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AN INVESTIGATION OF TRIBOLOGICAL BEHAVIOUR OF LUBRICATING OIL WITH THE ADDITION OF NANOPARTICLE ADDITIVES

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ABSTRACT
In this paper the tribological behaviour of silicon oxides (20nm) Nanoparticles and Nickel carbon coted (20nm) nanoparticles additives on 10W30 engine lubricating oil for improve the tribological properties of lubricants is presented. These nanoparticle were add to lubricating oil and which are made of different concentrations (0.5, 1, and 2 wt. %). The tribological behaviour was evaluated on a four ball oil testing machine according to ASTM D4172 B and also viscosity measured on Redwood viscometer. Result show that the each set of Nanoparticle significantly reduces the friction coefficient and wear of friction pairs and wear surfaces were analyses by scanning electron microscope (SEM).

KEYWORDS: Friction coefficient, Lubricating oil, nanoparticles, nanotubes, Wear behavior.

INTRODUCTION
Modern Internal combustion engine which has complicated design, structure and number of moving parts must be lubricated in order to prolong increase its life. A lubricant done these a number of critical function . Lubricant comprises a base fluid and an additive nanoparticals . The primary function of the base oil is to lubricate and act as a carrier of additives. The function of additives is an already-existing property of the base fluid or to add a new property. The examples of already-existing properties include viscosity index, pour point, flash point and oxidation resistance, wear resistance and extreme pressure properties. The examples of new properties include cleaning and suspending ability, anti-wear performance, and corrosion control.

LITERATURE REVIEW
GU Cai-xiang et al have studied lubricating oils containing CeO2 and TiO2 nanoparticles and the tribological properties of the oils were tested on four-ball tribotester. The results show that when the concentration by weight of CeO2 and TiO2 nanoparticles is 1:3, and the total weight fraction is 0.6%, the lubricating oil shows optimal anti-wear and friction control properties.(1)

R. Chou et al has reported addition of 20 nm diameter nickel nanoparticles with PAO6 synthetic oil and check the tribological behaviour on four-ball machine and concluded the addition of nickel nanoparticles to PAO6 results in a decrease in friction and wear and an increase in the load-carrying capacity of base oil.(2)

Harshwardhan H. Patil et al has been presented the tribological behaviour of SiO2 nanoparticles as additives in Paraffin based SN-500 oil and all tests conducted under variable load and concentration of nanoparticles in lubricating oil on tribotester. The experimental results show that nanoparticles SiO2 added into base oil shows good friction reduction and anti-wear properties (3).

M. Asrul et al has looked out CuO (50nm) nanoparticle was mix at 0.2, 0.25, 2 and 3% in liquid paraffin using four-ball machine. The lowest coefficient of friction was 0.185 obtained for a nanoparticle content of 0.2% concentrated CuO and the highest was for a 3% CuO concentration at 0.247 for liquid Paraffin +CuO without modification suspensions (4).
Juozas Padgurskas et al have presented tribological testing were performed on mineral oil containing Fe, Cu and Co nanoparticles and their combinations. The tests showed that each set of nanolubricants lower the friction coefficient and wear (up to 1.5 times) of friction pairs (5).

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V. Zin et al have reported different kinds of nanoparticles were tested as additives to engine oil to improve lubrication. Copper and titanium oxide nanoparticles and single walled carbon nano horns (SWCNHs) the suspension viscosity and stability were also tested. Wear tests also carried out and showing a reduction of wear rate up to nearly 50% for Cu nanoparticles (150 nm diameter) and around 30% for SWCNHs (6).

LauraPeña-Parás et al have been presented tribological properties of friction, wear, and extreme pressure of two synthetic lubricants (SAE75W-85) fully-formulated oil and Poly-alpha olefin 8(PAO8) used as a base oil. These lubricants were doped at various filler concentrations (0.5, 1.0, and2.0wt %) of CuO and Al2O3 nanoparticle additives. Anti-wear tests were performed with an extreme pressure tests on four-ball tribotester. Results showed a decrease of upto18% and 14% on coefficient of friction (COF) and WSD with 2wt%CuO/PAO8 and The load carrying capacity by 14% and 273%, respectively, with the addition of CuO nanoparticles (11)

MATERIALS AND METHOD

Materials

Silicone oxide and Nickel (Carbon coted) nanoparticles fig 1and fig 2 were used for additive in SAE 10W30 Lubricating oil which has no additive. These Nanoparticles was purchased from Intelligent Materials Pvt.Ltd. The specifications of the nanoparticles and lubricating oil are shown in Table 1, 2 and 3 respectively.

Silicon Oxide(SiO2)

Fig 1: Silicon Oxide (SiO2) Nanoparticle

Table I. Specification of Silicon oxide (SiO2) nanoparticle

Silicon oxide (SiO2) nanoparticle	
Appearance	White
Purity	99 %(Amorphous)
APS	20-30 nm
SSA	110-120 m^2 /g
Bulk Density	<0.10g/cm^3
Ultraviolet Reflectivity	>75%
SiOx	10ppm
Al	10ppm
Fe	30ppm
Sr	40ppm
Ca	20ppm
Mg	20ppm
Cl	10ppm

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- *Nickel (Ni) carbon coated*

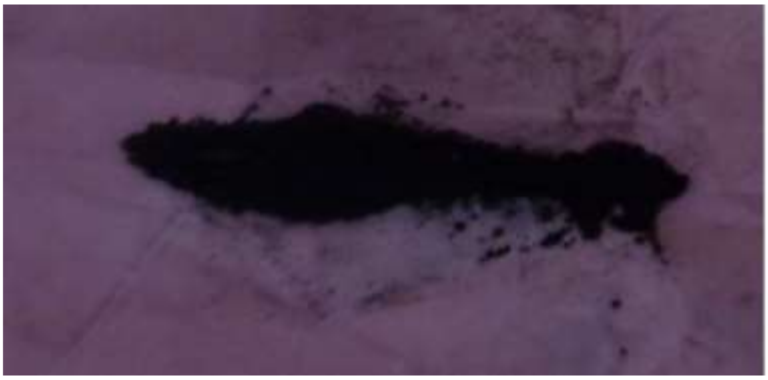

Fig. 2: Nickel (NI) carbon coated Nanoparticle

Table II. Specification of Nickel (Ni) carbon coated Nanoparticle

Nickel (Ni) carbon coated nanoparticle	
Appearance	Grey and black powder
Purity	99%(metal basis)
APS	20 nm
SSA	30-50 m^2 /g
Morphology	Spherical
Bulk Density	0.10-0.25/cm^3

Apparatus

A magnetic stirrer ASMS 84 (MFG.by REMI EQUIPMENTS, Mumbai, India) was used for dispersion of nanoparticles in SAE 10W30 engine oil shown in fig.3, Four Ball Tester TR-30L-IAS (MFG. by DUCOM, Bangalore, India) was used for performed wear and friction test at Amrutvahini College of engineering, Sangamner, india. Shown in fig.4 Also Redwood Viscometer was used for viscosity test.

Fig.3: Magnetic stirrer mfg.by Remi Equipments,Mumbai,India

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Fig.4: Four ball tester mfg.by Ducom,Bangalor,India

Preparation of testing materials

The conventional method magnetic stirrer mixer was used for Preparation of nanolubricants. The concentration of nanoparticles with 10W30 engine oil was prepared to 0.5, 1, and 2 wt. %.shown in Table. III

Table III. Preparation of nanoparticle

Samples		Title	Nanoparticle	Content of nanoparticle(g/50 ml)
Viscosity	*Wear*			
A_1	B_1	SAE 10W30		
A_2	B_2	SAE 10W30 +Sio2	Sio2	0.5
A_3	B_3	SAE 10W30 +Sio2	Sio2	1
A_4	B_4	SAE 10W30 +Sio2	Sio2	2
A_5	B_5	SAE 10W30 +Ni	Ni	0.5
A_6	B_6	SAE 10W30 +Ni	Ni	1
A_7	B_7	SAE 10W30 +Ni	Ni	2
A_8	B_8	SAE 10W30 +Sio2 +Ni	Sio2 +Ni	0.25+0.25
A_9	B_9	SAE 10W30 +Sio2+Ni	Sio2 +Ni	0.5+0.5
A_{10}	B_{10}	SAE 10W30 +Sio2+Ni	Sio2 +Ni	1+1

EXPERIMENTAL

Viscosity test

Kinematic viscosity of the base oil and also nanoparticle lubricant samples which were made at (0.5, 1, 2 wt. %) different concentrations, were measured on the basis of American Society for Testing and Materials Redwood viscometer (ASTM) D-445.In this test 50ml of oil was used for each test. The each test taken 50, 60 and 70^0 C also each test was repeated three time and the measured results are shown in table IV.

Table IV. Kinematic viscosity results

Sample	50^0C	60^0C	70^0C
A_1	54.28	47.17	26
A_2	70.72	53.38	39.95

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A_3	72.44	58.95	42.2
A_4	82.02	60.73	45.34
A_5	58.28	48.92	38.6
A_6	61.17	44.67	34.07
A_7	67.17	45.36	37.24
A_8	65.17	51.6	43.1
A_9	67.91	58.95	37.09
A_{10}	66.13	50.12	44.28

The rate of oil resistance against flowing is called viscosity. The obtained results are shown in table IV and fig.5, 6, 7 and 8.As it can be seen that the viscosity of nanolubricants at each sample of the 50, 60 and70°C temperatures had increased by increasing the concentration of nanoparticals. The highest amount of increase in viscosity with respect to the base fluid is 82.02 cst which is SiO2 2Wt% concentration and 50°C temperature.

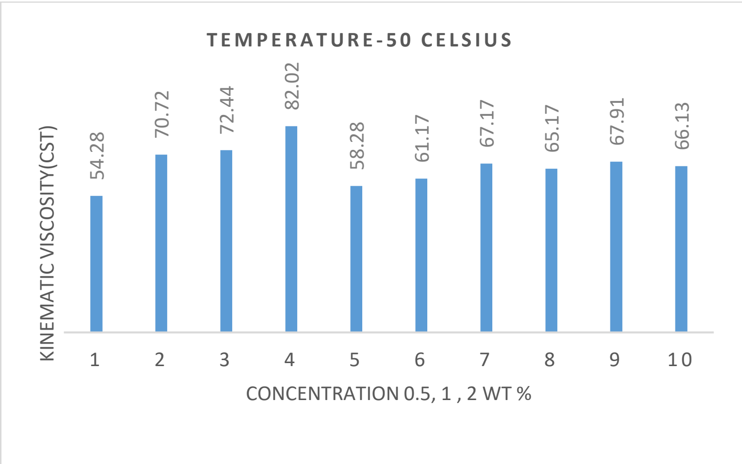

***Fig. 5: Kinematic viscosity graph of 50^{0}C Temperature*.**

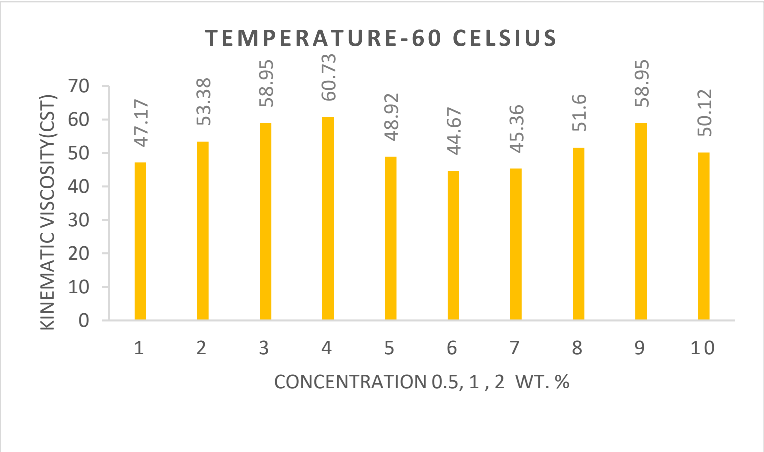

Fig. 6: Kinematic viscosity graph of 60^{0}C Temperature.

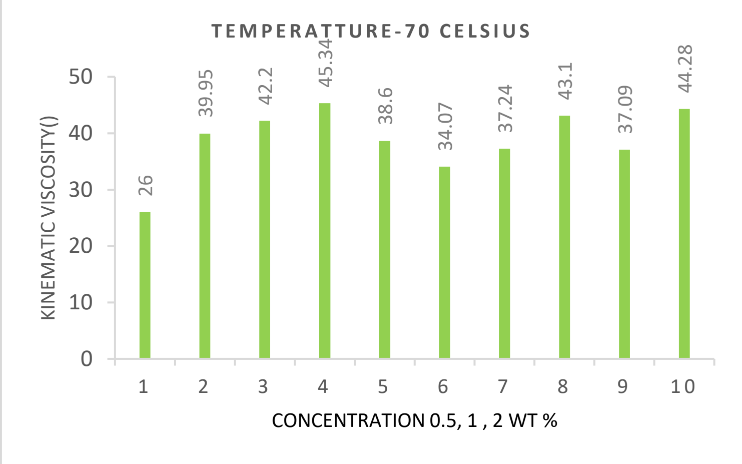

Fig. 7: Kinematic viscosity graph of 50^{0}C Temperature.

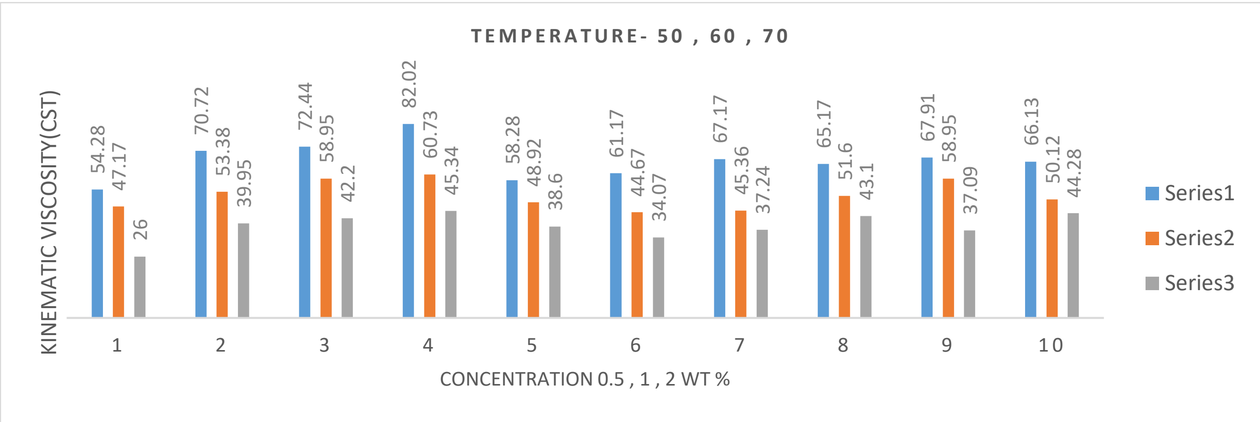

Fig. 8: Kinematic viscosity graph of 50,60,70^{0}C Temperature.

Tribological tests

The tribological test was done on four ball tribotester TR-30L-IAS (MFG. by DUCOM, Bangalore, India). All test components before and after each test were cleaned using acetone. The wear tests were performed at ASTM D4172B, speed 1200rpm, load 40kg (392 N), Temp- 75^{0}C and test duration 1 hour shown in fig.9 the four bearing steel ball 12.7 mm diameter were used for this test.

Fig.9: ASTM D4172B conditions.

The three lower balls wear scar diameter measured using computerized image acquisition system and optical microscope (MFG. by DUCOM, Bangalore, India) shown in fig.10 and the three lower balls average wear scar diameter was calculated in this experiment. All tests coefficient of friction were stored automatically by the computer linked with four ball tester during each test.

Table IV. Results of wear test

Title	Wear scar diameter(micron)			
	Ball 1	*Ball 2*	*Ball 3*	*Average*
10W30	609	622	632	621
10W30+SiO2 (0.5%)	600	555	622	592.33
10W30+Ni (0.5%)	547	607	555	569.66
10W30+Sio+Ni (0.25+0.25)	517	555	515	529
10W30 +SiO2 1%	517	448	473	479.33

Fig.10: Image Acquisition system mfg.by Ducom Bangalore, India.

Table IV shows the obtained results of wear test. And fig.11, 12, 13 and 14 gives the mean wear scar diameter which measured using microscope.

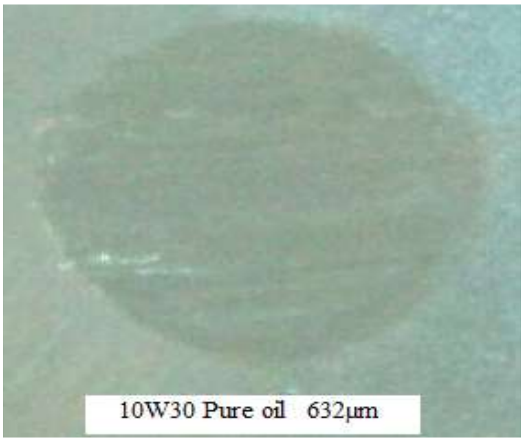

Fig.11: SEM micrograph worn surface on 10W30 ball under lubricated

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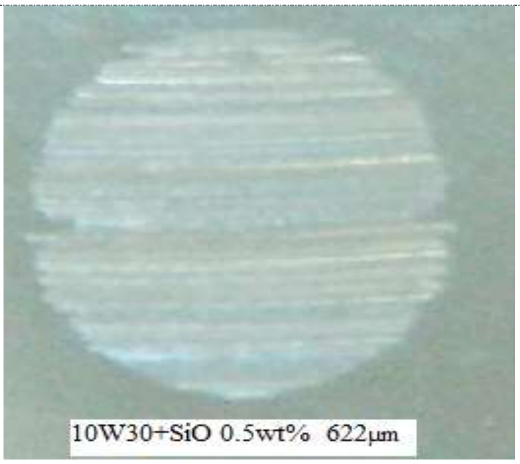

Fig.12: SEM micrograph worn surface on 10W30+SiO 0.5 wt. % ball under lubricated conditions

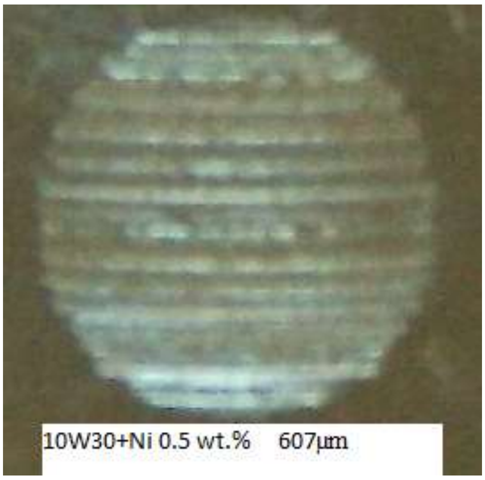

Fig.13: SEM micrograph worn surface on 10W30+Ni 0.5 wt. % ball under lubricated conditions

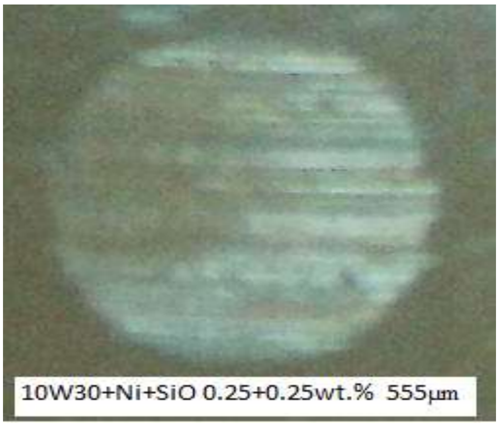

Fig.14: SEM micrograph worn surface on 10W30+SiO+Ni 0.25+0.25 wt. % ball under lubricated conditions

Result shown that concentrated nanoparticle in base oil possesses excellent anti wear property and its reducing wear scar diameter and decrease in coefficient of friction shown in fig.15 and fig.16. The lowest coefficient of friction was obtained at 1% SiO2 blend with SAE 10W30 base oil.

The wear scar diameter and coefficient of friction have been reduced effectively at different concentration. The lowest friction coefficient (COF) was 0.09 obtained from 1 wt. % SiO2 with 10W30 lubricating engine oil and the highest was 0.16 SAE 10W30 pure lubricating oil.

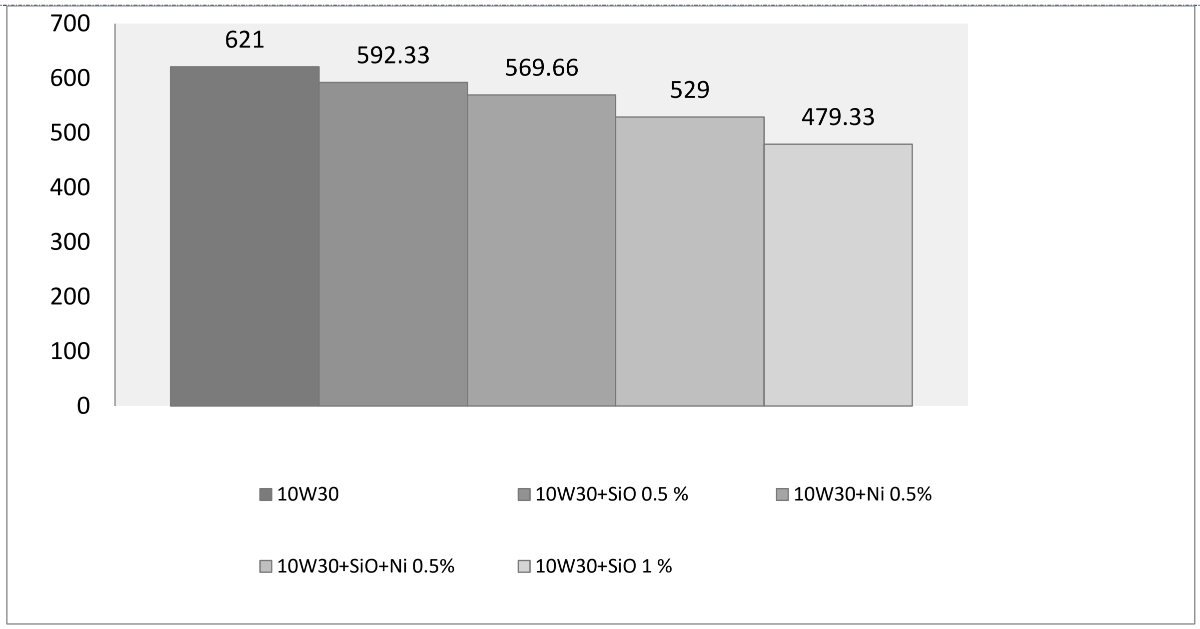

Fig.15.wear scar diameter for test suspensions

Table V Different concentration coefficient of friction

Title	Coefficient of friction
10W30	0.14
10W30+SiO2 (0.5%)	0.10
10W30+Ni (0.5%)	0.11
10W30+Sio+Ni (0.25+0.25)	0.12
10W30 +SiO2 1%	0.09

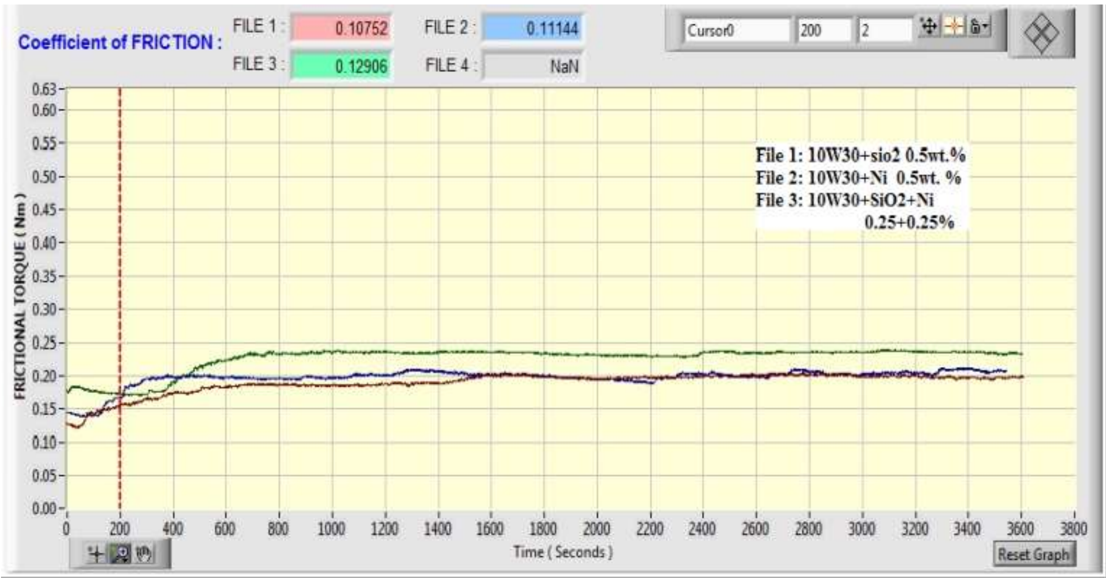

Fig.16: comparison between 0.5wt. % nanoparticle concentration with base oil

CONCLUSION

So finally, it can be conclude that Nickel (carbon coated) and Silicon Oxide effectively blend with SAE 10W30 base oil and were shown the better tribological results.

As a result the viscosity of nanolubricants were increase at higher temperature and best results come SiO2 1% concentration.
All nanolubricants decreased the average friction coefficient and wear with respect to SAE 10W30 lubricating oil. The friction reduction was between 8% and 35% and wear was decreased between 4.6% and 23%.

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