An Introduction to Fluid Film Bearing Materials

AUTHORS

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Originally defined by various compositions of babbitt and bronze, fluid film bearing materials for turbomachinery now include a range of options with distinct performance characteristics. These options have developed in response to the expanding range of operating conditions for high-performing rotating equipment.

As machine loads, speeds and temperatures increase, the main limitation for a bearing is frequently the bearing's surface temperature. Other equipment requires low friction operation in process fluids or the ability to handle contaminants in the fluid. Yet other priorities may include a reduction in power loss or increased load capacity. Advances in fluid film bearing materials have made it possible to achieve these goals.

Today, popular and emerging fluid film bearing materials for turbomachinery include:

- Babbitt (whitemetal)
- Bronze
- Aluminum tin
- Engineered polymers
- Ceramics and cermets
- Polycrystalline diamond (PCD)

} Typically categorized as "advanced materials."

KEY FLUID FILM BEARING MATERIAL CHARACTERISTICS

- **Compatibility** – the resistance to seizure during a metal-to-metal contact event
- **Conformability** – the bearing's ability to conform to minor variations in the counter surface
- **Embedability** – the degree to which the material can accept small amounts of foreign particles in the lubricant

} Together, these qualities reduce the likelihood of damage to the shaft during start-up and shutdown, or from upset conditions, misalignments or occasional ingestion of contaminants.

- **Compressive strength** – the bearing's ability to support load without yielding or creep
- **Fatigue strength** – the bearing's ability to support cyclic loading
- **Corrosion resistance**
- **Wear resistance**

BALANCING MATERIAL AND DESIGN

While material selection is important to bearing performance, it cannot be separated from the mechanical design. The geometry of the bearing, the viscosity of the lubrication, and the manufacturing tolerance will all play a part. In addition, temperatures and loads must be considered over the whole operating duty cycle.

BABBITT

Tin-based babbitt, also referred to as whitemetal, has long been a standard for oil-lubricated fluid film bearings. Babbitt is a soft metal that exhibits excellent conformability, compatibility and embedability, allowing the bearing to bear the brunt of potential damage instead of the more expensive shaft. For example, babbitt can absorb small amounts of debris and prevent scoring of the shaft; it is considered a forgiving and rugged material.

The babbitt typically used by Waukesha Bearings is ASTM B-23 Grade 2, made up mostly of tin, antimony and copper. A babbitt bearing is more accurately babbitt-lined, with steel or copper-chrome (CuCr) backing. Due to CuCr's high thermal conductivity, CuCr-backed babbitt runs cooler and experiences less thermal distortion than steel-backed babbitt, thus increasing the bearing's load capacity.

Typical industry practice is to limit the maximum operating temperature of babbitt bearings to 130°C (266°F) because babbitt loses strength at elevated temperatures. Babbitt also has a relatively low fatigue strength compared to advanced materials. In extreme cases of dynamic loading, low fatigue strength can result in premature bearing damage.

Combination tilt pad bearing with copper-backed babbitt thrust pads and steel-backed babbitt journal pads.

BRONZE

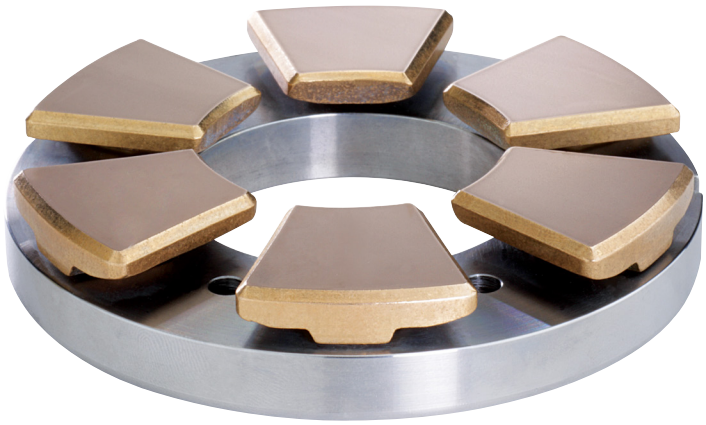
Where operating temperatures are above the limits of babbitt but loads remain relatively low, bronze bearing surfaces may be employed to provide additional safety margin. Successful operational experience of bronze bearings exists at lubricating oil temperatures beyond 150°C (302°F) and at loads below 2 megapascals (MPa) (290 pounds per square inch [psi]).

Because of bronze's relatively low embedability compared to babbitt, however, it provides very little acceptance of contamination in the lubricating oil, which can lead to bearing and shaft damage. In addition, bronze's conformability characteristics are inferior to those of babbitt, making bronze bearings more sensitive to misalignments.

ALUMINUM TIN

For oil-lubricated machines, aluminum-tin (AlSn) bearings may provide drop-in replacement for babbitt bearings to increase both temperature and load capability within the same envelope. Able to operate at temperatures up to 160°C (320°F), with a much higher fatigue strength than babbitt, AlSn bearings can handle loads up to 60% higher than babbitt bearings.

Being a metallic material like babbitt, AlSn allows existing protocols (thermo-sensors) to be used for monitoring bearing health. And, like babbitt, AlSn can be applied to either steel or CuCr backing – the former for copper-free applications, the latter to suit high speed, high load capacity designs. AlSn bearings can also increase safety margin in case of an unexpected upset condition such as accidental overload.



Bronze Deflection Pad® bearing. Bronze bearings can be monolithic cast or tilt pad designs, including Flexure Pivot® tilt pad bearings.

ENGINEERED POLYMERS

Backed by more than 30 years of materials development, engineered polymers have been proven in applications requiring high load capacity at operating temperatures of 200°C (392°F) and higher. Engineered polymers combine higher strength at elevated temperatures and higher fatigue strength than babbitt with embedability and conformability comparable to babbitt's.

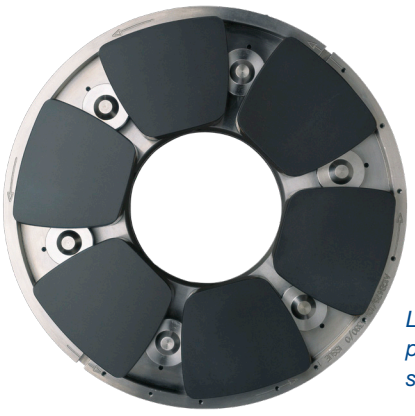
With oil lubrication, these characteristics give polymer bearings a higher load-carrying capacity than metallic bearings, which enables bearing size reduction and, therefore, a reduction in power loss. Polymers can also withstand high temperatures at shutdown without the need for continuous cooling oil.

Polymer-lined tilt pad journal bearing.

With clean low-viscosity lubricants (such as water), polymer bearing designs have proven to operate reliably on a relatively thin film and have good compatibility when running against a steel rotor.

Most of Waukesha's polymer fluid film bearings are tilt pad bearings with proprietary PEEK-blend pad linings on steel backing, although solid PEEK pads are also available for both thrust and journal bearings. Solid polymer is typically chosen for large quantity orders or for metallic-free applications.

Polymer bearings have the additional benefits of being less susceptible to chemical attack than babbitt and insulating against electrical currents. With the right material composition, polymer bearings can also better withstand film disruptions due to overload or temporary loss of lubrication, compared to babbitt-lined bearings.



Large polymer-lined tilt pad thrust bearing for subsea application.

CERAMICS AND CERMETS

Ceramic and cermet (ceramic-metallic composite) materials further extend the load and temperature capabilities of bearings, retaining high strength at temperatures of 300°C (572°F) and higher.

Given their superior strength and hardness, as well as their thermal conductivity, ceramic/cermet materials are frequently used in process lubrication where films are very thin and/or contamination of the lubricant is possible. Like polymers, ceramics can operate on thin films, but while polymers embed debris that enters the lubricant, ceramic/cermet materials grind it down.

For these bearings to operate reliably under any conditions, however, the mating surface must be made of equally hard material and must be carefully selected for good compatibility. The reliable operation of these pairings is typically validated first by in-house testing, then by field trials.

Ceramic journal and thrust bearings for a water injection pump. Ceramic materials are used for tilt pad as well as fixed profile bearings.

Hidrax™ HT cermet tilt pad thrust bearing for electric submersible pump.

POLYCRYSTALLINE DIAMOND (PCD)

Diamond surfaces are a super-hard bearing material that can provide reliable operation in multiphase fluid or with relatively large amount of abrasives in the lubricant. The superior wear resistance of man-made polycrystalline diamond (PCD) surfaces, which is thicker than diamond coating, is complemented by high thermal conductivity, a low coefficient of friction, and high hardness and fracture toughness.

With a tilt pad thrust bearing design, PCD bearings can provide superior bearing performance and extended life in equipment operating at high loads and speeds in low-viscosity lubricants, abrasive fluids or corrosive chemicals. Because PCD bearings can use the process fluid as a lubricant, they can potentially eliminate the need for shaft end seals and lubricating systems in certain applications.

PCD tilt pad thrust bearing and collar. As with ceramic bearings, PCD bearings must be paired with an equally hard mating surface.

COMPARISON OF FLUID FILM BEARING MATERIALS' TYPICAL CHARACTERISTICS

MATERIAL	TYPICAL MAX TEMPERATURE	LOAD CAPACITY	EMBEDABILITY	CONFORMABILITY	LOW VISCOSITY LUBRICANT	ABRASIVES IN LUBRICANT
Babbitt (tin-based)	130°C (266°F)	Low to Medium	High	High	No	No
Bronze	150°C (302°F)	Low	Low	Medium	No	No
Aluminum Tin	160°C (320°F)	Medium	Medium	Medium	No	No
Polymer	200°C (392°F)	High	High	High	Yes	No
Ceramic/Cermet	300°C (572°F)	High	Very Low	Low	Yes	Yes
Polycrystalline Diamond (PCD)	200°C (392°F)	Very High	Very Low	Low	Yes	Yes

ABOUT THE AUTHORS

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