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Address:-Ashok Yakkaldevi 258/34, Raviwar Peth, Solapur - 413 005 Maharashtra, India
Cell : 9595 359 435, Ph No: 02172372010 Email: ayisrj@yahoo.in Website: www.isrj.net

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ORIGINAL ARTICLE

EFFICIENCY OF MULTI WALL CARBON NANO TUBES IN NANOLUBRICANT

SHUBRAJIT BHAUMIK AND S.PRABHU

School of Mechanical Engineering, SRM University , Chennai, India ,

Abstract:

The paper predicts the exceptional extreme pressure properties of multi walled carbon nano tube as compared with traditional mineral oil which also contained some additives and graphite. The extreme pressure property was predicted by four ball tester. In the test the load bearing capacity of the newly developed nano oil was predicted to have a better value than the commercial available mineral oil. The weld load of the nanolubricant was found to be 200kgf as compared with the base mineral oil which got welded at 160kgf. Moreover, it has also been observed that with the increase in concentration of the nanoparticles the performance charecteristcs of the lubricants may also decrease. Thus, the finding would be helpful in developing new nanolubricants which would increase the life of the mating parts, reducing the chances of failure of machine and increasing the productivity.

KEYWORDS:

mineral oil , multi walled carbon nano tube(MWCNT) , pass load , weld load , load bearing capacity, carbon nano tube(CNT)

1. INTRODUCTION

With the advancement of new technologies, new critical applications have also taken their birth in various fields. The birth of critical applications has also made the researchers to think regarding the protection of the parent material. Lubrication is an important phenomenon in any process industries. Initially, mineral oil was commonly used. With the advancement of the modern era of mechanisms, the researchers are trying to extend the life of the mating parts. For that, various types of additives have been formulated and added to the base mineral oil. For many years phosphorus, sulfur, nitrogen and chlorine compounds are used as successful AW and EP additives. The use of these compounds decreased because of increase in price of sulfur and nitrogen compounds. These compounds also pose environmental and toxicological hazards. So current research is focused on development of eco friendly additives .In recent years graphite and molybdenum disulfide have attracted the attention because of their excellent emergency running properties which are essential when oil base begins to break down they act as emergency solid lubricating compounds at extreme high temperature due to their high thermal stability. The nanoscale materials have drawn ample attention of researchers from distinct research fields in recent years because of its propitious physical and chemical properties. In tribology some nanomaterials have been proved to have greater potential as lubricating materials. Carbon nanotubes are one such nanomaterial whose existence was observed recently. These nanomaterials have unusual properties which are very essential in the field of tribology. There are two types of carbon nanotubes known as single walled and multi walled carbon nanotubes where both of them have been shown to improve the wear resistance of lubricants and provides low friction and minimal deformation.

Curasu et al[1] predicted the frictional reduction capability and excellent AW/EP properties of SWCNTs and obtained the optimum concentration as 0.5 wt% SWCNTs. Hong et al[2] concluded that CNT greases distinguish themselves from more common graphitic materials that of many years have been commonly used as solid grease additives. The performance of CNT grease could be much better with the improvement of nanotube quality and purity. Libo Wang et al [3] concluded that when CaF_2 nanocrystals are used as lubricant additive in lithium grease, it can improve the wear resistance, load carrying capacity and anti friction ability of lithium grease and obtained the optimum concentration is around 1 wt%. Xianbing Ji et al [5] concluded that when $CaCo_3$ nanoparticles as an additive in lithium grease significally improve its anti-wear performance, friction reduction property, load carrying capacity, and extreme pressure property. The optimum concentration is 5 wt%.

Many eminent researchers have worked on aqueous solutions using nanoparticles but very few works are available using industrial mineral oil.In this paper we studied the performance of MWNTs as an additives to base mineral oil in different percentages (0.1, 0.5 and 0.6 wt %). The extreme pressure properties of the specimens were compared to that of the base mineral oil without additives and the graphite as an additive. A Four Ball Tester is used to evaluate the tribological properties. The properties of the specimens are listed as follows:

Table 1 Physical properties of the lubricants

Property	Mineral oil + 0.1% CNT	Mineral oil + 0.5% CNT	Mineral oil + 0.6% CNT	Mineral oil + 0.5% graphite
Viscosity	249.70	251.85	242.56	249
Fire point	220	218	222	218
Flash point	232	228	234	226

2. EXPERIMENTAL DETAILS:

2.1 Materials:

2.1.1 Base oil:

Industrial gear mineral oil is chosen because we are interested in formulating a lubricant for heavy duty industrial applications like gear box used in cement mills.

2.1.2 Additives:

Multi-walled carbon nanotubes are used as an additive for comparing the tribological properties with classical additives (Graphite).

2.2 Preparation of nano lubricant:

Though CNT have good dispersibility in mineral oil but agglomeration of CNT occurs within no time. In order to get a stable lubricant, we can either use a surfactant or mix CNT to the mineral oil using ultra sonication. In our experimental procedure we obtained a stable lubricant for a longer time using ultra sonication without the help of surfactant. Ultra sonication is the process in which the length of the CNT are broken to increase the ease of dispersion of CNT in oil and hence maintains stability for a longer time.

Specimens with various concentrations of MWNTs dispersed in mineral oil were stable up to 156 hours.

2.3. Extreme pressure test

2.3.1 Four ball tester:

A Four Ball Tester is used to evaluate the Extreme Pressure of lubricant. The tribosystem consists of three stationary balls fixed in a ball pot and pressed against the fourth ball fixed to the collet at required pressure. The top ball rotates at defined speed according to the test standards. The load is uniformly distributed over the three points where the three balls touch the fourth ball. The pot is filled with the lubricant. Rotation of the driving spindle causes a frictional torque that produces a scar on the lower balls. The test balls used had a 12.7mm diameter and a roughness of R = 0.016mm and were made of AISI E 52100 steel. The test standards were performed according to the ASTM D-2783 standard.

The test is performed by adding weights to the apparatus and will run the apparatus for specific time according to the test standards. After the completion of test with respective weight the balls will be removed from the apparatus and are observed. We can find some scars on the balls after the completion of the experiment. If the scar diameter is above 4mm or if the ball gets welded then the respective load is called weld load of the specimen and the previous load where the balls don't get welded or the scar diameter is below 4mm is called pass load.

2.3.2 SEM analysis:

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with electrons in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The morphology of the rubbed surfaces was investigated using an FEI Inspect scanning electron microscope with a maximum resolution of 3nm.

3. RESULTS AND DISCUSSIONS:

3.1 Four ball test results

To study the behavior of MWNTs under the above mentioned conditions, five specimens were compared under same conditions: , base mineral oil, base mineral oil with CNT as an additive in three different concentrations (0.1, 0.5 and 0.6 wt%) and base mineral oil with graphite as an additive. The Four Ball Test results in Table 3.1. shows the load bearing capacity of each specimen.

Table 3.1. Shows Pass Load and Weld Load values from the Four Ball Test

Specimen	Pass Load (Kg)	Weld Load (Kg)
Base Mineral Oil	126	160
Base Mineral Oil + 0.1 wt% CNT	160	200
Base Mineral Oil + 0.5 wt% CNT	160	200
Base Mineral Oil + 0.6 wt% CNT	160	200
Base Mineral Oil + Graphite	160	200

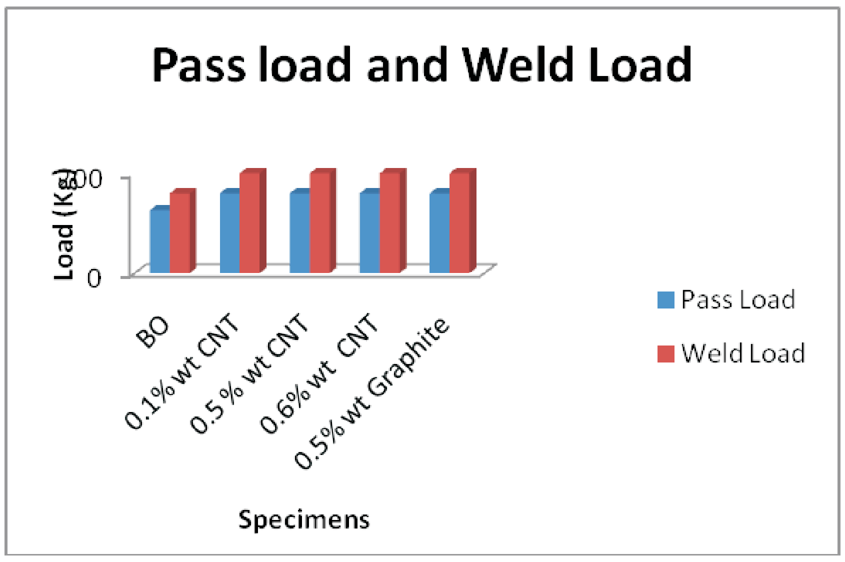


Figure 3.1 Graphical representations of obtained Pass Load and Weld Load values from the Four Ball Test setup.

As observed from Figure 3.1 and Table 3.1 the pass load and weld load of the base mineral oil is very less when compared to that of the other specimens. We also compared our CNT specimens with Graphite additive specimen because industries are using Graphite widely these days. From Figure 3.1 we can observe that pass load and weld load values of CNT specimens and graphite specimens are same. This may be because both the additives are allotropes of carbon. Since the pass load and weld load values are same it doesn't mean that all the specimens have same efficiency. The most efficient lubricant among the additive added specimens can be obtained by comparing the scar diameter at their pass Loads. The lower the scar diameter the higher is the load bearing capacity. The scar diameters of the four additive added specimens are shown in Table 3.2.

Table 3.2. Scar diameters

Specimen	Scar Diameter at Pass Load (mm)
Base Mineral Oil + 0.1 wt% CNT	2.431
Base Mineral Oil + 0.5 wt% CNT	2.225
Base Mineral Oil + 0.6 wt% CNT	2.313
Base Mineral Oil + Graphite	3.136

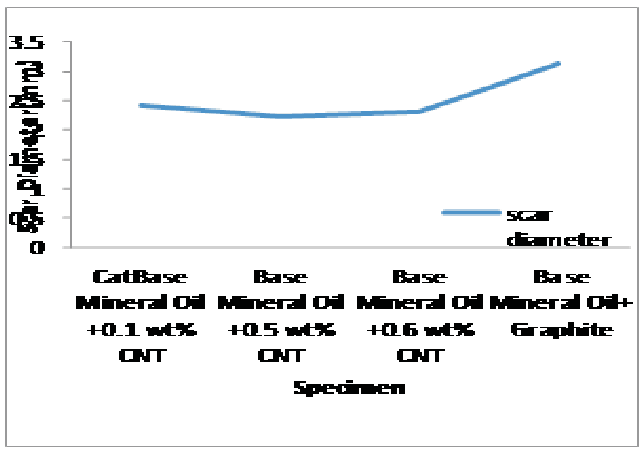
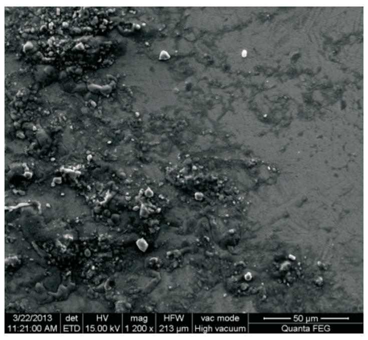


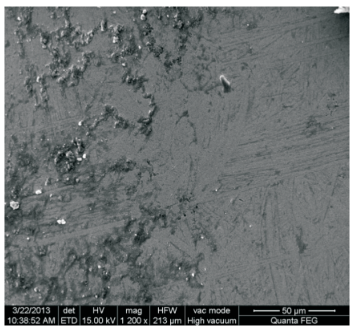
Figure 3.2 graphical representation of scar diameters

Though the graphite and CNT are allotropes of carbon, CNT have better physical properties compared to that of graphite. As the elastic modulus of CNT is more than graphite, the CNT has higher capacity of absorbing and frictional impact/torque. Thus, graphite added specimen has high scar diameter compared to CNT specimens. Among the CNT added specimens there exists variation in scar diameters because of different concentrations of CNT. In 0.1 wt% specimen the amount of CNT present is not sufficient to make it a better efficient lubricant where as in 0.6 wt% specimen the amount of CNT present became excess.This may be due to the fact that both the oil and the parent metal might have absorbed MWCNT physically/chemically and the excess amount of MWCNT has resulted in agglomeration of MWCNT which might have increased the drag force , thus increasing the internal friction , which has resulted in the increase in scar due to the wear of parent metal and lubrication film breakage.The present work predicts that 0.5 wt % specimen is more efficient compared to all the CMT specimens.

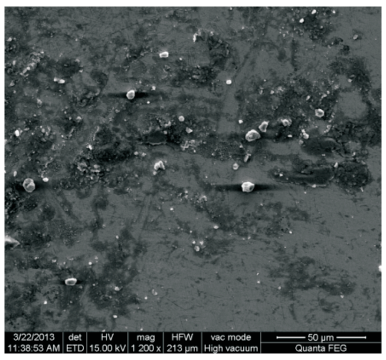
3.2 SEM analysis:



(a)



(b)



(c)

Figure 3.3 shows the SEM image of metal ball used in four ball tester for pass load of (a) mineral oil. (b) Mineral oil +0.5% wt CNT. (c) Mineral oil + 0.5% Graphite.

SEM images predict the microstructure of the balls. It can be predicted that the heat generated in case of the mineral oil and mineral oil + 0.5% graphite sample is higher due to which white layers are been observed in Figure 3.3 (a) and (c). Thus, it can be predicted that the lubricant film is not stable in case of mineral oil and mineral oil + 0.5% Graphite. On the contrary, the image of mineral oil + 0.5% CNT predicts lesser formation of heat effected zone. Thus, CNT lubricant film is predicted to be more stable than the mineral oil and mineral oil + 0.5% Graphite sample.

4. CONCLUSION

From the results predicted in the present work it can be concluded that MWCNTs are much more efficient additives than commonly used graphite. The lesser scar diameter indicates higher fluid film stability. The present work predicts the excellent extreme pressure property of MWCNT as compared with graphite. The load carrying capacity which is an important parameter far the lubricant has been predicted to be higher in case of nano lubricants than the conventional lubricant. It has also been observed that the agglomeration property of nano particles can have a negative effect as predicted in the present work. Thus, 0.5% wt MWCNT has been found to have better results as compared with other samples.The present result would be beneficial in developing new nano fluids.

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