THE EFFECT OF A MAGNETIC LUBRICANT ON THE INTERNAL COMBUSTION ENGINES

Adelci Menezes de Oliveira, am.oliveira@petrobras.com.br
Petróleo Brasileiro S.A (Petrobras), Brazil
Antônio Moreira dos Santos, asantos@sc.usp.br
Engineering School of São Carlos, University of São Paulo - Department of Mechanical Engineering, Brazil

Abstract. *Magnetic microparticles were synthesized in order to work as lubricant additives. These particles were named CIL (Lubricant Intermetalic Compound) and they were used to modify a base oil for comparison with commercial motor oil. The magnetic lubricant containing 0.25 wt. % was tribologically compared to a SAE 20W50, API SL oil, in a four ball machine. The tests were performed at 60 ºC, 100 ºC and 150 ºC, at 1500 rpm, for 30 minutes. The friction energy and the bath oil temperature were monitored, and, after the tests, all scars were measured optically. The magnetic lubricant had a better performance at all temperature, presenting lower friction and wear. The resultant lubricant film was formed by a combination of the magnetic attraction obtained during the frictional process between the surfaces and the contact generated heat.*

Keywords: *Sliding friction, Magnetic lubricant, Lubricant Additives.*

1. INTRODUCTION

Internal combustion engines have been the most widely used machine for the past 100 years, and they will continue to be used due to their low manufacturing costs and high reliability (Becker, 2004). Nowadays better combustion processes, materials and lubricants projects are being developed. Emission reduction and fuel economy are now essential parameters and lubricants have an important role in reaching these objectives.

Different additives have been developed, either liquid or solid, in order to reduce friction and wear in all types of machines. Zinc Dialkyl Dithiophosphate (ZDDP) was used as an anti-wear (AW) product, but it had a malefic effect on the automotive catalytic system (Ballentine, 2003 and Grossiord, 2000). Nowadays molybdenum dithiocarbamate (MoDTC), molybdenum dithiophosphate (MoDTP) and other solid compounds are used, such as molybdenum disulphide (Ma *et al.*,2004, Tung and McMillan, 2004, Gansheimer and Holinski, 1972), copper nanoparticles and tungsten disulphide nanoparticles (Rapoport *et al*,2002a, 2003b, Rapoport *et al,* 1999, Tenne, 2002 and Feldman *et al,* 2000), graphite, polytetrafluorethylene (PTFE), zinc borate and zinc oxide nanoparticles (Battez *et al,* 2006). This work evaluates the tribological performance of a mixture of iron nitride and carbonitride compounds in a magnetic lubricant and compares their performance with commercial oil. It further discusses the possible mechanism of those magnetized particles in the base oil

2. EXPERIMENTS

2.1 Materials

A SAE 20W50 commercial lubricant was compared with another prepared with the CIL particles in the base oil, in such a way that the viscosity at 100 ºC was equal to the viscosity of the commercial oil.

The specimen balls were tested in a four ball machine, where the balls were made of AISI 52100 steel with a median hardness of between 64-66 RC and with highly polished surfaces.

The lubricant containing CIL particles was prepared in an ultrasound and mechanical mixer at 15,000 rpm. The particle concentration was 0.25 wt. %, before being magnetized in an electromagnetic coil, under a magnetic field of 2 Teslas.

The materials used are listed in Table 1.

Table 1 Material properties.

MATERIAL	PROPERTIES
CIL particles	*Morphology: nearly spherical* *Size: 5 μm*
Lubricants	
SAE 20W50	*Density: 0,89* *Viscosity: 18,5 cSt (100 ºC)*
SAE 50 CIL	*Density: 0,88* *Viscosity: 18,44 CSt (100 ºC)*

2.2 Wear and friction test procedures.

All test specimen balls were cleaned in a bath of acetone and heptane, after that they were air dried before and after the tests. The tests were carried out in a four ball TE 92 Plint tribometer.

The tribometer controls speed, temperature and load and provides a means of measuring the friction torque and oil bath temperature. The configuration of the balls is shown in Figure 1.

The tests were performed in a four ball machine, in an accelerated condition. The configuration of the balls is shown on the Figure 1.

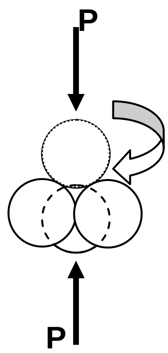


Figure 1. Schematic contact between the four spheres in a four ball tribometer.

In this kind of wear machine, the spheres are submitted to a determined load for the sliding test and the upper one rotates at the programmed speed. The bottom balls are tightly clamped and the temperature of the oil bath is kept at the pre-defined level. Once prepared, the clutch is turned on and the test conducted for the pre-established time.

The tests were performed at 60 ºC and 100 ºC, 1500 rpm, for 30 minutes, using a load stepping from 98 N to 490 N. The tests were stopped at the times presented in Figure 2, in order to understand the anti-wear and anti-friction mechanisms.

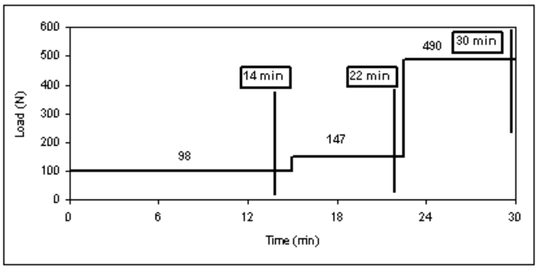
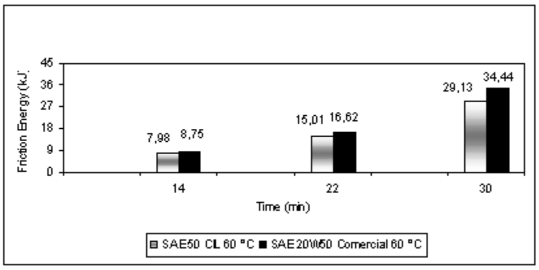


Figure 2. Loading procedure and interruption times.

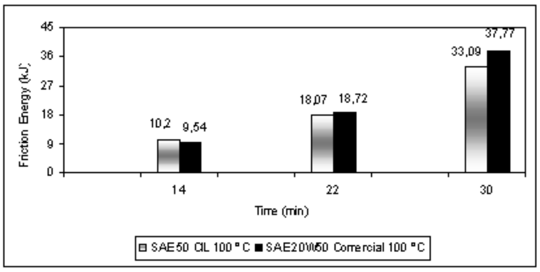
3. RESULTS AND DISCUSSION

Both the compared oils have main agents to form anti-friction and anti-wear film on the contacting surfaces. In the commercial oil, the polar ZDDP compound under high temperatures reacts chemically with the metallic surface and forms, probably, iron sulfide. In the case of the oil containing CIL, the magnetic particles are attracted to the ferrous surface and the carbonitrides protect the rubbed surfaces.

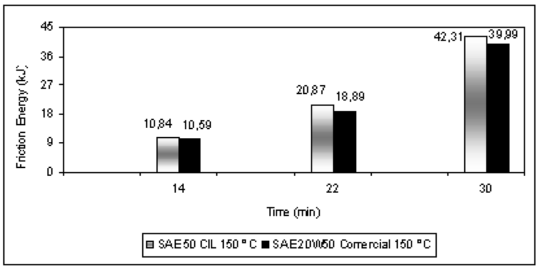
The higher the load and the lower the temperature of tests, the greater the difference between the friction energy of the oil containing CIL and the commercial oil. This is shown in Figure 3.



(a)



(b)



(c)

Figure 3. Results of friction energy. (a) Tests carried out at 60 ºC. (b) Tests carried out at 100 ºC. (b) Tests carried out at 150 ºC.

The higher friction energy difference obtained in the tests performed at all temperatures helps to confirm that the oil containing CIL acts magnetically on the ferrous surface, under sliding movement. The lower friction reduction at 60 ºC and 100 ºC corresponds to the lower load level. As the load increases, the magnetic effect provoked by the sliding process, increases, also, and the CIL magnetic particles go to the contact point, resulting in a more efficient anti-friction film.

For the tests performed at 150 ºC, there was no improvement, when comparing both lubricants. As shown in Figure 4, as the temperature increases, the friction reduction and the magnetic effect of CIL decrease.

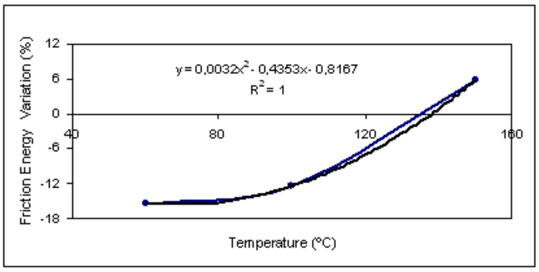


Figure 4. Friction reduction dependence on test temperature.

For the magnetic oil, there is a critical temperature (137,9 ºC), above that, the CIL particles have no effect. For wear, the magnetic oil presented lower incremental wear than the commercial oil, as shown in Figure 5.

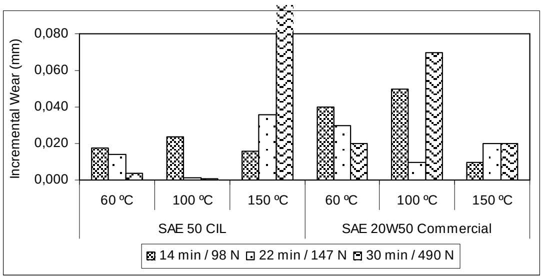


Figure 5. Result of incremental wear.

Considering wear, for magnetic lubricant, as the test of time increases at 60 ºC and 100 ºC, the incremental wear decreases and this is because a good anti-wear film was formed. When the temperature rises to 150 ºC, desorption thermal process is prevalent, competing to magnetic effects, and there is an abrupt wear increase. On the other hand for commercial oil, as the temperature rises, the lubricant film formation mechanism is prevalent, and because of that, at 150 ºC, it had a better behavior than magnetic oil.

This work proposes that the mechanism of the CIL particles containing lubricant result from the interaction between mechanical and thermal loads. In order to understand the mechanisms, it is shown in Fig. 6 the action of the CIL particles, when submitted only to mechanical load.

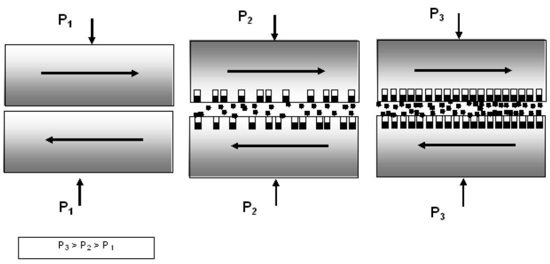


Figure 6. Schematic model showing the action of the CIL particles, in a contact submitted to load only.

When two surfaces (at least one ferrous) move against each other, the superficial layers of the metal are magnetized due to the rubbing process, resulting in the attraction of the CIL particles to the contacting surfaces and because of that, high performance anti-wear and anti-friction films are formed. As the load increases, the magnetization process is intensified and more particles contribute to form the protective lubricant film. The combined effect of the heat and load is shown in Figure 7.

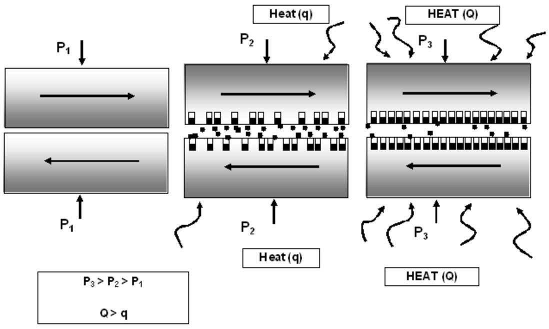


Figure 7. Schematic model showing the action of the CIL particles in a contact submitted to load and heat.

At lower temperatures, the magnetic effect of the CIL particles is predominant and the magnetization of the superficial layers of ferrous materials combined with the magnetic particles in the lubricant oil are responsible for the formation of anti-friction and anti-wear films. At high temperatures, for magnetic oil, a good lubricant film is not reached because of the desorption process.

4. CONCLUSIONS

The following conclusions can be drawn from the results presented in the work:

- Iron nitrides and carbonitrides can be used as additives for lubricants.
- The oil containing CIL had a better performance than the commercial oil, at temperatures of 60 ºC and 100 ºC, while at 150 ºC the thermal effects avoid the formation of a good lubricant film.
- It appears that there is a critical temperature, for the magnetic oil, above which the lubricant film is unstable and friction and wear increase.
- The CIL particles act by magnetic attraction to the contacting surfaces, due to the combination of the attraction force caused by friction magnetism and the magnetism of the particles.
- During the formation of the CIL lubricant film, the attractions forces compete with the thermal effects. That is because at high temperatures the evaluated magnetic oil was not so efficient, under the tested conditions.

5. ACKNOWLEDGEMENTS

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