

# CHEMICAL ENGINEERING

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# Mechanical Carbon In Chemical Processing Equipment

**This self-lubricating material offers advantages when used for components that are running submerged in the process fluid**

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Metallized Carbon Corp.

**F**requently, in chemical processing equipment it is possible to place the shaft support bearings in the chemical that is being processed. In some cases, this precludes the use of oil- or grease-lubricated bearings because the operating conditions are not conducive to the use of such materials. For example, bearings that are lubricated with oil or grease can be problematic when submerged in liquids such as water or other solvents, liquefied gases, heat transfer oils and corrosive chemicals. For these operating conditions, self-lubricating, mechanical carbon bearings are often the best solution.

This article takes a close look at mechanical carbons, describing what they are and how they function when running submerged in chemical processing equipment.

## Compositions

Mechanical carbons contain graphite, which they rely on for their self-lubricating characteristics. To make mechanical carbons, fine graphite particles are bonded with a hard, strong, amorphous-carbon binder to produce a mechanical carbon material that is called carbon-graphite. Further heat treatment, to approximately 5,100°F (2,800°C), causes the amorphous-carbon binder to become graphitized, resulting in a material known as electrographite.

The electrographite is generally softer

and weaker than the carbon-graphite material, but has superior chemical resistance, oxidation resistance and thermal conductivity compared to the carbon-graphite (Figure 1).

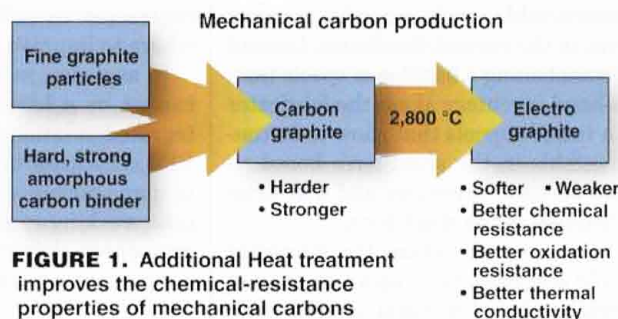
## Impregnation

Both carbon-graphite and electrographite are normally produced so that they contain approximately 15% porosity by volume. To produce mechanical carbon grades with enhanced properties, the porosity in the carbon-graphite and electrographite materials can be impregnated — by vacuum or pressure processes — with thermal setting resins, metals or inorganic salts, as explained below:

**Resins.** The most common thermal setting resins used are phenolic, polyester, epoxy and furan resins. Resin impregnation produces materials that are impermeable (to 100 psi air) and have improved lubricating characteristics.

**Metals.** The most common metal impregnations are babbitt (an alloy of tin, antimony and copper that is used to make bearings), copper, antimony, bronze, nickel-chrome and silver. Metal impregnation produces materials that are harder, stronger and impermeable (to 100 psi air), with improved lubricating qualities and better thermal and electrical conductivity.

**Inorganic salt.** The inorganic salt impregnations are proprietary formulations that provide improved lubricating qualities. These salt im-



pregnated materials also exhibit improved resistance to oxidation of the carbon-graphite or electrographite base material.

## Running submerged

The coefficient of friction and wear rate of two rubbing metal parts is extremely low when they are separated by a hydrodynamic film of oil or grease. However, when metal parts are rubbed together in low viscosity liquids, such as water or gasoline, the hydrodynamic film is too thin and metal-to-metal contact can occur. When metal-to-metal contact occurs, the metal atoms in sliding contact have strong atomic attraction, which results in high friction, wear, galling, and seizing.

When carbon is rubbed against metal in a low viscosity liquid, the resulting thin, hydrodynamic film is normally adequate to provide lubrication. Since there is no strong atomic attraction between mechanical carbon and metal, a hydrodynamic film that is only a few microns thick is sufficient to prevent rubbing contact, even for high-speed and high-load applications. Since mechanical carbon is a self-polishing material, a polished finish on the counter material will quickly polish the mechanical carbon material. The thin hydrodynamic film that is created by low viscosity liquids can then separate the two polished surfaces.

Using the fluid being handled as the

**FIGURE 2.** The photos to the right depict bearings made from two mechanical carbons.

These babbitt-impregnated, carbon/graphite materials are designed for running submerged in low viscosity liquids where conventional, oil or grease lubricants would be washed away



**FIGURE 3.** Shown to the left is a mechanical carbon, steel encased bearing. This self-lubricating product is used for operating temperatures between 700 and 1,000° F, where conventional, oil or grease lubricants would breakdown and fail



**FIGURE 4.** The photo above depicts another mechanical carbon — an antimony impregnated, carbon/graphite material — designed to run dry or submerged in environments where oil and grease lubrication cannot be used

working lubricant greatly simplifies the design of many rubbing mechanical parts. Carbon parts for these submerged applications include bearings and thrust washers for pumps and mixers that handle water, hot water, solvents, acids, alkalis, fuels, heat transfer fluids and liquefied gases. Mechanical carbon is also used extensively for mechanical-seal primary rings for sealing these same low viscosity liquids. Other applications include vanes, rotors, and endplates for rotary pumps; ball-valve seats handling hot oil; bearings for liquid meters; case wear rings for centrifugal pumps; and radial or axial seal rings for gear boxes and aircraft engines.

#### **Wear: Factors to consider**

The wear rate of mechanical carbons running submerged is negligible under full fluid film, or hydrodynamic, lubricated conditions. To assure fully lubricated conditions, application engineers must consider the application load, speed, counter material, counter material surface finish, liquid viscosity, liquid flow and chemical resistance.

**Load.** The maximum load that is normally supported by mechanical carbons with full-fluid-film lubrication is

#### **EXAMPLE 1**

**A**n example of a mechanical carbon bearing running submerged in strong chemicals is in the chemical pump industry. Nickel-chrome impregnated, carbon-graphite bearings are used in a stainless-steel, rotary vane pump for handling a broad range of chemicals. The nickel-chrome impregnated, carbon-graphite bearings carry a load of 830 psi (58.4 kg/cm<sup>2</sup>) at a surface speed of up to 284 ft/min (1.44 m/sec). This gives a PV factor of 237,700 psi × ft/min (84.1 kg/cm<sup>2</sup> × m/sec). The pump is warranted for one year, but field experience indicates that these pumps normally give several years of continuous running service. □

approximately 1,000 psi (70 kg/cm<sup>2</sup>). Application PV (pressure-times-velocity) factors of over 2,000,000 psi × ft/min (773 kg/cm<sup>2</sup> × m/sec) have been achieved with sliding speeds of over 3,600 ft/min (18.7 kg/cm<sup>2</sup> × m/sec).

**Counter material.** The counter material rubbing against the mechanical carbon must meet specifications of hardness, surface finish and corrosion resistance. The hardness should be greater than about Rc 45 (Rockwell C scale), but better results are achieved with even harder counter materials.

**Surface finish.** The surface finish on the counter material should be 16 micro-inch (0.4 micron) or better. Wear rate continues to improve with finer surface finish until an 8 micro-inch (0.2 micron) finish is reached.

These high finishes are required because the hydrodynamic film with low viscosity liquids is extremely thin. With coarser finishes on the counter material, the asperities (rough edges) on the counter material would break through the hydrodynamic film and "grind away" the mechanical carbon.

**Viscosity.** The liquid viscosity should be in the range from about 100 centipoise (cP) (light machine oil, for example) to 0.3 cP (acetone for example).

**Liquid flow.** A continuous flow of liquid to the rubbing surface is important to the performance of submerged mechanical carbon parts. If the flow of liquid is not sufficient, frictional heat will evaporate the liquid and the parts will revert to the dry running condition, where the wear rate is much higher.

An important benefit of mechanical carbon parts is that the parts can run dry without catastrophic failure if the flow of liquid is briefly interrupted.

**Chemical attack.** The chemical composition of the liquid must be considered because chemical attack of the counter material, or the mechanical carbon, will increase the wear rate. Chemical attack of the counter material is particularly harmful because

## Engineering Practice

it causes pits and surface roughness that will disrupt the hydrodynamic film, resulting in a high wear rate. The most corrosion-resistant mechanical-carbon grades can withstand all liquid chemicals except for a few extremely strong oxidizing agents, such as hot, concentrated nitric acid.

**Abrasion.** Abrasive grit in the liquid being handled can also be extremely detrimental to mechanical carbon parts. The abrasive grit disrupts the hydrodynamic film, erodes the softer mechanical carbon material and can destroy the fine surface finish on the counter material.

### Applications engineering

Any mechanical carbon manufacturer can determine if it has a material that can satisfy specific application requirements, and can also recommend its best mechanical-carbon grade for each specific application. They should also be able to recommend dimensions

and dimensional tolerances for new mechanical carbon parts to assure proper press-fit or shrink-fit interference and shaft running clearance. It is also critically important to the success of mechanical carbon applications that correct mating material and mating-material surface finishes are specified.

Mechanical carbon materials have provided solutions to a wide variety of lubrication challenges for more than a century. For example, in recent years a growing concern for the environment and air quality has resulted in an increased use of mechanical seals that use carbon primary rings because they allow less leakage compared to other seal types. Today, new mechanical carbon materials are continually

## EXAMPLE 2

An example of mechanical carbon running at high PV with hydrodynamic film lubrication is in the mechanical seal industry. An antimony impregnated, carbon-graphite mechanical-seal primary ring, sealing low viscosity hydrocarbon liquids, runs against a polished, solid silicon-carbide counter face with a face loading of about 600 psi (42 kg/cm<sup>2</sup>) and a rubbing speed of about 3,400 ft/min (18.7 m/sec). This gives a PV factor of about 2,000,000 psi × ft/sec (785 kg/cm<sup>2</sup> m/sec) and the seal rings normally last for about three years of continuous running. □

being developed to meet ever more demanding mechanical applications. ■

*Edited by Gerald Ondrey*

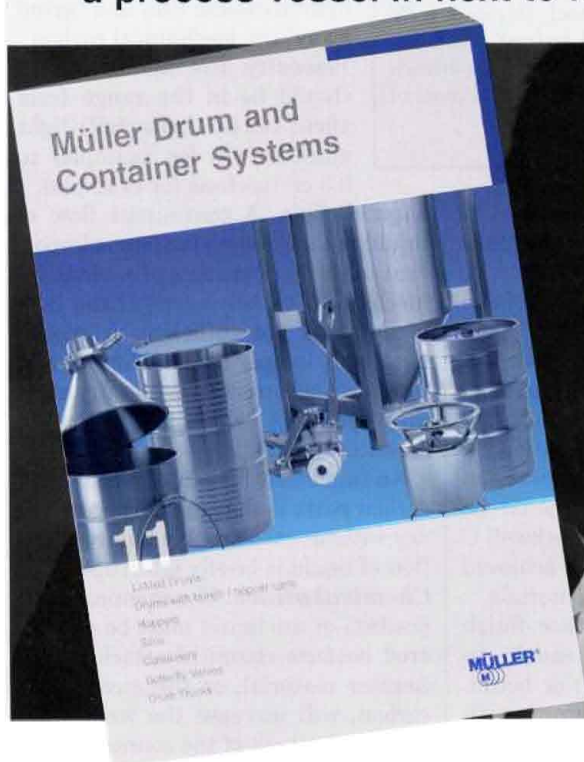
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