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Increase Efficiency of Large Bearings Working by Parameters Optimization

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Abstract-In wind power plant system, the bearings are extremely important components, the elements that support the movement of the entire assembly. This work studying the possibility of optimizing the bearing operation by minimizing deformation occurring at the contact of rolling elements. Modeling is done using FEM analysis and the results are confirmed by laboratory experiments processed by statistical methods.

Keywords- *finite elements analysis, hollow rollers, deformations*

I. INTRODUCTION

Correctly determination of factors that influence the operation of a large bearing, mounted in a wind power plant, that can be controlled, allows optimizing the entire system through judicious choice of the values of these factors, so that the system response to random factors is as small. Reducing inertial masses, reducing temperature and optimize lubrication leads to increased bearing lifetime.

This research focuses on changes to the rolling elements consisting in decrease of their mass by using hollow rollers. Dynamic study of forces who acts on rollers is practical study which determines their resistance and lifetime of the large bearing. In analyzing of bearing, dynamic loading is an essential element in the definition and mathematical modeling. Dynamic loading occurs between rolling elements and raceways caused by the movements of rolling elements around of bearing axis and its axis. These movements performed at higher speed or lower speed, depending on the use of bearing, generates interacting forces and produce tensions between rolling elements and raceways.

Control of tensions that occur on the surface of rolling elements leads to increased lifetime of bearings and efficiency improvements in operating bearings. In the case of cylindrical roller bearings with large dimensions, due to their mass, the main component, directly proportional in computation of the forces and torques, tensions are higher and generate significant defects and a high cost of maintenance.[1] Reducing masses of large bearings becomes a necessary problem who leads directly to increase their lifetime and lower maintenance costs. Extensive use of bearings with hollow roller in the construction of wind power plants determine the usefulness of this study.

II. DYNAMIC MODELING OF BEARINGS PROVIDED WITH HOLLOW ROLLERS

Defining elements in dynamic analysis of bearing is made, considering rolling movement assimilated with a rotation around a given axis and the sliding movement assimilated of the rectilinear movement assigned to a mass point. In general, a bearing analysis consists in studying its lifetime and the system where is mounted. [2, 3]. Reducing system sensitivity to influence factors, lead to increase bearing lifetime.

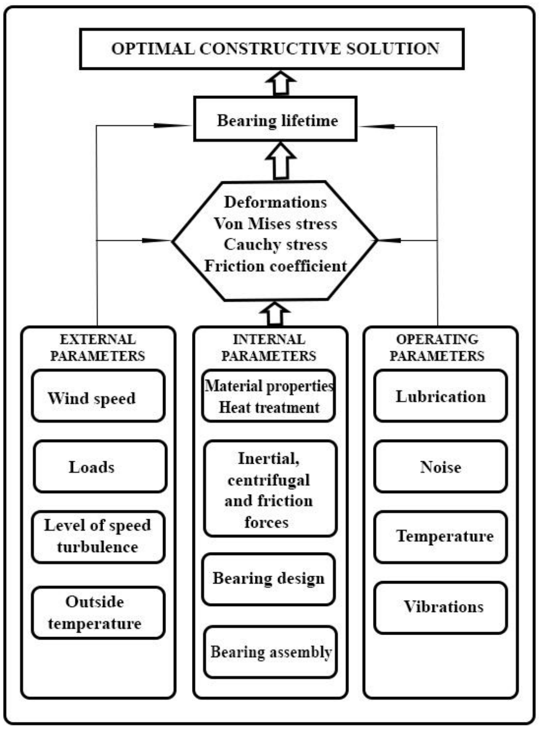

Figure 1. *Logical diagram* of the interaction of factors who influence the functioning of large bearings

In the design of a large bearing, with functionality in a wind power energy assemblies, factors that determine the shape, dimensions, material its properties, are: eternal parameters, internal parameters and operating parameters (Figure 1)

The selection of optimal constructive alternative is influenced by these factors. Their influence is quantified and measured by using the finite element analysis (Von Mises stress and Cauchy stress, deformations), and by direct measurement (hardness, friction coefficient, deformations, roughness).

The purpose of research is to study the constructive solution of hollow roller bearings in the construction of large bearings who equips wind power plants. The cavity, the size and the shape are features of rollers subjected to optimize, starting from the basic necessity of keeping conditions for initial functionality. Each category of factors interact and influence the logical end point of the scheme, namely lifetime. Both, the static load created by the construction of the bearing and dynamic loading mainly due to external conditions of wind and temperature directly determines the appearance of contact stresses and deformations. The constructive shape of the roller, material and heat treatment conditions are designed to counteract the negative effects of varying loads and temperature generating additional frictional forces. A properly lubrication system, reduced loads by reducing inertial masses, a system respond more quickly and clearly to external disturbances is a result of using hollow rollers in large bearings construction.

Wind speed is the random factor who determine variation of bearing forces. In Table I are shown loads occurring in a gyroscope bearing. [4, 5]

(Values are conform to ISO standard 76 in which the static capacity calculation of a rolling bearing for wind power plants is based on Hertz contact and is calculated for the most loading roller and does not exceed 4000 MPa. International Organization for Standardization, ISO Standard 76, “Rolling Bearings—Static Load Ratings,” 1989).

TABLE I. LOAD PARAMETERS FOR DIFFERENT WIND SPEED

No.	Wind speed (m/s)	Radial Force F_r (kN)	Axial Force F_a (kN)	Loading Momement M (kNm)	Loading Force Q (kN)
1	6.25	30.6	250	89.27	25
2	9	52.96	250	178.4	50
3	11.6	57.18	250	233.7	75
4	13.4	67	250	241.5	100
5	18	55	250	248.9	125
6	22	52.51	250	251.3	150
7	25	46.91	250	263.3	175
8	27	42.155	250	270.24	200
9	30	40.94	250	273.2	225
10	33	36.05	250	300	250
Maxim load		150	250	300	275

Deformation h_0, occurred between two cylindrical surfaces [6, 7] can be written as:

$$h_0 = \frac{2Q}{\pi \cdot LE}\left[\ln\left(\frac{2 \cdot R_1 - 2 \cdot r}{b}\right) + 0.407\right] + \left[\ln\left(\frac{2 \cdot R_2}{b}\right) + 0.407\right] \quad (1)$$

where: h_o is deformation occurred to the contact between roller and inner ring[mm]; [8,9]

Q is load force [kN];

E is Young’s elastic modulus [kN/mm2];

R1 is hollow roller radius [mm];

R2 is inner ring radius [mm];

R is hollowness radius [mm];

B is length of solid contact between surfaces [mm].

The model of contact is shown in Figure 2.

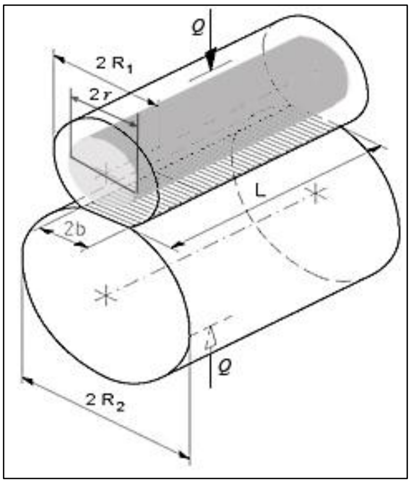

Figure 2. Contact deformations in large bearings with hollow rollers

Because the deformation occurred in inner ring is much smaller then deformation of roller, in the research is considered the whole deformation to belong to roller.

$$h_0 = h_i + h_r \quad (2)$$

where: hi is deformations of inner ring [mm];

hr is deformation of roller [mm].

and:

$$h_i << h_r \quad (3)$$

$$h_r = \frac{2Q}{\pi \cdot LE}\left[\ln\left(\frac{2 \cdot R_1 - 2 \cdot r}{b}\right) + 0.407\right] + \left[\ln\left(\frac{2 \cdot R_2}{b}\right) + 0.407\right] \quad (4)$$

III. FEM Analysis for Hollow Rollers with Variable Load

For finite element analysis of large bearing who equips wind energy assemblies was chosen a bearing with D=1900 mm, d=1420 mm, and B=440 mm. The roller has following dimensions: D=100 mm, L=200 mm. For hollow rollers d_1=40 mm, d_2=60 mm and d_3=80 mm. The used material for rollers was SAE 4320 with chemical composition, shown in Table II.

Other properties of used material: Rocwell Hardness – 62 HRC, E=210 kN/mm^2.

TABLE II. Chemical Compozition of SAE 4320

Steel	Chemical compozition[%]							
	C	Mn	Si	Cr	Ni	Mo	S	P
SAE 4320	0.17 0.22	0.45 0.60	0.15 0.35	0.40 0.60	1.65 2.00	0.20 0.30	max 0.035	max 0.04

The deformations occurred in rollers are calculated with Nastran software by finite element analysis in cases of variable load.

TABLE III. Deformations for Different Loads

Load	25kN	50 kN	75kN	100kN	125kN	150kN
Roller type	h_r [µm]	h_r [µm]	h_r [µm]	h_r [µm]	h_r [µm]	h_r [µm]
1	15.1	15.5	15.8	16.3	16.7	17.1
2	16.8	17.3	17.7	17.9	18.4	18.5
3	18.7	18.4	18.9	19.5	20.1	20.6
4	19.8	19.9	20.5	20.8	21.3	21.7
5	16.7	17.1	17.6	18.2	18.5	18.9

TABLE IV. Deformations for Different Loads

Load	175kN	200 kN	225kN	250kN	275kN
Roller type	h_r [µm]	h_r [µm]	h_r [µm]	h_r [µm]	h_r [µm]
1	17.4	17.8	18.5	19.3	20.1
2	19.0	19.7	20.4	20.9	21.4
3	20.9	21.4	21.9	22.3	22.8
4	22.2	22.8	23.5	24.0	24.6
5	19.3	19.9	20.6	21.2	21.5

where 1 is solid roller, 2 is hollow roller with d=40 mm, 3 is hollow roller with d=60 mm, 4 is hollow roller with d=80 mm and 5 is hollow roller with d=60 mm and covers.

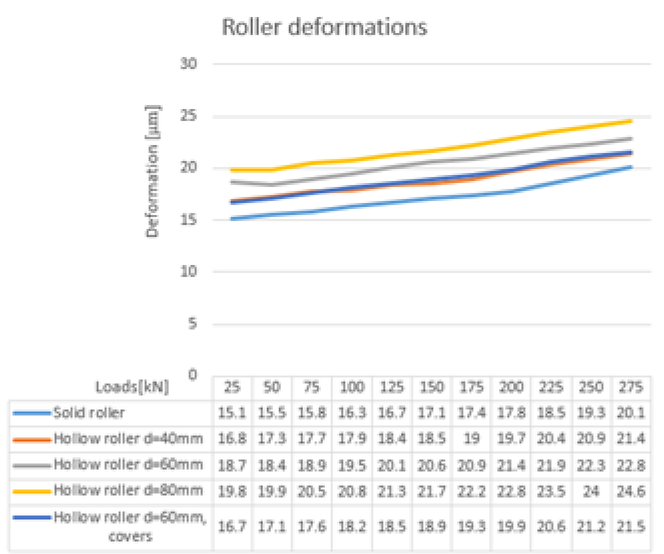

Figure 3. Deformations with finite elements analysis for hollow rollers

The results of finite elements analysis made for different type of rollers and for different values of loads presented in Table III and Table IV and in graphics in Figure 3, show a slight increase in deformation with loads increasing.

For bearing with solid rollers and for all bearings with hollow rollers was made the finite element analysis with Nastran software.

When applied finite element analysis method to rollers, was used iteration cinematic method, that assumes that the nodal forces are known by evenly distributing, remaining to calculate the contact forces. The value of these forces is determined by successive iterations resulting when the speed of the node is null.

IV. Experimental Work

The rollers were fixed in angular supports and the equivalent force was applied to midst of them. Basically it was measured the ability of the rollers to deform elastically and measured this deformation on a digital electromechanical universal machine / floor model with a column / force cell 300 KN Model: Testometric Tensile Tester FS300 AT/CT. For each loads was made 5 measurements and the results were statistically processed.

TABLE V. DEFORMATIONS FOR DIFFERENT LOADS

Exp.	Loads 25 kN						
	1	2	3	4	5		
Roller type	Deformation [µm]					Arithmetic mean	Standard deviation
1	15	14	14	16	15	14.8	0.68313
2	16	17	18	15	16	16.4	0.930949
3	18	16	17	18	19	17.6	0.930949
4	20	21	19	20	20	20	0.57735
5	16	18	17	18	16	17	0.816497
Exp.	Loads 100 kN						
	1	2	3	4	5		
Roller type	Deformation [µm]					Arithmetic mean	Standard deviation
1	16	17	18	16	16	16.6	0.730297
2	18	17	18	19	19	18.2	0.68313
3	19	21	20	21	22	20.6	0.930949
4	20	21	22	20	22	21	0.816497
5	17	18	17	18	18	17.6	0.447214
Exp.	Loads 200 kN						
	1	2	3	4	5		
Roller type	Deformation [µm]					Arithmetic mean	Standard deviation
1	18	17	18	19	19	18.2	0.68313
2	20	21	22	21	20	20.8	0.68313
3	22	21	22	23	20	21.6	0.930949
4	23	25	24	23	22	23.4	0.930949
5	20	22	20	21	21	20.8	0.68313
Exp.	Loads 275 kN						
	1	2	3	4	5		
Roller type	Deformation [µm]					Arithmetic mean	Standard deviation
1	19	20	21	20	21	20.2	0.68313
2	22	21	20	23	22	21.6	0.930949
3	23	24	21	24	23	23	1
4	25	26	26	24	27	25.6	0.930949
5	22	21	21	22	21	21.4	0.447214

Comparing the data obtained experimental with data obtained by finite element analysis, extremely small differences can be seen, allowing to validate the results obtained on the computer. Fig. 4 shows these differences.

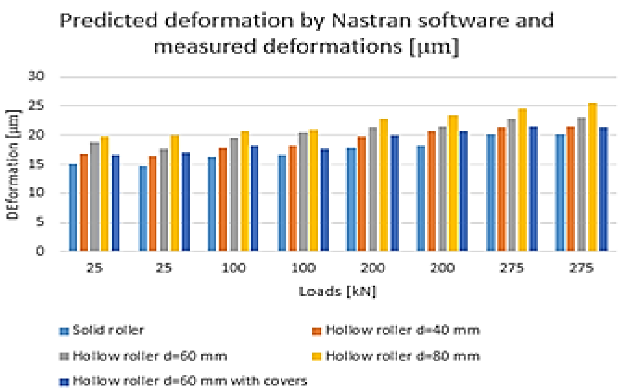

Figure 4. Comparison of deformations obtained by FEA with those obtained experimentally

V. CONCLUSIONS

The graphic shows that the deformations have an upward trend with increasing cavitation. Mounting of covers makes tensions to decline due to stiffening of system.

Finite element analysis performed with Nastran program revealed a slight increase in deformations and strains, insignificant for the modification of geometry of hollow rollers.

Reducing inertia in this type of bearings lead to increased stopping accuracy reduces energy startup and runs smoother. The importance of developing green energy, increasing the energy efficiency of wind power plants and their wide distribution, turn maintenance process, a matter of great importance.

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