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Possible Potential Application of Graphite Nanoparticles as Lubricant Additive in Cold Aluminium Rolling Mills

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Abstract: The use of nanoparticles in the Aluminium rolling mill oils can optimize the efficiency of the plant at the same time help in the conservation of the oil. This study describes the production of graphite nanoparticles under a low magnetic field using the chemical reagents calcium citrate and nitric acid (HNO3). It also describes how graphite nanoparticles may be used as a lubricant additive in Aluminium rolling mills. High strength, high hardness, and superior heat conductivity are just a few of the remarkable qualities that carbon nanotubes (CNTs) possess. Laboratory experiments have demonstrated a 45–65% decrease in friction in mineral oil and are useful for enhancing lubricant characteristics in difficult industrial settings. Graphite is a good lubricant because they are 99.99% pure carbon, small circular geometry graphite nanoparticles that can slide when force is applied. As such, Regular lubricants can benefit from the use of graphite nanoparticles as a lubricant additive. Graphite nanoparticles improve lubrication through decreased friction coefficient and wear volume, enhance tribological performance, and reduce wear scar as evidenced through experiments using SEM. As a result, adding it to lubricant in cold rolling mills for Aluminium can improve process efficiency and aid in lubricant conservation. Thus, a new area of research in the Aluminium cold rolling mills can be opened up by conducting experiments to optimize the plant's efficiency with the use of Graphite nanoparticles as a lubricant additive.

Key Words: *Graphite Nanoparticles, SEM, Carbon Nanotubes (CNTs), Lubricant Additive*

1. Introduction

The physical and chemical characteristics of nanoparticles differ from those of their parent materials (Alivisatos 1997; El-Sayed 2004; Hodes 2007). Because of their high surface-to-volume ratio, nanoparticles differ from bulk materials in their properties (Goesmann and Feldmann 2007; Peng 2009). The remarkable characteristics of nanoparticles may be applied in a wide range of fields, including energy conversion, mechanical and electrical applications, magnetic storage, and nanomedicine. (Lohse and Murphy 2012; Semonin et al. 2012; Talapin et al. 2010; Lee et al. 2007; Wang et al. 2008; Bouzigues et al. 2011; Reddy et al. 2012 For a broad variety of chemicals, such as actinide-based compounds, transition metal oxides, chalcogenides, lanthanide base compounds, and noble metals, nanoparticles of different sizes, compositions, and forms may be produced. (Kwon and Hyeon 2008; Park et al 2007; Rao et al 2007; Jun et al 2006; Jun et al 2005).

The unique properties of graphite nanoparticles like huge surface area, outstanding structural stability, corrosion resistance, good electrical and thermal conductivity, and enhanced chemical and biocompatibility are widely used for making Supercapacitors, batteries, fuel cells, biosensors, composite materials, transistors, and other equipment. (Wang et al. 2002; Shenderova et al. 2002; Wisser 2006; Zhang et al. 2006; Lu et al. 2009).

Linear Paraffin products in the C12-C17 series have been used as base oils since the 1980s in the Aluminium cold rolling mills. However, a lack of supply and their comparatively expensive price is making hydrotreated kerosene fractions and diesel range goods with comparable viscosities more popular. (Jane Wang and Wah Chung 2013).

The use of nanoparticles in the Aluminium rolling mill oils can optimize the efficiency of the plant at the same time help in the conservation of the oil. This study describes the production of graphite nanoparticles under a low magnetic field using the chemical reagents calcium citrate and nitric acid (HNO3). It also describes how graphite nanoparticles may be used as a lubricant additive in Aluminium rolling mills.

2. Aluminium Rolling Oils

Eastern Petroleum Pvt. Ltd., Mumbai's Eastto Aluminium Rolling Oils (GRADES: 80 and 110) are straight mineral oils with low viscosity that are specifically designed for the cold rolling of Aluminium foils, sheets, and strips. Their high IBP and narrow boiling ranges slow down evaporation, thus reducing the amount of oil (roll coolant) used. The intrinsic oiliness attribute aids in metal reduction without any slippage and greatly lowers friction. For the benefit of seamless manufacturing, Aluminium producers add fats and alcohols to it, and it is non-staining, non-corrosive, and has good additive solubility.

3. Aluminium Rolling Oils - Types and Characters

For cold rolling Aluminium sheets, strips, or foils, Aluminium rolling oils 80 and 110 are suggested. Below are some common features of Aluminium rolling oils:

Types and Characters of Aluminium Rolling Oils

Kinematic Viscosity at 40ºC., cSt, for 80, 1.50 - 2.10 for 110, 1.80 – 2.30 respectively
Flash Point, COC,°C, Min. for 80, 105 - for 110, 110 respectively
TAN, mg KOH / gm for 80, 0.002for 110, 0.002 respectively
Distillation Range, a) IBP for 80, 210 for 110,240 respectively
b) FBP for 80, 250 for 110, 280 respectively

4. Method for Preparation of Graphite Nanoparticles

The methodology described by Gopal Krishna & Rao (2015) for the preparation of graphite nanoparticles is generally followed to prepare graphite nanoparticles in the laboratory. Graphite nanoparticles are also commercially available in the market. Graphite, calcium citrate, and concentrated nitric acid (HNO3) are the raw ingredients used in the manufacture of graphite nanoparticles. Initially, 15mℓ of nitric acid is added gradually to 5.0g of graphite in a cylindrical, non-magnetic container. The mixture is then exposed to a magnetic field of 10-2 to 10-3 Tesla, citrate is progressively added, and it is left in the air at 50 degrees Celsius for 12 hours. Most of the graphite precipitates to the bottom, but some carbons that have reacted with the calcium citrate float and could be removed easily by filtering. The floating carbon compounds are dried, filtered, and submerged in water. The filtered and dried carbon samples so obtained are graphite nanoparticles (Ago et al. 2002; Dai et al. 1999).

5. Advantage of Graphite Nanoparticles as Lubricant Additive

Graphite Nanoparticles are good Lubricant additives. It increases lubricant properties in oils, greases, fuel additives, etc. It is very good for friction reduction applications. For example, graphite grease is very effective in reducing friction. In the market, Graphite Nanoparticles are available that are fully synthetic have 5-15 layers of thickness, and are cheap and scalable with high-volume synthesis. Tests in the laboratories have shown that Graphite Nanoparticles can reduce 45-65% friction when added to mineral oil. Graphite oil lubricant is highly recommended for challenging applications. Graphite needs to be modified to be used in applications like nano lubricant agents. In doing so, various dispersion methods are suggested to improve the dispersion stability of graphite and the suspension of nanoparticles in a palm-oil-based lubricant appears to have a positive impact on tribological performance. In this case, nano lubricants are obtained followed by 2 steps including a high-sheer homogenizer and magnetic stirrer. There are other physical and chemical treatments like the use of a particular surfactant and pH control as well as surface modification to achieve a stable suspension.

Nano-additives have proven to be effective at lowering lubricant wear and friction even at concentrations below 1 weight percent. (Shah et al., 2021). It has been made feasible in many ways: The ball-bearing effect lowers wear and friction by using nanoparticles to effectively function as ball bearings between two surfaces. (Lee et al.2009). High strength, high hardness, and superior heat conductivity are just a few of the remarkable qualities that carbon nanotubes (CNTs) possess in one special combination. Comparing CNTs' 2000 W/m.K. thermal conductivity to Ag's 419 W/m.K thermal conductivity, it is clear that CNTs are one of the most promising nano-additives for lubricating lubricants. Good thermal conductivity, increasing the engine's overall performance efficiency, and boosting heat dissipation efficiency are also some of their outstanding qualities. (Hong et al.2016)

6. Characters of Graphite Nanoparticles in Support of Their Use as Lubricant Additive

Graphite nanoparticles lubricant additive is 100% carbon. Graphite nanoparticles are spherical, black, graphitic carbon with a high surface area. They are a crystalline form of carbon that occurs naturally as a black powder. In normal conditions, graphite nanoparticles are viewed as the most enduring carbon form. These nanoparticles have a specific surface area (SSA) between 30 and 50 m2/g and their size varies from 10 to 45 nm. Graphite is a black spherical graphitic carbon with a large surface area, and it can be found in forms such as nano-powder, nanodots, or nanoparticles. Additionally, graphite particles at the nanoscale are accessible, with an average size of 75 to 100 nm and a specific surface area of approximately between 2 and 10 m2/g. They are also offered as dispersion as well. In general, suspended nanoparticles in solution made using surface charge or surfactant technology are referred to as nanofluids. The mechanical and thermal conductivity of carbon nanoparticles are exceptional. Since they are made entirely of carbon, they are low in toxicity, very stable, and ecologically benign. It is a fantastic new hydrophobic additive with excellent friction-reducing capabilities. Laboratory experiments have demonstrated a 45–65% decrease in friction in mineral oil and are useful for enhancing lubricant characteristics in difficult industrial settings. Graphite is a good lubricant because they are 99.99% pure carbon, small circular geometry graphite nanoparticles that can slide when force is applied. As such, Regular lubricants can benefit from the use of graphite nanoparticles as a lubricant additive.

Some major properties of the Graphite Nanoparticles/Nanopowder are as follows:

- Molecular Weight is 12.01 with a Black Powder Appearance.
- The melting Point is3550 °C and Boiling point is 4027 °C
- Density is 1.8 g/cm3 and True Density is 2.26 g/cm3with a Tensile Strength of 18 MPa (Ultimate)
- The Average Particle Size is less than 50 nm and the Specific Surface Area is greater than 100 m2/g (BET)
- Thermal Conductivity is 6.0 W/m-K with a Thermal Expansion capacity of 4.9 µm/m-K
- Young's Modulus value is 21 GPa

7. Improvisation of Lubrication Using Graphite Nanoparticles

Graphite nanoparticles improvise lubrication through:

a) Decrease friction coefficient and wear volume: Graphite nanoparticles' tiny size and high surface energy allow them to physically deposit as a layer on friction surfaces.
b) Improve in tribological performance: Strong covalent connections bind the layers of graphite nanoparticles' layered crystal structure together. At the same time, The weak van der Waals keeps the molecular layers comparatively widely apart.
c) Reduce average wear scar diameter: Graphite oxide derivatives can reduce the average wear scar diameter by 66–69% compared to oil-based lubricants and grease. The viscosity of the lubricant decreases with increasing temperatures in proportion to the concentration of nanoparticles, up to a certain point but after that point, viscosity increases with temperature. Therefore, it is very important to maintain the level and temperature while using nanoparticles in lubricants.

Graphite, when in a powdered state, can serve as both a lubricant and an additive. As a solid powder lubricant, its friction coefficients range from 0.5 to 0.6 under dry conditions, and from 0.1 to 0.2 in moist conditions. It is widely used in various industries as a lubricant in micro-scale powder form (Bryant PJ et al. (1964), Buckley DH et al. (1975), and Spreadborough J. (1962). Lee et al. (2009) researched the use of graphite as an additive to industrial gear oil. The oil had a kinematic viscosity of 220 cSt at 20 degrees Celsius, which is equivalent to 220 mm²/s. The Scanning Electron Microscope (SEM) images in Figure 1 depict the initial state of the surface (a) and the condition of the surface when combined with nanoparticles (0.5% volume) of the lubricant (b). The study found that graphite nanoparticles act like spacers in ball bearings, minimizing metal-to-metal contact during sliding movements. Recently Martorana et al. (2010) examined the lubricating capabilities of graphite-containing ethanol for gear pumps. Graphite demonstrated remarkable robustness under working settings without experiencing scission or deterioration. Power consumption was unaffected by the effective concentration of nanoparticles, which is stated to be between 400 and 1600 ppm in this instance. This investigation will demonstrate that carbon nanoparticles improve volumetric efficiency without appreciably raising the working fluid's viscosity. Hwang et al. (2011) looked at the impact of adding graphite. The size and form effects of nanoparticles on the tribology behaviors of mineral oils were investigated using the disc-on-disc teribo tester. The presence of spherical nanoparticles in the graphite mixture preserved sliding surfaces with little damage and wear. (Fig. 2)

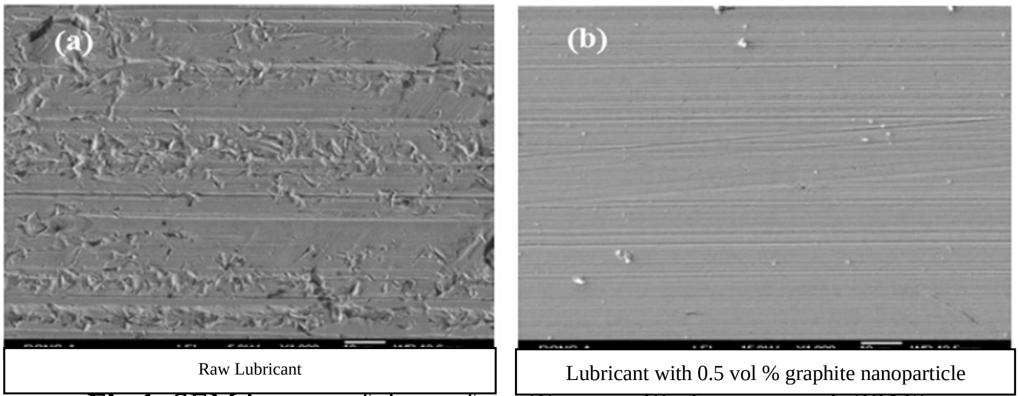

Fig.1. SEM images of the surface (Source: Shahnazar et al. 2016)

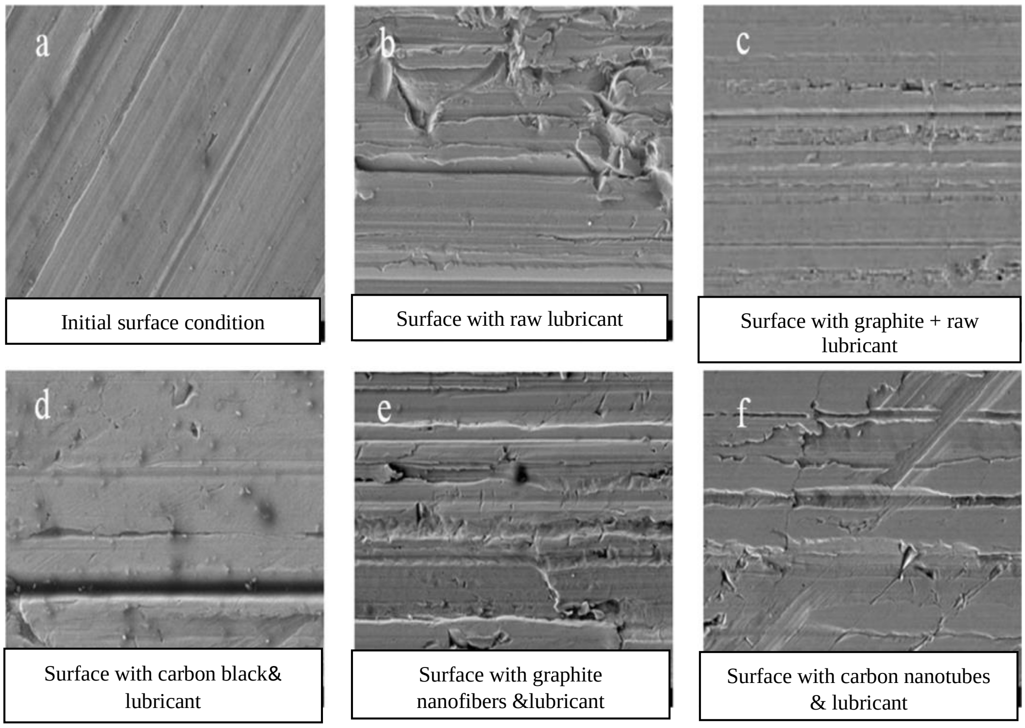

Fig.2. SEM images (Shahnazar et al. 2016)

(Niu and Qu, 2018) In their study incorporated nano-graphite into titanium complex grease to improve its tribological properties. They examined the effect of three different average diameters of nano-graphite (2 µm, 3.5 µm, and 6 µm) on the tribological properties of the grease. They discovered that the optimal concentrations for these three sizes of nano-graphite were 0.8 wt%, 1.0 wt%, and 1.2 wt%, respectively. Moreover, the ideal grease is titanium complex grease that has been changed with 0.8 weight percent of nano-graphite. "It was found that the optimal additive concentration of Nano Graphite (N-G) varies with its size. For an average diameter of 2 µm, the ideal N-G concentration in titanium complex grease was determined to be 0.8% by weight. This titanium complex nano-graphite grease showed better wear resistance and friction reduction properties compared to the standard grease."

8. Conclusion and Future Scopes

The scope and content of tribology has changed rapidly in the past years. Tribology incorporates physics advancements into its purview. Our knowledge of friction, wear, and sliding movements has changed as a result of this science's entry into the micro and nanoscales. Our understanding of nanoparticles' tribological behaviour remains limited, despite decades of research on the material and its properties. While this communication discusses and summarises the many benefits of using graphite nanoparticles as oil additives, it also highlights several challenges associated with their application. The primary challenge is in creating and preserving uniform blends of oils and nanostructure particles, as the potent van der Waals interaction among the particles leads to their aggregation in solutions. Accordingly, different methods for stabilizing nanoparticles in all classes of base oils to be utilized as lubricants must be investigated to generate lubricants that are both chemically and physically stable. High particle concentrations cause the system's viscosity to rise, which in turn causes a large pressure drop and increased power consumption. Most of the literature has reported that to improve the tribological quality nanoparticles of small amounts even less than or equal to 1% are needed but the shape and size also deciding factors for the frictional reduction and anti-wear behaviours. Considerations should also be given to improve the production techniques of nanoparticles so that their applications are more economically feasible.

Graphite nanoparticles improve lubrication through decreased friction coefficient and wear volume, enhance tribological performance, and reduce wear scar as evidenced through experiments using SEM. As a result, adding it to lubricant in cold rolling mills for Aluminium can improve process efficiency and aid in lubricant conservation. Thus, a new area of research in the Aluminium cold rolling mills can be opened up by conducting experiments to optimize the plant's efficiency with the use of Graphite nanoparticles as a lubricant additive.

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