FEM MODELLING AND CHARACTERISTICS RESEARCH OF CYLINDRICAL JOURNAL BEARING FOR CONE INERTIAL CRUSHER /KID - 300/

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Abstract. This article presents finite element modeling and simulation analysis of vertical cylindrical journal bearing for cone inertial crusher (KID-300). The research is done through changing different technical and constructive bearing parameters. There is obtained results about pressure distribution and power losses in the bearing. Throughout analysis of those results, determinates the most suitable working regime for the bearing according to minimization of the power loses in the bearing. The presented research methodic is suitable for examination of bearing behavior in different working regimes of the crusher.

Keywords: cylindrical journal bearing, simulation study, finite element modelling

1. Introduction

In previous work [3] is developed and described a methodic for analytical calculations of basic bearing parameters for vertical cylindrical journal bearing used in cone inertial crusher (KID 300). Cone inertial crusher [2] is a stone crusher for middle to fine size crushing of mineral materials with dynamical excitation.

The vertical journal bearing is a problematic assembly of the crusher through different speed and force regimes of the crusher.

According to analytical methodic [3] in this paper is presented the simulation methodic for research ad analysis of different bearing regimes. The results of FEM simulation is processed and analyzes with statistical instruments and it is developed a mathematical model described those parameters.

2. Research parameters and factors

The research is focused over the following parameters:

- pressure distribution in the cylindrical bearing;
- mechanical power loses in the cylindrical bearing according to the sliding friction.

Those bearing parameters depend on the changing the following factors:

- angular velocity - ω_d [rad/s] - of the bearing bush witch holds the unbalanced excitator of the crusher. Angular velocity is changed in the different working regimes of the crusher;
- dynamical viscosity - μ [N·s/m^2] - of the lubrication oil. Dynamical viscosity of bearing is temperature dependent and with the heating of the machine it is changing;
- lubrication system mass flow capacity - Q_m [kg/s]. This parameter is changing through oil filters contamination, oil contamination and inappropriate oil pump regulation.

Simulated regimes corresponds with the analytical research [3, 4, 5] and also there is accounted the factors concerning ordinary usage of the crusher and bearing assembly, as following:

- surface roughness - ε [µm]. This factor is changing due to improper exploitation of the bearing assembly, usage with contaminated oil and usage of unsuitable oil and also due to starting regimes with unstable oil lubrication in the journal. There is used the sand grain roughness equivalency parameter noted with ε. Connection between sand grain roughness ε and average peak roughness R_z according [1] is $\varepsilon = 0.978{\cdot}R_z$ [µm].
- bearing clearance - s, mm. This parameter is changing due to bearing damage and repair through moving in the different repair dimensions.

3. FEM model setup and creation

Figure 1 presents axial section of the cylindrical journal bearing with flow boundaries and geometrical parameters - the bush length and clearance.

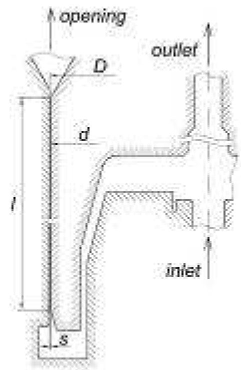

Figure 1. Cylindrical bearing situation and boundaries

Researched assembly is meshed - presented in Figure 2 with parameters of the mesh - number of the mesh elements 53976, with 12357 nodes, and average aspect ratio is 34, and here in this research is used tetrahedral 10 node elements.

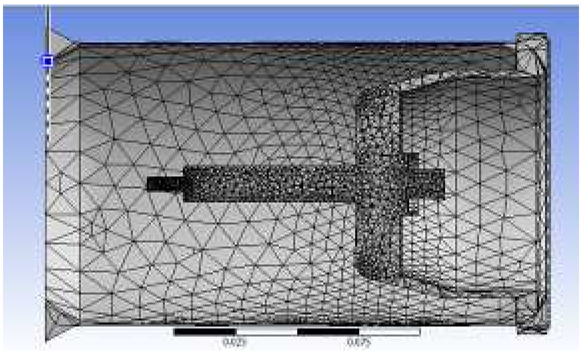

Figure 2. Meshing of the bearing

The simulation setup is shown on Figure 3. The simulation is made with inlet flow source value, angular velocity value, oil viscosity value and valued statical (reference) pressure on the outputs of the bearing. This setup is stable in different regime simulations and show stability of the achieved results. A different setup with inlet pressure value show instability in different regimes research.

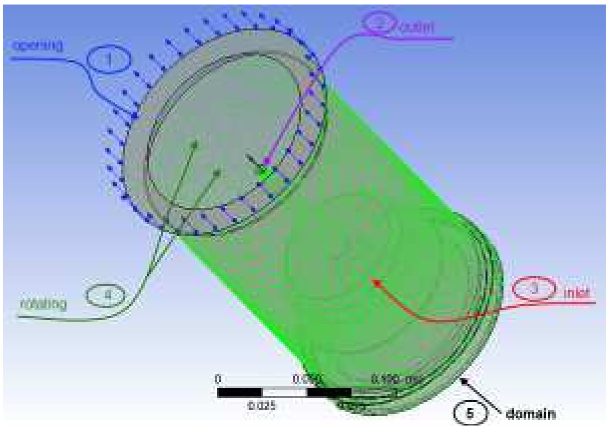

Figure 3. Setup of the simulation model

4. FEM simulation results

The problem setting is researched with ANSIS Workbench and there is achieved results of distribution for tangential wall shearing pressure distribution and full pressure distribution over the length of the bearing as presented in figures 4 ÷ 7.

Table 1 shows all simulation results systematized, where is shown:

- F_τ [N] – tangential resistance bearing force;
- p_τ [Pa] – tangential area averaged pressure witch presents wall friction pressure:

$$p_\tau = \frac{F_\tau}{d \cdot l}, \quad (1)$$

where d = 0.117 m is bearing shaft diameter and l = 0.17 m is the bearing length (height) (Figure 1);

- M_r [N·m] – bearing resistance moment (torque):

$$M_r = 0.5 \cdot F_\tau \cdot D, \quad (2)$$

where D = 0.118 m is bearing bush diameter (Figure 1);

- N_r [W] – mechanical power loses according to the sliding friction:

$$N_r = \omega_d \cdot M_r; \quad (3)$$

- p_{max} [Pa] – maximal value of the bearing pressure;
- p_{out} [Pa] – maximal output pressure value.

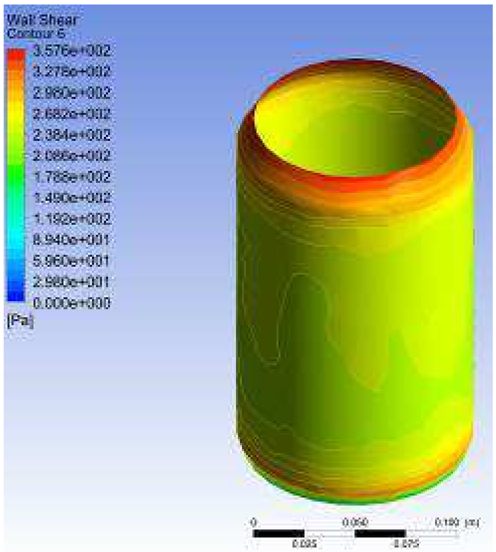

Figure 4. Wall shear distribution over the bearing length in regime with: s = 0.5 mm; Q_m = 0.08 kg/s; R_z = 6.54 μm; ω_d =191.11 rad/s; t = 30 °C

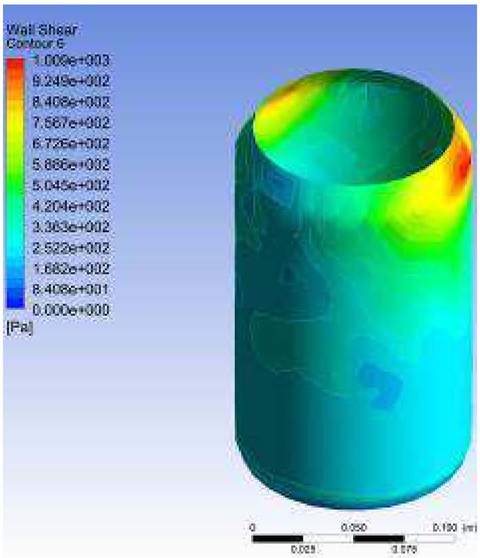

Figure 5. Wall shear distribution over the bearing length in regime with: s = 1 mm; Q_m = 0.08 kg/s; R_z= 6.54 μm; ω_d = 191.11 rad/s; t = 30 ºC

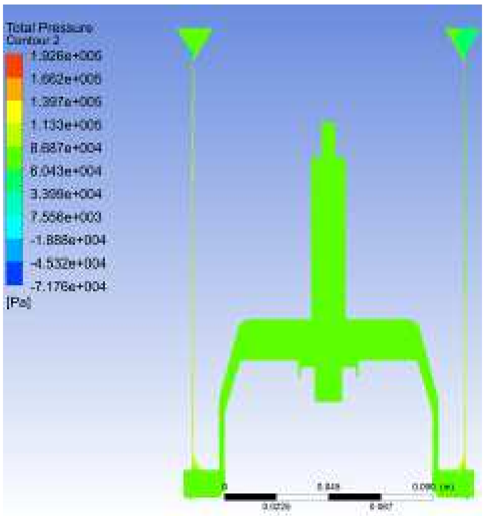

Figure 6. Total pressure distribution for regime with: s = 0.5 mm; Q_m = 0.119 kg/s; R_z = 6.54 μm; ω_d = 191.11 rad/s; t = 15 °C

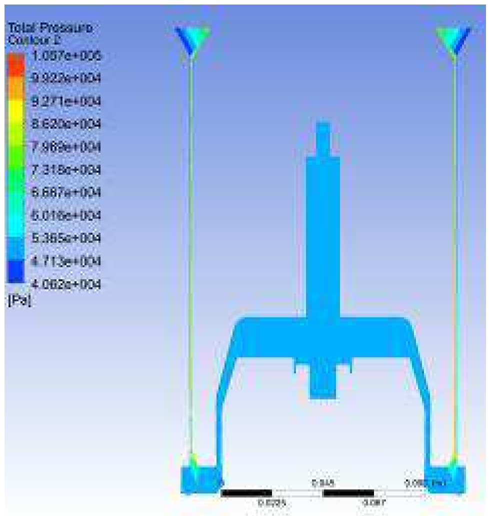

Figure 7. Total pressure distribution for regime with: s = 1 mm; Q_m = 0.119 kg/s; R_z = 6.54 μm; ω_d = 191.11 rad/s; t = 15 °C

Simulation results shown in Table 1 are processed with statistical analysis product STATGRAPHICS and there is developed a mathematical model. The statistical adequacy of the model is over 97.6 %.

Table 1. Results of the study for N_c and p_{max}

factors									parameters					
№	t	ρ	μ	ε	R_z	s	Q_m	ω_d	p_τ	F_τ	M_r	N_r	p_{max}	p_{out}
	°C	kg/m^3	N·s/m^2	μm	μm	mm	kg/s	rad/s	Pa	N	N·m	W	Pa	Pa
1	15	890	0.2535	6.4	6.54	0.5	0.119	220.96	2189.3	43.5	2.57	567.68	541812	1263350
2	15	890	0.2535	6.4	6.54	0.5	0.119	191.11	1851.3	36.8	2.17	415.18	528428	1287170
3	15	890	0.2535	32	32.7	0.5	0.119	153.31	1428.6	28.4	1.68	257.01	483758	1239830
4	15	890	0.2535	16	16.4	0.5	0.119	111.63	447.2	8.9	0.52	58.58	176032	423986
5	30	890	0.1279	3.2	3.27	0.5	0.080	220.96	1490.0	29.6	1.75	386.36	238316	400922
6	30	890	0.1279	6.4	6.54	0.5	0.080	191.11	1098.8	21.9	1.29	246.43	214558	401382
7	30	890	0.1279	16	16.4	0.5	0.080	153.31	589.8	11.7	0.69	106.10	87682	72186
8	30	890	0.1279	16	16.4	0.5	0.080	111.63	355.2	7.1	0.42	46.52	83868	144207
9	45	890	0.0512	32	32.7	0.5	0.119	220.96	1289.6	25.6	1.51	334.38	143666	114219
10	45	890	0.0512	6.4	6.54	0.5	0.119	191.11	962.2	19.1	1.13	215.79	121586	112910
11	45	890	0.0512	16	16.4	0.5	0.080	153.31	638.2	12.7	0.75	114.82	101353	117676
12	45	890	0.0512	3.2	3.27	0.5	0.080	111.63	335.8	6.7	0.39	43.99	77197	98380
13	60	890	0.0232	32	32.7	0.5	0.080	220.96	1243.4	24.7	1.46	322.42	129433	55357
14	60	890	0.0232	3.2	3.27	0.5	0.080	191.11	899.5	17.9	1.06	201.72	108663	56909
15	60	890	0.0232	16	16.4	0.5	0.080	153.31	596.3	11.9	0.70	107.28	86780	59430
16	60	890	0.0232	6.4	6.54	0.5	0.119	111.63	328.3	6.5	0.39	43.00	71106	57872
17	15	890	0.2535	32	32.7	0.75	0.080	220.96	1128.8	22.5	1.32	292.69	121399	46330
18	30	890	0.1279	3.2	3.27	0.75	0.119	191.11	894.6	17.8	1.05	200.63	105733	45190
19	45	890	0.0512	16	16.4	0.75	0.040	153.31	574.5	11.4	0.67	103.36	78975	43984
20	60	890	0.0232	6.4	6.54	0.75	0.040	111.63	303.5	6.0	0.36	39.75	61315	42311
21	60	890	0.0232	32	32.7	1	0.119	220.96	1222.1	24.3	1.43	316.88	120084	49294
22	30	890	0.1279	3.2	3.27	1	0.119	191.11	907.0	18.0	1.06	203.42	100782	42275
23	45	890	0.0512	16	16.4	1	0.040	153.31	579.3	11.5	0.68	104.23	77492	44057
24	15	890	0.2535	6.4	6.54	1	0.080	111.63	177.3	3.5	0.21	23.23	60537	40908

This model describes hyperplane dependence of the bearing parameters and factors. Easy work and explanation needs some simple diagrams with some factors fixed in one value and the other factors changed in some steps or diapason. For example, Figure 8 shown power losses in the bearing in dependence of the mass flow rate (0.04÷0.119 kg/s) due to different roughness and constant oil temperature and angular velocity.

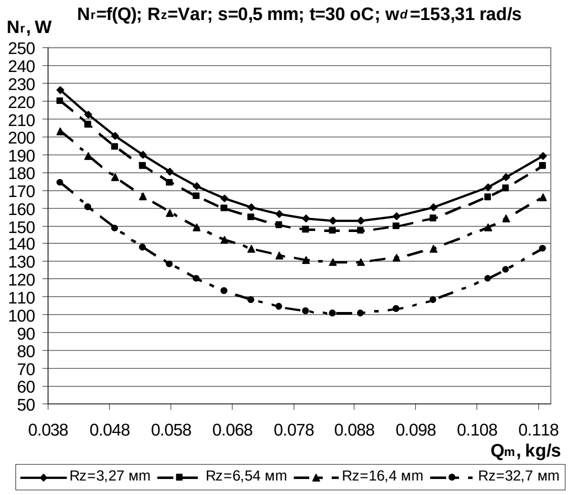

Figure 8. Power loses dependence from inlet mass flow rate diagrams due to different bearing roughness values

Figure 9 describes bearing behavior with different bearing clearance and constant roughness and angular velocity.

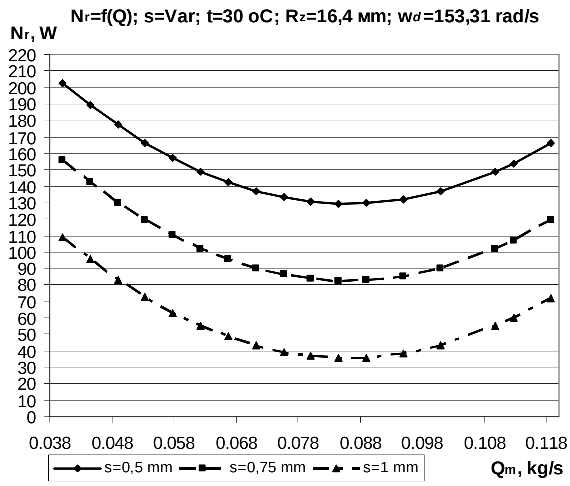

Figure 9. Power loses dependence from inlet mass flow rate diagrams due to different bearing clearance values

Figures 10 and 11 shows power loses changes in dependence of the oil temperature (15÷60 °C) and inlet mass flow rate (0.04÷0.119 kg/s) in noted diapasons for constant bearing surface roughness, bearing clearance and bearing angular velocity.

5. Conclusions

The research results (Figures 8 ÷ 11) shown that the most suitable regime in a view of minimization of power loses is by: R_z=32.7 μm; s = 1 mm; Q_m = 0.08÷0.09 kg/s; t = 40÷60 °C.

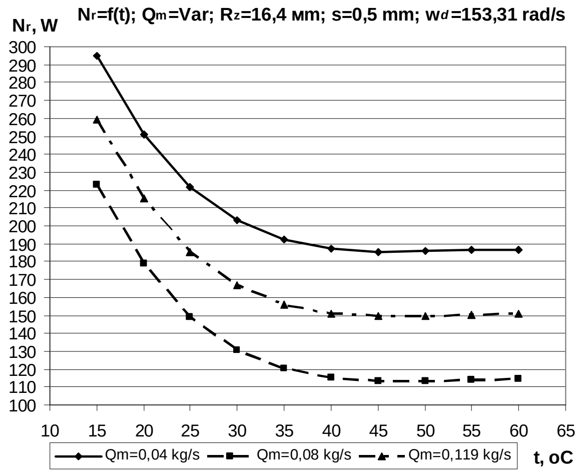

Figure 10. Power loses dependence from oil temperature diagrams due to different mass flow rates

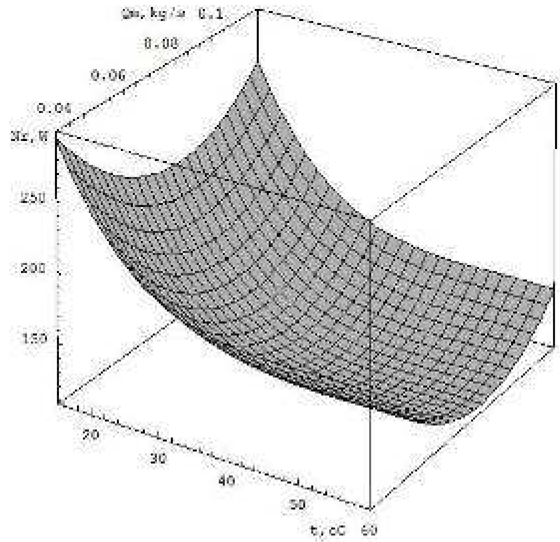

Figure 11. Power loses in dependence of oil temperature and inlet flow rate

The shown methodic allows choosing and supporting on most suitable parameters for the journal bearing assembly. The methodic may serve in the optimization of bearing working regimes based on five factors in view of reliability and durability. The factors are as follows:

Technical factors:

1. characteristics and behavior of the lubrication oil - dynamical viscosity temperature stability);
2. bearing bush angular velocity;
3. mass flow capacity of the oil lubrication system;

Constructive factors:

4. bearing surface roughness;
5. bearing clearance.

Methodic is useful for research over working regimes change. The basic interest for result comes from the increased bearing length.

As a further development of the present paper:

- approval of the model for work with dynamical load;
- synthesis of model allows research, calculation and analysis of summary bearing losses - mechanical, thermal and flow losses.

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