
Major Research Achievements of Nano Materials Application

Nano-Diamond Lubricant Essence to Reduce Friction, Wear, Tear & Noise

Introduction to a Patent Product (Patent No. ZL 02131228.1)

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1 Urgently unresolved problems of the lubricant industry

Petrochemical industry veteran academicians of two institutions Hou Xianglin has pointed out: **“For high load equipment such as helicopters reducer, the more reactive extreme pressure anti-wear agent also must be added to the synthetic oil. Compounds that are relatively stable at high temperatures are often not resistant to pressure or abrasion. On the other hand, compounds that are highly resistant to pressure and abrasion decompose easily in high temperatures, under mining the stability of the base oil, corroding the metal.”** Using our nano-diamond modified after surface modification as extreme pressure anti-wear agent solves the problem easily, but experts who have conducted themselves in petrochemical work for long will not be able to accept our viewpoint easily.

2 Starting point of research

To develop lubricating oil that involves an oil film being able to withstand a substantial increase in bearing capacity, new ways must be ventured. This is because the organic chemical method popular right now has proved to be futile. By adding nano-diamond touted as today's best extreme pressure wear-resistant agent to the commercially available lubricating oil, a unique anti-friction and anti-wear effect is produced. However, it does not change the conventional physical and chemical properties of the lubricant. Internationally, the key unresolved issue is the dispersion and suspension of nano-diamond in the oil, so we must find a breakthrough for those problems.

This project belongs to the intersection of a new material – nano-material and mechanical friction, wear and lubrication. Once the key difficulties are resolved, it will be able to change sliding friction to rolling friction, producing anti-friction and anti-wear effects that are beyond expectations. To facilitate promotion and to save transport costs, it must be made into lubricant essence of high concentration; generally 2-5% should be added into commercially viable lubricating oils. For different types of lubricating oil, various corresponding lubricant essence were developed. The current focus is engine oil essence and gear oil essence.

3 Nano-diamond lubricant essence's exceptional properties

3.1 Engine Bench Test

The vehicle bench test conducted by the experiment center of the Chinese People's Liberation Army Academy of Military Transportation shows, this product can increase the engine power P_e at an average of 4.2%, up to a maximum of 6.4%, from 83.4kw to 88.8kw

(at high speed 2700r/min). The average fuel consumption rate is reduced by 4.7%, up to a maximum of 10.3%, where it drops from 364.09g/kw·h to 344.92g/kw·h (at low speed 1600r/min). Energy saving indicators exceed national standard: reasonable lubrication technology code GB / T 13608, level II (highest level) energy saving lubricant indicators (2.7% energy saved). Exhaust emissions are greatly reduced. Idling emissions of HC reduced by 60%, down from 875ppm to 350ppm; NO_x decreased by 20.5%, down from 166ppm to 132ppm. The cylinder pressure is substantially increased. Cylinder pressure is lifted from 4.5kgf/cm² to 5.8kgf/cm², increased by 28.9%. Idle speed is improved significantly. In the case of not any adjustment of the engine, after using this product, idle speed is up from 597r/min to 658r/min, which is an increase of 10.2%.

3.2 Lower coefficient of friction

When the load is 100~300N (Newton) (11 measurement points), the lubricating oil containing nano diamond can reduce the friction coefficient of steel/copper to 9.92% lower on average (School of Mechanical Engineering of Tianjin University).

By adding 2% of lubricant essence into Mobil ISO 68 super cycle oil, the friction coefficient is reduced by 27% (School of Mechanical Engineering of National Cheng Kung University in Taiwan).

3.3 Significant reduction in wear & tear amount

When the load is 100~300N(Newton) (11 measurement points), the wear loss of steel/copper friction pair is 30.10% lower on average, and the wear loss of steel/copper friction pair on average is 21.31% lower (School of Mechanical Engineering of Tianjin University).

Adding 3% lubricant essence, wear loss will reduce 43.9% lower on average (9 measurement points); adding 20% of lubricant essence, the depth of grinding marks will drop steeply from 4.94um to 0.07um (School of Mechanical Engineering of National Cheng Kung University in Taiwan).

With a 3kg load, sliding speed at 0.036m/s, sliding time at 30min, sliding distance at 216m, by adding 5% of lubricant essence, there will be a 70% reduction in wear loss of AISI 1205 steel, and wear loss of AISI 1045 steel will be reduced by 82% (Taiwan Ocean University).

3.4 The oil film bearing capacity increases multiple times

By adding 2% lubricant essence, it will be able to increase the minimum energy required to destruct the oil film from 66.81kJ to 128.33kJ ((School of Mechanical Engineering of National Cheng Kung University in Taiwan)

By adding 3% nano-diamond hydraulic guide rail oil essence to Mobil Vacuoline 1409 hydraulic guide rail oil, the stiffness coefficient of oil film will rise substantially, and it can rise above 30% during high load (Taiwan Chung Yuan Christian University)

This is extremely beneficial to high-speed load equipment.

3.5 Significant reduction in friction power and oil temperature

Adding 2% of lubricant essence can reduce the friction power loss from 76.05W to 55.56W, which is a relative reduction of 26.9% (School of Mechanical Engineering of National Cheng Kung University in Taiwan).

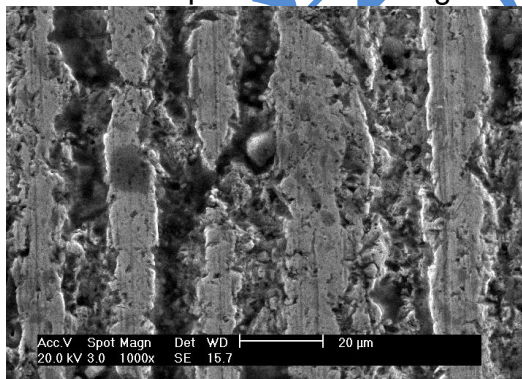
Z12V-190 diesel generator sets used by Shengli Oilfield has a rated power of 882kW, with an oil temperature at 75°C. After adding 2% engine oil essence, the oil temperature dropped to 72.5°C; the diesel consumption rate dropped from 225.25g/kW.h to 210.72g/kW.h.

3.6 Increase in efficiency of transmission machinery

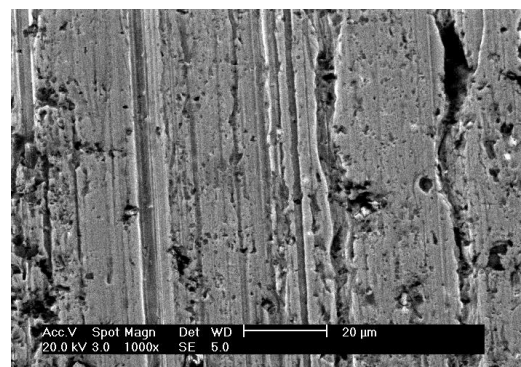
When the output torque is 4.0 ~ 14.0 N.m (Newton meters) under load (four measurement points), the mechanical efficiency of the lubricants containing nano diamonds can increase the mechanical efficiency of micro-worm gear speed reducer to 2.25% on average (School of Mechanical Engineering of Tianjin University).

3.7 Self repair function for friction pair

Figure 1 shows the scanned electron micrographs of the friction surface of the specimen. This uses oil sample 1 (commercially available 460 synthetic oil) and oil sample 3 (Nano diamond instead of extreme pressure anti-wear agent in 460 synthetic oil) as basis of comparison for the experiment, both are observed after 3 hours under the same conditions when friction is applied. The surface morphology, as the figure shows, of the lubricating oil containing nano-diamond not only shows clear effects of being friction-and-wear-resistant but also has self-repair function for the friction pair. This is unparalleled in any other current lubricating oil. It makes the friction pair surface to be smoother, which is impossible for conventional precision machining. Figure 1(a) shows little difference compared with the original before friction.



(a) Oil sample 1



(b) Oil sample 3

Figure 1 Friction surface electron micrographs of specimen under different lubricants

Note: Experiment was conducted at the School of Mechanical Engineering of Tianjin University.

3.8 Redouble extension in service life of lubricating oil

Trial results of multiple cars have proved that the life cycle of lubricating oil has been extended by 1-3 times. This is of particular importance to military equipment that faces

possible long-term lack of supplies.

3.9 For best running-in effects

To conduct comparison running-in tests for two kinds of petroleum products according to specific running-in specifications, using nano-diamond run-in oil allows surface roughness of cylinder liner to decrease from 0.95 to 0.78 after application of oil, and cylinder pressure see an increase from 856kPa to 982kPa with current run-in oil as comparison.

When engine oil essence is added to some new cars, during the running-in period after driving for a distance of 2,000 miles and hence a need to change oil for the strong gauge, it is found that the engine oil is still clean and so no need arises to change oil after check.

3.10 Reduction in vibration and noise

Some cars tend to have more vibration, however after adding in engine oil essence and idle running of about a minute, the vibration is clearly reduced. After adding nano-diamond gear oil essence in the gearbox, the distance of the neutral gear glide has extended almost doubly, changing of gear for the gearbox has also become much smoother, which applies for auto-gear cars too.

Using Germany-made SRV reciprocating wear and tear tester for test process, when the load is 50N, researchers add 2%, 6.67% and 20% of lubricant essence respectively, and the occlusion time to stabilize has reduced from 2146s to 948s, 278s and 0s respectively. (National Cheng Kung University Engineering School)

For 2X-8 rotational vacuum pump, conventional DVE 100 vacuum pump oil is used, and 3% vacuum pump oil essence was added for comparison experiment. It shows, when the pressure is about 7hPa, noise will reduce from 69.3dB to 66.5dB, and the decrease is 2.8dB(comparatively decreased by 4%)(Zibo Vacuum Equipment Plant Co., Ltd, Shandong Province Vacuum Equipment Engineering Technology Research Center).

Currently, there is no quantitative data yet that directly determine that engine and gear drive system reduce noise and vibration, however according to the statistical analysis above, the conclusion should be certain.

3.11 Equipped with free removal cleaning features

Some cars have not experienced major overhauls even after running for a few hundred thousand miles, thus showcasing insufficient power and poor emissions. By adding in engine oil essence, we can feel improvement in performance after travelling for just a few hundred miles, and after releasing the engine oil we find it very dirty, which is because the engine cleaning has been completed in the meantime.

After using engine oil essence for a long time, test shows that some cars have not only achieved the purpose of energy saving, but also their cylinder wall is clean and smooth after cylinder checks by big car repair companies.

Furthermore, this product also has the following exceptional properties:

Engine cold start is improved, easier to ignite in winter seasons.

Acid-free, non-corrosive to engine parts.

In conclusion, the correct use of nano-diamond engine oil essence, gear oil essence can allow engine, high-rotation speed shaft, gear drive and other equipment to be kept at best condition for longer time, greatly increasing the reliability of the equipment, reducing the repair time and costs while being energy-saving and lower emission at the same time.

4. Progress of project

2004 Soon after Chinese New Year, at the first lubrication optimization symposium hosted by Director Xu Kuang Di, our project person-in-charge has given a special report on this topic.(The other 2 reports are introducing a product of USA.)

2005 In September, the patent for invention was obtained. Patent No. ZL 02131228.1.

2005 On Sep 29, the Appraisal meeting was organized by Tianjin Science and Technology Committee held in Tianjin University, at which a comprehensive evaluation was conducted and an International leading was awarded to this product.

2006 Product won third prize of Tianjin Science and Technology Invention Award.

2007 Product is certified as energy-saving product.

2008 In June, product won Gold Award in cross-straits union innovation exhibition, and obtained 3rd runner-up prize in China National Machinery Industry, Science and Technology Award, under the invention category.

Tianjin TV Station, Zhejiang TV Station, etc. have delivered special reports of this project, and it has also been repeatedly broadcast.

2007 In August, at the national ultra-fine diamond technical symposium, Zhang Shuda from our company has been unanimously recommended to draft the national standard of nano diamond. Currently, this project is in progress.

In recent years, National Cheng Kung University in Taiwan, Ocean University, Kun Shan Technological University, Chung Yuan Christian University and many other tertiary educational institutions have used the lubricant essence that we have provided to establish projects for professors' research or as Master's and Doctorate's test objects for their thesis. As shown in Professor Kang Yuan's online resources, who is from Chung Yuan Christian University: on a National Science Council project - NSC 94-2212-E-033-012, he has published 10 papers and applied for 3 patents based on this project. With the different equipments and different methods they adopted, all tests have testified the exceptional properties of the nano-diamond oil essence.

Note: The reason for being awarded 3rd runner-up is because of the lack of sales volume.

Product Properties Advantages Comparison Table

Serial Number	Item	Lubricating oil in the market	After adding nano-diamond lubricating oil
1	Oil agent and extreme pressure antiwear agent (adding tribological materials)	Mostly organic additives or micron, submicron solid particles.	Nano-diamond
2	Film-forming mechanism	Formation of chemical protective film through physical adsorption and chemisorption, which fails easily in high temperature and is easily decomposed or wear off	Lubricating film based on the structure of nano-diamond, which is an ultra-temperature tolerant, wear-resistant, excellent adsorption breakage resistant oil film.
3	Self-repair function	Formation of protective film only on the surface, easily falling off and containing no real repair materials, no stable repair results, which corrodes parts	Has a unique self-repair function, is able to permeate into places of friction to conduct repairs. It also enables precise polishing of tips or convex surfaces so that the friction surface can form a smooth flat surface
4	Friction-reduction mechanism	All adopts sliding friction.	Diamond nano particles inside the micro-ball allow sliding to switch to rolling friction, hence the friction coefficient is significantly reduced.
5	Anti wear-and-tear function	As a chemical membrane, strength is not high, and it easily falls off or is easily decomposed at high temperatures	Lubricating film based on nano-diamond, and film's carrying capacity is greatly increased, with excellent wear resistance.
6	Fuel efficiency	As a reference for comparison.	Saving rate of 4 to 20 percent, far higher than conventional oils.
7	Environmental efficiency	As a chemical additive, it often contains phosphorus, sulfur, chlorine etc., with certain amount of non-polluting substance.	No corrosive chemicals are added, and it significantly reduces exhaust emissions, thus it is green and energy-saving.
8	Sub-Surface modification after friction	NIL	Carburizing, strengthening sclerosis.
9	Disassembly hassle-free and cleaning function	NIL	Carbon deposition film sludge within the cylinder can be washed off.

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