Cylindrical Oilless Bushings | High-Performance Self-Lubricating Bearings for Demanding Industrial Applications

Introduction

Why choose cylindrical oilless bushings over traditional bearings?

In modern industrial machinery, bearing reliability directly determines equipment uptime, maintenance costs, and operational efficiency. Traditional plain bearings depend on continuous oil or grease supply, making them vulnerable to lubrication failure under high temperatures, dust contamination, underwater operation, or heavy-load low-speed conditions. When lubrication is compromised, galling, accelerated wear, and unplanned downtime become inevitable.

Cylindrical oilless bushings offer a fundamentally different approach. By embedding solid lubricants within high-strength metal matrices, these components achieve self-lubrication without external oil supply. The result is maintenance-free operation across a wide spectrum of demanding environments—from steel mill furnaces to hydropower turbines, from offshore platforms to chemical processing plants.

This comprehensive guide explores the technology, materials, performance characteristics, and application considerations for cylindrical oilless bushings, providing engineers and procurement professionals with the technical foundation needed for informed selection and successful implementation.

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1. Technical Principles & Material Technology

1.1 How Oilless Bushings Work: The Transfer Film Mechanism

Cylindrical oilless bushings operate on a principle fundamentally distinct from fluid-lubricated bearings. Rather than relying on an external oil film maintained by continuous supply, these bearings contain their lubricant within the bearing material itself.

The mechanism unfolds in three stages:

- **Stage 1: Initial Contact**

When the bearing begins operation, the solid lubricant embedded in the metal matrix contacts the mating shaft surface.

- **Stage 2: Transfer Film Formation**

Frictional heat and mechanical shear cause the lubricant to transfer from the bushing to the shaft surface, forming a thin, uniform film.

- **Stage 3: Self-Regenerating Lubrication**

The transfer film continuously replenishes during operation. Even if localized film breakdown occurs, additional lubricant from the inlays restores the protective layer.

This self-regenerating mechanism enables continuous operation without external lubrication, eliminates the risk of lubricant starvation, and provides inherent tolerance to contamination and extreme conditions.

1.2 Solid Lubricants: The Friction-Reducing Interface

Two primary solid lubricant systems are available, each with distinct performance characteristics.

Lubricant Type	Composition	Key Properties	Temperature Limit	Best Applications
SL1 (Graphite)	High-purity graphite with proprietary additives	Excellent wear resistance; chemical stability; self-lubricating at high temperatures	400°C	High-temperature furnaces, atmospheric environments, general industrial machinery
PLTF (PTFE)	PTFE with specialized additives	Extremely low friction coefficient; superior water lubrication; minimal start-up friction	300°C	Marine equipment, hydraulic turbines, water pumps, food and pharmaceutical machinery

Why Lubricant Selection Matters:

Graphite and PTFE operate on fundamentally different principles. Graphite's lamellar crystal structure allows easy shear between layers, while PTFE's polymer chains align in the direction of motion. Graphite excels in high-temperature and atmospheric applications. PTFE provides superior performance in water environments—where water molecules interact with the polymer surface to further reduce friction—and in applications with frequent start-stop cycles where minimal breakaway friction is critical.

1.3 Matrix Materials: The Load-Bearing Foundation

The matrix material provides structural integrity, load capacity, and heat dissipation. Multiple material options are available to match specific application requirements.

Material Code	Composition	Density (g/cm³)	Hardness	Tensile Strength (N/mm²)	Temperature Range (°C)	Max Load (N/mm²)	Max Speed (m/min)	Max PV
JDB(500#)	CuZn25Al5Mn3Fe3	8	>210 HB	>750	-40~+300	100	15	200
JDB(500#S1)	CuZn25Al5Mn3Fe3	8	>250 HB	>800	-40~+150	120	15	200
JDB(500#S2)	CuAl9FeNi4Mn2	8.5	>150 HB	>800	-40~+400	150	20	60
JDB(500#S3)	CuSn6Pb5Zn5	8.9	>70 HB	>200	-40~+400	60	10	60
JDB(500#S4)	CuSn12	9.05	>80 HB	>260	-40~+400	70	10	80
JDB(HT250)	Cast Iron	7.3	>190 HB	>250	-40~+400	80	8	40
JDB(Gcr15)	Bearing Steel	7.8	>58 HRC	>1500	-40~+400	200	5	150

Selection Guidance by Material:

Material	Optimal Applications	Key Attributes
JDB(500#)	General industrial, high load, low speed	Best balance of strength and wear resistance; most widely specified
JDB(500#S1)	Ultra-high load, extreme pressure conditions	Enhanced hardness for maximum load capacity
JDB(500#S2)	Corrosive environments, medium load, medium speed	Aluminum bronze provides exceptional corrosion resistance; stable to 400°C
JDB(500#S3/S4)	Medium load, cost-sensitive applications	Tin bronze alloys with good conformability and wear characteristics
JDB(HT250)	Economical, medium load, low speed	Cast iron for cost-effective solutions
JDB(Gcr15)	Extreme load, highest strength requirements	Bearing steel with superior load capacity

1.4 Matrix-Lubricant Synergy: What the Tables Don't Show

Beyond individual material properties, the combination of matrix and lubricant creates synergistic effects that significantly impact performance:

- **Thermal Expansion Matching:**

High-strength brass and graphite have nearly identical coefficients of thermal expansion (approximately 1.9×10^{-6}/°C), maintaining interfacial integrity across temperature excursions

- **Interfacial Adhesion:**

PTFE exhibits superior adhesion to aluminum bronze matrices, making this combination ideal for corrosive environments

- **Start-Up Behavior:**

PTFE-based systems deliver immediate low friction, while graphite systems require a brief run-in period to establish the transfer film

2. Performance Data & Engineering Parameters

2.1 Wear Life Estimation Methodology

Bearing life is primarily determined by inner diameter wear depth. The fundamental relationship is:

$$W = K \times P \times V \times T$$

Parameter	Description	Typical Range
W	Wear depth (mm)	Application dependent
K	Coefficient of friction	(1~5) × 10^{-6} base value
P	Load pressure (N/mm²)	5–200 depending on material
V	Linear speed (m/min)	5–20 depending on material
T	Operating time (hours)	Design life target

2.2 Mating Shaft Requirements

The mating shaft is an active participant in the tribological system, not merely a passive counterpart.

Parameter	Specification	Why It Matters
Material	#35 carbon steel or higher, Cr12, 9SiCr	Provides adequate strength and wear resistance
Hardness	1.2–1.5 × bearing hardness	Prevents shaft wear without excessive bearing cutting
Surface Roughness	Ra ≤ 0.4 μm	Ensures stable oil film formation
Heat Treatment	Quenching + tempering	Achieves required hardness and dimensional stability

Surface Treatment Options:

Treatment	Best For	Benefit
Hard Chrome Plating	General applications	Corrosion resistance; reduced abrasive wear
Multi-Layer Chrome (2–3 layers)	Seawater, corrosive environments	Improved adhesion; defect tolerance
Induction Hardening	High-load, impact applications	Case depth with tough core
Nitriding	Precision applications	Minimal distortion, high surface hardness

2.3 Multi-Factor Wear Correction

Because the coefficient of friction varies with operating conditions, practical wear estimation requires correction factors:

$$K_{actual} = C_0 \times C_1 \times C_2 \times C_3 \times k_{ideal}$$

Factor	Parameter Range	Coefficient Value	Key Insight
Sliding Condition C_0	Load ≤5 N/mm², Speed ≤1 m/min	8–10	Higher loads and speeds multiply wear rates significantly; speed has a proportionally larger effect than load
	Load ≤5 N/mm², Speed 1–10 m/min	10–12	
	Load ≤5 N/mm², Speed 10–30 m/min	12–18	
	Load 5–25 N/mm², Speed ≤1 m/min	12–18	
	Load 5–25 N/mm², Speed 1–10 m/min	18–25	
	Load 5–25 N/mm², Speed 10–30 m/min	25–30	
	Load 25–50 N/mm², Speed ≤1 m/min	18–25	
	Load 25–50 N/mm², Speed 1–10 m/min	25–30	
	Load 25–50 N/mm², Speed 10–30 m/min	30–40	
Temperature Condition C_1	≤100°C	1–2	Above 200°C, lubricant degradation and matrix softening accelerate wear by up to an order of magnitude
	100–200°C	3–5	
	200–400°C	5–10	
Environmental Condition C_2	General Indoor	1–2	Dust is the most significant wear accelerator—proper sealing can reduce effective wear rate by 90% or more
	Outdoor	5–10	
	Dusty Conditions	10–30	
Application Environment C_3	Atmosphere	1.9	Water reduces wear rate compared to atmosphere—a significant advantage for PTFE-based systems where water acts as a boundary lubricant
	Water	0.8	
	Seawater	1.2	

2.4 PV Value: The Thermal Operating Limit

PV value (pressure × velocity) represents the bearing's thermal operating boundary. Exceeding the maximum PV value causes heat accumulation that can lead to lubricant film breakdown and eventual seizure.

Maximum PV Values by Material:

Material	Max PV (N/mm²·m/min)	Thermal Limit
JDB(500#), JDB(500#S1)	200	Highest thermal capacity
JDB(500#S4)	80	Moderate
JDB(500#S2), JDB(500#S3)	60	Lower due to material properties
JDB(HT250)	40	Thermal management critical
JDB(Gcr15)	150	High capacity, low speed

PV Value Calculation Methods:

Bearing Type	Load Pressure Formula	Linear Speed Formula
Cylindrical Bushing	$P = F/(d \times L)$	$V = \pi dn/60{,}000$
Thrust Washer	$P = \frac{4F}{\pi(D^2 - d^2)}$	$V = \frac{\pi n \sqrt{2(D^2 + d^2)}}{120{,}000}$
Sliding Plate	$P = F/(B \times L)$	$V = 60S/T \times 1000$

Parameter Definitions:

Parameter	Description
• F	Load (N)
• d	Inner diameter (mm)
• D	Outer diameter (mm)
• L	Length (mm)
• B	Width (mm)
• n	Rotational speed (rpm)
• S	Stroke length (mm)
• B	Time per reciprocation (sec)

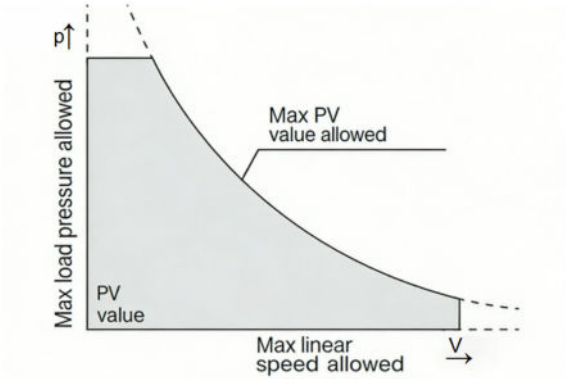

Fig 1 : Bearing PV Value Diagram

2.5 Geometric Design Parameters

L/D Ratio Selection:

L/D Range	Characteristics	Recommended Applications
<0.8	Excellent alignment tolerance; superior cooling	High-speed; applications with shaft deflection
0.8–1.5	Optimal balance for most applications	General industrial machinery
>1.5	Lower unit pressure; reduced cooling efficiency	Low-speed, high-load; well-aligned shafts

Critical Note: For high-load applications with potential eccentric contact or high-speed operation, L/D ratios below 1.0 are recommended.

Wall Thickness Formula:

$$t = (0.05 \sim 0.07)d + (2 \sim 5)\ mm$$

Wall Thickness Guidelines:

Wall Thickness Coefficient $\phi_t = t/d \times 100\%$	Classification	Considerations
<5%	Thin-wall	Requires careful assembly; potential elliptical deformation
5–8%	Optimal	Balance of strength, heat dissipation, and assembly
>8%	Thick-wall	Reduced self-cooling; may require PV derating

2.6 Assembly: Press-Fit Shrinkage Calculation

When pressed into a housing, the bearing inner diameter shrinks according to:

$$\Delta = \frac{10D_h}{7D_h + 3d_0} \times \delta$$

Symbol	Description
• Δ	Inner diameter shrinkage (mm)
• δ	Outer diameter interference (mm)
• d_h	Inner diameter before pressing (mm)
• D_h	Housing inner diameter (mm)

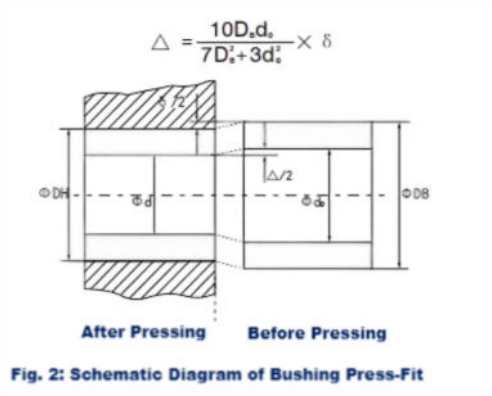

Fig. 2: Schematic Diagram of Bushing Press-Fit

Engineering Implication: *Post-assembly inner diameter differs from free-state dimensions and must be considered in clearance calculations to ensure proper shaft fit.*

Assembly Best Practices:

Step	Action	Critical Requirement
1	Surface inspection	Ensure no foreign matter on mating surfaces
2	Apply assembly lubricant	Facilitates installation; shortens run-in period
3	Align properly	Prevents angular misalignment causing edge loading
4	Press slowly	Controlled speed prevents damage
5	No hammering	Hammering may distort or damage the bushing

For high-load or reciprocating motion applications: Screw fixation is recommended to prevent axial movement.

3. Application Industries

3.1 Industry Coverage

Industry Sector	Specific Applications
Automotive	Stamping dies, sliding guides, assembly lines, tool supports, cover mold presses
Steel & Metallurgy	Furnace bearings, conveyor rollers, rolling mills, blast furnaces, sintering equipment
Heavy Machinery	Construction equipment, mining machinery, crushers, mixers, grinding mills
Hydraulic Structures	Dam gates, weir plants, hydraulic turbines, gate bearings, spillway structures
Marine & Offshore	Deck cranes, anchor windlasses, rudder arms, hatch covers, dredging equipment
Injection Molding	Machines, tooling, connecting toggle links, tie bar bushings
Chemical Processing	Chemical plants, food machinery, pharmaceutical equipment, electroplating lines
Power Generation	Nuclear reactors, steam generators, wind turbines, hydroelectric equipment
Material Handling	Conveyors, lifting equipment, elevators, bridges, crane systems

3.2 Application-Specific Recommendations

Operating Condition	Recommended Material	Lubricant	Key Design Considerations
High Temperature (200–400°C)	JDB(500#S2)	Graphite (SL1)	hermal expansion management; select graphite for stabili
Water / Seawater	JDB(500#)	PTFE (PLTF)	Chrome-plated or stainless steel shaft; Ra ≤0.4 μm
Heavy Load, Low Speed	JDB(500#S1) or JDB(Gcr15)	Graphite (SL1)	L/D <1.0; monitor alignment carefully
Reciprocating Motion	JDB(500#S3)	PTFE (PLTF)	Lubricant placement aligned with stroke direction
Frequent Start-Stop	JDB(500#)	PTFE (PLTF)	PTFE provides minimal breakaway friction
Dusty Environments	JDB(500#S1)	Graphite (SL1)	Sealing critical; higher hardness matrix
Chemical / Corrosive	JDB(500#S2)	Verify compatibility	Aluminum bronze for acid resistance

4. Selection Guide

4.1 Step-by-Step Selection Process

Step 1: Define Operating Parameters

- Load magnitude and type (radial/axial, static/dynamic)
- Motion type (rotary, reciprocating, oscillating)
- Speed range (m/min or rpm)
- Temperature range (minimum and maximum)
- Environmental conditions (dust, water, chemicals)

Step 2: Calculate PV Value

- Select appropriate formula based on bearing type
- Calculate maximum PV value
- Compare with material limits in properties table

Step 3: Select Matrix Material

- Match load, speed, temperature, and corrosion requirements
- Refer to material properties comparison table
- Prioritize standard specifications where possible

Step 4: Select Lubricant Type

- High temperature (>200°C): Graphite (SL1)
- Water/seawater: PTFE (PLTF)
- Frequent start-stop: PTFE (PLTF)
- General atmosphere: Either, based on other factors

Step 5: Determine Geometry

- L/D ratio: 0.8–1.5 for general use; <1.0 for high-load or high-speed
- Wall thickness: Apply empirical formula; target φ_t = 5–8%

Step 6: Specify Mating Shaft

- Material: #35 carbon steel or higher
- Hardness: 1.2–1.5 × bearing hardness
- Surface roughness: Ra ≤0.4 μm
- Surface treatment: Per environmental requirements

Step 7: Calculate Post-Assembly Clearance

- Apply press-fit shrinkage formula
- Verify final clearance with shaft diameter
- Adjust specifications if clearance outside acceptable range

Step 8: Estimate Service Life

- Apply multi-factor wear correction
- Calculate wear depth over target operating hours
- Apply safety factor (1.5–2.0) for critical applications

4.2 Quick Selection Reference Table

Application Profile	Recommended Material	Lubricant	L/D	Mating Shaft Requirement
General industrial, high load, low speed	JDB(500#)	Graphite	1.0–1.5	Hardened steel, Ra ≤0.4
Extreme load, low speed	JDB(500#S1) or JDB(Gcr15)	Graphite	0.8–1.0	Tool steel, hard chrome plated
Medium load, medium speed	JDB(500#S2)	Graphite	1.0–1.5	Quenched and tempered steel
Marine, water environments	JDB(500#)	PTFE	1.0–1.5	Stainless steel or chrome plated
High temperature (200–400°C)	JDB(500#S2)	Graphite	1.0–1.5	Heat-resistant steel
Reciprocating, oscillating	JDB(500#S3)	PTFE	0.8–1.0	Hard chrome plated, Ra ≤0.4
Dusty, contaminated	JDB(500#S1)	Graphite	1.0–1.5	High hardness, sealed system
Chemical processing	JDB(500#S2)	As required	1.0–1.5	Corrosion-resistant material

4.3 Critical Selection Considerations

Consideration	Guidance
Standardization	Use standard specifications whenever possible to simplify procurement and reduce lead times
Surface Inspection	Before assembly, verify mating surfaces are free of foreign matter
Post-Use Appearance	Black or dark gray film on sliding surface is normal—this is the solid lubricant transfer film; do not wipe off
Installation Method	Press slowly; never hammer—hammering can distort or damage the bushing
Screw Fixation	For high-load or reciprocating motion, use screw fixation to prevent axial movement
Water/Seawater Applications	Stainless steel or chrome-plated mating shafts are essential for corrosion resistance

5. Quality & Performance Features

5.1 Key Advantages

Feature	Benefit
Maintenance-Free	No scheduled lubrication required; eliminates lubrication-related labor and material costs
Wear Resistant	Superior performance under diverse operating conditions; extended service intervals
Low Friction	Reduced energy consumption and heat generation; improved efficiency
Wide Temperature Tolerance	Operation from -40°C to +400°C depending on material selection
Clean Operation	No lubricant discharge; no contamination of product or environment
Corrosion Resistant	Material options available for aggressive environments
Impact Resistant	Suitable for shock-loaded applications; maintains integrity under vibration
Stick-Slip Free	Smooth operation even under oscillating motion; no jerking or chatter
Long Service Life	Extended replacement cycles; reduced downtime and maintenance costs

5.2 After-Use Note

During operation, a black or dark gray film may appear on the sliding surface. This is the transfer film formed by the solid lubricant and is essential for proper lubrication. Do not wipe it off. Continue using the bearing as is—this film ensures continued low-friction operation.

6. Technical Support & Custom Solutions

For applications requiring custom dimensions, non-standard materials, or specialized operating condition validation, engineering support is available to assist with:

- Application-specific material selection
- Custom geometry and lubrication pattern design
- Prototype testing and performance validation
- Tolerance analysis and assembly procedure development
- Life estimation for critical applications