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Study on the Anti-Wear and Anti-Friction Properties of Graphene and Boron Magnetic Rare Earth Complexity

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Using graphene and boron magnetic rare earth lubricating oil additive, different mass fraction of graphene boron magnetic rare earth lubricating oil samples were configured with, anti-wear anti-friction effects were tested with different mass fraction of graphene boron magnetic rare earth samples in the four-ball test machine experiment. The experimental results show that the graphene materials used in this paper are multi-layered and have some impurities and defects. Adding a small amount of graphene to the base oil the lubricationcan be significantly improved, and in the sample range, the best quality score of graphene used with dispersant is 0.03%. Graphene and boron magnetic rare earth (T2012) oil additives have a good synergistic effect.

1. Introduction

Lubricating oil is composed of lube base oil and additives two parts. Lubricating oil additives, according to its function, can be divided into extreme pressure anti-wear agent, dispersing agent, viscosity index improve agent, friction modifier, corrosion inhibitor, antioxidant, emulsifier and so on. A single additive can only improve one or several performance indexes of lubricating oil, and it is impossible to make the lubricating oil achieve an ideal state by adding only one single agent. As a result, at present, compound additive is often used. That is to say, different kinds of additives are mixed in a certain proportion and added into the base oil to play a role in improving the comprehensive performance of the oil. According to the references, it is known that scholars at home and abroad have carried out relevant research. Peng Liqiong and other scholars introduced optical microscope, scanning electron microscope (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM), Raman spectroscopy (Raman), infrared spectroscopy (IR), X ray photoelectron spectroscopy (XPS) and UV Vis spectra (UV-Vis) and other several main methods used to characterize graphite ene (Brown et al., 2016). Huang Guojia reviewed the surface function correction study of graphene and graphene oxide in recent years. Eswaraiah V used a new technique based on focusing solar radiation for peeling off of graphite oxide, to prepare thin graphene (UG). Graphene engine oil nanofluids were prepared, and their friction characteristics (FC), anti-wear (AW) and extreme pressure (EP) performance were evaluated. Tribological properties of lubricating oil composite nanoparticles additives were studied by Song Lilei. Zhang Wei studied the preparation of graphene by liquid phase method and their tribological properties.

They explained the phenomenon of lubrication with the "thin film lubrication" principle. Figure 1 is a distribution diagram of the film lubrication mechanism, where h represents the thickness of the friction film between the lubricating film, Ra represents the friction surface roughness of the contact surface, h / Ra is defined as the number of layers of the oil film. The more lubricant film layers, the more tend to film lubrication. With the addition of graphene, graphene continuously covers the surface of the friction pair, the surface roughness of the friction pair is replaced by the roughness of the graphene surface, Ra decreases, while h remains unchanged, so the lubrication mechanism gradually tends to the film lubrication, lubrication Improve the mechanical properties. When the mass fraction of graphene increases, the graphene buildup on the surface of the friction pair, blocking the formation of the lubricating oil film, h decreases sharply, then the h / Ra decreases, and the lubrication mechanism turns back to the mixed lubrication zone, but the frictional performance of the lubricating oil decreases.

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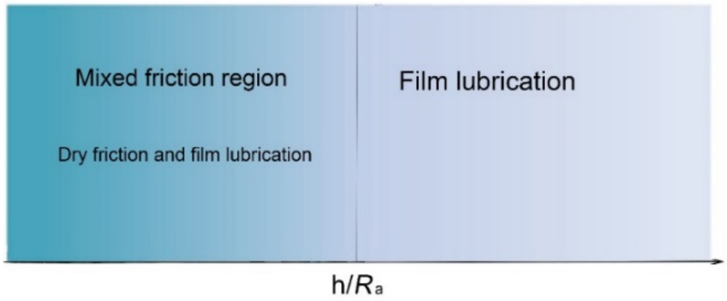


Figure 1: Film lubrication mechanism.

Senatore A discussed the tribological behaviors of graphene oxide nanomaterials from boundary, mixed lubrication, and elastic fluid mechanics. Li Rui and other scholars studied the effects of carbon nanotubes and graphene on friction and wear properties of carbon nanotubes and graphene as lubricating oil additives by using four ball machine (Cheng et al., 2015). He Zhiwei studied the preparation, characterization and application of functional graphene nanosheets. Wang Yanxu invented a boron rare earth magnetic lubricating oil additive and the preparation method. In order to improve the lubrication conditions of military equipment engine under bad working conditions, a kind of Molybdenum alkyl dithiocarbamate (MoDTC) and graphene composite lubricating oil additive were prepared by Jing Zhiyuan (Guo et al., 2016).
According to the above analysis, the present literature has not documented the relevant study of graphene and boron magnetic rare earth lubricating oil additive (T2012). Boron magnet rare earth is a kind of lubricating oil additives with environmental protection and good effect. In order to to achieve better anti-wear performance, this paper makes full use of the advantages of good and high temperature properties of graphene, graphene and boron rare earth magnetic lubricating oil additive (T2012) compound is applied, and then the research of anti-wear and anti-friction property is carried out.

2. Configuration of oil sample for compound test

The configuration of oil sample should strictly comply with the laboratory standard operation process. Use high precision electronic balance and dropper to ensure that the concentration error of additives is controlled within a reasonable range, and to ensure that the oil sample meets the test requirements (Tarasov et al., 2017). After mixing the base oil with additives, the oil samples were stirred on a magnetic mixer for 30min, stirring temperature was controlled at about 50 degrees, and ultrasonic vibration was conducted for 30 minutes. The specific oil sample configuration is as follows:
Add 1.5wt% boron magnetic rare earth into the base oil and stir to prepare the oil sample for use.
Add 1.5wt% boron magnetic rare earth and 3wt% lubricating oil additive with span-80 processing into the base oil, and then stir to prepare oil samples for use. The final mass fraction of graphene was 0.03wt%.

3. Experiment of anti-wear and friction reduction of graphene and boron magnetic rare earth

3.1 Effect of the mixture of graphene and boron magnetic rare earth on the wear spot diameter

The boron magnetic rare earth used in the compound test is a kind of complex type lubricating oil additives, and the sulfur content is low, which is a kind of environment-friendly additives. The wear scar diameter (WSD) values obtained after graphene and boron magnetic rare earth compound experiment are shown in Table 1, where G is the graphene, and T2012 refers to boron magnetic rare earth (Mandava et al., 2016).

Table 1: The diameter of each oil-sample grinding under the test of graphene and boron magnetic rare earth complex test

Materials	Base oil	Base oil +0.03wt%G	Base oil +1.5wt%T2012	Base oil+0.03wt%G +1.5wt%T2012
Wear scar diameter (mm)	0.559	0.471	0.442	0.398

As shown in Table 1, after the addition of graphene and boron magnetic rare earth in the base oil, the test wear scar diameter decreases. To add 1.5wt%T2012 has better effect than to add 0.03wt% graphene. Graphene and boron magnetic rare earth compound oil sample has smaller wear scar diameter compared with single addition of graphene and boron magnetic rare earth with the same quality. It should be both played a synergistic effect of lubrication.

3.2 Effect of composite of graphene and boron magnetic rare earth on friction coefficient

The maximum seizure load (PB) value of graphene and boron magnetic rare earth composite test is shown in Table 2.

Table 2: The friction coefficient of the oil samples of graphene and boron magnetic rare earth complex test

Materials	Base oil	Base oil +0.03wt%G	Base oil +1.5wt%T2012	Base oil+0.03wt%G +1.5wt%T2012
Coefficient of friction (COF)	0.116	0.096	0.087	0.076

It can be seen from Table 2 that the friction coefficient of graphene and boron magnetic rare earth oil is lower than that of base oil, and the friction coefficient of the composite oil sample is 0.076, which is about 34.5% lower than that of base oil (Pourarian et al., 2015).
The relationship between the friction coefficient of four kinds of oil samples with time during the long grinding test of graphene and boron magnetic rare earth is shown in Figure 2, the horizontal coordinate is time, the longitudinal coordinate is friction coefficient, and the long grinding test time is 30min. Figure 2 shows that the friction coefficient of the boron rare earth magnetic oil is steadily growing before 450S, and after 450S, it becomes gradually stabilized (Pandey et al., 2015). The friction coefficient is lower than that of graphene oil sample. After the compound, before 850S, the friction coefficient has been growing steadily and tended to be stable after 850S. The friction coefficient of compound oil sample was lower than that of single addition of the same quality graphene and boron magnetic rare earth.

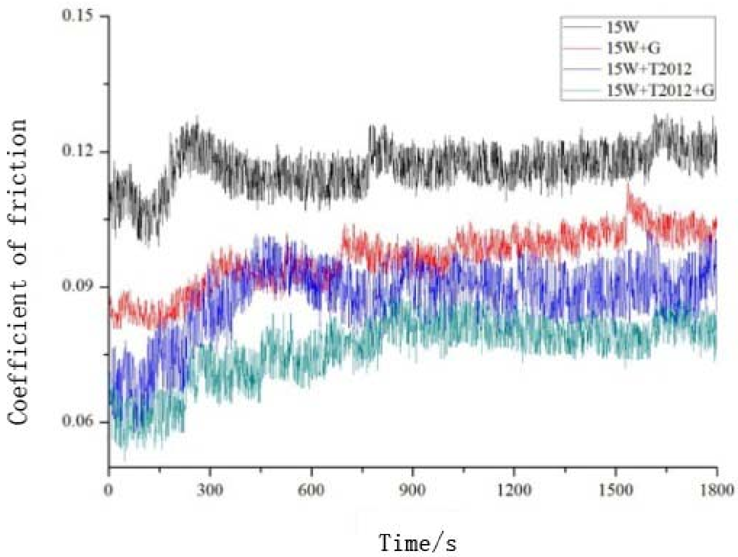


Figure 2: Variation of friction coefficient over time of graphene and boron magnetic rare earth complex test

3.3 Effect of graphene and boron magnetic rare earth complex on PB value

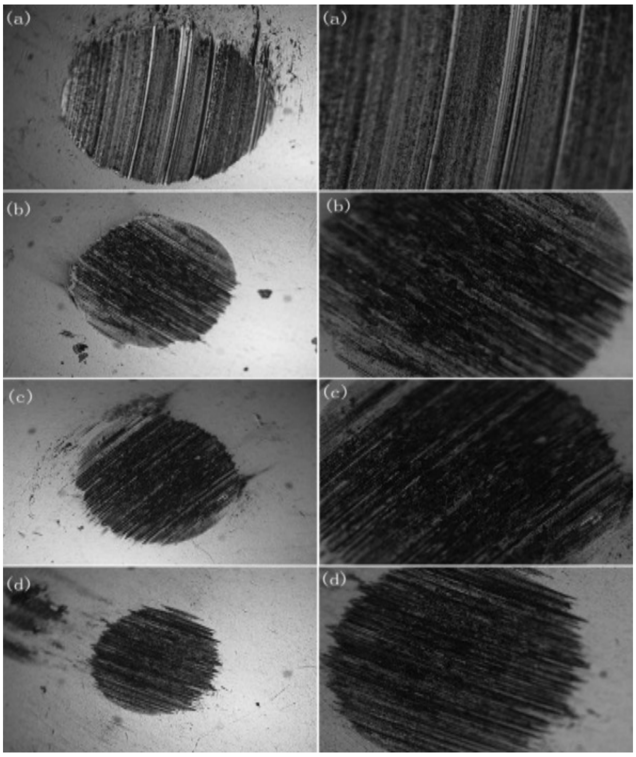
The maximum seizure load (PB) value of graphene and boron magnetic rare earth after the composite test is shown in Table 3. From Table 3, it is known that the maximum seizure load increased after single addition of graphene and boron magnetic rare earth into base oil. And the effect is more obvious for adding 1.5wt% boron magnetic rare earth compared with adding 0.03wt% graphene. After the composition test of graphene and boron magnetic rare earth, the maximum seizure load increased significantly than when used alone. The composite oil sample, compared with base oil, the maximum seizure load increased by about 72.9% (Kruse et al., 2017).

Table 3: PB value of the oil samples of graphene and boron magnetic rare earth complex test

Materials	Base oil	Base oil +0.03wt%G	Base oil +1.5wt%T2012	Base oil+0.03wt%G +1.5wt%T2012
The maximum seizure load (N)	686	853	960	1186

4. Study on the synergistic mechanism of graphene and boron magnetic rare earth

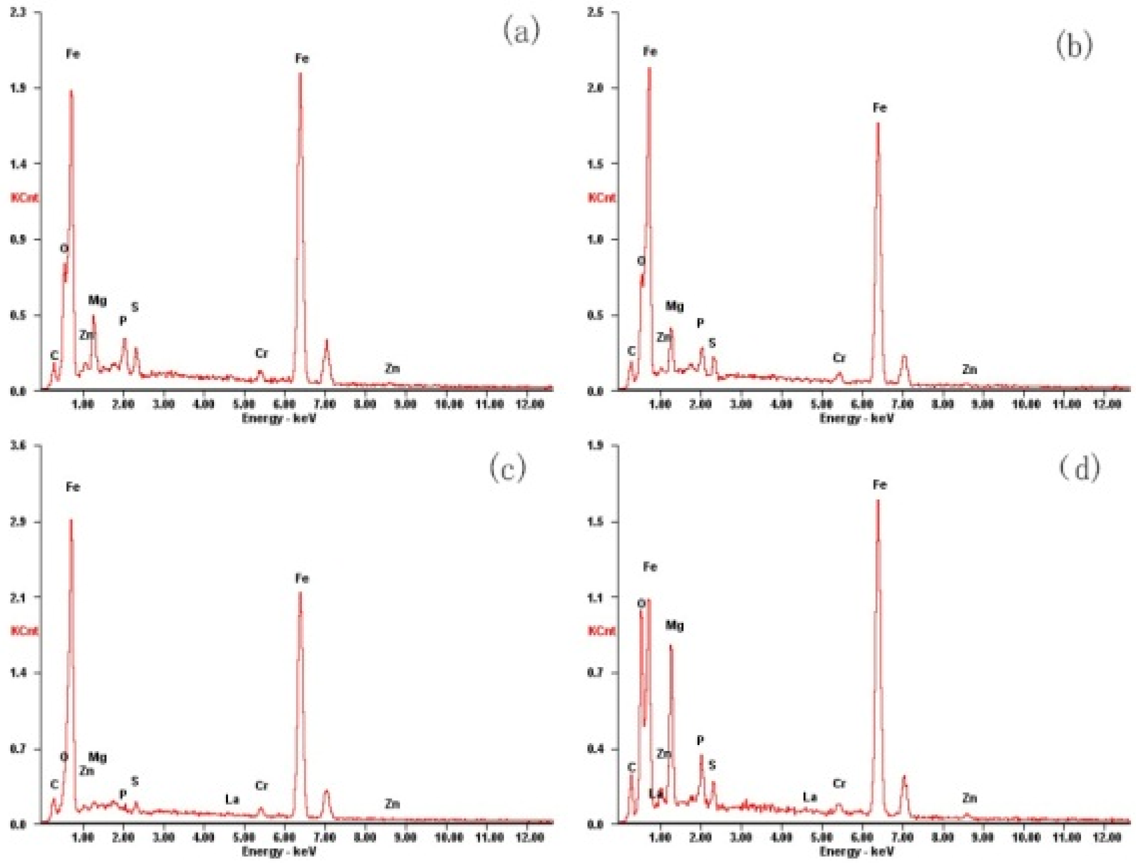
After the compound test of graphene and boron magnetic rare earth, Figure 3 is obtained, which is the surface topography of the grinding spots of the steel balls corresponding to different oil samples. In Figure 3, the left is the morphology with optical microscope after 100 times magnification, and the right is the graph with the magnification of 200 times. It can be sen that the wear scar diameter of the base oil is larger and on the surface, there is deep stretch marks (Walton et al., 2015). For graphene and T2012 compound oil, the wear scar diameter is the smallest. The worn surface is relatively smooth compared with the base oil, and the compound oil and the single addition of graphene or T2012 all improve the lubrication condition.



(a) base oil (b) base oil+0.03wt%G (c) base oil+1.5wt%T2012 (d) base oil+0.03wt%G+1.5wt%T2012

Figure 3: Surface topography of steel beads of graphene and boron magnetic rare earth complex test

The EDS energy spectrum of each oil sample after the compounding test of graphene and boron magnetic rare earth (T2012) is shown in Figure 4. The EDS energy spectrum elements of four kinds of oil samples are shown in Table 4. Boron magnetic rare earth is a kind of complex type lubricating oil additives. The composition is complex, and according to the product specification, it has good anti-wear and friction reduction effect, which itself belongs to parathion additive (Zheng et al., 2016). In the preparation process, it also added lanthanum oxide, rare earth carbonate and other ingredients. According to the research of rare earth additives by related literature, rare earth elements have a chemical reaction in friction surface, generating lubricant film containing rare earth elements. And rare earth elements can penetrate into the metal matrix. At the same time, it can promote the friction and diffusion of boron, enhance the material hardness, and improve the wear resistance (Batalu et al., 2015). EDS analysis showed that although graphene is a multi-layer structure and there are some defects, its high-temperature performance is good. After compounded with T2012, the steel worn surface is greatly reduced, which may be due to the joint effort of parathion composition, rare earth elements, and graphene.



(a) base oil (b) base oil+0.03wt%G (c) base oil+1.5wt%T2012 (d) base oil+0.03wt%G+1.5wt%T2012

Figure 4: EDS spectra of four different oil samples

Table 4: Content of the surface element of four oil - sample steel beads with graphene and boron magnetic rare earth complex test

Categories of oil	C	O	Mg	P	S	La	Cr	Fe	Zn
Base oil	7.16	9.04	5.18	1.78	0.98	-	1.56	74.06	0.24
Base oil+G	9.44	9.25	5.08	1.74	1.14	-	1.40	71.66	0.3
Base oil+T2012	11.57	5.28	0.91	0.28	0.62	0.68	1.52	78.96	0.19
Base oil+G+T2012	12.61	12.81	10.56	2.11	1.03	1.18	1.22	58.11	0.37

5. Conclusion

This paper mainly studies the synergistic effect of the graphene and boron magnetic rare earth (T2012).
By scanning electron microscopy and EDS device, surface morphology of different oil samples steel wear scar is observed and elemental characterization is carried out.
In addition, the mechanism of synergistic effect of graphene and additives is analyzed.
Experimental results show that:
Graphene and boron magnetic rare earth compound have better effect;
the friction coefficient and the wear scar diameter decrease after the composition of the two, and the maximum seizure load increases;
EDS analysis showed that there were rare earth elements on the worn surface of the composite oil ball, which may due to the synergistic role between them.

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