Plastic and Non-Metallic Bearings

C. PLASTIC AND NON-METALLIC BEARINGS

1.0 GENERAL CHARACTERISTICS

Among the significant characteristics of plastic bearings, the following are noteworthy:

- Low wear rates
- Relatively high performance rating (PV) among sleeve bearing materials
- Bearing O.D.'s compatible with standard sintered bronze sizes for upgrading existing equipment
- Kinetic and static coefficient of friction virtually the same under heavy loads
- Extremely low coefficient of friction as shown in Figure 1
- Light weight
- Ability to conform under load

The design characteristics of plastic and non-metallic bearings bear both similarities and differences relative to those of porous-metal bearings. This will now be described in greater detail.

2.0 PROPERTIES OF PLASTIC AND NON-METALLIC BEARING MATERIALS

Plastics (such as acetyl, nylon, PTFE). carbon graphite and other non-metallic materials have been increasingly used as self-lubricating bearings. Their composition has been refined over many years so as to obtain favorable bearing characteristics. These include low friction, corrosion resistance, ability to conform under load (plastic bearings), ability to function over substantial temperature ranges and substantial load-carrying capability. Although temperature ranges, dimensional stability and load limitations of plastic gears are in general less than for metallic bearings, plastic bearings are remarkably versatile and economical.

A summary of characteristics of representative plastic and non-metallic materials has been given by Machine Design Magazine (Vol. 54, #14, June17, 1982, p. 132) with whose permission the following material is reprinted:

Phenolics: Composite materials consisting of cotton fabric, asbestos, or other fillers bonded with phenolic resin. The good compatibility of the phenolics makes them easily lubricated by various fluids.

They have replaced wood bearings and metals in such applications as propeller and rubber-shaft bearings in ships, and electrical switch-gear, rolling-mill, and water-turbine bearings. In small instruments and clock motors, laminated phenolics serve as structural members as well as a bearing material. They have excellent strength and shock resistance, coupled with resistance to water, acid, and alkali solutions.

Some precautions must be observed with phenolic bearings. Thermal conductivity is low, so heat generated by bearing friction cannot readily be transmitted through the bearing liner. Consequently, larger, heavily loaded bearings must have a generous feed of water or lubricating oil to carry away heat. Some swelling and warping of these bearings occurs in the larger sizes, so larger-than-normal shaft clearances are required.

Nylon: Although the phenolics have predominated in heavy-duty applications, they are frequently replaced by nylon, which has the widest use in bearings. Nylon bushings exhibit low friction and require no lubrication. Nylon is quiet in operation, resists abrasion, wears at a low rate, and is easily molded, cast, or machined to close tolerances. Possible problems with cold flow at high loads can be minimized by using a thin liner of the material in a well-supported metal sleeve.

Improvement in mechanical properties, rigidity, and wear resistance is obtained by adding fillers such as graphite and molybdenum disulfide to nylon. While the maximum recommended continuous service temperature for ordinary nylon is 170°F, and 250°F for heat-stabilized compositions, filled- nylon parts resist distortion at temperatures up to 300°F.

PTFE: Has an exceptionally low coefficient of friction and high self-lubricating characteristics, resistance to attack by almost any chemical, and an ability to operate under a wide temperature range. High cost combined with low toad capacity has frequently caused FIFE resin to be selected only In some modified form. PTFE Is used as a bearing material in automotive knuckle and ball joints, chemical and (cod processing equipment, aircraft accessories, textile machinery, and business machines.

Although unmodified PTFE can be used to a PV value of only 1,000, PTFE filled with glass fiber, graphite, or other inert materials, can be used at PV values up to 10,000 or more. In general, higher PV values can be used with PTFE bearings at low speeds where its coefficient of friction may be as low as 0.05 to 0.1.

One bearing material combines the low friction and good wear resistance of lead-filled PTFE with the strength and thermal conductivity of a bronze and steel supporting structure. A plated steel backing is covered with a thin layer of sintered, spherical, bronze particle8. The porous bronze is then impregnated with a mixture of PTFE and lead to provide a thin surface layer. Service temperatures of —330 to +536°F are possible.

Woven PTFE fabrics are often readily handled and applied. With their resistance to cold flow, they are used as bearings in a wide variety of high-load applications as automotive thrust washers, ball- and-socket joints, aircraft controls and accessories, bridge bearings, and electrical switch gear. To provide a strong bond to either steel or other rigid backing material, a secondary fiber such as poiyester, cotton, or glass is commonly Interwoven with the PTFE. The woven fabric then Is bonded to a steel backing.

Improved versions of this type of bearing have woven or braided “socks” (of PTFE and a bondable material). The bearing sleeve is then filament wound with a fiberglass-epoxy shell. These bearings have been rer rted to carry dynamic loads as high as 50,000 psi.

Acetal: Has been used for inexpensive bearings in a wide variety of automotive, appliance, and industrial applications. It is particularly useful in wet environments because of its stability and resistance to wet abrasion.

Polyimide, Polysultone, Potyptienylene sulfide: High-temperature materials with excellent resistance to both chemical attack and burning. With suitable fillers, these moldable plastics are useful for PV factors to 20,000 and 30,000. Polyimide molding compounds employing graphite as a self- lubricating filler show promise in bearing, seal, and piston ring applications at temperatures to 500°F. Polyphenylene sulfide cart be applied as a coating through use of a slurry spray, dry powder, or fluidized bed; These coating techniquee require a final bake at about 700° F.

Ultrehigh-Molecular-Weight, Polyethylene: Resists abrasion and has a smooth, low-friction surface. Often an ideal material for parts commonly made from acetal, nylon, or PTFE materials.

Carbon-Graphite:The self-lubricating properties of carbon bearings, their stability at temperatures up to 750°F, and their resistance to attack by chemicals and solvents, give them important advantages in fieldswhere other bearing materials are unsatisfactory. Carbon-graphite bearings are used where contamination by oil or grease is undesirable, as In textile machinery, food handling machinery, and pharmaceutical processing equipment. They are used as bearings in and around ovens, furnaces, boilers, and jet engines where temperatures are too high for conventional lubricants. They are also used with low-viscosity and corrosive liquids in such applications as metering devices or pumps for gasoline, kerosene, hot and cold-water, sea water, chemical process streams, acids, alkalis, and solvents.

The composition and processing used with carbon bearings can be varied to provide characteristict required for particular applications. Carbon-graphite has from 5% to 20% porosity. These pores can be filled with a phenolic or epoxy resin for Improved strength and hardness, or with oil or metals (such as silver, copper, bronze, cadmium, or babbitt) to improve compatibility properties.

A PV limit of 15000 ordinarily can be used for dry operation of carbon bearings. This should be reduced for Continuous running with a steady load over a long period of time to avoid excessive wear. When operating with liquids which permit the development of a supporting fluid film, much higher PV values can be used.

A hard, rust-resistant shaft with at least a 10-µin, finish should be used. Hardened toot steel or chrome plate is recommended for heavy loads and high-speed applications. Steal having a hardness over Rockwell C50, bronzes, 18-8 stainless steels, and various carbides and ceramics also can be used.

Certain precautions should be observed in applying carbon-graphite. Since this material is brittle, It Is chipped or cracked easily if struck on an edge or a corner, or if subjected to high thermal, tensile, or bending stresses. Edges should be relieved with a chamfer. Sharp corners, thin sections, keyways, and blind holes should be avoided wherever possible. Because of brittleness and low coefficient of expansion (about ¼ that of steel), carbon-graphite bearings are often shrunk into a steel sleeve. This minimizes changes in shaft clearance with temperature variations and provides mechanical support for the carbon-graphite elements."

The comparative properties of three proprietary materials are summarized In Table 1.

TABLE 1

COMPARATIVE PROPERTIES OF GRAPHITAR,(i) OIL.ON PV® _80(ii)) AND RULON(iii)

Property	Graphitar (Carbon-Graphite)	Oilon PV®-80 (TFE)	Rulon® (TFE)
Coefficient of friction	0.04 to 0.25	0.05 to 0.10	0.15 to 0.20
Temperature range	Cryogenic to 1000°F in some grades	-40°F to +250°F	-400°F to+550°F
Approx. max. PV (unlubricated)	15,000	18,000	10,000 (Sleeve bearing)
Max. P	*	3000 pal	1000 psi
Max. V	*	1700 ft/mm.	400 ft/mm.
Recommended shaft surface finish	+=30rms	*	8-32 rms
Recommended shaft clearance	0.003 nun for most unlubricated applications	$(tw)10^{-4}$ +0.004" t = temp. °F w = bearing wall thickness (in.)	*
Typical elastic modulus	$(0.5 \text{ to } 3.5)10^{6}$ psi	$(3.5 = 3.8)10^{6}$ psi	*
Tensile strength	1000 — 9500 psi, depending on grade	7200 psi	*
*Consult manufacturer			

Data reprinted with the permission of the following manufacturers:

(I) "Graphitar" Wickes, 1621 Holland Ave., Saginaw, Mich. 48601;

(ii) "Oilon PV®_80 Design Guide", TFE lndustries, 148 Parkway Kalamazoo, Mich. 49006;

(iii) "Rulon® Standard Stock Bearings, Engineering Manual, Cat. 75", Dixon Corp.. Div. of Dixon Industries, Bristol, RI., 02839.

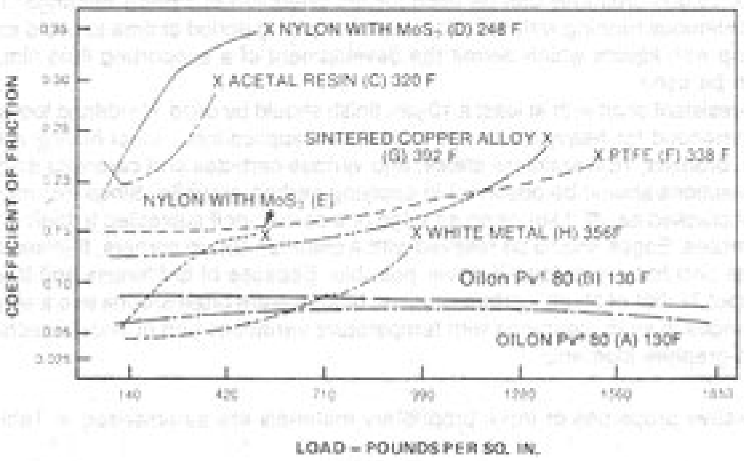

Figure 1 Coefficient of Friction vs. Load for Various Materials*

(A) Oilon Pv® —80—Class I
(B) Oilon Pv® —80-—Class II
(C) Acetal—Class I
(D) Nylon MoS_2—Class II
(E) Nylon MoS_2—Class I
(F) PTFE glass filled—Class II
(G) Oil impregnated sintered copper alloy—Class II
(H) White Metal—Class I

Class I—Grease applied externally prior to start-up.
Class II—No grease applied prior to start-up.

Test Conditions:

Velocity — 46 ft/mm. (350 RPM)
Load — 140 lbs./sq.in., addition applied at 10 mm. intervals
Dimensions of Test Specimen — 5/8” O.D. x 318” I.D. x 3/8” long
Mating Material — Steel 113°F HR—B 90

A comparison of frictional characteristics of various metallic and plastic materials is given in Figure 1. in some Plastic materials the coefficient of friction decreases with load, thereby greatly reducing or eliminating the stick-slip problem in the start-up of machinery.

In recent years the properties of plastic bearing materials have been materially enhanced by the addition of fillers (such as fiber, powder, graphite and molybdenum disulfide) and composites (metal or other backings). If the cost is warranted the mechanical properties of such bearings can be dramatically improved.

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* Reproduced with the permission of TFE Industries, 148 Parkway, Kalamazoo, Michigan, 49006, from “OILON Pv® 80 Design Guide”, p.5.

3.0 SIZING PLASTIC AND NON-METALLIC BEARINGS

The load-carrying capacity of plastic and non-metallic bearings is determined by means ol the PVfactor, as described ri the section on porous-metal bearings.

The upper bound or limiting value of the PV factor again depends on operating conditions (speed. temperature, etc.) and a limit on the allowable unit loading. In addition to its use as a design guide for limiting load/speed values the PV factor can also be used to estimate a relative wear factor, K.

Table 2 summarizes data for the PV and K factors for typical and non-metallic bearing materials.

TABLE 2
PV FACTORS AND K FACTORS FOR NON-METALLIC BEARING MATERIALS*

The PV factor, used as a load-speed limit also provide a basis or estimating relative wear rates The bid volume of material worn away is approximately proportional to the total normal load multiplied by the distance traveed in length of time. Thus R=K(PV)T, where Ft - radial wear in a sleeve beating in.; K=wear factor in.^{3}-min/ft-lb.h:P load, pet V=surface velocity, fpm: T=time,h. This equation does not niways pronide accurate absolute velsea for wear rate, liuf it is useful br aetimating relative wear rain for alternative materials, tn general, K wear values with tillers are lower than for unfilled materials. If wear values are important for specific componente, life teals should be wade. These might employ these might employ moderatly accelerated load and speed condtitona to obtain a K value representative of the plastic, the shaft and its finish, and the application conditions K veluee should be mrrcreaaed by 50% tor cast Iron and bronze shafts, and more than 5 fimes with sell stainless steel or aluminum alloys Increased surface hardness can markedly reduce wear, while aurtace roughness of shaft often loss an optimum value in the 4-14 µin..rms. range. Lubrication also bee a pronounced influence on wear. with oil lmprednation, wear rates commonly drop to negligible values with Plastic, wood, and porous metals.

	Load Capacity (psi)	Max Temp (°F)	Max Speed (fpm)	Pv Limit (Unlubricated)
Phenolics	6.000	200	2,500	15,000
Nylon	2,000	200	600	3,000
PTFE	500	500	50	1,000
Fille PTFE	2,500	500	1,000	10,000
PTFE	60,000	500	150	25,000
Polycarbonate	1,000	220	1,000	3,000
acetale	2,000	200	600	3,000
Carbo-Graphite	600	750	2,500	15,000
Rubber	50	150	4,000	-
Wood	2,000	160	2,000	12,000

	Wear Factor K(in.3-min/ft-lb-h) Filled*	No Filler
Nylon	16 x 10^{-10}	200 x 10^{-10}
Polyester	20 x 10^{-10}	-
Polycarbon	30 x 10^{-10}	2,500 x 10^{-10}
Polyurethane	35 x 10^{-10}	-
Polypropylene	36 x 10^{-10}	-
Styrene acrylonitrile	65 x 10^{-10}	-
Polysulfone	70 x 10^{-10}	-
Acetal	200 x 10^{-10}	65 x 10^{-10}

For 40 per load at 2000 PV oprating against carbon steel of hardened 20 Ro with a 6-12 microm finish
* Filled with 30%(by weight) glass fiber 15%(by weight)PTFE

* This table is reprinted with the permiaslon of Machine Design Magazine (Vol. 54, #14, June 17, 1982, p. 134)

A more detailed treatment of the PV-curve for any particular material involves additional data, which can often be obtained from the material manufacturer. For example, in the case of Oilon Pv®8O, Figure 2 presents such additional information.

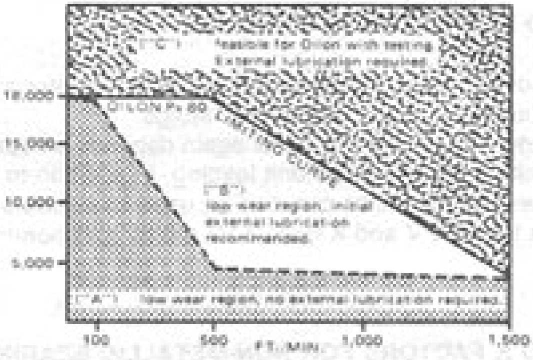

Figure 2 Limiting PV Curve for Ollon Pve —.80 showing regIons (A, B, C) with different operating requirements and/or characteristics*

("A")—low wear region, no external lubrication required.
("B")—low wear region, initial external lubrication recommended.
("C")—feasible for Oilon with testing. External lubrication required.

4.0 CONCLUSION

Plastic and non-metallic bearings are widely used in appliances, toys, general machinery and applications ranging from cameras and toys to office machinery and automobiles. When property designed their light weight and economy can be highly attractive. Calculations of bearing loads on page T31 are also applicable to plastic and non-metallic bearings.

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* Reprinted with the permission of TFE Industries, 148 Parkway, Kalamazoo, Michigan, 49006; from p.7 of "Oilon Pv®—80 Design Guide".