# INFLUENCE OF DEFORMATION FEED ON THE ROUGHNESS AND SHAPE PRECISION OF COLD WORKED SURFACES

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***Abstract:*** The paper describes the outcome of our experimental research achieved further to the cold working of the running tracks of two types of radial ball bearings. It tackles the influence of deformation feed on the roughness and shape deviations – out-of-roundness and circularity – suffered by the running tracks. The values thus obtained are shown in the tables and illustrated in the figures, and they ground our conclusions related to the favorable influence intervals.
***Key words:*** plastic deformation, feed, roughness, out-of-roundness, circularity.

## 1. INTRODUCTION

The cold or hot working issue is very old and it is generally known and used in the machinery construction industry. Scientists of famous schools from the former Soviet Union, Germany, Japan, USA, etc., plus the Romanian ones (Gavrilaş, I. & Maier, A., 1987; Ishikawa, H., et al, 1990; Muscă, G. & Rusu, B., 1993; Pruteanu, O.V. & Neagu, S., 1990), have been interested in the influence of the working parameters of surface or deep plastic deformation on the operation characteristics of the parts. The technological development has brought about the development of operation equipment: machinery, devices, tools.
Given its unquestionable advantages, the plastic deformation method (Pruteanu, O.V. & Neagu, S., 1990; Pruteanu, O.V. et al, 2008; Nedelcu, D., et al., 2009) was first used in the bearing manufacture industry in Romania by SC Rulmenți SA Bârlad, in order to process the running tracks of radial ball bearings, further to a research contract concluded with the TCM (Machinery Construction Technology) Department of the "Gh. Asachi" Technical University of Iaşi City. The object of the contract was the research carried out on the influence of the equipment operation parameters (deformation force and feed, number of revolutions of the half-finished product driving roll) on the quality parameters of the bearings' running tracks (roughness, out-of-roundness and circularity).

## 2. EXPERIMENTAL CONDITIONS

For our experimental research we used the existing equipment of SAC Rulmenți SA Bârlad, that is:
a. material: 100Cr6 – specific for bearing manufacture, having the mechanical characteristics in table 1;
b. half-finished product: hot formed and rolled rings, with sizes corresponding to the types of bearing they are supposed to fit;
c. equipment: special CRF 120 OR machinery for outer rings (figure 1) and CRF 70 IR for inner rings;

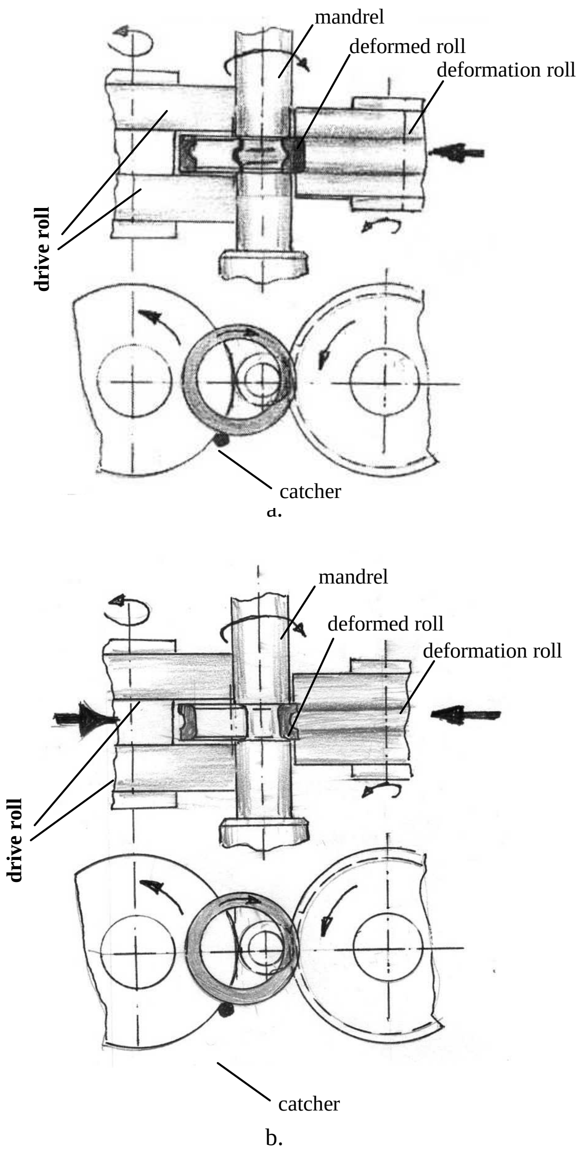



Fig. 1. Working diagram: a. CRF 120 OR; b. CRF 70 IR

d. tools: properly shaped mandrels and rolls, corresponding to the shapes of the types of bearing they are supposed to fit;

e. measurement and control devices:

- for roughness: Taylor Hobson Formtalysurf, series 2,
- for shape deviations: Perthometyer Marsurf CD 120.

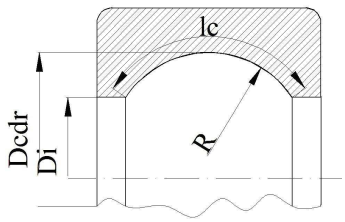
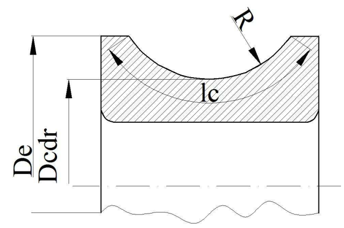
## 3. EXPERIMENTAL RESULTS

Table 2 shows the results achieved further to the processing of 6207 and 6210 bearing rings, concerning the roughness, out-of-roundness and circularity of their cold-worked running tracks.

Table 1. Mechanical characteristics of the 100Cr6 material

| 100Cr6 | Force 0.2 daN | Ultimate strength daN | Yield point $F_{p0,2}$ daN/mm$^2$ | Stretching resistance Rm daN/mm$^2$ | Elongation at rupture A % | Hardness HB |
|---|---|---|---|---|---|---|
| rolled | 7510-7550 | 51.50-52.50 | 82.45-95.60 | 97.75 – 113.30 | 3 - 5 | 329 - 345 |
| annealed | 5120 | 53.50 | 65.20 | 72.50 | 7 | 219 |

Table 2. Experimental results

| Ring | Feed A [mm/min] | Roughness Ra [µm] | Out-of-roughness Ov [mm] | Circularity deviation Cir [µm] | Figure |
|---|---|---|---|---|---|
| **6207 – 10** | F = 140 kN; n = 95 rpm* | | | |  |
| $D_{cdr}$=64,26 mm | 28 | 0.46 | 0.27 | 21.0 | |
| $D_i$ = 60,20 mm | 30 | 0.41 | 0.20 | 16.0 | |
| R = 5,20 mm | 32 | 0.45 | 0.24 | 17.0 | |
| $l_c$ = 9,50 mm | 34 | 0.42 | 0.18 | 10.0 | |
| **6210 – 10** | F = 140 kN; n = 95 rpm | | | | |
| $D_{cdr}$=82,40 mm | 28 | 0.09 | 0.63 | 378.0 | |
| $D_i$ = 77,90mm | 30 | 0.12 | 0.42 | 255.0 | |
| R = 6,67 mm | 32 | 0.18 | 0.42 | 237.0 | |
| $l_c$ = 11,30 mm | 34 | 0.10 | 0.32 | 196.0 | |
| **6207 – 20** | F = 57 kN; n = 95 rpm | | | |  |
| De=46,95 mm | 35 | 0.41 | 0.32 | 142.0 | |
| $D_{cdr}$=42,60mm | 40 | 0.45 | 0.10 | 93.0 | |
| R = 5,61 mm | 45 | 0.43 | 0.20 | 113.0 | |
| $l_c$ = 10,20 mm | 50 | 0.37 | 0.12 | 63.0 | |
| **6210 – 20** | F = 57 kN; n = 95 rpm | | | | |
| De=62,35 mm | 35 | 0.40 | 0.16 | 184.0 | |
| $D_{cdr}$=57,50mm | 40 | 0.27 | 0.07 | 63.0 | |
| R = 6,24 mm | 45 | 0.26 | 0.22 | 194.0 | |
| $l_c$ = 11,40 mm | 50 | 0.27 | 0.21 | 197.0 | |

* F – deformation force; n – driving roll rotations/min

The results in table 2 enjoy a graphic representation in figures 2 – 7, where F – deformation force, KN; n – number of revolutions of the roll, rpm; v – half-finished product rotation speed, m/min; De – external diameter of the half-finished product, mm; Dcdr - diameter of the running track, mm; R- radius of the running track, mm; lc – length of the contact arch, mm.

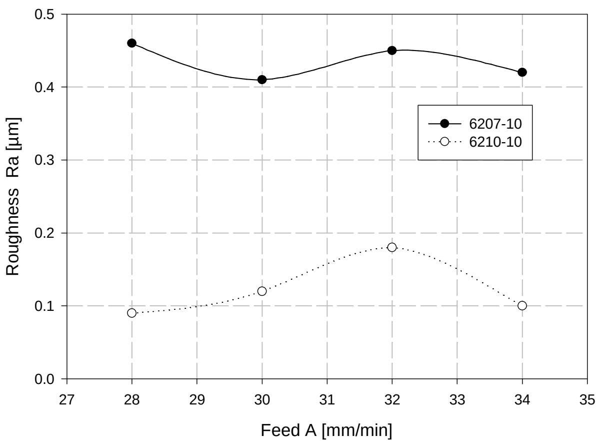



Fig. 2. Influence of the feed on the roughness of the bearing external rings (10)

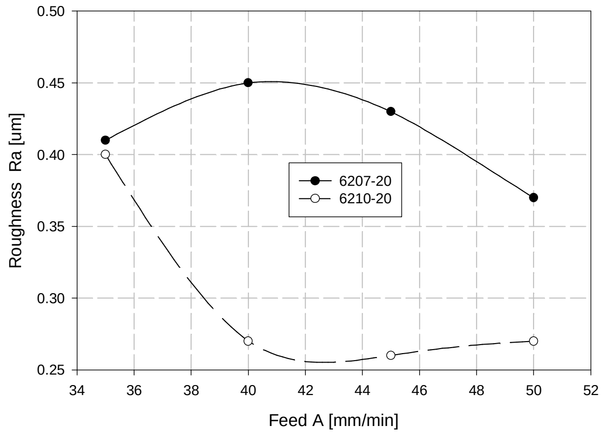



Fig. 3. Influence of the feed on the roughness of the bearing internal rings (20)

## 4. MATHEMATICAL MODELLING OF THE EXPERIMENT RESULTS

For the deduction of empirical relations and the representation of work parameters influences, the following functions were taken into account:

$F_1(x) = a + b.x$ – linear function

F2(x) = a.$e^{b.x}$ – exponential function
$F_3$(x) = a+b.1n x – logarithmic function
$F_4$(x) = a+b/x – inverted function
$F_5$(x) = a+b.x + c.$x^2$ – quadric function

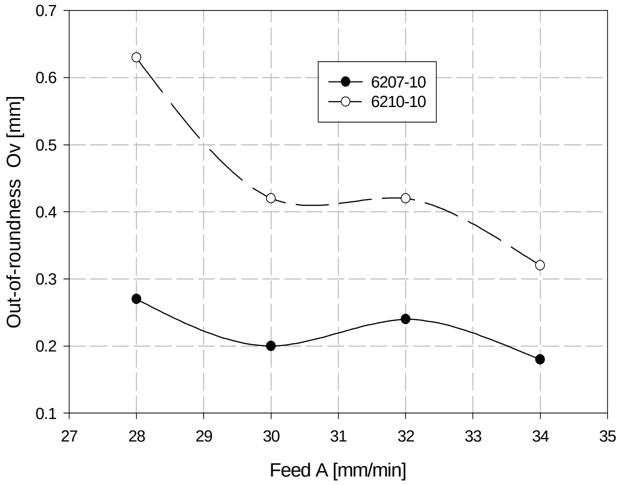



Fig. 4. Influence of the feed on the out-of-roundness of the bearing external rings (10)

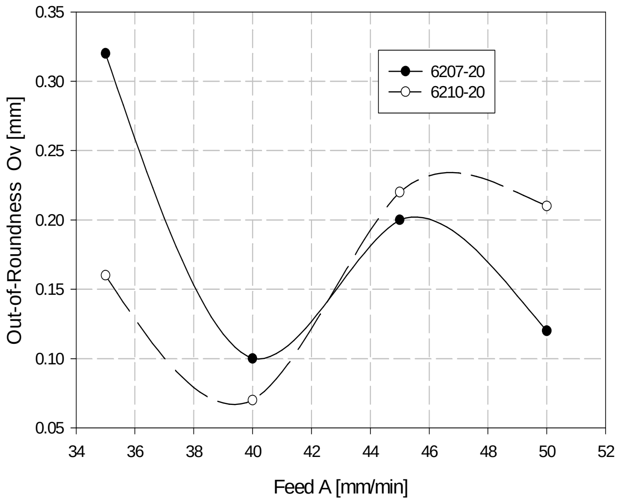



Fig. 5. Influence of the feed on the out-of-roundness of the bearing internal rings (20)

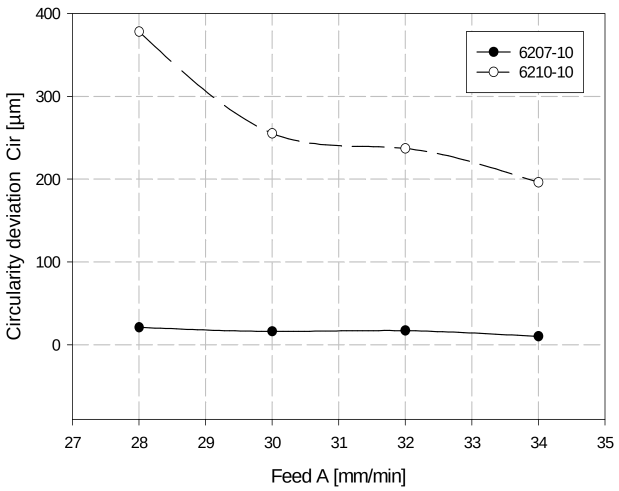



Fig. 6. Influence of the feed on the circularity deviation of the bearing external rings (10)

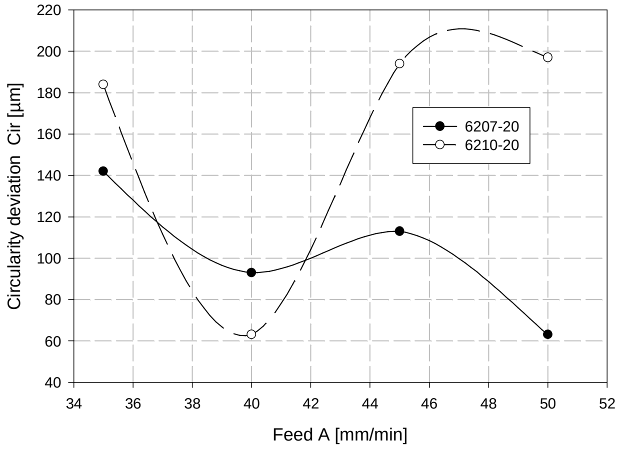



Fig. 7. Influence of the feed on the circularity deviation of the bearing internal rings (20)

The correlation coefficient R was deducted, the estimated error, the significance test F was applied, and through comparison, the most appropriate model was established for the experiment data. The data processing and realization of tested empirical models' graphics were done with the help of the SPSS program version 13.0.

Based on the values mentioned in table 2, the coefficients functions were deducted in the tabels 3-8. The mathematic expression of the models that best describes the deformation feed influence on roughness, ovality and circularity are presented in relations 1-6.

Table 3. Estimated parameters of the model Ra=f(A) for 6210-10 ring

| Model type | The model sinthesis | | | | | Estimated parameters | | |
|---|---|---|---|---|---|---|---|---|
| | $R^2$ | F | df1 | df2 | Signi-ficance | a | b | c |
| Linear | .083 | .181 | 1 | 2 | .712 | -.017 | .005 | |
| Loga-rithmic | .096 | .213 | 1 | 2 | .690 | -.391 | .150 | |
| Inverted | .110 | .248 | 1 | 2 | .668 | .282 | -4.928 | |
| Quadra-tic | .704 | 1.187 | 2 | 1 | .544 | -6.589 | .431 | -.007 |
| Expo-nential | .093 | .206 | 1 | 2 | .695 | .039 | .036 | |

$$Ra = -6.589 + 0.431 \cdot A - 0.007 \cdot A^2 \quad (\mu m) \quad (1)$$

Table 4. Estimated parameters of the model Ra=f(A) for 6210-20 ring

| Model type | The model sinthesis | | | | | Estimated parameters | | |
|---|---|---|---|---|---|---|---|---|
| | $R^2$ | F | df1 | df2 | Signi-ficance | a | b | c |
| Linear | .597 | 2.963 | 1 | 2 | .227 | .640 | -.008 | |
| Loga-rithmic | .647 | 3.660 | 1 | 2 | .196 | 1.609 | -.350 | |
| Inverted | .695 | 4.556 | 1 | 2 | .166 | -.061 | 15.062 | |
| **Quadra-tic** | **.963** | **12.900** | **2** | **1** | **.193** | **3.125** | **-.127** | **.001** |
| Expo-nential | .595 | 2.943 | 1 | 2 | .228 | .830 | -.024 | |

$$Ra = 3.125 - 0.127 \cdot A + 0.001 \cdot A^2 \quad (\mu m) \quad (2)$$

Table 5. Estimated parameters of the model Ov=f(A) for 6210-10 ring

| Model type | The model sinthesis | | | | | Estimated parameters | | |
|---|---|---|---|---|---|---|---|---|
| | $R^2$ | F | df1 | df2 | Signi-ficance | a | b | c |
| Linear | .543 | 2.372 | 1 | 2 | .263 | .579 | -.012 | |
| Loga-rithmic | .546 | 2.405 | 1 | 2 | .261 | 1.446 | -.356 | |
| **Inverted** | **.549** | **2.438** | **1** | **2** | **.259** | **-.134** | **11.007** | |
| Quadra-tic | .548 | .605 | 2 | 1 | .673 | 1.177 | -.050 | .001 |
| Expo-nential | .541 | 2.356 | 1 | 2 | .265 | 1.092 | -.052 | |

$$Ov = -0.134 + \frac{11.007}{A} \quad (mm) \qquad (3)$$

Table 6. Estimated parameters of the model Ov=f(A) for 6210-20 ring

| Model type | The model sinthesis | | | | | Estimated parameters | | |
|---|---|---|---|---|---|---|---|---|
| | $R^2$ | F | df1 | df2 | Signi-ficance | a | b | c |
| Linear | .418 | 1.437 | 1 | 2 | .353 | .610 | -.010 | |
| Loga-rithmic | .447 | 1.620 | 1 | 2 | .331 | 1.812 | -.435 | |
| **Inverted** | **.477** | **1.827** | **1** | **2** | **.309** | **-.262** | **18.648** | |
| Quadra-tic | .582 | .696 | 2 | 1 | .647 | 3.095 | -.129 | .001 |
| Expo-nential | .306 | .880 | 1 | 2 | .447 | 1.126 | -.045 | |

$$Ov = -0.262 + \frac{18.648}{A} \quad (mm) \qquad (4)$$

Table 7. Estimated parameters of the model Cir=f(A) for 6210-10 ring

| Model type | The model sinthesis | | | | | Estimated parameters | | |
|---|---|---|---|---|---|---|---|---|
| | $R^2$ | F | df1 | df2 | Signi-ficance | a | b | c |
| Linear | .864 | 12.723 | 1 | 2 | .070 | 1140.700 | -28.200 | |
| Loga-rithmic | .880 | 14.677 | 1 | 2 | .062 | 3283.817 | -879.332 | |
| Inverted | .895 | 17.038 | 1 | 2 | .054 | -618.690 | 27297.643 | |
| Quadra-tic | .955 | 10.734 | 2 | 1 | .211 | 6040.200 | -345.950 | 5.125 |
| **Expo-nential** | **.913** | **20.956** | **1** | **2** | **.045** | **6143.029** | **-.102** | |

$$Cir = 6143.029 \cdot e^{-0.102 \cdot A} \quad (\mu m) \qquad (5)$$

Table 8 Estimated parameters of the model Cir=f(A) for 6210-20 ring

| Model type | The model sinthesis | | | | | Estimated parameters | | |
|---|---|---|---|---|---|---|---|---|
| | $R^2$ | F | df1 | df2 | Signi-ficance | a | b | c |
| Linear | .116 | .261 | 1 | 2 | .660 | 15.000 | 3.400 | |
| Loga-rithmic | .095 | .209 | 1 | 2 | .692 | -324.851 | 129.480 | |
| Inverted | .075 | .161 | 1 | 2 | .727 | 273.755 | -4770.86 | |
| **Quadra-tic** | **.423** | **.366** | **2** | **1** | **.760** | **2216.0** | **-102.0** | **1.24** |
| Expo-nential | .095 | .210 | 1 | 2 | .692 | 46.861 | .027 | |

$$Cir = 2216 - 102 \cdot A + 1.24 \cdot A^2 \quad (\mu m) \qquad (6)$$

## 5. CONCLUSIONS

- the roughness of the 6207 outer and inner bearing rings running tracks has approximately the same values, varying between 0.40 and 0.46 μm, with a difference of only 0.06 μm, the lowest values being those for the 34 and 50 mm/min feed, respectively (the maximum feeds employed). The same conclusions may be drawn about the roughness of the outer and inner rings of the 6210 type bearing, in which the best results were achieved for the same maximum feed values,
- the out-of-roundness of the 6207 outer and inner bearing ring running track varies between 0.10 and 0.27 mm, with minimum values for maximum feed; the out-of-roundness of the 6210 bearing ring varies considerably, from 0.07 mm for the 40 mm/min feed in the inner ring, to 0.63 mm for the 28 mm/min feed in the outer ring. The minimum out-of-roundness values for these rings occur when the deformation feeds are (34 – 40)mm/min,
- ring circularity also varies significantly for both of the rings of the two types of bearings, from 10μm up to 378μm. The minimum values vary, for all the rings, within the (34 – 40)mm/min feed interval.

## 11. REFERENCES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