The Singular Function of Modified Nanometer Diamond in Lubricant Oil

1. The Function for Engine Oil

Bench test has made in Automobile Test Center of PLA Military Transportation College.

Modified nano-diamond engine oil is made by Tianjin Chanyu Superhard Sci-Tech Co., Ltd., which a certain percentage of modified nano-diamond is added into the primary engine oil. The test result shows that the modified nano-diamond engine oil had a great improvement in output, economic, discharge, sealness and reducing friction properties.

1.1 Equipments

EQ6100-1 Engine produced by China No. 2 Automobile Group.

1.2 Experiment Method

It is tested according to the QC/ T524-1999 rules of china standard.

After the modified surface treatment, a certain percentage of ultra dispersive diamond is added into the common engine oil, it becomes the modified engine oil of type SDZ-02. It is a kind of general oil which is available for gasoline and diesel engine. There is a compare test between the primary engine oil and modified engine oil SDZ-02. The first hand engine oil is gasoline oil, Great Wall Brand (API: SE, SAE: 15W/40) produced by China Petroleum Chemical Stock Limited Company, Great Wall Lubricant Sub-company.

1.3 Output Property

In figure 1, the output property shows that the engine power has differently increased in whole rotational speed range. At n=2700r/min, power raise 6.47%, and average power increased by 4.2%.

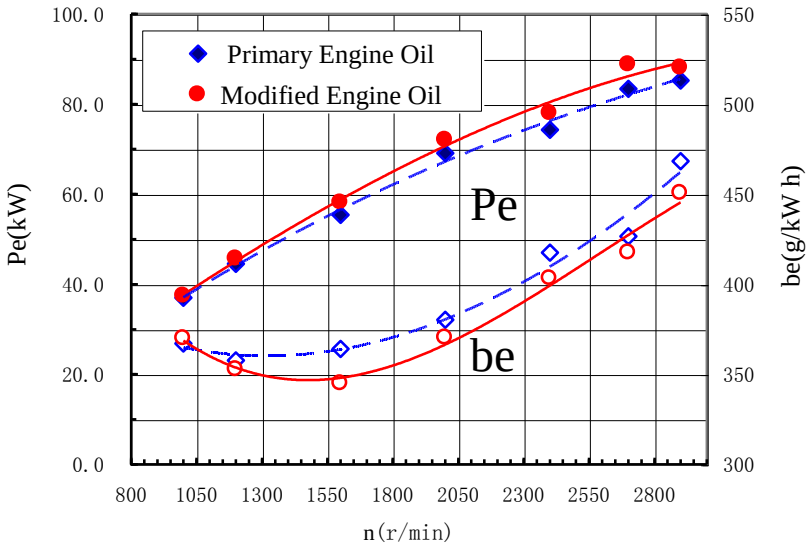


Fig. 1 Compare Curvere of Engine Output Property

1.4 Economic

Loading property of engine is measured at the rotational speed 1600, 2000, 2400r/min separately. All of them can save oil. Figure 5 is shown the loading property curve at the rotational speed 1600r/min. At this condition, average saving oil is 8.7%.

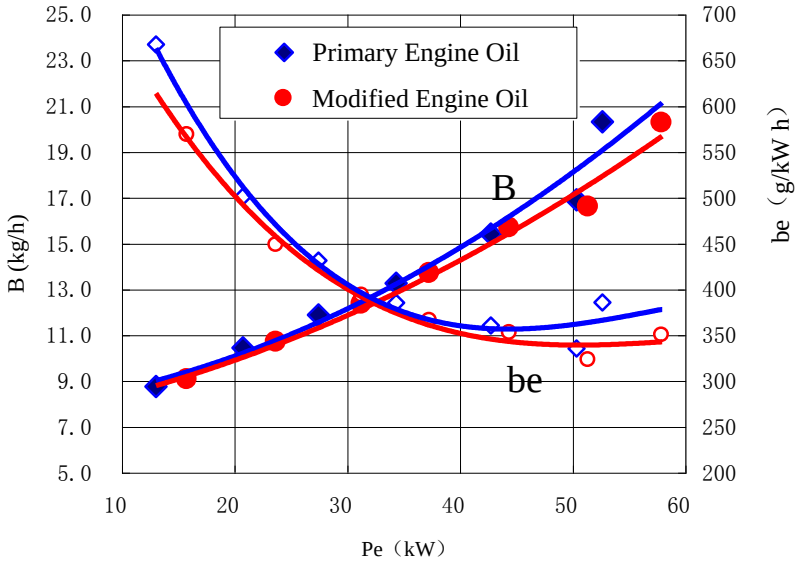


Fig. 2 Loading Property at 1600r/min

1.5 Discharge

It is of great benefit to our environment by using the modified nano-diamond engine oil. The test report says that the tick-over discharge HC is decreased from 875 to 350(PPm), dropped by 60%. And the tick-over discharge NO_X decreased from 166 to 132(PPm), reduced by 20.5%.

1.6 Sealness

Cylinder pressure increases clearly. Using primary engine oil, kindle cylinder pressure is 0.441MPa. While using modified engine oil, cylinder pressure is up to 0.568MPa, increase by 28.9% oppositely. It means the later can improve the cylinder sealness obviously.

1.7 Reducing Friction

The engine hasn't been done any adjustment, except changed the engine oil, the tick-over increased from 597r/min to 658r/min, the increasing rate is 10.2%. This is caused by the good sealness and reducing friction factor.

1.8 The Automobiles Test

Using the modified nano-engine oil on automobiles obtained good results. 6 typical samples chosen from our customer is listed as below.

Sample 1: XiaLi brand 1.0 which has run over 800,000km is depleted lubricant 2L/1000km. By using modified nano-diamond engine oil, the consumption of lubricant dropped to 0.03 L/1000km, only equal to 1/66 of before.

Sample 2: Chang'an brand, the highest speed can be reached 105 km/h, cylinder pressure 7~8Mpa. By using this product, the highest speed increased to 120km/h, and cylinder pressure increased to 12.5Mpa, increase by 56%. When the velocity is in 90-110km/h, fuel consumption decreases from 9.20L/100km to 7.03L/100km. After the product is added into the gear case, coasting distance has been prolonged a lot.

Sample 3: Beijing brand 130 light truck, it needs 24 second from velocity 0 to 80km/h. By using this product, the time is shorten to 20 second, accelerate increase by ~17%.

Sample 4: Diesel oil electric generator, type Z12V-190 650KW, consumption of diesel oil is 1.57L/min; By using the product, diesel oil consumption is 1.445 L/min, drop rate is 7.8%, and the oil temperature decrease 2.5°C (from 75°C to 72.5°C), the lubricant using life is prolonged more than one time.

Sample 5: Due to different mechanism of reducing friction and antiwear, the maintenance function of modified nano-diamond lubricant is unexpected. A taxi, XiaLi TJ7100, is made in 1998. After run 160,000km, the car used twice of this product. Now it had run 53800km (till Aug. 2005) and hadn't been overhauled. Now the car's condition is perfect. It shows that the modified nano-diamond lubricant has an excellent function of long time maintenance for friction-pair.

Sample 6: A XiaLi 1.0, made in 2001, has run over 100,000 km. By using this product, fuel consumption decrease from 6.4 L/100km to 5.4 L/100km, and lubricant serving life has been prolonged from 5000km to 15000km. Even in 15000km, the lubricant is still very clean. The owner dismantled the cylinder in order to check whether the product has any effect for the car's cylinder. The result shows that the inner wall of the cylinder is very clean and smooth.

2. The Function for Worm Oil

2.1 Reduce Wear Quantity

When nano particle of Fe, Cu and diamond is added in lubricant respectively, the best result for reducing friction and antiwear is nano-diamond. We made different oil samples in this experiment:

Oil Sample 1: 460 synthetic extreme-press worm oil produced by Shenyang Chemical Plant;
Oil Sample 2: semi-finished products of 460 synthetic extreme press worm oil which didn't add oilness additive and extreme-press antiwear additive;
Oil Sample 3: add 0.2% nano-diamond into oil sample 2, which is made by Tianjin Chanyu Superhard Sci-Tech Co., Ltd.;
Oil Sample 4: add 0.5% nano-Fe powder into oil sample 2;
Oil Sample 5: add 0.9% nano-Cu powder into oil sample 2.

The test is at Machine Engineering College, Tianjin University. We measured the friction moment by MM—200 Wear and Tear Test Equipment, calculated the friction factor, observed the friction surface by XL30-1 Scanning Electronic Microscope (SEM). Upper test works: 45

steel, quenching, hardness 45~50HRC. Lower test works is the same material with upper works. Under every kind of loading, the wear quantities of oil sample 3 are the lowest. Fig. 3 is shown the wear quantity of the steel/copper friction-pair loading with 240N.

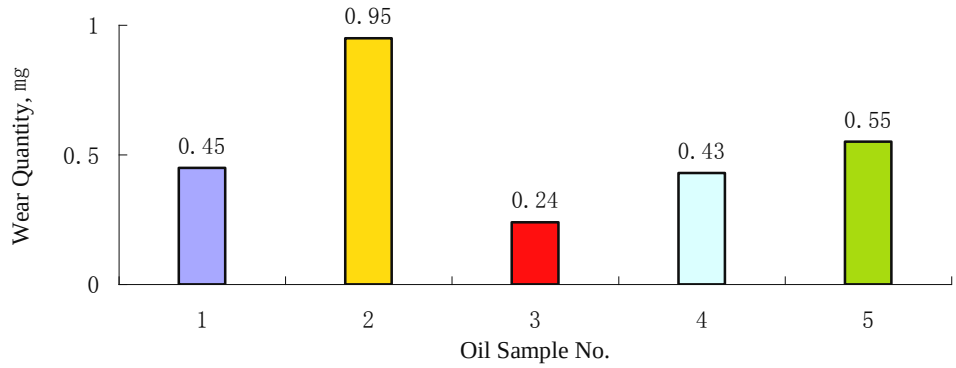


Fig. 3 The Wear Quantity of The Steel/Steel Friction-pair Loading with 240N

In worm transmission, turbine is usually made by Cu-alloy, Al-alloy or cast iron. But their common weakness is higher produce cost, lower carrying ability and shorter serving life. Experts have high regard for making worm by steel. The basic reason for hindering its application is that steel/steel friction-pair has stronger dissolubility each other. When it's working, once the oil film is broken, the steel/steel friction-pair is easily stick together, even glue together. The key problem is to look for a new kind of lubricant that has better ability of extreme-pressure. The question has been already solved by using modified nano-diamond worm oil. Fig. 3 shows the wear quantity of steel/steel friction-pair by using different lubricant. The wear quantity of oil sample 3 only equals about 1/2 of oil sample 1's. It is obvious that using nano-diamond can get good result of antiwear instead of oilness additive and extreme-pressure antiwear additive.

2.2 Decrease the Friction Factor

Fig. 4 shows the friction factor μ of oil sample 3 is always lower than oil sample1.

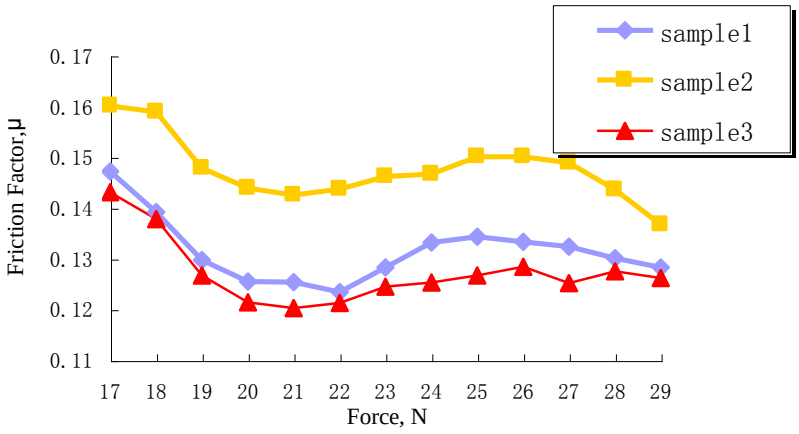


Fig. 4 The Varies of The Friction Factor with the Force for The Steel/Copper Friction-pair

2.3 Increase Machine Efficiency

We measured the influence of mechanical efficiency by Mini Worm Retarder.

Equipments: VWA42 Worm Retarder produced by Tianjin Beixing Mini Worm Retarder Plant. Transmission rotational moment is measured by JC rotational moment and rotational speed sensor. Machine efficiency is measured by PC201 efficiency test equipment. The test result is shown as in table 1.

Table 1. The Variation of Mechanical Efficiency

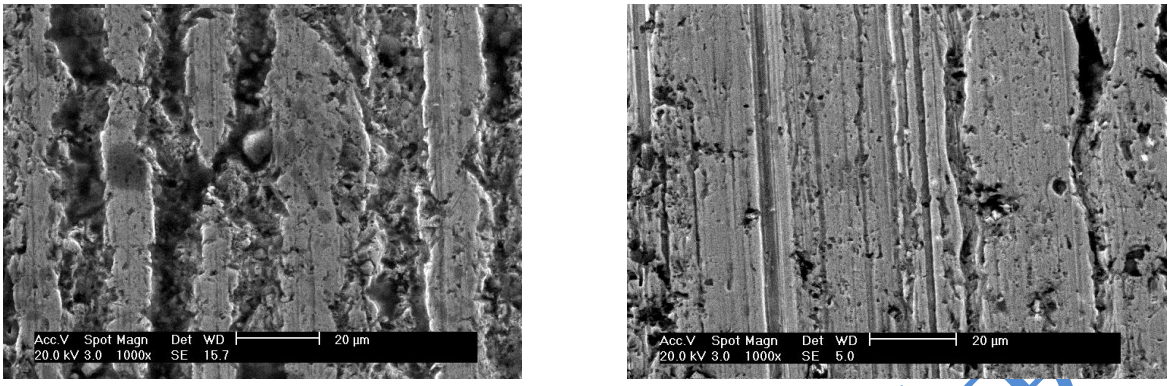
Output N • m	4.0	8.0	12.0	14.0	Average
Relative Machine Efficiency Increasing {(Oil Sample 3/ Oil Sample 1) －1}	2.84%	1.41%	1.90%	2.84%	2.25%

When its' output is 4.0, 8.0, 12.0 and 14.0(N.m), relative machine efficiency (oil sample 3/ oil sample 1) has been increased by 2.84, 1.41, 1.90 and 2.84(%) respectively, average output increased by 2.25%.

2.4 Self-restore Function for the Friction-pair

Fig. 5 is the SEM of friction surface of lower test works. This is a compare test between oil sample 1 and 3. Both are under the same condition and rubbed 3 hours. From the photographs, we know that lubricant with nano-diamond not only has obvious reducing friction function, but also has self-restore function for the friction-pair. It is the singular function that none of other lubricant can compare with until now. Figure 5a is not much different with the original works before rubbed.

Diamond is the hardest material in the world. Lubricant with nano-diamond is one of the best polishing liquid. It can quickly diminish the tiny-top of friction-pair surface. This distinctive strong point is that the other lubricant cannot have. Therefore, it causes the real touch square of friction-pair enlarged many times, such as hundreds times. And friction coefficient sudden drops.



(a) (b)

Fig. 5 SEM Photographs of The Testing Working Piece Friction Surface for Using Difference Lubricant

(a) Oil Sample 1 (b) Oil Sample 3

3. Modified Nano-diamond Hydraulic Slideway Oil

Compare with other lubricants, the main characteristics of hydraulic slideway oil should be have an excellent anti-stick-slip capacity and stronger load-carrying capacity of oil film. This work measured the static slicle fluidic impedance coefficient, static slicle area coefficient and inflexibility coefficient. They can truly and all-sidedly show the above-mentioned characteristics of modified nano-diamond hydraulic slideway oil.

We made a compare test with modified nano-diamond hydraulic slideway oil CLH 0150 which is researched and made by Tianjin Chanyu Superhard Sci-Tech Co., Ltd. and Mobil 1409 oil sold in market. Fig. 6a~c is tested under the same condition.

Fluidic Impedance Coefficient R_h

$R_h=P_r/Q\mu$ (1)

Where Pr—Oil cavity pressure of static slicle (N/m^2); Q—flux (m^3/s), μ—viscosity (Pa s)

Fig. 6a shows the difference of this two kinds of oils. R_h of CLH0150 is always bigger, and increase quickly with the increasing of P_r/P_s. P_s is supplying oil pressure. When P_r/P_s = 0.40, R_h of CLH0150 is higher more than 20%.

Static Slicle Area Coefficient α_f

$\alpha_f = W/A_P P_r$ (2)

Where W—load weight (kg); A_P—Oil area (m^2).

From Fig. 6b we can see, α_f of CLH0150 is higher than Mobil 1409. When W=1400kg, α_f of CLH0150 is higher about 18%. From developing trend we can see, along with W increasing, the difference between them rapid increases.

Inflexibility Coefficient Sc

Theoretic value:

$$S_c = \frac{dW}{dh_{av}} = \frac{3W_0}{h_{0,av}}(1-\beta_0) \quad (3)$$

Where:W_0—beginning load(kg),
$h_{0,av}$—beginning average oil film thickness(m), β_0—average oil cavity pressure / supplying oil pressure.
Determination value:

$$S_c = \lim_{\Delta h_{av} \to 0} \frac{\Delta W}{\Delta h_{av}} \qquad (4)$$

Where ΔW—load micro-variations(kg);

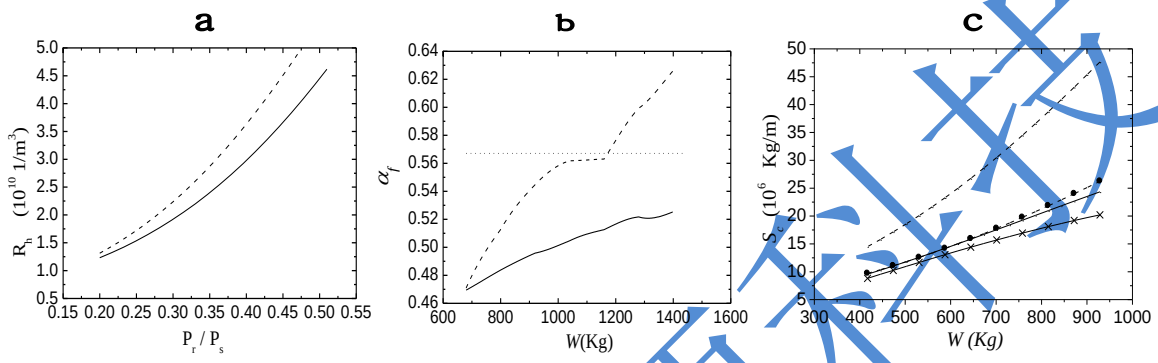


Fig. 6 The Singular Function of Modified Nano-diamond Hydraulic Slideway Oil
a: Fluidic Impedance Coefficient（—：Mobil 1409，- - - -：CLH 0150）

b: **S**tatic Slicle Area Cefficient（· · · · ·：Theoretic value，—：Mobil 1409，- - -：CLH 0150）

c: Inflexibility Coefficient
Theoretic value：—Mobil 1409，- - - CLH 0150
Determination value：—×— Mobil 1409，—•— CLH 0150
Δh_{av}—oil film thickness micro- variations.

Under the same load, the bigger Sc value, the smaller change of oil film thickness. Under the same equipment, the bigger Sc value, the finer machining precision of the work. From Fig. 6c we can see that both theoretic value and determination value, S_c of CLH0150 are obvious higher than Mobil 1409. When W=940kg, the actual value of CLH0150's S_c is bigger about 30%.

4. Reducing friction and anti-wear function

Test machine is SRV vibration friction test machine made in Germany Optimol Co. Upper test work is Cr-steel ball of diameter 7mm, lower test work is SKH51 high-speed steel. Mobil DTE 26 anti-wear hydraulic oil (ISO68) as reference oil sample, it is added 3 kinds of different percentage of modified nano-diamond lubricant essence, and made 4 types oil sample. Then friction coefficient, scoring depth and occlusion time is measured respectively. Total measure time of each sample is 5000 second. Original data of loading in 100N is shown in Fig. 5. Correspond to Fig. 5b, 5c, 5d and 5e, its occlusion time is 2754s, 2643s, 2345s and 551s respectively. Friction coefficient in Fig. 5a is the average value of total 5000s. Compare with Fig. 5, when loading is 50N, friction coefficient, scoring depth and occlusion time is

more obvious diminished. For example, scoring depth is decreased from 4.94μ of Mobil DTE 26 anti-wear hydraulic oil to 0.07μ of 20vol.% oil sample[20].

After modified nano-diamond gear oil made by Tianjin Chanyu Superhard Sci-Tech Co., Ltd. is added into wheel box of automobile, driver can feel easy and smooth when change speed.

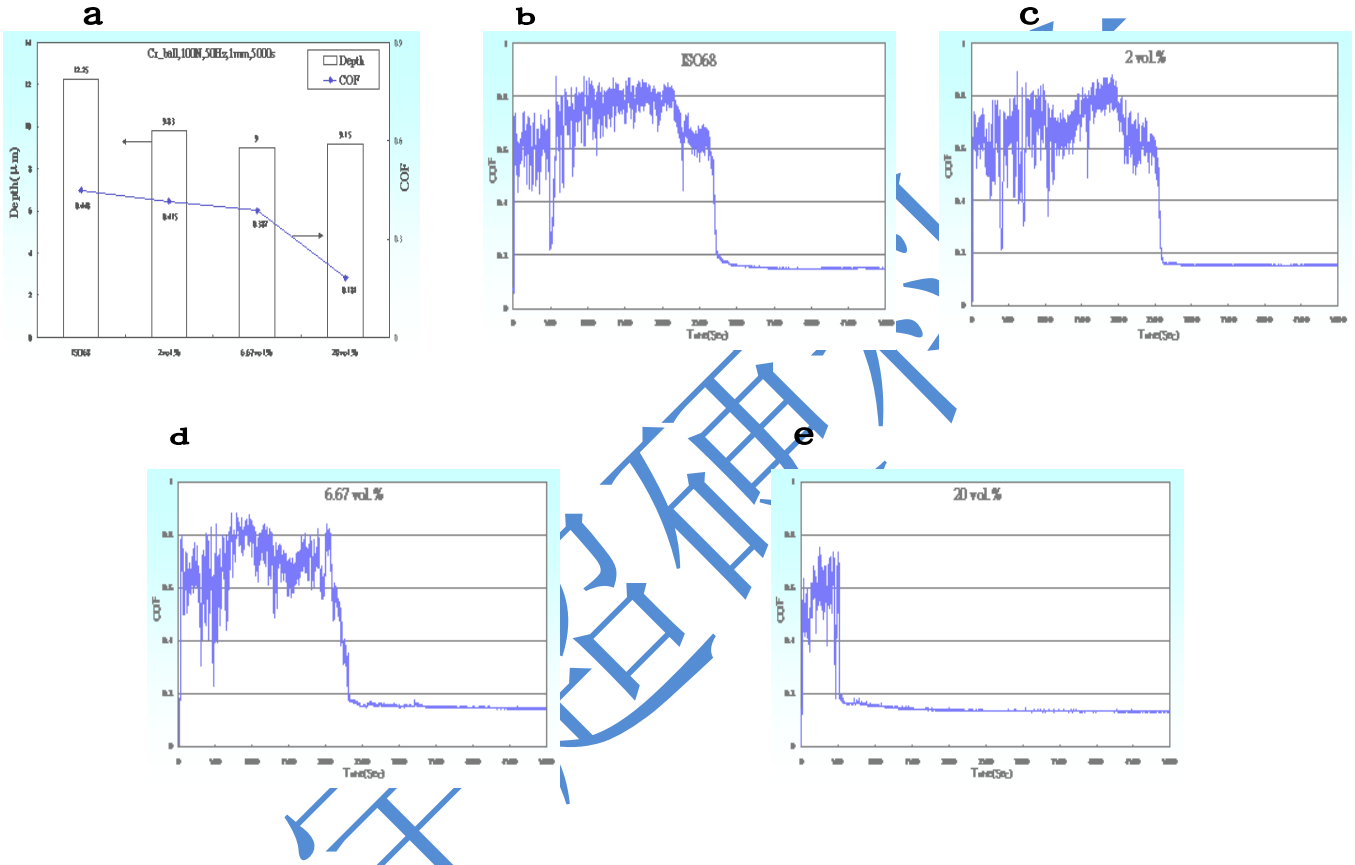


Fig. 7 Reducing Friction and Antiwear Function of Modified Nano-diamond lubricant at loading 100N.

a: Comparison of Friction Coefficient and Scoring Depth. 2 vol.%, 6.67 vol.% and 20 vol.% are volume percentage of modified nano-diamond lubricant essence in which is added into Mobil DTE 26 anti-wear hydraulic oil.

b~e: Friction Coefficient Comparison of Hydraulic Oil which is included different volume percentage modified nano-diamond lubricant essence.

5. Conclusions and Prospect

5.1 After surface modified, nano-diamond has been added into lubricant oil. A lot of singular functions appeared unexpected. While gasoline (diesel oil, general oil) engine oil with the nano-diamond has been used, the engine's output, economic, discharged and sealness

performances have been obviously improved. The power increased by 6.4% (at 2700r/min), average saving fuel oil 8.7% (at the rotational speed 1600/min), the air cylinder pressure increased by 28.9%, the tick-over speed raised by 10.2%, the tick-over discharge HC and NO_X decreased by 60% and 20.5% respectively.

5.2 Added the nano-diamond into worm oil, it makes the friction factor reduces, the wear quantity decreases, the mechanical efficiency increases, as well as to self-restore function exists for the friction-pair.

5.3 Compare with the best hydraulic slideway oil in market, nano-diamond hydraulic slide-way oil has an excellent anti- stick-slip capacity and stronger load-carrying capacity of oil film. When $P_r/P_s = 0.40$, R_h of CLH0150 is higher more than 20%. When W=1400kg, α_f of CLH0150 is higher about 18%. When W=940kg, the actual value of CLH0150's S_c is bigger about 30%.

5.4 These oils have self-restore Function for the Friction-pair and their serving life can prolong several times.

5.5 Many people have not predicted these singular functions of nano-diamond in lubricant. It is not only for engine oil, worm oil and hydraulic slideway oil, but also used for gear oil, vacuum pump oil, machine tool oil, etc. If it is used in the press for synthetic diamond, the pressure dropping is greatly reduced during keeping pressure period. The service life of machines will be extended enormously. The wear quantity of working cylinder and increasing pressure device will be reduced. Thus it is beneficial for improving the diamond quality and lowering the producing cost.

5.6 According to the forecast of Freedonia Group Co., increasing rate of lubricant consumption of the whole world during 2003~2008 is 2.2%, from 35.3 million ton to 39.3 million ton. But the annual increasing rate of sales is 4.7%, from 286 billion US$ in 2003 to 360 billion US$ in 2008. The result of sales increasing will be an effect by upgrade quality, enlarging sales volume and rising price together. It is estimated that the demand of non-regular, high quality and protected environment lubricant will be risen, and annual increasing rate will be over 5.4%. Automobile lubricant in 2004 is 57% of demand of finished lubricant in the whole world. So we can expect that modified nano-diamond lubricant will be played an important role. It has incomparable singular functions. Modified nano-diamond gear oil and modified nano-diamond hydraulic oil have many advantages above-mentioned. If they are used in construction machinery and equipment, they will prolong serving life of equipments and improve machine's reliable. Modified nano-diamond lubricant has a great potential benefit in economy and society.