POWER Engineering

# Mechanical Carbon Parts Solve Tricky Lube Problems

*Mechanical carbon materials can sometimes be the only workable solution for moving machine parts where rubbing must occur.*

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For more than a hundred years, machine parts composed of mechanical carbon have provided an alternative solution in applications where temperature and atmospheric conditions prevent the use of oil-grease lubricants. Mechanical carbon materials contain graphite, and are relied upon for their self-lubricating characteristics.

Mechanical carbon materials can be an effective solution, and sometimes the only workable solution, for moving machine parts where rubbing must occur with low wear and low friction and where oil-grease lubrication cannot be used.

Mechanical carbon applications can be divided into two categories: dry running applications, where the carbon parts are running in a gas, and submerged applications, where the carbon parts are running in a liquid. This article considers some challenges and solutions for each category.

Bonding fine graphite particles with a hard, strong, amorphous carbon binder produces a mechanical carbon material called "carbon-graphite." Further heat-treating to approximately 5,100 F (2,800 C) causes the amorphous carbon binder to become graphitized. This material is called "electrographite."

The electrographite material 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 material. Both carbon-graphite and electrographite are normally produced so they contain around 15 percent 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-pressure with thermal setting resins, metals, or inorganic salts, as explained below:

**Resins** – The most common thermal-setting resins used are phenolics, polyesters, epoxies and furan resins. Resin impregnation produces materials that are impermeable and have improved lubricating characteristics.

**Metals** – The most common metal impregnations are babbitt, copper, antimony, bronze, nickel-chrome and silver. Metal impregnation produces materials that are harder, stronger and impermeable, with improved lubricating qualities and better thermal and electrical conductivity.

**Inorganic Salt** – Inorganic salt impregnations are proprietary formulations that provide improved lubricating qualities and improve the oxidation resistance of the carbon-graphite or electrographite base material.

The most accurate way to determine the wear rate of mechanical carbon is to test-run sample mechanical carbon parts in a prototype machine at the proposed operating conditions.

## Loading

To avoid cracking, chipping and breaking of the mechanical carbon material, the loading is normally limited to about 1,000 psi ( 70 kg/cm2). This load is less than 10 percent of the compressive strength of most mechanical carbon materials. The high safety factor is required because the actual load on the carbon part is often much higher than the calculated loading. This occurs because of the "line contact" of new carbon bearings with shafts that have the recommended running clearance. The line contact disappears quickly after rotation begins and the shaft "beds into" the carbon bearing.

## Temperature Limitations

Mechanical carbon parts are limited in temperature mainly because some carbon-graphite materials begin to oxidize in air at a temperature of about 600 F. Some electrographite grades begin to oxidize in air at about 750 F. The oxidation reaction is $C + O_2 = CO_2$ .

Oxidation is a diffusion-controlled reaction, and the solid carbon material is changed to $CO_2$ or CO gas and removed from the outside surface of the carbon material. The oxidation onset temperature can be increased by about 100 F by impregnating the base carbon material with oxidation inhibiter salt solutions. The oxidation inhibiter salts are beneficial because they help create the burnish graphite film on the metal counter surface and they react chemically with the carbon material to inhibit the oxidation reaction.

Carbon-graphite grades will show some shrinkage when heated in a neutral atmosphere above 1,800 F. Electrographite grades do not show any significant dimensional change even when heated to 5,100 F in a non-oxidizing atmosphere. With metal impregnated grades, the melting point of the metal cannot be exceeded. With resin-impregnated materials, the dissociation temperature of the resin cannot be exceeded.

## Friction

The coefficient of friction of dry running mechanical carbon parts depends on several factors: the load, speed, counter material and condition of the surfaces. The coefficient of friction of mechanical carbon parts sliding against metals is normally in the range of 0.1 to 0.3, which is higher than the coefficient of friction for oil-grease lubricated metal parts. Oil grease lubricated metal parts can show a coefficient of friction as low as approximately 0.02, therefore dry running carbon parts can exhibit up to 10 times the amount of friction as oil-grease lubricated metal parts. This higher coefficient of friction for mechanical carbon parts must be taken into consideration when designing equipment using dry running mechanical carbon parts.

## 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.

## Dry Running Applications

If two metal parts are rubbed together without oil-grease lubrication between them, the oxide film on the metal parts will quickly wear off and the two metals will exhibit strong atomic attraction. This attraction results in high friction, high wear and—at higher speed or loads—galling and seizing.

On the other hand, when carbon materials are rubbed against metal, oil-grease lubricants are not needed. Since no strong atomic attraction exists between carbon and metals, a thin film of graphite is automatically burnished onto the metal surface when mechanical carbon materials are rubbed against metals. This thin layer permits rubbing with low friction and low wear.

For many dry running applications, oil-grease lubrication is excluded as an option because the machines operate at elevated temperatures. At temperatures exceeding 300 F (150 C), oil-grease lubricants can lose their viscosity, volatilize or carbonize, making them ineffective for lubricating metal parts.

Another problem occurs at low temperatures. At temperatures between -30 F and -450 F, oil-grease lubricants can become too thick or even solidify. In a full or partial vacuum, oil-grease lubricants can volatilize and contaminate the environment. Additionally, oil-grease lubricants are not permitted in some gas compressors and air pumps because the pumped gas must be kept oil-grease free.

Because of its ability to function without oil-grease lubrication, mechanical carbon is used for many dry running applications such as bearings and thrust washers for high temperature conveyers; bearings for hot air dampers; bearings, vanes and endplates for rotary air and vacuum pumps; and radial and axial seal rings for steam turbines, blowers and jet engines. Other typical mechanical carbon applications include seal rings for rotary steam joints, faces for dry running mechanical seals, piston rings and guide rings for gas compressors and seats for high temperature gas valves.

## Wear Issues

The primary limitation for dry running mechanical carbon parts is wear. Mechanical carbons are softer than the metal parts they rub against, therefore the mechanical carbon parts wear and the metal parts do not.

The wear rate of the carbon part is roughly proportional to the rubbing speed, V, (ft/min) multiplied by the face loading, P (psi). This product, or PV factor, represents the intensity of rubbing. If the PV factor is less than 500 psi X ft/min (0.19 kg/cm2 m/sec), the temperature is less than 850 F and the allowable wear is at least 0.050 inches (1.3 mm) per year, then it is usually possible to specify a mechanical carbon and counter material combination that will meet the wear requirement. If the PV factor or the temperature is lower, the wear rate will also be lower.

Other factors that affect the wear rate are counter material and counter material surface finish. Counter material should be at least Rc 20 hard. Even harder counter material gives better wear rates. The counter material should have at least a 16 micro-inch (0.4 micron) surface finish. With counter material surface finishes rougher than about 16 micro-inch (0.4 micron), the asperities on the counter material are too tall and cannot be covered by the graphite-burnished film that is essential for a low dry-running wear rate. The uncoated asperities on the counter material can "grind" the softer mechanical carbon material and cause a higher wear rate.

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.

Carbon parts for submerged applications include bearings and thrust washers for pumps 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.

## Wear Rate

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. The maximum load that is normally supported by mechanical carbons with full fluid film lubrication is around 1,000 psi (70 kg/cm$^2$).

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, but better results are achieved with even harder counter materials.

The surface finish on the counter material should be 16 micro-inch (0.4 micron) or better. These high finishes are required because the hydrodynamic film with low viscosity liquids is extremely thin. With courser finishes on the counter material, the asperities on the counter material would break through the hydrodynamic film and "grind away" the mechanical carbon. The liquid viscosity should be in the range of about 100 centipoises (light machine oil) to 0.3 centipoises (acetone).

A continuous flow of liquid to the rubbing surface is important to the performance of submerged running 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. 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, causing pits and surface roughness that will disrupt the hydrodynamic film, resulting in a high wear rate.

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

Most mechanical carbon manufacturers can determine if they have a material that can satisfy specific application requirements. They also can recommend their best mechanical carbon grade for each specific application as well as recommend dimensions and dimensional tolerances for new mechanical carbon parts to assure proper press-fit or shrink-fit interference and shaft running clearance.

Mechanical carbon materials have provided solutions to a wide variety of lubrication challenges for more than a century. New mechanical carbon materials are continually being developed to meet ever more demanding mechanical applications.

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