A Study on Tribological Properties of different Nanoparticles as additives in various Lubricants

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Abstract:

This article deals on the prose review of the nanoparticles mixed with different base oils. The synthesis of few of the nanoparticels and its effect on friction and wear has been analyzed. It is been studied that the optimum concentration of the nanparticels in the base oils has given significant improvement in the friction co-efficient, scar diameter and the increasing life of rubbing components. The tribological behavior of different nanoparticles with different lubricants were reviewed,also,the review of tribological properties of WS_2 Nanorods, rare earth (REN) and $ZnAl_2O_4$ nanoparticles in base oils has been presented.

Keywords: WS_2 Nano rods, four ball tester, SEM, tribological properties.

1. Introduction

In industries, the mating mechanical components which work under high pressure, increases the temperature on the surfaces, to reduce this it requires lubrication. The increase in the temperature increases the wear between the mating surfaces which results in the failure of the components [33]. To minimize this failure traditional lubrication plays a chief in industries. In order to improve the life of these lubricants, additives like nanoparticles are used.

The addition of nanoparticles as additives to the base oil has reduced the friction and wear of the mating parts [34]. The nanoparticles of (1 to 100nm) based on the synthesis has shown considerable improvement [35]. The tribological properties of any components changes with the shape like spherical, cubic, nanotube, nanorods .etc..,Significant efforts have been directed for synthesis of nanoparticles by various methods like friction reduction, self reduction, hydrothermal..etc., the addition of some nanoparticles in base oil had not given good tribological properties due to its improper dispersion. To overcome this, additions of agents have been introduced for better results.

The concentration of nanoparticles as oil additives should also be considered for optimum results [38]. The tribological properties can be examined by performing test on various equipments like four ball testers, ball on disc, pin on disc, disc on disc etc., there are several factors that affect the tribological properties of the mating components.

2. Overview of Lubricants:

Lubrication is the traditional method to decrease the wear and friction between the rolling and sliding contact [39]. This develops a thin protective film between the contact surfaces. Flash point, pour point, viscosity index oxidization resistance and thermal stability are some of the factors that affect the lubrication performance [1-4].

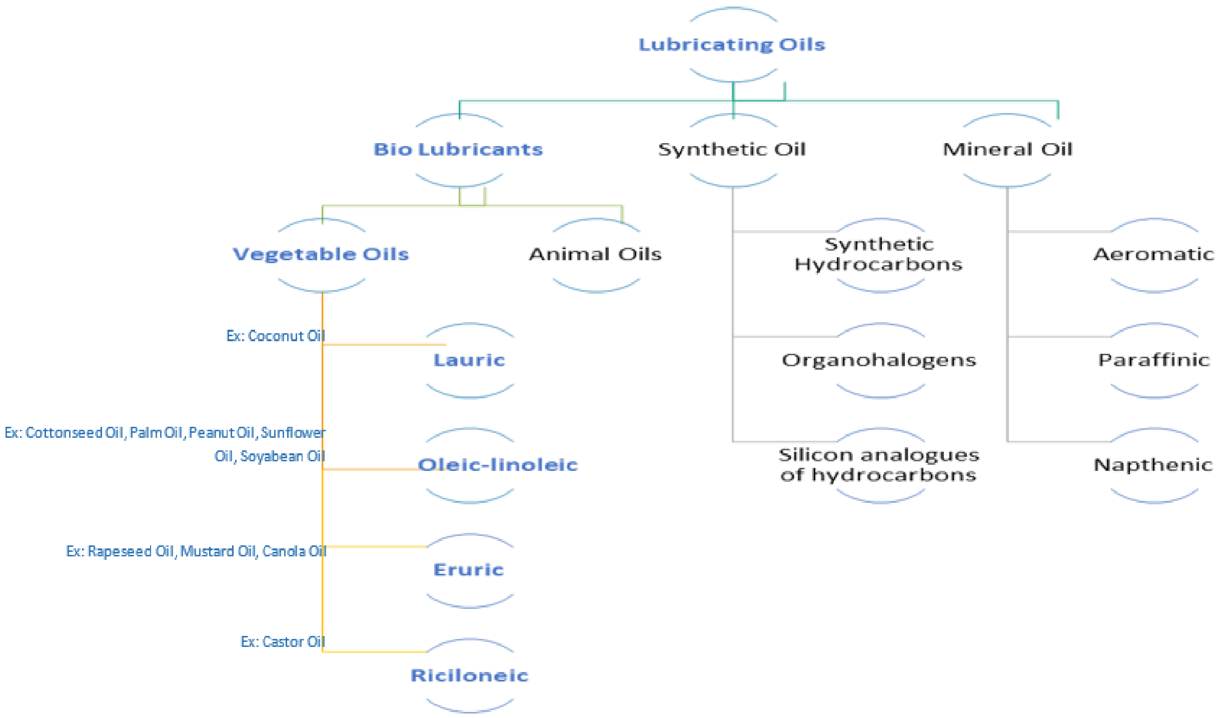


Fig 1: Classification of Lubricants

2.1 Mechanism of Nanoparticles in Lubricants

Mineral oils are formed by the fractional distillation of crude oils, hydrocarbons contribution to the mineral oils are considered to be the most important because of its chemical structures like naphthenic, aromatic and paraffinic[5]. Animal fats and vegetable oil come under bio lubricants [6]. Vegetable oils have glycerol and fatty acids which gives excellent lubricating and thermal properties [7]. Synthetic oils are man made lubricants which is the best alternative for mineral and bio lubricants due to its capability to withstand from extremely low to high temperature. To improve the tribological properties of the mating parts it is necessary to know the mechanism of the nanoparticles in lubrication, because, addition of these nanoparticles has showed good tribological properties [8].

In ball bearing mechanism the particles are usually spherical or quasi- spherical in shape which rolls between the mating surfaces to give better tribological properties [9-11]. Where as in tribo film formation mechanism an unstructured layer is formed on the mating surface which reduces the friction by the formation. [12-15]. At the wheel work piece interface the surface quality obtained by the nanofluids was found to be better due to the ball bearing and polishing affect [16].

In polishing effect mechanism, the nanoparticles will fill the gap in between the rough surface which was caused due to the rubbing action [40]. This mechanism smoothen the rough surface and hence called smoothing effect [17-19]. In mending effect mechanism the nanoparticles gets deposited in the grooves of the rough surface and reduce the roughness, which called a self repairing mechanism [20, 21].

2.2 Analysis of Nanolubricants (Synthesis):

L.L.Zhang has synthesized WS_2 nanorods as nano additives in lubricant by ball milling process which was carried out at ambient temperature by a planetary ball milling machine with a rotational speed of 450 rpm for 12 hrs which led to the formation of precursor nanosheets [22]. These nanosheets were synthesized by putting into autoclave filled with 80% of alcohol and maintained at 240^0C for 24 hrs followed by annealing process. These sheets were dispersed in the base oil by a sorbitol monoleate dispersing agent for the equal suspension in T-18 high dispersion machine for 20min [23].

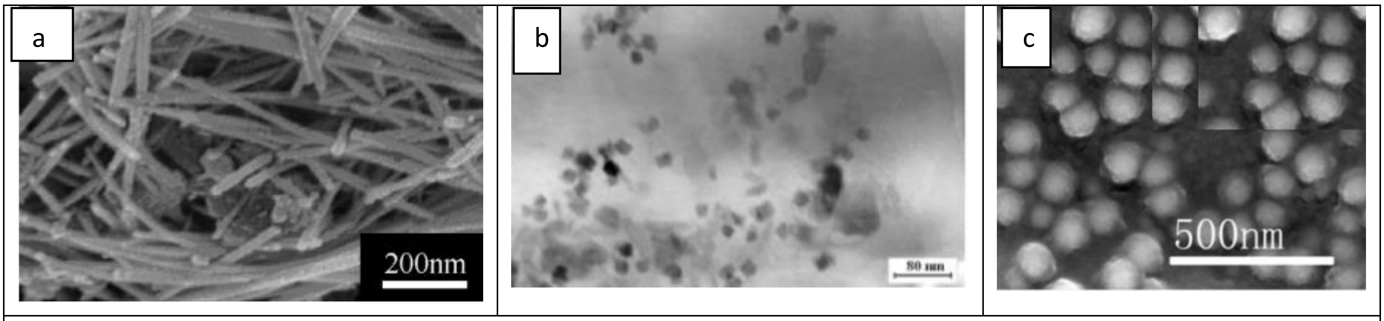


Fig 2. SEM images of a) WS_2 Nano rods [23] b)Rare earth[22] c) $ZnAl_2O_4$ nanoparticles [24]

Rende Liu has took a small portion of REN, VG26 lubricant and surface improving agent in a container and blended thoroughly. The Mixture was excited at 60ºC in absolute alcohol and diluted aqueous hydrazine solution. The byproduct naphthenic acid was formed by putting triethylene tetra mine into the container. Finally the water is separated from the solution by using vacuum pump and the surface modified REN were obtained [22].

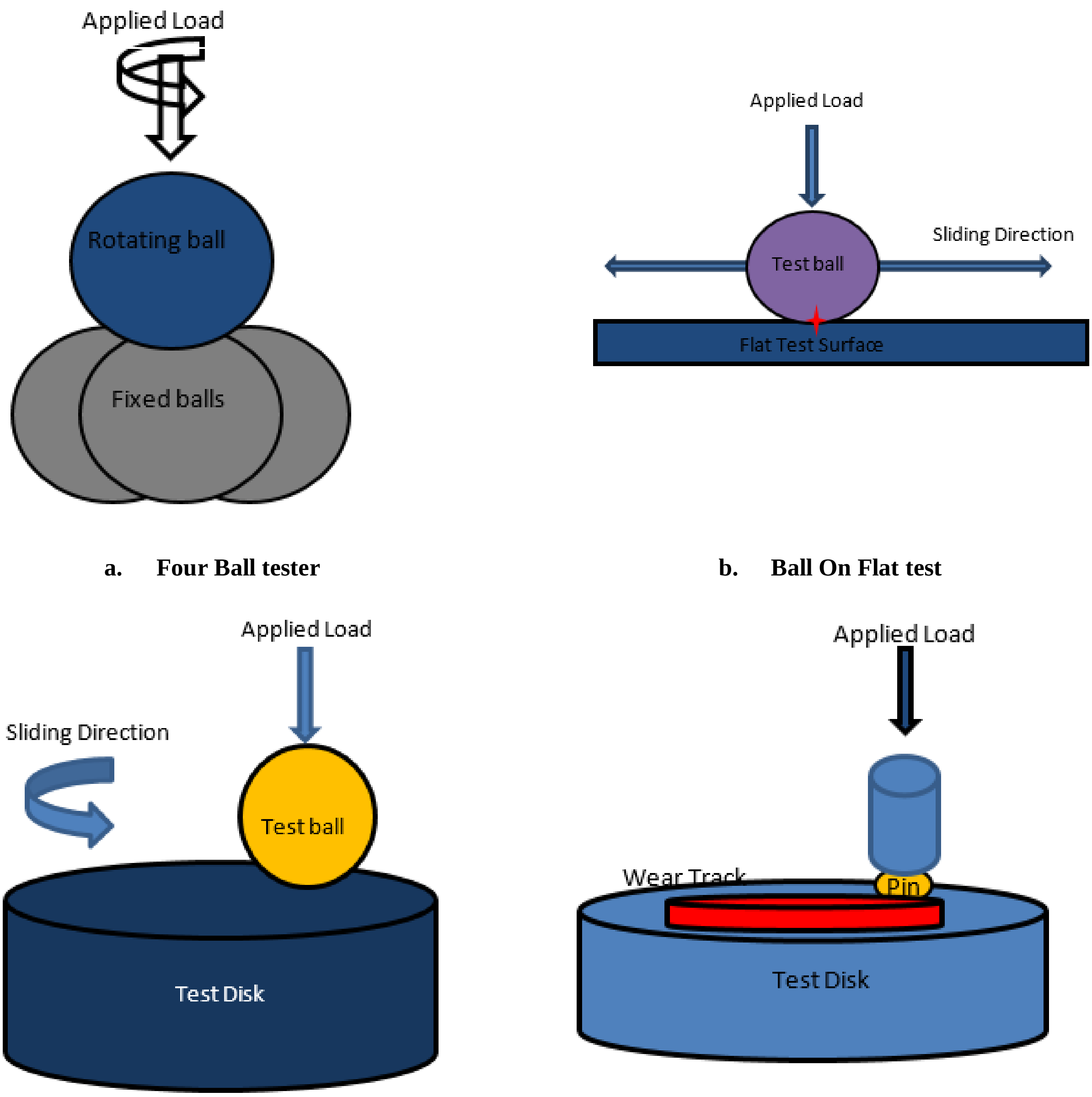
Xiaoyun Song prepared $ZnAl_2O_4$ nanoparticles by dissolving 1MZn $(Ac)_2$ $2H_2O$ and 2M Al (NO_3) $9H_2O$ into alcoholic solution by adding 0.3wt % of polyethylene glycol. Later ammonia was added to the solution to form a gel by mechanical stirring and ultrasonic dispersion which was then washed with alcohol for 3times [41]. The mixture of these two gels was put into an autoclave and fully stirred at 220^0 C for 24 hrs, further the as prepared $ZnAl_2O_4$ nanoparticles were mixed with different amount of oleic acid like 3, 6, and 9 %wt at different temperatures say 30^0, 70^0, 110^0C. By changing the percentage weight of oleic acid in $ZnAl_2O_4$ series of modified nanoparticles were formed [24].

3. Tribological properties:

L.L.Zhang investigated the friction and wear by using a four ball tester under varying loads like 170,245 and 320N for 30min. by using optical microscope with an accuracy ±0.01mm,the WSD of the steel balls were measured. Rende Liu evaluated the properties on MS-800 four ball tester under a load of 294N at 1450rpm for 30min near ambient temperature [25]. The author followed the ASME D2783 and ASME D4172 for measuring the COF, WSD and maximum non-seize load. Xiayun deliberate the WSD and COF of ZnAl2O4 nanoparticles in the base oil by two different test procedures wiz. Four ball tester and thrust ring test [26]. The test in the four ball tester was conducted under a load thrust ring at 1450rpm for 1800sec near 348K, while in thrust ring test it was under200N at 1200rpm for 1800sec near 348K.

S.No	Material	Size (nm)	Shape	Morphology	Lubricant	Tribology Test	Ref.
1	Cu	25	Nearly Spherical	TEM	PAO6	Block-on-Ring	[47]
2	Pb	2.2	Spherical	TEM	Liquid Paraffin	Pin-on-disc	[48]
3	CuO	5	Spherical like	TEM	Chemically Modified rapseed oil	Four-ball Tester	[49]
4	CuO	5	Spherical Like	TEM	Chemically modified palm oil	Piston ring-cylinder liner	[49]
5	WS_2	100	Spherical	AFM	Paraffin oil	Pin on disc	[36]
6	MoS_2	350	Layered	TEM	Surface Modified Coconut Oil	Four ball Tester	[42]
7	ZnO	11.7	Nearly Spherical	SEM	PAO6	Block On Ring	[48]
8	TiO2	80	Spherical	TEM	Liquid paraffin	Four Ball tester	[51]
9	Boron Nitride	70	Spherical	SEM	PAO10	Piston Skirt Cylinder Liner	[52]
10	ZrO_2/SiO_2 nano Composite	50-80	Nearly Spherical	TEM	Surface Modified machine oil	Thrust Ring	[50]
11	$Al2O_3/SiO_2$ Nanocomposite	70	Elliptical	TEM	Surface Modified Machine Oil	Thrust Ring	[53]
12	Nickel	20	Nearly Spherical	TEM	PAO6		[48]

Table: 1 Summary of different nanoparticles as additives and tribological properties studied by various researchers



a. Four Ball tester **b. Ball On Flat test**

c. Ball On Disk **d. Pin On Disk**

Fig 3. Schematic diagrams of Tribological tests.

Four Ball tester:

As the name indicates it has four balls which operates in sliding or rotating motion. One ball rotates over the other three balls [27]. These balls are stainless steel and are coated with the lubricating film. The rotating ball rotates at a given speed under the applied load. The ball is rotated until it gets seized. This test is used to find the characteristics of the lubricant. This is operated under certain standards usually called as ASTM D-2266(Grease) or ASTM D-4172 (Oils) [28].

Ball on Flat Test:

In this experiment the ball made of steel is made to slide on the flat surface in to and fro motion. The size of the ball is taken as per the AISI standards [29]. The lubricating film passes between the ball and the flat surface [43]. Due to the friction between the rubbing surfaces, heat is produced leading to wear in the mating parts. [54]

Ball on Disk Test:

In this ball is in continuous contact with the disk and hence this is used for checking the mechanical component surfaces which are subject to sliding motion [30]. Its robust design can help in withstanding the high loads and with greater velocities and therefore can be used under various test conditions [44] .

Pin On Disc Test:

Pin On disc tribometer consists of a pin that is stationary loaded against a disc which is rotating. This is also one of the methods to characterize the wear properties and find the performance of the lubricants [31].

4. Morphology:

The author used SIRIONJY/T010-1996 SEM to examine the morphology ofWs_2 Nano rods as additives in the lubricant [32]. For rare earth nanoparticles the author investigated the tribological morphology by using Auger electro spectroscopy (AES) and XPS[46] . It was observed that the description of $ZnAl_2O_4$ nanoparticles with base oil by SEM with a FEI FEG quanta 250 microscope and XRD onD8Advance radiation.

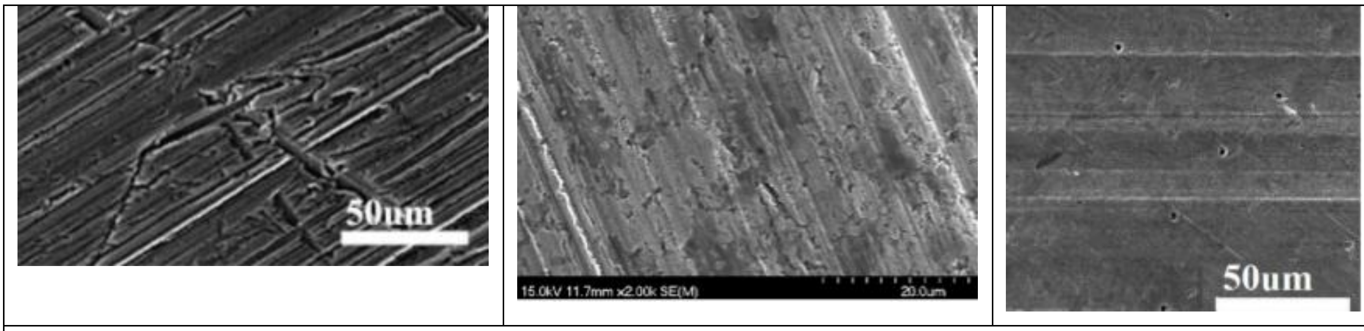


Fig 4. SEM Image of worn surface of a) Pure base oil b)Base oil with Ws_2 Nanorods[23] c) Base oil with $ZnAl_2O_4$ [24]

5. Conclusion:

This article exposes the exclusive evaluation on use of various nanoadditives for lubrication. The synthesis and characterization of nanoparticles in different shapes, size and based on method of preparation were analyzed. It was observed that the addition of nano additives in the lubrication with different concentrations gave improved results when compared pure lubricant. The WSD, COF and various tribological properties were improved in oil instance.

- The mating surfaces were improved in friction and wear when WS_2 nanorods along with the base oil were used.
- The improved REN showed excellent tribological properties when blended with the lubricant.
- $ZnAl_2O_4$ nanoparticles showed good tribological properties with optimum nanoparticle concentration.

Future work:

The investigations can be towards the procurement of new nano additive, which can be used as lubricants in various industrial and automotive applications. Nanoparticles with various base oils were used as the potential lubricants under suitable conditions.

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