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Comparative Study of Anti-Wear and Extreme Pressure Properties of Some Bio Oils with PAO_4 Base Oil

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***Abstract* - The research is to investigate the extreme pressure and anti-wear characteristics of bio-based lubricating oils and compares them to the extreme pressure and anti-wear characteristics of PAO_4 base oilI have chosen onion, pumpkin, avocado, and karanja oils as bio-based lubricating oils for this investigation. I adhere to ASTM D5783 and ASTM D4172 in this investigation. I adhere to ASTM D5783 for extreme pressure qualities and ASTM D4172 for anti-wear properties. The following are the weld points for the various oils: 1554N for karanja, 1541N for avocado, 1553N for pumpkin, 1534N for onion, and 1556N for PAO_4 base oil. The bio-based oils' weld points are somewhat lower than those of PAO_4 base oil. The load wear index values for the following oils are available: karanja oil (95.78N), avocado oil (124N), pumpkin oil (89.82N), onion oil (105.35N), and PAO_4 (94.24N). The bio oils' load wear index is comparable to that of PAO_4 base oil. Onion and avocado oils have greater load wear indices than PAO_4 base oil. The average wear scar diameter (AWSD) is used to calculate the anti-wear property; the higher the AWSD, the more wear occurs. The average width of the oil is 699.33 µm for karanja, 939 µm for avocado, 763 µm for onion, 717 µm for pumpkin, and 607 µm for PAO_4 base oil. The bio oil's AWSD is higher than that of the PAO_4 base oil.**

Keywords: Extreme pressure, Anti-wear, Oils, PAO_4, ASWD.

I. INTRODUCTION

The process of lubricating-that is, putting a lubricant between two moving, touching surfaces-reduces friction between them, which is amaterial with lower shear strength than the surfaces. While lubricants can lessen the frequency of asperities and weaken their connections, they cannot always entirely prevent them. Thus, lubrication also lowers the sliding wear rate; for many dry engineered materials, µ is rarely less than 0.5 and is typically much higher. High values would result in significant frictional forces, leading to energy losses and likely elevated wear rates. Lubricants are commonly used because µ can be quite low (» 0.001) when used properly. A major factor in manufacturing costs is the durability of rotating and moving parts in machinery. For example, wear in parts from tribological errors or poor lubrication can harm production capacity by raising maintenance expenses, downtime for machines, and part replacement costs. The principal expenses related to wear in industrial sectors like transportation, manufacturing, energy, and residential range from 20% to 55%, according to statistical results [1]. Wear and friction, however, have advantages in applications like mining and material removal procedures. Researchers generally recommended several strategies for adjusting the lubricants' viscosity, friction, wear, oxidation, and detergent capabilities in order to take advantage of the benefits and drawbacks of friction and wear.[2] .The ability to produce nanomaterials at higher concentrations and with varied morphologies, such as Fe, Cu,Co, HBN, onion-like carbon (OLC), and fullerene, has created new possibilities for improving lubricant characteristics [2,5]. The size, shape, number of layers (for 2D Nano additives), surface area, mechanical characteristics, and chemical makeup of these additives all affect the lubricants' tribological and physical characteristics.

Of all these materials, carbon-based nano additives have garnered the most interest for use in manufacturing, energy storage, and the creation of biomedical devices. The study prepared three samples at concentrations of 0.01% w/w, 0.05 w/w, and 0.1% w/w in order to evaluate the effects of reduced graphene oxide (rGO) nano platelets as an additive to improve the wear and friction characteristics of oil-based lubricants. Using a liquid lubricant of 99.9% pure oil, the direct impact of rGO nano platelets on tribological properties was examined [6], One way to achieve lubrication for two sliding surfaces is to place a layer of sheared-resistant material between them, protecting the surfaces from damage. First, the layer keeps opposing asperities from coming into

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metallic contact, which stops them from fusing and ripping. Second, albeit it is a secondary necessity, it helps to lessen the friction between the surfaces. There are multiple lubrication regimes in a basic system with two surfaces passing one another while a lubricant is present. Frictional behavior is dictated by the fluid characteristics of the lubricant when the surfaces are separated by a reasonably thick film of fluid, which often happens at low loads and fast sliding speeds. This virtually completely replaces metal-to-metal shear. Surface wear is minimal and the coefficient of friction is quite low in this area. In these circumstances, lubrication is referred to as "hydrodynamic".

When contact pressures are high, the lubricating oil's viscosity is impacted by the pressure, causing elastic surface distortion. The "Elasto-hydrodynamic" lubrication regime is this one. Maintaining an entire fluid film between rubbing surfaces may not always be feasible under greater loads or lower sliding speeds, and the hydrodynamic film may be thinner than the surface asperities that allow the lubricant to seep through. The "Boundary" lubrication type of lubrication is influenced by films that are created on the contact points as a result of chemical or physical interactions between the metal and active molecules in the lubricating fluid. A pure hydrocarbon cannot interact in this way; therefore, it needs agents added in order to operate as a boundary lubricant. There is some surface-active substance, which works well as a boundary lubricant, in regular mineral oil. So-called Anti-Wear (AW) additives are thought to work by generating adsorbed coatings on the rubbing surfaces under intermediate stresses. Long-chain fatty acids, esters, and amines are common anti-wear additives; however, as adsorption is essential to this regime, many long-chain polar compounds have some degree of effectiveness. Adsorbed films have less of a tendency to stay on the surface and the anti-wear films degrade when the pressure at the contact points increases and the contact temperature rises. A more stable Extreme-Pressure film must so emerge in order to provide boundary lubrication under these circumstances [7]. When the degree of surface contact is such that naturally occurring protective oxide films are destroyed and other surface active species in the oil are not reactive enough to deposit a protective film, EP additives are intended to prevent metal to metal adhesion or welding. To improve the mach inability properties of cutting fluids, EP additives are added to engine oils, gear oils, and even cutting fluids. When rolling ferrite stainless steel, EP ingredient ZDDP in the lubricant exhibits extremely remarkable scratch resistance, helping to eliminate sticking faults [9]. Even the deep groove ball bearing's fatigue life is impacted by EP additives when thin film lubrication is present. When comparing oils with sulfur/phosphorus EP additions to base oils, the S/P EP often exhibits a higher degree of discoloration.[10].

II. RESEARCH METHODOLOGY

a) Machine

Reducing friction and wear losses in machinery requires the use of lubrication technology and oil. Lubricants (grease, oil, and solid lubricants) are essential to the frictional system's efficiency. The Four Ball Tester, sometimes referred to as the Shell Four Ball Tester, is a tool used to evaluate the characteristics of lubricants, including wear prevention (WP), extreme pressure (EP), and frictional behavior (the following list of testing standards are).

b) Four Ball Extreme Pressure Test

Testing a lubricant's severe pressure properties determines its ability to function under extreme pressure conditions. At the "low" loads where the test starts, the lubricant functions as intended, an appropriate lubricant film forms, and no convulsions are noticed. According to the test standard, the load is progressively increased until the lubrication fails, which occurs when surface-to-surface contact occurs and the lubricant film is no longer able to separate the surfaces. Finally, the load is raised until a catastrophic failure takes place. This last failure is known as "welding" and is typified by abrupt changes in the friction signal, elevated noise levels, etc. Various formulas can be created based on how well a lubricant performs in this test.

c) Four Ball Wear Test

The lubricant's performance in terms of wear can also be evaluated using the four-ball test. The higher ball is rotated in opposition to the other fixed balls during the test. In contrast to the extreme pressure test, the load is carried out under set conditions (load, temperature, speed, etc.). Following the test, wear scar measurements are taken using tools like optical profilometry, which can be used to assess a lubricant's wear performance. Since friction force is measured during this test, it may also be examined.

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Four-ball tester utilization serves as the foundation for the testing standards listed below.

ASTMD2783: EP Test for lubricating fluids(ASTMD2596for grease).
IP239: EP and AW tests for lubricants.
DIN51350-02: Extreme pressure properties test for liquid lubricants.
ASTMD4172: WP tests for lubricating fluids (ASTM D2266forgreases).
ASTMD5183: Coefficient of friction of lubricants.
DIN51350-03: Wear test for liquid lubricants.

The tester consists of four balls in the configuration of an equilateral tetrahedron. The upper ball rotates and is in contact against the lower three balls, which are held in a fixed position The machine has a vertical spindle that rotates a 12.7mm diameter maleballchuckwithanalloysteelballatdifferentrpmasdescribedbyASTMD.Underneath it, three other identical balls that form an equilateral tetrahedron with the first ball are clamped together in a pot with a lock ring that is filled with the lubricant to be tested. The pot is mounted on a disc over a thrust bearing which automatically centers the top ball held in the chuck. The load is thus evenly distributed over threepointsofcontactbetweenthetoprotatingballandthethreestationaryballsunderneath. Loads in the range of 63–630 kg were applied to the thrust bearing. Rotation of the driving spindle causes frictional torque, which produces a scar on the three lower balls.

d) Balls

Steel bearing balls measuring 12.7 mm (0.5 in.) in diameter and hardened to RC 65–66 (UNE 7-424–1) with a roughness of Ra = 0.035 mm were utilized. They were formed from AISI E 52100 (UNE 36-027) steel that had been carbon vacuum deoxidized in a single heat.

Table1: Constituent elements of AISIE52100 steel balls

Element	C	Si	Mn	P	S	Cr	Fe
%age	0.95-1.1	0.2-0.35	0.25-0.45	0.025	0.025	1.3-1.6	remaining

Table 2: Mechanical propertiesAISIE52100 steel balls

Properties	Value
Young‘s Modulus	2,00,000MPa
Tensile Strength	650-880 MPa
Elongation	8 -25 %
Poison‘s ratio	0.27-0.30
Yield Strength	a

e) Procedure for Weld Point and Load Wear Index

- Switch on the compressor and power supply. Switch on the four ball tester machine and bring machine to zero load condition and operate machine at 27ºCand 1760 rpm and 10 seconds duration.
- Fill the test-lubricant cup with the three test balls. After covering the test balls with the lock ring, tighten the nut. Cover all three test balls with the lubricating fluid that is going to be tested.
- Bring the lubricant and cup to a temperature between 18 and 35°C (65 and 95°F).).
- Mount the chuck into the chuck-holder after pressing one ball into the ball chuck)
- Fit the test apparatus in contact with the fourth ball with the test-lubricant cup assembly. Put the spacer in between the thrust bearing and the cup.
- To achieve a base test load of 784 N (80 kg), position the weight tray and enough weights on the horizontal arm in the appropriate notch. Make sure the spacer and cup assembly are centered before releasing the lever arm and gently applying the test load to the balls. Use the clip and wire to connect the calibrated arm on the test-lubricant cup to the indicator spring if the optional friction-measuring device is being utilized.
- Turn on the motor and run it for 10 + 0.2 seconds.
- Take out the test-lubricant cup assembly; throw away the ball and remove the chuck.

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III. RESULTS AND DISCUSSIONS

a) For Weld Load

- To find the weld point or weld load, I follow the test ASTMD5783 test standard. According to this standard the test parameters areas follows.
- Load is not constant, increase the load after every test till the weld of the 4balls occurs. The load at which weld occurs is the weld point of the given lubricant.
- Durationofthetestis10seconds.
- Temperature of the test is28 ±5ºC
- Speed of the testis 1760 RPM

The weld point or weld load obtained of different bio oils (karanja oil, avocado oil, pumpkinoil and onion oil) and PAO_4 baseoil are given in the table 3.

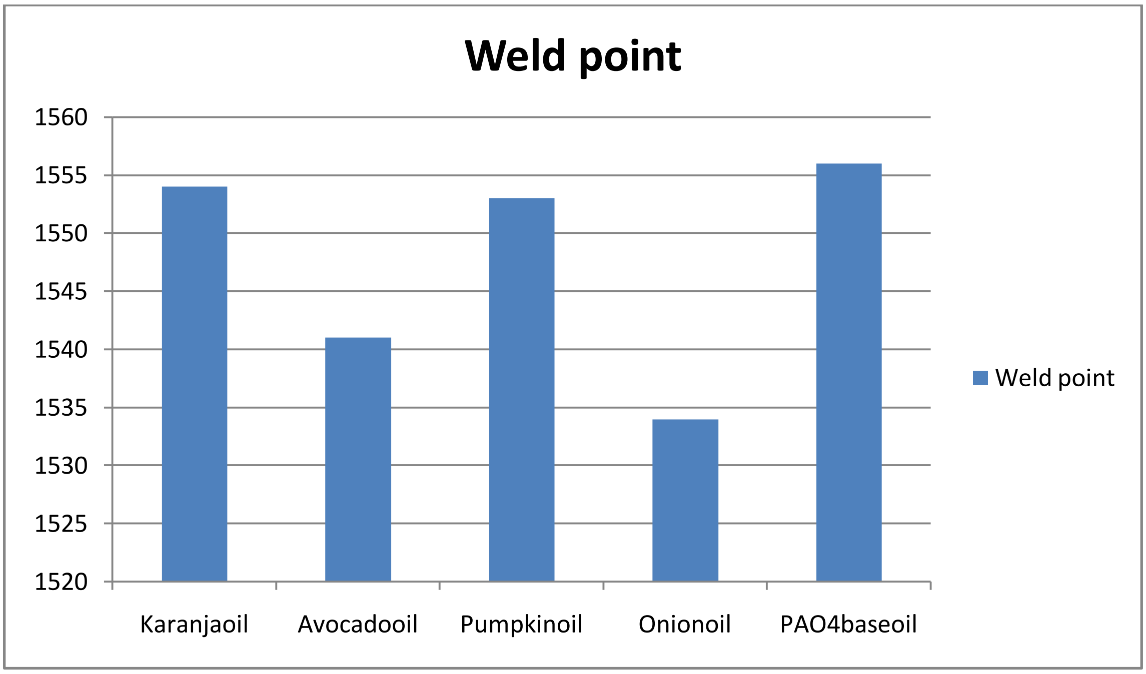

Figure1: Graphical representation of weld point

Table 3: Weld loads of bio oils and base oil

Biooils	Weld point
Karanjaoil	1554N
Avocadooil	1541N
Pumpkinoil	1553N
Onionoil	1534N
PAO_4 baseoil	1556N

From table we can make comparison of weld point of bio oils with the PAO_4 base oil. The weld point of bio oils is slightly lesser than the base oil. So the bio oils have the potential of lubrication. If we do little modification in the bio based lubricant they can be used as lubricant in the heavy machinery.

These oils contain chlorine, phosphorus and sulphur. Karanja oil and avocado oil contains chlorine, pumpkin oil contains phosphorus and onion oil contains sulphur. These elements are good for extreme pressure properties.

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b) Results of load wear index

Load wear index is calculated after taking the scar diameter of the all balls with the help of a microscope installed on the 4 ball tester machine that have been used in particular extreme pressure test. The microscope show the diameter of the scared balls and these scar diameters were used to calculate the average scar diameter (X). The suggested form for calculating the load wear index is shown in Table 4. The 4 table is according to the ASTMD5783standard. According to this standard the test parameters are given below.

- For every scar diameter the load is different, take the scars till the weld point occurs.
- Temperatureis28 ±5ºC
- Duration of test 10seconds
- Speed of test is1760RPM

Table 4: Suggested form for calculating test results

Column 1 Applied Load, kg(L)	Column 2 Average Scar Diameter, mm(X)	Column 3 Compensation Scar Diameter, mm	Column 4 LDh Factor	Column 5 Corrected Load, kg(LDh/X)
6		0.21	0.95	
8		0.21	1.40	
10		0.21	1.88	
13		0.23	2.67	
16		0.25	3.52	
20		0.27	4.74	
24		0.28	6.05	
32		0.31	8.87	
40		0,33	11.96	
50		0.36	16.10	
63		0.39	21.86	
80		0.42	30.08	
100		0.46	40.5	
126		0.50	55.2	
160		0.54	75.8	
200		0.59	102.2	
250		0.59	137.5	
315		0.59	187.1	
400		0.59	258	
500		0.59	347	

The load wear index of bio oils (karanja oil, avocado oil, pumpkin oil, onion oil) and PAO_4 baseoil is given in the table 5.

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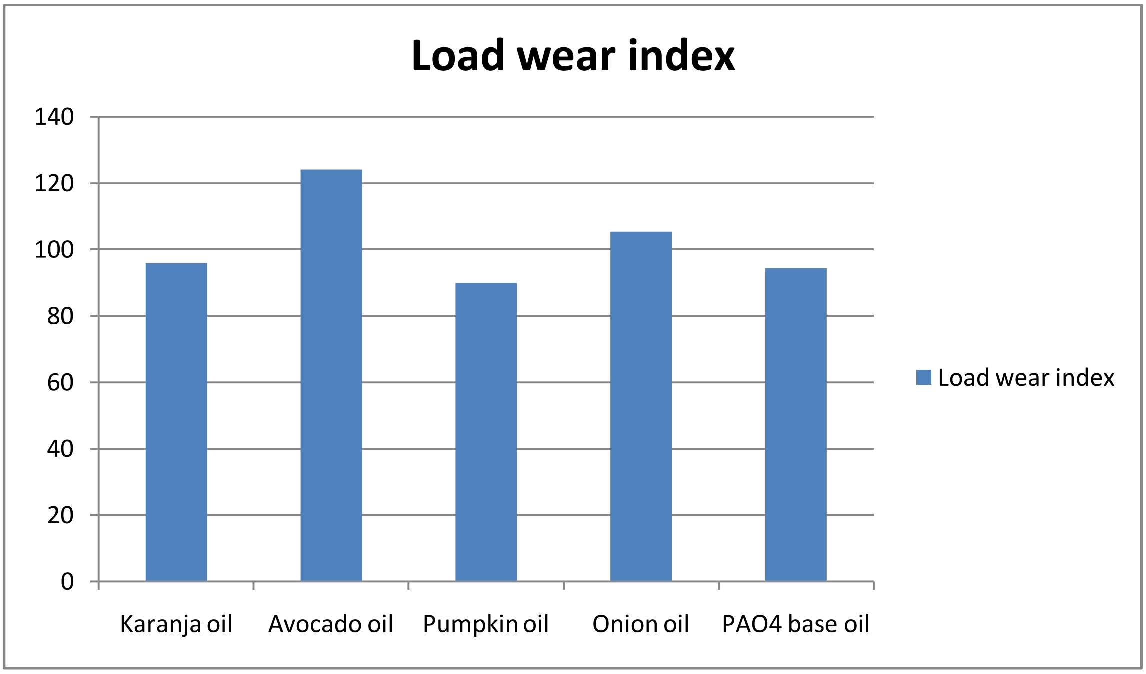

Figure 2: Graphical representation of Load wear Index

Table 5: Load wear index of bio oils and base oil

Oils	Load wear index (N)
Karanja oil	95.78
Avocado oil	124
Pumpkin oil	89.82
Onion oil	105.35
PAO4 base oil	94.24

c) Results of anti-wear properties

For the results of anti-wear I follow the ASTMD 4172. According to this standard the anti-wear properties are calculated from the average wear scar diameter (AWSD) of the steel balls used in the test. More is the AWSD more is the wear caused by that lubricant oil used in the test.

The test conditions of this standard are given below.

Temperature of the test	75 ± 2°
Speed	1200± 60 rpm
Duration	60 ± 1 min
Load	392± 2N

The different bio oils are karanja oil, avocado oil, onion oil and pumpkin oil. I follow the ASTMD 4172 to calculate the AWSD of the abovementioned bio oils.

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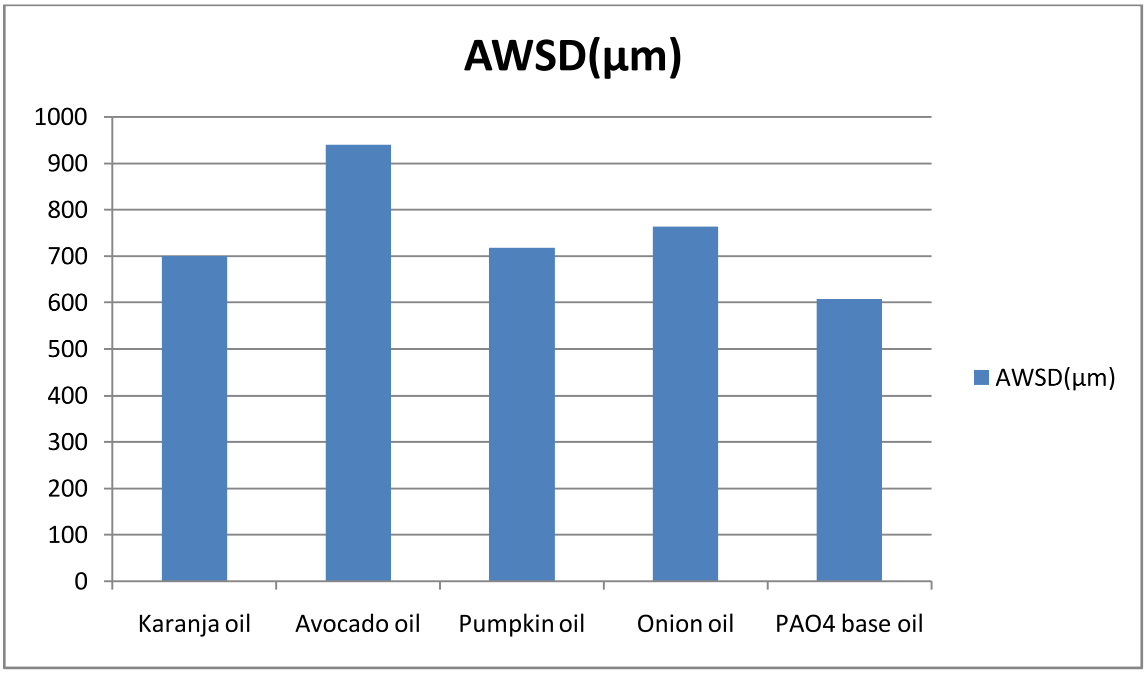

Figure 3: Graphical representation of AWSD

Table 6: Shows the AWSD of bio oil sand PAO_4 base oil

Oils	AWSD(µm)
Karanja oil	699.33
Avocado oil	939
Pumpkin oil	717
Onion oil	763
PAO_4 base oil	607

IV. CONCLUSION

In this study, the extreme pressure properties of different bio oils like karanja oil, avocado oil, onion oil, pumpkin oil and PAO4 base oil, were studied using a four ball tester. The test results revealed that the load wear index and weld load of abovementioned bio oils when get compared with PAO_4 base oil, I got that there is no too much difference in extreme pressure properties and in anti-wear properties.

The above mentioned bio oils contains sulphur, phosphorus and chlorine, the elements are good for extreme pressure properties and anti-wear properties.

So these bio oils can be used as lubricant under high load as well. These bio oil lubricants are environmentally friendly. The following conclusions can be drawn from this study:

It has been observed from this study that the weld point of the above mentioned bio oils are almost same, form the ASTMD 5783 these bio oils gets weld on single load that is 1569N. The weld point of base oil is also same that is 1569N. So in comparison of weld load of bio oils and PAO_4 both the oils perform same.

TheLWIofkaranjaoilis95.78N, LWIofavocadooilis124N, LWI of pumpkin oil is 89.82N, LWI of onion oil is 105.35N and LWI of PAO_4 is 94.24N. LWI of the bio oils are around the LWI of PAO_4 base oil. The LWI of avocado oil and onion oil is higher than PAO_4 base oil.

The anti-wear of bio oils is comparatively good. The avocado oil depicts AWSD equal to 939 mm which is out of the accepted range for commodity oils (510 mm-870mm) [66]. There st bio oils fall in within the accepting range for commodity. The

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AWSD of karanja oil is 699mm, AWSD of onion oil is 763mm, AWSD of pumpkin oil is 717mm and the AWSD of PAO_4 is 607mm.

These bio-oil lubricants are environmentally friendly and easy to synthesize, so we can use them as lubricants. Using the bio based lubricants increases the demand in the agricultural field and hence increases the price of agricultural products (karanja, avocado, pumpkin, onion etc.) A little modification in these bio based lubricants can enhance the properties of the lubricants. Adding nano-partials as extreme pressure additives can increase the extreme pressure properties and also can increase the anti-wear property (ZDDP, HBN etc).

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