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EXPERIMENTAL INVESTIGATION TO ENHANCE THE TRIBOLOGICAL CHARACTERISTICS OF A LUBRICANT USING NANOPARTICLE ADDITIVE

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ABSTRACT

Copper oxide (CuO) nanoparticles were found to be an excellent additive to the lubricant in order to reduce the friction and wear between piston ring and cylinder liner. Friction and wear tests have been done experimentally using a pin on disc machine. Input parameters like load, speed, distance travelled are varied for each test, so that an effective combination for the minimal friction and wear have been obtained. The effect of adding additive is also found by varying the percentage of the nanoparticle in the lubricant. Also, after the best ratio for the additive in lubricant is selected, it can be used to run the engine in the laboratory, so that the performance and emissions of the engine with the new lubricant can be obtained. Finally, comparison can be made with the engine using existing lubricant.

Keywords: *Piston ring, Cylinder liner and CuO Nanoparticles.*

1. Introduction

To reduce friction and wear, the engine tribologist is required to achieve lubrication of all moving engine components, with minimum adverse effect on the environment. This task is particularly difficult given the wide range of operating conditions of Load, Speed, Temperature and Chemical reactivity experienced in an engine.

Improvements in the tribological performance of engines can yield

- Reduced fuel consumption
- Increased engine power output
- Reduced oil consumption
- A reduction in harmful exhaust emissions

Improved Durability, Reliability and Engine life and reduced maintenance requirements and longer service interval [1].

With such large numbers of reciprocating Internal Combustion engines (Figure 1) in service, even the smallest improvements in engine efficiency, emission levels and durability can have a major effect on the world economy and the environment in the medium to long term. It is interesting to consider where the energy derived from combustion of fuel is apportioned in an engine. Anderson [2] showed the distribution of fuel energy for a medium sized passenger car during urban cycle. Only 12% of the available energy in the fuel is available to drive the wheels, with some 15% being dissipated as mechanical mainly frictional losses. Based on the fuel consumption data [4], a 10% reduction in mechanical losses would lead to a 1.5% reduction in fuel consumption. The worldwide economic implications of this are startling in both resource and financial terms and the prospect for significant improvement in efficiency by modest reductions in friction is clear.

Concerning energy consumption within the engine as shown in the figure 1.1, friction loss is the major portion of the energy consumption (48%) developed in an engine. The other portion are the acceleration resistance (35%) and the cruising resistance (17%).

If one looks into the entire friction loss portion, engine friction is 41% and the transmission and gears are approximately 7%. Concerning engine friction loss only, sliding of the piston rings and piston skirt against the cylinder wall is undoubtedly the largest contributor of friction in an engine. Frictional losses arising from the rotating engine bearings (notably the crankshaft and camshaft journal bearings) are the next most significant

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followed by the valve train (principally at the cam and follower interface), and the auxiliaries such as the oil pump, water pump and the alternator.

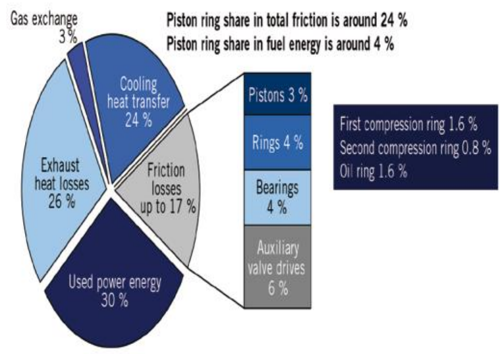

Fig. 1 Energy consumption developed in an engine.

The relative proportions of these losses and their total, vary with the engine type, component design, operating conditions, choice of engine lubricant and the service history of the vehicle (i.e., worn condition of the components). Understanding and controlling the wear of the piston assembly is crucial to successful engine performance. Manufacturers through long experience have come to rely on the early life wear of the piston rings and cylinder wall to modify the profile and roughness of the interacting surfaces to achieve acceptable performance as part of the running process. However, a clear understanding of the complex interactions between lubrication and wear of these components has only recently started to emerge [3].

In order to analyse their complex phenomenon, a pin-on-disc machine was used in the research work. Lubricant can be fed between the pin and the disc while the disc is constantly rotating. Several input conditions similar to the engine load, speed, and travel distance are mentioned as the input parameters. And the output result will be the frictional force and wear in the form of a graph [5].

Also, several researchers have reported that, using nanoparticle additive in the lubricant helps in the effective reduction of the friction and wear [6]. In order to estimate this, two different ratios of nanoparticles are added to the lubricant and a comparative study between them is made in this research work.

2. Experimental Work

All Experiments were performed on a pin – on disc machine. The pin and Disc were made as per the ASTM standards as described in Fig 2. The pin was heated to a higher temperature using a heating element. In order to insert the heating element into the pin, a hole of 1.5 mm was drilled upto an inch in the pin. A counter shunk hole of 6 mm diameter was drilled on the top face of the disc, through which a screw will be inserted when the disc was tested in the machine. Both pin and disc were washed with alcohol, dried and weighed before and after the experiment. In order to implement the Taguchi concept with L9 orthogonal array for 4 factors and 3 levels, the input parameters were modified for each experiment [7, 8]

- The 4 factors that were modified are –
  1. Type of Lubricating Oil
  2. Load
  3. Pin Temperature
  4. Travel Distance
- In the lubricant type, three different oils were used.
  1. Oil A - Base oil without additives
  2. Oil B – Oil with 0.1% CuO
  3. Oil C – Oil with 0.2% CuO

In the load applied, three different loads were used – 80N, 130N and 180N. In the distance travelled, three different distances were set – 1000 m, 2000 m and 3000 m. Hence, with all the above different parameters, 9 different experiments were performed with each experiment, in a different combination. The details of the experiments are given in Table 2. At the end of each experiment, frictional force and wear are recorded from the machine. Coefficient of friction graph was generated automatically when the pin moves on the disc. In all the 9 experiments, there was a constant flow of lubricant at 1cc/sec and a constant speed of 1500rpm.

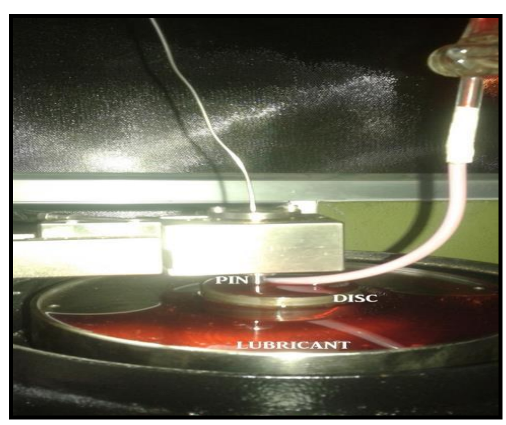

Fig. 2 Experimental setup with WINDUCOM software

Table 2. Details of experiments

t	Type of Lubricant	Load (in N)	Travel distance (in m)	Pin Temperature (^oc)	Coefficient of friction
1	A	80	1000	50	0.092
2	A	130	2000	100	0.116
3	A	180	3000	150	0.000
4	B	80	2000	150	0.111
5	B	130	3000	50	0.023
6	B	180	1000	100	0.110
7	C	80	3000	100	0.123
8	C	130	1000	150	0.080
9	C	180	2000	50	0.011

2.1. Model Calculation

Track radius (R) = 20 mm

So, the distance travelled in a revolution of disc

= $2\pi R$ = 125.6 mm

If the distance is to be as 1000 m or 1000000mm and rpm as 1000, then number of revolutions needed to cover the 1000000mm is = 1000000 / 125.6

= 7961.78 revolutions

Therefore, Time needed = total no of revolutions/ no of revolutions in a min

= 7961.78 / 1000

= 7.961 minutes

Velocity = distance / time taken

= 1000/ (7.961 x 60)

= 2.093 m

3. Results and Discussion

Experiment 1: Lubricant – A, load – 80N, Temp – 50^{o}C, distance travelled – 1000m.

Figure 3 shows the lubricant used here is without any additives and hence a considerable frictional force was obtained between the pin and disc. The coefficient of friction lies between 0.09 to 0.15. The wear was found to be minimal due to the fact that, the travel distance was only 1000 m in this experiment.

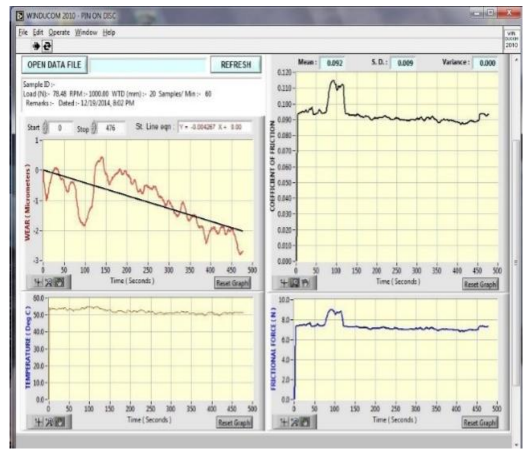

Fig.3 Test Result of Experiment No 1.

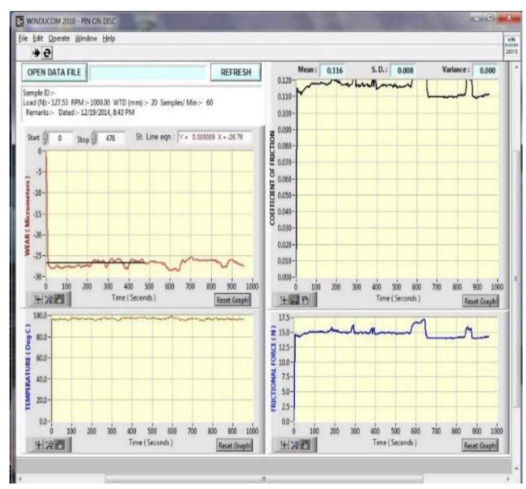

Fig.4 Test Result of Experiment No 2

Figure 4 indicates the lubricant used here is without any additives and hence a considerable frictional force was obtained between the pin and disc. The coefficient of friction lies between 0.10 to 0.20. The wear was found to be minimal due to the fact that, the travel distance was only 2000 m in this experiment. But the wear was slightly lower than the previous one. This may be due to the fact that the pin which was at a higher temperature than the previous one, tried to make a film over it due to the oil heating.

Experiment 3: Lubricant – A, Load – 180N, Temp –150^{o}C, Distance travelled – 3000m

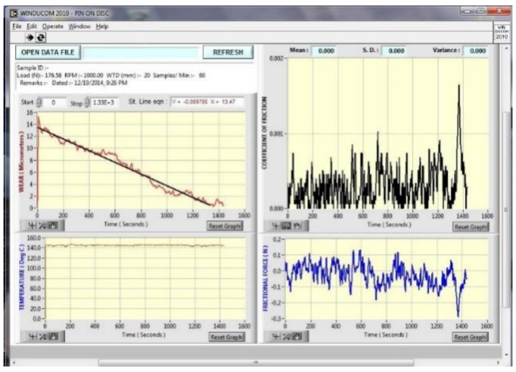

Fig.5 Test Result of Experiment No 3

Figure 5 shows the wear was found higher when comparing the above 2 experiments. This may be due to very high load and very high temperature. Due to which, oil may be squeezed out from the interface at the beginning of the experiment [9]. This results in the direct contact between the pin and disc which leads to a greater wear. But, the coefficient of friction and frictional force was found to be minimal. As time proceeds, a film may be formed and it results in the above phenomenon.

Experiment 4: Lubricant – B, Load – 80N, Temp – 150^{o}C, Distance travelled – 2000m

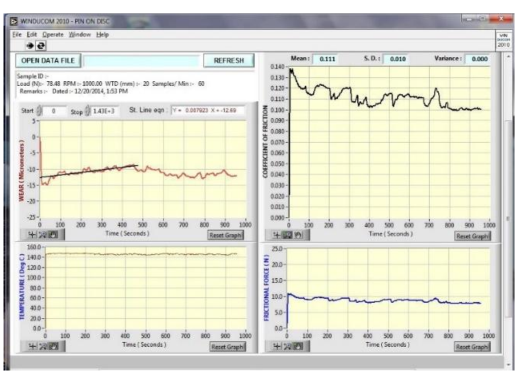

Fig.6 Test Result of Experiment No 4

Figure 6 indicates addition of nano particles have greatly influenced in the wear, coefficient of friction graph. It shows, considerable reduction compared to the base oil but frictional force, after some time tries to increase. This is because of the oil over heating upto 150^{o}C. Though the force increases, the CuO film that have formed results in blocking the direct metal to metal contact and hence leads to lower wear and coefficient of friction.

Experiment 5: Lubricant – B, Load – 130N, Temp– 50^{o}C, Distance travelled 3000m

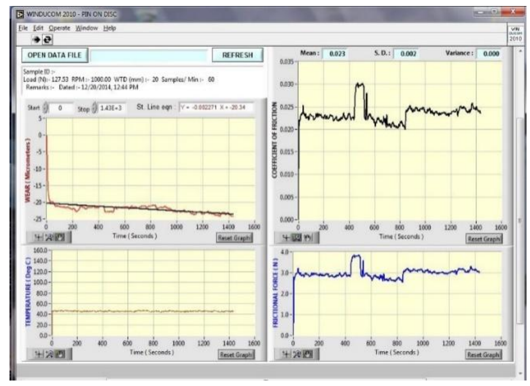

Fig.7 Test Result of Experiment No 5

Figure 7 show the temperature of the lubricant is very minimum in this experiment. This leads to higher density of the lubricant. This denser lubricant is found as a film and does not get squeezed out due to its consistency. This is the reason for the very low wear, frictional force and the coefficient of friction.

Experiment 6: Lubricant – B, Load – 180N, Temp – 100^{o}C, Distance travelled – 1000m

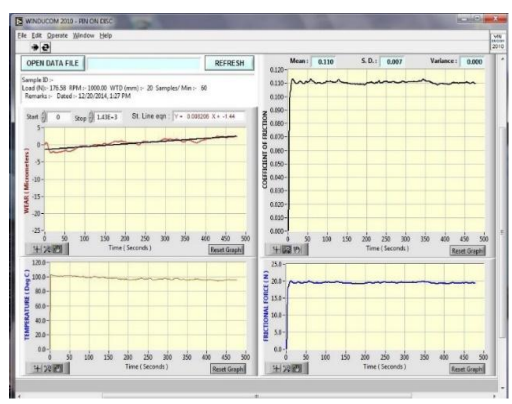

Fig.8 Test Result of Experiment No 6

Figure 8 shows the highest load of 180N is applied to the pin. Force directly depends upon the load applied. Hence, a greater frictional force is obtained. Though there is higher force, the coefficient of friction and wear were nominal due to the tribo film action. The distance travelled is less here and hence the effect of longer distance is needed to get the accurate results.

Experiment 7: Lubricant – C, Load – 80N, Temp – 100^{o}C, Distance travelled – 3000m

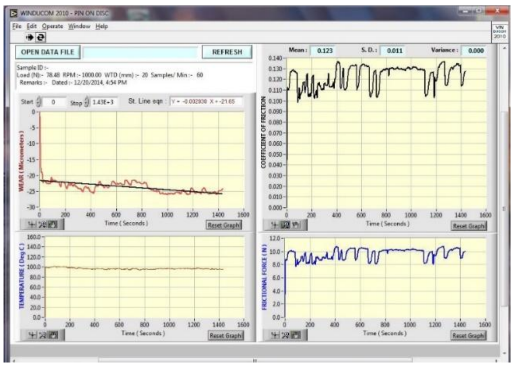

Fig.9 Test Result of Experiment No 7

Figure 9 explains the distance travelled is higher, the load is kept very small in this experiment. Due to which, there is reduced wear and friction. Wear, when compared to the previous type of lubricant is higher here. This is because of the extra 0.2% CuO particles. As reported from the literature survey, the addition of nanoparticles must be kept minimum i.e., around 0.1%, in order to get minimum friction as well as minimum wear.

Experiment 8: Lubricant – C, Load – 130N, Temp – 150^{o}C, Distance travelled – 1000m

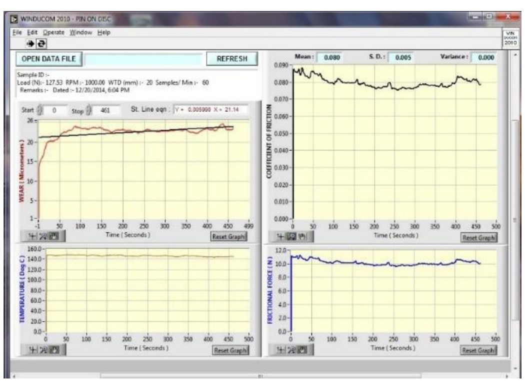

Fig. 10 Test Result of Experiment No 8

Figure 10 shows that highest load of 130 N is applied to the pin. As the load increases from the previous test, the frictional force also increased simultaneously. As the distance travelled is less here, the time given for the formation of film is also minimum. Due to which, metal to metal contact is easily possible and resulting in higher wear.

Experiment 9: Lubricant – C, Load – 180N, Temp – 50^{o}C, Distance travelled – 2000m

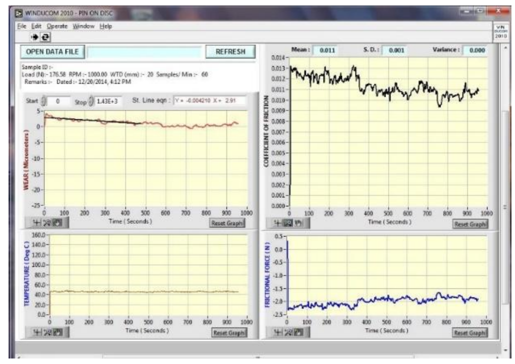

Fig. 11 Test Result of Experiment No 9

Figure 11 explains due to lower temperature of oil, the frictional force and the coefficient of friction are very much smaller than the previous one but, the higher load on the top of the pin, presses the pin tip against the disc, leading to a very small wear. Distance travelled, is the average between the previous two experiments and hence the other parameters too lies in the average value of the previous two experiments.

4. Conclusions

Some of the important conclusions derived from this investigation are listed below:

In initial experiments 1-3, there were no modifications done on the oil. From these experiments, it can be concluded that heating the pin to a greater temperature (150^{o}C) leads to heating of the lubricant and thereby increasing the chance of metal to metal contact. Also, if the travel distance is increased to a greater value (3000m), the reverse effect occurs, i.e., increase in friction and wear. Hence an optimised value would be having average pin temperature and minimum load and travel distance but several applications like in engine requires a higher load, temperature and travel distance. In order to achieve this a lubricant modification is required, hence experiments 4- 9 dealt with the modifications. From these experiments, we can conclude that, addition of nanoparticles to the lubricant considerably reduces the wear and frictional force but the experiments 4-6 had a lesser friction force and wear compared to the experiments 7-9. This showed that adding greater amounts of nanoparticle (0.2%) leads to hampering effect and thus increasing the friction and wear.

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