Secure Systems Design and Technology Development. Veliko Tarnovo, Bulgaria
Proceedings of the International Scientific Conference, 2026. Volume II, 85-89

Methodology for Testing Bearings by the Dampling Oscillation Method

Kliment Krumov Georgiev
Technical University of Sofia, branch Plovdiv
Faculty of Mechanical Engineering;
Department: Mechanical and Instrument Engineering
Plovdiv, Bulgaria
k.georgiev@tu-plovdiv.bg

Iva Naydenova
Technical University of Sofia, branch Plovdiv
Faculty of Mechanical Engineering;
Department of Mathematics, Physics, Chemistry
Plovdiv, Bulgaria
iva.naydenova@tu-plovdiv.bg

Pavlina Tsanova Katsarova
Technical University of Sofia, branch Plovdiv
Faculty of Mechanical Engineering;
Department: Mechanical and Instrument Engineering
Plovdiv, Bulgaria
p_katsarova@abv.bg

***Abstract*— Rolling bearings are machine components widely used in mechanical engineering. They are used under various operating and load conditions. Their widespread use makes it necessary to test them under certain conditions to study their behavior. This paper presents a methodology for testing bearings using the damped oscillation method. A specially designed test rig is used in accordance with the method described. The bearing is fixed to the stand by the inner strap and an axle with a movable weight, of the physical pendulum type, is fixed to its outer strap. Decay oscillations are read on an angular scale from 30° to -30°. Experiments have been performed and results obtained with different starting points (10°, 20°, and 30°) and different positions of the weight along the axis. The results obtained are processed using statistical software and presented in the form of graphs and tables. The methodology described can be used both in practice and for training students in laboratory conditions.**

Keywords*— *Bearings, Bearings testing, Dampling oscillation, Methodology, Rolling bearing.

I. Introduction

The damping oscillation method is a widely utilized technique in laboratory-oriented ball bearing testing, allowing the assessment of dynamic parameters such as stiffness, damping coefficients, and the influence of tribological effects. This method is particularly critical in applications ranging from failure diagnostics to predictive maintenance of rolling-element bearings. Despite its importance, explicit research on the development of standardized training methodologies and technical frameworks for the damping oscillation method remains sparse, demanding a deeper investigation into existing experimental setups, modeling techniques, and standardization efforts.

The reviewed literature provides a foundation for understanding the state of experimental methodologies and modeling approaches in ball bearing testing under dynamic conditions. Early studies, such as Kraus et al. [1], introduced an in situ modal analysis method as a pioneering framework for identifying damping and stiffness in fully operational rotor-bearing systems. This was later expanded upon by works such as Dietl et al. [2], Wensing et al. [3], and Lambert et al. [4], which developed experimental setups and theoretical models that accounted for critical damping contributions, including elastohydrodynamic lubrication, bearing preload, and time-dependent system stiffness. A major focus of these studies has been controlling damping variability during testing, with experimental designs such as monolithic bearing assemblies [5, 6] and frequency-domain transfer function analyses [7] addressing the influence of boundary conditions and assembly errors.

In recent years, modeling efforts have emphasized nonlinear and transient damping effects. Peng et al. [8] proposed a multigrid method to incorporate lubrication and load effects into comprehensive damping calculations, while Kong et al. [9] linked lubricant viscosity and grease effects to damping variations in defective bearings. These theoretical and experimental advancements present opportunities to expand the utility of the damping oscillation method for failure mode recognition and diagnostic purposes. Despite these developments, efforts to unify such methodologies under standardized frameworks are limited. Notably, Ratcliffe et al. [10] proposed general vibration testing standardization strategies, but these lack specific application to ball bearing damping oscillation testing.

Online ISSN 3044-7771
https://doi.org/10.68302/std2026.vol2.7

The critical gap remains the absence of explicit efforts to translate these methodologies into consistent training programs for laboratory technicians and researchers. The integration of dynamic modeling insights with hands-on experimental setups could improve skill reproducibility and foster standardization in this largely decentralized field. This gap underlines the need for future research that bridges experimental setups, advanced modeling techniques, and technician-oriented training frameworks.

II. Materials and Methods

A. Materials

The testing methodology for bearings using the damped vibration method was developed for the test rig shown in Fig. 1. The design and construction of the test rig used are described in detail in "DESIGN, PRODUCTION, AND APPLICATION OF A STAND FOR TESTING FRICTION OF THE BEARINGS" by Katsarova P. et al [11].

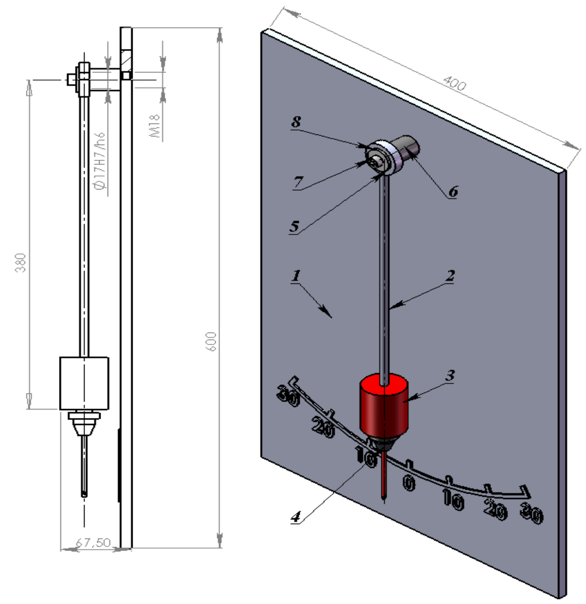

Fig. 1 Bearing testing stand [11]

The stand is composed of the following elements, as illustrated in Figure 1:

- A base (1) constructed from laminated fabric, capable of fixed installation on a wall.
- A pendulum comprising an axis (2), a weight (3), and a control nut (4), all manufactured from steel. The position of the weight relative to the axis of rotation can be adjusted by the control 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 (48, 49) are used for axial fixation of the bearing. The parameters of the stand area are as follows:

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

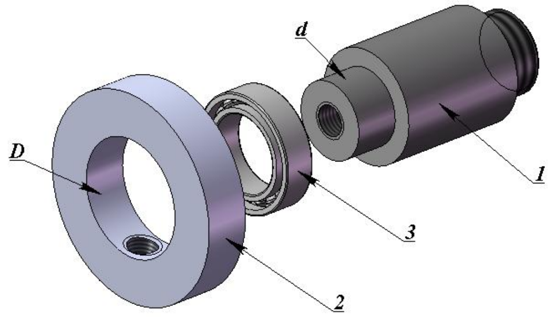

Fig. 2 Friction rig assembly [11]

B. Materials

The testing methodology for bearings entails the use of damping oscillations to assess their performance. This approach is founded on the principle of measuring the change in potential energy of a pendulum during its oscillatory motion.

The stand employed in this methodology is designed to ascertain the friction moment in different bearing supports by means of the damping oscillation method. The pendulum axis is suspended from the bearing support under test and permitted to oscillate freely. Friction in the bearing results in damping oscillations. The damping oscillations are characterized by a gradual decrease in amplitude with decreasing pendulum deflection angle (see Fig. 3) [12,13].

The potential energy of the pendulum is associated with the amplitude changes that occur during its motion.

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

where:

U - the potential energy of the pendulum;
G – weight of the pendulum;
h – length of the pendulum.

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

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

The work of the friction forces during the specified time interval of the pendulum from α_0 to α_n can be calculated by multiplying the friction torque M_{Tp} by the sum of the pendulum angles of oscillation:

$$A_{Tp} = M_{Tp}(\alpha_0 + 2\alpha_1 + 2\alpha_2 + 2\alpha_3 + \dots 2\alpha_{n-1} + \alpha_n) \qquad (3)$$

Taking into consideration that:

$$\alpha_0 + \alpha_n = 2\alpha_{mean} \quad \text{and}$$

$$\alpha_1 + \alpha_2 + \alpha_3 + \dots \alpha_{n-1} = (n-1)\alpha_{mean} \qquad (4)$$

The work of friction is received by us:

$$A_{Тр} = M_{Тр} 2\, n\, \alpha_{mean} \tag{5}$$

The pendulum potential energy change is equivalent to the work of the friction forces because the friction in the bearing is the sole energy consumer. Subsequent to the equalization of ΔU from (2) to $A_{Тр}$ from (3), the ensuing dependence is obtained:

$$M_{TP} = Gl\frac{\alpha_0 - \alpha_n}{2n} \tag{6}$$

or

$$M_{TP} = Gl\frac{\alpha_0 - \alpha_n}{4N} \tag{7}$$

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];
$\alpha_0 \div \alpha_n$ – angles of oscillation of the pendulum [rad];
n – number of the semi-periods;
N - number of the oscillation periods of the pendulum - $N = \frac{n}{2}$;

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

$$M_{TP} = F.f.r \tag{8}$$

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

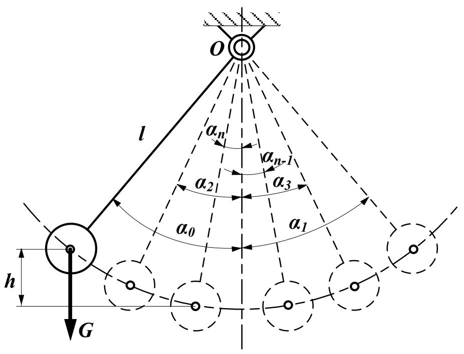

Fig. 3 Theoretical setup

III. Figures, Tables and Equations

In order to ensure the accuracy and adequate interpretation of experimental results, it is essential that the operator possesses a comprehensive understanding of the theoretical framework and the methodology employed. The bench methodology is delineated in eight points.

1. The following text presents a theoretical exposition of the method of damping oscillations. It includes a comprehensive introduction to the operator within the theoretical framework of the method of damping oscillations, as outlined in the section entitled "Methods."

2. The operator is required to become acquainted with the stand's design. This involves an examination of the stand's characteristics, features, and capabilities. Refer to Figure 1 for a visual representation of the stand.

3. A consideration of the bearing types is warranted, given that the types of bearing pairs that suit the design features of the rig are of paramount importance.

4. The following steps are taken in order to prepare the stand for operation. At this point, the bearing to be tested is mounted to the stand (see Fig. 2). Once the bearing is fitted and the stand is assembled, the position of the weight is adjusted. The weight can be placed at different heights along the axis of the pendulum, which allows for a multitude of experiments to be conducted. For the present experiment, the NMB SSR-4HH bearing was selected. Once prepared, the characteristics of the rig are as follows:

- Radius of the tested bearing r = 8,5 mm;
- Weight of the pendulum G = 10 N;
- Length of the pendulum l = 380 mm;

5. The experiment is meticulously planned, with a detailed plan of the experimental part being formulated. The heights of the weights and the initial angles are selected with precision α_0. In this example, two weight positions are selected: 1) weight in the lowest position, and 2) weight in the top position. For each pendulum weight position, three experiments were conducted with starting angles $\alpha_0 = 10^\circ$; 20°; 30°.

6. The collection of experimental data is to be carried out by conducting the requisite number of experiments, as outlined in Section 5. The resulting data shall be presented in tabular form, and the results of the experiments are to be displayed in Figures 4, 5, 6, and 7.

Weight in top position																										
Semiperiod n																										
Angle,°	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
30	30	-30	28	-26	26	-24	24	-22	20	-20	20	-18	18	-16	16	-16	14	-14	12	-12	12	-10	10	-10	8	-8
20	20	-20	18	-18	16	-18	16	-16	14	-14	12	-12	10	-10	10	-10	8	-8	8	-6	6	-4	4	-4	4	-2
10	10	-10	10	-10	8	-8	8	-8	6	-6	6	-6	6	-4	4	-4	2	-2	2	-2	2	-2	2	-2	0	0

Fig. 4 – Weight in top position – part 1

Weight in top position																									
Semiperiod n																									
Angle,°	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
30	8	-6	6	-6	6	-6	4	-4	4	-4	2	-2	2	-2	2	-2	0	0	0	0	0	0	0	0	0
20	2	-2	2	-2	2	-2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	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

Fig. 5 – Weight in top position – part 2

Weight at lowest point																										
Semiperiod n																										
Angle,°	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
30	30	-30	28	-26	26	-24	24	-22	22	-20	20	-20	18	-18	18	-18	16	-16	16	-14	14	-12	12	-12	10	-10
20	20	-20	18	-18	18	-16	16	-16	14	-14	12	-12	12	-10	10	-10	8	-8	8	-6	6	-6	6	-4	4	-4
10	10	-10	10	-10	10	-8	8	-8	8	-6	6	-6	6	-6	6	-4	4	-4	4	-2	2	-2	2	-2	2	-2

Fig. 6 – Weight in lowest position – part 1

Weight at lowest point																									
Semiperiod n																									
Angle,°	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
30	10	-8	8	-8	8	-6	6	-6	4	-4	4	-4	2	-2	2	-2	2	-2	2	-2	2	-2	2	0	0
20	4	-4	4	-2	2	-2	2	-2	2	-2	2	-2	2	-2	0	0	0	0	0	0	0	0	0	0	0
10	2	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 7 – Weight in lowest position – part 2

7. Data Processing

Following the execution of the experimental phase, the collected data must undergo processing. This processing involves the construction of graphs depicting damping oscillations, alongside the calculation of the MTP coefficient values utilizing Formula 7. The calculation of the friction moment is performed by employing the relationship between α_0 - α_n = α_{mean}. The graphical representation of the results is illustrated in Figures 8 and 9. The values of the friction moment are enumerated in Table 1.

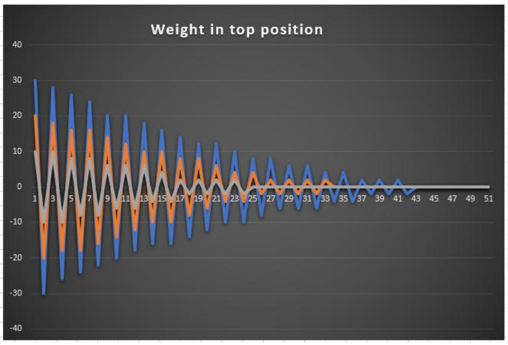

Fig. 8 Weight in top position chart

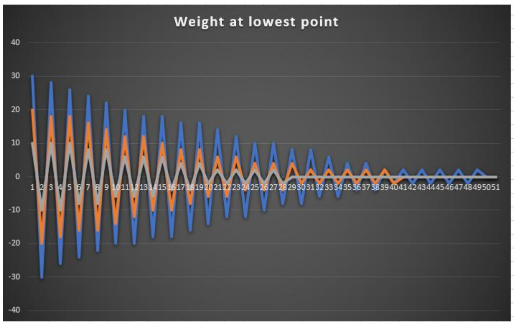

Fig. 9 Weight in lowest position chart

Table 1 Friction torque M_{TP}

Friction pair – Steel/Steel		
	α_0,°;	*M_{TP}, N;*
Top position	*30*	*0.012*
	20	*0.006*
	10	*0.003*
Lowest position	*30*	*0.014*
	20	*0.009*
	10	*0.010*

8. Analysis

The data obtained from the experiments and calculations are subjected to rigorous analysis.

IV. Conclussions

1. The methodology presented herein can be utilized in both teaching and practice settings.
2. The obtained results demonstrate the reliability of the methodology and the efficacy of the rig.
3. The methodology presented herein can be applied to the study of friction in different pairs of bearings.

Aknowledgements

The author/s would like to thank the Research and Development Sector at the Technical University of Sofia for the financial support."

REFERENCES

[1] Kraus, J. J. J. S. G., Blech, J. J., & Braun, S. G. (1987). In situ determination of rolling bearing stiffness and damping by modal analysis.

[2] Dietl P, Wensing J, van Nijen GC. Rolling bearing damping for dynamic analysis of multi-body systems—experimental and theoretical results. Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics. 2000;214(1):33-43. doi: https://doi.org/10.1243/1464419001544124

[3] Wensing JA, van Nijen GC. The dynamic behaviour of a system that includes a rolling bearing. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*. 2001;215(6):509-518. doi: https://doi.org/10.1243/1350650011543763

[4] Lambert RJ, Pollard A, Stone BJ. Some characteristics of rolling-element bearings under oscillating conditions. Part 1: Theory and rig design. Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics. 2006;220(3):157-170. doi: https://doi.org/10.1243/1464419JMBD12

[5] Mitsuya, Y., Sawai, H., Shimizu, M., & Aono, Y. (1998). Damping in vibration transfer through deep-groove ball bearings.

[6] Mitsuya, Y., Tonoi, S., Shimizu, M., Aono, Y. (1992). Damping performance of vibration transmission through deep groove ball bearings

[7] Zeillinger, R., Springer, H., & Köttritsch, H. (1994, June). Experimental determination of damping in rolling bearing joints. In *Turbo Expo: Power for Land, Sea, and Air* (Vol. 78873, p. V005T14A016). American Society of Mechanical Engineers.

[8] Sun, P., Chen, W., Shen, Y., & Wang, D. (2020). Calculation method for comprehensive damping of ball bearings based on multigrid method. *Industrial Lubrication and Tribology*, *72*(7), 937-945.

[9] Kong F, Huang W, Jiang Y, Wang W, Zhao X. Research on effect of damping variation on vibration response of defective bearings. *Advances in Mechanical Engineering*. 2019;11(3). doi: https://doi.org/10.1177/1687814019827733

[10] Ratcliffe, Colin P., Crane, Roger M., Capone, Dean, Koudela, Kevin (1998). Standardized Procedure for Experimental Vibration Testing of Damping Test Specimens.

[11] KATSAROVA, P., NIKOLOV, S., & TASHEV, M. DESIGN, PRODUCTION, AND APPLICATION OF A STAND FOR TESTING FRICTION OF THE BEARINGS.

[12] Nedev,Tc.,Jivkov,P., Lilov Al.,*Guidance for laboratory exercises on elements of apparatus and machines,* Technika, Sofia, ISBN 621.81(076),1978,p.p.3-7

[13] Nedev,Tc,*Elements of the apparatus and machines*, Technika, Sofia, ISBN 621.1(075.8), 1979,p.p.136-154