The HISTORY of PTFE

For over sixty years, our world and the quality of its inhabitant's lives have been improved by a resin known as polytetrafluoroethylene, or PTFE. Yet the widespread use of this phenomenon seems to have become the world's best kept secret, with the exception of DuPont's Teflon® (a member of the PTFE resin family).

PTFE - a history

Discovery

True to the discovery pattern of so many great inventions, PTFE burst upon the scene quite by accident. In 1938 a DuPont chemist, Mr. Roy J. Plunkett, was working on the development of a new refrigerant when he discovered "polytetrafluoroethylene," shortened to PTFE and often more descriptively referred to as PTFE resins. Upon examination, DuPont learned that PTFE provided a combination of friction, temperature, chemical, mechanical and electrical resisting properties unmatched by any other material, and registered the Teflon® trademark.[1]

Promise

Plunkett had struck gold. Tough and weather resistant, PTFE immediately showed promise; a promise that would culminate in recognition as the slickest substance known to man.

Guiness

This "slickest substance" phenomenon is recorded in The Guiness Book of World Records. In the PHYSICAL EXTREMES section under the heading Lowest Friction it declares, "The lowest coefficient of static and dynamic friction of any solid is 0.02, in the case of polytetrafluoroethylene ($[C_2F_4]n$), called PTFE - equivalent to wet ice on wet ice."[2]

War

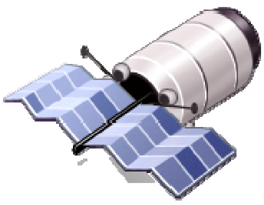
As with many technological efforts during the early 1940s, initial production of PTFE was directed toward the demands of

World War II. PTFE had surfaced just in time to play decisive roles, including development of the weapon that would end the war; Plunkett's invention contributed to the Manhattan Project, created in 1942 to produce the first atomic bomb.[3] PTFE provided material for gaskets, packings and linings to handle the corrosive uranium hexafluorides, and made development of this critical weapon possible.[4]

Space

Rapid expression of the technology began as PTFE proved critical to space travel. While not the exclusive focus, space applications grew to include:

- Use in early rockets through Mercury, Apollo and Space Shuttle programs, communication satellites and "star wars" defense systems.[5]
- Rocket fuel tanks utilized PTFE in linings and to support fuel lines.[6]
- NASA used PTFE electric insulation in space ships from the first Mercury programs.[7]
- The Apollo astronauts' space suits contained layers of PTFE fabric.[8]
- In the Space Shuttle, the liquid oxygen tank's precious cargo was protected with PTFE insulation.[10]
- PTFE was used in fabrication of the Space Shuttle's critical Thermal Protection System.[11]
- PTFE proved effective as cage material in the Space Shuttle's main engine's high pressure oxygen pump bearings.[12]



- PTFE composites reduced friction and wear when utilized as dry lubricants in aerospace bearing applications.[13]
- In the "star wars" Strategic Defense Initiative, PTFE was used in light, quick valve system seals.[14]

Flight

No less important than aerospace were applications in other modes of flight. Many bearings associated with flight-control applications in fixed wing aircraft and helicopters employed thin layers of PTFE based composites bonded to metal surfaces.[16] "Vertical take off and landing" (VTOL) aircraft achieved essential friction reduction with PTFE in bearing rings on which the whole propeller housing of the VTOL equipment moved.[17] And PTFE mated with steel counterfaces in dry bearings was used extensively in aircraft and helicopters.[18]

Speed

Closer to earth but also enhancing rapid mobility, PTFE proved a dry film lubricant of choice in the automotive racing industry through "coating" of friction surfaces. Application was achieved through a complex process involving metal preparation followed by spraying on and baking of the PTFE.[19] While occasional peeling and flaking in early applications caused initial skepticism, coating re-emerged as a viable engine performance and longevity enhancement technique.[20]

Industry

Also, in heavy industry, self-lubricated PTFE is now applied to bearings and thrust washers in applications as diverse as earth-moving machinery and snow blowers.[21] In a vast variety of other industrial applications, usage has spread from tubing and hoses to protective coatings for fabrics, to high performance films, to industrial coatings, to textile fibers, to wire and cable industries,[22] and beyond to gaskets and seals, [23/24] electrical components and tape, "spaghetti" tubing,[25] computers, industrial electronics and other demanding high-tech applications.[26]

Diverse

Other uses proved invaluable in overcoming problems related to environmental hazards, exposure to ultraviolet light and oxidation, discolouration and embrittlement,[27] heat and cold and diverse climactic conditions.[28] Uses in fabrics range from the sportsman's favored Gore-Tex® fabric[29] to exotic applications demanding great fabric strength and resistance, and chemical and microbial attack.[30]

Gamut

Today, PTFE applications run the gamut, from low-tech non-stick frying pan surfaces to high-tech exotic medical and hospital uses including implants, surgical instruments and test equipment,[31] and dramatic uses in fire fighting equipment.[32] Applications for Mr. Plunkett's invention have grown from early use in the devastating Manhattan Project to the recent Statue of Liberty Restoration Project.[33]

FABRICATION

PTFE
Engineering problems involved in the production of the monomer TFE are simple compared with the polymerization and processing of the various types of PTFE. TFE must be polymerized to extremely high molecular weight so that the desired properties are achieved to meet the needs of end-use applications. Polymerization and processing of PTFE to achieve desired properties is very demanding, involving complex engineering problems.[34]

Affect
The exact manner in which the fabrication of the polymer is carried out affects certain intrinsic qualities in PTFE such as molecular weight, crystallinity, orientation and the presence of voids and interfaces. These in turn influence certain properties, notably tensile strength, elongation, and dielectric strength.[35]

Molding and sintering conditions have an impact on mechanical, chemical and electrical properties of PTFE. Most notably affected are shear stress, flex life, permeability, stiffness, resiliency and impact strength.[36/37]

Names
PTFE is best recognized by DuPont's trade name Teflon®, but its many names assigned by other manufacturers include Halon®, Hostaflon®, Fluon®, Algoflon®, and Fluoroplast®. Utilized worldwide, PTFE resins are manufactured by many industrialized nations, including the former USSR and recently The People's Republic of Red China.[38]

FRICTION

Low

The low coefficient of friction with PTFE has been widely known, first published in 1949 when K.V. Shooter and P.H. Thomas measured coefficient of friction using a Bowden-Leben machine.[39] With loads of between 1 and 4 kg (2.2 and 8.8 lb.) and sliding velocities of 0.1 and 10 mm/s (0.02 to 2 ft/min.), they reported that the coefficient of friction was 0.04. It is significant that a coefficient of 0.01 was reported with a load of 1360 kg (3000lb.) in a later test.[40]

Slide

When PTFE comes in contact with another surface, it provides lubrication by sliding. The PTFE does not peel off, but simply slides along on its own surfaces. Also, the orientation of the resins plays a role in reduced friction. When the polymers slide along the chain, coefficient is lowered by 39%, as compared to sliding across the chain.[41]

Increase = decrease

Another critical factor is that static friction of PTFE decreases with an increase in load.[42] Static coefficient of friction is lower than the dynamic coefficient and avoids stick-slip problems.[43]

Oil

When oil comes in contact with PTFE, it slides off because of the low coefficient of friction. PTFE uses this property to advantage by reducing energy loss to oil drag. Oil flows more readily over lubricated components, increasing oil's capacity to cool.[44]

FRICTION

Uses

- Recognition of potential to reduce friction and related problems of wear and heat has led to growing use of PTFE as a dry-film lubricant:
- In heavy industry, self-lubricated PTFE composites have displaced traditional oil-lubricated metallic composites for many journal bearings and thrust washers in applications as diverse as earth-moving machinery and snow blowers.[45]
- PTFE was used as a lubricant in the Statue of Liberty restoration project.[46]
- Most bearings associated with flight-control applications in fixed wing aircraft and helicopters use thin layers of PTFE based composites bonded to metal substrate.[47]
- Studies indicate that PTFE shows promise of improving ice-shedding characteristics of helicopter rotor blades.[48]
- In space travel, where lack of gravity poses unique challenges to fluid lubrication, use of PTFE has proven vital, especially when reduced wear and friction of PTFE composites proved valuable to aerospace dry bearing applications.[49]
- NASA sponsored tests on journal bearings with PTFE lubricating liners showed friction and wear characteristics compatible with airframe bearing requirements.[50]
- Tests on space manipulator drive bearings with PTFE composite retainers gave excellent wear characteristics and extended lifetime.[51]
- Studies of vacuum (space) usage of bearings, gears, cams, guides and slides, solenoids, commutators, motor brushes and sliprings with PTFE lubrication shows even longer than normal life due to lack of oxygen and water.[52]

Coating

In the automotive racing industry, “coating” of engine friction surfaces with PTFE or composites has proven attractive in light of the potential to improve performance and reduce wear.

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