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Revolutionizing Grease Additives and Transmission Systems: Harnessing Titanium and Titanium Carbide with Nanotechnology

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Abstract

Nanomaterials, with their unique microstructure and quantum size effect, have found applications in numerous industries. In addition, it has several benefits that aren't seen in more conventional materials. High temperature tolerance, zero pollution, and other features make nanometer-sized titanium (Ti) and titanium carbide (TiC) ideal for use in grease additives as inorganic nonmetal high-tech materials. Grease additives might have improved tribological properties by utilizing special qualities like odorless ness and tasteless ness. Similarly, grease is an ingredient that isn't used in the making of machinery. It is critical to monitor and enhance service performance on a constant basis. Investigate how the concept of nanoparticles might inspire fresh approaches to transmission grease additives; evaluated the pros and cons of nanotechnology and analyse its potential for further growth and fusion in the field of application . The research methodology of detailed study of specific topics will be used in this article to compare facts and draw conclusions. According to the findings, 80% of the grease required for lubrication is reserved for rolling bearings. Ti added to lubricating grease can increase additive stability by 26%, maximizing the grease's useful life. As a result, nano-technology is utilized to actively develop and enhance the technical level by complete absorption and reform in line with the features of the current period. This study examines the many application challenges and research potential, and then suggests the realization road toward better chemical coatings. These ideas help direct research and development, gaining vital insight for widespread nanotechnology usage.

Keywords

Grease, Nanotechnology, Friction lubrication

Introduction

Grease is an extremely ubiquitous substance that serves an indispensable function in lubricating bearings and preserving components throughout the assembly of machinery. While corrosion resistance, oxidation resistance, fatigue resistance, etc. are universally sought for in lubricating grease, the specific needs of certain industries vary greatly in the context of real manufacturing [1].

TiC and nanoscale Ti both benefit greatly from the size effect and the macroscopic quantum tunnelling effect, two of the unique features of nanometer materials. More and more businesses have begun using it as an addition since it considerably increases grease's effectiveness and efficiently finds solutions to a wide range of issues. Nanomaterials, or materials with tiny basic units, are both high-quality materials and cutting-edge technologies. Nanotechnology is now often employed in the production of many goods [2]. Aerospace, medical health, and environmental energy are among of its primary areas of study and application, and its breadth of civil usage is steadily expanding. "The most promising material in the 21st century" is how scientists describe it. Combining photothermal magnetism with chemistry can result in nanomaterials with a wide range of desirable features. Potential applications include electronic chips, photoelectric conversion, absorbing light and radar waves, and more [3, 4]. Moreover, the one-of-a-kind three-dimensional mesh structure is perfect for dealing with critical challenges in the lubrication industry. It is a key lubricant for reducing equipment wear and increasing its useful life because of its great resistance to heat, high hardness, and microscopic particle size. Because of the increasing specialization and accuracy in mechanical production, lubricating grease containing micro-Ti and TiC has a large potential market [5, 6]. These days, grease is a standard lubricant in many manufacturing settings. It can make machines more productive, cut down on energy use, and prevent pollution.

It's a great method that fits in well with the progress of eco-friendly chemistry in recent years. However, when put to the test in the real world against high-tech machinery and stringent application criteria, regular grease eventually falls short. Thus, grease is treated with additives and given processing so that it can fulfil the needs of its applications. Greasing often has additional useful compounds added to it. When confronted with rigorous technological requirements, however, standard lubricating grease additives have significant drawbacks. Nanomaterials and lubrication technologies have recently become the focus of research and development [7-9].

More and more researchers [10, 11] are focusing on nanomaterial additives because of ongoing experimental and theoretical innovation study. Its unconventional qualities make it an intriguing study subject with promising practical applications in the grease industry. There has been a lot of research done on the lubricating characteristics of grease additives by academics both here and in other countries. Western industrialized nations had a head start on developing ideal systems, and there is a fair amount of relevant literature [12]. To study the effects of changing variables such oil viscosity, soap fibre content, and additive presence on rolling contact wear, the evaluation of grease performance with different components generates a wealth of experimental data [13, 14]. Because of its high hardness, minimum coefficient of thermal expansion, and outstanding thermal conductivity, TiC has become an important topic of study among material scientists throughout the world. Grease's performance can be enhanced by a physical therapy procedure that follows up on the first application, according to the findings of the study. Researchers [15] from the United States found that the friction performance of lubricating grease was much enhanced after testing and adding modified nano-Ti using a four-ball machine to investigate wear and wear. Ti nanoparticles are focused on the wear surface during the friction process, forming a boundary lubricating coating that aids in wear surface restoration. Adding nanomaterials like TiC has seen comparatively little study as of now. This method helps reduce waste while also enhancing the functionality of lubricating grease without altering its chemical make-up [16, 17]. The topic of this study is lubricating grease, specifically grease including nano-Ti and TiC, as well as the synthesis and qualities of grease containing modified nano-Ti. Authors investigate how the additive's improved performance affects friction and how it changes the additive's real application [18].

This study examines the research difficulties associated with enhancing the friction performance of grease additives for usage in industrial settings, beginning with the definition and properties of TiC and Ti. It goes into further detail on the technological challenges, scientific background, and chemical properties of nano-Ti. Its primary focus is on analyzing the challenges of switching to a formulation with many additives that considers the unique properties of nanoscience and technology and developing strategies for overcoming such challenges. This research examines the interaction between nanotechnology and Ti with an emphasis on the enhancement of grease application effects [19]. This study intends to give useful technological insights for the chemical material production industry's future. A further advantage of our analysis is the objective viewpoint it provides on future expansion. By upgrading production technology and employing contemporary materials, by increasing the manufacturing capacity of high-quality equipment, promote environmental protection, and expand the distribution of information. To create the theoretical foundation for growing nanotechnology, it is essential to identify research parallels and differences between China and the West, to learn from cutting-edge experiences, to suggest superior methodologies, and to adapt to new development strategies.

Methodology

Materials

Nano-Ti: Nanotechnology has become increasingly widespread in recent years; its superior performance has been increasingly well-known. It has been discovered to be quite popular in the equipment manufacturing business due to its corrosion resistance, wear resistance, and toughness. Its one-of-a-kind internal structure is the primary reason for its overall outstanding performance [20, 21]. When the interlayer is affected by the three-dimensional network structure, stress levels tend to be low. The molecular structure of Ti is so small and robust that it may still contribute in high-temperature conditions and aid increase bearing capacity. This compound can be used to increase the load-bearing capacity of an oil film and as an addition for high-temperature grease. Consequently, grease is a suitable parallel for nanotechnology. Ti usage as an addition is not only useful, but also sustainable and cost-effective. Pollutant emissions may be lowered, and an all-encompassing sustainable development framework set up with its help. Because nanoparticles have such a short radius, their diffusivity, thickening, and thixotropy are all improved above those of conventional materials. As a result, nano-Ti is an excellent choice for use in lubricating grease. When structured in the chemical formula, Ti unique layered structure forms an ordered polymer structure that is joined into layers by common vertex atoms. Its distinctive layered structure not only yields a steady effect when subjected to shear strain, but also interlayer slip, which contributes to its advantageous lubricating quality.

TiC: TiC is commonly utilized since it is a typical covalent bonding material. Carbotitanium, another name for TiC, is also sometimes used to refer to tungstenite. Titanium carbide occurs in nature with a very distinct crystal structure. Its extreme hardness can be attributed to its molecular composition. A tetrahedron is made up of four Ti atoms, with each carbon atom at its core. The outermost Ti atom's four unpaired electrons hook up with the outermost carbon atoms' single unpaired electron to create a covalent bond. The atomic structure of Ti resembles that of four carbon atoms. The point in the middle of a tetrahedron. Because of their unique structure, crystals with this quality are very tough. TiC is translucent, has no melting point, and has no discernible colour. Consequently, TiC composites find widespread application in the current industrial sector. Mechanical sealing materials are the most common use for TiC. A high degree of hardness is necessary to prevent hot fractures and thermal strains in the sliding rotation of the sealing materials. TiC, when combined with nanotechnology, may generate self-lubricating qualities that can be included into grease additives to significantly cut down on frictional losses. TiC works well as a refractory and as a structural material under extreme heat. To shielding thermocouples, its high heat conductivity and outstanding stability make it an ideal base plate. In addition, it may be utilised to manufacture high-precision bearings for use in the mechanical sector, particularly in low-temperature environments where they will be used to clean the seals of mud pumps containing solid particles.

Grease: Grease, a type of lubricant, is made by transforming basic oil from a semifluid to a solid state with the addition of a thickener. Since the advent of mass-produced huge machines in the wake of the Industrial Revolution, this spare part has rapidly gained indispensability in the manufacturing environment. Intelligent humans employed animal grease as the first kind of lubrication for wheeled vehicles before the invention of the machine. Animal and vegetable oil, while effective in the past, are now easily worn away by friction and no longer sufficient to fulfil modern demands. Lime was added to animal and vegetable oils as a means of making lubricants. Thickeners were made from saponified animal oils and lime, whereas base oils were made from unsaponifiable animal and vegetable oils. The operating time and usage load of mechanical equipment have been significantly enhanced, and their complexity has increased with time. Saponifying oils from plants and animals using caustic soda has allowed humans to create better lubricating grease and soap. As the refining of petroleum has advanced, petroleum lubricants have begun to replace their vegetable and animal oil predecessors. The scientific and technological content of additives continues to rise in today's manufacturing environments. In addition to its lubricating properties, it also boasts superior damping and bearing capacities. Like oil, some greases may be manipulated into a fluid state. It's evolved into a crucial component of all sorts of tools and machines.

Research methods

This work uses a chemical analysis of nano-Ti and TiC, together with the features of usage, to develop a technique for producing lubricating grease with added friction-reducing capabilities. Carbothermal reduction is the primary extraction technique. This approach is consistent with the research mode since it is straightforward to implement, yields straightforward extractable and trackable experimental outcomes, and has a low experimental cost [22].

$$CH_4CSNH_2 + 2H_2O + H^+ = CH_3COOH + NH_4^+ + H_2S \uparrow \quad (1)$$

$$4H_2S + Na_2MoO_4 = Na_2MoS_4 + 4H_2O \quad (2)$$

$$H_2MoS_4 = MoS_3 \downarrow + H_2S \uparrow \quad (3)$$

$$MoS_3 + H_2 \rightarrow MoS_2 + H_2S \quad (4)$$

Using only the laws of chemistry as a guide. In the first place, when titanium oxide and carbon react, two gases are released: carbon monoxide and titanium oxide. The combination of titanium oxide gas and solid carbon results in TiC. TiC is synthesized via this process during the carbothermal reduction stage. TiC is believed to be formed around a carbon atom, with the carbon atom's shape and size influencing the carbide's final form and qualities. Tiny flecks of TiC are mined and refined into additives. Nucleation activation energy appropriate for additions can only be formed when test particles come into touch with one another and react strongly. The process-derived additive has the potential to speed up reactions, boost efficiency, and lower activation energy needs. To hasten the carbothermal reduction process, crystalline TiC powder is crucial. This methodology can therefore give theoretical grounding to produce TiC and Ti, allowing for the rapid and extensive deployment of additives. To maintain the proper and secure functioning of mechanical devices, the addition of nano-Ti to the lubricating grease additive is crucial. Selecting a lubricating grease requires consideration of both the operating environment and the mechanical components themselves. Learn about lubricating grease's functionality, then examine it using several tools and techniques designed for that purpose.

Mechanisms of grease lubrication

Synthetic hydrocarbon: The additive composition of lubricating grease achieved enormous strides in the 1990s thanks to the unrelenting march of science and technology, and people's investigation of precise equipment has never ceased. Polyolefin and polyalkylcyclopentane, two components of synthetic hydrocarbon oil, offer advantages in polymerization such as low volatility and good quality. Its superior versatility, low evaporation rate, and resistance to thermal oxidation at high temperatures set it apart from conventional liquid lubricants while also making it an ideal choice for the next generation of lubricating grease. Synthetic lubricants with a higher viscosity index and synthetic hydrocarbon are the preferred option for many businesses when the standard has been established. Cyclopentadiene is commonly alkylated, hydrogenated, and purified in the earliest stages of the production of synthetic hydrocarbons. Because of its additive compatibility, high temperature performance, thermal stability, and ultra-low volatility, it has the potential to replace perfluoropolyether as a lubricant in many mechanical applications.

Base oil: Grease is an essential component of industrial machinery, and the type of grease used depends on the environment. While the structure of additives will vary depending on the application, all lubricating greases have three fundamental components. The effectiveness of grease lubricants is significantly affected by the base oil used in their production. It makes up around 80% of lubricating grease's liquid component and is therefore essential. The efficiency of lubricating grease is, to some part, determined by the composition of the base oil used to make it. Base oil technology has also been evolving for quite some time, with constant upgrades and improvements. Starting with refined mineral oil, moving on to synthetic cool, and finally landing on synthetic hydrocarbon lubricant made from perfluoropolyether. The primary ingredient in lubricating grease is refined mineral oil, which has a low volatility and moderate reactivity with other chemicals. The use of mineral oil in space applications is quickly being phased out in favour of synthetic oil due to its high volatility and poor temperature characteristics in vacuum. Ti oil consists of polysiloxane, which is a liquid. It has superior stability to the preceding few compounds and excellent erecting temperature and hydrolysis resistance. However, it has been shown that polymer deposition on the friction surface may easily occur, which has consequences for equipment operation. As a result, friction performance will increasingly be considered in the future additive selection process.

Thickener: The thickener used in the production and application of lubricating grease is a crucial component. Five to thirty % of a lubricant's quality is determined by its composition. The content may not look like the major material, but it is essential for turning the lubricating oil from a fluid to a semi-solid grease. Saponification thickeners, hydrocarbon thickeners, organic thickeners, and inorganic thickeners are the primary categories. The aircraft sector must undergo a transition from lubrication to grease to advance. In the absence of gravity, the fluid lubricant can flow freely, causing several issues. This is why both organic and inorganic thickeners, as well as the more unusual composite buried soap, have been included. Thickening and lubricating grease in the civil context will undergo a technical revolution as science and technology advance, and the market must support this development. Slowly but surely, it permeated the metalworking, automotive, and bearings sectors. As an added bonus, the composite base grease is an effective and long-lasting all-purpose lubricant, as it has a low coefficient of friction and excellent resistance to fretting wear.

Experimentation

Data

The study on creating efficient lubricating grease using nano-Ti and TiC involved several key steps. These steps encompassed assessing the lubricating grease's performance, its application onto an epoxy resin coating, and the careful selection of base oil and thickener. The properties of the chosen base oil were significantly influenced by the overall properties of the grease. The primary features of space grease were researched and assessed, and nano-Ti was added as an antifriction and antiwear agent to extend the grease's useful life. It is shown to be extremely resistant to wear and impact, as well as scratching and bending.

Micro powder was generated using the conventional carbothermal reduction method, employing TiC as the source of Ti, carbon black as the source of carbon, iron oxide as an additive, and sodium oxide as a catalyst. TiC micro powder yield and shape were investigated [23] as a function of temperature holding time during catalyst manufacturing. Table 1 displays the outcomes of the tests.

Experiment process

After the fabrication of a nano-Ti hollow ball test device, a series of steps is undertaken. Initially, 2.5 mmol of sodium croybate and 15 mmol of thioacetamide are dissolved in 100 ml of deionized water. The mixture is then heated and continuously stirred for 5 min at a temperature of around 90 °C. Subsequently, the solution is allowed to naturally cool down to 85 °C. Shortly after this cooling phase, 10 ml of ethanol and 11 ml of 12.0 mol/l hydrochloric acid are swiftly added to the mixture, leading to the precipitation of the precursor from the reaction mixture. The result is brown trisulfide powder, which is obtained through filtration, washing, and drying processes.

Second, a suspension of nano-Ti in ethanol was created after thorough examination of its micro morphology. After 15 min of ultrasonic dispersion, the morphology was analyzed. Dissolve the sodium citrate and sodium sulphide in enough distilled water to reach the desired volume using a stir bar. Brown trisulfide key is obtained by filtering, washing, and drying the product when the reaction is complete. After 15 min of ultrasonic dispersal, a suspension of nano-Ti with a surface modification was prepared by dispersing it in an organic slurry mostly constituted of ethyl acetate for coating. The precursor precipitated out and the reaction began instantly.

Finally, check out how the friction coefficient shifts after being exposed to varying amounts of Ti. The Ti content is reduced by 0.5 wt.%, from 2.0 wt.% to 1.0 wt.%, when a 2.0 wt.% addition is made. The friction coefficient drops off to zero as Ti content drops. When the percentage of MW CNTs in the grease is lowered to 0.5, the coefficient of friction curve is noticeably smoothed down. There has been a 19% improvement in the friction coefficient, which has gone from 0.026 to 0.021. Watch how the anti-friction properties of the lubricating grease develop over time. Similarly low friction coefficients were observed with compound file grease including many types of MW CNTs.

Table 1: Grease's physicochemical characteristics as a lubricant.

Specimen	Penetration (1/4 mm)	Corrosion of copper (100 °C, 1 day)	Dropping temperature (°C)
[P888p] [Dehp]	76	1a	295
PAO 10	74	1a	335
[P88814] [DEHP]	79	1a	360
[P88814] [AOT]	70	1a	215

Resolution of the experiment

Tribological behavior of nano-Ti grease studies indicated that by combining theoretical understanding of nano-Ti with basic principles of tribology, researchers were able to successfully match appropriate nano-Ti lubricating additives to operating circumstances. For the evolution of grease as a lubricant, this represents a watershed moment. The potential usefulness in real-world settings is also clear. Using electrohydrodynamic theory as a framework for preparing additives for lubricating grease and analyzing friction performance is a generally acknowledged way in the academic community at present. Many mechanical devices have oil shortages after extensive use due to prolonged wear. Lubricant should not be added to machinery at random; doing so might cause malfunctions and even harm the machinery. Now more than ever, a correct assessment of film thickness is crucial, but it also presents significant challenges. Ti nitride's friction performance and contact fatigue failure process might be clarified by experimenting with this layer thickness parameter. The research reveals that by incorporating TiC nanoparticles with an average diameter of 500 nm and an average thickness of 15 nm into paraffin oil, significant improvements are achieved. To evaluate these enhancements, friction and wear tests are performed using both a four-ball machine and a pin on disc tester. The results clearly indicate superior anti-wear properties and a reduction in the friction coefficient. This improvement can be attributed to the formation of a transfer film as a key mechanism. Furthermore, the study demonstrates that the nano-Ti protective coating possesses a relatively thin profile, which serves as evidence of its enhanced friction-reducing and anti-wear capabilities.

Discussion

Mechanism of friction and wear

Friction is essential for investigating grease's potential applications. By contrasting various additives, it was observed that there are distinct approaches to analyzing experimental data. Particularly noticeable in space grease are Ti anti-friction and anti-wear qualities. The primary causes are the various processes of friction and wear. Lamellar structure best describes micro-Ti. The shear of the contact surface is highly correlated with the lubricating effect of the friction surface during the additive application process. There was no tribochemical reaction leading to the formation of a chemical reaction film, and no physical adsorption film was formed by the micro-Ti on the friction surface. The major cause is that micron additives are too big to be stable at low temperatures. This means that we now have the raw materials necessary to create genuine grease additives, as well as a benchmark for measuring friction performance. As a result, the friction-reducing and wear-preventing capabilities of nano-Ti are superior to those of micro-Ti. The study data is best separated in a hermetically sealed environment.

When it comes to friction and wear processes in space, nano-Ti sheets have had a significant influence due to their small size, area, adsorption, maximal chemical activity, and active edge. The existence of several friction and wear processes, including tribochemical reaction, the development of a chemical reaction layer, the separation of friction pairs, and the absence of direct contact, all contribute to space grease's efficiency in these regards. As a result, nano-Ti has superior anti-wear and anti-friction properties compared to those of some TiC hollow spheres. The difference between sliding and rolling friction reduction may be because a lubricating coating may be more easily produced on the former due to the higher concentration of oxidation products on the friction surface. The complex procedure of producing the best grease additive is shown in figure 1.

Study of nano grease tribological properties

Extreme pressure: Ti grease is initially added to increase the metal's inherent compressive strength. Heavy machinery and equipment account for a disproportionate share of mechanical production. The maximum non-seize load change value must be within tolerance before additives may be added. Nano-Ti and TiC are suitable for severe pressure for the grease. They are considered an additive because they fortify the oil film that acts as a barrier between the frictional surface and the air. High impact on the friction pair's surface reduces its compressive capacity. TiC and Ti, as seen in figure 2, are two relatively stable materials.

Performance of anti-friction and anti-wear: Ti low cost and high stability make it an attractive choice as a friction-reducing ingredient to lubricant. The results of the experiment show that nano-Ti has a friction-reducing effect that is distinct from that of other contact materials. The level of friction reduction is not only superior to that of other materials, but also rather modest.

Shear forces with bigger contact areas have friction coefficients that grow with time spent in friction. Figure 3 demonstrates how the shear effect on nano-Ti content varies with period of usage.

Effect of load: The friction system and operational conditions determine the relative load needs of various grease systems. Peeling and flaking occurring on the wear surface during regular grease lubrication indicates that the wear process in friction materials involves a mix of adhesion wear

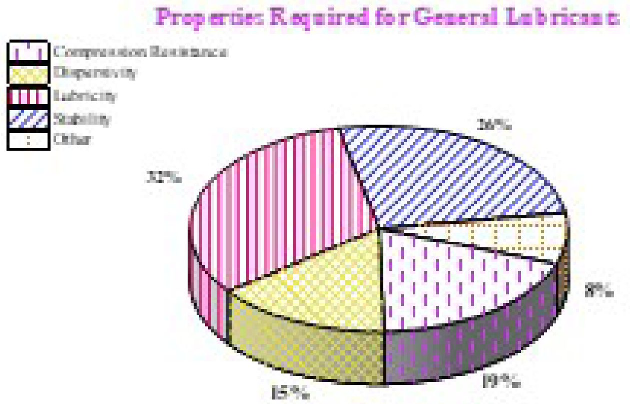

Figure 1: Essential features for all-purpose lubricants.

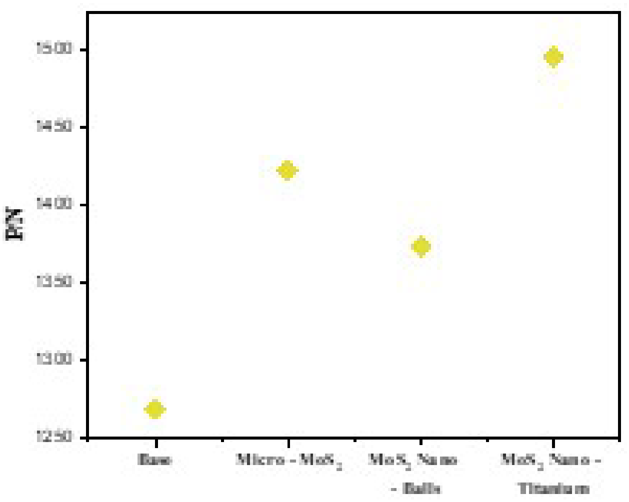

Figure 2: Impact of Ti on extreme pressure of grease.

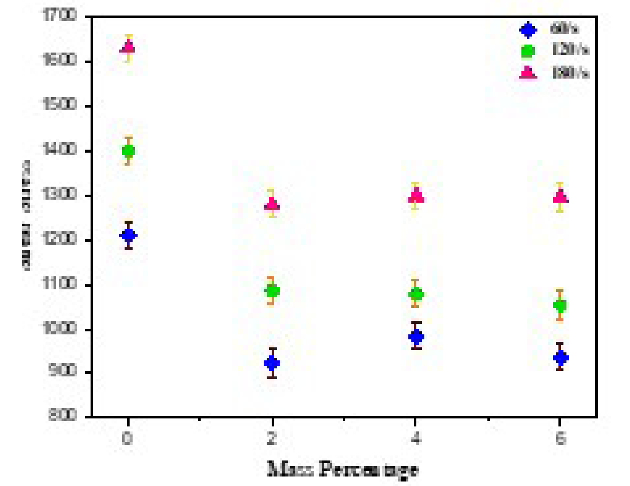

Figure 3: Nano-scale Ti effect on shear.

and abrasive wear. To address this issue, it is recommended to generously apply oil, reduce the load, and use small-diameter steel balls in the worn areas. This helps create a protective layer with anti-friction and wear properties.

Conclusion

Mechanical systems deteriorate due in large part to friction and wear. Assuring the smooth functioning and long life of a mechanical system may be done in part by minimising the amount of friction and wear it experiences. Regular preventative maintenance is essential for a long service life and lower operating expenses. Grease has evolved into an effective preventative tool for this procedure. Choosing the correct grease means considering not just how the machine is typically used, but also how the additives in the grease have evolved over time.

Grease is a lubricant that can range in consistency from a fluid to a solid, depending on the basic oil used to create it. The anti-corrosion function was prioritised first, then the emphasis shifted to aesthetics, and lastly the professional appearance was highlighted. It can work with nano materials like Ti and TiC. Wear, friction, and the lifespan of mechanical devices are all improved. Increased use of high-speed mechanical components, maximum temperature and high-load has increased demands for lubricating materials. Grease, on the other hand, exhibits thixotropy, desizing, swelling, and adsorption, all of which are colloidal properties.

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None.

Conflict of Interest

None.

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