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INVESTIGATION OF TRIBOLOGICAL PROPERTIES OF POLYMER GREASE MANUFACTURED FROM PALM ESTER WITH BORON NITRIDE AND POLY ALPHA OLEFIN WITH BORON NITRIDE

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Abstract. Greases are lubricants that are used to reduce friction, heating, distortion, torsion in gears and machines. General method of manufacturing grease is using mineral salts. As mineral salts become more expensive, research for alternative materials that can replace grease increased. A novel method for manufacturing grease is to use polymers as thickener agents. In this study, 12% polypropylene was used to produce grease from palm ester and poly alpha olefin, which are different greases from each other. In order to increase greases' high-pressure properties, 2% hexagonal boron nitride was added. Manufactured palm ester greases were compared to poly alpha olefin greases which have been produced. Both samples were tested on ball-on-disc tribometer on mirror polished 4140 and results were discussed.

Keywords. Friction, greases, PAO, Palm ester.

1. INTRODUCTION

Lubricating oils and greases are the most common technical lubricants. Greases are preferred in situations where lubricant leakage from lubricated joints under the action of gravity or capillarity needs to be avoided. In particular, greases are extensively used as a component of distributed lubricating systems in modern cars and construction vehicles, which are supposed to work well in any climatic condition, from extreme cold to extreme hot. As known, low temperatures cause grease thickening, which may disturb the operation of the distributed lubricating systems in a cold climate.

The type of base oil used in grease production is one of the key determinants of grease performance at various temperatures. Mineral oils used by grease manufacturers can be divided into two major groups: naphthenic oils and paraffinic oils. Each of these groups of base oils have their own advantages and disadvantages [1].

The importance of the base oil type on friction torque was illustrated by Cousseau et al. [2]. Authors tested seven greases on an axially loaded thrust ball bearing and found that bearing friction was primarily a function of the base oil type and not so much of the viscosity, thickener type or additive package. The ranking, starting with the lowest friction was PAO, Ester and Mineral oil. Similar results were found by De-Laurentis et al. [3] using single contact grease testing.

Poly(alpha-olefin)s can be prepared via organometallic polymerization of C_{10}-C_{18} alpha-olefins, and exhibit thermoplastic elastomeric properties having high melt strength, strong shear thinning and large stretchability.

An "alpha-olefin" is an olefin having a double bond at the alpha (or 1-) position. A "linear alpha-olefin" or "LAO" is an olefin with a double bond at the alpha position and a linear hydrocarbon chain. A "poly(alpha-olefin)" or "PAO" is a polymer having two or more alpha-olefin units [4].

Synthetic esters, such as isooctyl sebacate, pentaerythritol esters and trimethylolpropane trioleate, have shown great promise as lubricants due to strong interactions between the polar ester groups and the

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surface atoms of the metal components [5-6]. However, these ester oils are usually produced by the esterification of the branched-chain carboxylic acids and alcohols [7]. Despite polar ester groups adhering to the metal surface to form the adsorption film for lubrication, such molecular configuration, which only contains branched chains, merely provides the limited anchoring strength to the ester groups, and emasculates the compactness of the lubricant molecules packing on the sliding surface, leading to the inferior service and poor load-capacity. Hence, to design and synthesize the novel ester lubricants bearing molecular structures that facilitate multi-interactions to enhance their tribological performances is still desired urgently [8].

Applying lubricant additives has been widely considered as a convenient way to enhance tribological performances for the lubricating system. Currently, two-dimensional (2D) materials such as graphene, black phosphorus, MoS_2, and their derivatives have been demonstrated to be potential lubricant additives due to their attractive layered structure [9–10]. Particularly, hexagonal boron nitride (h-BN), a typical layered 2D material, has a unique structure in which van der Waals forces exist between two covalently bonded sheets. Accordingly, h-BN exhibits superior mechanical strength and can easily shear at the contact interfaces as employed as lubricant additives [11–12]. Gupta et al [11] investigated the influence of the h-BN particle sizes on tribo-performances of the filled oils and found that all the nano-, submicron-, and micron-sized h-BN particles exhibited better tribological performances than the base oil. Deepika et al [13] reported that BN nanosheets obtained by wet ball milling greatly reduced the friction and wear as a lubricating additive in the base oil. Moreover, h-BN particles can improve the thermal stability and conductivity of the dispersed oil, which is also beneficial for lubricating.

Although metallic salts are used in most grease manufacturing polymers can be used for grease as well. In this study, the effect of hBN addition to polymer grease manufactured using polypropylenes with different base oils were investigated. The novelty of this method is the addition of hBN during grease production. Thus, base oil and additive mixture is achieved in higher efficiency [14–16].

2. MATERIALS AND METHOD

2.1. Additives and base oil.

The base oil used in all the experiments was PAO 6 (obtained from Gemaoil, Turkey) and a commercial trimethylolpropane tri- oleate (Palmester 2088, TMPT) was used as the base oil supplied by KLK OLEO from Malaysia. Characteristics of base oils are given at Table 1.

High purity nano sized hBN was obtained from BORTEK, Turkey. Pure isotactic polypropylene was obtained from Petkim.

Table 1. The Feature of the base oils.

Parameter	PAO 6	Palmester 2088
Density (20 °C, g/cm^3)	0.823	0.9
Kinematic viscosity, mm^2 /s		
40 °C	30.56	48
100 °C	5.81	9.5
Viscosity index	136	187

2.2. Experimental Procedure.

Grease was manufactured according to patent pending method invented by Ay et. al. Each base oil was mixed with 12% PP and 2% hBN. Produced grease was homogenized and prepared for tribological tests. Grease A was produced from POA and grease B was produced using Palm Ester.

Table 2. Testing conditions for grease samples.

Test No	Speed (mm/s)	Load (N)	Hertzian Pressure (GPa)
1	10	5	2.2
2	30	5	2.2
3	50	5	2.2
4	10	2	1.6
5	10	1	1.2

Ball on disc test was conducted on AISI 4140 substrate. 0.5 mm thick grease was applied to substrate sample.5 different load and speed conditions were tested. The testing conditions are given at Table 2.

Each test was conducted for one cycle.

3. RESULT AND DISCUSSION

The results of ball-on-disc experiments are give below. At Figure 1 coefficient of friction change in PAO 6 samples with distance are given. A1-A2-A3-A4 and A5 shows test number of the experiments at the table 2 respectively.

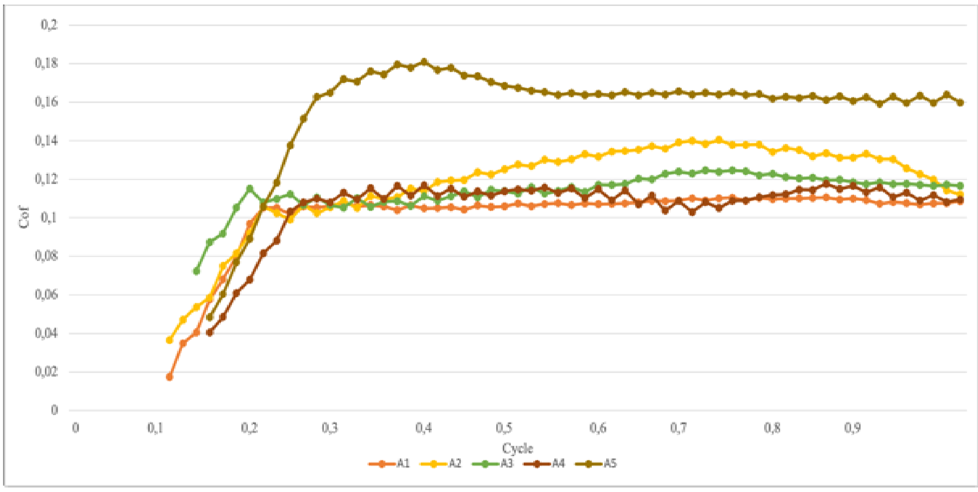

Figure 1. Coefficient of friction change in PAO 6.

At Figure 2 coefficient of friction change in Palm Ester samples with distance are given. B1-B2-B3-B4 and B5 shows test number of the experiments at the table 2 respectively.

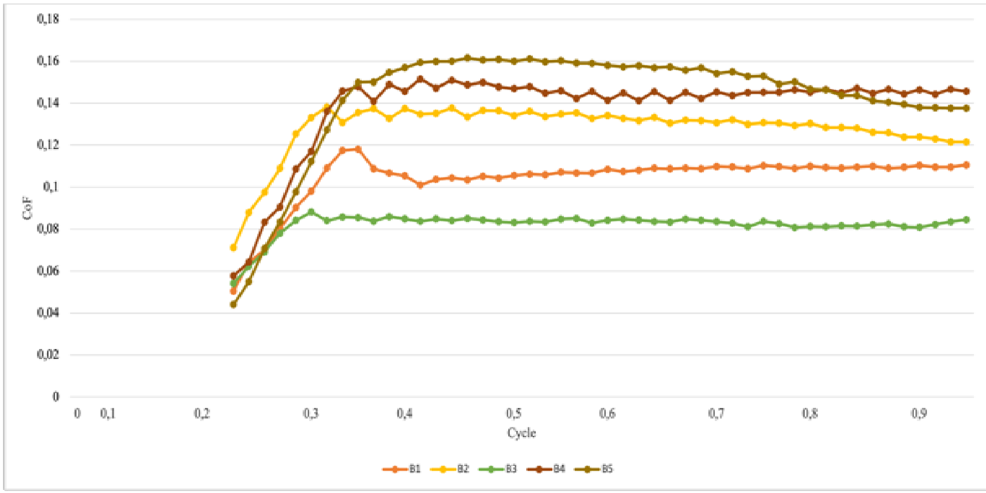

Figure 2. Coefficient of friction change in Palmester 2088.

Observing Figures 1 and 2 shows that both base oils show a higher friction coefficient at lower speeds and lower loads. Although this seems counterintuitive it is because of solid lubricant properties of hBN in greases. At lower speeds, solid lubricant particles act as third body particles and result in an increase in friction. At higher loads and high speeds hBN particles act as high-pressure additive and decrease the friction under stress.

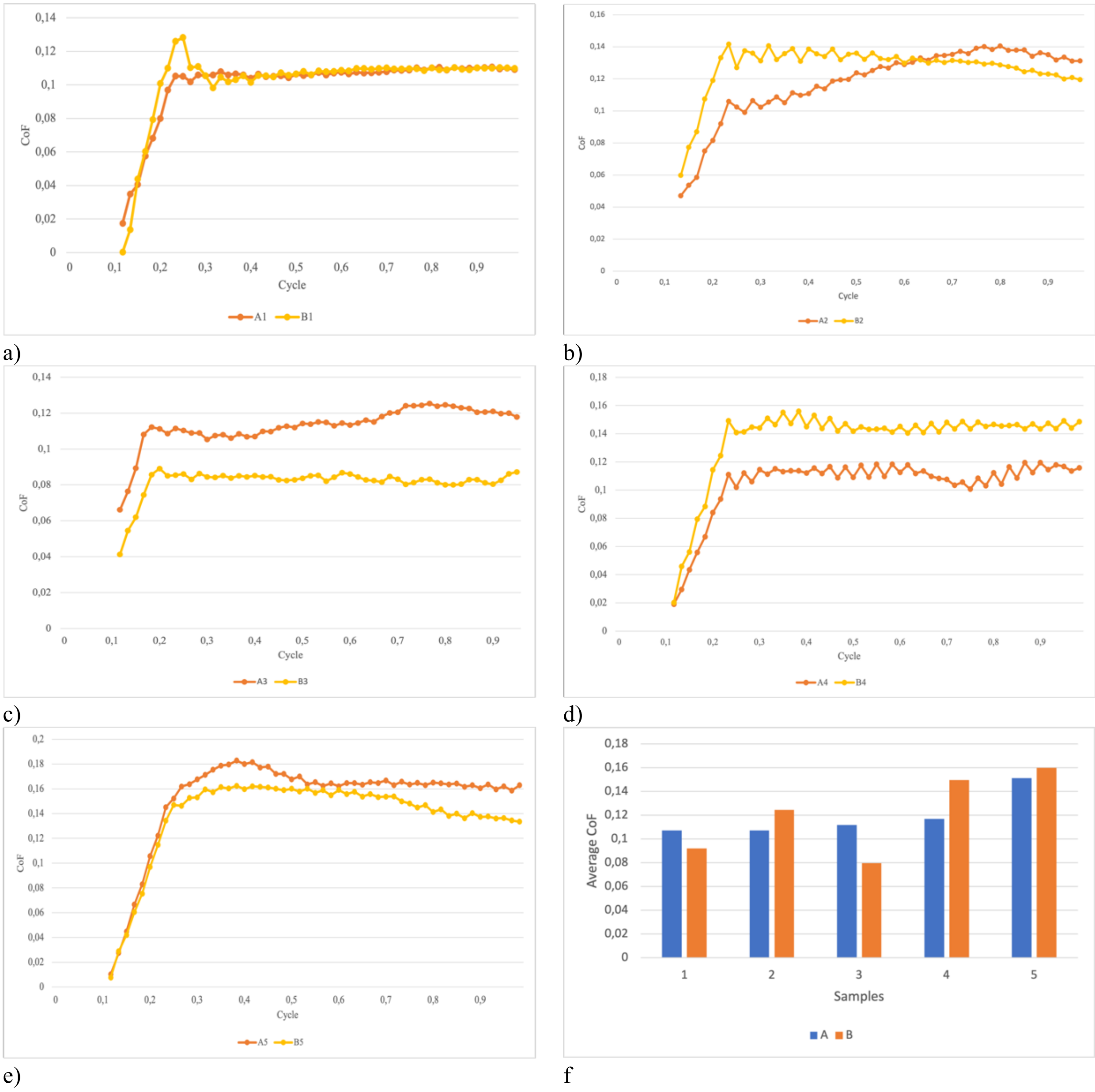

Figure 3. CoF with respect to distance graphs a) A1-B1, b) A2-B2, c) A3-B3, d) A4-B4, e) A5-B5, f) Comparing of Two Base oil's Samples.

At Figure 3 coefficient of friction of each base oil at the same conditions are given. The results show that palm ester is better at high load and high-speed applications. This is the result of slight difference between viscosities of POA and Palm Ester. Higher viscosity of palm ester enables better load carrying capacity.

4. CONCLUSION

In this study grease with polypropylene thickener was produced using two different base oils and hBN additive. Samples were tested on Ball-on-Disc tribometer, and the results were investigated. It was found that:

1. hBN addition resulted in better high load friction properties but worse low-pressure performance.
2. Palm esters have better high pressure tribological performance as a result of higher viscosity of base oil.

This study shows that the novel method of manufacturing polymeric grease with hBN addition is a viable method for high pressure grease applications.

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REFERENCES

[1] Salomonsson L., Stang G., Zhmud B. Oil/Thickener Interactions and Rheology of Lubricating Greases. Tribology Transactions, 50 (3) (2007), p. 302–309.
[2] Cousseau T., Grac B.M., Campos A.V., Seabra J.H.O. Influence of grease rheology on thrust ball bearings friction torque. Tribology International, 46 (1) (2012), pp. 106–113 [37th Leeds-Lyon symposium on tribology special issue: tribology for sustainability: economic, environmental, and quality of life].
[3] De-Laurentis N., Cann P.M., Lugt P.M., Kadiric A. The influence of bearing grease composition on friction in rolling/sliding concentrated contacts. Tribology International, 94 (2016), pp. 624–632.
[4] Poly(alpha-olefin)s and methods thereof, CROSS-REFERENCE TO RELATED APPLICATIONS. This application claims priority to and the benefit of U.S. Ser. No. 62/772, 916, filed Nov. 29, 2018.
[5] Yu H.X., Chen H.J., Zheng Z.W., Ba Z.W., Qiao D., Feng D.P., et al. Transformation mechanism between the frictional interface under dioctyl sebacate lubrication. Tribology International, 155 (2021), Article 106745.
[6] Liñeira del Río G.M., Guimarey M.J.G., Comuñas M.J.P., López E.R., Amigo A., Fernández J. Thermophysical and tribological properties of dispersions of graphene in a trimethylolpropane trioleate based oil. J Mol Liq, 268 (2018), pp. 854–866.
[7] Shuang Ch., Tingting W., Chen Z. Conversion of lipid into high-viscosity branched bio-lubricant base oil. Green Chem, 22 (2020), pp. 7348–7354.
[8] Qianqian Y., Haojie M., Rui D., Yunyun Y., Ping W., Mingjin F. Salicylate ester derivatives as lubricant: Snergism of multiple interactions to improve tribological performances. Tribology International, 169 (2022), 107489.
[9] Kogovšek J., Kalin M. Lubrication performance of graphene-containing oil on steel and DLC-coated surfaces. Tribology International, 138 (2019), pp. 59–67.
[10] Tang G., Su F., Xu X., Chu PK. 2D black phosphorus dotted with silver nanoparticles: An excellent lubricant additive for tribological applications. *Chemical Engineering Journal, 392 (*2020), 123631.
[11] Gupta M.K., Bijwe J., Padhan M. Role of size of hexagonal boron nitride particles on tribo-performance of nano and micro oils. *Lubr Sci*. 30 (2018), (8): 441–456.
[12] Yıldırım Ç.V., Sarıkaya M., Kıvak T., Şirin Ş. The effect of addition of hBN nanoparticles to nanofluid MQL on tool wear patterns, tool life, roughness and temperature in turning of Ni-based Inconel 625. Tribology International, 134 (2019), 443–456.
[13] Deepika L.L.H., Glushenkov A.M., Hait S.K., Hodgson P., Chen Y. High-efficient production of boron nitride nanosheets via an optimized ball milling process for lubrication in oil. *Sci Rep*., 4 (2014), 7288.
[14] Gonçalves D., Graça B., Campos Armando V., Seabra J. On the friction behaviour of polymer greases. Tribology International, 93 (2016), 399–410.
[15] Muller D., Matta C., Thijssen R., bin Yusof M.N., van Eijk M.C.P., Chatra S. Novel polymer grease microstructure and its proposed lubrication mechanism in rolling/sliding contacts. Tribology International, 110 (2017), 278–290.
[16] Gonçalves D., Pinho S., Graça B., Campos Armando V., Seabra Jorge H.O. Friction torque in thrust ball bearings lubricated with polymer greases of different thickener content. Tribology International, 96 (2016), 87–96.