E-ISSN 2581 – 7957
P-ISSN 2277 – 3916

CVR Journal of Science and Technology, Volume 20, June 2021
DOI: 10.32377/cvrjst2023

Characterization of ZnO-TiO_2 Hybrid Nano based SAE 15W-40 Oil

G. Naveen Kumar[1] and G. Bharath reddy[2]
[1]Assoc. Prof., CVR College of Engineering/Mechanical Engg. Department, Hyderabad, India
Email: g.naveenkumar@cvr.ac.in
[2]Asst. Prof., CVR College of Engineering/Mechanical Engg. Department, Hyderabad, India
Email: g.bharathreddy@cvr.ac.in

Abstract: **The main aim of the present investigation was to characterize the lubricant dispersed with ZnO-TiO_2 hybrid nanoparticles. The work includes a dispersion of nanoparticles with varying proportions of 0.02 to 0.08 with an incremental step of 0.02 wt. % of base oil. Further, the samples were used to study the thermo-physical properties. The characterization result includes crystallinity and particle size of Zinc-oxide and titania nanoparticles, whereas the nano-based lubricant is characterized for its chemical compatibility, thermal conductivity, viscosity, and thermal stability. The result favors enhancing the thermo-physical properties of nano-based lubricant.**

Index Terms: nanoparticles, lubricant, thermal conductivity.

I. Introduction

Organic lubricants are most popular in the various fields for operational enhancement. They can reduce friction between surfaces in mutual contact, ultimately reduces the heat generated when the surfaces move [1]. The property of reducing friction is known as lubricity. Typically, it also has additional functions of cooling the hotspots. Typically lubricants hold 90% base oil (mainly petroleum fractions, called mineral oils) and less than 10% additives. Synthetic liquids such as hydrogenated silicones, polyolefins, esters, fluorocarbons, and many others are sometimes used as base oils. Vegetable oils or synthetic liquids such as hydrogenated polyolefins, esters, silicones, fluorocarbons, and many others were sometimes used as base oils [2]. Additives can reduce friction and wear, increased viscosity, improved viscosity index, resistance to corrosion and oxidation, aging or contamination, etc. however, there is still much space for enhancing the thermo-physical properties of the lubricant.

The thermal conductivity of lubricants is an important factor in determining the cooling behavior; nevertheless, the low thermal conductivity of conventional lubricants confines their performance [14]. Researchers enhanced the thermal conductivity of lubricant with nano inclusions in it. Dispersed 7% Vol. fraction of ZrO2 nanoparticles, there was an appreciable enhancement of thermal conductivity. ZnO nanoparticles were dispersed in EG base fluid and achieved thermal conductivity enhancement of 9.13% [3]. Several researchers attempted enhancing the thermal conductivity of lubricant with nanoparticles dispersion. Nevertheless, hybrid ZnO-TiO_2 nanoparticles combination with SAE 15W-40 lubricant has not been tried for thermo-physical enhancement.

II. Materials and Instruments

SAE 15W-40 lubricant procured from sigma Aldrich, Titanium dioxide, and Zinc Oxide nanoparticles were procured from Alfa Aesar, GT SONIC-QTD model for effective dispersion of nanoparticles in SAE 15W-40 lubricant. Rheometer instrument, HR 20 model, for measuring the viscosity of the sample, Fourier transform infrared spectroscopy to study the chemical compatibility of the sample, Thermogravimetric analyzer (TGA) SDT 650 model to study decomposition temperature of the sample, the thermal conductivity analyzer (TCA), FOX 200 model to measure thermal conductivity of the samples.

III. Methodology

The conventional SAE 15W-40 lubricant was tested to thermo-physical characteristics; further ZnO-TiO_2 nanoparticles were dispersed in the lubricant with varying from 0.02 to 0.08 with the incremental step of 0.02 wt. %. The agglomerated nanoparticles were ultrasonicated to de-agglomerate and to have a nano effect. The five samples (1 conventional lubricant and 4 nano based lubricant) were tested to study thermo-physical properties with an increased percentage of nanoparticles.

IV. Hybrid Nano Based Oil Preparation

The combined effect of ZnO and TiO_2 nanoparticles were used in the oil for the preparation of hybrid nano-based oil. Table 1 shows the different samples. Sample 1 was the base oil without any nano effect, whereas the nanoparticles were dispersed in the oil varying from 0.02 to 0.08 weight percentage of oil with the increment of 0.02%.

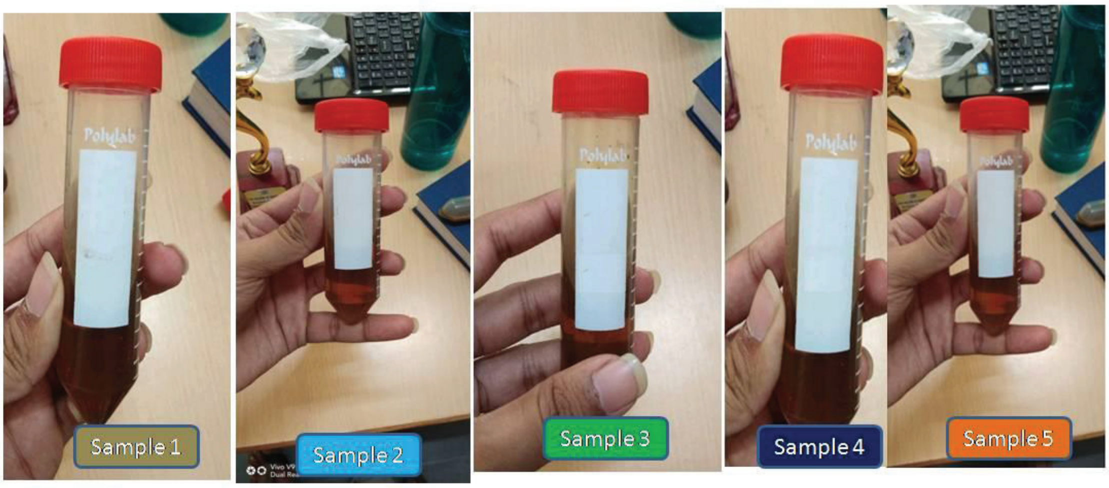

Figure 1. Pure and Hybrid nano based oil samples

TABLE I.
HYBRID TITANIA - ZINCOXIDE BASED OIL PREPARATION

Sample No.	Oil (ml)	TiO_2 (wt. %)	ZnO (wt. %)	Total hybrid nano%	
1	20	0	0	0	
2	20	0.01	0.01	0.02	
3	20	0.02	0.02	0.04	
4	20	0.03	0.03	0.06	
5	20	0.04	0.04	0.08	

TABLE II.
INSTRUMENT SPECIFICATION

S. No	Instrument	Purpose
1	Particle Size Analyzer	Size of particles
2	Probe sonicator	Nanoparticles dispersion in fluid
3	Fourier Transformer Infrared spectroscopy	Chemical compatibility
4	Thermogravimetric analyzer	Decomposition temperature
5	Rheometer	Viscosity
6	Thermal conductivity Analyzer	Thermal conductivity

V. RESULTS AND DISCUSSIONS

A. Particle Size Analysis

The nanoparticles were procured for dispersion in the oil for preparing hybrid nano-based oil preparation; particle size analysis was performed to study the size distribution range. Figure 2 depicts that the particle range from 42 nm to 95 nm, and the average particle particles are around 70 nm with an intensity of almost 47%. There are traces of noise disturbances that can be seen in figure 2.

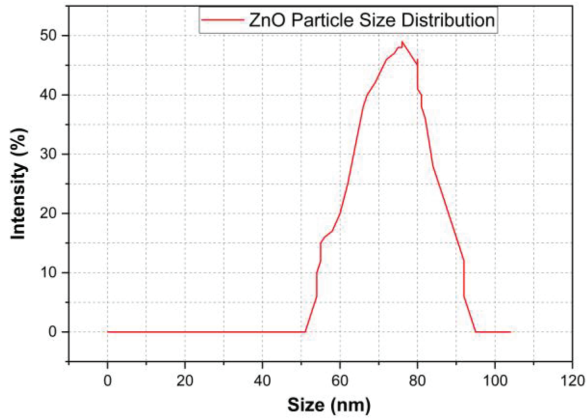

Figure 2. ZnO nano particle size distribution curve

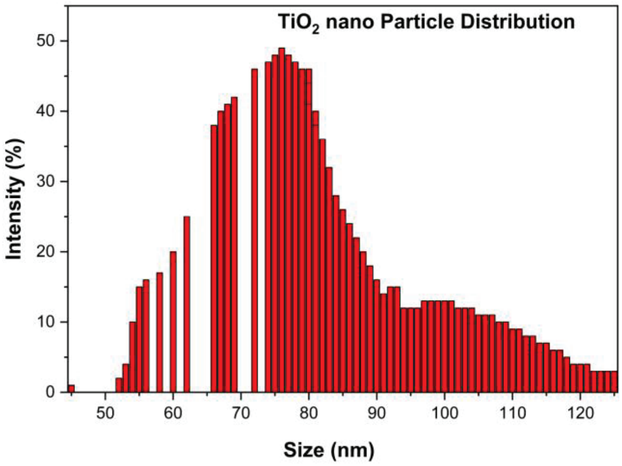

Figure 3. TiO_2 nano particle size distribution.

The TiO_2 nanoparticles procured were used for nano oil preparation, and before using it, to confirm its particle range particle size analysis was done. The results depict that the particles range from 52 nm to almost 125 nm however, the average particle was close to 78 nm with an intensity of almost 50%. This confirms that the particles are nano range.

Most of the particles with high intensity lie in the range of 65 nm to 80 nm approximately.

TABLE III.
RESULTS OVERVIEW

S. No.	Thermal conductivity (W/m K)	Viscosity (cS)	Decomposition temperature (°C)
1	0.136	14.8	120.71
2	0.143	15.1	167.26
3	0.153	15.2	169.87
4	0.155	15.3	170.12
5	0.156	15.4	173.62

B. Viscosity

A Rheometer was used to determine the viscosity of the sample; this instrument is incorporated with a circulating water bath which can measure viscosity in the range of 1 to 6,000,000 mPa.s. The viscosity of samples was tested at a temperature of 70 °C. The base oil viscosity was 14.8 cS with the increased percentage of nanoparticles in viscosity was increased gradually. There was 4.05% increment of viscosity; the main reason behind increased viscosity was colloidal solution [4]. The increment of viscosity due to nanodispersion was negligible, which was also acceptable [5].

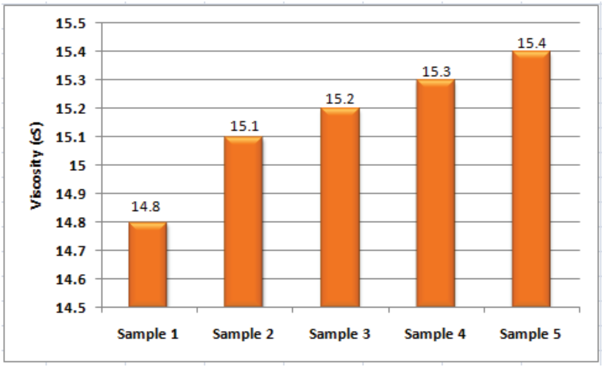

Figure 4. Viscosity of various samples at 70 °C.

C. Chemical compatibility

FTIR instrument was used to study the chemical compatibility between two materials. In the present work ZnO-TiO_2 nanoparticles were dispersed in the SAE 15W-40 lubricant for enhancing thermal conductivity. Mean while it is important to study the chemical interaction between nanoparticles and the lubricant if any. The FTIR test results reveals that the peaks induced at 3441 cm^{-1} corresponds to alcoholic group. The stretching vibrations at 2924 and 2854 cm^{-1} belongs to C-H group. The peak induced at 1032 cm^{-1} attributes to stretching vibration of C-O functional group. When nanoparticles were dispersed in oil there was no shift in functional group which depicts no chemical reaction between them, any changes in properties is mainly due to physical interaction [6, 7].

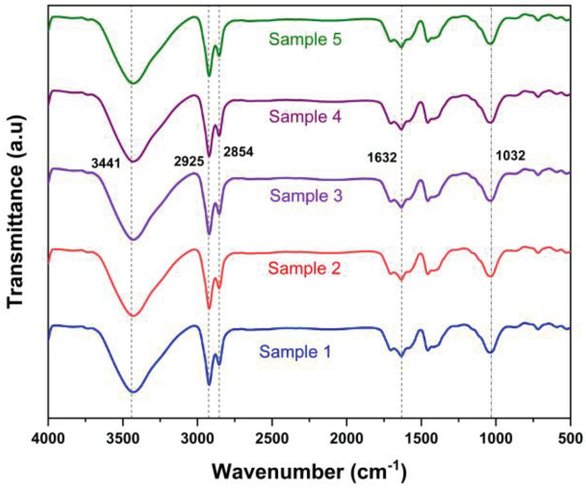

Figure 5. FTIR results of pure and nano based oil.

D. Thermal conductivity

The lubricating oil, apart from reducing friction between mating parts, should also provide cooling action to the working components. The thermal conductivity of the base oil is 0.136 W/mK, and with an increased percentage of nano inclusions in the oil, thermal conductivity value was increased. The thermal conductivty was increased gradualy however, there was an appreciable increase in thermal conductivity, and almost from sample 4, the enhancement was stagnated. This may be due to the setllement of excess particles at the bottom.

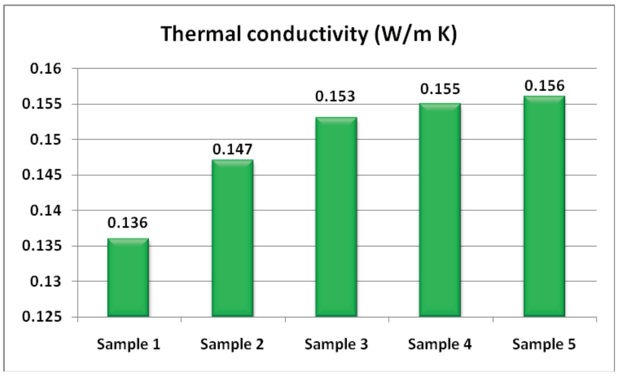

Figure 6. Thermal conductivity of samples at room temperature.

The main reason behind thermal conductivity enhancement is that when the particles are floating in the liquid it forms thermal networking and also act as nucleation site [8, 9]. The nano aprticles forming thermal networking play a prominent role in transferring heat [10]. However, sample 4 was optimised beyond which the particles will be excessive with respect to the fluid proportion and may settle down with no effect. If settlement increase, there is a possibity of increased viscosity which is not recommended.

E. Thermogravimetric analysis

The Main intention of performing Thermogravimetric analysis is to study the decomposition temperature. With the increased temperature of sample slowly sample is heated up and from the graph it is evident that the base oil starts its decomposition at the temperature of 120 °C approximately, when hybrid nano particles were dispersed in base oil, the decomposition temperature is gradually increasing and it was maximum 173.62 °C for sample 5. Almost 53 °C was shifted which exhibits a great thermal stability when nanoparticles when dispersed in the oil which is of great advantage [11-13]. This confirms clearly that nano inclusion in the oil increases thermal stability. Considering thermal conductivity, sample 4 was optimized and the decomposition temperature for sample 4 is 170.12 °C which is having a slight difference in decomposition temperature of approximately 3 °C which is very less in comparison with sample 5.

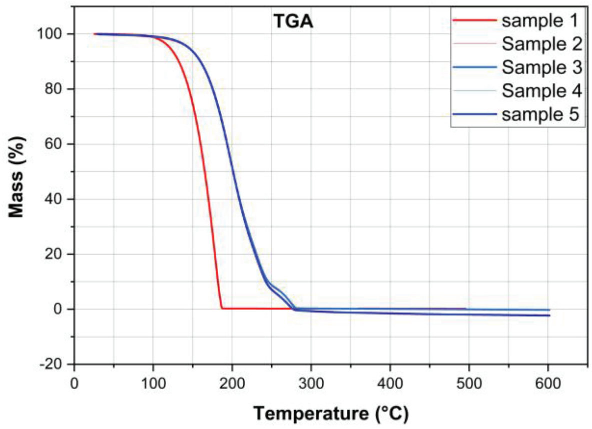

Figure 7. Thremogravimetric analysis of samples.

VI. Conclusions

The following points were concluded after analyzing the results.

1. The procured ZnO and TiO_2 nanoparticles were in the nano range which is evident from particle size analysis results.
2. There was no chemical reaction between nanoparticles and the base fluid, the changes in the properties of oil is mainly due to physical interaction. This confirms the chemical stability of hybrid nano based lubricant.
3. There was appreciable increase in thermal conductivity of oil with nano inclusions.
4. In spite of enhanced thermal conductivity, there was a slight increase in viscosity. However, the increment is negligible.
5. Hybrid nanoparticles were used in the oil, there was shift of 53 °C in the decomposition temperature when compared with base oil. This clearly shows good thermal stability.

References

[1]. K.M.B.Karthikeyan, Vijayanand K, Arun, Vaddi Seshagiri Rao, Thermophysical and wear properties of eco-friendly nano lubricants, "*Materials Today: proceedings",* Volume 39, Part 1, 2021, Pages 285-291.

[2]. Teng Gao, Changhe Li, MinYang, Yanbin Zhang, Dong zhou Jia, Wenfeng Ding, Sujan Debnath, Tianbiao Yu, Zafar Said, JunWang, Mechanics analysis and predictive force models for the single-diamond grain grinding of carbon fiber reinforced polymers using CNT nano-lubricant, "Journal of Materials Processing Technology", Volume 290, April 2021, 116976.

[3]. Desari, B.Z., Davoobi, D., 2016. Assessing the lubrication performance of vegetable oil-based nano-lubricants for environmentally conscious metal forming processes. "J. Clean. Prod." 135, 1198-1209.

[4]. Lv, T., Huang, S.Q., Liu, E.T., Ma, Y.L., Xu, X.F., 2018. Tribological and machining characteristics of an electrostatic minimum quantity lubrication (EMQL) technology using graphene nano-lubricants as cutting fluids. "J. Manuf. Process." 34, 225-237.

[5]. Bakunin VN, Suslov AY, Kuzmina GN, Parenago OP, Topchiev AV (2004) Synthesis and application of inorganic nanoparticles as lubricant components – a review. "J Nanopart Res" 6:273–284.

[6]. Wu Y, Tsuia W, Liub T (2007) Experimentalvanalysis of tribological properties of lubricating oils with nanoparticle additives.Wear 262:819–825

[7]. L. Liu, Z. Fang, A. Gu, Z. Guo, Lubrication effect of the paraffin oil filled with Functionalized Multiwalled Carbon Nanotubes for Bismaleimide Resin, "*Tribology Letters"* 42 2011) 59–65.

[8]. Wan Q, Jin Y, Sun P, Ding Y (2015) Tribological behavior of lubricant oil containing boron nitride nanoparticles. *"Proc Eng"* 102:1038–1045

[9]. Lijesh KP, Muzakkir SM, Hirani M (2015) Experimental Tribological Performance Evaluation of Nano Lubricant Using Multi-Walled Carbon Nano-Tubes (MWCNT*). "Int J Appl Eng Res"* 10(6):14543–14550.

[10]. Thottackkad MV, Perikinalil RK, Kumarapillai PN (2012)Experimental evaluation on the tribological properties of coconut oil by the addition of CuO nanoparticles. *"Int J Precis Eng Manuf"*, 13(1):111–116

[11]. Pak BC, Cho YI (1998) Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles. Experiment "*Heat Transf Int J.",* 11(2):151–170

[12]. Y.M. Shashidhara, S.R. Jayaram, Tribological Studies on AISI 1040 with Raw and Modified Versions of Pongam and Jatropha Vegetable Oils as Lubricants, *"Hindawi Publishing Corporation Advances in Tribology",* Volume 2012, Article ID 560175, pp. 1–6.

[13]. S.U. Ilyas, R. Pendyala, M. Narahari, L. Susin, Stability, rheology and thermal analysis of functionalized alumina-thermal oil-based nanofluids for advanced cooling systems, *Energy Convers. Manag*. 142 (2017) 215–229.

[14]. M.K. Moraveji, S. Razvarz, Experimental investigation of aluminum oxide nanofluid on heat pipe thermal performance, Int. Commun. Heat Mass Transf. 39 (2012) 1444–1448.