Technical Topic

Lubricant Biodegradability and Why It Is Important

Introduction

Despite significant advances in connector, hose, and seal technology in recent years, there is no guarantee that lubricating systems won't leak. Leaks can still result from improper assembly, misapplication, and simple wear and tear of the equipment. There now exists greater awareness for the need to reduce leakage in lubricating systems. The US Environmental Protection Agency (EPA) and other worldwide regulatory bodies have sought to reduce spills through stricter regulation, including the possibility for fines, penalties and costly remediation. Increasingly, there is awareness that lubricants coming into contact with soil, water, wetlands, and other sensitive areas can negatively impact the environment. This has both manufacturers and users of lubricating systems switching to more environmentally acceptable alternatives, such as those that are biodegradable and non-toxic. These biodegradable and non-toxic lubricants can offer performance comparable to mineral oil-based fluids in some applications.

Customers have found the use of biodegradable and nontoxic lubricants to be suitable for environmentally sensitive applications in construction, mining, forestry, agriculture, hydroelectric dams, and various marine uses including dockside cargo handling, harbor dredging, off-shore drilling, stern tubes, azipods, and deck hydraulic equipment.

This document will examine one of the two main properties of an environmentally aware lubricant, biodegradability. A separate tech topic will address aquatic toxicity. Of course, a suitable environmentally aware lubricant will also provide required performance in the areas of viscosity, oxidation, wear, foaming, demulsibility, and other desired characteristics.

Defining Lubricant Biodegradability

Biodegradation is one of three processes that transform or break down materials that enter the environment (the other two being physical (or weathering) and chemical (sometimes referred to as photoxidation). Biodegradation is the chemical breakdown of materials by living organisms (or their enzymes) in the environment. The organisms include bacteria, yeast, protozoans, and fungi, which break down molecules for sustenance, typically yielding carbon dioxide and water. Certain chemical structures are more susceptible to microbial breakdown than others; vegetable oils and synthetic esters, for example, will in general biodegrade more rapidly than mineral oils under the same conditions.

Because lubricants coming into contact with water and other sensitive areas can negatively impact the environment, manufacturers and users of lubricant systems are switching to more acceptable alternatives, such as those that are biodegradable and non-toxic.

The U.S. Federal Trade Commission (FTC) has defined criteria for marketing statements or claims for biodegradable products in their 1992 Guidelines on Environmental Marketing Claims 16 CFR Part 260. The FTC guidelines provide that a biodegradable claim should be substantiated by evidence that the entire product will completely break down and return to nature, that is, decompose into elements found in nature within a reasonably short period of time after customary disposal. The reasonably short period of time is not defined by the FTC. The qualification for claims regarding the time factor as required by the FTC is: "Claims of degradability, biodegradability or photodegradability should be qualified to the extent necessary to avoid consumer deception about: (1) the product or package's ability to degrade in the environment where it is customarily disposed; and (2) the rate and extent of degradation."

Outside the U.S., various other countries including Germany (i.e. Blue Angel standard) Japan (Eco-mark) and regions (Nordic Swan, Europa Ecolabel, Nordic Eco-label for lubricants) have definitions for use of the biodegradable term when applying for eco-labels.

Examining Lubricant Biodegradability

There are many tests for measuring the extent of biodegradation. This testing is typically conducted in a controlled soil or aqueous (water) medium containing an inoculum of aerobic sewage sludge (as a source of organisms detailed previously) obtained from a local waste water treatment plant) .

Depending on the test design, it can measure primary biodegradability or ultimate biodegradability. Primary biodegradability is a measure of the loss of the parent chemical or product, but it does not measure the degree of degradation, that is, partial to complete (to carbon dioxide, water, and inorganic substances), or characterize the by-products of degradation. It merely determines the percentage of the material that disappears over the term of the test, or conversely, the time required to reach a certain percentage of loss. A primary biodegradation test in use today is the CEC-L-33-A-93 Biodegradability of Two-Stroke Cycle Outboard Engine Oils in Water (can be used for other lubricants as well). It measures the disappearance of the test material (depletion of CH2-CH3 bonds, or more simply, carbon-hydrogen bonds) using infrared absorbance, and relates that to a biodegradation level. The assumption in this test is that the entire product that has disappeared is completely biodegraded. In actuality, this may not be the case, because the test does not measure complete biodegradation, but only the loss of the original material. In the US, this test has less favor because ultimate biodegradation is considered far more representative of the biodegradation processes occurring in the environment, and regulatory authorities such as the EPA and the FTC in the US, Umwelt Bundes Amt (UBA) and Nordic Swan in Europe, and those in Japan now require the use of ultimate biodegradability methods for determining the biodegradation of lubricants and their components.

Testing Lubricant Biodegradability

Ultimate biodegradability describes the percentage of the substance that undergoes complete degradation, i.e., degrades to carbon dioxide, water, and inorganic substances over the length of the test or, conversely, describes how long it takes to achieve a specified percentage of degradation. Ultimate biodegradation is usually evaluated indirectly, by measuring “demand for oxygen” or “carbon dioxide evolution.” In the former, the total amount of oxygen consumed during the 28 day test is measured and compared to the theoretical oxygen demand required for complete oxidation of the test material. In the latter, the carbon dioxide evolved is trapped in an alkaline solution and the remaining base is back-titrated to determine the amount of carbon dioxide evolved during the 28 day test.

In general, tests of ultimate biodegradation should be considered comparable whether carbon dioxide production or oxygen consumption is measured. When two materials are to be compared, the most reliable comparison would come from concurrent testing in the same system, using the same organisms.

Ultimate biodegradation testing is used to determine if a material is inherently biodegradable or readily biodegradable. The rate of biodegradation is defined as inherent or ready. Inherently biodegradable means biodegradation greater than 20% in 28 days or 12 weeks, depending on the test. Readily biodegradable or ready biodegradability means biodegradation greater than 60% in 28 days, and the 60% level is reached within 10 days of reaching the 10% mark (“10-day window” criterion) using unacclimated bacteria (no prior exposure to the material prior to starting the test). This means that if the test material reaches the 10% carbon dioxide evolution (oxygen uptake) level at day 5, the material must exceed 60% carbon dioxide evolution (oxygen uptake) by day 15. Only a few tests measure ready biodegradability. In general, a readily biodegradable material biodegrades more rapidly and more completely than an inherently biodegradable material. The order of biodegradability, most to least, is vegetable oil > ester > mineral oil. For formulated products, the terms rapidly and extensively are terminology approved for use under ASTM 6046, Standard Classification of Hydraulic Fluids for Environmental Impact, when >60% biodegradability is achieved in one of the ready biodegradation tests.

ExxonMobil uses the US EPA Test 560/6-82-003, CG-200, Aerobic Aquatic Biodegradation Test (US EPA Shake Flask Test), the OECD (Organization for Economic Cooperation and Development) 301B Carbon Dioxide Evolution (Modified Sturm) Test, and the OECD 301F Manometric Respirometry (Oxygen Uptake Measurements) Test for its US manufactured environmentally aware lubricant (EAL) products. US EPA Test 560/6-82-03 is similar to ASTM D 6139, Standard Test Method for Determining the Aerobic Aquatic Biodegradation of Lubricants or their Components Using the Gledhill Shake Flask. These particular tests have been found to provide consistent results. Both of the latter are tests that measure ready biodegradability.

ExxonMobil environmentally aware lubricant products are rapidly & extensively biodegraded, and degraded to >60%, in the ready biodegradability tests.

Meeting Readily Biodegradable Criteria

Comparable biodegradation data should be developed using a consistent organism source, and in the same time frame, due to the variation of organism populations over time. As with most laboratory test procedures, results cannot be directly extrapolated to natural settings, but provide a good approximation. A complete description of biodegradation terms may be found in ASTM D 6046, Standard Classification of Hydraulic Fluids for Environmental Impact.

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