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"AN INVESTIGATION OF TRIBOLOGICAL BEHAVIOUR OF LUBRICATING OIL WITH THE ADDITION OF NANOPARTICALE ADDITIVES"

[1]Ravindra M.Kanse, [2]Raj M.Nibe , [3]Shubham V.Sasane, [4]Sadik Y.Shaikh, [5] Manoj B.Thorat
[1]Lecturer in Automobile Department, [2]Student, [3]Student,[4] Student,[5] Lecturer
Automobile Engineering Department,Pravara Polytechnic,Loni,Mahatrastra,India.

Abstract: This project presents the tribological behavior of silicon oxide (20 nm), ZDDP, and hBN nanoparticle additives in castor vegetable oil to enhance the lubricating performance. The nanoparticles were dispersed in the base oil at different concentrations (0.3%, 0.4%, and 0.6%). The prepared nano-lubricants were evaluated for their physical and tribological properties, including viscosity (using a Redwood viscometer), viscosity index, flash point, fire point, and pour point.

The results indicate that the addition of nanoparticles significantly improves lubrication performance by reducing friction coefficient and wear. Surface analysis using scanning electron microscopy (SEM) confirmed the formation of protective films on the worn surfaces, which contributed to improved anti-wear characteristics.

Keywords: *Friction coefficient, lubricating oil, nanoparticles, wear behavior, SEM analysis*

***Index Terms* - viscosity, flash point, fire point, density, and pour point**

I. INTRODUCTION

Modern lubricants with varied properties are widely used in mechanical systems, especially internal combustion engines, to reduce friction, wear, and heat generation, which are major causes of energy loss. The performance of lubrication depends on factors such as load, surface condition, speed, temperature, and material properties. Lubricants consist of a base oil and additives; the base oil provides lubrication and acts as a carrier, while additives enhance existing properties like viscosity, oxidation resistance, and wear protection or introduce new functions such as cleaning, anti-wear, and corrosion control.

With advancements in **tribology**, there is a growing focus on eco-friendly and efficient additives, particularly nanoparticles and nanotubes. **Nano-lubricants**, made by dispersing nanostructures in base oils, exhibit superior anti-friction, anti-wear, and thermal conductivity properties compared to conventional lubricants. Nanoparticles such as copper oxide, titanium dioxide, fullerene, and carbon nanotubes improve engine efficiency, reduce fuel consumption, and lower maintenance costs. Additionally, nanofluids—formed by dispersing nanoparticles in fluids like water or oil—enhance heat transfer due to increased thermal conductivity. Overall, nanotechnology has significantly improved lubricant performance, making it a promising solution for energy efficiency and advanced mechanical applications.

II. LITERATURE REVIEW

Gu Cai-xiang et al. (2009) investigated the tribological effects of oxide-based nanoparticles in lubricating oils using a four-ball tribotester. The study revealed that a combination of CeO_2 and TiO_2 nanoparticles in a weight ratio of 1:3, with a total concentration of 0.6 wt%, provided optimal anti-wear and friction-reducing performance.

R. Chou et al. (2010) examined the influence of 20 nm nickel nanoparticles on synthetic oil (PAO6). Experimental results showed that the addition of nickel nanoparticles significantly reduced friction and wear while improving the load-carrying capacity of the base oil.

Xianbing Ji et al. (2011) studied $CaCO_3$ nanoparticles (≈45 nm) as additives in lithium grease. The results demonstrated improved anti-wear, friction-reduction, load-carrying capacity, and extreme pressure properties. A protective boundary film consisting of $CaCO_3$, CaO, and iron oxides was formed during operation.

Harshwardhan H. Patil et al. (2013) investigated SiO_2 nanoparticles in SN-500 base oil under varying loads and concentrations. The study reported significant reductions in friction coefficient (up to 61%) and enhanced anti-wear properties at optimal concentrations.

M. Asrul et al. (2013) analyzed CuO nanoparticles (50 nm) dispersed in liquid paraffin. The lowest coefficient of friction (0.185) was achieved at 0.2% concentration, indicating that nanoparticle concentration plays a critical role in tribological performance.

Juozas Padgurskas et al. (2013) evaluated Fe, Cu, and Co nanoparticles in mineral oil. Their findings indicated a reduction in friction and wear (up to 1.5 times), with copper nanoparticles showing the most effective performance due to surface deposition during operation.

Sudeep Ingole et al. (2013) studied TiO_2 nanoparticles in base oil using a pin-on-disk setup. Although friction coefficient slightly increased, the nanoparticles stabilized friction behavior and reduced variability.

Yue Gu et al. (2014) developed dual-coated TiO_2 nanoparticles for water-based lubrication. Surface modification improved dispersion stability and significantly enhanced load-carrying, anti-wear, and friction-reduction properties.

Yufu Xu et al. (2015) investigated La_2O_3 nanoparticles in pyrolysis bio-oil. The results showed improved tribological properties compared to conventional bio-oil, indicating potential for alternative fuel lubrication systems.

V. Zin et al. (2015) studied Cu, TiO_2, and carbon nanohorns as additives in engine oil. Results showed wear reduction up to 50% with Cu nanoparticles and about 30% with carbon nanohorns.

Laura Peña-Parás et al. (2015) evaluated CuO and Al_2O_3 nanoparticles in synthetic oils. The study reported reductions in friction (up to 18%) and wear, along with a significant increase in load-carrying capacity.

Muhammad et al. (2015) optimized hybrid nanoparticles (hBN and Al_2O_3) in diesel engine oil. The optimal composition (0.5% hBN + 0.3% surfactant) resulted in a lower coefficient of friction.

J.E. Fernández et al. (2015) studied CuO nanoparticle suspensions in PAO6 oil. The results showed reduced friction and wear, with best performance at around 0.5 wt% concentration.

E. Prakash et al. investigated $CaCO_3$ nanoparticles (≈285 nm) in grease. Similar to earlier findings, improved tribological performance was observed due to the formation of a protective boundary film on contact surfaces.

Sharanabasava V. Ganachari et al. synthesized NiO nanoparticles (20–40 nm) using a combustion method, confirming their suitability for tribological applications due to controlled size and structure.

III. PROBLEM STATEMENT

The conventional lubricants used for various mechanical systems consist of different types of conventional additives. The additives help to improve the lubricating and anti-wear properties of the lubricant. But these conventional additives have certain limitations at heavy loads. They are not able to maintain their original properties and thus show poor lubricating and anti-wear properties at these heavy loads. So there should be development in the additives so as to increase the working range of the lubricant.

IV. OBJECTIVES

The primary aim of this work is to enhance the performance of lubricants through the incorporation of nanoparticles. The specific objectives are as follows:

1. To develop an eco-friendly nano-lubricant based on cottonseed oil incorporated with nanoparticle additives such as ZDDP, Sio2, and hBN.
2. To evaluate the physical, tribological, and thermal properties of the formulated nano-lubricant.
3. To compare the performance of the developed nano-lubricant with conventional lubricants in terms of efficiency, wear resistance, and durability.

V. MATERIALS

5.1 Materials

Silicon oxide (SiO_2), ZDDP, and hBN nanoparticles (Fig. 5.1–5.4) were used as additives in castor oil, which was free from any additives. These nanoparticles were procured from Intelligent Materials Pvt. Ltd. The specifications of the nanoparticles and the base lubricating oil are presented in Tables I, II, and III, respectively.

5.1.1 Silicon Oxide(SiO2)

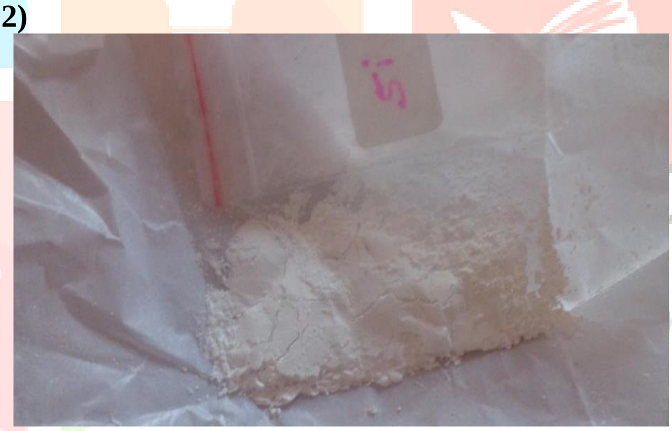

Fig 5.1: Silicon Oxide (SiO2) Nanoparticle

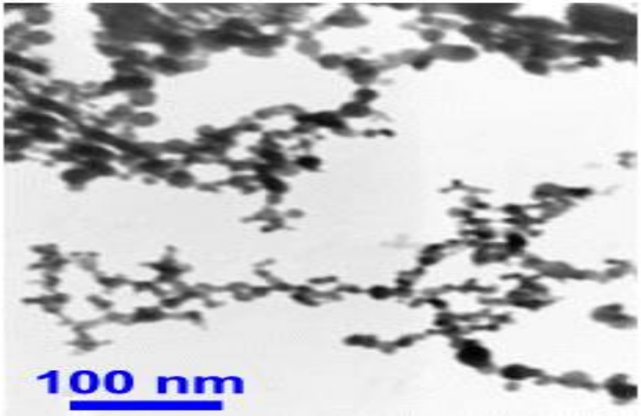

Fig.5.2: SEM Micrographs of Silicon Oxide.

Table 5.1: Specification of Silicon oxide (SiO_2) nanoparticle

Silicon oxide (SiO_2) nanoparticle	
Appearance	White
Purity	99 %(Amorphous)
APS	20-30 nm
SSA	110-120 m^2 /g
Bulk Density	<0.10g/cm^3
Ultraviolet Reflectivity	>75%
SiOx	10ppm
Al	10ppm
Fe	30ppm
Sr	40ppm
Ca	20ppm
Mg	20ppm
Cl	10ppm

5.2 ZDDP (Zinc Dialkyldithiophosphate)

Zinc Dialkyldithiophosphate (ZDDP) is one of the most widely used additives in lubricating oils, particularly in automotive engine oils. It primarily functions as an anti-wear and antioxidant additive. Under conditions of high pressure and temperature, ZDDP forms a thin protective film on metal surfaces, which reduces direct metal-to-metal contact and minimizes friction and wear. Additionally, it inhibits oxidation of the lubricant, thereby extending its service life. ZDDP also enhances engine performance and provides protection to critical components such as camshafts and bearings. Owing to its excellent tribological characteristics, it is extensively used in modern lubrication systems.

5.3 hBN (Hexagonal Boron Nitride)

Hexagonal Boron Nitride (hBN) is a solid lubricant commonly referred to as “white graphite” due to its layered crystal structure, similar to graphite. It exhibits excellent lubricating properties and remains stable at very high temperatures. When added as nanoparticles to lubricating oil, hBN reduces friction and wear between moving components by forming a smooth protective layer on contact surfaces. This enhances sliding performance and reduces energy losses. Furthermore, hBN possesses high thermal conductivity and chemical stability, allowing it to maintain performance under extreme operating conditions. Its inert nature makes it safe and compatible with other materials, making it an effective nano-additive for improving the tribological performance of lubricants.

5.4 Apparatus and Experimental Procedures

1. Redwood Viscometer Test Procedure

1. Clean and dry the viscometer thoroughly.
2. Close the orifice using the ball valve.
3. Fill the oil sample up to the specified level.
4. Heat the oil bath to the desired temperature (40°C or 100°C).
5. Allow the temperature to stabilize.
6. Open the ball valve and start the stopwatch simultaneously.
7. Record the time required for 50 ml of oil to flow out (in Redwood seconds).
8. Repeat the test and calculate the average value.

2. Flash Point and Fire Point Test (Cleveland Open Cup)

1. Clean the test cup and fill it with the oil sample up to the marked level.
2. Heat the oil at a uniform rate.
3. At regular temperature intervals, pass a test flame over the oil surface.
4. Record the temperature at which a flash appears (Flash Point).
5. Continue heating and reapply the test flame.
6. Record the temperature at which the oil sustains continuous combustion (Fire Point).

3. Pour Point Test Procedure

1. Pour the oil sample into a test jar.
2. Place the jar in a cooling bath.
3. Reduce the temperature gradually at specified intervals.
4. At every 3°C drop, tilt the jar to observe flow.
5. Record the temperature at which the oil ceases to flow (Pour Point).

VI. METHODS

6.1 Methodology for Sample Preparation

The Nano-lubricant samples were prepared using a controlled and systematic procedure as described below:

Step 1: Preparation of Apparatus

All glassware and containers were thoroughly cleaned and dried to eliminate any contaminants that could affect the results.

Step 2: Measurement of Constituents

The base oil and additives were measured accurately using a measuring cylinder and electronic weighing balance to ensure consistency in formulation.

Step 3: Initial Mixing

The measured quantity of cottonseed oil was transferred into a clean mixing container. ZDDP was added gradually and mixed thoroughly to ensure proper blending with the base oil.

Step 4: Addition of Nanoparticles

MoS_2 and hBN nanoparticles were added slowly into the mixture while continuously stirring. Care was taken to avoid the formation of lumps or agglomerates.

Step 5: Mechanical Stirring

The mixture was subjected to mechanical stirring for a duration of **20–30 minutes** to achieve uniform dispersion of nanoparticles within the base oil.

Step 6: Stabilization

The prepared samples were stored in airtight containers and kept undisturbed for **24 hours** to evaluate their stability and check for any sedimentation.

6.1 Viscosity test

Viscosity Test Procedure (Redwood Viscometer)

1. Preparation of Sample:

Clean and dry the Redwood viscometer and ensure no previous oil residue is present. Take the lubricant sample to be tested.

2. Filling the Oil Cup:

Close the orifice with a ball valve and fill the oil cup with the sample up to the marked level.

3. Heating the Sample:

Heat the oil bath slowly to the required test temperature (e.g., 40°C or 100°C) while stirring gently to maintain uniform temperature.

4. Temperature Stabilization:

Allow the oil to reach and stabilize at the desired temperature.

5. Measurement:

Remove the ball valve to allow oil to flow through the orifice. Simultaneously start the stopwatch.

6. Time Recording:

Measure the time taken for **50 ml of oil** to collect in the receiving flask. This time is recorded as **Redwood seconds**.

7. Repeat Test:

Repeat the experiment at least two times and take the average value for accuracy.

8. Calculation:

Convert Redwood seconds into kinematic viscosity using standard conversion charts or formulas.

6.2 Viscosity 40°C Test

This test measures the viscosity of lubricating oil at 40°C. It indicates the oil’s thickness under normal temperature conditions. Proper viscosity ensures smooth lubrication and reduces friction. Addition of nanoparticles may slightly increase viscosity, improving load-carrying capacity. This test is important for evaluating oil flow behavior in standard conditions.

6.2 Viscosity 100°C Test

This test determines the viscosity of oil at 100°C. It shows how the lubricant behaves at high operating temperatures. Good oil should maintain stable viscosity even at high temperature. Nanoparticle additives help in improving thermal stability. This ensures better engine protection during heavy operation.

6.4 Fire Point Test

Fire point is the temperature at which oil vapors ignite and burn continuously. It indicates the maximum temperature limit for safe use. Higher fire point means better safety and performance. Nanoparticles can increase the fire point slightly. This test is important for high-temperature applications.

6.5 Flash Point Test

Flash point is the lowest temperature at which oil vapors ignite momentarily. It helps to determine the flammability of oil. Higher flash point indicates safer lubricant. Addition of nanoparticles improves resistance to ignition. This test is essential for storage and handling safety

6.6 Pour Point Test

Pour point is the lowest temperature at which oil can flow. It indicates the oil’s performance in cold conditions. Lower pour point is desirable for better cold start performance. Nanoparticles can improve low-temperature flow behavior. This test is important for applications in cold environments.

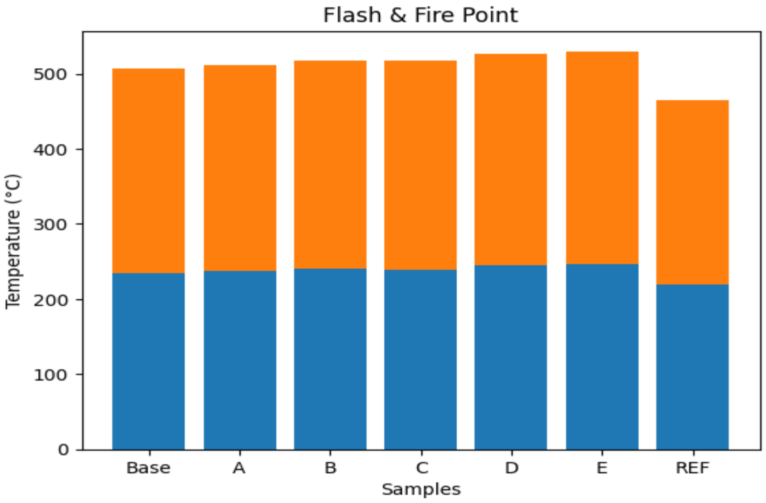

Fig 6.1 :Flash and Fire Point

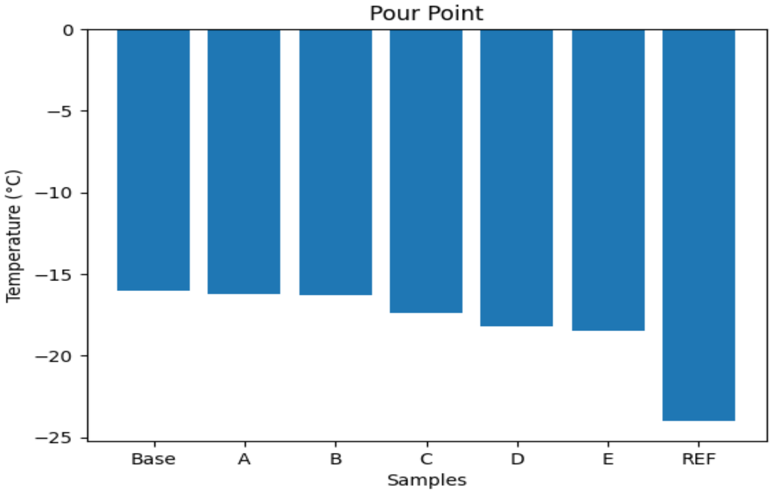

Fig 6.2 : pour Point

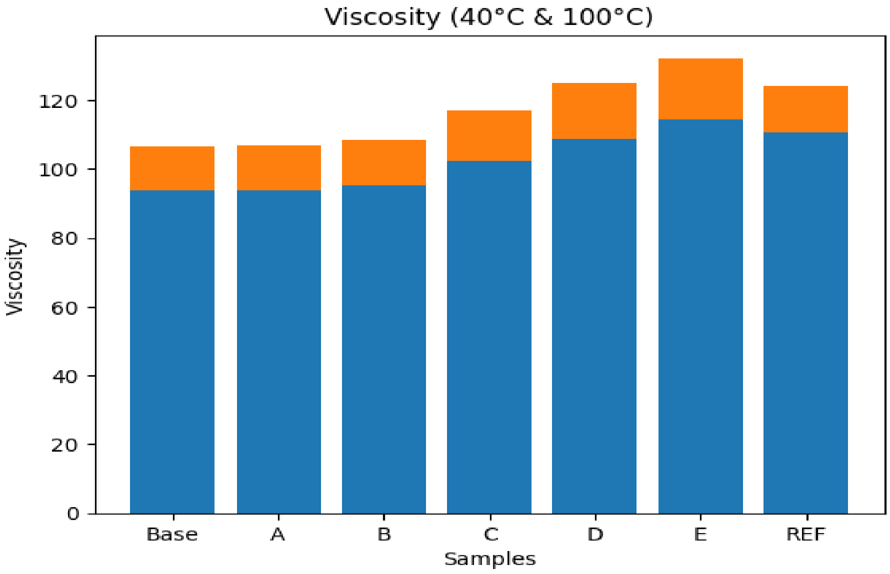

Fig 6.3; Velocity (40°C and 100°C)

6.7 Results

Table 6.1:Sample Test Table

Parameter	*Viscosity (40°)*	Viscosity (100°)	Fire Point	Flash Point	Pour Point
Sample Base oil castor oil total 100ml	93.8	12.6	272	235	-16
Sample A Castor oil +0.4%ZDDP+0.3%SiO2+0.3%HBN	93.9	12.9	274	238	-16.2
Sample B Castor oil +0.4%ZDDP+0.4%SiO2+0.4%HBN	95.2	13.1	277	240	-16.3

Sample C Castor oil +0.6%ZDDP+0.5%SiO2+0.4%HBN	102.6	14.3	278	239	-17.4
Sample D Castor oil +0.6%ZDDP+0.6%SiO2+0.6%HBN	108.7	16.1	281	245	-18.2
Sample E Castor oil +0.8%ZDDP+0.6%SiO2+0.6%HBN	114.4	17.8	284	246	-18.5
Sample REF Oil SAE 15W40 Engine oil	110.6	13.69	245	220	-24

VII. CONCLUSION

The experimental study demonstrates that the addition of nanoparticles (ZDDP, SiO_2, and hBN) to castor oil significantly improves its lubricating properties. The viscosity at both 40°C and 100°C increases progressively with higher nanoparticle concentration, indicating improved film strength and better load-carrying capacity.

The flash point and fire point values also show a noticeable increase from the base oil to Sample E, confirming enhanced thermal stability and safer operation at elevated temperatures. Among all samples, **Sample E** exhibits the highest viscosity and thermal properties, making it the best-performing nano-lubricant formulation.

The pour point values slightly decrease (become more negative), indicating marginal improvement in low-temperature performance, although the conventional SAE 15W-40 oil still shows better pour point characteristics.

Overall, the nano-additive blended castor oil demonstrates superior tribological and thermal performance compared to base oil and is comparable or better than conventional engine oil in most parameters. Hence, it can be considered a promising eco-friendly alternative lubricant, with further scope for improving low-temperature behavior.

REFERENCES

[1] Gu, C.-X., Zhu, G.-J., Li, L., Tian, X.-Y., & Zhu, G.-Y. (2009). *Tribological effects of oxide-based nanoparticles in lubricating oils*. Journal of Marine Science and Application, 8, 71–76. https://doi.org/10.1007/s11804-009-8008-1

[2] Chou, R., Hernández Battez, A., Cabello, J. J., Viesca, J. L., Osorio, A., & Sagastume, A. (2010). *Tribological behavior of polyalpha olefin with the addition of nickel nanoparticles*. Tribology International, 43, 2327–2332.

[3] Ji, X., Chen, Y., Zhao, G., Wang, X., & Liu, W. (2011). *Tribological properties of* $CaCO_3$ *nanoparticles as an additive in lithium grease*. Tribology Letters, 41, 113–119. https://doi.org/10.1007/s11249-010-9688-z

[4] Patil, H. H., Chavan, D. S., & Pise, A. T. (2013). *Tribological properties of* SiO_2 *nanoparticles added in SN-500 base oil*. International Journal of Engineering Research & Technology, 2(5).

[5] Asrul, M., Zulkifli, N. W. M., Masjuki, H. H., & Kalam, M. A. (2013). *Tribological properties and lubricant mechanism of nanoparticles in engine oil*. Procedia Engineering, 68, 320–325.

[6] Padgurskas, J., Rukuiza, R., Prosycevas, I., & Kreivaitis, R. (2013). *Tribological properties of lubricant additives of Fe, Cu, and Co nanoparticles*. Tribology International, 60, 224–232.

[7] Ingole, S., Charanpahari, A., Kakade, A., Umare, S. S., Bhatt, D. V., & Menghani, J. (2013). *Tribological behavior of nano-TiO_2 as an additive in base oil*. Wear, 301, 776–785.

[8] Fernández, J. E., Viesca, J. L., & Hernández Battez, A. *Tribological behaviour of copper oxide nanoparticle suspension*.

[9] Gu, Y., Zhao, X., Liu, Y., & Lv, Y. (2014). *Preparation and tribological properties of dual-coated TiO_2 nanoparticles as water-based lubricant additives*. Journal of Nanomaterials, Article ID 785680.

[10] Zin, V., Agresti, F., Barison, S., Colla, L., & Fabrizio, M. (2015). *Influence of Cu, TiO_2 nanoparticles and carbon nano-horns on tribological properties of engine oil*. Journal of Nanoscience and Nanotechnology, 15(5).

[11] Ganachari, S. V., Bhat, R., Deshpande, R., & Venkataraman, A. (2012). *Synthesis and characterization of nickel oxide nanoparticles by self-propagating low-temperature combustion method*. Recent Research in Science and Technology, 4(4), 50–53.

[12] Peña-Parás, L., Taha-Tijerina, J., Garza, L., Maldonado-Cortés, D., Michalczewski, R., & Lapray, C. (2015). *Effect of CuO and Al_2O_3 nanoparticle additives on the tribological behavior of fully formulated oils*. Wear, 332–333, 1256–1261.

[13] Abdullah, M. I. H. C., Abdollah, M. F. B., Amiruddin, H., Tamaldin, N., & Mat Nuri, N. R. (2013). *Optimization of tribological performance of hBN/Al_2O_3 nanoparticles as engine oil additives*. Procedia Engineering, 68, 313–319.

[14] Fernández, J. E., Viesca, J. L., & Hernández Battez, A. *Tribological behaviour of copper oxide nanoparticle suspension*.