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Biodegradable Lubricants

Introduction

Environmental compatibility is usually viewed in respect to biodegradability and toxicity. While the first issue is reached by using a suitable biodegradable base fluid, low toxicity requires additives that are also environmentally friendly. However, lubricant performance (friction, wear, lifetime, load bearing, efficiency etc.) has a major impact on its overall environmental compatibility.

The replacement of mineral oils by biodegradable products is one of the ways to reduce adverse effects on the ecosystem. At the same time, products eco-labelled in the EU scheme can give you the guarantee that their compliance with established ecological criteria has been tested by independent third parties, the national and regional Eco-label Competent Bodies. Providing information about the environmental effects of a product during its whole life-cycle will be essential in order to support sustainable consumption.

1. Regulations and policies about biolubricant

Several national eco-labels/schemes and one international standard have been developed in the recent years setting requirements for the ecological and technical characteristics of lubricants: Nordic White Swan (Nordic Countries), Swedish Standard SS 15 54 34 (Sweden), EU Llincwa, Blue Angel, Eco-label RAL-UZ (Germany), German positive list, VAMIL regulation (The Netherlands), ISO 15380 (International Standard), European Ecolabel EEL 1005/360/CE etc.

2. Biolubricants requirements

There are other requirements that a biolubricant has to fulfil if they are also considered as environmentally friendly products:

- High biodegradability (rapid removal from environment)
- Low ecotoxicity (impact on the environment).
- Technical specifications (adequate performance as a lubricant)
- Contains a significant level of renewable raw material (sustainability)

The fact is that no universal agreement exists concerning the chemical composition of a biolubricant.

Primary biodegradation is the measure of conversion by biological system of the original organic into different products. This is the first step in biodegradation.

Readily biodegradation occurs when biodegradation performance is greater than a certain relative fixed percentage of ultimate biodegradation.

Ultimate biodegradation is the complete conversion of the original substance into carbon dioxide, water, and new microbial biomass. This process is also referred to as mineralisation.

2.1. Biodegradation requirements

The biodegradability of a biolubricant is best assessed using a "ready biodegradability test as published by OECD and adopted by the European Union. In view of the low solubility of biolubricants in water, only respirometric methods are suitable for testing. The two recommended methods are OECD 301 B and OECD 301 F.

A substance is considered **ultimately biodegradable** (aerobic) if: -

- in a 28-day biodegradation study according to OECD 301 A-F or equivalent tests the following levels of biodegradation are achieved;
- in OECD 301 tests based upon dissolved organic carbon > 70%;
- it can be rapidly and extensively biodegraded in the environment, and
- it can be used in a "biodegradable" or "environmentally acceptable" product.

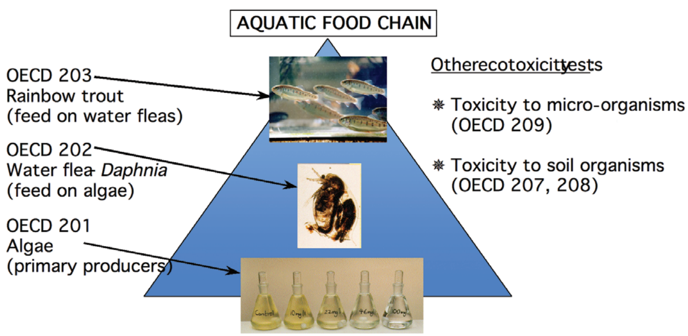
A substance is considered **inherently biodegradable** if it shows: -

- biodegradation > 20% but < 60% after 28 days in the OECD 301 tests.
- Based on oxygen depletion or carbon dioxide generation;
- Has only the potential to be biodegraded in the environment

2.2. Aquatic toxicity requirements

Toxicity to the environment is usually assessed using short term aquatic toxicity tests as published by the OECD (Test Guidelines 201, 202 and 203). The OECD methods are: -

Figure 1



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3. Biolubricants Applications

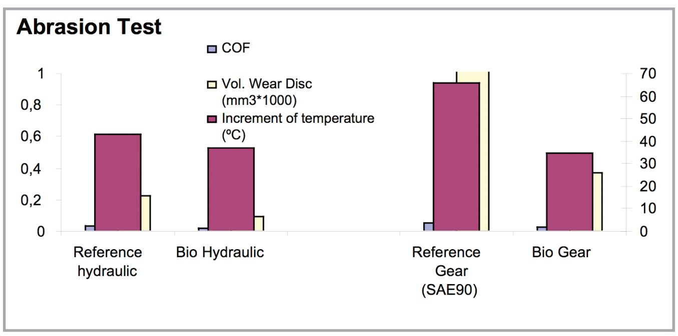
- Hydraulic and Gear Oils
- Greases
- Engine Oils
- Transmission Oils
- Forming and cutting applications Oils

3.1. Hydraulic and Gear Oils

Newly developed lubricants based on high oleic sunflower oil are biodegradable and "not harmful" to aquatic organisms.

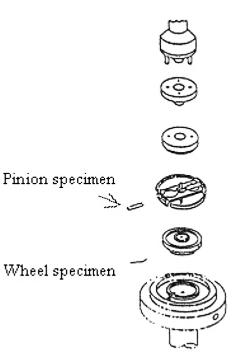
Tribological tests represented in Graphic 1 show good friction and wear behaviour in an abrasion test.

Graphic 1

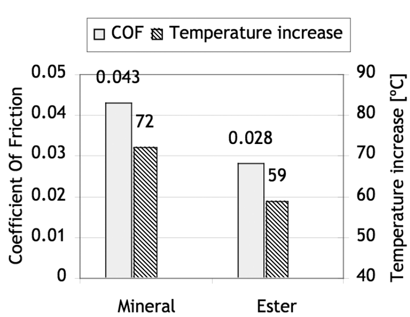


In order to simulate the wear and friction of gears a wear test configuration (figure 2) was compared with real gear tests carried out in the European projects: SUNOIL, BIOGREASE, BIOMON and EREBIO. The sliding/rolling percentage selected is similar to the real gear as well as the operating conditions. The average coefficient of friction during the test and the total increase of lubricant temperature are represented in graphic 2. The friction coefficient measured for the mineral lubricant was 54% higher than the value measured for the Ester. A similar result was also demonstrated for temperature increase, with ester based oil being, 13°C lower.

Figure 2



Graphic 2



Four ball test "Extreme Pressure Test"

The EP-four ball test was carried out according to standard ASTM D 2783. These tests are useful to evaluate the load carrying capacity of lubricants. Table 1 shows that the new lubricants have higher load resistance than the reference oils.

Table 1

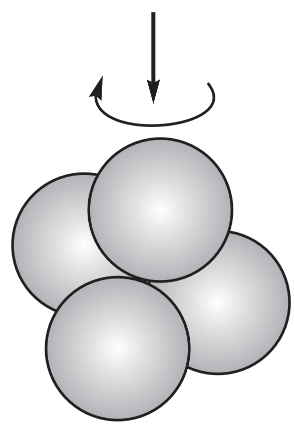
Lubricants	Welding Load (Kgf)
Reference Hydraulic oil	160
Bio hydraulic Oil	**250**
Reference Gear Oil (SAE 90)	126
Bio gear Oil	**315**

3.2. Greases/Biogreases

Replacing mineral oils with biodegradable and non-toxic products is one of the ways to reduce adverse effects on the ecosystem caused by the use of lubricants.
There has been a great challenge in producing greases for heavy-duty applications, for example for those greases used in excavators. During the European BIOGREASE project, a mineral grease has been compared with a newly developed bio-grease composed of a high oleic sunflower oil, a viscosity improver, a synthetic ester and a polymer thickener.
In a "Four Ball" tribometer (Figure 3) two kinds of standard tests have been carried out:

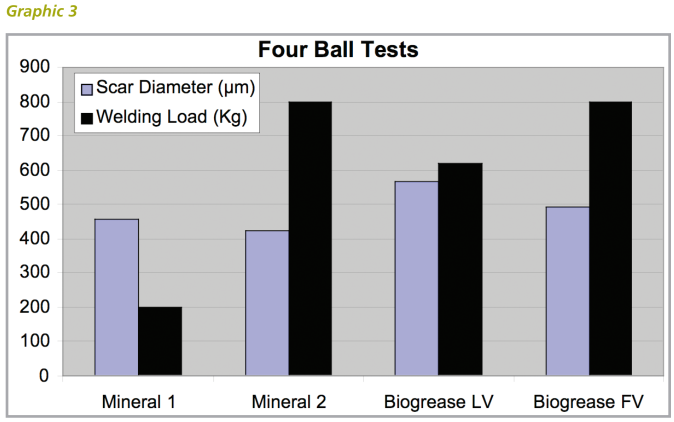
- ASTM D2266: to measure anti-wear properties.
- ASTM D2596: to compare extreme pressure properties

Figure 3



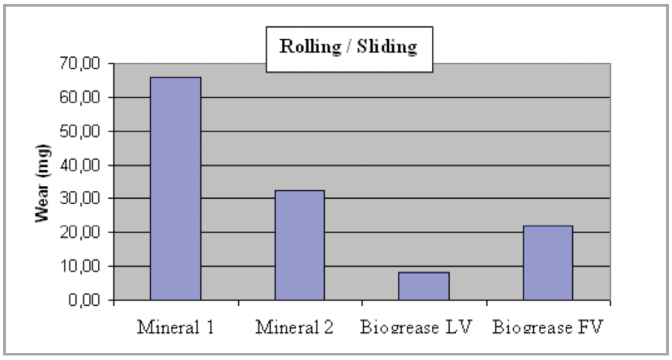
The Biogrease FV (final version) was compared with the mineral reference oils, showing an increase in the load carrying capacity with similar wear resistance (graphic 3).

Graphic 3



In order to simulate contact geometry in gears, it was used in the gear simulation configuration (figure 2) with a Falex MultiSpecimen Machine. The Biogreases developed presented higher wear resistance (graphic 4) than the reference lubricating grease.

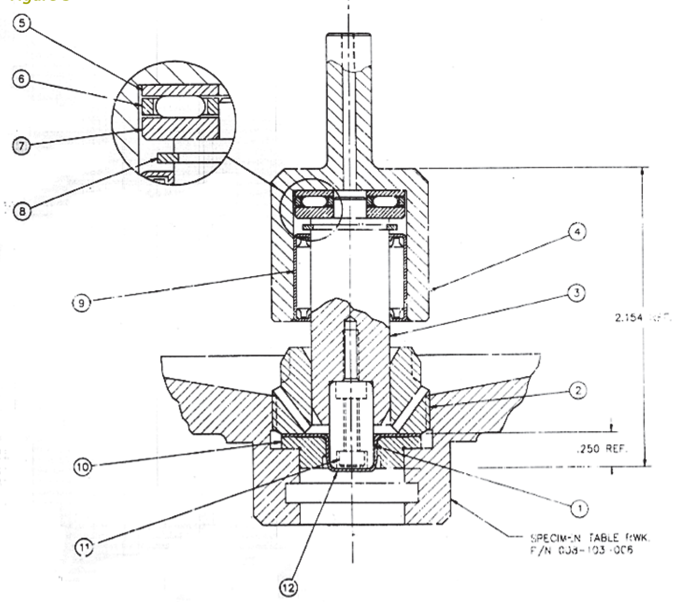
Graphic 4



3.3. Engine oils

A study of biodegradability and tribological properties has been conducted for engine oils. Different candidate engine oils for the PCMO (Passenger car engine oil) have been investigated. They were biodegradable, non toxic and with reduced metal-organic additives, so called EPC-48 and EPC-49.
Tribological tests were performed to simulate different engine critical components from car engines like piston rings and journal bearings. Piston Ring Simulation is shown in Figure 5.

Figure 5



The Table 2 shows that the new lubricants EPC 48 and 49 present a higher resistance to piston ring seizure than reference PCMO oils.

Table 2

Piston rings	Lubricants	Extreme Pressure Conditions		
		Time at which failure occurs (minutes)	*The highest friction load at which no failure occurs (N)*	*Type of failure**
Steel coated	Ref. PCMO	28	1300	Stroke < 0,3 mm
	EPC-48	**41**	**2000**	**No failure**
	EPC-49	**41**	**2000**	**No failure**

3.4. Cutting and forming applications

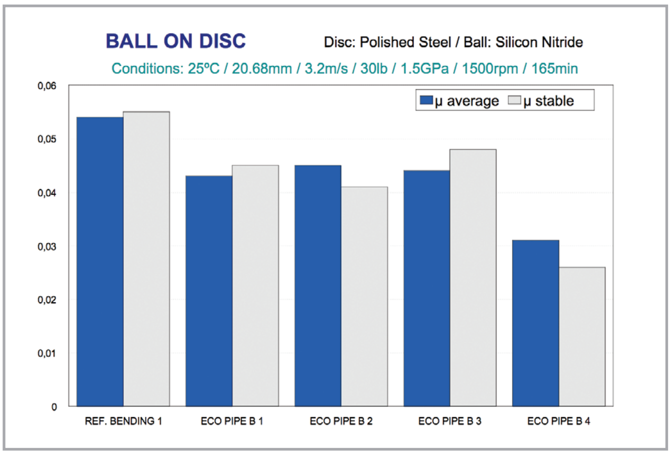
Cutting fluids were tested in the SRV tribotester (Ring on Disc configuration) using a sheet material (HSS, AISI 304) typical for this application. Very strong abrasion was observed in the test performed with Reference Cutting Oil. The abrasion process was considerably reduced, when testing with Ecopipe Cutting 3 lubricant (Table 3).

Table 3

Lubricant	Friction	Sheet Wear (mg)	Wear mechanism
Reference Cutting	0.429	1.38	Very strong abrasion/adhesion
Eco pipe Cutting 3	0.347	0.44	Moderate abrasion

For Pipe bending applications, the new ecological fluid "Ecopipe bending 4" reduced the friction to half that of the reference mineral oil. Also the wear was lower in real applications (Graphic 5).

Graphic 5

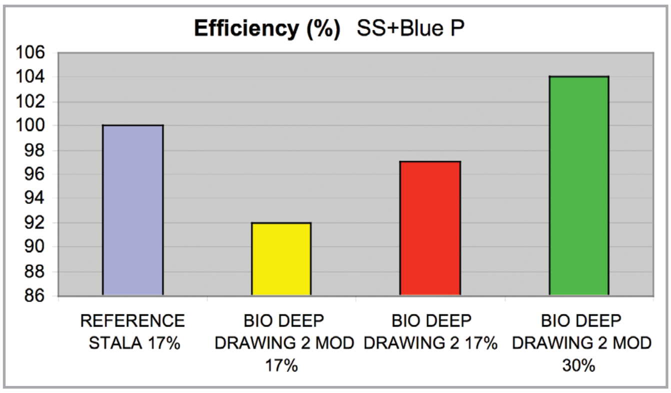


3.5. Biolubricants for Deep Drawing

Two lubricants have been developed for deep-drawing applications when used diluted in water. Both lubricants are formulated with native esters, sulphur additives and potassium soap.

Their behaviour was compared with the reference water-soluble lubricant. Tests at the Tapping Torque machine show that when increasing the concentration of the mixture from 17% and 30% an increase of deep drawing efficiency of 4% was achieved (graphic 6).

Graphic 6



4. Life cycle analysis (LCA) UNE-EN ISO 14040

LCA is a technique to evaluate environmental impacts and potential impacts associated with the product, process or activity by means of: -

- The recompilation of an inventory of the inputs and outputs (energy, raw materials and emissions) in a system.
- The evaluation of potential environmental impacts associated with these inputs and outputs.
- The interpretation of the results in the phase of the analysis of the inventory and the evaluation of the impact according to the objectives.

Main Steps in an LCA:

The main steps describe which emissions will occur and which raw materials are used during the life of a product. The evaluation assesses the impacts of these emissions and the effect in the raw materials depletion.

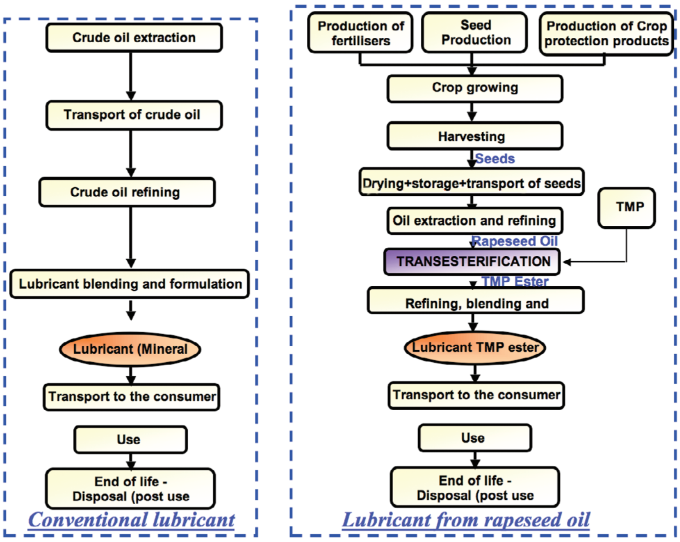
The evaluation has different steps:

- Classification of the inventory table into impact categories.
- Characterisation: Aggregation within the category.
- Normalisation: relative size, effect on a person during a period time.
- Evaluation: Weighting of different categories.

Comparative Life Cycle Process Tree for lubricants

In the figure 6, the comparative Life Cycle process tree can be seen for a mineral and the rapeseed ester oil. The overall environmental impact of the rapeseed ester was lower than the mineral oil.

Figure 6



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