

ENVIRONMENTALLY FRIENDLY LUBRICANTS FOR MILL BRASSES

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Abstract

IN SPITE of environmental, safety and hygiene pressures to eradicate their use, large quantities of asphaltic oils are still used for the lubrication of mill brasses in sugarcane mills. Since about 1980, people have been encouraged to find a solution to the contamination resulting from the use of asphaltic oils and, at the same time, have started to identify significant related costs. Lubricant technology has advanced, introducing new products to provide an effective solution to the contamination problem. This paper shows the evolution of technology from asphaltic oils to very high viscosity oils. These high viscosity oils cause very low environmental impact, are used in small quantities, and are considered biodegradable, with low-toxicity. Some products are considered food-grade.

Introduction

In spite of environmental, safety and hygiene pressures to eradicate their use, large quantities of asphaltic oils are still used for lubrication of mill brasses in sugarcane mills. 'Mill brasses' is the common name for the large plain bearings (journal bearings) of sugarcane mills.

The mill brass is one of the mill components with the greatest mechanical stress, since it is subjected to:

- Very high load: 5 to 10 MPa.
- Very high operating temperature: up to 100°C.
- Very low speed: from 4 to 7 r/min.

These operating conditions constitute a specific 'lubrication regime' and, in this situation, wear by friction is potentially important. It is necessary to know the lubrication regime to design the best lubricant for the application. These regimes can be identified in the Stribeck/Hersey curve, developed by Stribeck (1902) and Hersey (1914). The Stribeck/Hersey curve determines the coefficient of friction as a function of viscosity (Z), velocity (N) and load (P).

Figure 1 shows that, for a velocity close to 0 and with high loads, the viscosity of the lubricant 'Z' is the parameter that must increase in order to ideally let us get away from the regime of 'boundary lubrication'. However, 'hydrodynamic' lubrication, in which there is no metal-to-metal contact between the roll shaft and the bearing, cannot be reached. The possibility of providing effective flow of sufficient lubricant is, in practice, between 100 and 200 times inferior to what is required. Consequently, the lubrication regime of mill brasses remains '*boundary lubrication*' (Hargreaves, 1984).

In addition to the actual operating conditions of mill brasses, as defined by the ZN/P expression, **high temperatures** of the order of 100°C can also be developed in the roll shaft-bearing interface. Contaminants such as water, cane juice and bagasse add to the problem, and should be counteracted with design of proper mechanical protection arrangements, alignment and adjustment between the roll shaft and the bearing.

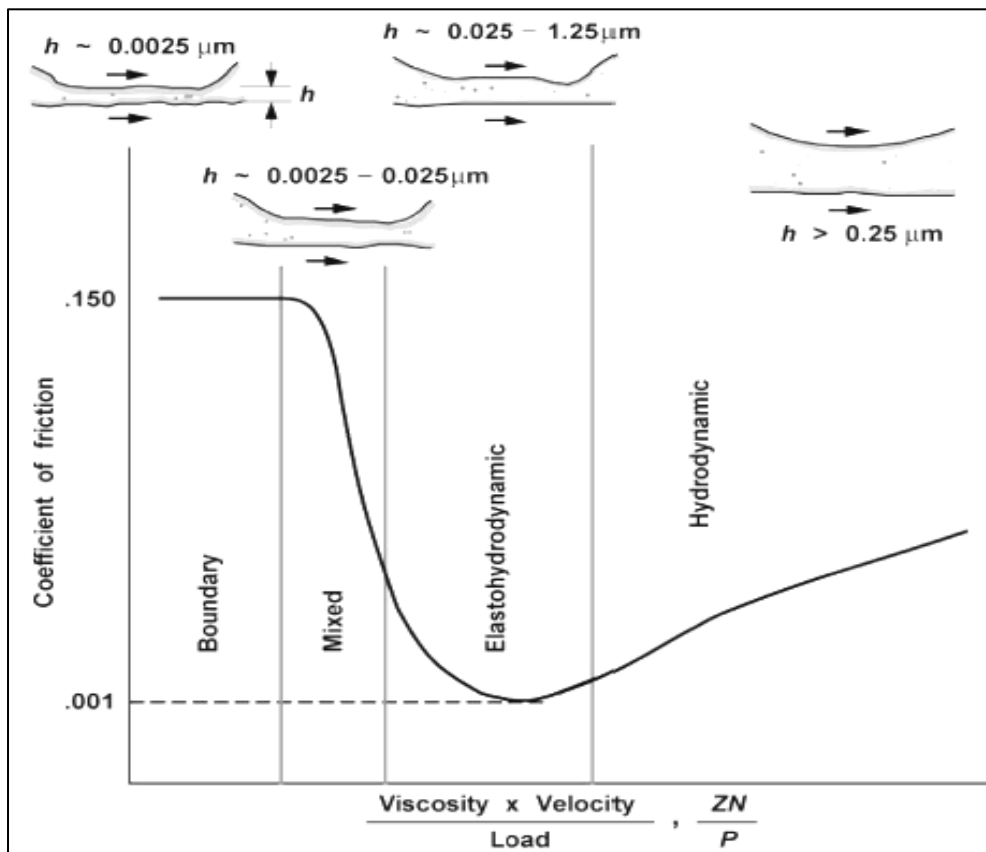


Fig. 1 – Coefficient of friction as a function of viscosity (Stribeck, 1902)

Requirements for designing better lubricants

The design of better lubricants primarily requires that ZN/P is as high as possible. Therefore, viscosity Z will be as high as possible. Viscosity, however, is not the only important condition. Other requirements must be taken into account, given the need to improve the environmental, safety and hygiene performance of mill brass lubricants and to extend the useful life of equipment. The guidelines for the design of a suitable lubricant should be as follows:

Tribologic requirements of lubricant

1. Very high viscosity at 100°C
2. Must provide metal adherence for longer residence time in the roll shaft-bearing interface
3. Must avoid or minimise water, cane juice or bagasse input
4. Enough thermal stability at high operating temperature
5. In 'boundary lubrication' regime, must have EP capacity necessary to prevent micro-welding when the lubricating layer is thin (four-ball test, ASTM D 2783, weld load ≥ 620 kg).

Distribution requirements of lubricant

6. Must be fluid so as to enable its handling and pumping in centralised lubrication systems
7. Its structure must be homogenous, without getting dispersed, in view of repeated pressurisation-release cycles

Chemical resistance requirements of lubricant

8. Must not attack valve and pump seals
9. Must withstand contamination by water
10. Must withstand contamination by cane juice

Requirements for environment and security and hygiene

11. Must enable lubrication with very low application quantity; 10 times less than asphalts.
12. Must be clear and non-irritating
13. Must be highly biodegradable according to environmental international standards
14. Must have low toxicity
15. Must credit food grade certifications, H1 if required
16. Must derive from renewable resources

Evolution of lubricants for mill brasses

After asphaltic oils, there have been two main evolutions in lubricant types: graphite greases with solid lubricants (graphite) that were originally used for lubrication of open gears in mine and cement industries and, in recent years, very high viscosity oils.

Table 1 shows the performance of the different technologies of lubricants for mill brasses. The numbers in the table relate to the 16 lubricant requirements (reproduced below). The **white** box signifies poor lubrication, the **yellow** box signifies good lubrication and the **green** box signifies excellent lubrication.

Table 1—fulfilled requirements of mill brasses of lubricant.

				1980s decade				1990s decade				2000s decade				At present			
Asphaltic oils				Graphite greases or European type				Very high viscosity oils				Very high viscosity oils BIODEGRADABLE				Very high viscosity oils BIOBASED			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8
9	10	11	12	9	10	11	12	9	10	11	12	9	10	11	12	9	10	11	12
13	14	15	16	13	14	15	16	13	14	15	16	13	14	15	16	13	14	15	16

Theoretical calculation of oil viscosity for a mill brass

Assumptions

A mill top roll brass has been analysed for a mill crushing between 4500 and 5000 tonnes of cane per day and the following configuration:

- Diameter main mill brass: 480 mm
- Effective length of brass: 550 mm
- Mean diameter of roller: 1000 mm
- Length of roller: 2000 mm
- Diameter of hydraulic cylinder: 356 mm

Table 2 relates the top roll hydraulic pressure to the pressure on the top roll brass.

Table 2—Typical field operation conditions of mill brasses.

Hydraulic pressure (MPa)	Pressure onto main mill brasses (MPa)
20	5.9
18	5.3
16	4.7
15	4.4
14	4.2

Lubrication parameters

The following parameters should be considered when determining the lubricant viscosity:

1. Lubricant viscosity at rating temperature
2. Pressure between contact surfaces
3. Rotational speed
4. Separation between surfaces (clearance)
5. Materials used (very important for effective lubrication)
6. Quality degree of surfaces.
7. l/d ratio (bearing length/bearing diameter)

It is quite complex to relate all these terms, and so a simplified formula has been adopted, (Martinet, 1985)

$$K = \mu * n * 10^8 / P$$

μ : viscosity (kg.s/m²)
 n : rotational speed (r.p.s)
 P : specific pressure in the main bearings (kg f/m²)

For the purposes of this specific study we will distinguish three types of lubrication:

- Boundary lubrication: metallic rubbing between the journal-brass.
- Mixed lubrication: in some parts, friction is metallic; in others, it is fluid by means of lubricant
- Hydrodynamic lubrication: lubricant layer is installed on the whole mill brass surface.

The method to determine if our case tends to fall in the last mode is by evaluating K value
 If $K < 5$, hydrodynamic lubrication is not possible.

If $K \geq 5$, superficial termination will be with 0.005 mm roughness and antifriction material.

If $K \geq 15$, rectified journal and bronze bearing.

Thus, in our case we look for oil for which the K value must be ≥ 15

Comparison: Asphaltic oil - Very high viscosity biodegradable oil

Table 3 shows K values for different values of speed, temperature and pressure in main mill brasses for an asphaltic oil. Note that the unit of viscosity (kg*seg/m²) is the same as that used in the above formula (kg.s/m²). Table 4 shows K values for a very high viscosity biodegradable oil. It is clear that the K values are considerably higher for the very high viscosity oil than for the asphaltic oil.

Table 3—K value for asphaltic lubricated mill brass.

Temperature	40°C			50°C			60°C			70°C			Hydraulic pressure	Pressure onto brass
Z (kg*seg/m ²)	0.20			0.13			0.08			0.06				
n (r/min.)	4	5	6	4	5	6	4	5	6	4	5	6		
K	3.15	3.97	4.77	2.05	2.58	3.10	1.26	1.59	1.91	0.96	1.21	1.46	140	419 219
	2.94	3.71	4.46	1.91	2.41	2.90	1.18	1.49	1.78	0.90	1.13	1.36	150	448 711
	2.75	3.48	4.17	1.79	2.26	2.71	1.10	1.39	1.67	0.84	1.06	1.27	160	479 258
	2.45	3.09	3.71	1.59	2.01	2.41	0.98	1.24	1.48	0.75	0.94	1.13	180	539 296
	2.21	2.78	3.34	1.43	1.81	2.17	0.88	1.11	1.34	0.67	0.85	1.02	200	598 282

(Kg*seg/m²) by 9807 ≈ cSt

Table 4—K value for very high viscosity biodegradable oil lubricated mill brass.

Temperature	40°C			50°C			60°C			70°C			Hydraulic pressure	Pressure onto brass
Z (kg*seg/m ²)	1.61			1.04			0.70			0.34				
n (r/min.)	4	5	6	4	5	6	4	5	6	4	5	6		
K	25.35	31.99	38.40	16.37	20.67	24.81	11.02	13.91	16.70	5.35	6.76	8.11	140	419 219
	23.68	29.89	35.88	15.30	19.31	23.18	10.30	13.00	15.60	5.00	6.31	7.58	150	448 711
	22.17	27.98	33.59	14.32	18.08	21.70	9.64	12.17	14.61	4.68	5.91	7.09	160	479 258
	19.70	24.87	29.85	12.73	16.06	19.28	8.57	10.81	12.98	4.16	5.25	6.30	180	539 296
	17.76	22.42	26.91	11.47	14.48	17.38	7.72	9.75	11.70	3.75	4.73	5.68	200	598 282

(Kg*seg/m²) by 9807 ≈ cSt

Case study

Lubricant performance was measured in a sugarcane mill with a milling tandem consisting of five 1981 mm mills crushing 12 000 tonnes of cane per day. The mill brasses were lubricated with 16 500 cSt @40°C very high viscosity biodegradable oil. The lubricant consumption is shown in Figure 2. The average lubricant consumption was 10 litres per day (0.9 g per tonne of cane). This lubricant consumption was 80% less than is typical of black or asphaltic oils.

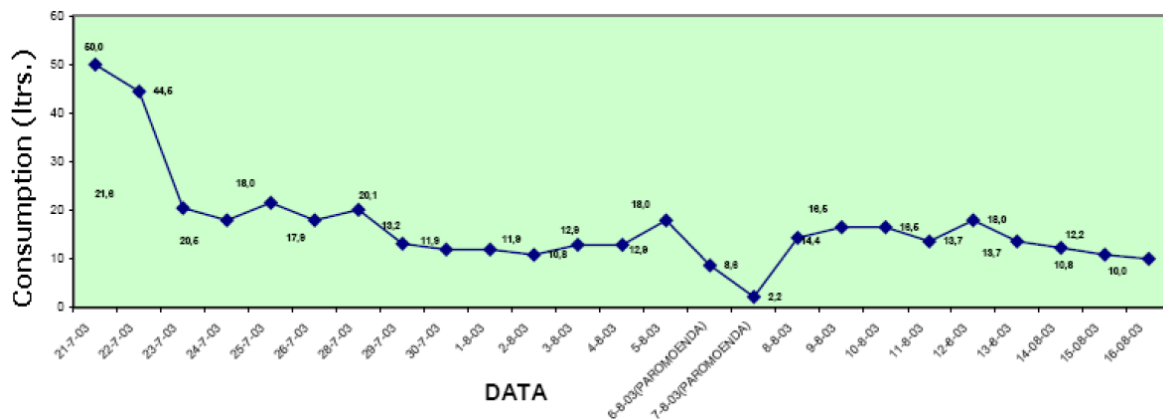


Fig. 2—Measured lubricant consumption.

The operating temperature was kept stable, as shown in Figures 3 and 4 for the first and final mills respectively.

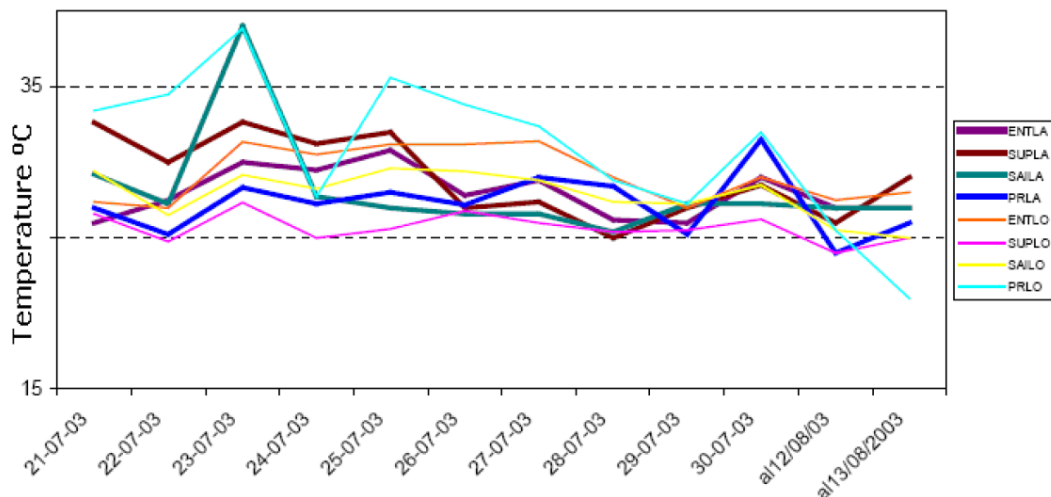


Fig. 3—Operating temperature for first mill.

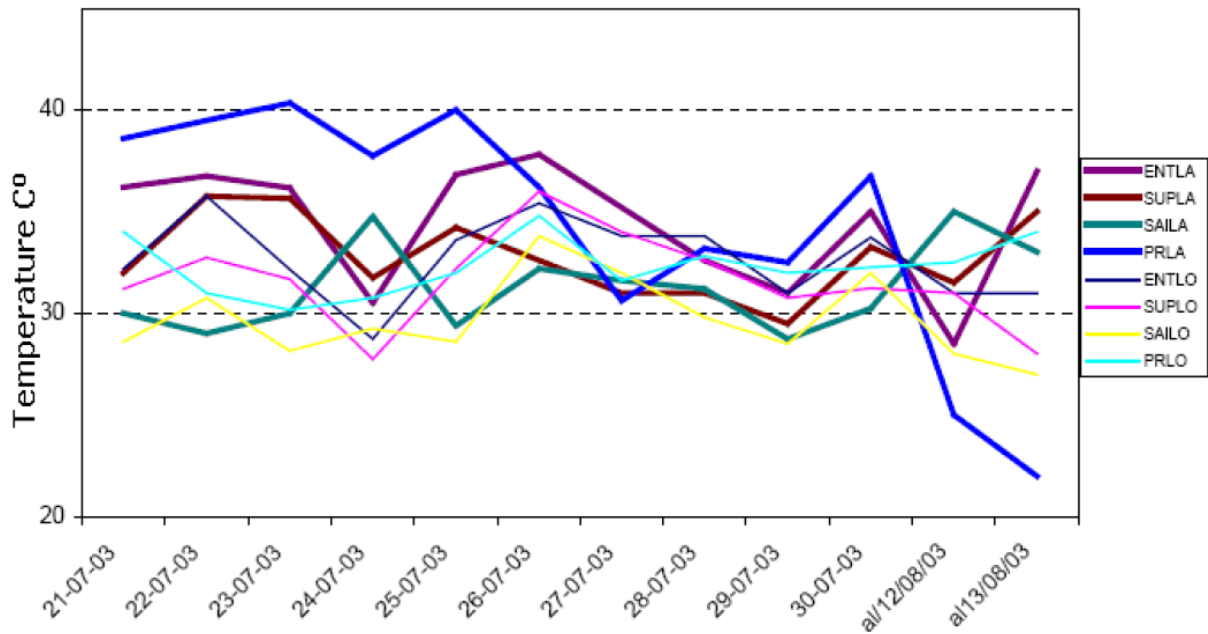


Fig. 4—Operating temperature for final mill.

At the end of the first season of operation, the brasses and the roll shafts was both in good condition (Figure 5).



Fig. 5—The good condition of the brasses and roll shafts.

With the new lubricant, there was minimal spillage of lubricant on the factory floor (Figure 6). The absence of spills improves workplace safety.



Fig. 6—The absence of spills on the floor prevents accidents.

Conclusion

Asphaltic oil and graphite greases cannot fulfil the requirements of mill brass lubrication. The high K values required can, however, be achieved with very high viscosity oil. The very high viscosity oil causes very low environmental impact, as much less lubricant is required and is considered biodegradable, with low-toxicity.

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LUBRIFIANTS POUR COUSSINETS DE MOULINS SANS EFFETS NOCIFS POUR L'ENVIRONNEMENT

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**MOTS-CLES: Coussinets, Lubrifiant,
Moulin, Viscosité.**

Résumé

EN DEPIT de l'environnement, de la sécurité et de l'hygiène, de grandes quantités d'huiles bitumineuses sont toujours utilisées pour la lubrification des coussinets de moulin dans les usines a canne. Depuis 1980, le personnel a été encouragé à trouver une solution à la contamination résultant de l'utilisation d'huiles bitumineuses et, en même temps, on a commencé à identifier les coûts associés a cette contamination. La technologie de lubrifiant a progressée et on a lance de nouveaux produits afin de fournir une solution efficace aux problèmes de contamination. Ce papier montre l'évolution de la technologie d'huiles bitumineuses vers des huiles de très haute viscosité. Ces huiles de haute viscosité provoquent un impact environnemental très faible, sont utilisées en petites quantités et sont considérées comme biodégradables, avec une faible toxicité. Certains produits sont même considérés acceptables comme aliments.

LUBRICANTES AMBIENTALMENTE AMIGABLES PARA BRONCES DE MOLINOS

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**PALABRAS CLAVE: Bronce, Lubricantes,
Molino, Viscosidad.**

Abstract

A PESAR de las presiones ambientales, de higiene y de seguridad para erradicar su uso, se siguen empleando grandes cantidades de aceites asfálticos para la lubricación de cojinetes de bronce en molinos de caña. Alrededor de 1980 se incentivó la búsqueda de soluciones a la contaminación causada por los aceites asfálticos y al mismo tiempo se comenzó a identificar los costos asociados al tema. La tecnología de lubricantes ha avanzado, introduciendo nuevos productos para proveer una solución efectiva al problema. Este trabajo trata sobre la evolución de la tecnología desde los aceites asfálticos hasta los aceites de muy alta viscosidad. Estos aceites causan un muy bajo impacto ambiental ores cantidades, y se consideran biodegradables, con baja toxicidad. Algunos de estos productos son considerados de grado alimenticio.