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INFLUENCE OF DISPERSING LITHIUM GREASE BY HYBRID NANO TITANIUM AND SILICON OXIDES ON FRICTION COEFFICIENT

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ABSTRACT
This paper examines the influence of dispersing lithium grease by hybrid nano titanium and silicon oxides on friction coefficient. Nano titanium, silicon and hybrid nano oxides at five concentration levels were used to disperse the lithium grease. Experiments were carried out using an aluminum disc sliding against stainless steel pin. Results show that, nano oxides particles have shown good friction characteristics and even at concentrations of 6 wt. % and 8 wt. %. Moreover, friction coefficient is improved because of the self-repair role of hybrid nano oxides particles on contact surfaces.

KEYWORDS
Frictional coefficient, nano oxides, hybrid, lithium grease, lubricant systems.

INTRODUCTION
Advanced additive technologies used in today's high-performance lubrication oils and grease are capable of inducing the required reactions on the surfaces of bearings, thus providing reliable damage protection even under severe operating conditions The tribological behavior and lubrication mechanisms of main classes of nanoparticles as lubricating oil additive to reduce wear and friction .Addition of nano particles size, less than 100 micron size, have a great influence on viscosity, friction factor, wear and thermal properties like heat transfer of the lubricant. Nano particles helps in improving the life of the lubricating oil and consequently life of the bearing in machineries can save millions of dollars in emergency maintenance costs. The different methods for preparation of Nano-grease were investigated .The most commonly used method is the 'Direct mixing method'. In this method, the nano-particles are directly mixed with grease under heavy mechanical stirring, [1]. The tribological properties of CaF_2 nano-crystals as lithium grease additives on a four ball tester. Reduction of 29 % and 19 % in wear scar diameter and friction respectively was reported. The improvement in tribological properties of CaF_2 added grease is not proportional to concentration of CaF_2. In general, there exists a limiting value of nano-additives up to which tribological properties can be improved, [2]. Copper and copper oxide nanoparticles used in different base oils, [3]. It was found that the nano-oil mixed with copper nanoparticles

has a lower friction coefficient and less wear on the friction surface, indicated that copper nanoparticles improved the lubrication properties of raw oil. Also they observed that nanoparticles have shown good friction and wear reduction characteristics even at concentrations below 2 wt. %. Wear of friction couples was decreased by a factor of 1.2 - 3, and friction coefficient was decreased by a factor of 1.3 - 2. The addition of Cu ultrafine particles was tribological detrimental these experiments were conducted with modified transmission oils, it founded that their corrosion resistance, as well as the antioxidant properties of the oils, did not change, [4]. It is showed that the friction coefficient was decreased by 40-50 % in comparison with the solution without Al_2O_3 particles, [5, 6]. Modified SiO_2 had better tribological properties in terms of load-carrying capacity, anti-wear and friction reduction, [7, 8]. It is found that their anti-wear and anti-friction performances are better than those of pure Al_2O_3 or SiO2 nanoparticles, [9]. The results show a reduction of 41 % vibration amplitude. Their lubricity tests were conducted using a three roller/ ring testing machine, and the frictional force and abrasion loss of the rollers (made of bearing metal or phosphor bronze) were measured. The abrasive wear in sliding friction was reduced when lubricating oils or greases containing >1% BN were applied to the friction surfaces. The reduction in abrasive wear was greatly affected by the crystallization of the BN. However, the amount of reduction in abrasive wear was decreased by dispersing agents in the lubricants [11] .The oil lubricating performance using such Nano particles as additives was improved in comparison with pureAl_2O_3 or SiO_2 particles, which was investigated by thrust-ring test and four-ball test. There was an optimal concentration of additive which was 0.5 wt. % for the tested Al_2O_3/SiO_2 composite nano particles. The absorbed nanoparticles may result in rolling effect between rubbing surfaces, and the situation of friction is changed from sliding to rolling. Therefore, the friction coefficient was reduced, [12, 13]. Alumina/silica (Al_2O_3/SiO_2) composite nanoparticles were synthesized with a hydrothermal method and modified by silane coupling agent. The tribological properties of the modified Al_2O_3/SiO_2 composite nanoparticles as lubricating oil additives were investigated by four-ball and thrust-ring tests in terms of wear scar diameter, friction coefficient, and the morphology of thrust-ring, [14]. It is found that their anti-wear and anti-friction performances are better than those of pure Al_2O_3 or SiO_2 nanoparticles. Nano-calcium borate (NCB) with an average particle size of about 70 nm was synthesized via ethanol supercritical fluid drying technique were characterized. The friction and wear behavior of the NCB as additive in lithium grease were evaluated with an oscillating friction and wear tester, [15]. The result demonstrated that the anti-wear and load-carrying capacities of the lithium grease were significantly improved, and the friction coefficient of the lithium grease decreased with the addition of NCB additive. Eight titanium complex greases which contains PTFE, or nano-titanium dioxide, or nano-silicon dioxide were synthesized using 3-L reaction vessel. The physical characteristics were characterized and their tribological properties were evaluated by using a four-ball tester, [16]. Results show titanium complex greases containing PTFE, or nano-titanium dioxide, or nano-silicon dioxide exhibited excellent tribological performance. TiO_2/CuO nano-particles were dispersed into lithium grease to improve the lubricating properties of the greases. Then, the process of sliding friction was tested, [17]. The friction force of the contact interface between a ball and a flat surface with TiO_2/CuO nano-grease was measured for a ball on a flat sliding wear

tester. Silica sand with different particle sizes and iron (Fe) powder of five concentrations were dispersed in lithium grease, [18]. The effect of sliding velocity and normal load on friction and wear properties of stainless steel pin sliding against an aluminum disc was investigated. It was found that, Fe particles have shown good friction and wear reduction even at low concentration as 2 wt. % and 4 wt. %. The tribological properties of the $CaCO_3$ nanoparticles as an additive in lithium grease were evaluated with a four-ball tester, [19]. The results show that these $CaCO_3$ nanoparticles exhibit good performance in anti-wear and friction-reduction, load-carrying capacity, and extreme pressure properties. The tribological properties of carbon nano tubes CNTs as an additive on lithium grease were evaluated with a four ball tester, [20]. The results show that the grease with CNTs exhibit good performance in anti-wear and decrease the wear scare diameter about 63%, decrease friction reduction about 81.5%, and increase the extreme pressure properties and load carrying capacity about 52% with only 1% wt. of CNTs added to lithium grease. Furthermore, the. The vibration amplitude was improved due to increase of concentration of carbon nanotubes CNTs, [21]. The objective of this work is to study the effect of the type of additives and verify the best percentage of adding to improve the properties of lithium grease. The lubrication additives used in this paper are silicon oxide, titanium oxide and the hybrid nano particles.

EXPERIMENTS

Materials and Methods

Lithium grease was used. Generally different materials such as TiO_2 particle size (20 - 30 nm), SiO_2 particle size (40 - 50 nm) and hybrid nano oxides all at five concentration levels were added to grease. Nano oxides material concentration is 2, 4, 6, 8 and 10 wt. % of the lithium grease. The tribology tests were conducted using pin on disk friction pair.

The Tribological Test

The tribological tests were carried out using vertical universal friction and wear testing machine model MM-W1A. It is a Multi-Specimen Friction and Wear Testing Machine. It is designed for simulating, evaluating and testing almost all kinds of oil, Fig. 1. The MM-W1A machine consists of mainframe, grips, oil boxes, heater and measure system, spring load system under close-loop control, indicator board and cabinet. The testing machine contained step washer friction couple for measuring wear rate under the condition of oil auto-lubricating contact, and used to measure friction force. The tribological properties of different lubricant systems are tested. Lithium grease without additive was used as a basic lubricant. The tests were conducted using pin samples with flat surfaces in the contact region, where the applied normal force was in the range of 25 to 100 N. Velocities were between 200 to 1000 rpm, with 200 rpm step, at room temperature. Tests were conducted using 1.0 g of Li-based grease. Prior to each test, the disk, pin, disk holder and ball holder were cleaned for getting rid of unwanted material such as metal chips or lubricant adhering to the holders. The pin-on-disk test is generally used as a comparative test in which controlled wear is performed on the samples to be studied. The volume lost allows calculating the wear rate of the material.

Since the action performed on all samples is identical, the wear rate can be used as a quantitative comparative value for wear resistance.

Fig. 1 Vertical universal friction and Wear testing machine [MM-W1A].

Fig. 2 Pin on-Disc Friction Pair.

RESULTS AND DISCUSSION

The variation the friction coefficient of the nano oxides particles as lubrication additives for pin on disk friction pair with time (sec) is presented. In the experiment, the friction coefficient was determined every second. The friction coefficient averaged from every 20 min., where original data were displayed in Figs. (3 - 4). It is important to notice that the friction coefficient of lubricant with nano oxides particles is lower than that of pure lubricating grease. It can be concluded that the friction coefficient was improved due to increase of concentration of nano oxides particles that gave best result at 6.0 wt. %. Figure 3 illustrates the friction coefficient of the nano titanium oxide TiO_2 for different speed versus the time at constant load 50 N. The friction coefficient of Nano titanium dioxide at speed 200 rpm displays highest values. while 1000 rpm speed displays lowest values at 6.0 wt. %. It is found that friction coefficient decreased when the rotating speed increased. The friction coefficient of the nano titanium oxide TiO_2 for different load at 200 rpm constant speed is presented in Fig. (4). It is noticed that friction coefficient was constant when load increased at 6.0 wt. %.

Effect of Speed

The variation of the friction coefficient of nano titanium oxide TiO_2 versus the rotating speed at constant load 50 N is shown in Fig. 5. It is important to notice that lithium grease dispersed by 2 wt. % TiO_2 displays highest value, while 6 wt. % displays lowest value of friction coefficient. It can be concluded that friction coefficient was improved due to adding nano titanium oxide with concentration of 6 wt. %. Increase the friction coefficient to 8 wt. % may be due to the increase of additive concentration that causes the increase of grease viscosity. Figure 6 illustrates friction coefficient of the nano silicon oxide SiO_2 for different concentration versus the rotating speed at constant load 50 N. It

is showed that nano SiO_2 at high speed give good result because the friction coefficient almost constant, while friction coefficient decreased with increased concentration at 2 wt. % displays highest value and 8 wt. % displays lowest value. Friction coefficient for hybrid nano oxides for different concentration versus the rotating speed at constant load 50 N is presented in Fig. 7. It is found that hybrid nano oxides at high speed give good result because the friction coefficient values were constant when rotating speed increased at different concentration of the hybrid particles. Friction coefficient at 2 wt. % displays highest value and 6 wt. % displays lowest value.

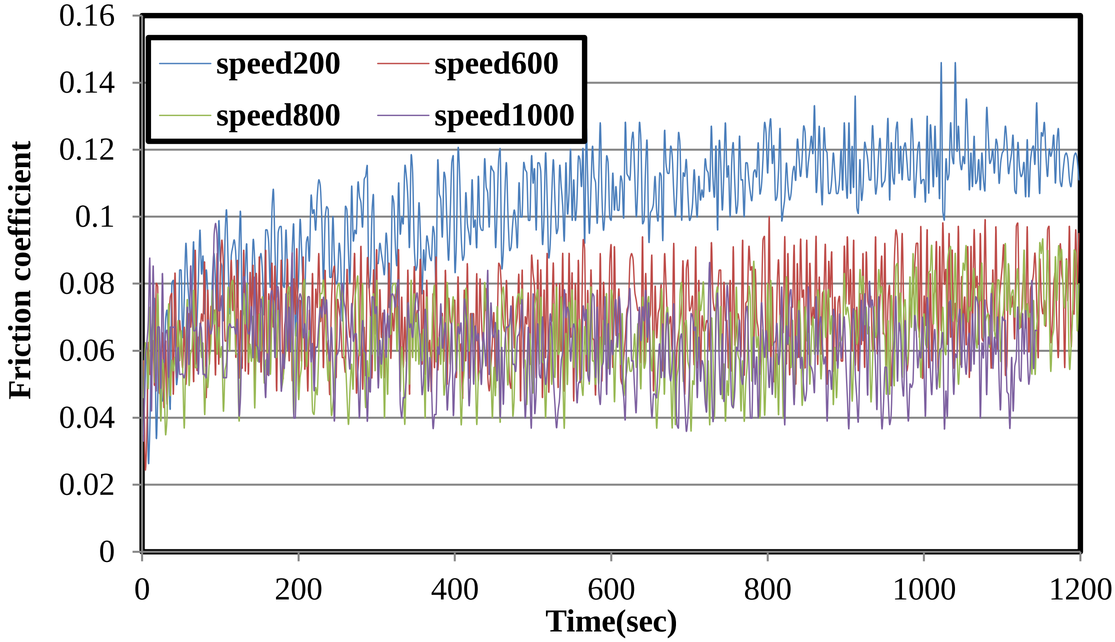

Fig. 3 Friction coefficient with time for different speed (rpm) at 6 wt. % titanium oxide.

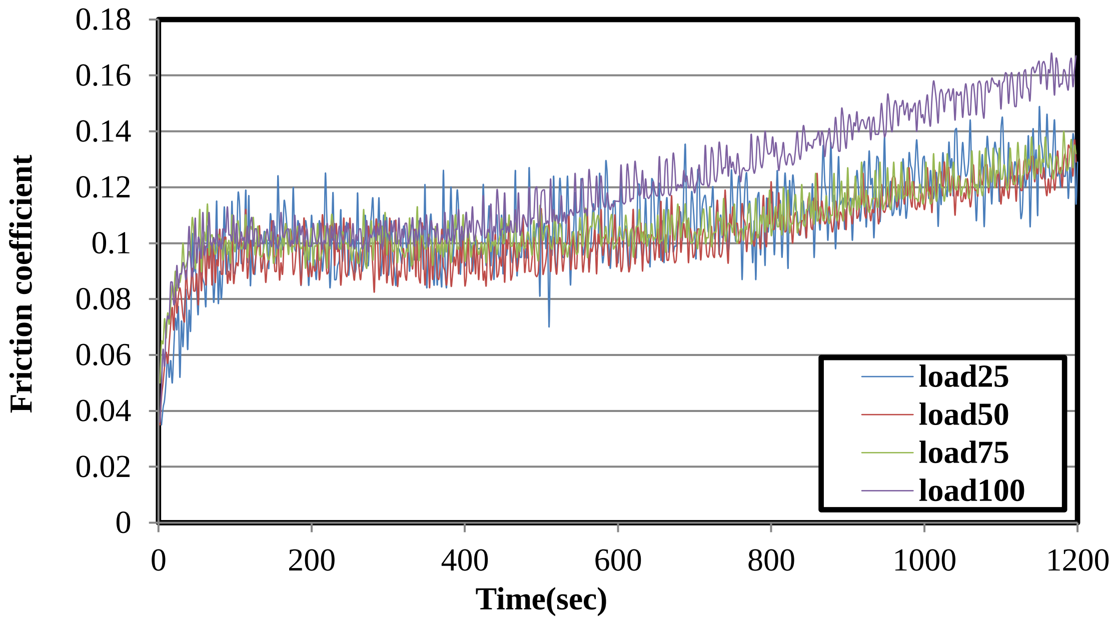

Fig. 4 Friction coefficient for different load values.

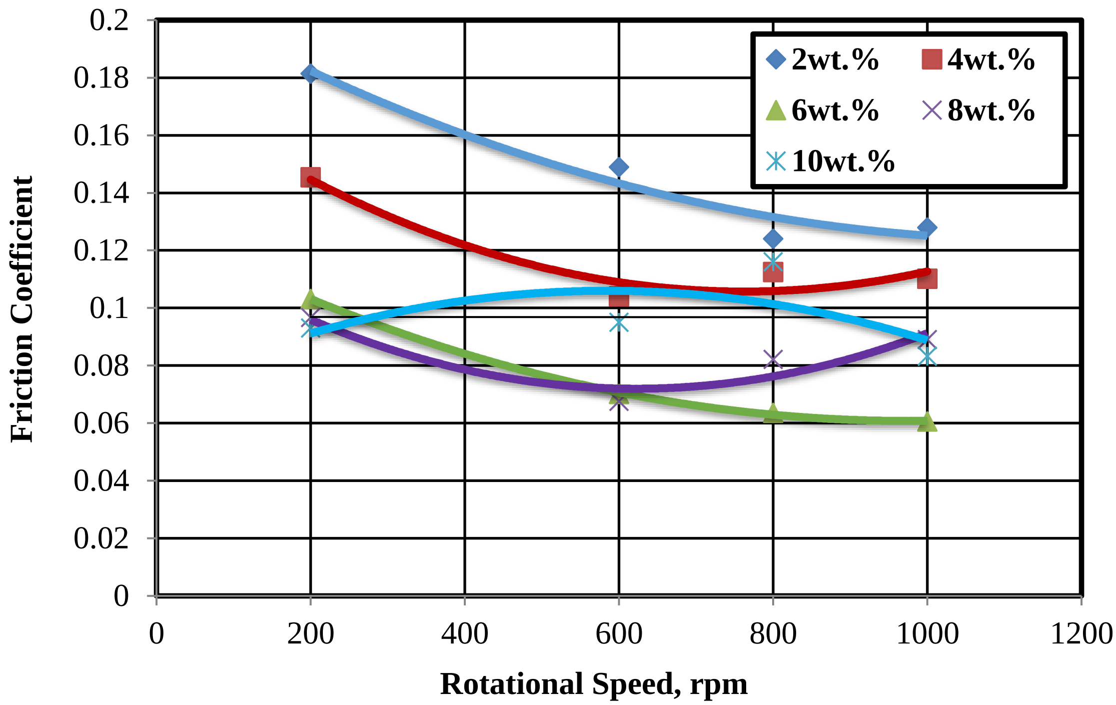

Fig. 5 Friction coefficient measured of nano titanium oxide.

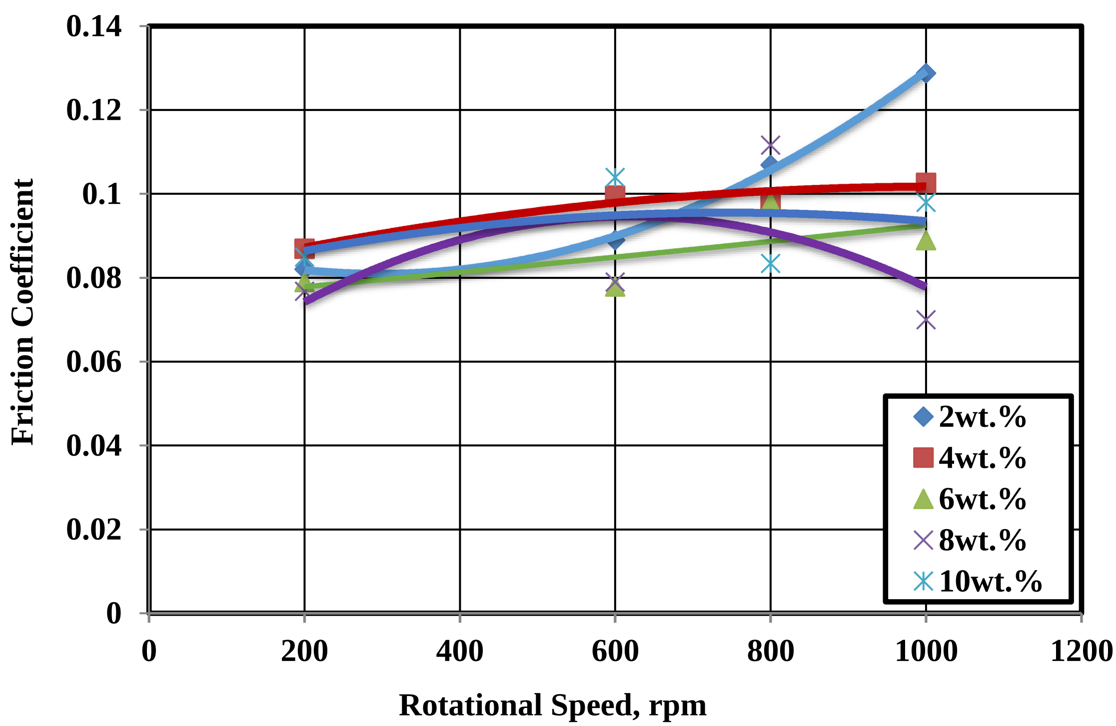

Fig. 6 Friction coefficient curves measured of nano silicon oxide.

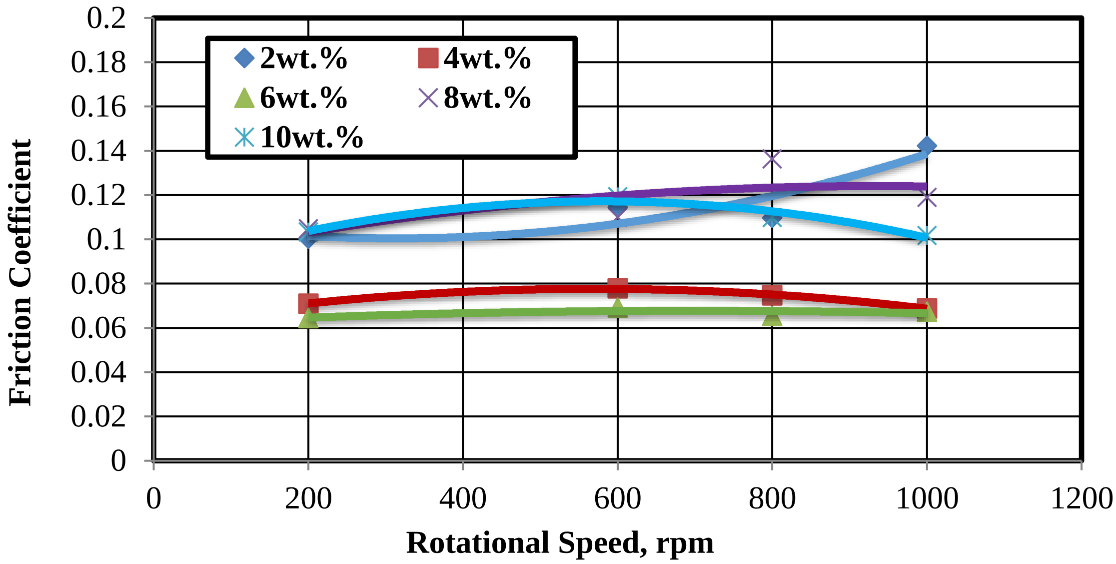

Fig. 7 Friction coefficient curves with speed measured of hybrid nano oxides.

The effect of rotating speed on the friction coefficient are presented at 6 wt.% in Fig. 8. It is seen that friction coefficient of nano TiO_2 as addition to lithium grease decreased when rotational speed increased and nano SiO_2 and hybrid nano oxides are constant when rotational speed increased so they gave best result at high speed.

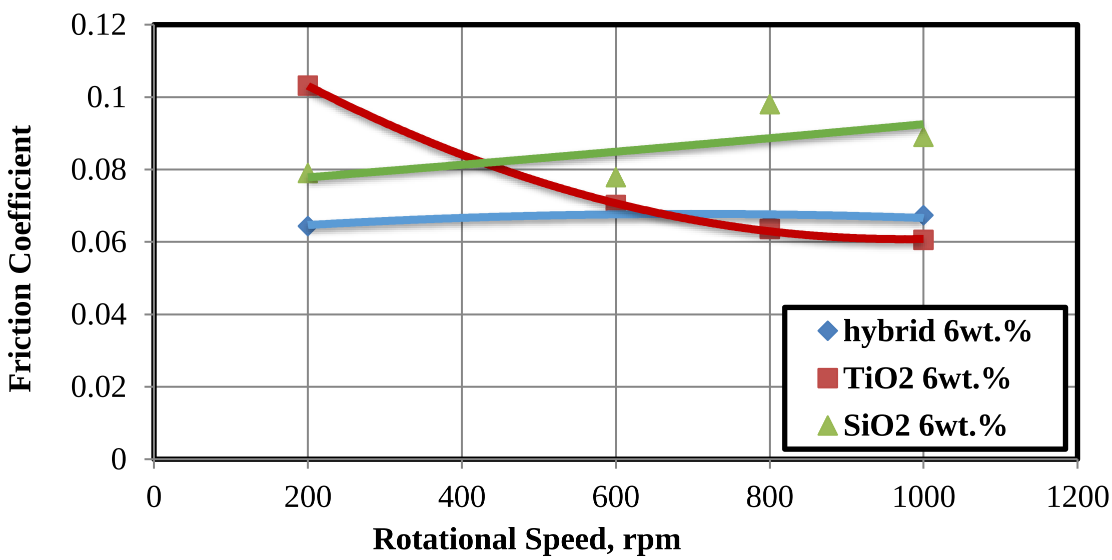

Fig. 8 Friction coefficient curves for 6 wt. % of different additives.

Effect of Load

Friction coefficient with the variation of normal load at constant speed 200 rpm is presented in Fig. 9. Friction coefficient decreased with the increase of normal load within the observed range at 4 wt. %. Friction coefficient at 2 wt. % displays highest value at 4 wt. % and 6 wt. % displays lowest value. It can be concluded that nano TiO_2 at high load gives best result of friction coefficient. Friction coefficient with load for

different concentration of the nano silicon oxide SiO_2 at constant speed 200 rpm is shown in Fig. 10. It is noticed that friction coefficient decreased with increased concentration. Grease dispersed by 4 wt. % additives displays highest value while that of 8 wt. % displays lowest value. Friction coefficient of nano silicon oxide SiO_2 increased with increasing load. Figure 11 illustrates friction coefficient with the variation of normal load at 200 rpm speed. It is found that, friction coefficient at 4 wt. % displays highest value, while 10 wt. % displays lowest value and the friction coefficient values is increased when load increased.

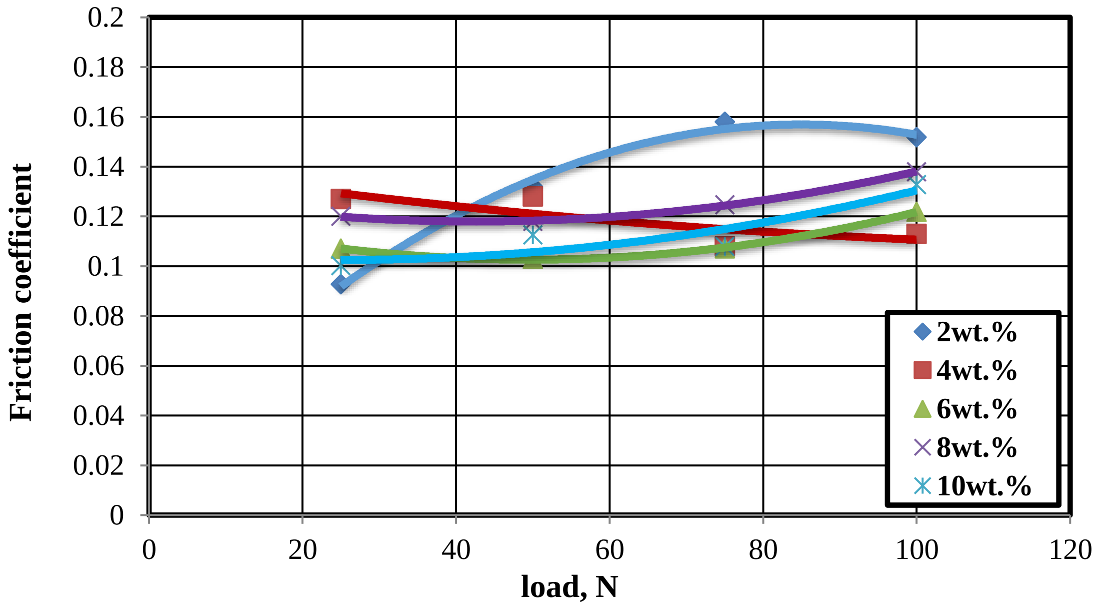

Fig. 9 Friction coefficient curves with load measured of nano titanium oxide.

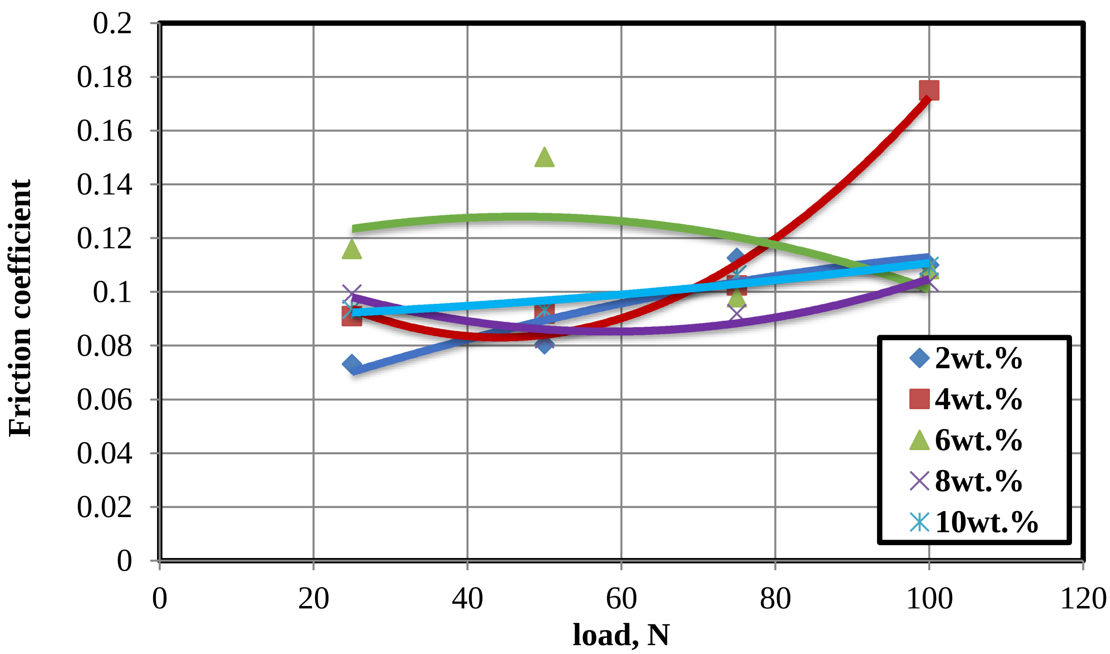

Fig. 10 Friction coefficient curves with load measured of Nano Silicon oxide.

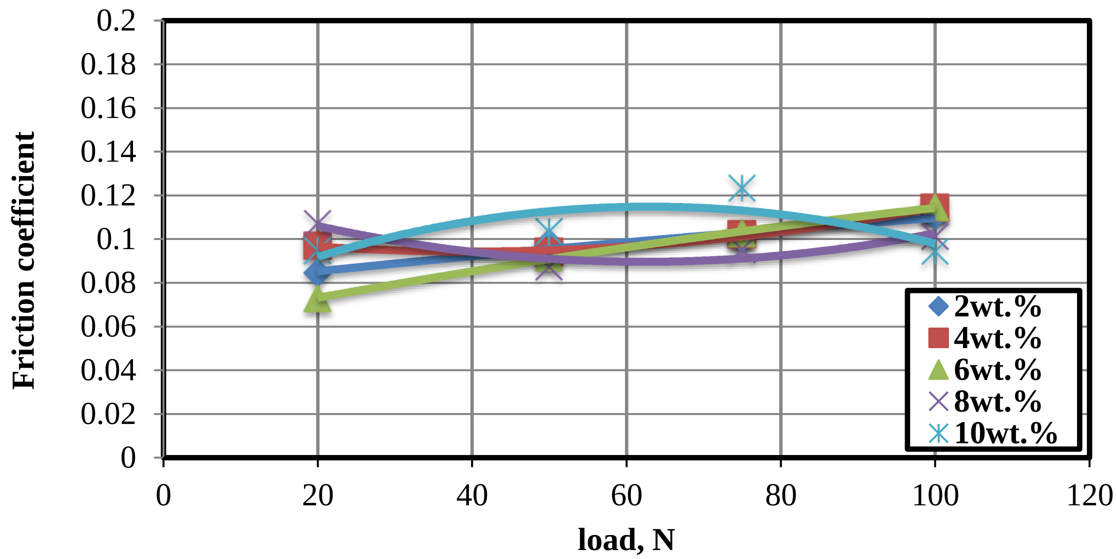

Fig. 11 Friction coefficient curves with load measured of hybrid nano oxides.

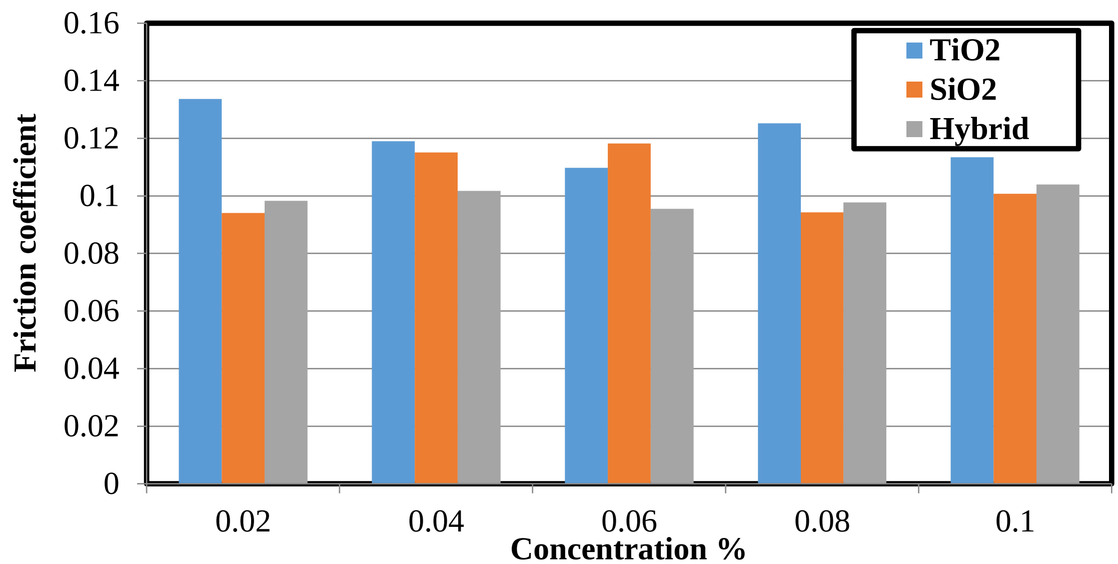

Fig.12 Effect of additives content on the friction coefficient with different loading.

Nano oxides particles exhibit different tendencies of friction behavior depending on additive content. Shape, size and hardness should be considered when using solid additives. Comparison between the friction coefficient at different load and 200 rpm rotational speed is shown in Fig. 12. It is important to notice that hybrid, SiO_2 at 6 and 8 wt. % gave the best result of friction coefficient. Effect of different Nano oxides particles content in lithium grease on friction coefficient of the test specimens at different rotational speed and 50 N load is presented as comparison to the study in Fig. 13. It is seen that hybrid, TiO_2 at 6 wt. % gave best result of friction coefficient. At different rotating speed and load, TiO_2, SiO_2 nano-particle additives can efficiently improve the lubricating properties of the lithium grease but hybrid nano oxides at high speed and load gave best result, where friction coefficient decreased with increasing concentration

of nano oxides particles. Friction coefficient of the rubbing interface is reduced by 40 %, at 6 and 8 wt. % of nano-particles dispersed in lithium grease.

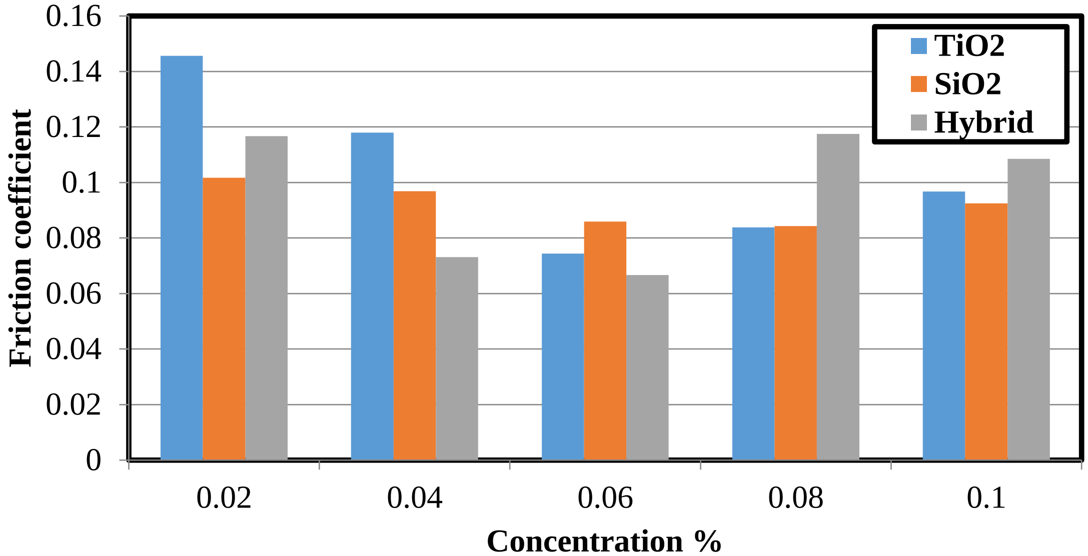

Fig.13 Effect of additives content on the friction coefficient with different rotational speed.

CONCLUSIONS

Based on the results from the experimental work (tribological properties), the following conclusions can be drawn:

1. Due to nano oxides particles, introduced in lithium grease, friction coefficient of pin on disk friction pair is reduced by 40 % at 6, 8 wt. % concentration.

2. Nano SiO_2 at high speed gave good result represented in consistent friction coefficient.

5. Friction coefficient is decreased when concentration of nano oxide material increased and gave the best result at 6 wt. % and 8 wt. %.

6. Different rotating speed and constant load hybrid, TiO_2 and SiO_2 Nano-particle gives minimum value for friction coefficient at 6 wt. %.

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