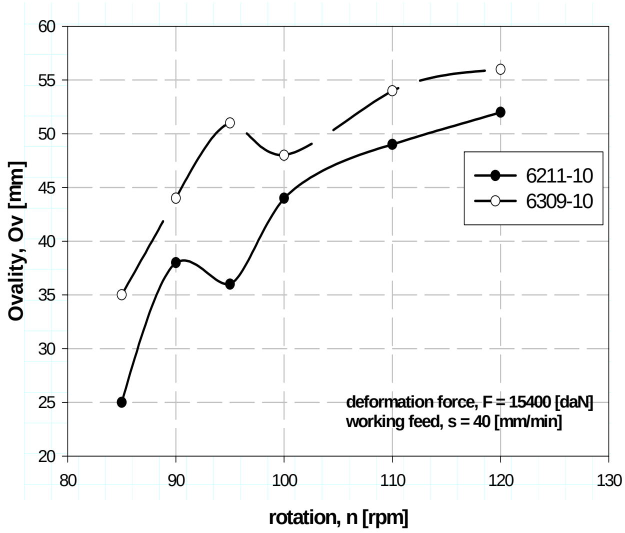


Fig. 4. Variation of the roughness (a.), ovality (b.) and circularity (c.) with the feed rate, s



a.



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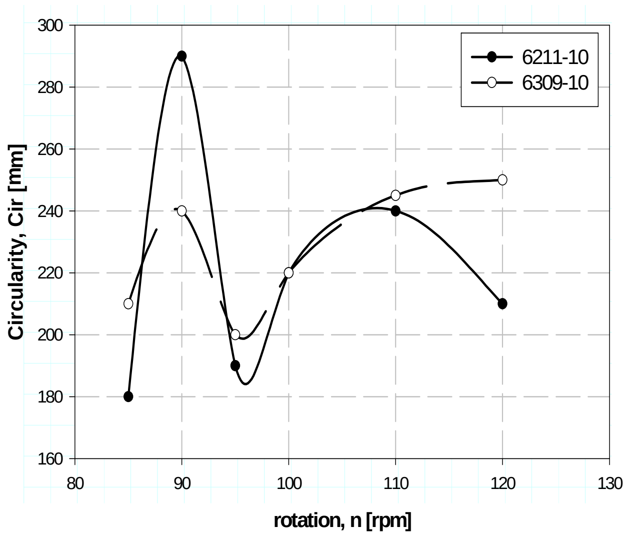
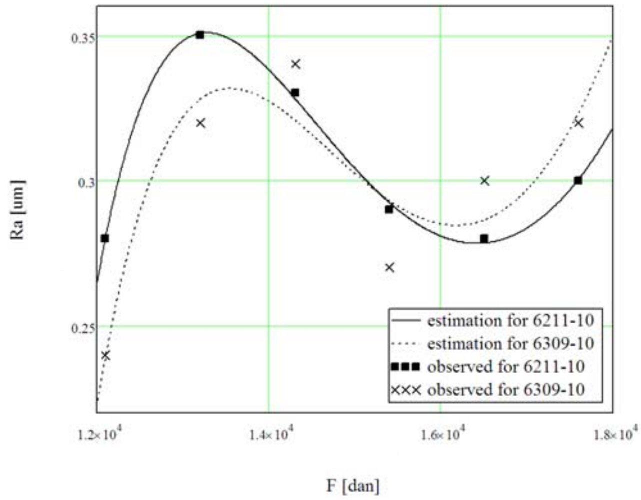


c.

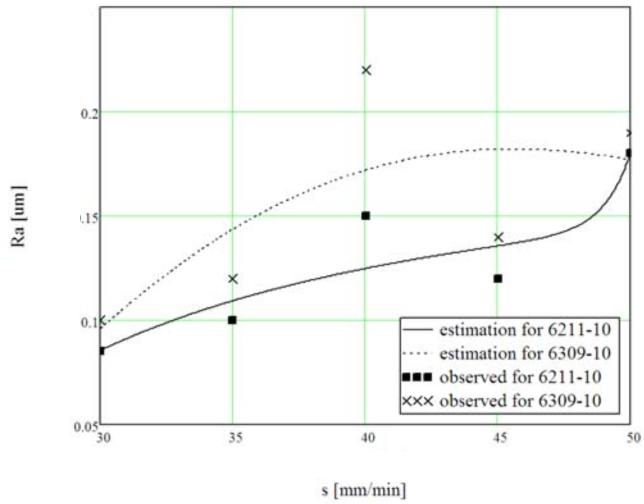
Fig. 5. Variation of roughness (a.), ovality (b.) and circularity (c.) with the rotation of the roller, n

The correlation coefficient R^2 was deducted, the estimated error, the significance test F was applied, and through comparison the most appropriate model was established for the experiment data [Levin, 1998]. The mathematic expression of the models which best describe the factor influences – deformation force, feed rate and rotation - on roughness, ovality and circularity are presented in table 3.

The graphical representation of these functions and the experimental values are presented in figures 6-7.



a.



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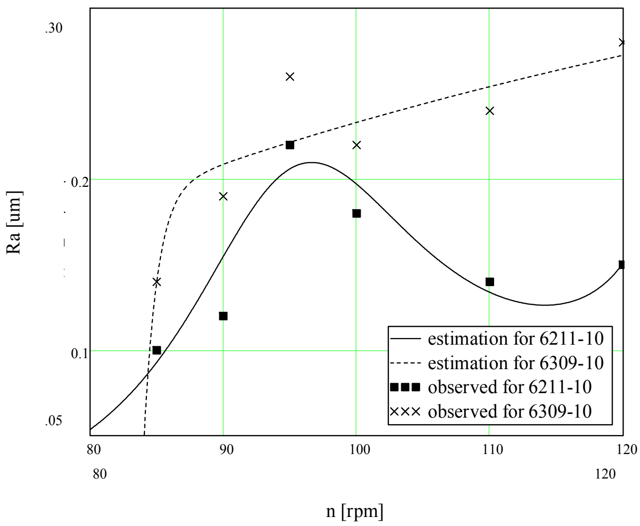
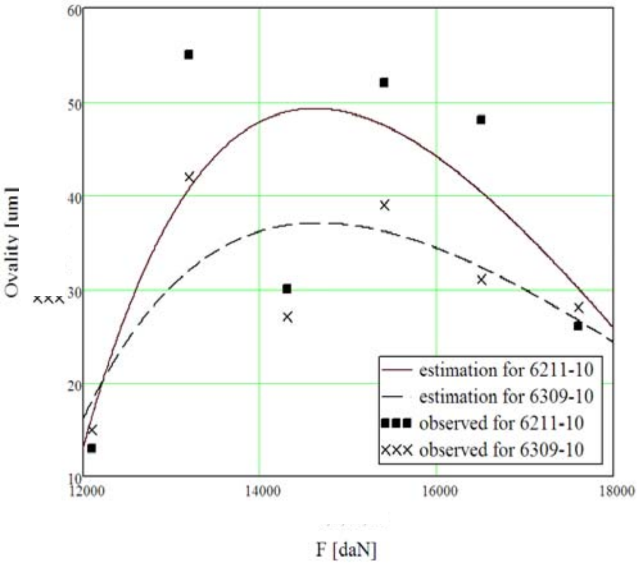


c.

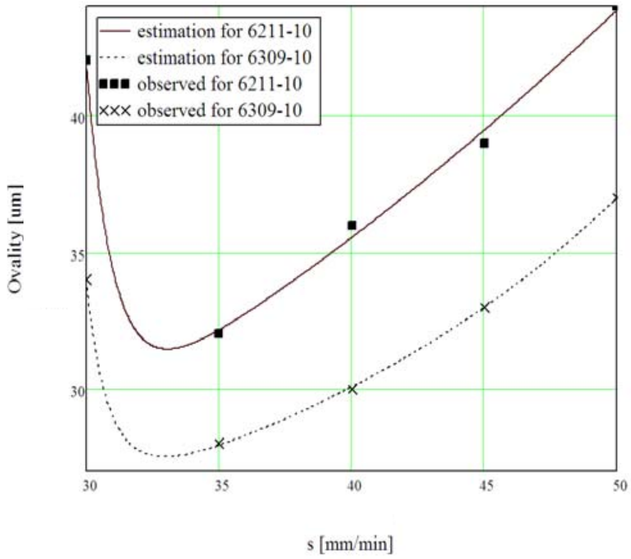
Fig. 6. Estimated influences of deformation force (a.), feed rates (b.) and rotation (c.) on roughness, Ra

Table 3. The mathematic expression of the models which describe the factor influences on roughness, ovality and circularity

Parameter	Factor	Ring	Mathematical expression	R^2	Significance test F
Rougness, Ra	Force, F	6211-10	$Ra = a + \frac{b}{F} + c\cdot\frac{\ln F}{F^2} + \frac{d}{F^2}$, with: a = 22.656; b = -1336876.8; c = 9.8856e+9; d = -8.003e+10	0.997	239.69
		6309-10	$Ra = a + b\cdot\ln F + c\cdot\frac{\ln F}{F} + \frac{d}{F}$, with: a = -1187.08; b = 102.29; c = 1516398.7; d = -11524812	0.832	3.3
	Feed, s	6211-10	$Ra = a + b\cdot e^{s} + \frac{c}{s^2}$, with: a = 0.1752; b = 7.1357e-24; c = -80.72	0.835	5.078
		6309-10	$Ra = a + \frac{b}{\ln s} + c\cdot\frac{\ln s}{s}$, with: a = -24.908; b = 148.51; c = -164.58	0.514	1.058
	Rotation, n	6211-10	$Ra = \frac{1}{a + b\cdot n + c\cdot n^2 + d\cdot n^3}$, with: a = 1347.16, b = -38.71; c = 0.3699; d = -0.00117	0.8065	2.779
		6309-10	$Ra = a + \frac{b}{\ln n} + c\cdot e^{-n}$, with: a = 1.265; b = -4.7496; c = -4.573e+35	0.825	7.07
Ovality, Ov	Force, F	6211-10	$Ov = a + b\cdot\frac{\ln F}{F^2} + \frac{c}{F^2}$, with: a = -306.05; b = 1.519e+11; c = -1.381e+12	0.529	1.683
		6309-10	$Ov = a + b\cdot\frac{\ln F}{F^2} + \frac{c}{F^2}$, with: a = -161.2; b = 8.525e+10; c = -7.752e+11	0.532	1.705
	Feed, s	6211-10	$Ov = a + b\cdot s^2 + c\cdot e^{-s}$, with a = 20.756; b = 0.0092; c = 1.38e+14	0.995	190.6
		6309-10	$Ov = \frac{1}{a + b\cdot s^2 + c\cdot e^{-s}}$, with a = 0.0443; b = -6.909e-6; c = -9.27e+10	0.9998	5639.5
	Rotation, n	6211-10	$Ov = \sqrt{a + \frac{b}{n^2}}$, with a = 4849.53; b = - 30102524	0.937	59.897
		6309-10	$Ov = \sqrt{a + \frac{b}{n^2}}$, with a = 5202.78; b = -27570432	0.887	31.508
Circularity, Cir	Force, F	6211-10	$Cir = a + b\cdot F^2 + c\cdot F^4$, with a = -623.85; b = 7.777e-6; c = 1.674e-14	0.835	5.079
		6309-10	$Cir = a + b\cdot F^2 + c\cdot F^4$, with a = -739.46; b = 8.888e-6; c = 1.901e-14	0.514	1.06
	Feed, s	6211-10	$Cir = a + b\cdot s^2 + c\cdot s^4$, with a = 582.204; b = -1177014; c = 3708704.6	0.835	5.079
		6309-10	$Cir = \frac{1}{a + \frac{b}{\ln s} + c\cdot\frac{\ln s}{s}}$, with: a = 0.4744; b = -2.77; c = 3.055	0.514	1.058
	Rotation, n	6211-10	$Cir = a + b\cdot\frac{\ln n}{n^2} + \frac{c}{n^2} + d\cdot e^{-n}$, with: a=1029.975; b = -18790161; c = 78380667; d = -1.1865e+39	0.8065	2.779
		6309-10	$Cir = a + b\cdot x + \frac{c}{\ln x} + \frac{d}{\sqrt{n}}$, with: a = 46262991; b = -7351.03; c = -3.5865e+8; d = 3.235e+8	.825	7.07



a.



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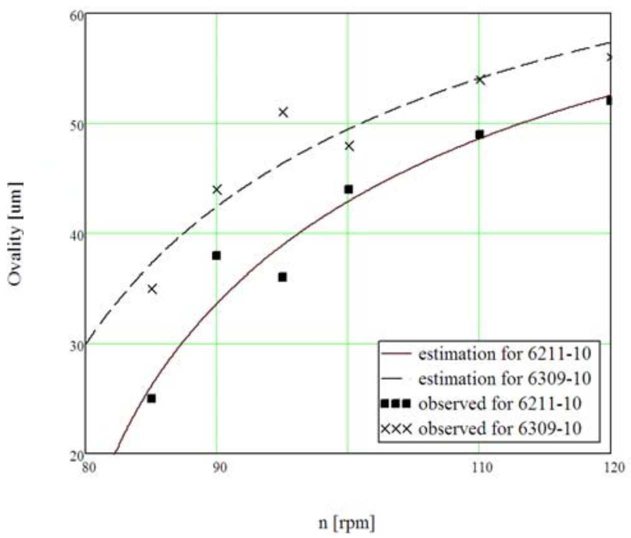

c.

Fig. 7. Estimated influences of deformation force (a.), feed rates (b.) and rotation (c.) on ovality

5. CONCLUSIONS

Following the graphic representation of the values of the quality parameters depending on the work parameters of the machine to be processed by cold plastic deformation, one can reach the following conclusions:

- the increase of the deformation force, there occurs an increase on the roughness for both types of bearings, fig. 3-a, with smaller values being registered at the 6309-10 type as a result of a bigger contact surface between the race and the roller; the same aspect also occurs in fig. 1-a;
- the shape, ovality and circularity deviations, fig. 3-b and fig. 3-c generally increase by the increase of the deformation force up to the force of 16500 [daN] with one exception at the force of 14300 [daN], after which one may notice a relatively small increase of deviations. The cause of this variation can be explained by the vibrations and self-vibrations in the technological system;
- feed rate, the roughness of the processed surfaces also increases, fig. 4-a, with a bigger influence on the ring 6309-10, as well as on shape deviations, fig. 4-b and fig. 4-c, with a reduction around the value of 35-40 mm/min; the same tendency may be noticed in fig. 2-a and 2-b of the specialized literature. This tendency can be explained via the bigger sizes of the contact surface between the unfinished goods and the roller.

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Received: December 14, 2010 / Accepted: May 30, 2011 / Paper published online: June 10, 2011