JOURNAL OF ENGINEERING
annals OF
FACULTY OF ENGINEERING HUNEDOARA
Tome V (year 2007), Fascicole 2, (ISSN 1584 – 2665)

DESIGN, PRODUCTION, AND APPLICATION OF A STAND FOR TESTING FRICTION OF THE BEARINGS

Pavlina KATSAROVA, Stilian NIKOLOV, Miltso TASHEV

TECHNICAL UNIVERSITY – SOFIA,BRANCH OF PLOVDIV,
JOHN ATANASSOV TECHNICAL COLLEGE, PLOVDIV, BULGARIA

ABSTRACT:
A pendulum-stand was designed and produced for the purpose of testing the friction of the bearings applying the method of the dying oscillations. The stand gives possibilities to carry out friction tests of sliding and antifriction bearings. Experiments with two sliding bearing pairs (steel/laminated fabric and steel/steel) were carried out on the suggested methodic. The received results were shown in tables and graphs that prove the work capacity of the created stand. The so suggested stand can be used for experimental friction studies of wide range of sliding and antifriction bearings.

KEY WORDS:
bearings, sliding bearing, friction pair, kinematical analysis

1. INTRODUCTION

The bearings are devices that support the rotating or oscillating machine elements in definite position, carry their load and transfer it to the stand permitting constrained relative motion at the same time [1,4].

The purpose of this work is to study the friction of the bearings using the method of the dying oscillations. A stand was designed and produced in order to determine the friction torque in different bearings by a pendulum with dying oscillations. The pendulum axis is suspended on the bearing and allowed to oscillate freely. The friction of the bearing leads to a process of dying oscillations. A gradual amplitude decrease (decrease of the pendulum angle of deviation) is characteristic for the process of the dying oscillations [1,3] fig.1.

The potential energy of the pendulum which is connected with the amplitude changes during the motion:

$$\Delta \Pi = Gh = Gh(\cos\alpha_n - \cos\alpha_0) \qquad (1)$$

where:

Π is the potential energy of the pendulum;
G – the weight of the pendulum;
h – the length of the pendulum.

When the deviation angles are small (α < 8-10^0), cosα can be replaced by 1-$\frac{\alpha^2}{2}$ and the dependence (1) acquire the following form:

$$\Delta П = Gl\frac{(\alpha_0 - \alpha_n)(\alpha_0 - \alpha_n)}{2} = Gl(\alpha_0 - \alpha_n)\,\alpha_{cp} \quad (2)$$

The work of the friction forces of the considered time interval of the pendulum from α_0 to α_n can be received by multiplying the friction torque $M_{тр}$ by the sum of the pendulum angles of oscillation:

$$A_{тр} = M_{тр}(\alpha_0 + 2\alpha_1 + 2\alpha_2 + 2\alpha_3 + \ldots\ldots.2\alpha_{n-1} + \alpha_n) \quad (3)$$

Taking into consideration that:

$$\alpha_0 + \alpha_n = 2\alpha_{cp} \text{ и } \alpha_1 + \alpha_2 + \alpha_3 + \ldots\ldots\alpha_{n-1} = (n-1)\alpha_{cp} \quad (4)$$

We receive for the work of the friction:

$$A_{тр} = M_{тр} 2\, n\, \alpha_{cp} \quad (5)$$

The pendulum potential energy change is equal to the work of the friction forces because the friction in the bearing is the only energy consumer. After equalization of $\Delta П$ from (2) to the $A_{тр}$ from (3) we receive the following dependence:

$$M_{TP} = Gl\frac{\alpha_0 - \alpha_n}{2n} \quad (6)$$

or

$$M_{TP} = Gl\frac{\alpha_0 - \alpha_n}{4N} \quad (7),$$

where:

M_{TP} – friction torque [N m];
G – weight of the pendulum [N];
l – length of the pendulum [m];
h – difference of the pendulum height at initial and final position. [m];
$a_0 \div a_n$ – angles of oscillation of the pendulum [rad];
n – number of the semi-periods [бр.];
N - number of the oscillation periods of the pendulum - $N = \frac{n}{2}$ [бр.].

The connection between the friction torque and the value of the reduced friction coefficient is:

$$M_{TP} = F.f.r \quad (8),$$

where:

F – loading force [N];
f - friction coefficient ;
r – bearing's radius [m].

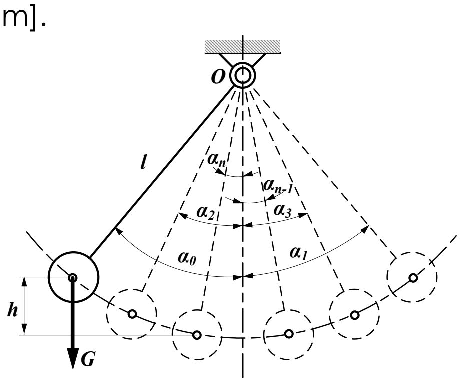


Fig.1. Theoretical treatment

2. PRINCIPLES OF OPERATION OF THE STAND

The stand consists of the following elements – Fig.2: base (1) made of laminated fabric with possibilities of immovable fixation to a wall. Pendulum which consists of: axis (2), weight (3) and controlling nut (4) all made of steel. The weight position toward the axes of rotation can be changed by the controlling nut up to 100[mm]. The tested bearing bush (5) is fastened in the upper part of the pendulum by a threaded joint (M8). The shaft (6) with the bearing bush is mounted to the base by a threaded joint M18. The bearing bush is mounted on the bearing journal with clearance fit H7/h6. The bolt and the nut M8 (7, 8) are used for axial fixation of the bearing. The parameters of the stand area:

- Overall dimensions- 67,5/400/600 [mm]
- Mass of the weight (3, fig.2) of the pendulum - 0,5÷1 [kg].
- Length of the pendulum *l* - 0,28÷0,38 [m];
- Diameter of the tested friction surfaces *D* (fig.3) - 10÷30 [mm].

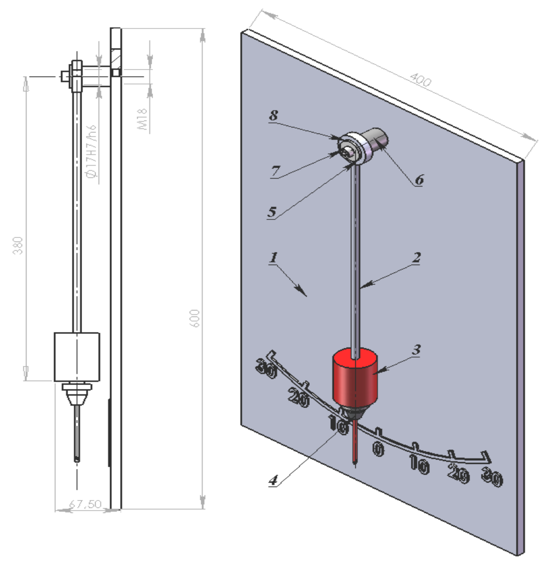


Fig. 2 Design of the pendulum stand

The stand gives possibilities of testing sliding bearings with different materials taking part in the friction pairs of the tested bearing bushes and shafts according to fig.3. The diameter *D* of the bearing's friction pairs determines the overall dimensions of the bush and shaft.

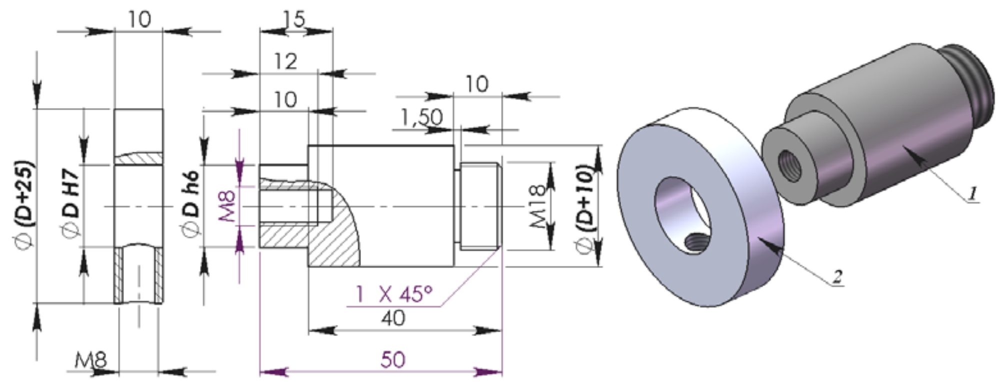


Fig.3 Design of the bearing bushes and shafts of the sliding bearings.
1-shaft with a bearing journal; 2- bearing bush

The tested bearing has to be positioned on the stand according to fig.4. The diameters D and d of the bearing bush and shaft depend on the dimensions of the tested bearing and determine the overall dimensions of the bush and the shaft according to fig. 3.

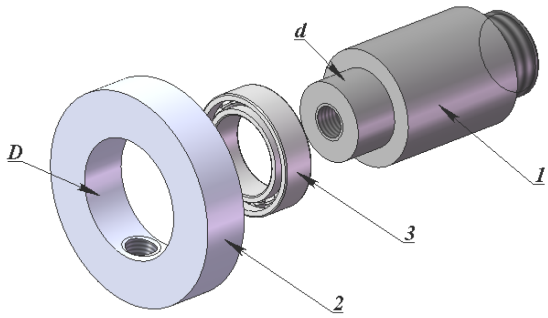


Fig.3 Design of the bearing bushes and shafts of the antifriction bearings.
1-shaft with a bearing journal; 2-bearing bush; 3- tested antifriction bearing

3. METHODIC USED FOR THE EXPERIMENT

1. Preparation of the stand for the experiment. The preparation is made according to the diagram fig.5.

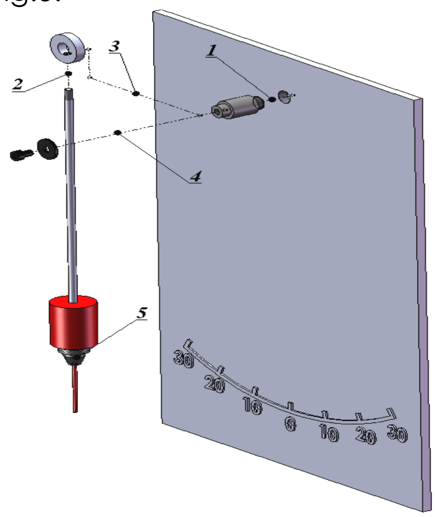


Fig.5 Diagram of the stand preparation
1- shaft fastening to the base; 2- bush fastening to the pendulum axis; 3-fitting of the friction pair; 4-axial fixation of the friction pair; 5-control of the pendulum length

2. Determining the stand characteristic. The characteristic of the stand *Gl* is determined by measuring the mass and the length of the pendulum.

3. Carrying out the experiment. The pendulum is deviated to the necessary angle α_0 and than the final angle α_n and the number of the periods *N* are given for which this angle is reached. The separate tests of the experiment are repeated several times and the received results for α_n are averaged.

4. Calculation of the friction torque M_{TP}. The calculation is made according to (7) using the received results.

5. Determination of the reduced friction coefficient *f*. It is carried out according to formula (8), taking into consideration the radius of the tested friction pair.

6. Analysis of the received results.

4. RESULTS

Two sliding bearings with friction pairs consisting of steel/laminated fabric and steel/steel were studied of fiction by the suggested stand according to the above described methodic. The characteristics of the stand were determined after preparing it for work and producing the bearings:

- Radius of the tested bearing *r* - 0, 0085 [m].
- Weight of the pendulum *G* - 10 [N];
- Length of the pendulum *l* – 0,38 [m];

The experiment was carried out at three initial angles for each pair:

α_0 *-10°=0,175*[rad]; *20°=0,349*[rad]; *30°=0,524*[rad].

Some of the received results and the calculated on this basis values are given in Tabl.1. The values of α_n are determined as mean value of five consecutive tests results at constant angle α_0. The value of M_{TP} is also determined as mean value.

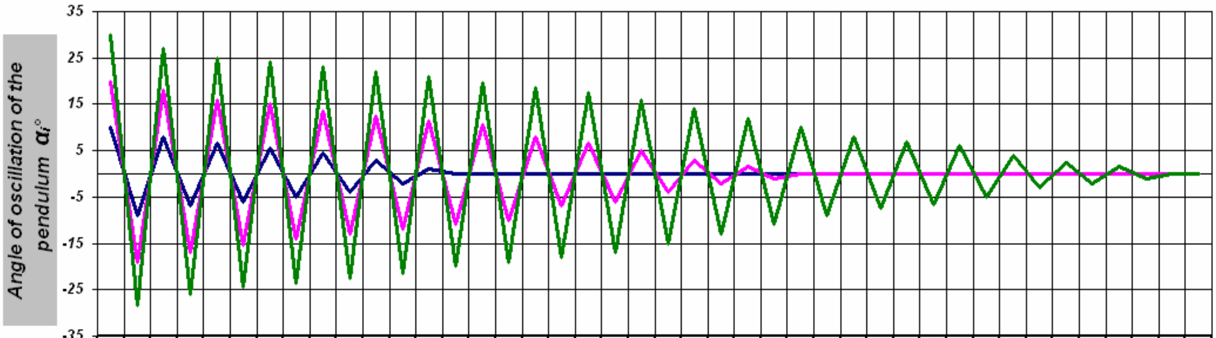
Table 1

Type of the friction pair in the tested bearing		Experimentally determined data			Calculated values according to formulae (2) and (3)		
		α_0°	α_n°	N [бр.]	M_{TPi} [N]	M_{TP} [N]	f
1	Steel/steel	10	2	4	0,033	0,033	0,39
		20	8	6	0,033		
		30	9,5	10	0,034		
2	Steel/laminated fabric	10	4	5	0,020	0,021	0,25
		20	10	8	0,021		
		30	17	10	0,023		

The experimentally determined friction coefficients in the two friction pairs correspond to the data published in [2] for the friction coefficients of such type of pairs. They are as follows:

- Steel/laminated fabric - *f=0,15÷0,25*.
- Steel/steel - *f=0,39÷0,41*;

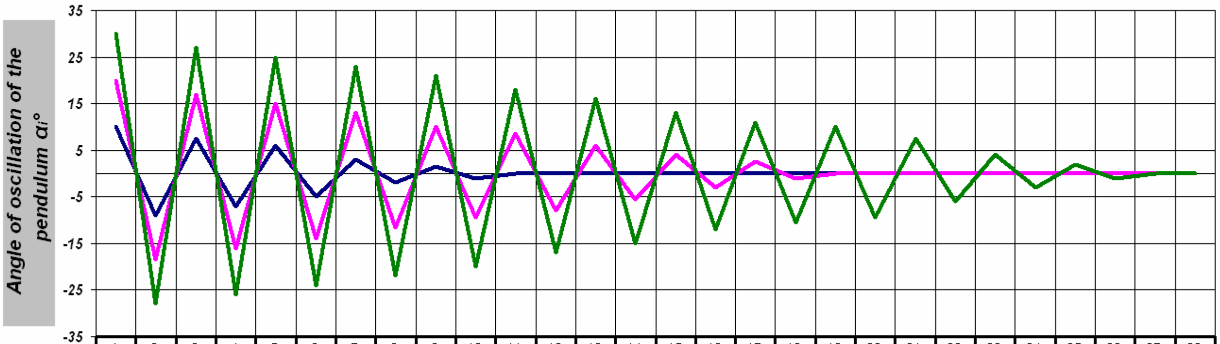
The received results and their graphical presentation are shown as follows: fig.6 – for a friction pair steel/ laminated fabric and fig.7 – for a friction pair steel/ steel. The graphs describe the pendulum movement. The values of the pendulum oscillation angles α_i are determined as mean value of five consecutive tests results at constant angle α_0.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
α=10°	10	-9	8	-7	6,5	-6	5,5	-5	4,5	-4	3	-2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
α=20°	20	-19	18	-17	16	-16	15	-14	14	-13	13	-12	12	-11	11	-10	8	-7	6,5	-6	5	-4	3	-2	1,5	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
α=30°	30	-29	27	-26	25	-25	24	-24	23	-23	22	-22	21	-20	20	-19	19	-18	18	-17	16	-15	14	-13	12	-11	10	-9	8	-8	7	-7	6	-5	4	-3	2,5	-2	1,5	-1	0	0

Semi-periods n

Fig.6. Results from the experiment with a friction pair steel/laminate fabric



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
α=10°	10	-9	7,5	-7	6	-5	3	-2	1,5	-1	0	0	0	0
α=20°	20	-18,5	17	-16	15	-14	13	-11,5	10	-9,5	8,5	-8	6	-5,5
α=30°	30	-28	27	-26	25	-24	23	-22	21	-20	18	-17	16	-15

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
α=10°	0	0	0	0	0	0	0	0	0	0	0	0	0	0
α=20°	4	-3	2,5	-1	0	0	0	0	0	0	0	0	0	0
α=30°	13	-12	11	-10,5	10	-9,5	7,5	-6	4	-3	2	-1	0	0

Semi-periods n

Fig.7. Results from the experiment with a friction pair steel/steel

5. CONCLUSIONS

- The results received by the experiment correspond to the data published in different literature sources.
- The so suggested stand can be used for experimental friction studies of wide range of sliding and antifriction bearings.
- The pendulum-stand gives possibilities of studying different friction pairs at definite working conditions.
- The suggested experimental methodic is accessible for the laboratory

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