Study of wear on AISI E52100 steel using a lithium complex grease and a calcium sulfonate grease

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Abstract

The purpose of this work was to study the antiwear and extreme pressure properties of two synthetic greases on AISI E52100 steel which is widely used in the construction of bearing elements. One of them is made up of a lithium complex thickener and the other of calcium sulfonate, these are classified by the ISO 6743-9 standard as LX and CS respectively and both are commonly used in bearings. The NLGI data in 2018 support that both greases are widely produced and marketed around the world.

The experimental results in the wear tests showed that both thickeners have a similar performance. However, when the samples are subjected to extreme pressure tests, it was found that the calcium sulfonate grease offers better properties at much higher contact pressures.

Introduction

An important function of lubricating greases is to avoid direct contact between the elements of the machines during their operation, but it must also be able to protect during the low lubrication conditions that occur in the equipment starting and stopping stages. In addition, due to their high viscosity, they are capable of operating adhered to the surface, which allows them to operate when some conditions of low gravity and large centrifugal forces, this property also allows them to operate more efficiently at high conditions of temperature and load. The flow capacity of greases is determined by the viscosity of the base oil, the type and percentage of its thickening soap [1].

There are greases with soap thickeners and greases with non-soap thickeners. In both groups, the base oil can consist of mineral oil or synthetic oil [2,3]. The grease based on LX is the highest quality lithium soap grease manufactured with vegetable greasy acids, oils highly refined minerals. On the other hand, the lubricant grease produced from CS is constituted by refined mineral oil [4].

The microstructure of a grease soap is created in the process of crystallization when the thickening agent, the particles, and the substances together formed the grease. If the relation (length/diameter) of the fibers formed is higher, the performance at high temperatures is better because resistance to the flow of the grease increases [5] also, the small number of empty spaces significantly reduce water penetration thus improving protecting against oxide and corrosion [6]. The microstructure of the fibers of CS and LX are shown in Fig. 1 a) and 1 b).

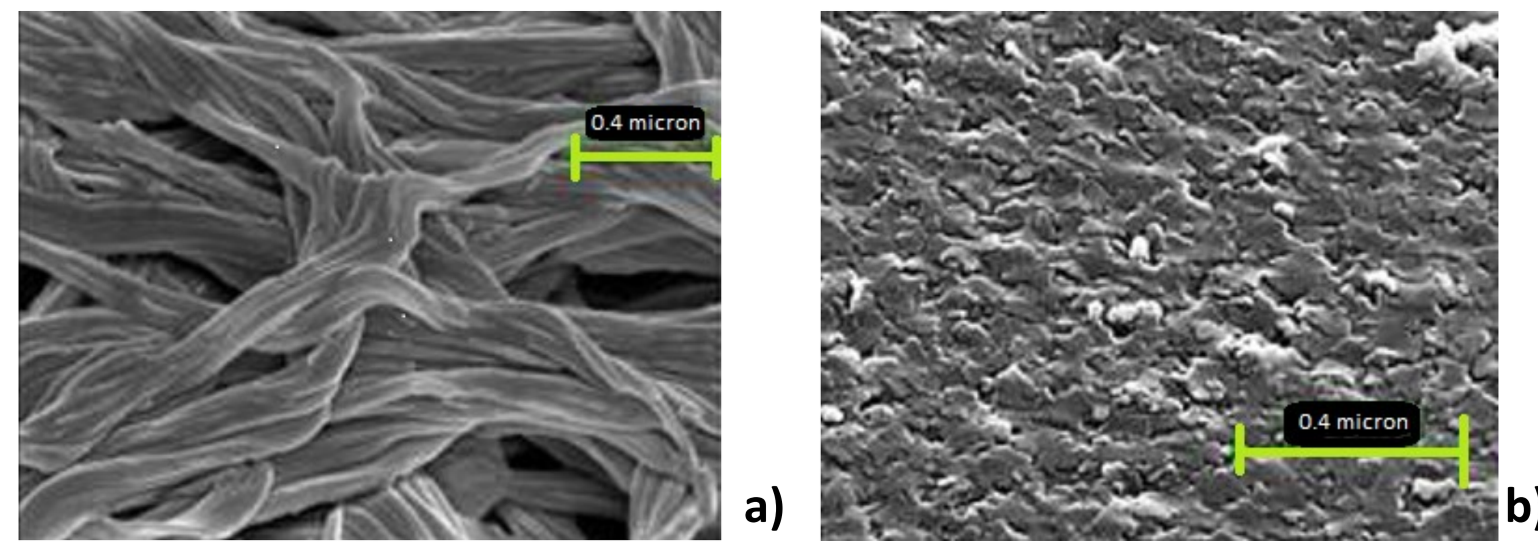

Fig. 1. Microstructure of greases. a) Lithium complex. b) Calcium sulfonate. [7]

The Caribbean, together with Central and South America, produced about 3% of the world production of lubricating greases in 2018 [8, 9], see Fig. 2. The Greases with lithium thickeners and lithium complex predominate the producing countries with 72% (850,000 Tons) of the total lubricating grease produced worldwide, while the greases with anhydrous calcium thickeners and sulfonate of calcium covered 9% in 2018 [8, 9], see Fig. 3.

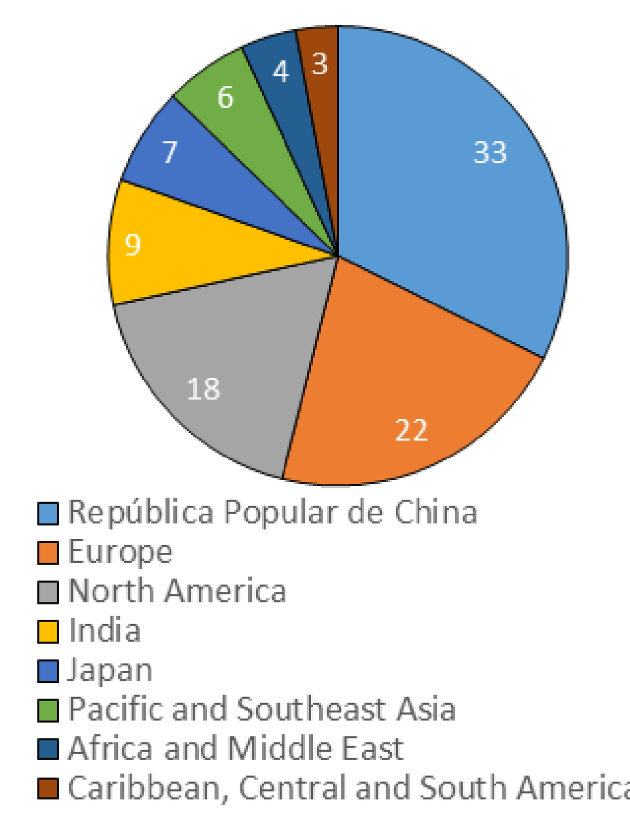

Fig. 2. Percentages of production of lubricating greases around the world in 2018.

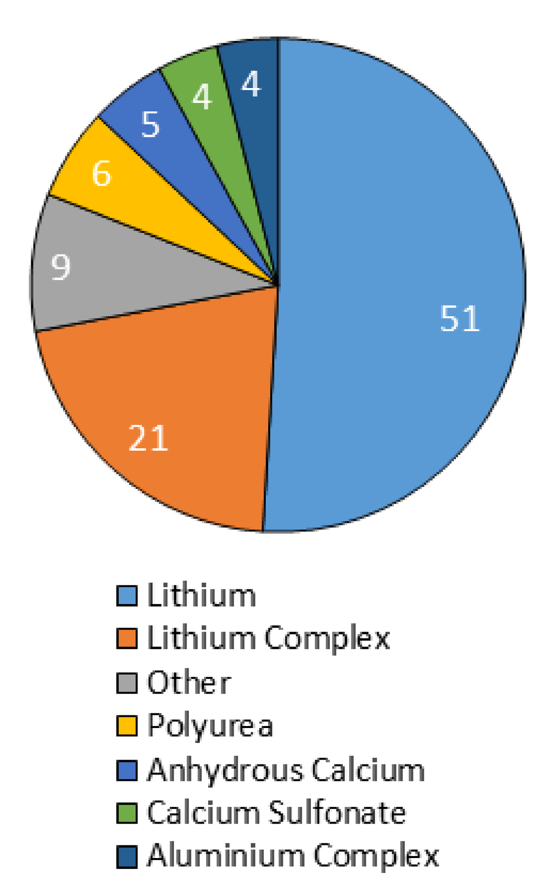

Fig. 3. Percentages of types of lubricating greases produced around the world in 2018.

Analysis of production from 2012 to 2018 determined that the grease production with a lithium thickener decreased, while the grease with a lithium complex thickener increased.

On the other hand, the grease production with hydrated calcium thickener decreased while the grease production with anhydrous calcium thickener and calcium sulfonate increased. Besides, new thickener technologies such as polyurea and aluminum complex developed and grew in this period [8, 9].

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Four ball testing machine

The four ball testing machines is a tribometer which is used to evaluate the protective properties of oils and greases lubricating under conditions of extreme and not extreme [10]. The geometric configuration consists of a tetrahedral arrangement of four AISI E52100 steel spheres. Three of them are placed inside the bottom of a pot and they are tightly squeezed, while the top fourth sphere is fixed in the rotary shaft. The load is applied and regulated between the bottom spheres and the top sphere throughout the test, as shown in Fig. 4.

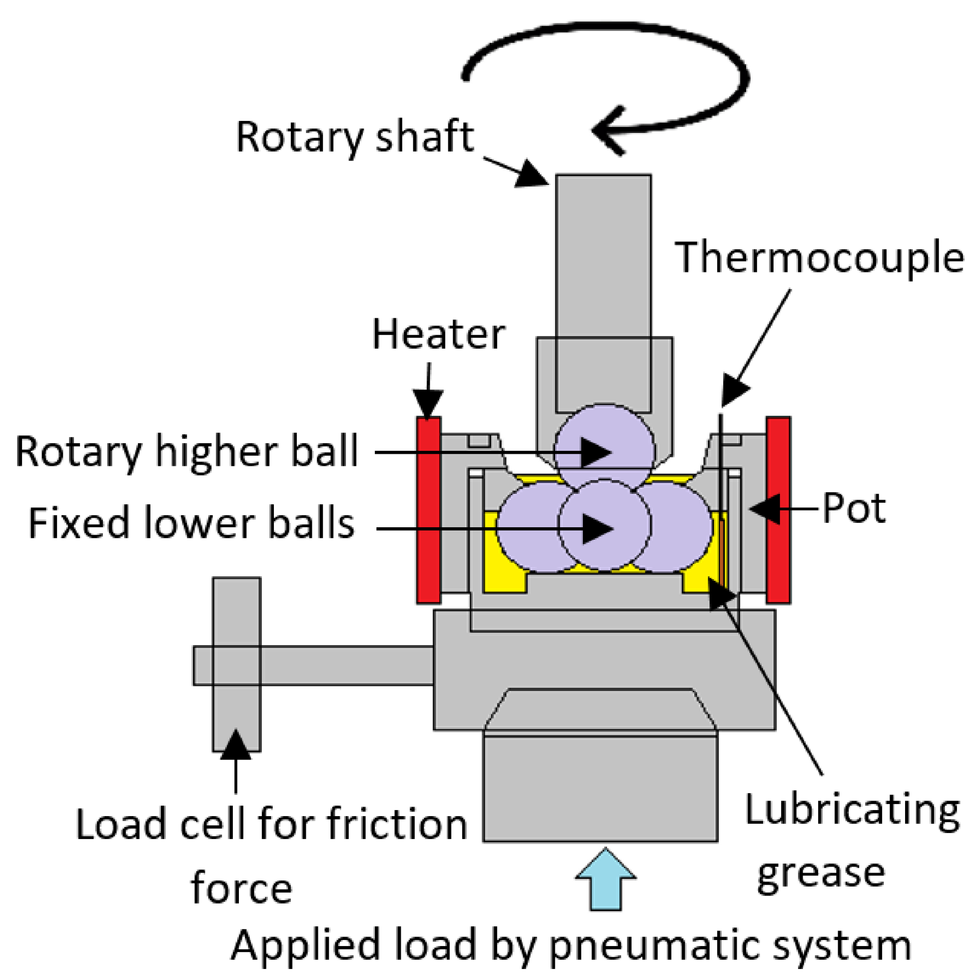

Fig. 4. Diagram of the four ball testing machine

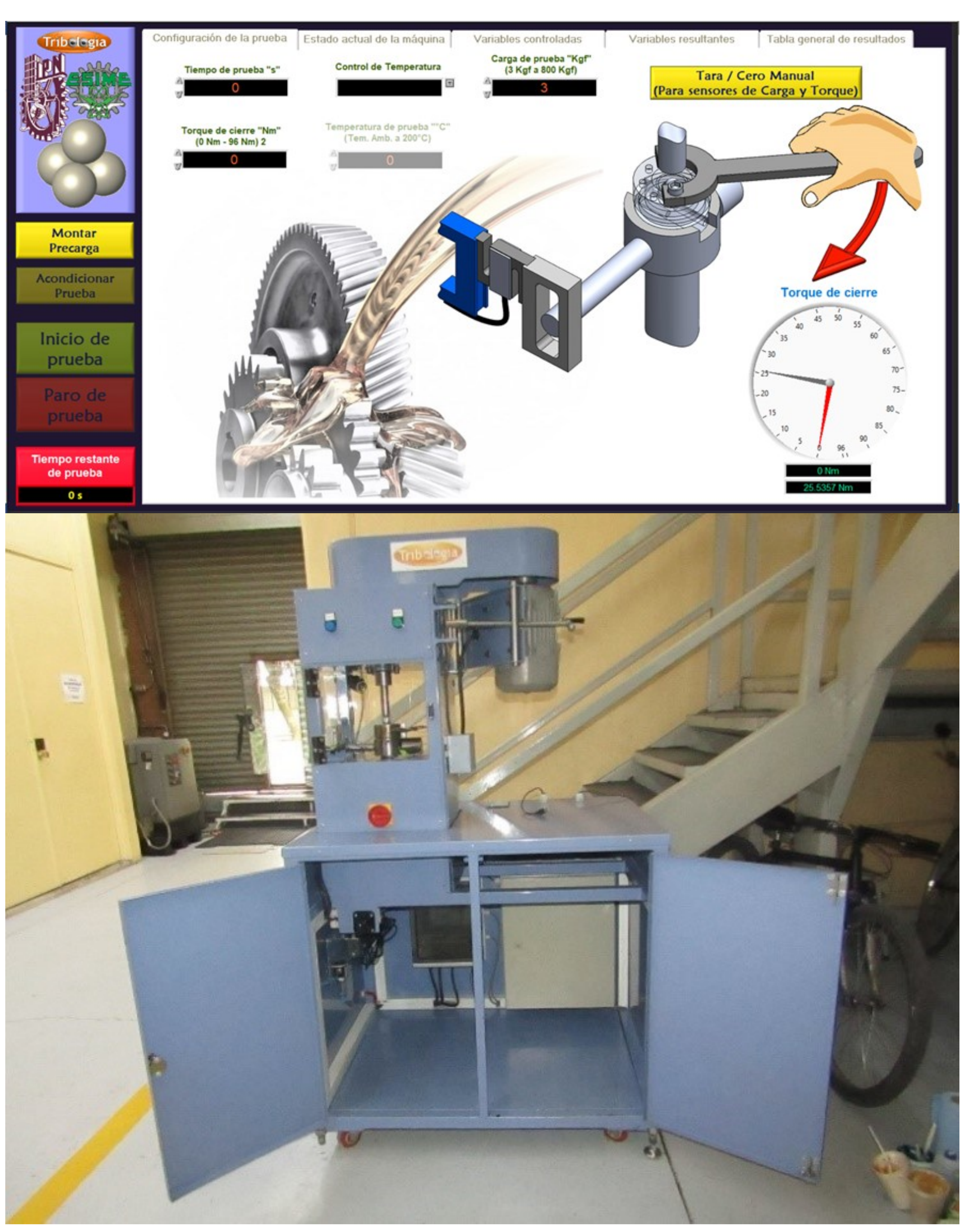

Fig. 5. Four ball testing machine with automatic control and computational interface, they were designed and manufactured by IPN, Tribology Group, SEPI - ESIME UZ [11,12]

Friction and wear tests

The tests are presented according to the method described in the ASTM D 2266 standard [13]. The test parameters are showed in Table 1.

Table 1. Parameters of wear tests.

Load applied	40 Kg
Temperature	75 °C
Angular speed	1200 rpm
Time	1 Hr.

Extreme pressure tests

The extreme pressure tests were performed according to the ASTM D 2596 standard [14]. Test parameters are showed in Table 2.

Table 2. Parameters of extreme pressure test .

Load applied	Exponencial increase of load
Temperature	27°C
Angular speed	1770 rpm
Time	10 s

Results of wear tests

Fig. 6 and Fig. 7 show the friction coefficients behavior for five tests carried out with CS and LX.

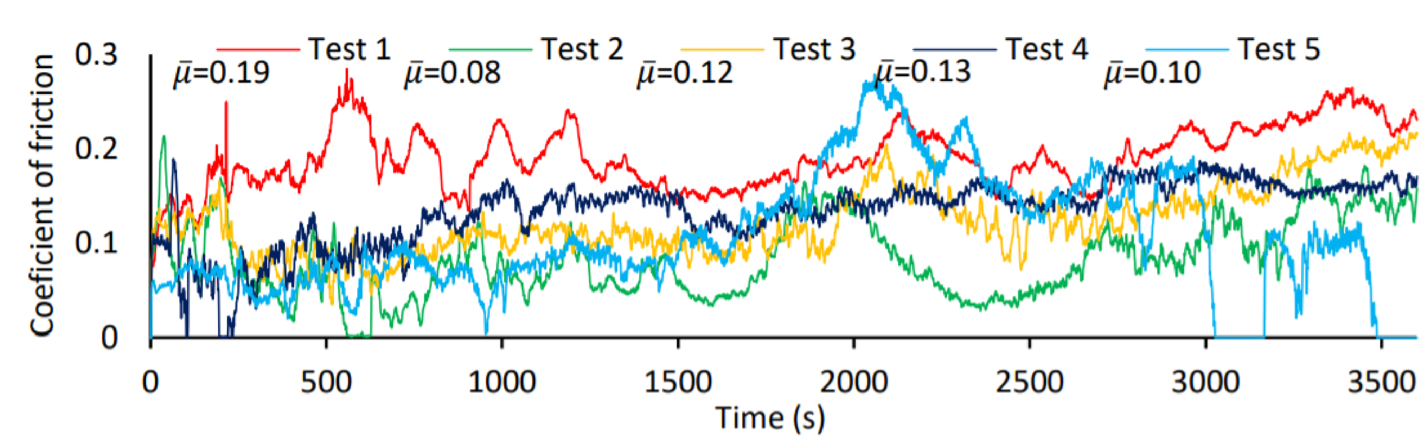

Fig.6. Coefficients of friction of the tests with LX.

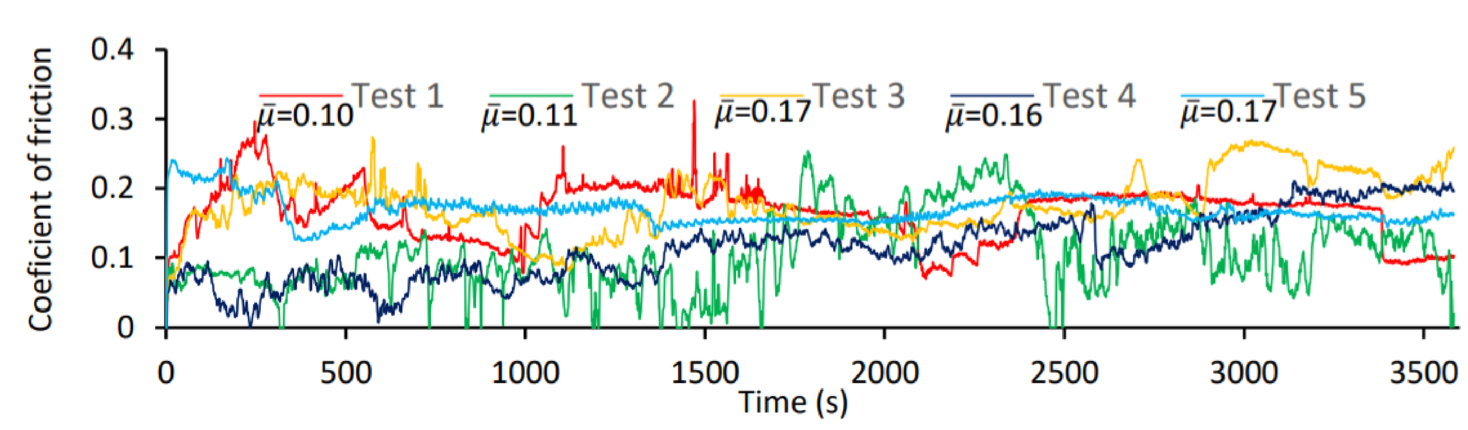

Fig.7. Coefficients of friction of the tests with CS.

By another hand, the averages of the wear scar diameters of the five wear tests performed with CS and LX are shown in Table 3

Table 3. Parameters of extreme pressure test .

Test number	CS (wear scar diameter)	Contact Pressure at the end of the test of CS (MPa)	LX (wear scar diameter)	Contact Pressure at the end of the test of LX (MPa)
1	0.4150 mm	945	0.5539 mm	708
2	0.4572 mm	857	0.5223 mm	751
3	0.5662 mm	692	0.5229 mm	750
4	0.5270 mm	744	0.5385 mm	728
5	0.5836 mm	672	0.4800 mm	817

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Results of extreme pressure tests

Fig. 8 shows areas without seizure phenomenon conformed by the trajectories from A to B for CS meanwhile A´ to B´ by LX the areas with incipient seizure are located from B to C for CS and from B´ to C´ for LX, immediate seizure regions were located from C to D for CS and from C´ to D´ for LX. The melting points were at E for CS and E´ for LX.

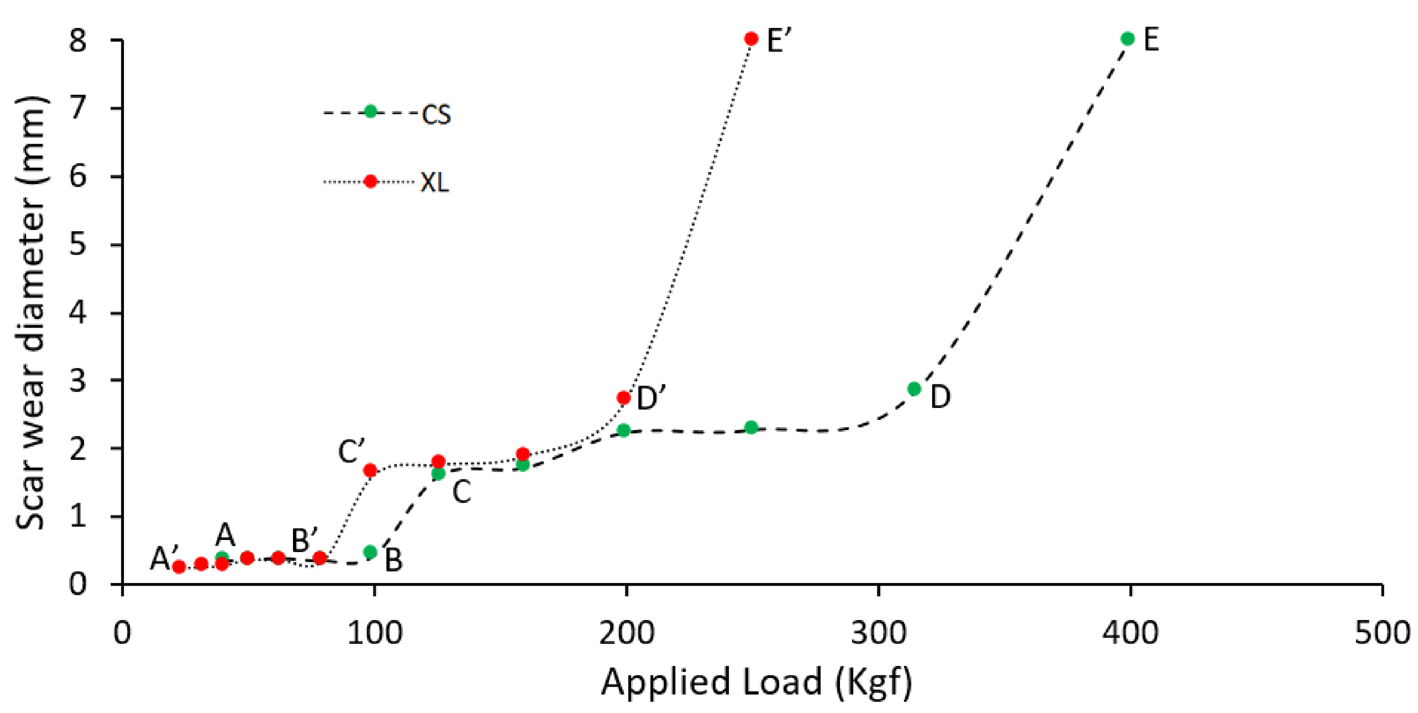

Fig. 8. Phases of surface damage CS and LX while the load was increased.

Of the previous tests. The Fig. 9 shows changes in contact pressures. When the load was increased, we can reach a maximum point, after that, it falls sharply due to the contact area rise precisely in the regions near the beginning of the seizure wear phenomenon.

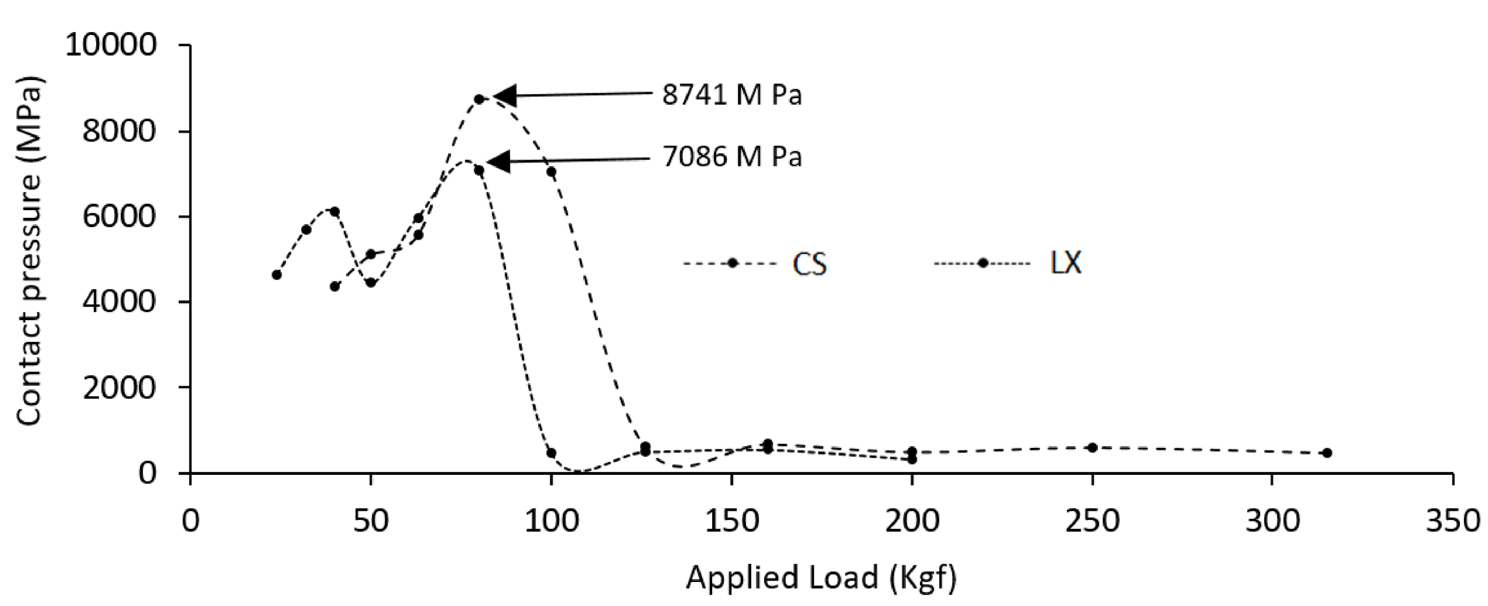

Fig. 9. Contact pressure in the extreme pressure tests.

Discussion

The term seizure is defined as a process where high contact pressure caused by the increasing of applied load induce to the union of small surfaces areas by the process of metallic flow, where the surfaces sliding causes fracture at union points, rejoining continuously during the interaction of the surfaces. The damaged surface generates a nominal area where a seizure point occurs [15].

When CS grease is subjected to loads from 40 Kg to 80 Kg, mainly micro-cutting can be observed on the steel balls surfaces. In contrast, when LX grease is subjected to loads from 24 Kg to 50 Kg, mechanisms micro-cutting is presented in the same way, and there is also micro-plowing for all tests in this load range. Applied a load of 126 Kg for CS grease another of 100 Kg in LX grease, appearing the wear mechanisms such as pitting on the surfaces for both cases. When reaching the critical loads of 126 Kg and 100 Kg with CS and LX greases respectively by another hand seizure phenomenon starting to create stresses and fractures and plowing and regions with material plastically deformed these wear mechanisms severely grown up when load increased.

Using 400 Kg as loading in CS another LX grease of 315 Kg, the soaps fibers in both cases broken up to release the oil, it evaporated quickly by the substantial increase in temperature owing to sliding contact, simultaneously is strongly welding and interrupting sliding between these surfaces.

The conditions of extreme pressure tests present relevant data. Both greases reached their maximum contact pressure level without seizure damage. In case that employs a load 126 Kg in CS grease and a load 100 Kg used to LX grease, then contact pressure starting to severe damage on the fibers of the structure of the lubricating soap, releasing the oil, this diminishes the performance of lubrication over the surface, and is presented seizure phenomenon, for this reason increase the damage.

Conclusions

- The thickeners derived from Lithium and Calcium are the most used to produce a better quantity of lubricating greases worldwide, using it with vegetable oil could contribute significantly to the environment.
- In the wear tests of greases with the CS and XL thickeners, none significant difference was seen in the behavior of the coefficient of friction. On the other hand, the wear scar diameters were of acceptable size but without significant differences.
- The structure of thickener contributes to improving the physicochemical, and tribological properties of lubricating grease.
- For those that present a higher density in its fibers have better tribological properties, especially in high contact pressures, so grease CS thickener have better performed in high contact pressure.

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