Near-Frictionless Carbon Coatings Offer Significant Industrial Benefits

Background

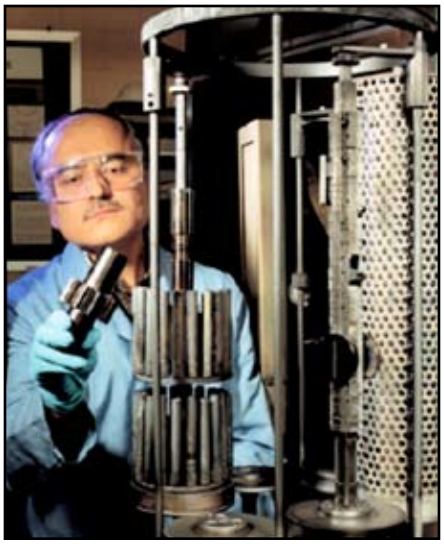
The many moving mechanical assemblies in advanced transportation vehicles present complex challenges for automotive engineers. These systems must operate under increasingly severe sliding conditions (such as high loads, speeds, and temperatures) that currently available materials and lubricants cannot tolerate. Engineers must improve the surface friction and wear characteristics of the mechanical system components by using hard, slippery surface films.

With funding from the U.S. Department of Energy's FreedomCAR and Vehicle Technologies Program, researchers at Argonne National Laboratory have developed and patented a smooth, wear-resistant near-frictionless carbon (NFC) film that features an exceptionally low coefficient of friction, enabling components to last longer and potentially reducing parasitic losses associated with friction. The film can also reduce friction and wear under starved (diminished) or boundary lubricated sliding conditions. Sulfur, for example, is an inherent lubricant in diesel fuel. Because the sulfur content of diesel fuel will be lower in the future as a result of standards, NFC film can replace this lubrication. Similarly, the technology may prove indispensable for the moving parts of hydrogen-powered vehicles.

The Technology

The main concept behind NFC film is a modification of the hydrogen to carbon ratio. Because of its extremely low friction coefficient and wear rate, the film offers a way to make rolling, sliding, or rotating machine parts more efficient and long-lasting through a reduction in friction by factors of 20 to 100 below the levels feasible with existing low-friction materials, coatings, or lubricants. In aerospace and transportation systems, such a reduction in friction translates directly into higher efficiency and better/quieter performance, while less wear results in longer engine lifespans and lower maintenance costs.

Key advantages expected from these carbon films in moving mechanical assemblies are extended wear life, reduced maintenance costs, improved reliability, reduced environmental emissions, and most important, increased energy efficiency resulting from decreased frictional losses. Combining high hardness with ultralow-friction diamond and diamond-like carbon films can provide long-term wear resistance and



An Argonne researcher observes a sample of near-frictionless carbon film that is 50 times slicker than Teflon™.

lubrication to reduce material and energy losses. The low friction of diamond and diamond-like carbon is associated with their very inert nature. These materials are very hard and do not stick to rubbing surfaces, and because of the strong covalent bonding between carbon atoms, they have extremely low wear rates.

Argonne's NFC film possesses a unique combination of qualities that make it potentially useful for a wide range of applications. The film's friction coefficient is perhaps the lowest reported to date for a solid material, and its wear resistance is

the highest. In terms of durability, the film has an extremely long endurance life. In a recent evaluation, researchers tested a 1-micrometer-thick application of the film on H23 steel under dry sliding conditions in a clean test environment; it accumulated over 14 million sliding cycles without wearing through. In addition, the film can be deposited at room temperature on any kind of substrate (i.e., steel, aluminum and titanium alloys; ceramics; glass; hard and high-temperature plastics) and at fairly high deposition rates.

Commercialization

Argonne is working with several industrial partners to further develop the near-frictionless carbon surface coating to increase engine efficiency, reduce engine wear, and decrease maintenance costs for motor vehicles. Currently, two major coating machine manufacturers are in discussion with Argonne regarding potential licensing agreements.

Argonne believes there is a distinct possibility that this new material will find its way into commercial applications outside of the automotive industry, including cryogenic, space, aircraft, micro-electromechanical, and ultra-high-vacuum instrument applications. In this regard, the Laboratory is interested in subjecting NFC film to more study and evaluation and continues to seek industrial partners for assistance in completing the development and optimization of this technology for a range of applications. NFC surface coating is patented and may be made available to industry via a license or joint venture. Argonne also offers technical support to ensure thorough technology transfer.

Benefits

- Friction coefficients of 0.001 – 0.006 in a dry, inert environment are about 50 times less than Teflon's friction coefficient of 0.05.
- Allows for simultaneous modification of hardness and the friction coefficient
- Wear resistant: increases component life
- Improves performance in rolling, sliding, and rotating applications
- Can be applied at room temperature
- Usable with complex shapes on any kind of substrate
- Requires no post-application machining
- Corrosion resistant
- Excellent deposition rate
- Stress-free structure

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