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BEARING RINGS PROCESSING BY COLD PLASTIC DEFORMATION

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Cold plastic deformation is high productivity processing solution of bearing rings. In this paper, experimental research aimed at establishing the influence of the deformation feed on quality parameters (roughness, out-of-roundness and circularity deviations of bearing rings raceways). The bearing rings raceways from the current production of SC Rulmenţi SA Bârlad have been processed by cold plastic deformation. The paper presents the results of the aforementioned quality parameters based on the limit values of technological equipment for working parameters (deformation force 18000 daN, rapid feed 180 mm/min, work feed 30 - 50 mm/min). There are graphs of variation of roughness, out-of-roundness and circularity deviations for different values of the work feed; then, by mathematical processing using specific functions (linear, logarithmic, reversed, square, exponential), were established empirical relationships.

Keywords: cold plastic deformation, feed, roughness, out-of-roundness, circularity deviations

Prelucarea prin deformare plastică la rece este o soluţie de prelucrare a inelelor de rulmenţi de înaltă productivitate. În această lucrare, cercetarea experimentală urmăreşte stabilirea influenţei avansului de deformare asupra unor parametri calitativi ai procesului (rugozitatea, ovalitatea şi abaterea de la circularitate a căilor de rulare a inelelor de rulmenţi). Căile de rulare a inelelor de rulmenţi din producţia curentă a S.C. Rulmenţi Bârlad SA au fost prelucrate prin deformare plastică la rece. Lucrarea prezintă rezultatele obţinute asupra parametrilor calitativi mai sus menţionaţi la prelucrarea pe echipamentul tehnologic oentru parametrii de lucru (forţa de deformare 18000 daN, avansul rapid 180 mm/min, avansul de lucru cuprins între 30-50 mm/min). Sunt prezentate graficele de variaţie a rugozităţii, ovalităţii şi abaterii de la circularitate pentru diferite valori ale avansului de lucru. Ulterior, prin prelucrarea matematică utilizând diferite funcţii specifice (liniară, logaritmică, inversă, pătratică, exponanţială) au fost stabilite relaţiile empirice ale acestor variaţii.

Cuvinte-cheie: deformare plastică la rece, avans, rugozitate, ovalitate, abaterea de la circularitate

INTRODUCTION

Cold plastic deformation has taken a relatively large expansion at the expense of mechanical processing by cutting [1]. Among the main advantages compared to mechanical processing by cutting we can mention:

- material savings by using almost entirely the blank material,
- high productivity due to multiple possibilities of mechanization and automation of production,
- dimentional and shape accuracy of products,
- high roduct quality, low cost etc.

Processing has become widespread in the motor industry: electrical machinery and appliances, vehicle construction, fine mechanics and construction of agricultural machinery [2].

Due to the development of the motor industry, special machines for cold plastic deformation of metals were designed and built. These include special machines of Japanese origin that are used for processing by cold deformation of bearing rings raceways - CRF 120 OR used for outer rings processing and CRF 70 IR used for inner rings processing. Both products were purchased by SC Rulmenţi SA Bârlad for processing by cold plastic deformation of outer and inner rings of deep groove ball bearings raceways, with a possibility of extension to the processing of cylindrical and tapered rolls bearings raceways [3, 4, 5].

EXPERIMENTATION CONDITION

The eperiments have been conducted at SC Rulmenti SA Bârlad and the following materials were used during experimentation:

- material: bearing steel 100Cr6;
- hot rolled and forged blank material;
- special equipment CRF 120 OR for proccessing outer rings raceways;
- measuring and control devices;
- Taylor Hobson – for measuring roughness, Perthometer Marsurf CD120 – for measuring shape deviations.

RESULTS

During the experiment the outer ring raceway of the bearing 6207-10 was processed by cold plastic deformation.

We have followed the influence that the deformation advance f [mm/min] had on the quality parameteres: roughness of the processed surfaces Ra [µm], out-of-roundness [mm], circularity deviation [µm].

The tests were carried out with a variable deformation advance, while maintaining a constant deformation force and piece roundness.

The values shown in Table 1 were obtained as a result.

Table 1. Quality parameters according to the deformation feed.
Deformation force F =6.5 MPa;
workpiece revolution n = 95 rpm

Feed, f [mm/min]	Roughness Ra [µm]	Out-of-roundness [mm]	Circularity deviation [µm]
28	0.46	0.27	20.77
30	0.41	0.20	15.85
32	0.45	0.24	17.22
34	0.42	0.18	10.33

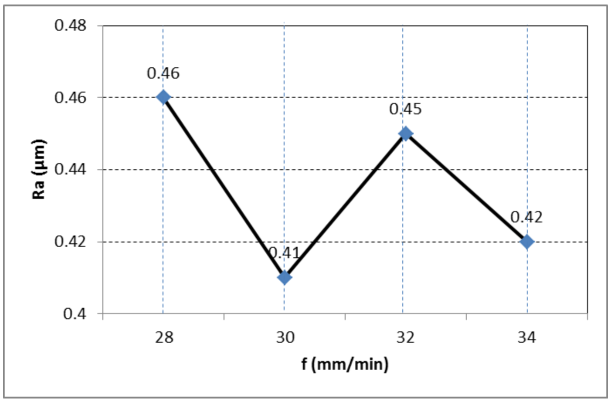

Fig. 1. Influence of the deformation feed (f) on roughness

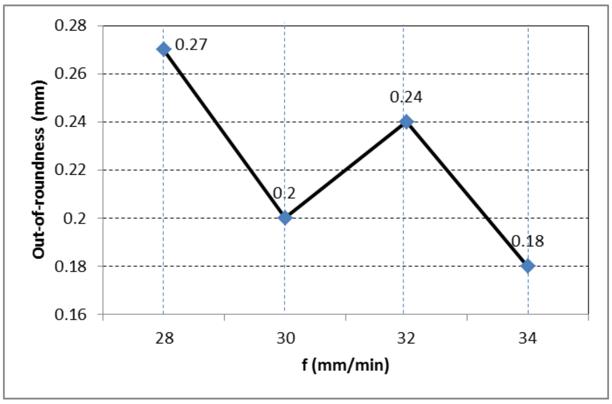

Fig. 2. Influence of the deformation feed (f) on the out-of-roundness

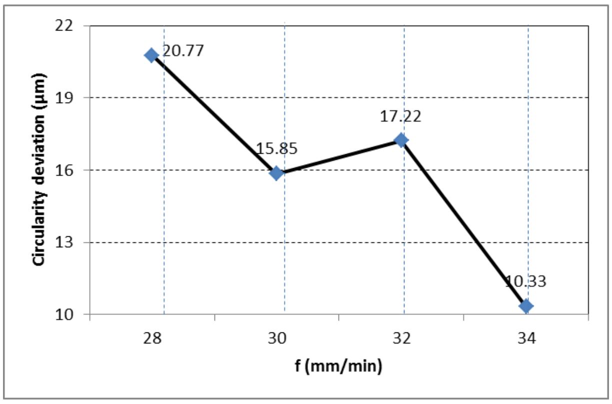

Fig. 3. Influence of the deformation feed on circularity deviations

Graphical representation of the quality parameters based on the deformation feed is shown as follows: fig. 1 – the raceway roughness, fig. 2 – the out-of-roundness and fig. 3 – the circularity deviations.

MATHEMATICAL PROCESSING OF EXPERIMENTAL DATA

The experimental data were statistically processed in order to obtain empirical relations that describe the influence of operating parameters on the quality parameters. In order to achieve the empirical relations, the following functions have been taken into consideration:

$F_1(x) = a.x + b$ - *linear function,* $F_2(x) = a.e^{b.x}$ - *exponential function,*

$F_3(x) = a + b.\ln x$ - *logarithmic function,* $F_4(x) = a + b/x$ - *reverse function*

$F_5(x) = a + b.x + c.x^2$ = *square function.*

The correlation coefficient R has been deducted, the error has been estimated, the F test for significance has been applied and by comparison, the most suitable model for the experimental data has been established.

The data processing and the graphic representation of the tested empirical models have been perfomed using SPSS vcer. 23.0.

The influence of the deformation feed on the roughness of bearing rings raceways is shown in Table 2. The influence of the deformation feed on the out-of-roundness is shown in Table 3 and Table 4 shows the influence of the deformation feed on the circularity deviations.

Table 2. Estimated parameters of the model.
Dependent variable: roughness, Ra.
Independent variable: deformation feed, f

Model type	Model synthesis					Estimated parameters		
	R^2	F	f1	df2	Significance level	a	b	c
linear	0.217	0.554	1	2	0.534	0.558	-0.004	
logarithmic	0.226	0.584	1	2	0.525	0.862	-0.125	
reverse	**0.235**	**0.615**	**1**	**2**	**0.515**	**0.309**	**3.872**	
square	0.295	0.209	2	1	0.840	1.691	-0.078	0.001
exponential	0.208	0.525	1	2	0.544	0.573	-0.009	

The mathematical expression of the model that best describes the influence of the deformation feed on the roughness is:

$$Ra = 0.309 + 3.872/f, [\mu m] \qquad (1)$$

Fig. 4 shows the graphical variation of experimental functions regarding the influence of the deformation feed on the roughness of the bearing rings raceways.

The influence that the deformation feed has on the out-of-roundness of bearing rings raceways processed using cold plastic deformation is shown in Table 3.

The mathematical expression of the model that best describes the influence of the deformation feed on the out-of-roundness is:

$$Ov = - 0.112 + 10.272/f, [mm] \qquad (2)$$

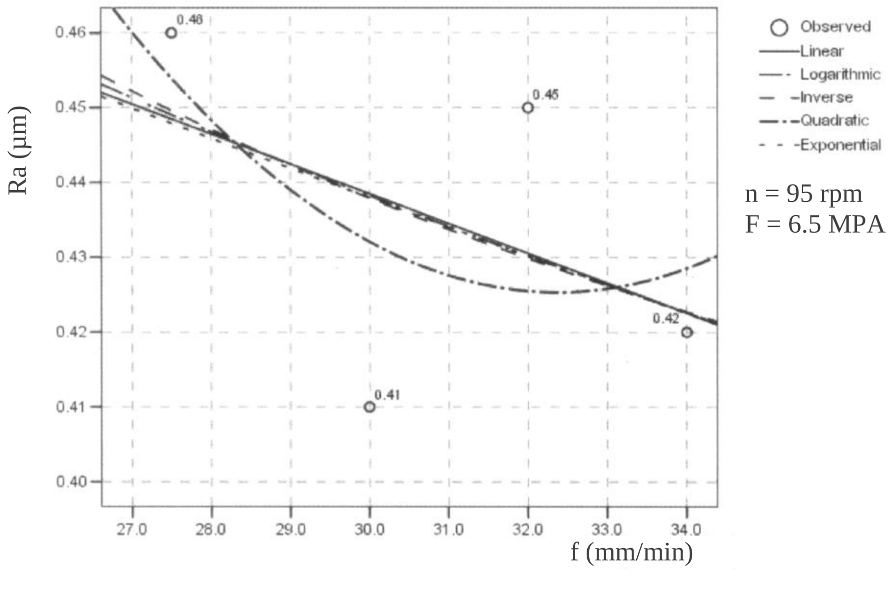

Fig. 4. Empirical models of the roughness variation Ra with the deformation feed

Table 3. Estimated parameters of the model.
Dependent variable: out-of-roundness.
Independent variable: deformation feed f

Model type	Model synthesis					Estimated parameters		
	R^2	F	f1	df2	Level of significance	a	b	c
linear	0.570	2.647	1	2	0.345	0.560	-0.011	
logarithmic	0.574	2.692	1	2	0.243	1.374	-0.336	
reverse	**0.578**	**2.735**	**1**	**2**	**0.240**	**-0.112**	**10.272**	
square	0.576	0.679	2	1	0.651	1.103	-0.046	0.001
exponential	0.564	2.578	1	2	0.249	0.999	-0.49	

Fig. 5 shows the graphical variation of experimental functions regarding the influence of the deformation feed on the out-of-roundness of the bearing rings raceways.

The influence that the deformation feed has on the circularity deviations of bearing rings raceways processed using cold plastic deformation is shown in Table 4.

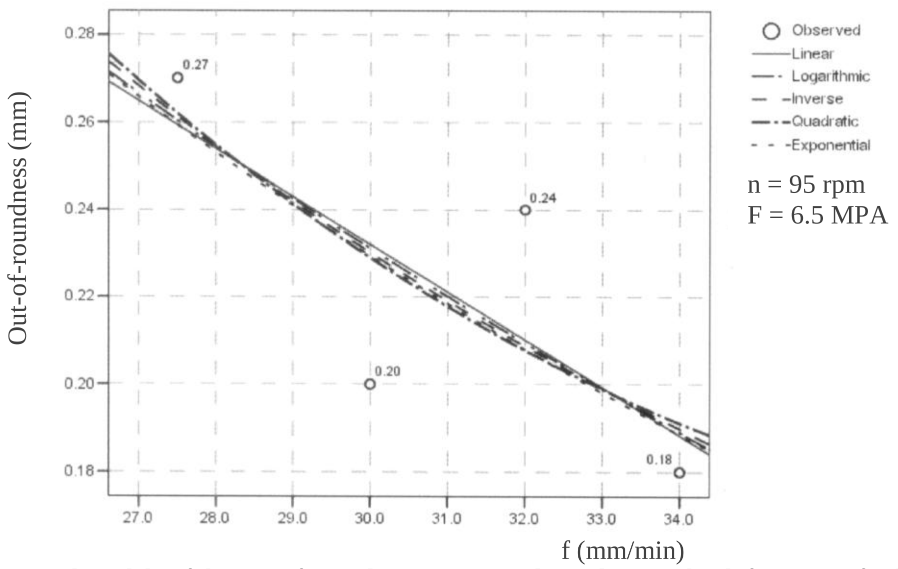

Fig. 5. Empirical models of the out-of-roundness variation depending on the deformation feed

Tabel 4. Estimated parameters of the model.
Dependent variable: circularity deviation.
Independent variable: deformation feed

Model type	Model synthesis					Estimated parameters		
	R^2	F	f1	df2	Level of significance	a	b	c
linear	**0.798**	**7.919**	**1**	**2**	**0.106**	**59.069**	**-1.394**	
logarithmic	0.790	7.513	1	2	0.111	1612.381	-42.411	
reverse	0.780	7.105	1	2	0.117	-25.809	1284.190	
square	0.820	2.282	2	1	0.424	-50.465	5.782	-0.117
exponential	0.766	6.559	1	2	0.125	274.946	-0.093	

The mathematical expression of the model that best describes the influence of the deformation feed on the circularity deviation is:

$$Cir = 59.069 - 1.394 \cdot f, [\mu m] \qquad (3)$$

Fig. 6 shows the graphical variation of experimental functions regarding the influence of the deformation feed on the circularity deviations of the bearing rings raceways.

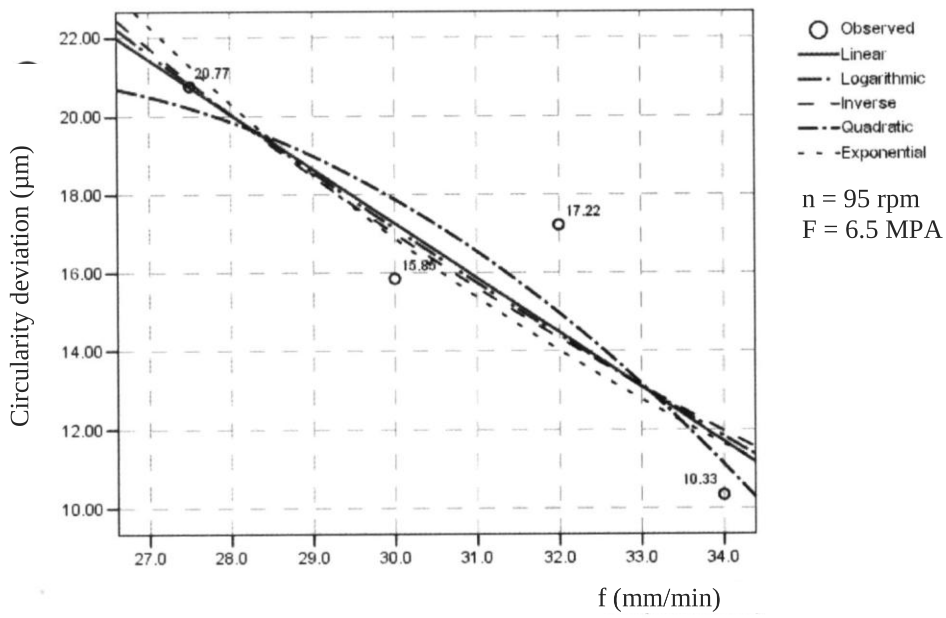

Fig. 6. Empirical models of the circularity deviation variation depending on the deformation feed

CONCLUSIONS

From the graphical representations and the mathematical processing of the obtained values of quality parameters, the following conclusions can be drawn:

- by reducing the deformation feed, the raceways roughness decreases with the favorable value of 30 mm /min,
- by increasing the deformation feed, the raceways out-of-roundness decreases with the minimum value for f = 34 mm / min,
- by increasing the deformation feed, the circularity deviation decrease with the minimum value for f = 34 mm / min.

It should be mentioned that the optimal value for the deformation feed is f = 34 mm / min.

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