CONSIDERATIONS REGARDING THE EMPIRICAL SIMULATION OF THE VARIATION OF THE MICROHARDNESS ON THE DEPTH OF THE DEFORMED 6210-20 BEARING RING

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ABSTRACT.
The empirical simulation of the deformation phenomena in the mechanics of the continuous environments is a current practice, widely used in the activities of scientific research, of design work of the structures and for the improvement of the technologies. The numerical simulation in the mechanics of the continuous environments became possible as the numerical calculation technique developed. There are several methods of numerical simulation of the phenomena specific to the continuous environments.

Key words*:* simulation, micro-hardness, bearing ring, feed, pressure

1.- INTRODUCTION

The development of the research in the bearings industry develops directly, to improve the working parameters of the devices, as well as indirectly through simulations of the technological processes, having the advantage of some important time saving and economy of materials necessary for the research. On the present paper we verify the empirical simulation of the micro-hardness variation on the depth of the deformed 6210-20 bearing ring.

2. PRECONDITIONS AND MEANSFOR RESORVING THE PROBLEM

2.1. *Theoretical considerations*
To deduct the empirical relations and the representation of the influences of the working parameters we took into consideration the following functions, which need the determination of two elements (terms or elements):

$F_1(x) = a \cdot x + b$ **- linear function;**

$F_2(x) = a \cdot e^{b \cdot x}$ **- exponential function;**

$F_3(x) = a + b \cdot \ln x$ **- logarithmic function;**

$F_4(x) = a + \frac{b}{x}$ **- reversed function**

We also took into consideration the square model (with three coefficients which must be determined a, b, c):

$$F_5(x) = a + b \cdot x + c \cdot x^2$$

Because of the fact that this last function needs 3 coefficients, we considered more appropriate such a model only in limit situations (when the significance of the other models was reduced), the variation of the hardness after a parabola not being, generally adequate.
We concluded the correlation coefficient R, the estimated error, we applied the F test for significance and through comparison we established the most suitable model for the data in the experiment.

2.2. Experimental determinations
The experimental data have been statistically processed deducting empirical relations which describe the influence of the working parameters on the hardness of the bearing ring
a. Influence of the pressure, P *a1*.*for* *P = 4,5 MPa*
The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 293{,}045 - \frac{10{,}779}{h}$$

where: *h is* the bearing race section (mm).

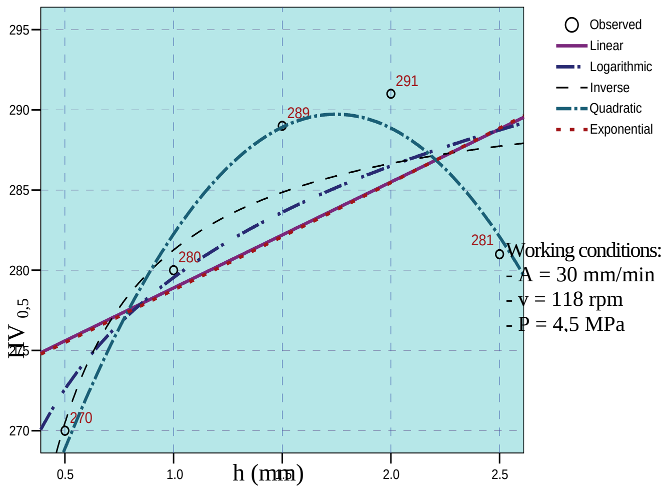

Fig. 1. Empirical models of micro-hardness variation in the bearing race section

Table 1. Estimated parameters of the model for: P = 4,5 MPa,
A = 30 mm/min, v = 118 rpm
Dependent variable: $HV_{0,5}$
Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Thresh old of signifi-cance	a	b	c
Linear	.391	1.923	1	3	.260	272.300	6.600	
Logarithmic	.584	4.206	1	3	.133	279.547	10.036	
Inverse	**.702**	**7.053**	**1**	**3**	**.077**	**292.045**	**-10.779**	
Quadratic	.957	22.014	2	2	.043	248.800	46.886	-13.429
Exponential	.396	1.965	1	3	.256	272.256	.024	

a2. for ***P = 4,0 MPa***

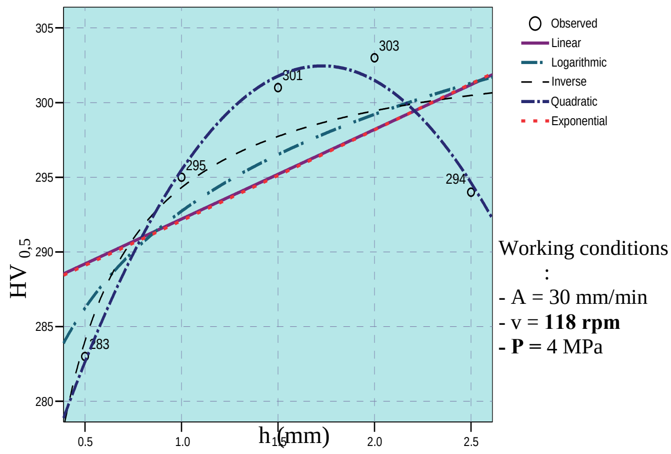

Fig. 2. Empirical models of micro-hardness variation in the bearing race section

Table 2. Estimated parameters of the model for **:** P = 4,0 Mpa,
A = 30 mm/min, v = 118 rpm
Dependent variable: $HV_{0,5}$
Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Threshold of signifi-cance	a	b	c
Linear	.368	1.744	1	3	.278	286.200	6.000	
Logarithmic	.578	4.104	1	3	.136	292.727	9.356	
Inverse	.727	8.002	1	3	.066	304.593	-10.284	
Quadratic	.985	65.938	2	2	.015	263.200	45.429	-13.143
Exponential	.372	1.774	1	3	.275	286.135	.021	

The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 304{,}593 - \frac{10{,}284}{h}$$

where: *h is* the bearing race section (mm).

a3. *for* ***P = 3,5 MPa***

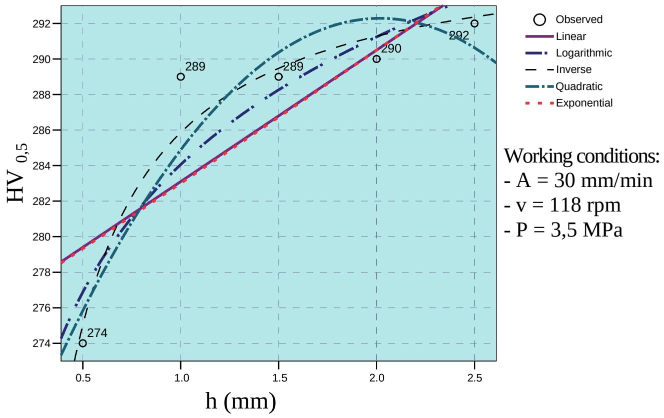

Fig. 3. Empirical models of micro-hardness variation in the bearing race section

Table 3. Estimated parameters of the model for : P = 3,5 MPa,
A = 30 mm/min, v = 118 rpm
Dependent variable: $HV_{0,5}$
Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Threshold of signifi-cance	a	b	
Linear	.649	5.558	1	3	.100	275.700	7.400	
Logarithmic	.824	14.005	1	3	.033	284.060	10.367	
Inverse	.939	46.043	1	3	.007	296.702	-10.842	
Quadratic	.861	6.205	2	2	.139	263.200	28.829	-7.143
Expon-en-tial	.645	5.460	1	3	.102	275.700	.026	

The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 296,702 - \frac{10,842}{h}$$

where: *h is* the bearing race section (mm).

a4. *for* ***P = 3,0 MPa***
The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 246 + 63,114 \cdot h - 22,571 \cdot h^2$$

where: *h is* the bearing race section (mm).

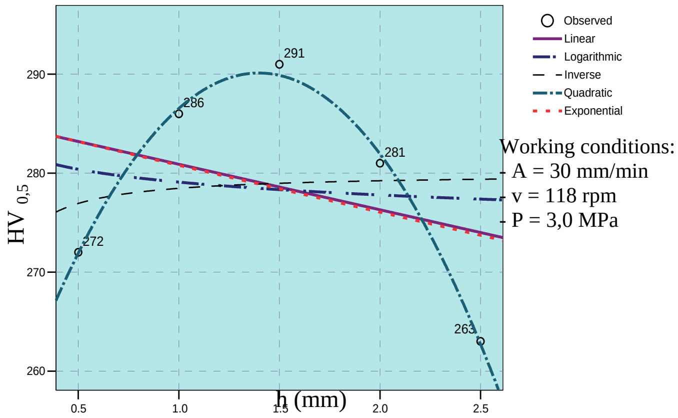

Fig. 4. Empirical models of micro-hardness variation in the bearing race section

Table 4. Estimated parameters of the model for: P = 3,0 MPa,
A = 30 mm/min, v = 118 rpm
Dependent variable: $HV_{0,5}$
Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Threshold of signifi-cance	a	b	
Linear	.106	.354	1	3	.594	285.500	-4.600	
Logarithmic	.011	.034	1	3	.865	279.095	-1.874	
Inverse	.008	.024	1	3	.887	279.996	-1.529	
Quadratic	.995	198.341	2	2	.005	246.000	63.114	-22.571
Expon-en-tial	.110	.371	1	3	.585	285.604	-.017	

3. CONCLUSION.

The empirical models which describe best the variation of the hardness $HV_{0,5}$ with the depth h of the ring are inverse function (except are in the case of the litle deepths, p $\leq$ 3 MPa).

b. The influence of the feed

b1. for A = 27,5 mm/min

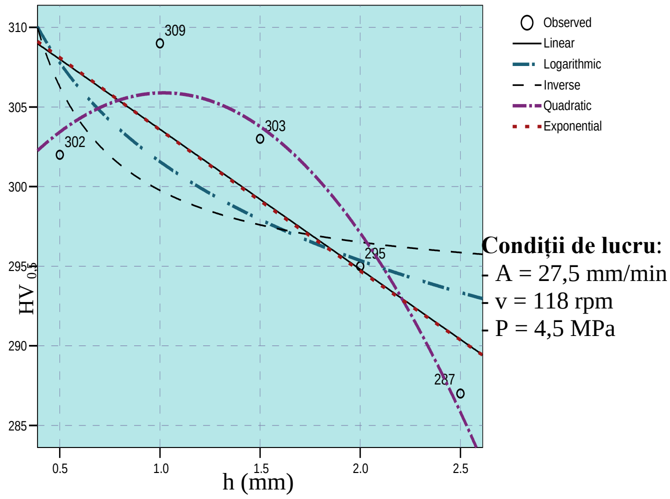

Fig. 5. Empirical models of micro-hardness variation in the bearing race section

The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 258{,}6 + 46{,}114 \cdot h - 16{,}571 \cdot h^2$$

where: *h is* the bearing race section (mm).

Table 5. Estimated parameters of the model for: A = 27,5 mm/min, P = 4,5 MPa, v = 118 rpm
Dependent variable $HV_{0,5}$

Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Threshold of significance	a	b	
Linear	.098	.326	1	3	.608	287.600	-3.600	
Logarithmic	.019	.059	1	3	.824	282.724	-1.984	
Inverse	.000	.000	1	3	.999	282.207	-.008	
Quadratic	.824	4.692	2	2	.176	258.600	46.114	-16.571
Exponen-tial	.105	.350	1	3	.596	287.776	-.013	

b2.for A = 25 mm/min

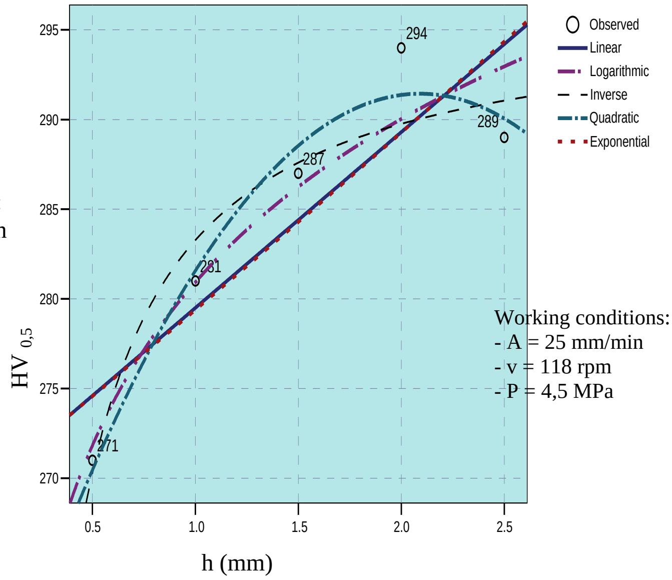

Fig.6. Empirical models of micro-hardness variation in the bearing race section

Table 6. Estimated parameters of the model for : A = 25 mm/min, P = 4,5 MPa, v = 118 rpm
Dependent variable:$HV_{0,5}$
Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Threshold of signifi-cance	a	b	
Linear	.772	10.131	1	3	.050	269.700	9.800	
Logarithmic	.895	25.559	1	3	.015	280.929	13.130	
Inverse	**.909**	**30.077**	**1**	**3**	**.012**	296.241	-12.965	
Quadratic	.965	27.218	2	2	.035	255.200	34.657	-8.286
Exponen-tial	.772	10.147	1	3	.050	269.843	.035	

The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 296{,}241 - \frac{12{,}965}{h}$$

where: *h is* the bearing race section (mm).

b3. for A = 22,5 mm/min

The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 294{,}771 - \frac{12{,}45}{h}$$

where: *h is* the bearing race section (mm).

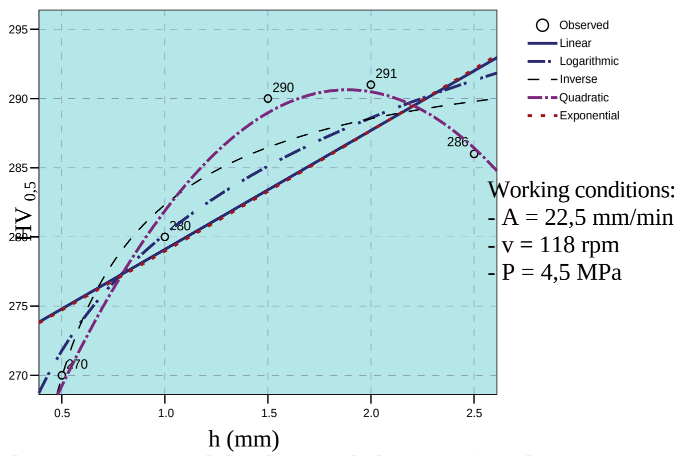

Fig. 7. Empirical models of micro-hardness variation in the bearing race section

Table 7. Estimated parameters of the model for: A = 22,5 mm/min, P = 4,5 MPa, v = 118 rpm

Dependent variable: $HV_{0,5}$

Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Threshold of signifi-cance	a	b	
Linear	.618	4.853	1	3	.115	270.500	8.600	
Logarithmic	.796	11.703	1	3	.042	280.190	12.142	
Inverse	.872	20.466	1	3	.020	294.771	-12.450	
Quadratic	.981	51.889	2	2	.019	251.000	42.029	-11.143
Exponen-tial	.621	4.909	1	3	.114	270.529	.031	

4. Conclusion.

The empirical models which describe best the variation of the hardness $HV_{0,5}$ with the depth h of the ring are inverse function (except are in the case of the litle feed, A =27,5 mm/min)

c. Influence of the speed

c1. for v = 106 rpm

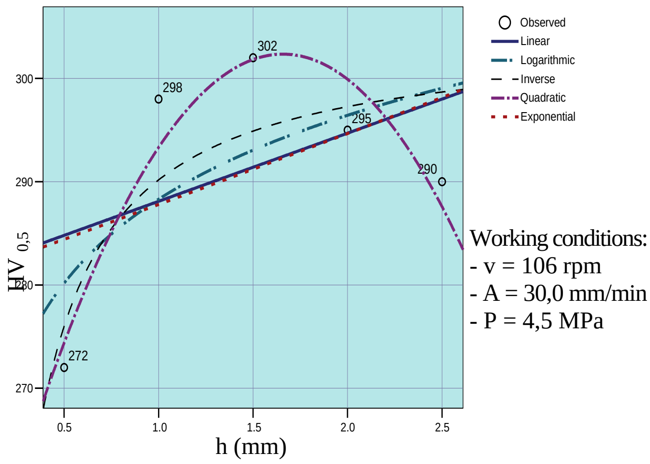

Fig. 8. Empirical models of micro-hardness variation in the bearing race section

The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 304{,}362 - \frac{14{,}192}{h}$$

where: *h is* the bearing race section (mm).

Table 8. Estimated parameters of the model for: v = 106 rpm, A = 30,0 mm/min, P = 4,5 MPa

Dependent variable: $HV_{0,5}$

Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Threshold of significance	a	b	
Linear	.199	.745	1	3	.451	281.500	6.600	
Logarithmic	.407	2.055	1	3	.247	288.298	11.735	
Inverse	.620	4.888	1	3	.114	304.362	-14.192	
Quadratic	.895	8.491	2	2	.105	245.000	69.171	-20.857
Exponen-tial	.208	.788	1	3	.440	281.076	.024	

c2. for v = 98 rpm

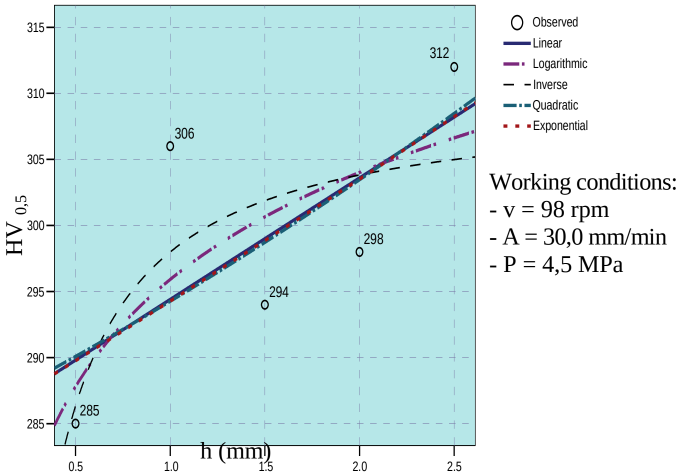

Fig. 9. Empirical models of micro-hardness variation in the bearing race section

Table 9. Estimated parameters of the model for: v = 98 rpm, A = 30,0 mm/min, P = 4,5 MPa
Dependent variable:$HV_{0,5}$
Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Threshold of significance	a	b	
Linear	.481	2.779	1	3	.194	285.200	9.200	
Logarithmic	.502	3.028	1	3	.180	295.908	11.696	
Inverse	.520	3.255	1	3	.169	309.651	-11.662	
Quadratic	.482	.929	2	2	.518	286.200	7.486	.571
Expon-ential	.483	2.807	1	3	.192	285.314	.031	

The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 309{,}651 - \frac{11{,}662}{h}$$

where: *h is* the bearing race section (mm).
c3. for v = 84 rpm

The equation that best describes the micro-hardness variation is:

$$HV_{0,5} = 291{,}284 + 10{,}275 \cdot \ln(h)$$

where: *h is* the bearing race section (mm).

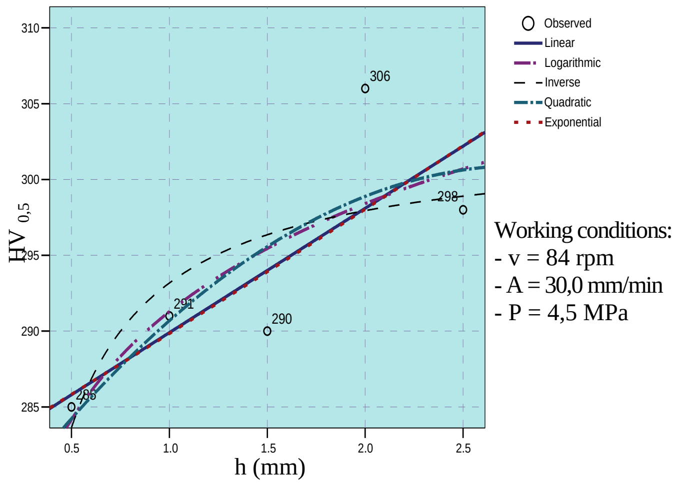

Fig. 10. Empirical models of micro-hardness variation in the bearing race section

Table 10. Estimated parameters of the model for: v = 84 rpm, A = 30,0 mm/min, P = 4,5 MPa
Dependent variable: $HV_{0,5}$
Independent variable: deepth h (mm)

Typ of model	Synthesis of model					Estimated parameters		
	R^2	F	df 1	df 2	Threshold of signifi-cance	a	b	
Linear	.632	5.151	1	3	.108	281.700	8.200	
Logarithmic	.641	5.361	1	3	.104	291.284	10.275	
Inverse	.576	4.083	1	3	.137	302.716	-9.543	
Quadratic	.664	1.980	2	2	.336	276.200	17.629	-3.143
Expon-ential	.639	5.320	1	3	.104	281.866	.028	

CONCLUSION

To the variation of the speed, the empirical models which describe best the variation of the hardness $HV_{0,5}$ with the depth of the ring are inverse function (except are in the case litle speeds, for the best solution are inverse function).

6. REFERENCES

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