Preparation of Modified Coconut based Nanofluid and its Tribological Studies on Mild Steel as a Lubricant

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***Abstract*: Vegetable oil based nanofluids are promising for industrial lubricants but low stability of nanoparticles in base fluid is one of the major drawback for long term usage. Therefore in this work improving the nanofluid stability through effective ultrasonic period. For this 0.5 weight% of reduced graphene oxide (RGO) was dispersed in modified coconut oil (20%PAO4+1%PPD+1.5% AO). The prepared solution to make homogenous mixture ultrasonication agitation was done by using an ultrasonic homogenizer at 60, 90, 120,150 and 180 min of durations. The prepared nanofluid stability with different ultrsonications was observed through SEM analysis, high quality sedimentation photographs and also through variation of thermo physical properties such as viscosity and thermal conductivity. After the preparation of nanofluid the friction and wear tests were conducted on mild steel using pin-on-disc tribometer for various sliding distances and loads the obtained results compared with modified coconut oil, bear coconut oil. From the results significant drop in friction and wear for mild steel is observed under modified coconut oil based nanofluid, modified coconut oil and compared to mineral oil.**

Keywords- Stability; Reduced graphene oxide; modified coconut oil; Ultrasonication

1. INTRODUCTION:

Modified vegetable oil based nanofluids used as a lubricant in various machining operations [1-2] However, during long term usage stability of nanofluids is most of the important criteria and efficiency during usage. In this regard, nanofluids are desired to have thermodynamic, kinetic, chemical and dispersion stabilities. Since nanofluids have been considered as advantageous in heat transfer applications due to their improved thermophysical properties. Therefore its stability improvement is needed. In this regard, a nanofluid with the stable dispersion can be defined in which the nanoparticles are mono-dispersed. Due to the presence of nanoparticle aggregates, the dispersion stability may decay with time [3]. To increase the lifetime, ultrasonication has been widely used, and has been accepted as an essential step in the production of nanofluids through two-step method [3]. However, no standard has been established to prepare nanofluids especially on how long should a nanofluid have to be homogenized, what type or durations of pulse mode should be used. Nevertheless, the National Institute of Standards and Technology (NIST, Gaithersburg, MD) with the Center for the Environmental Implications of Nanotechnology (CEINT of Duke University) has started to develop some standardized and validated protocols for the dispersion of nanoparticles[5]. Use of cooling bath, pulse mode operation, and cylindrical shaped flat-bottom beakers are some proposed guidelines. They urged that, the optimal ultrasonication parameters should be determined by considering different parameters of the ultrasound process. It could be noted that ultrasonication is a complicated physicochemical process, which can break down the agglomeration as well as create further aggregation, and many other effects together with chemical reactions [5]. However after evaluation stability of many researchers has been getting the contradictory results about the effect of ultrasonication duration on colloidal dispersion of nanoparticles [6-10]. However the prepared nanofluids in various heat transfer applications among which for machining applications widely used. For this various researchers prepared oils performance is initially evaluated through evaluation tribilogical properties[11]. An efficient lubricant reduces friction and wear, result in the decrease of energy consumption and improve the life of mechanical parts. Therefore, reduction of the friction and wear is an important issue, which needs to be study.

Therefore in this work, preparation of nanofluid with effective ultrasonication duration Further the prepared nanofluid its tribilogical studies were carried out on pin disc tribometer to evaluating the performance.

2. NANOFLUID PREPARATION THROUGH ULTRASONICATION

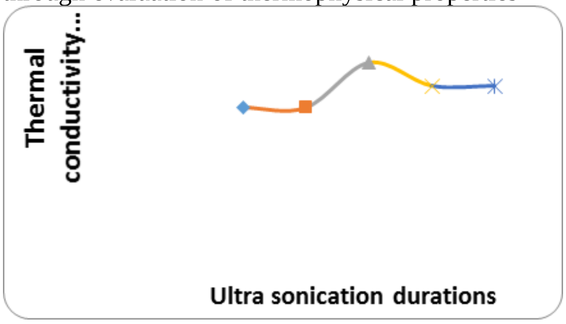
For this the prepared RGO[2] is dispersed in the base fluid at 0.5% of weight combination in the modified coconut oil [1], and the nanofluid is subjected to a ultrasonication frequency of 25 Hz for durations from 60-180 minutes insteps of 30 min. thereby in total five ultrasonicated nanofluid samples subjected to different sonication durations have been prepared using ultrasonic homogenizer

3. STABILITY EVALUATION THROUGH VARIATION OF THERMO PHYSICAL PROPERTIES

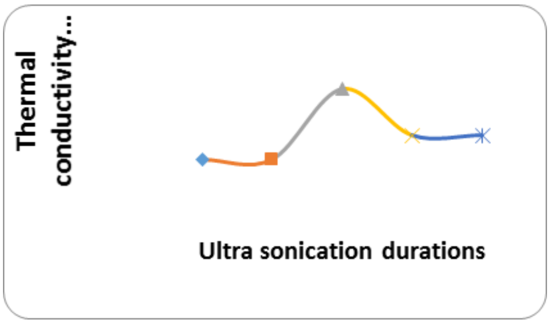
After ultrsonication agitation stability evaluation carried out through evaluation of thermophysical properties such as thermal conductivity and viscosity and also visualization and SEM analysis.

3.1 Variation of Thermal conductivity (day to day)

The thermal conductivity of the nanofluid at different concentrations and their variations different ultrasonication durations are plotted as shown in Fig.1. With the different ultrasonication durations of RGO thermal conductivity is found to be increasing after 60 minutes to 120 minutes ultrasonication durations at 20 and 30 days after preparation of oils. However, after 120 minutes ultrasonication thermal conductivity at 150 and 180 minutes gradually decreased but at 120 minutes of durations RGO was found to be stable upto 30 days of preparation.



(a) After 20 days

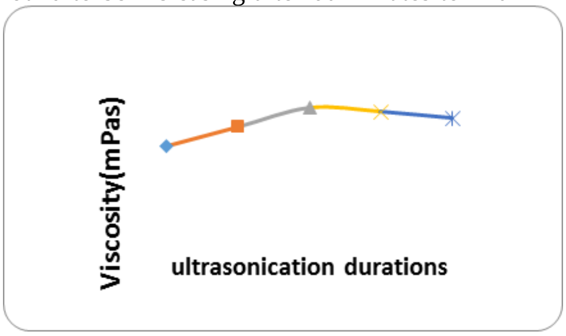


(b) After 30 days

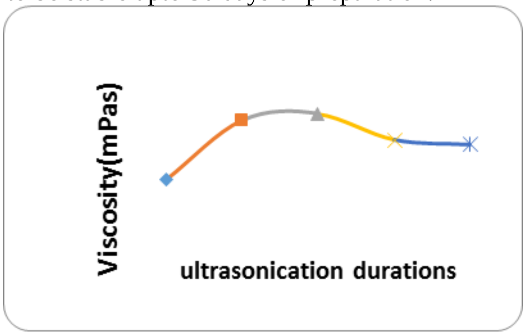
Figure 1: variation of thermal conductivity with respect to different ultrasonication durations

3.2 Variation of viscosity (day to day)

The viscosity of the nanofluid at different ultrasonications day to day are plotted as shown in Fig.2 With the different ultrasonication durations of nanofluid viscosity is found to be increasing after 60 minutes to 120 minutes ultrasonication durations at 20 and 30 days after preparation of oils. However, after 120 minutes ultrasonication viscosity at 150 and 180 minutes gradually decreased but at 120 minutes ultrasonication it was found to be stable upto 30 days of preparation.



(a) After 20 days



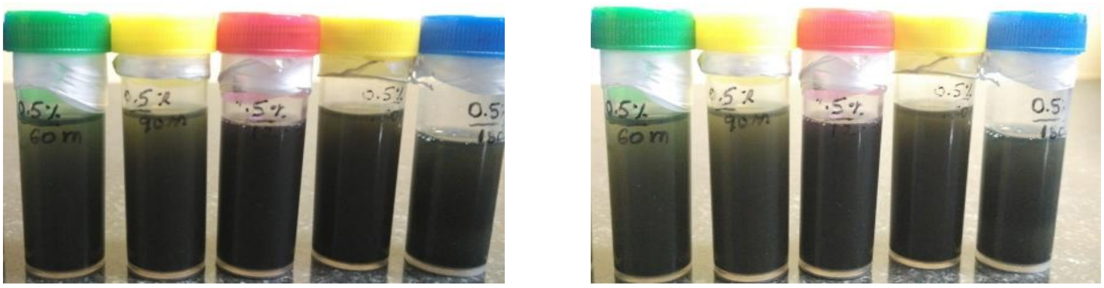
(b) After 30 days

Figure 2: Variation of viscosity with respect to different ultrasonication durations.

From the results it is observed that increasing ultrasonication duration of 120 min, dispersity of Nanoparticles became more even and homogeneous, and presence of agglomerates diminished significantly. This is attributed due to the fact that ultrasonic energy broke down the nanoparticle agglomerates, and it could yield a more homogeneous nanofluid sample. On the other hand, further increase of ultrasonication period resulted in a slight tendency for re-agglomeration, re-agglomeration of particles with the latter sonication period may be seen. Re-agglomeration of nanoparticles is an interesting phenomenon and from the ultrasonication point of view, it is due to higher power of ultrasonication could re-agglomerate the particles as a result of the increased collision of particles. The same phenomenon is further observed through sedimentation studies and SEM analysis in the following sections.

4. VISUALIZATION ANALYSIS OF NANOFLUID WITH DIFFERENT ULTRASONICATION DURATIONS

Fig.3(a)-(b) exhibit the sedimentation pictures of reduced graphene oxide-modified coconut oil nanofluid samples prepared through at different ultrasonic durations and after the 20 and 30days of preparation



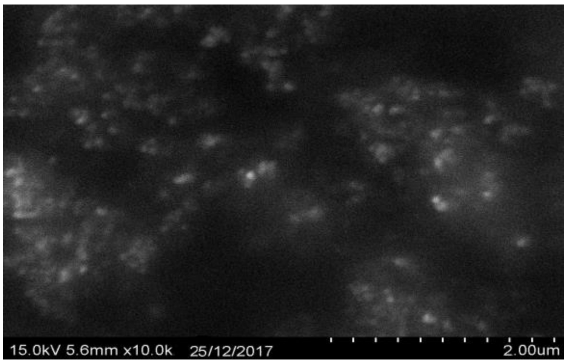
(a) After 20 days (b)After 30 days

Figure 3: Digital photographs of prepared nanofluid samples at different ultrasonication durations of 60-180 minutes insteps of 30 minutes

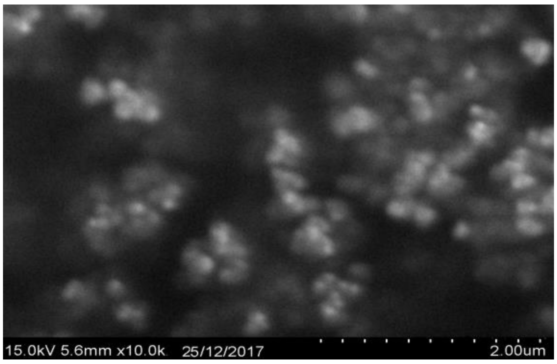
From the visual analysis it is observed that the sedimentation rate was found to very less for all the concentrations after the preparation of oil upto 20 days after that increase in time 30 days the rate was found to be increasing at all ultrasonic durations. But compared to other ultrasonication durations at 120 minutes is less.

5. MORPHOLOGY STUDIES OF NANOFLUID WITH DIFFERENT ULTRASONICATION DURATIONS.

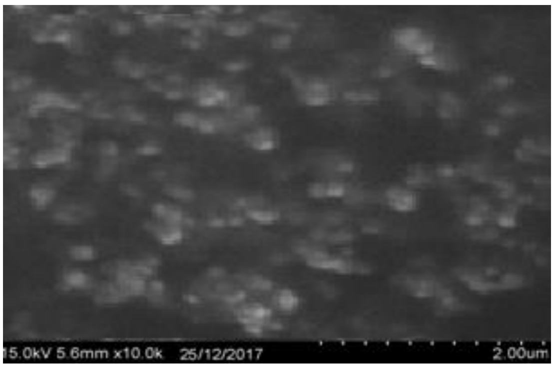
Effect of concentration of nanoparticles in base fluid was further analyzed through SEM images. The SEM images of the prepared nanofluid after 20 days of preparation are shown in Fig. 4(a)-(e). To obtain a better understanding of the colloidal structure, a wide range of 2-µm scale was chosen.



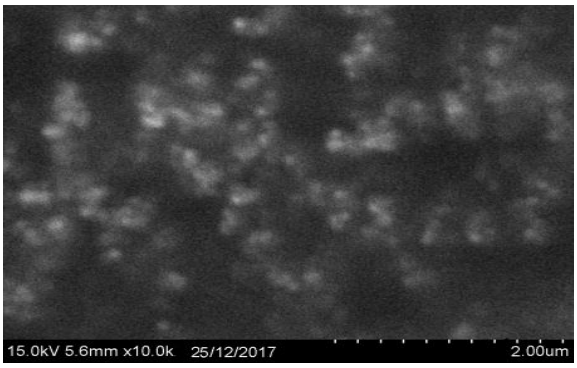
(a) 60 minutes



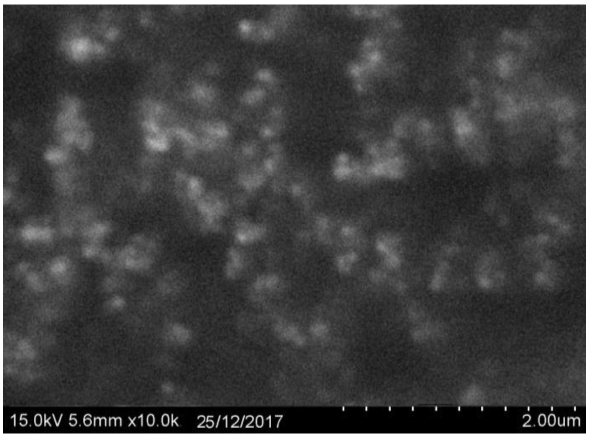
(b) 90 minutes



(c) 120 minutes



(d) 150 minutes



(e)180 minutes

Figure 4: SEM images at different ultrasonications periods after 20 Days of preparation.

From Fig. 4(a) shows the microstructure of RGO-modified coconut nanofluid at 60 min of duration. From Fig. 4(a) it is observed that dispersion of nanoparticles is coagulate with overlap of nanoparticles and also with some empty areas. At 90 minutes of ultrasonication periods, the phenomenon observed is similar to at 60 minutes of duration but more spreading of nanoparticles is seen with few empty spaces. However, some nanoparticles still overlap. At 120 minutes of ultrasonication it is clear that the nanoparticles were well dispersed and there was no empty spaces compared to other ultrasonication durations which is observed through Fig. 4(c) After further enhancement in ultrasonication durations more aggregation of nanoparticles due to re-agglomeration of nanoparticles has been observed which is found to be undesirable and the aggregation of particles can be observed through Fig. 4 (d)-(e).

After the addition of ultrasonication with a frequency of 25 Hertz and upto a duration of 120 minutes resulted giving better stabilization upto 20 days.

Afterwards the stability of nanoparticles within the base fluid was improved through effective ultrasonication. Since the prepared nanofluid is intended for manufacturing application. Therefore the tribological performance of the prepared oil is ascertained under different loading conditions as well as distances.

6. EXPERIMENTAL DETAILS FOR TRIBOLOGICAL STUDIES

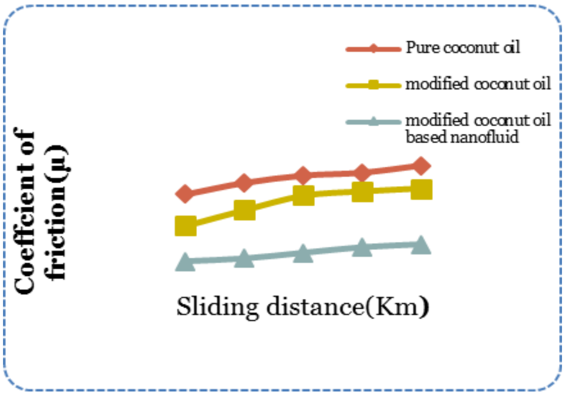
After preparation of nanofluid friction and wear tests were conducted using pin on disc tribometer by using mild steel pins, with the wear track diameter of 70 mm and sliding speed of 3 m/s. The tests were conducted at various loadings ranging from 2-8 kg under the influence of coconut oil, modified and the prepared nanofluid.

6.1 Results and Discussion

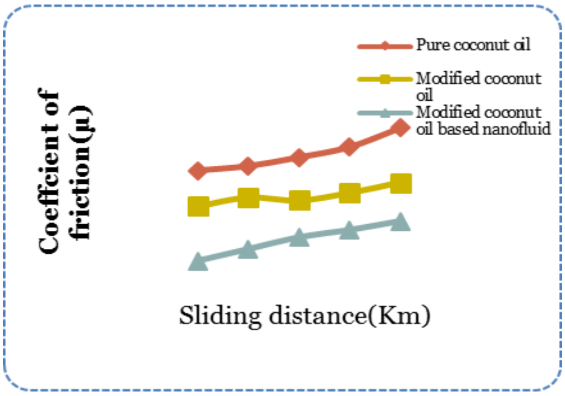
After conducting the experiments, analysis of friction and wear behavior of mild steel pins under different lubricant environments discussed in following section 6.1.1 and 6.1.2

6.1.1 Friction Behavior under different lubricant conditions.

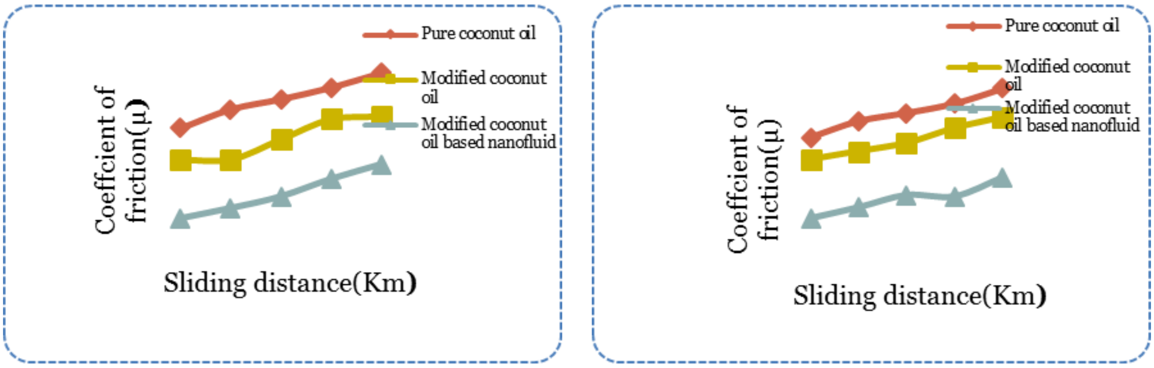
After conducting the experiments variation of friction coefficient with respect to different sliding distances and loads were plotted through Fig. 5(a)-(d) under the influence of the prepared nanofluid and the obtained results compared with bear coconut oil and modified coconut oil.



(a) At 2 kg Load



(b) At 4 kg load



(c) At 6 kg Load (d) At 8 Kg Load

Figure 5: Variation of coefficient of friction with respect to different sliding distance and loads

It can be seen from Fig. 5(a)-(d) that under bear coconut oil, with the increase of sliding distance, the friction coefficient is getting increase at all loads. Under the environment of modified coconut oil the friction coefficient gradually decreased compared to pure coconut oil which can be attributed to the formation of higher oxide film compared to the pure coconut oil environment. But, under the influence of nanofluid environment the obtained friction coefficient are much lower than that of modified coconut oil almost for all sliding distances. This indicated that RGO nanoparticles played an important role in reducing the coefficient of friction.

It is also observed from the above figures that the friction coefficient under nanofluid environment found to decrease compared to pure coconut oil under different loads ranging from 2-8 kg insteps 2 kg this phenomena can be attributed the fact that RGO particles could easily penetrate into the contact surfaces with increase in load.

6.1.2 Wear Behavior

For the study of wear behavior of mild steel pins under the different loading conditions and sliding distances with the different lubricanting environments were plotted through Fig.6(a)-(d)

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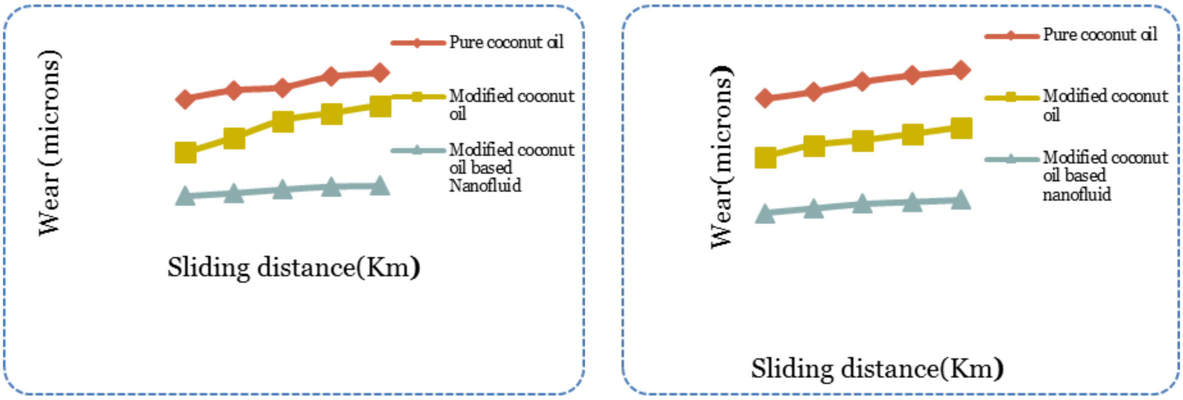
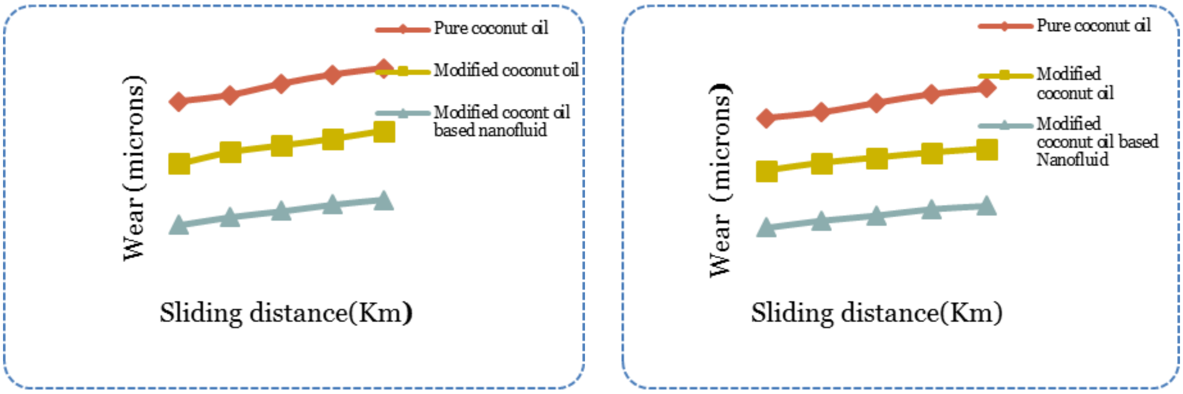


(a) 2 kg load (b) 4 kg load



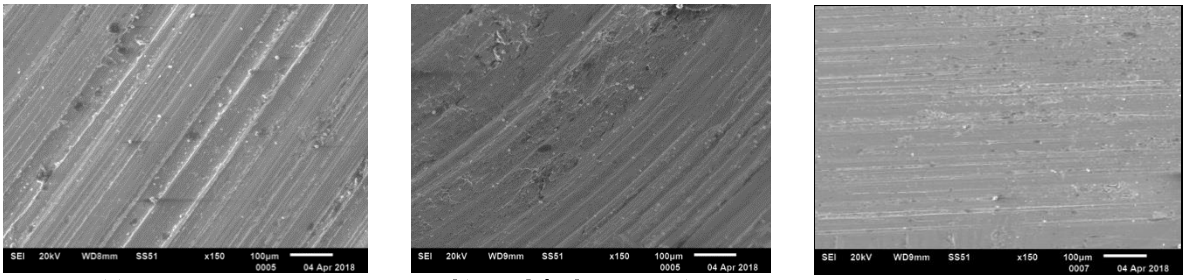
(C) 6 kg Load (d) 8 kg load

Figure 6: Variation of coefficient of friction with respect to different sliding distance

From the above figures it is observed that the wear of mild steel increased irrespective of normal force with sliding distance. Moreover, under the environment of modified coconut oil wear is gradually decreased compared with pure coconut oil. Wear under the influence of nanofluid was further reduced compared to modified coconut oil almost for all sliding distances.

6.1.3 Analysis of wear tracks

After conducting the experiments the morphological studies on mild steel pins were conducted through SEM for study of wear scars of pins for various lubrication environments shown in Fig. 7.



(a) Pure coconut (b) Modified coconut (MC) (c) MC+ RGO

Figure 7: SEM images of the friction surfaces of the pin under different lubricant conditions

It can be seen from Fig.7 that the wear scars under bear coconut oil, modified coconut oil and modified coconut oil based nanofluid friction and wear condition were characterized by obvious scuffing and deep furrows which are shown in Fig. 7 (a) – (c). Application of modified coconut oil with or without nanoparticles exhibited smoother wear scars than bear coconut oil, especially using modified coconut oil nanofluid Fig.7 (c) Further, the furrows on the surfaces of wear scars were smother and slender in case of modified coconut oil which can be observed through Fig. 7 (b) and 7 (c).

7.CONCLUSIONS

In this study, it is aimed to prepare a stable nanofluid via two-step method to investigate the effects of the ultrasonication process on the colloidal dispersion and prepared nanofluid its tribilogical studies from the obtained results the following conclusions has been drawn

From the results ultrasonication at 25 Hz upto 120 min duration resulted for uniform stabilization of nanoparticles upto 20 days of preparation at 0.5% of nanoparticle concentration. At these conditions of preparation the thermal conductivity and viscosity of the nanofluid are increased further.

Further under different loading and sliding conditions the prepared nanofluid triblogical performance was evaluated and compared with bear and modified coconut oil by the study of friction and wear behavior. Experiments were done on pin on disc tribometer with mild steel pins and the obtained results were analyzed. It was observed that a significant reduction in friction and wear was observed under modified coconut oil nanofluid compared to modified coconut oil and bear oil.

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