Spray lubricants

Formulating environmentally friendly lubricants using nanoparticulate boron compounds.

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There are many different types of lubricants available for a whole host of applications. Lubricants are very specialized for each individual use. Traditional petroleum oil-based lubricants are being replaced by water-based formulations in order to conserve natural resources and reduce costs. Furthermore, lubricants formulated using plant-based oils, such as vegetable oil, are becoming much more popular. The advantages of lubricants based on plant-derived oils include the use of renewable resources, but there are limitations on available technology.

Additives are available to improve the lubricating properties of oils, both petroleum and plant-based, as well as water. Many traditional additives are being phased out of formulations in favor of more environmentally friendly or safer materials. For example, one of the oldest classes of lubricant additives, chlorinated paraffins, has been under health, safety, and environmental scrutiny for many years. Fortunately, additive technology has been able to keep pace with the changing demands and boron additives, which are typically environmentally safe to use, have been at the forefront.

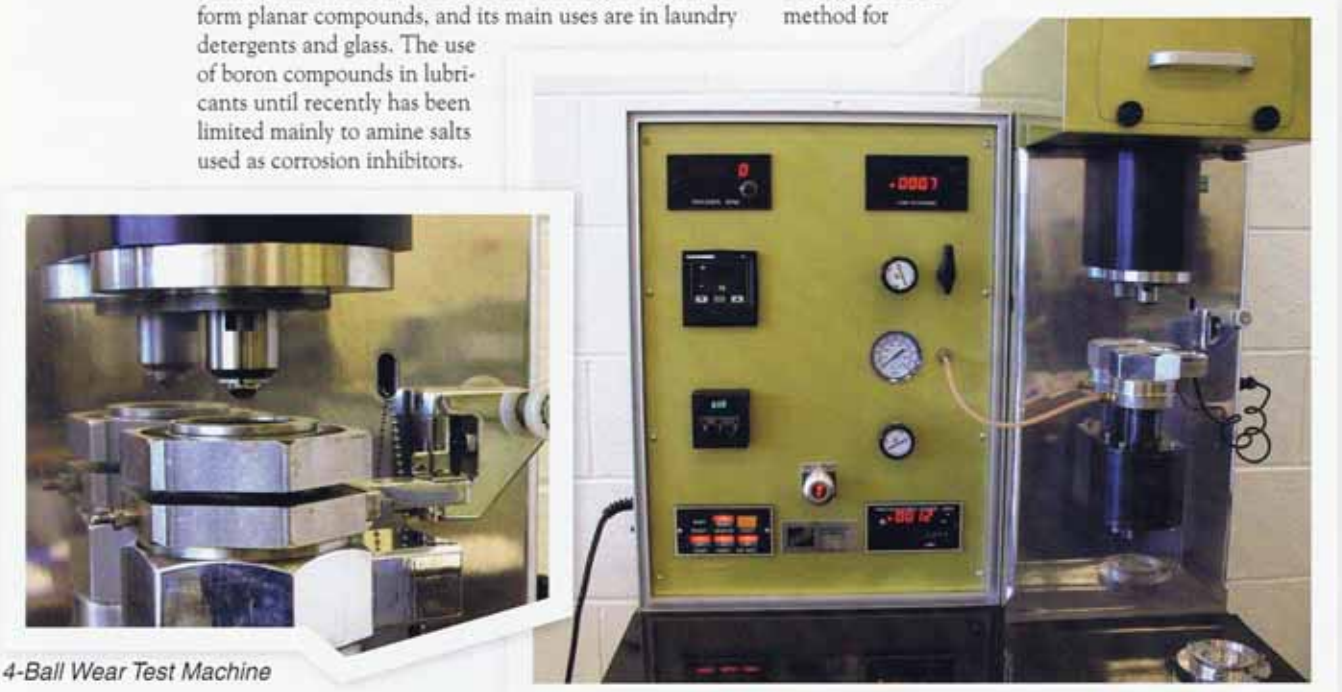
The element boron was discovered in 1808 by Sir Humphrey Davy. In its elemental form it is a brittle, black, semi-metallic substance. Boron has a strong tendency to form planar compounds, and its main uses are in laundry detergents and glass. The use of boron compounds in lubricants until recently has been limited mainly to amine salts used as corrosion inhibitors.

One boron compound, boron nitride, established the use of boron in lubricants. Boron nitride has a planar hexagonal structure similar to graphite. This structure leads to layers of plates that slide across each other with low friction. It performs well as a solid lubricant and can be used at very high temperatures in environments such as ovens and steel mills.

There are some drawbacks to boron nitride. It can only be used as a solid lubricant or in suspension. Suspensions of boron nitride have a tendency to drop out over time, leaving little of the active ingredient available to function. Studies have also shown that using boron nitride can reduce friction but actually increase wear.[1]

Oil-soluble boric acid esters have been developed for use in engine oils. They showed some promise for wear reduction but were abandoned for the most part because of problems with hydrolytic stability. The esters would react with trace moisture present in the engine oil and revert back to insoluble materials that would drop out of solution. Similar work using borated amines for friction reduction in automatic transmission fluids met with disappointment when high treat rates were necessary for optimum results.

Most recently, the use of nanoparticulate boric acid has been probed as a method for



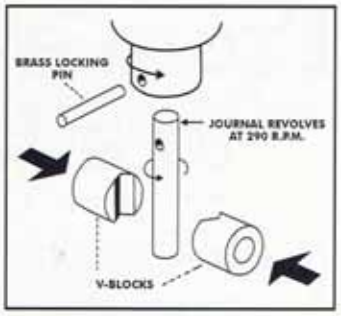
4-Ball Wear Test Machine

taking advantage of the demonstrated benefits of boron compounds while overcoming their limitations. The first use involved dispersing boric acid nanoparticles in diesel fuel in an attempt to improve fuel lubricity.[2] There was substantial reduction in friction as a result of using the nanoparticles but difficulties were encountered with the stability of the dispersion. Additionally, the dispersions could not tolerate exposure to water, which can cause the nanoparticles to agglomerate.[3] When this occurs, the boron compound settles out of suspension and can clog spray nozzles.

A recent report details a new development in boron-containing additive technology.[4] Using complex, highly surface-active esters as the matrix in which the boron compound nanoparticles are dispersed, a highly stable suspension can be produced that takes advantage of the demonstrated performance characteristics, yet eliminates the limitations. The esters actually perform as a delivery system for the nanoparticles, ensuring that they are able to perform at the point of contact between surfaces where friction is occurring. The esters are highly surface active and have a strong affinity for metal surfaces. Furthermore, the boron compound that is suspended is tolerant of water and can be used in aqueous environments. There is no agglomeration problem and no concomitant clogging of spray nozzles. An added benefit of the unique carrier is inherent rust protection which is a result of its surface activity.

The reduction in friction is made possible by the formation of strong self-healing lubrication films containing plates of the boron compound nanoparticles. A common test for measuring anti-wear performance is the 4-Ball Wear Test. It uses a spinning bearing that is pressed against three other stationary bearings and measures the wear on all four. The new additive showed a reduction in wear of 12.5% compared to standard anti-wear additives used in motor oil.

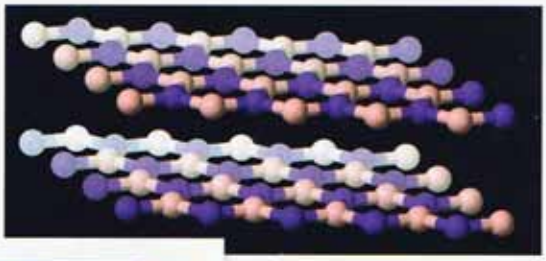
One of the most interesting applications for this new technology is the fact that it can tolerate water. The implication is that it can be used in an emulsion, producing a water-based high performance lubricant. This formulation would be very environmentally friendly and cost-effective since the main ingredient is water. Even more impressive is the opportunity to substitute vegetable or other plant-derived oil for petroleum oil in the emulsion. That leads to a lubricant with unprecedented environmental friendliness. Of growing concern is the content of volatile organic compounds (VOCs) in spray lubricant formulations. This new lubricant can lead to a product containing no VOC content if a non-VOC propellant is chosen.



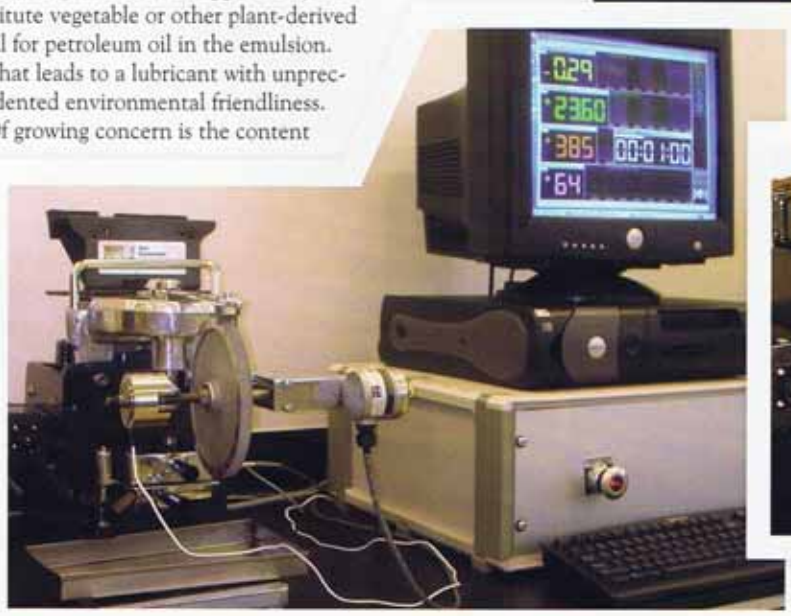
A blend of vegetable oil, nanoparticulate boron compound additive and emulsifier was mixed with water. The lubricating properties were tested using a Falex pin-and-vee machine, which measures the torque required to rotate a pin between two vee-shaped blocks as a continuously increasing load is applied. The blend performed eight times better than unadditized mineral oil and three times better than oil with polytetrafluoroethylene.

Nanoparticulate boron compounds can be used to prepare lubricants that have outstanding performance. These simple blends require a carrier, the nanoparticulate boron additive and, if water is used, a suitable surfactant. If steel packages are to be used then a small amount of a corrosion inhibitor may be required. VOC-free formulations can be produced if a non-VOC propellant is chosen. These non-VOC, environmentally friendly lubricants can be non-toxic, non-flammable, biodegradable, easy to spray and can be used in a wide variety of household and industrial applications. Formulations are easily adjustable and a variety of carriers can be used including petroleum oil, vegetable or other plant-based oils or even water. In addition, they are suitable for trigger spray applications. The additives do not agglomerate and drop out and thus do not clog the spray apparatus. SPRAY

[1] Kimura et al. Wear Volume 232, Issue 2, October 1999
[2] Argonne National Lab Transforum Vol. 7 No.2 August 2007
[3] Ali Erdemir, Nanolubricants, 2008 John Wiley & Sons
[4] Canter, N. Tribology and Lubrication Technology, August 2009



Boron Nitride structure



The Falex pin-and-vee machine