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# Effect of Nanoparticles in Lubricant Oil Performance - A Review

Anoop Pratap Singh [a], Ravi Kumar Dwivedi [a] & Amit Suhane [a]

[a] *MANIT Bhopal- 462003, India*

**Abstract**

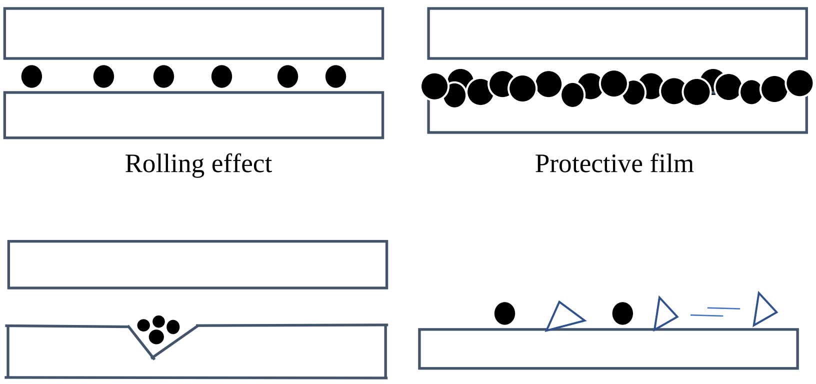
Lubrication is the sole need of any mechanical system. This makes the mechanical system function as desired with efficiency. The number of lubricants available to meet the lubrication requirement. As progress is being made, more efficient lubricants are being produced. In this order nanoparticles in lubricating oil perform very efficiently and can reduce the coefficient of friction (COF) and wear. Several nanoparticles are added to the lubricants and evaluated for their performance. There is an improvement in the performance of lubricating oil which has been cited by different researchers. This review summarizes the effect of nanoparticles on the performance of lubricating oil. Also, provide a guideline as to what level COF can be reduced along with the size of nanoparticles and base oil.

***Keywords**: Nanoparticles; lubricants; lubrication; tribology; nano lubricants.*

## 1. Introduction

Modern advances in mechanical components and mechanical systems create the need for more efficient lubricants than traditional lubricants. This need is fulfilled by the nano particle's addition to the lubricants. Lubricants with nanoparticles perform well and able to reduce the coefficient of friction and wear. Nano Particles of different materials, metal non-metals derivatives of carbon, etc are mixed with the lube oil and checked for their performance. Nanoparticles like Cu, CuO, Al, $Al_2O_3$, Diamond, Carbon tube (CNTs), etc mixed with the base oil like Poly alphaolphaline (PAO), Engine oil (5W-30), Diesel engine oil SAE 30, Mineral oil SN 650, and many more. Normally the size of the particles is less than 100 nm. Nanoparticles with the lube can effectively improve the tribological properties as well as improve the thermal requirements of the lube oil [1][2][3].

There is a question that arises in every mind with the different composition means a lube oil is a liquid substance and a nanomaterial is a solid substance then how can this mismatch improves the performance. This can be easily understood by the mechanism of the nanoparticles in between the tribological surfaces [4]–[7]. This can elaborate by fig. 1. As shown in the figure nanoparticles act as the tiny balls in between the tribo surfaces which convert sliding motion into rolling results lower the value of COF [5], [8], [9]. It can make a protective film over the tribo surface which prevents the direct rubbing of tribo surfaces which leads to lower the COF [10]–[12] As materials at the nano level have a large number of asperities and friction cracks even it looks smooth. Tiny balls of nanoparticles fill these cracks and make the tribe surface smoother [13]. In many cases, tribo surfaces can improve their surface roughness due to the seizure action of hard nanoparticles. This is also termed the polishing effect of the nano [14]–[16].





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*Corresponding Author's E-mail ID: anoop2651@gmail.com*

Mending effect Polishing effect

Figure 1 Nanoparticle mechanism.

This review shows the effect of nanoparticles in oil lubrication with nanoparticle size, base oil, and nanoparticle composition where the minimum value of COF is achieved. It also provides a guideline where the type of nanoparticles and the base oil can be selected based on the requirements.

## 2. Literature Review

Base oil is the main component of nano lubricants. The quality and composition of the base oil are directly related to its performance. There are various base oils covered by various researchers. Table 1 shows to what extent the nanoparticle can reduce the coefficient of friction and ultimately improve the performance of lubricating oil.

Table 1 Summary of nanoparticles with a base oil and minimum value of COF.

| S. No. | Nano Particles | Size | Base Oil | Min. COF with composition | Reference |
|---|---|---|---|---|---|
| 1 | $Al_2O_3$ | 78 nm | VI 95 | 0.047/0.1% | [17] |
| 2 | $Al_2O_3$ and $TiO_2$ | $Al_2O_3$: 8 - 12 nm<br>$TiO_2$: 10 nm | 5W-30 | 0.036 (Lube Oil + 0.25% of $Al_2O_3$)<br>0.038 (Lube Oil + 0.25% of $TiO_2$) | [18] |
| 3 | $Al_2O_3/SiO_2$ | $Al_2O_3$: 13 nm<br>$SiO_2$: 30 nm | Polyalkylene Glycol (PAG 46) | 0.0652 at 0.06% of $Al_2O_3/SiO_2$ | [19] |
| 4 | $Al_2O_3/TiO_2$ | 75 nm | VI 95 | 0.047/0.1% | [20] |
| 5 | Bi | 7 and 65 nm | BS900 BS6500 | 0.052 (BS6500)<br>0.047 (BS900) | [21] |
| 6 | BN | 100 - 120 nm | Epoxy | 0.06 with 0.5% of BN | [22] |
| | | 150 nm | PAO | 0.12 for borided surface | [23] |
| | | Diameter-120 nm<br>Thickness-30 nm | SE 15W-40 | 0.01 with 0.1% of BN | [24] |
| 9 | CNT | Length: 3 - 15 nm<br>Dia.:10 -20 nm | Caster Oil | 0.039 with 0.02% of CNTs | [25] |
| 10 | Cu | Not Mentioned | SAE 30 and 40 | 0.075 with 3% of Cu | [26] |
| | | 20 nm | Mineral oil SN 650 | 0.055 with 1% of Cu | [27] |
| | | 20 - 130 nm | 500SN | Mending effect shown | [13] |

| | | | | | |
|---|---|---|---|---|---|
| | | Not Mentoined | 5W- 40, 5W-40 and 5W-20 | 0.085 at 0.6% (5W40)<br>0.055at 0.8% (5W40)<br>0.05 at 1.6% (5W20) | [28] |
| | | 25 nm | Avocado oil | 0.022 at 1% of Cu | [29] |
| 15 | Cu/graphene oxide | 5 - 10 nm | Liquid paraffin | composites show better performance | [30] |
| 16 | CuO | 50 nm | Liquid paraffin | 0.2 with 0.2% of CuO | [31] |
| | | 50 nm | Caster oil and paraffin oil | 0.04 (CO + 0.1% CuO)<br>0.06 (PO + 1% CuO) | [32] |
| 18 | CuO and ZnO | ZnO: 11.71 nm CuO: 4.35 nm | Soybean oil<br>Sunflower oil<br>Mineral oil<br>Synthetic oil (polyalphaoleifin) | 0.05 (Sunflower oil and soybean oil shows the inverse effect on adding nanoparticle) | [33] |
| 19 | CuO and $Al_2O_3$ | ≤50 nm | GL-4 (SAE75W-85), PAO8 | 0.125 (PAO8 + 1% Al2O3)<br>0.111 (PAO8 + 2% CuO)<br>0.125 (GL4 + 0.5% Al2O3)<br>0.115 (GL4 + 0.5% CuO) | [34] |
| 20 | CuO, $TiO_2$ and Nano-Diamond | CuO: 5 nm<br>$TiO_2$: 80 nm<br>Nano-Diamond: 10 nm | VI 100<br>VI 107 | 0.084 (VI100)<br>0.096 (VI107) | [35] |
| 21 | Fe, Cu and Co | 50 - 80 nm | SAE 10 | Friction torque is min. with SAE10+Cu, SAE10+fe+Cu and SAE10+FeCu in its own groups | [36] |
| 22 | Graphene and $MoS_2$ | 2 µm | Hydraulic oil | $MoS_2$ shows better tribological performance | [37] |
| 23 | Graphene oxide nanoplates (GOPs) | 1.53 nm | 4010 AL base oil | 0.081 with 0.5% of GOPs | [38] |
| 24 | Graphene sheets | 10 µm | PAO 2 | Min. COF with 0.05% | [39] |
| 25 | hBN | 0.5 µm, 70 nm, 1.5 µm and 5.0 µm | Avocado oil | 0.015 with 70 nm | [40] |
| | | Not Mentoined | API Group III and 150N | Polyisobutylene succinimide (PIBSI) is most efficient | [41] |
| | | 70 nm | SAE 15W-40 | Maximum reduction of WSD at 800N with 0.5% | [42] |
| 28 | hBN/calcium borate | BN: 100 - 200nm<br>BCBN: 12 nm | Mineral-base oil (saturated cycloparaffin and paraffin hydrocarbon) | COF and Wear decrease with calcium borate as compare to BN Particle | [43] |
| 29 | $MoS_2$ | $MoS_2$: 50 - 100 nm | Dioctyl sebacate (DOS) | 0.06 with 0.5% of nano $MoS_2$ | [44] |

| | | | | | |
|---|---|---|---|---|---|
| | | 62 - 84 nm | Pentaerythrityl tetracaprylate/caprate ester | 0.103/0.5% | [45] |
| | | 250 nm | Plyolester and naphthenic oil | COF reduced 86% with 1% | [46] |
| | | ≤ 2 μm | Mineral base oil N-150 | 0.079 with 0.25% in four ball tester<br>0.0226 with 0.25% in Pin on roller | [47] |
| 33 | $MoS_2$ and $SiO_2$ | $MoS_2$:90 nm<br>$SiO_2$: 30 nm | EOT5 Engine oil | 0.045 with 0.7% of $SiO_2$ | [48] |
| 34 | MWCNTs/ZnO | MWCNTs OD: 20-30 nm<br>ID 8-10 nm<br>ZnO 100 nm | SAE 20W40 | Lube oil with nanoparticles having better tribological properties | [49] |
| 35 | Nanodiamond | 30 nm | Mineral oil and PAO oil | 0.08 (Mineral Oil with nanodiamond gives least COF at low load conditions) | [50] |
| 36 | Nanodiamond and $SiO_2$ | Nanodiamond: 110 nm<br>$SiO_2$: 92 nm | Liquid paraffin | 0.074 for nano diamond (0.2%)<br>0.075 for Sio2 (0.2%) | [51] |
| 37 | Oxidized graphite flakes | Not Mentoined | 10W40 | 0.128/0.05 % | [52] |
| 38 | $SiO_2$ | 102 ± 33 nm | Rust and oxidation lubricant (R&O) | 0.06 with BO68 | [53] |
| | | 58, 281, 684 nm | Liquid paraffin | 0.065/0.2% (58nm) | [54] |
| 40 | Stearic acid-capped cerium borate composite nanoparticles (SA/$CeBO_3$) | 5 - 30 nm | Rapeseed oil | RP+SA/$CeBO_3$ has the least COF (0.05) | [55] |
| 41 | $TiO_2$ | 10-25 nm | Engine oil Servo 4T Synth 10W-30 | 0.015 with 0.3% of $TiO_2$ | [56] |
| | | 50 - 100 nm | API -1509 | 0.06 with 0.5% of $TiO_2$ | [57] |
| | | 20 nm | Water | 0.04 with 1.6% of $TiO_2$ | [58] |
| 44 | $TiO_2$/$SiO_2$ | 35 nm | Water and Soybean oil | Nanoparticle presence shows the inverse effect with emulsion in COF | [59] |
| 45 | $WS_2$ | Not Mentioned | Polyalphaolefin - 4 (PAO 4) oil | 0.075 ± 0.005 with 1% of $WS_2$ coated nano particles | [60] |
| | | 200 nm | SN 90 and SN 150 | Remarkable improvements with nano particles | [61] |

| | | | | | |
|---|---|---|---|---|---|
| 47 | $WS_2/MoS_2$ | 100 nm | MACs (Multialkylated cyclopentanes) and CPSO (chlorinated-phenyl with methyl-terminated silicone oil) | 0.05 with $WS_2/MoS_2$-MACs<br>0.06 with $WS_2$–$MoS_2$/CPSO | [62] |
| 48 | ZnO | 53 nm | Epoxy resin (RE) | Resign + nano particle + IL shows better tribological properties | [63] |

Based on this review, the list of nanoparticles covered is outlined in Table 1. The size of nanoparticles and base oil is also mentioned with them. The minimum value of the coefficient of friction along with the optimal value of nanoparticle volume is also listed in the table. This review shows as the smaller the size of nanoparticles imparts in lower the value of COF. One of the researchers stated that SiO2 shows the best performance in the case of 58 nm particles when compared with other sizes of nanoparticles in the same position [54]. There are several base oil minerals as well as synthetic, evaluated for their tribological performance. There is an improvement in performance for light medium and heavy-duty base oils. Minerals oils like avocado, castor, etc. show better performance after addition to nanoparticles. The table shows the minimum value of the coefficient of friction with the value of nanoparticles where the minimum value was achieved. Minimum COF with optimum values of the nanoparticle can help in choosing base oil and nanoparticles based on their applications.

## 3. Conclusions

Nanoparticles show a positive effect on the performance of lubricating oil. The base oil and the size of nanoparticles have a clear effect on the performance of lube oil. Small size particles can improve the quality of base oil as compared to larger size particles. Almost all types of nanoparticles are studied equally. In this review, the optimum composition of the nanoparticle is mentioned along with base oil. The minimum value of COF along with the optimal value of nanoparticles provides a guideline for selecting nanoparticles according to requirements. This review cites important observations that provide a clear picture of nano lubricants and their future.

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