2.6 Conclusion

Sintered bearings are used widely in instruments and general machinery, in which their self-lubricating characteristics and load-carrying ability is very desirable. When properly designed, they can be both economical and highly functional.

Their manufacturing method consists of briquetting the metal powder mixtures to the proper density. Subsequently, they are sintered for different duration subject to the temperatures. Sintered bearings are then sized to obtain the required dimensional characteristics. This is followed by inspection and impregnation with a lubricating oil.

3.0 PLASTIC AND NONMETALLIC BEARINGS

3.1 General Characteristics

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

- Self-lubricating
- 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 3-1**
- Lightweight
- Ability to conform under load
- Resistance to chemicals

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

3.2 Properties of Plastic and Nonmetallic Bearing Materials

Plastics (such as acetal, nylon, PTFE), carbon graphite and other nonmetallic 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 wide temperature ranges and substantial load-carrying capability. Although temperature ranges, dimensional stability and load limitations of plastic bearings are in general less than for metallic bearings, plastic bearings are remarkably versatile and economical.

A summary of characteristics of representative plastic and nonmetallic materials has been given by *Machine Design* magazine (Vol. 54, #14, June 17, 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 load capacity has frequently caused PTFE resin to be selected only in some modified form. PTFE is used as a bearing material in automotive knuckle and ball joints, chemical and food processing equipment, aircraft accessories, textile machinery, and business machines.

Although unmodified PTFE can be used to a PV value of only 1000, PTFE filled with fiberglass, graphite, or other inert materials, can be used at PV values up to 10000 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 particles. The porous bronze is then impregnated with a mixture of PTFE and lead to provide a thin surface layer. Service temperatures of –330°F 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 polyester, 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 reported to carry dynamic loads as high as 50000 psi.

Acetal: Components made from acetal rod are dimensionally stable even under extremely wet or humid conditions and will not swell like nylon in these conditions. Additionally, it resists most organic solvents. Natural white acetal is an USDA/FDA approved material for food processing applications. Acetal is relatively easy to machine and does not burr easily. Acetal is a generic descriptive name for two polymers: Celcon® – a copolymer made by Celanese – and Delrin® – a homopolymer made by E. I. DuPont Nemours. Both types are tough enough and strong enough to replace metal for many applications.

Acetron® NS: is a patented acetal-based compound containing special solid lubricants which help provide superior performance in bearing and wear applications. These lubricants are uniformly dispersed in the base acetal, providing a premium, internally lubricated compound with high Pressure Velocity (PV) capabilities, a low coefficient of friction, and an extremely good "k" factor.

Table 3-1 Wear Rate, Coefficient of Friction and Limiting PV Data

Acetal	Wear Factor "k" (1)	Comparative Wear Rate to Acetron® NS	Coefficient of Friction		Limiting PV (4)
			Static (2)	Dynamic (3)	
Acetron® NS	48	1.0	.18 – .19	.20 – .21	8750
Delrin AF Blend	57	1.2	.18 – .19	.19 – .20	8300
Delrin AF	65	1.4	.18 – .19	.19 – .20	11000
Delrin 500 CL (a)	176	3.7	.22 – .24	.23 – .25	3500
Acetron® GP	200	4.2	.22 – .25	.22 – .28	2700
Turcite A	213	4.4	.29 – .34	.20 – .23	6560

(1) Measured on 1/2" I.D. journal at 5000 PV (118 fpm & 42.2 psi)
K= h/PVT x 10^{-10} (in^3 min/ft lb hr) where:
h = radial wear (in)
P = normal pressure (psi)
V = sliding speed (fm)
T = test duration (hrs)
(2) Measured on thrust washer bearing under a normal load of 50 lbs. Gradually increasing torque was applied until the bearing completed a 90° rotation in about one second.
(3) Measured on thrust washer testing machine, unlubricated @ 20 fpm & 250 psi.
(4) Limiting PV (Test valued — unlubricated @ 100 fpm (lb ft/in^2 min)
(a) Equivalent to DSM's MC® 901.

The additive system which delivers the lubrication is a patented composite. With it, the solid lubricants firmly locked in the acetal matrix are always exposed to the bearing surface. It's this constant source of lubrication which enables Acetron® NS acetal to outperform other bearing materials. It also provides lubrication during break-in of bearings and for enhanced wear-resistance.

Because the acetal and solid lubrication do not absorb significant quantities of moisture, Acetron® NS acetal is stable in both wet and dry environments. It is highly recommended for precision, close tolerance parts.

The presence of the lubricant system in the acetal matrix also allows very free machining. The result is a very competitively priced product which will outperform other filled acetals in most bearing and wear applications, and give it a noticeable advantage over more expensive, premium-priced, internally lubricated acetal compositions.

Polyamide, Polysulfone, Polyphenylene 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 20000 and 30000. Polyamide 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 can be applied as a coating through use of a slurry spray, dry powder, or fluidized bed. These coating techniques require a final bake at about 700°F.

Ultrahigh-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