International Journal of Scientific and Technical Advancements
ISSN: 2454-1532

A Review of Nano-Particles as Lubricant Additives for Friction and Wear Reduction

Siddhant Jandial[1], Himanshu Gandotra[2], Sumit Mahajan[3], Sanjeev Gupta[4#]
[1,2,3,4] Department of Mechanical Engineering, GCET Jammu University, Jammu, J&K, India-180015
[#]Email: [1]sid.jandial270693@gmail.com

***Abstract*—**In this paper, a comprehensive review has been presented regarding various nanoparticles that have been used to modify the lubricative properties of oils used for reducing friction and wear for contacting surfaces. Nanoparticles of IF - MX_2 type such as IF - MoS_2, IF - WS_2 etc have shown much promising results under various conditions. Besides these, oxides of various metals are also make good lubricants such as TiO_2, CuO and Graphene oxide. Solids lubricants like graphene, Al_2O_3 and h-BN have also shown good tribological results, but extensive research using them is still under way.

***Keywords*—** Friction reduction, Lubricants, Nano-particles, Tribological Properties, Wear reduction.

I. Introduction

Where ever there are any two or more mating surfaces having some kind of relative motion, there is a need of a friction and wear reducing agent, called as a lubricant. Lubricants are of various forms such as solid lubricants like talc, liquid lubricants like petroleum oils, semi-solid lubricants like greases and even gaseous lubricants like compressed air.

But the basic properties of lubricants need to be modified with some kind of additives as per need. Solid particles when added to oils have been known to enhance their lubricity. Moreover, nanoparticles are better lubricity enhancers due to their nano size and better dispersion.

With successful synthesis of inorganic fullerene type MX_2 (IF – MX_2) particles by Tenne et. al. [1], paved the way for extensive research for using such nanoparticles as lubricant additives. [2 - 9]. But with advances in research to improve lubricity of oils, other nanoparticles also showed excellent results like h – BN, TiO_2, CuO, Al_2O_3, graphite, graphene [10 - 14] etc.

II. Studies

Cizaire et. al. studied effects of concentration of IF – MoS2 nanoparticles as additives in 150NS and PAO using pin – on – flat tribometer under boundary lubrication conditions [2]. Boundary lubrication was achieved by using just two drops of oil per test. Further, they tested the lubricative properties of the modified oil in the form of a coating using Ultra High Vacuum (UHV) tribometer with pin – on – flat configuration. HRTEM and XPS analysis was considered to explain the wear mechanism.

L. Jolly-Pottuz et. al. used pin – on – flat tribometer for AISI 52100 steel to study effects of IF – WS_2 particles under boundary lubrication regime [3]. Different concentration of IF – WS2 was used to make solution in PAO oil without any dispersants. Contact pressure was varied from 0.33 to 1.72 GPa and test conditions were at ambient atmosphere with 2.5 mm/s sliding velocity and 2.5 mm stroke length. To explain the lubrication mechanism, HRTEM, SEM, XRD along with Raman Spectroscopy were used.

The tribochemistry of IF – MoS_2 nanoparticles was investigated by J. Tannous et. al. [4]. Rubbing surfaces made up of steel, alumina and diamond – like carbon were used on a pin – on – flat tribometern. Solutions of 1 wt.% IF – MoS_2 in PAO were made and tested under ambient conditions with 2.5 mm/s sliding velocity and 1.12 GPa contact pressure. XPS with AES were performed on the worn surface along with HRTEM and SEM images to analyse the worn surfaces.

The effect of shape, size and crystal structure of IF – MoS_2 were investigated by I. Lahouij [5]. Perfectly crystalline as well as poorly crystalline IF – MoS2 nanoparticles were synthesized, and then tribological tests were carried on a pin – on – flat tribometer at ambient conditions for 1 wt.% modified PAO6 oil with 3 m/s sliding velocity and 3 mm stroke length at 1.12 GPa contact pressure for 60 minutes. TEM, Raman spectra and XPS analysis were done to identify the variation of results.

Friction reduction benefits of IF – MoS_2 in SAE 5W30 engine oil for valve train system was reported by M. Sigroi [6]. Different concentrations were formulated and tested in a motorized engine head test rig. To analyse the surface, TEM imaging and XPS were used.

P. Rabaso et. al. [7] did an investigation on the reduced ability of IF - MoS_2 nanoparticles to reduce friction and wear in the presence of succinimide based dispersants. Tribological tests were performed on high frequency reciprocating rig and Nanovisu tribometer. Various quantities of nano particles along with dispersants were added to a fully formulated gear oil and a blend of PAO4 and PAO40 synthetic oils and were characterized using DLS and XPS.

In presence of ZDDP additives, the wear and friction reduction properties of IF - WS_2 particles was studied on rough surfaces by P. U. Aldana et. al. [8]. Tribological test were performed on a pin – on – flat tribometer with rough flat made of AISI 52100 (100Cr6) steel for 8 hours at 100 ºC of oil temperature. To characterize the surface, SEM with EDX and XPS were utilized.

M. F. Charoo et. al. [9] investigated the tribological properties of IF - MoS_2 nanoparticles as lubricant additive on cylinder liner and piston ring tribopair. Different concentrations of nanoparticles in SAE 20W40 were prepared and tested preliminary on a four ball wear test machine as per ASTM D 4172 and then with a pin – on – block universal tribometer.

Siddhant Jandial, Himanshu Gandotra, Sumit Mahajan, and Sanjeev Gupta, "A review of nano-particles as lubricant additives for friction and wear reduction," *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 143-146, 2018.

SEM and EDS analysis of the worn surfaces was carried out to find the causes for observed friction and wear behavior.

Optimal design parameters and statistically significant parameters for obtaining a low coefficient of friction with h - BN and Al_2O_3 nanoparticles, dispersed in SAE 15W40 were determined by M. Abdullah et. al. [10]. Tribological tests were conducted on four ball tester using ASTM D 4172 standard and Design of Experiments (DOE) was constructed using Taguchi method.

Q. Wan et. al. [11] formulated nano lubricants with varying concentrations of h – BN with SAE 15W40 and oleic acid as a dispersants. SEM, TEM and XRD were performed to observe the morphology of worn surfaces.

M. S. Charoo et. al. [12] studied the tribological properties of h - BN in SAE 20W50 engine oil to simulate cylinder liner and piston ring tribopair. Preliminary test results were performed on four ball tester as per ASTM D 4172 standard and after that using a pin – on – flat universal tribometer. The tests were performed at ambient temperature with normal load as a varying parameter. Finally, characterisation was done using SEM and Raman spectroscopy.

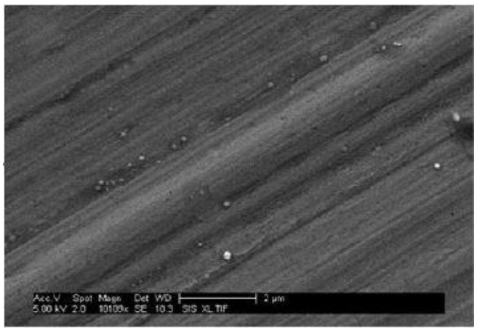
Jatropha oil, which is a bio based lubricant, was modified with h – BN and studied by N. Talib et. al. [13] for machining processes. Four ball tests and tapping torque tests were performed on the oils to understand their tribological characteristics.

The tribological characterization of graphene oxide (GO) as lubricant additive in SAE 20W50 engine oil on Al – 25 Si and steel tribo pair on universal tribometer was studied by P. Kumar et. al. [14]. SEM, EDS and Raman spectroscopy were used for characterization of GO and wear scars.

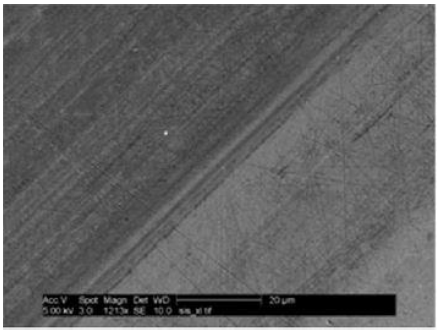
III. RESULTS

All the studies have shown good results with IF – MX_2 type nanoparticles.

Clearly, from the SEM images (Fig. 1) of wear tracks [5], 1 wt.% of poorly crystalline IF – MoS_2 nanoparticles show better wear reduction results than from perfectly crystalline nanoparticles as its wear track is smoother.



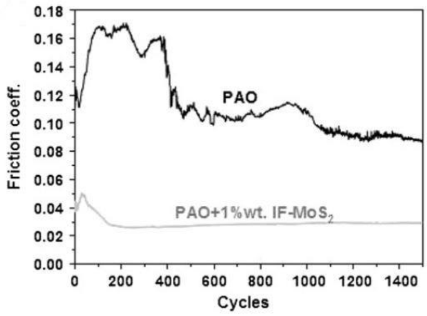
(a)



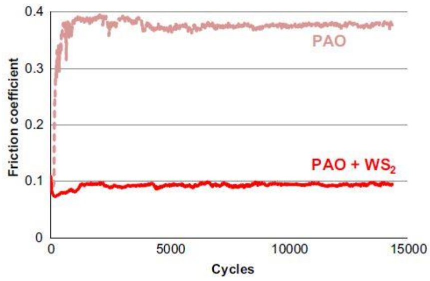
(b)

Fig. 1 SEM image of wear track with 1 wt. % IF – MoS_2 for (a) perfectly crystalline, and (b) poorly crystalline structure. [5]

Besides this it has been shown that adding even as little as 1 wt.% of nanoparticles, the friction and wear reduces by as much as 70% as compared to plain oil [2 – 9] (Fig. 2). This is true for synthetic base oils as well as in case of fully formulated oils.



(a)



(b)

Fig. 2 Friction results for IF – MX_2 type nanoparticles. [4, 8]

Similarly, h – BN has shown excellent results in friction and wear reduction, although it is required a little more (about 3 wt.%) [10 – 13]. This is also evident from Fig. 3. A decrease of nearly 30 – 35 % in coefficient of friction is well observed

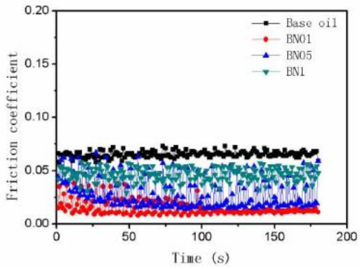


Fig. 3 Comparison of coefficient of friction for base oil and h – BN modified oil [11]

Siddhant Jandial, Himanshu Gandotra, Sumit Mahajan, and Sanjeev Gupta, "A review of nano-particles as lubricant additives for friction and wear reduction," *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 143-146, 2018.

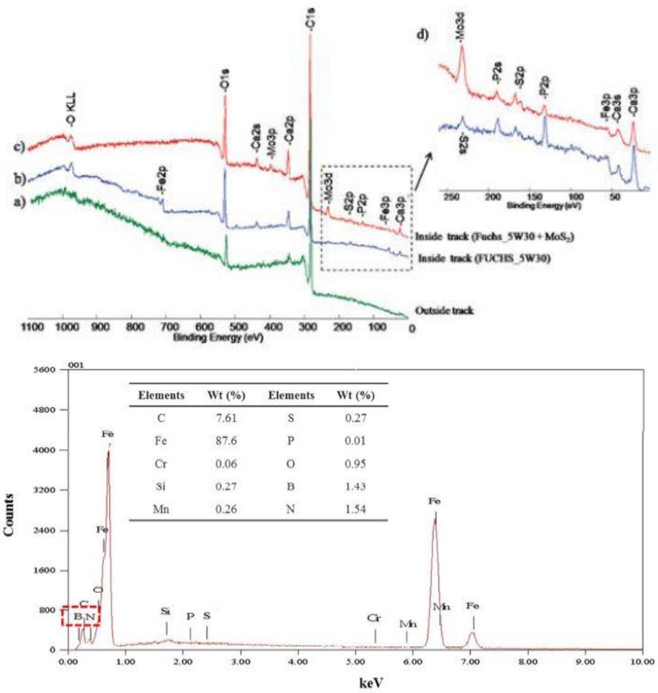
International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

over dry run, even addition of 0.5 wt.% of GO have shown a decrease in coefficient of friction of more than 70% [14].

To understand the tribological mechanism for friction and wear reduction, various analytical tools were used as mentioned in the previous section (Fig. 4). It has been well established that since the nanoparticles exfoliate and adhere to the friction surfaces, they act as nano bearings and help in increasing load carrying capacity. More over the due to weak Van Der Wall's force, the successive layers slide over each other easily, which helps in lowering the co-efficient of friction [14].

(a)



(b)

Fig. 4 Analytical results of worn surfaces of (a) IF – MoS2 modified oil [6] and (b) h –BN modified oil [13]

IV. CONCLUSION

So, it can be concluded from the above studies that adding certain nanoparticles at certain amounts, do help in increasing friction and wear reduction properties for oil. The concentration of nanoparticles may vary, but the friction reduction mechanism is more or less the same.

REFERENCES

[1] R.Tenne, L.Margulis, M.Genut, G.Hodes, "Polyhedral and cylindrical structures of tungsten disulphide", *Nature 360*, pp. 444–446, 1992.

[2] L. Cizaire, B. Vacher, T. Le – Mogne, J. M. Martine, L. Rapoport, A. Margolin, R. Tenne, "Mechanism Of Ultra – Low Friction By Hollow Fullerene – Like MoS_2 Nanoparticles", *Surface and Coatings Technology*, pp. 282 – 287, 2002.

[3] L. Joly-Pottuza, F. Dassenoya, M. Belina, B. Vachera, J.M. Martina, N. Fleischerb, "Ultralow-Friction And Wear Properties Of IF-WS_2 Under Boundary Lubrication", *Tribology Letters*, pp. 477 – 485, 2005.

[4] J. Tannous, F. Dassenoy, I. Lahouij, T. Le Mogne, B. Vacher, A. Bruhács, W. Tremel, "Understanding The Tribochemical Mechanisms Of IF-MoS_2 Nanoparticles Under Boundary Lubrication", *Tribology Letters*, pp. 55 – 64, 2011.

[5] I. Lahouij, B. Vacher, J. M. Martin, F. Dassenoy, "IF-MoS_2 Based Lubricants: Influence Of Size, Shape And Crystal Structure", *Wear*, pp. 558 – 567, 2012.

[6] M. Sgroi, F. Gili, D. Mangherini, I. Lahouij, F. Dassenoy, I. Garcia, I. Odriozola, G. Kraft, "Friction Reduction Benefits In Valve-Train System Using IF-MoS_2 Added Engine Oil", *Tribology Transactions*, pp. 207-214, 2015.

[7] P. Rabaso, F. Dassenoy, F. Ville, M. Diaby, B. Vacher, T. Le Mogne, M. Belin, J. Cavoret, "An Investigation On The Reduced Ability Of IF-MoS_2 Nanoparticles To Reduce Friction And Wear In The Presence Of Dispersants", *Tribology Letters*, pp. 503–516, 2014.

[8] P. U. Aldana, F. Dassenoy, B. Vacher, T. Le Mogne, B. Thiebaut, "WS_2 Nanoparticles Anti-Wear And Friction Reducing Properties On Rough Surfaces In The Presence Of ZDDP Additive", *Tribology International*, pp. 213 – 221, 2016.

[9] M. S. Charoo, M. F. Wani, "Tribological Properties Of IF-MoS_2 Nanoparticles As Lubricant Additive On Cylinder Liner And Piston Ring Tribo-Pair", *Tribology in Industry*, vol. 38, issue 2, pp. 156-162, 2016.

[10] M. Abdullaha, M. Abdollaha, H. Amiruddina, N. Tamaldina, N. R. Nuria, "Optimization of Tribological Performance of hBN/AL2O3 Nanoparticles as Engine Oil Additives", *Procedia Engineering*, pp. 313 – 319, 2013.

[11] Q. Wan, Y. Jina, P. Suna, Y. Dinga, "Tribological Behaviour Of A Lubricant Oil Containing Boron Nitride Nanoparticles", pp.1038 – 1045, 2015.

[12] M. S. Charoo, M. F. Wani, "Tribological Properties of h-BN Nanoparticles As Lubricant Additive On Cylinder Liner And Piston Ring", *Lubrication Science*, 2016.

[13] N. Talib, R.M. Nasir, E.A. Rahim, "Tribological Behavior Of Modified Jatropha Oil By Mixing Hexagonal Boron Nitride Nanoparticles As A Bio-Based Lubricant For Machining Processes", *Journal of Cleaner Production*, 2017.

[14] P. Kumar, M. F. Wani, "Tribological Characterisation of Graphene Oxide As Lubricant Additive On Hypereutectic Al-25Si/Steel Tribopair", *Tribology Transactions*, 2017.

Siddhant Jandial, Himanshu Gandotra, Sumit Mahajan, and Sanjeev Gupta, "A review of nano-particles as lubricant additives for friction and wear reduction," *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 143-146, 2018.