Experimental studies on vibration characteristics on ball bearing operated with copper oxide nano particle mixed lubricant

Prakash E [#1], Siva Kumar K [#2] and Muthu Kumar K[#3]

[#] Faculty of Department of Mechanical Engineering, Bannariamman Institute of Technology
Sathyamangalam, Erode, India-638401

[#] Faculty of Department of Bio-Technology, Bannariamman Institute of Technology
Sathyamangalam, Erode, India-638401

[1] prk_mek@yahoo.co.in

[2] ksk71@rediffmail.com

[3] kmuthukumarbit@gmail.com

***Abstract* – The purpose of this paper is to investigate the vibration suppression characteristics of ball bearing supplied with nano-copper oxide (CuO) mixed lubricant. CuO nanoparticles were synthesized by chemical method and characterized using XRD and TEM to study the crystallanity and ultrastructure. The synthesized CuO nanoparticles were of the size range 5-8 nm. 0.2%, 0.5%, and 1% (W/V) of CuO nanoparticles was added to the lubricant (ISO VG 68) and was used for further analysis. The test rig setup consists of a ball bearing and loading arrangement operated by a DC motor. The bearing (New, Ball defect and Outer defect) vibrations were measured using base lubricant and CuO lubricant mixture. Our results show a reduction of 41% vibration amplitude while using 0.2% (W/V) CuO nanoparticles in outer case defected compared to base lubricant.**

Keyword- Damping characteristics, Lubricant, Ball bearing, CuO Nanoparticles

I. INTRODUCTION

Machine components, gears and bearings runs at high speed and high load condition. These extreme conditions exert pressure on the working system. Therefore a lubricant is required to reduce the temperature and extreme pressure. This lubricant acts as blood for all mechanical systems. The use of lubricant prolongs the machine service life, working efficiency and also aids in noise reduction.

The additives present in the lubricant reduce the friction and wear between the contacting surfaces. This method has been in use for quite a long time. Sulphur, Chlorine and Phosphorous containing compounds were put in use to react chemically with the metal surfaces, forming easily sheared layers of sulphides, chlorines or phosphides, and thereby preventing severe wear and seizure [1]. The use of chlorine- and phosphorus-containing compound is restricted as lubricant additives for its adverse environmental effects. Therefore various researchers aim at developing new additives for the lubricant.

Nanotechnology is the most revolutionizing technology of the 21st century. The nano particles were synthesized and characterized by many researchers in recent years for their excellent physical and chemical properties [2-3]. In tribology, nano particles were added into the lubricant (oil or grease) to withstand extreme pressure (EP) conditions, anti-wear (AW) and friction-reduction. All the tribo-mechanical properties depend on the characteristics of nano particles, such as size, shape, and concentration [4-5]. Many researchers uses nano particles of size 5-100 nm. The suspended particles in the lubricant produces ball bearing effect, better load carrying capacity, acts as a protective film, mending effect and polishing effect [6-7]. All studies indicated that the nano particles are effective in reducing wear and friction.

In this research the CuO nano particles were prepared by chemical method and added as an additive into the paraffin oil (ISO VG 68). The vibration signatures were acquired using fabricated test rig, which consist of ball bearing, an accelerometer and data acquisition device. Comparison study was carried out with base lubricant and nano CuO mixed lubricant.

II. EXPERIMENTAL DETAILS

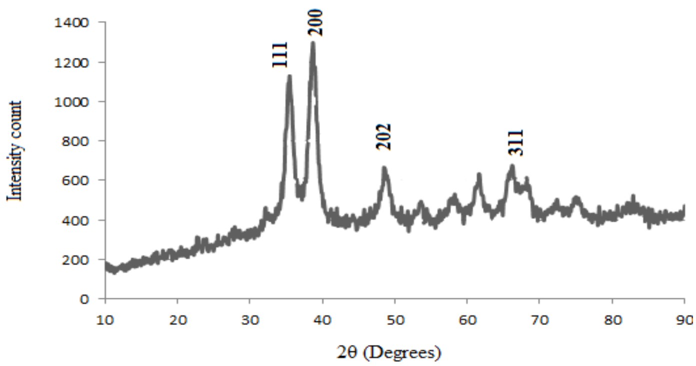
A. Preparations of CuO nano particles

Copper acetate monohydrate Cu $(CH_3COO)_2.H_2O$ and acetic acid glacial were purchased from Merck, India and was used without further treatments. Sodium hydroxide NaOH (pellets) and deionized water was used all throughout the experiment [8-10].

The details about the preparation procedures are as follows: An aqueous solution of copper acetate (0.02 mol) was prepared with deionized water in a round bottom flask. 1 ml glacial acetic acid was added to the above aqueous solution and heated to 65°C with constant stirring. 0.1 M NaOH was added to above heated solution till pH reaches to 6-7. Formation of a black precipitate is observed and the solution was stirred until the temperature reduces to room conditions. Prepared sample was centrifuged at 5000 rpm for 10 min and washed 3- 4 times with deionized water. The obtained precipitate was dried in air for 24 h to get the CuO nano particle.

B. Characterization

The XRD (LabX XRD, Shimadzu) pattern of the synthesized CuO nanoparticles is shown in Fig. 1 (a). The diffraction peaks match well with patterns (JCPDF Card no. 05-661) confirming the formation of CuO nanoparticles. The average crystal size (D) was calculated using Scherrer's relation: $D = 0.9\lambda / B \cos\theta$, where, λ is the wavelength of X-ray and B is full width of half maximum (FWHM).



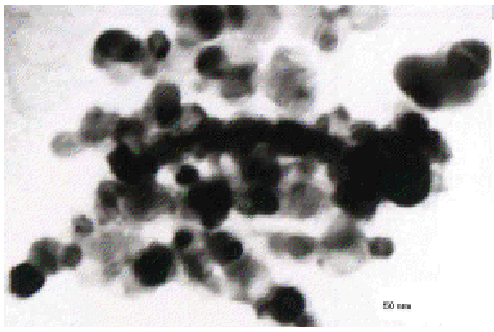


Fig. 1. (a) XRD pattern of CuO nano particles   Fig. 1. (b) TEM micrograph

There were no peaks of impurities found in XRD pattern. The average crystallite size of CuO nano particles is found to be 5-8 nm (Using Scherrer formula). The morphology of CuO were characterized by transmission electron microscope (JEOL TEM 2100) shown in Fig. 1 (b). Clear monolithic spherical shaped particles were observed during the test.

C. Dispersion of Nano particles

Table 1 shows the specifications of ISO VG 68 used as lubricant in most of industrial applications. CuO nano particles were dispersed into ISO VG 68 lubricant with different concentrations, 0.2%, 0.5%, and 1%wt. To avoid agglomeration the lubricant was sonicated for 2 min [11]. This forms uniform dispersion of nano particles into the lubricant.

TABLE 1
Typical Properties of ISO VG 68 lubricant

Properties of ISO VG 68 lubricant	
Density at 29.5°C	0.85
Viscosity index	115
KV at 40°C mm2/s	68
KV at 100°C mm2/s	9.3
Flash Point °C	210
Pour Point °C	-36

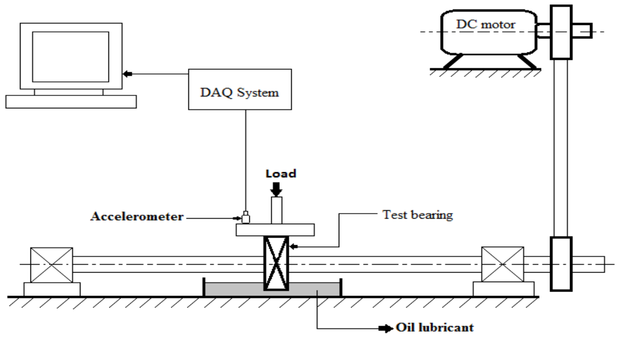


Fig. 2. Experimental setup for bearing vibration measurement

III. TEST RIG SETUP

The base lubricant and CuO nanoparticle added lubricant was applied to the ball bearings and vibration signals were acquired. Bearing test rig consists of motor driven shaft with SKF 6206K ball bearings on gear box casing. The bearings were partially oil bath lubricated. An accelerometer (IMI-627A01 SN8070) placed on the bearing housing in vertical direction to measure radial vibration. The accelerometer connected with the data acquisition device NI-cDAQ-9172 connected to PC via USB port [13].

The experiments were conducted by supplying base and nano-mixed lubricant (0.2%, 0.5%, and 1% wt. concentrations) at no load, 500N and 750 N with new, ball defected and outer defected bearing. The experiments were repeated for three times and average value was taken so as to minimize the standard deviation.

IV. RESULTS AND DISCUSSION

Fig. 3 shows that the variation of vibration amplitude as a function of nano particle concentration. Fig. 3 (a) shows, at no load conditions under different concentrations of nano mixture lubricant, the new bearing exhibits lower vibration level compared to other bearings. An appreciable difference in amplitude of vibration was observed in fig. 3 (c) compared to fig. 3 (b).

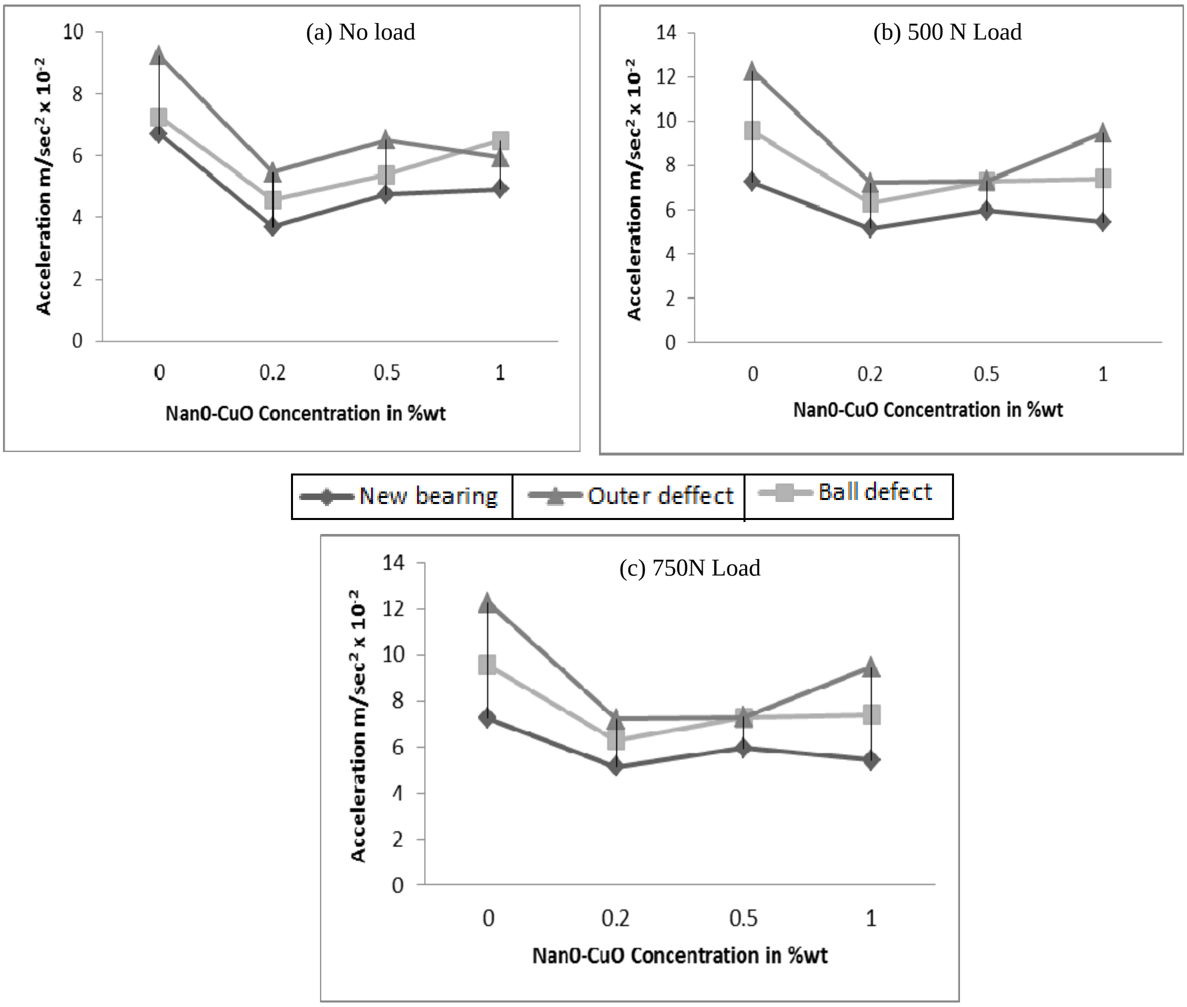


Fig. 3 Amplitude of vibration as a function of nano particle concentration

The vibration amplitude of different bearing running under different load and concentrations were tabulated in table 2. The new bearing showed 29% reduction of amplitude when operated with nano-lubricant containing 0.2% wt of CuO over the base lubricant. In other defected bearings, the ball defect exhibited 34% reduction whereas the outer defect amplitudes reduced to 41% at the concentration of 0.2%wt. The reason for the high reduction ratio was the formation of full film lubrication regime and increase of viscosity of lubricant. Among different concentrations, the 0.2%wt concentration of nano-particle seems to produce more reduction in vibration compared to other concentration shown in Fig. 4.

TABLE 2.Amplitude of vibration (m/sec^2)

Additive	**New Bearing**	**Ball defected**	**Outer defected**
None	0.072414	0.095636	0.122637
0.2% wt	0.051394	0.063054	0.072038
0.5% wt	0.059564	0.072743	0.073053
1% wt	0.054235	0.073862	0.094636

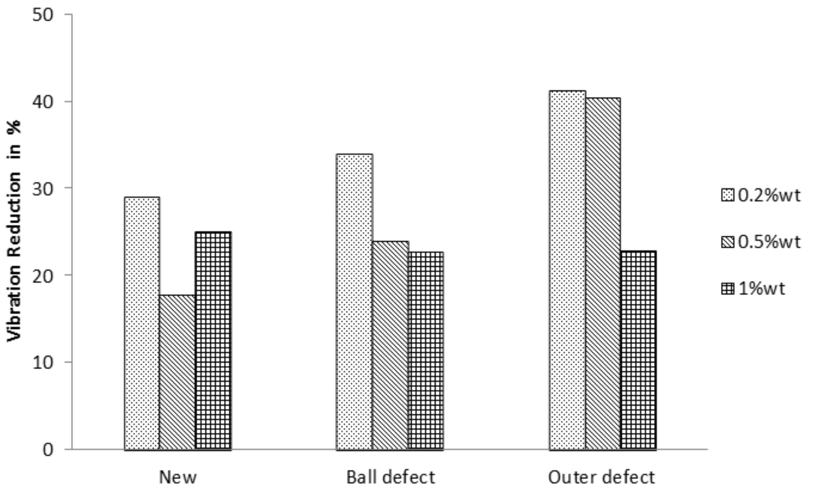


Fig. 4. Vibration reduction comparison of nano-lubricant with base lubricant under different concentrations of nano-CuO mixed oil

V. CONCLUSION

CuO nano particles were synthesized by the aqueous precipitation method and characterized using XRD and TEM. Nano CuO particles dispersed in ISO VG 68 lubricant and act as an additive. The vibration test results showed that the 0.2 %wt. CuO nano particle mixed lubricant functioning effectively in reducing vibrations of defected bearing compared to new bearing over the other concentrations. The following were the reasons for the dampening of the vibrations,

- Due to spherical shape of the nano-CuO, a rolling motion effect created, which reduced the wear of balls also the vibrations
- Formation of full film lubrication regime over defect area[12]
- As the nano CuO particle increases the viscosity of the lubricant[14]
- Formation of protected film of CuO over the surface and filling of the micro defects by the nano-particle and continue to maintain the film[15]

ACKNOWLEDGMENT

The authors like to thank Mr. Rajan, Karunya University, Coimbatore for helping us to carrying out XRD test. Authors also like to thank Centre for Nano technology and Advanced Biomaterials of SASTRA University, Tanjore in helping to carryout TEM studies.

REFERENCES

[1] A. Hernandez Battez, et al., “The tribological behaviour of ZnO nanoparticles as an additive to PAO6,” *Wear* 261,pp.256–263, 2006.
[2] De-Xing Peng, Yuan Kang, Cheng-Hsien Chen, Shih-Kang Chen Fu-chun Shu, “The tribological behavior of modified diamond nanoparticles in liquid paraffin,” *Industrial Lubrication and Tribology*, Vol. 61 Issue: 4 pp. 213 – 219,2009.
[3] S. Tarasov, et al., “Study of friction reduction by nano copper additives to motor oil,” *Wear* 252, 63–69, 2002.
[4] Y.Y. Wu, et al., “Experimental analysis of tribological properties of lubricating oils with nanoparticle additives,” *Wear* 262, pp. 819–825, 2007.
[5] M. Akbulut, “Nanoparticle-Based Lubrication Systems”, *J Powder Metallurg Mining*, 2011.
[6] Kwangho Lee, et al., “Understanding the Role of Nanoparticles in Nano-oil Lubrication” *Tribol Lett* 35:127–131, 2009.
[7] G. Liu, et al., “Investigation of the mending effect and mechanism of copper nano-particles on a tribologically stressed surface” *Tribology Letters*, Vol. 17, No. 4, Nov.2004.
[8] S. AmrutLanje, et al., “Synthesis and optical characterization of copper oxide nanoparticles” *Advances in Applied Science Research*, 1 (2): 36-40, 2010.
[9] Karim H Hassan, et al., “Study and Characterization of Copper Oxide Nanoparticles Prepared by Chemical Method using X-Ray Diffraction and Scanning Electron Microscope” *American Journal of Scientific Research*, pp.49-53, 2012.
[10] Dan Li, et al., “Preparation and properties of copper-oil-based nanofluids” *Nanoscale Research Letters* 2011.
[11] A. Hern´andez Battez et al., “Wear prevention behaviour of nanoparticle suspension under extreme pressure conditions” *Wear* 263, pp. 1568–1574, 2007.
[12] R. Serrato, et al., “Effect of lubricant viscosity grade on mechanical vibration of roller bearings” *Tribology International* 40, pp. 1270–1275, 2007.
[13] Pratesh Jayaswal, et al., “Machine Fault Signature Analysis” *International Journal of Rotating Machinery* Volume 2008.
[14] Kole M., Dey T.K., “Effect of aggregation on the viscosity of copper oxide gear oil nanofluids”, Int. J. Therm. Sci, Vol. 50, pp. 1741–1747, 2011.
[15] Liu G., Li X., Qin B., Xing D., Guo Y. and Fan R., “Investigation of the mending effect and mechanism of copper nano-particles on a tribologically stressed surface” Tribology Letters, Vol. 17, No. 4, pp. 961-966, 2004.