Evaluation of Tribological Characteristics of Carbon Nano Tubes for Lubricants at Extreme Pressure

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Abstract - *In the present work lubricant lithium and calcium with carbon nano tubes strengthened on grease were prepared. Multi-walled carbon nano tubes are allotropes of carbon with molecular structures that are tubular in shape. The carrying power of nano-lubricants was characterized at extreme pressure (EP). Carbon nano tubes displayed drastically improves load carrying ability and reduced frictional properties. The percentage of coefficient of friction reduced by 78.37% and the frictional torque decreased by 88 % at the same concentration. Because of these changes, the hallow multi-walled tubular shape and high elastic modulus will allow them to withstand the loads and thus decreases metal to metal contact.*

***Key Words*: CNT- Lubricant, Frictional coefficient, Extreme pressure**

1.INTRODUCTION

The introduction of different carbon nano lubricants has shown huge advantages, especially in improving the efficiency of industrial processes. Sridharan U et. al [1] and Shen B et. al [3] have shown many of the production processes profiting from the use of nano-lubricants and
Optimization of surface roughness on slitting knives by titanium dioxide nano particles as an additive in grinding lubricant. The benefits of nano-tubes additives have been a major reduction in the coefficient of friction (COF), decreasing the load carrying force in the machining process and a decrease in the process energy consumption. Rajmohan et. al [6] have shown modelling and analysis of cutting force in turning of AISI 316L stainless steel (SS) under nano cutting environment and Sharma AK et.al [11] have shown progress of nanofluid application in machining process. Rout IS et.al [5] have shown optimization of drilling parameters using nano fluid minimum quantity lubrication improve the manufacturing part's durability by reducing the thermal stress for high pressure application (EP) and Khalilpourazary S et.al [12] have shown Investigation of the effects of alumina nanoparticles on spur gear surface roughness and hob tool wear in hobbling process. Many research studies have focused on frictional reduction and lubricant load carrying ability with different types of nano-tubes Abdullah MIHC et.al [13] and Pena Paras L et.al [17]. As compared to the grease without the CNTs, the friction coefficient was reduced by 26%. Kobayashi et al. [16] has studied the effect of carbon nano-horn additives on grease lubrication to improve the wear, friction reduction, and EP properties. Masuda-Jindo K et al. [19] have shown Fracture and mechanical properties of nanotubes and nanowires. Yu M. et al. [22] have shown strength and breaking mechanism of multiwalled carbon nanotubes under tensile load, several research studies centered on friction reduction and lubricants load carrying ability with many types nano-tubes, it was for this reason that their exceptional mechanical properties such as a module of up to 1TPa and tensile strengths of 11-63GPa were explored. NiB, Sinnott S B et al. [23] have shown Tribological properties of carbon nanotube bundles predicted from atomistic simulations, the Ni and Sinnot tribological enhancement mechanism depends on the working conditions at low pressures CNTs pose a rolling/sliding mechanism, while CNTs move between the surfaces at high pressure like a tank belt. Bhaumik S. et al. [24] have shown Extreme pressure property of Carbon Nano Tubes (CNT) based nanolubricant and Thermal transport and tribological properties of Nano greases for metal-mechanic applications. Pena-Paras L et al. [25, 26]. Cornelio JAC et al. [27] have shown Tribological properties of carbon nanotubes as lubricant additive in oil and water for a wheel rail system, as shown in the literature, CNTs have greatly improved tribological characteristics of the lubricants. For example, Bhaumik [24] found that the load of synthetic grease with 0.1wt. % increased by 25% CNTs. Another research showed that the industrial grease pressure loss capacity was increased with CNTs by 10-15 % [26]. At 0.1wt.% CNTs, for deep drawing applications, the load carrying capacity of synthetic and mineral oil increased by 21% and 36% respectively. Finally, Cornelio JAC et al. [27] when tested in a wheel rail network, CNTs have friction reducing properties. The simulation of their modulus through molecular dynamics was predicted to range from 0.125 to 1.5TPa [29]. The carbon nano-tubes are created by circular CNTs that link their two ends. Since of this excellent properties and their overlap with CNTs, we suggest carbon nano-tubes as lubricant additives. In this research, nano-lubricants consist of different concentrations of carbon nano-tubes with a lubricant. Throughout this work, nano-lubricants consist of varying concentrations of carbon nano-tubes with lubricant; lithium and calcium-based lubricants are commonly used for metal forming and metal working applications and are prepared and checked to evaluate their tribological properties under EP condition [25]. In such conditions also the tribological mechanism is proposed. This paper is an extended version of the findings published at the congress of tribology.

CNTs added lubricants performance has been widely studied. However, literature available on multiwalled-CNTs added lithium and calcium-based lubricants performance is limited. Hence, current work aims to investigate the effect of various weight percentages of CNTs on tribological behaviour of CNTs added lithium and calcium grease and to conduct experiment in a different load conditions. The synthesized CNTs were used in the study as an additive. The structural, extreme pressure and friction characteristics of CNTs added grease was studied.

2. MATERIALS AND EXPERIMENTAL METHOD

2.1. Preparation of nano lubricants.

Nano lubricant of carbon nano tubes (CNTs) dispersed on lithium and calcium grease. As compared to the grease without the CNTs, the friction coefficient was reduced, has studied the effect of carbon nano-tube additives on grease lubrication to improve the wear, friction reduction, and EP properties. The percentage of CNTs have varied from 0.1wt.% to 1wt.% and speed also varied from 1760 to 3040.06 N. The extreme pressure parameter of lubricant used in the study is shown in table.1. Structural characterization of CNTs was employed using high-resolution transmission electronic microscopy (HRTEM).

Table -1: Extreme pressure test parameter

Parameters	Typical Values
Temperature	75^{0}C
Speed	1760 rpm
Time	10 minutes
Load	1667.13 to 3040.06 N

2.2. Tribological testing.

The load-carrying capacity of nano lubricants was determined with a four-ball testing machine, as shown in fig.1 (a), (b), (c), and (d), according to the ITEE-PIB Polish test method for testing lubricants under scuffing conditions. Three tests were run for each nano lubricant. Steel balls were of an AISI 52100 steel, with a diameter of 12.7mm. In this test nano lubricants are subjected to a linearly increasing load from 1667.13N to 3040.06N with a rotational speed of 1760rpm, a temperature of 75°C, for time 10minute. The scuffing load Point where occurs when a sudden increase in frictional torque appears along the run. When the frictional torque generated reaches 8.041 to 7.06N-m lubricant seizure occurs and the lubricant film is destroyed; the corresponding load at this point corresponds to the seizure load.

(a) Base Grease

(b) 0.4wt.% of CNTs

(c) 0.6wt.% of CNTs

(d) 1wt.% of CNTs

Fig-1: (a), (b), (c), and (d) the effect of percentage of CNTs under extreme pressure load

2.3. Study of viscosity of lubricant at elevated temperature.

The study of viscosity of lubricant at elevated temperature, the comparison of existing lubricant withstands at 180^{0}C and by adding percentage of CNTs with base grease and would operate at 262^{0}C. The effect of percentage of carbon nano tubes as shown in the Chart 1. By adding the CTNs, the optimal point of result is high temperature resistance.

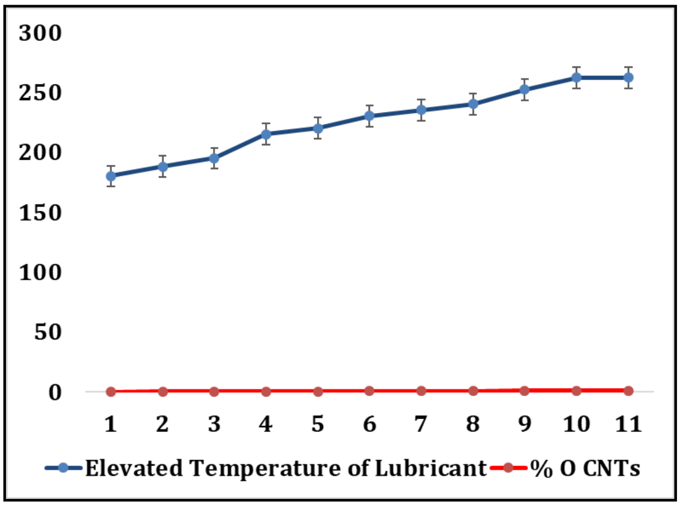


Chart -1: Effect of percentage of CNTs under elevated temperature

3. RESULTS AND DISCUSSIONS

3.1. Test analysis and compare electrical contact resistance (ECR) data.

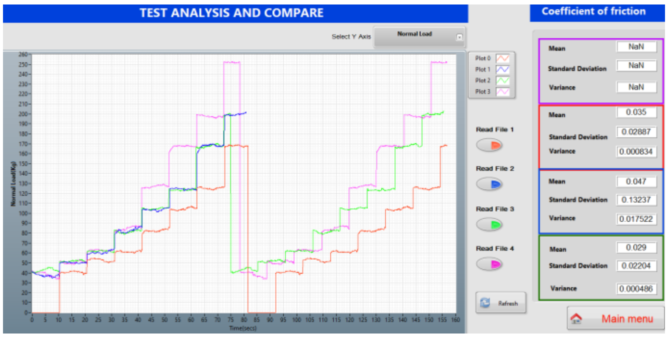
Consideration is provided to tribological behavior of electrical contacts, separable from the electrical connections by low contact charge. The strength of those connectors will lead to an excessive increase in contact resistance due to the fretting effect. This research analyzes various aspects of the fretting process from a tribological perspective, that friction is the primary cause of electrical directional degradation. Which friction is and is the primary cause of degradation of the electrical direction. The electric contact resistance and the frictional coefficient were measured using special tribological equipment (high data acquisition rate of 5000HZ) on the contact interface. The measurements were made in situ under various constant loading conditions for a simulated fretting environment. High contact load (1N) and high fretting frequency (1HZ) were observed resulting in high degree of friction coefficient fluctuation.

Consequently, the lowest wear rate and electrical contact resistance were observed for the same conditions. The lack of stable electrical contact and a high degree of fretting under low contact loads that eventually lead to prolonged open circuit periods may explain this. Experimental analysis shows an optimal loading condition in which fretting wear has lowest impact. Post fretting surface roughness and wear debris are analyzed in depth, as well as transfer film patterns to make the observed fretting phase clearer. Friction traces from the lithium and calcium grease and corresponding electrical contact resistance data for each of the test rotating a rotary motion of the extreme pressure condition for weld point, shows fig. 2(a) effect of percentage of carbon nano tubes on normal load under extreme pressure, pure grease load carrying capacity 1667.13N.

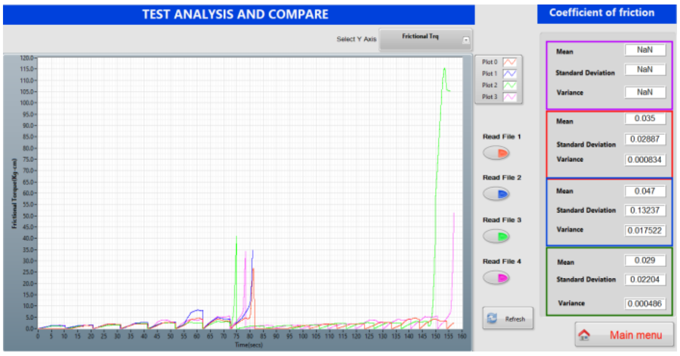
Fig. 2(b) showed the effect of percentage of carbon nano tubes on frictional torque under extreme pressure increasing percentage of CNTs at 0.1wt.% and also increase the load carrying capacity 1863.26 N. Fig. 2(c) shows, the effect of percentage of carbon nano-tubes on coefficient of friction under extreme pressure increase the percentage of CNTs at 0.6wt.% to 1wt.% and also increase the load carrying capacity 2843.92N to 3040.06N. The results shown, are indicate the lubricating films on ball to ball contact every seconds have recorded, if load increases decrease the coefficient of friction.

3.2. Effect of CNT addition on Tribological Behavior

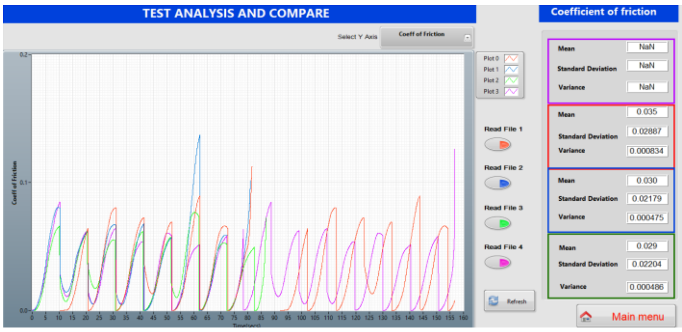
In the present study, influence of CNTs percentage on wear behavior of lithium and calcium lubricant was investigated. Further, CNTs percentage addition was varied from 0.1wt.% to 1wt.%. Fig.3, 4 and 5 illustrates the influence of CNTs addition percentage in lithium and calcium grease on extreme pressure on steel balls used in the study.



(a) Normal load under extreme pressure test



(b) Frictional torque under extreme pressure test



(c) Coefficient of friction under extreme

Fig-2: (a), (b) and (c) shows the effect of percentage of carbon nano tubes in different parameters

Tribological properties of CNTs. under extreme pressure (EP) and anti-wear (AW) conditions, the base grease lithium and calcium enhanced with carbon nano-tubes were prepared and characterized. Fig. 3 shows, effect of percentage of carbon nano tubes on load under extreme pressure condition concentration of CNTs under a load of 1667.13N to 3040.06N and rotational speed 1760rpm, every 10minutes constantly and gradually increase load up to weld point, fig. 4 shows, and effect of percentage of carbon nano tubes on frictional torque under the extreme pressure. Nano-lubricants showed a significant reduction in frictional torque for the EP study and a delay in initiation of scuffing, especially at concentration 0.6wt.% to 1wt.%. The load as

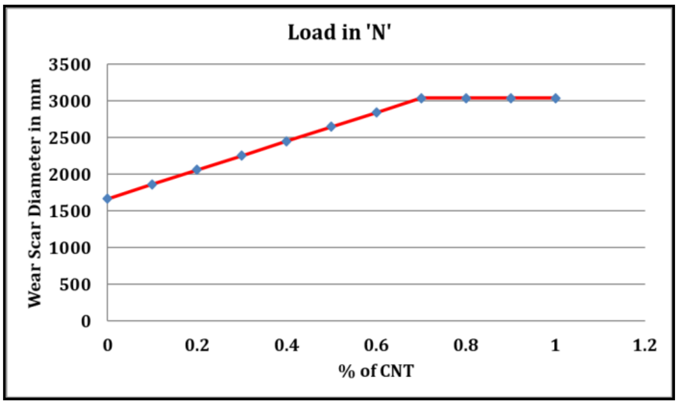


Fig-3: Effect of percentage of carbon nano tubes on load under extreme pressure condition

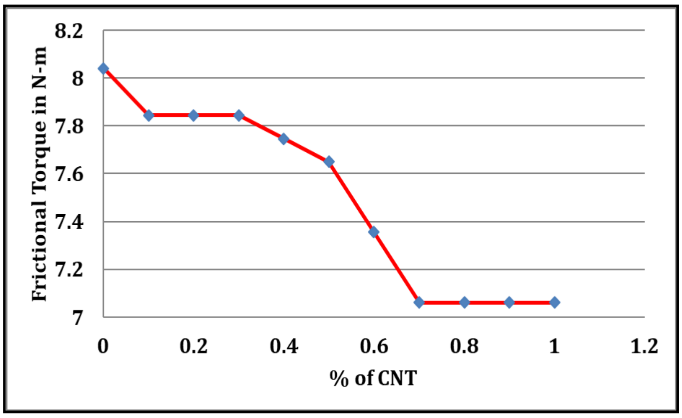


Fig-4: Effect of percentage of carbon nano tubes on frictional torque under extreme pressure condition

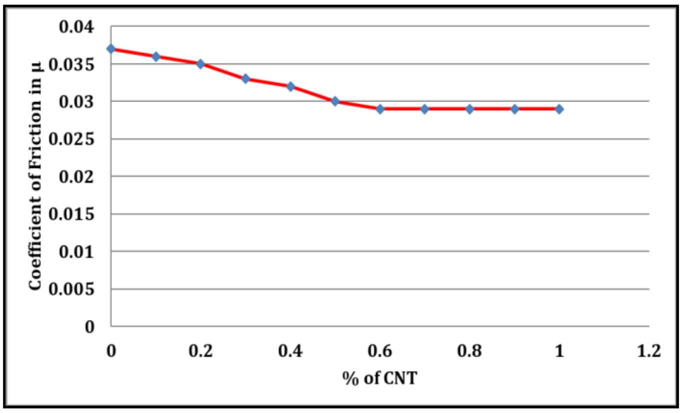


Fig-5: Effect of percentage of carbon nano tubes on coefficient of friction under extreme pressure condition

increasing gradually every 10minute to seizure point 2843.92N to 3040.06N. Such outstanding improvements are attributable to mechanical properties of carbon nano-tubes which during the able to withstand the pressure due to an effect of load bearing. While adding the CNTs with lubricant gradually decrease the frictional torque from 8.041N-m to 7.061N-m.

Fig. 5 shows the effect of percentage of carbon nano-tubes on the coefficient of friction under extreme pressure test by applying CNTs with base grease the coefficient of friction 0.037. For the anti-wear test with an increasing concentration of carbon nano-tubes material, a gradual reduction of the friction coefficient was found which restricted metal to metal due to rolling/sliding of nano-tubes. Extreme load carrying capacity pressure is high at this stage and the grease performance has been increased by 55%. This suggests that with clear proof, CNTs have excellent load carrying capacity, and an extreme pressure good property.

3.3. Weld test Extreme pressure

With four ball testing machines, the load carrying ability of the nano lubricant was calculated. The effect of the intense pressure test was shown in fig.6 on steel balls under load scuffing conditions of lubricant. Three tests were run for each sample of nano lubricant, and a surface roughness average of 0.28µm. In this test, nano lubricants are subjected to increasing load from 1667.13N to 3040.06N with a speed of 1760rpm and the load and frictional torque appear along the run every 10 minutes. The seizure load corresponds to the frictional torque produced by the seizure of 2.7Nm to 3Nm lubricant and the lubricant film is destroyed at this stage.

The load-carrying capacity of nano-lubricants was determined with a four-ball four ball test set up. The effect of extreme pressure test on balls under load weld point shown in Fig.1(a) base grease without CNTs seizer point and fig.1(d) optimal seizer point at 1wt.%. The friction coefficients were captured through data acquisition software connected to a four-ball tester. The friction force was recorded and divided by the applied load to obtain COF.

3.4. Elevated temperature of the viscosity of lubricant

The Elevated temperature of the viscosity of lubricant, the comparison of existing lubricant without CNTs withstand at 180°C and by adding percentage of CNTs with base grease it has been operated up to elevated temperature 262°C. The effect of percentage of carbon nano tubes as shown in the chart-1. By adding the CTNs, the optimal point of result is high temperature resistance.

4. CONCLUSIONS

The following findings can be summarized as set out in the results and discussion above,

- Nano-tubes with a lithium and calcium base and carbon-enhanced were prepared and characterized under extreme pressure (EP) and anti-wear (AW) conditions.
- Nano-lubricants showed as significant reduction in frictional torque for EP analysis and a delay in scuffing initiation, especially at 1wt. % concentrations.

- ❖ The loss-limit of scuffing, seizure load and pressure will be increased gradually every 10 minutes to a seizure point 2843.92N to 3040.06N.
- ❖ Carbon nano-tubes greatly increase the load carrying ability, even outstanding properties against wear and friction. Load capacity increased with 1wt.% by up to 55%. The percentage friction coefficients (COF) decreased by 78.37% and frictional torque decreased by 88%, at the same concentration, respectively.
- ❖ These impressive changes are attributable to the mechanical properties of carbon nano-tubes which have been able to withstand the extreme pressure due to the load bearing impact during the test.
- ❖ For the study, a gradual decrease in wear mass loss and COF with increased content was observed which restricted metal to metal contact due to rolling/sliding nano-particles.
- ❖ The findings in this paper suggest that carbon nano-tubes can be used as EP and AW additives for metal forming processes for lithium and calcium based lubricants.

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