Basics of sliding metallic-bearing materials — Part 2

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This is the second of a series on principles and characteristics of metallic plain bearing materials and how to optimize them in given uses. Part 1 appeared in June 1994, p. 36.*

We continue the discussion of bearing-material properties, covering some of the more important relationships among bearing-material properties and wear-damage mechanisms.

Compatibility. This is an antiseizure and antiscore characteristic. It relates mostly to the ease with which the bearing material surface can adhere or weld to a steel or iron journal surface with pressure and heat and no lubricant or other interfering surface film. Potential for scoring and seizure exists in all boundary and thin-film lubrication conditions.

There are only seven commercially significant elemental metals of good compatibility with ferrous journal surfaces: silver (Ag), cadmium (Cd), indium (In), tin (Sn), antimony (Sb), lead (Pb), and

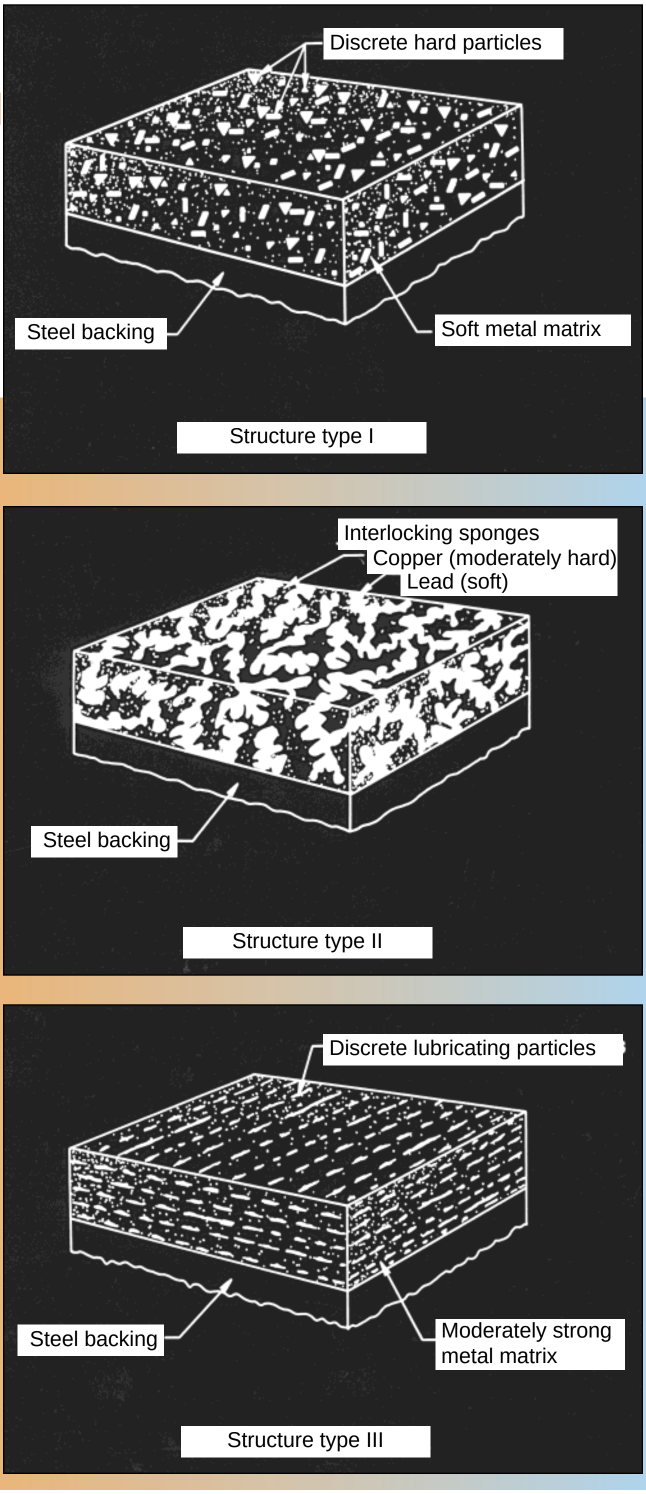

Figure 2 — Bearing alloy microstructural types schematically. Type I: discrete hard particles dispersed in soft matrix. Type II: interlocked soft phase and hard phase constituents. Type III: discrete soft particles dispersed in hard matrix. Courtesy, Glacier Vandervell Inc.

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*Material in this series is condensed from the chapter "Friction and Wear of Sliding Bearing Materials," by George R. Kingsbury, *ASM HANDBOOK, Friction, Lubrication and Wear Technology*, ASM International, Materials Park, Ohio, 1992, pages 741-757. For ordering information about the entire book, contact ASM International, Materials Park, OH 44073-0002, ph. (216)-338-4634.

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bismuth (Bi). Tin and lead show the most attractive combinations of cost, availability, and engineering properties. Both are used widely in bearing alloys because of their contributions to compatibility, either as the alloy base as in lead and tin babbitts, or as major alloy constituents as in leaded bronzes and aluminum-tin (Al-Sn) alloys.

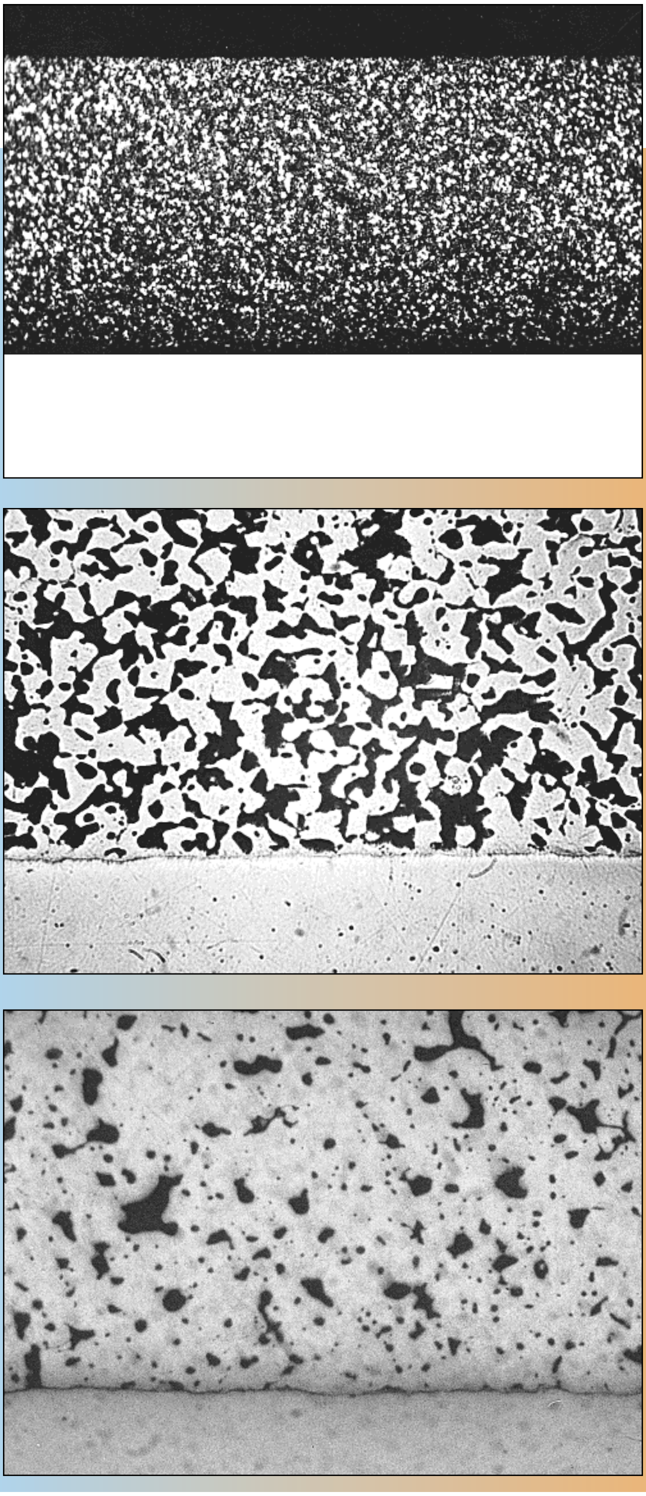


Figure 3 — Real bearing alloy microstructures. Type I: lead-base babbitt. Dark phase — Pb, light phase — Sb. Type II: copper-lead. Dark phase — Pb, light phase — Cu. Type III: medium-lead tin bronze. Dark phase — Pb, light phase Cu-Sn. Original magnification 100×. Courtesy, Glacier Vandervell Inc.

Many nonmetals also show useful compatibility with steel. They include synthetic resins, carbon, cemented carbides, intermetallic compounds, and ceramics.

Conformability & embeddability vs. hardness & fatigue strength. Conformability and embeddability depend on yielding and plastic flow of the loaded bearing material. Therefore, soft, weak, low-modulus metals such as tin and lead have the best of these characteristics. However, harder, stronger, higher-modulus metals such as copper (Cu) and aluminum have high fatigue strength. You can get useful compromises among these sets of opposed properties by alloying to produce polyphase structures with intermediate properties. Also, you can get such compromises with layered constructions where at least one harder, stronger backing layer reinforces softer and weaker surface layers.

Bearing material microstructures. All commercially significant bearing metals except silver are polyphase alloys. Three basic microstructural types are:

- Type I — Soft Matrix with Discrete Hard Particles, Figures 2 and 3. Lead and tin babbitts are of this type. These alloys have lower compatibility, conformability, and embeddability than unalloyed lead or tin — hard intermetallic and metalloid particles are present, effectively increasing bulk-strength properties.
- Type II — Interlocked Soft and Hard Continuous Phases, Figures 2 and 3. Many copper-lead and leaded bronze alloys are of this type. Structures consist of continuous, mutually supporting copper and lead sponges. A large volume of lead helps compatibility. Conformability, embeddability, hardness, and strength are intermediate between those of lead and those of copper.
- Type III — Strong Matrix with Discrete Soft-Phase Pockets, Figures 2 and 3. Low-lead bronzes and some aluminum-tin alloys are of this type. Structures consist of a continuous copper-base or aluminum-base metallic matrix that contains discrete pools or pockets of lead or tin.

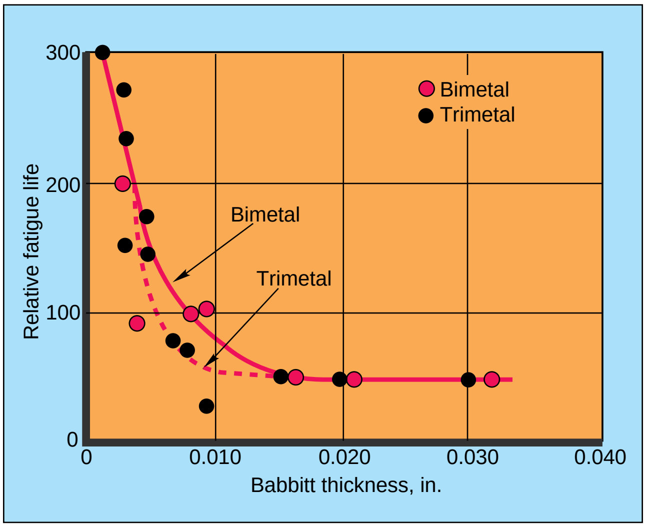


Figure 4 — Variation of bearing life with thickness of lead alloy layer. Bearing load: 2,000 psi. Courtesy, Glacier Vandervell Inc.

The strength of the matrix phase dictates conformability, embeddability, strength, and hardness. The soft metal phase exposed at the bearing surface enhances compatibility.

Alloys containing silicon (Si), such as aluminum-silicon-tin and aluminum-silicon-lead alloys are examples of mixed microstructures that combine Type I and Type III characteristics. Here, the aluminum matrix contains dispersed hard particles (silicon) and soft-phase (lead or tin) particles.

Bearing material design gained much with the recognition that effective load capacities and fatigue strengths of lead and tin alloys increase sharply when the alloys serve as thin layers intimately bonded to strong bearing backs of bronze or steel. Figure 4 shows the value of this principle in two-layer constructions like that of Figure 5 using a surface layer of lead or tin alloy, usually no more than 0.005 in. thick. Such a layer provides unimpaired compatibility, together with good conformability and embeddability. You can get other useful compromises between surface and bulk properties with an intermediate copper or aluminum alloy layer between the surface alloy layer and a steel back. In these three-layer constructions, surface layer thickness as low as 0.0005 in. offers even more favorable surface-and-bulk property compromises than you can get with two-layer construction.

Corrosion resistance. Bearing failure due to corrosion alone is rare. Corrosion usually interacts with mechanical and thermal factors to cause failure by fatigue or seizure in conditions the bearing could normally tolerate. You can avoid most bearing corrosion with oxidation inhibitors in commercial lubricating oils, and by periodic oil change. However, in some situations neither of these is dependable. There, use materials with inherently high corrosion resistance.

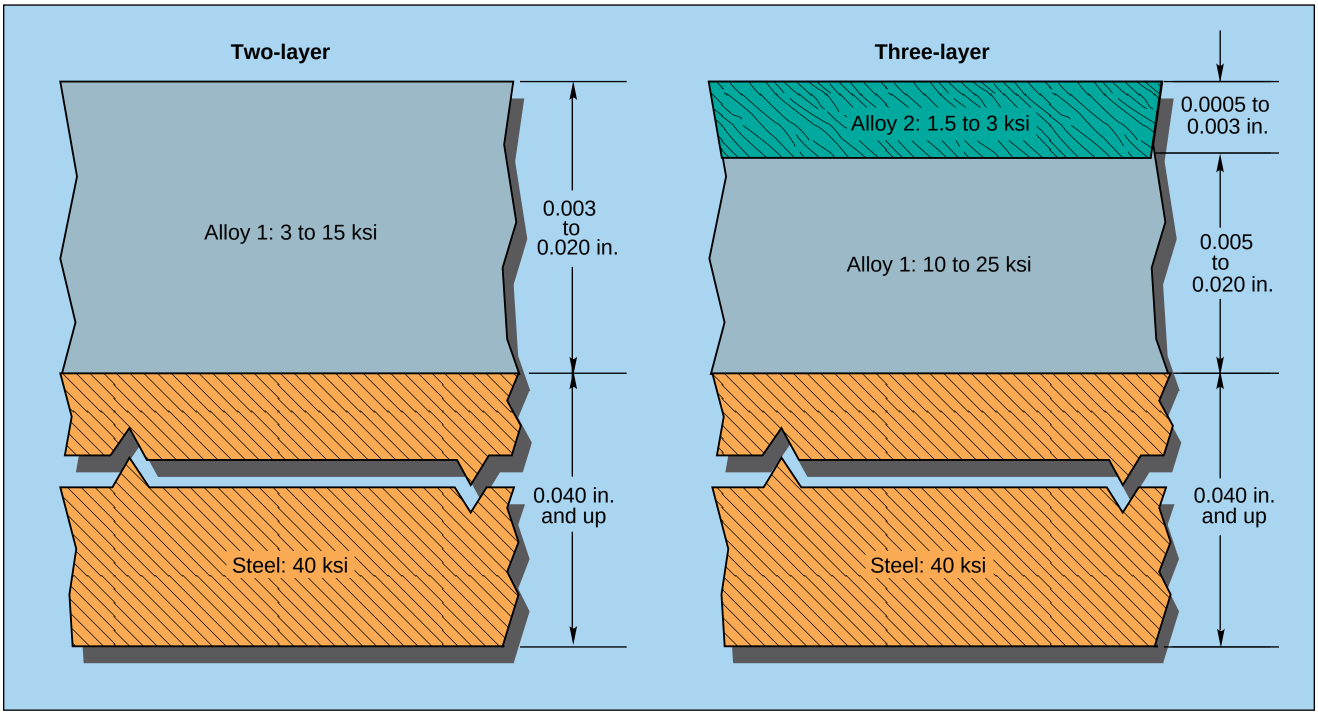
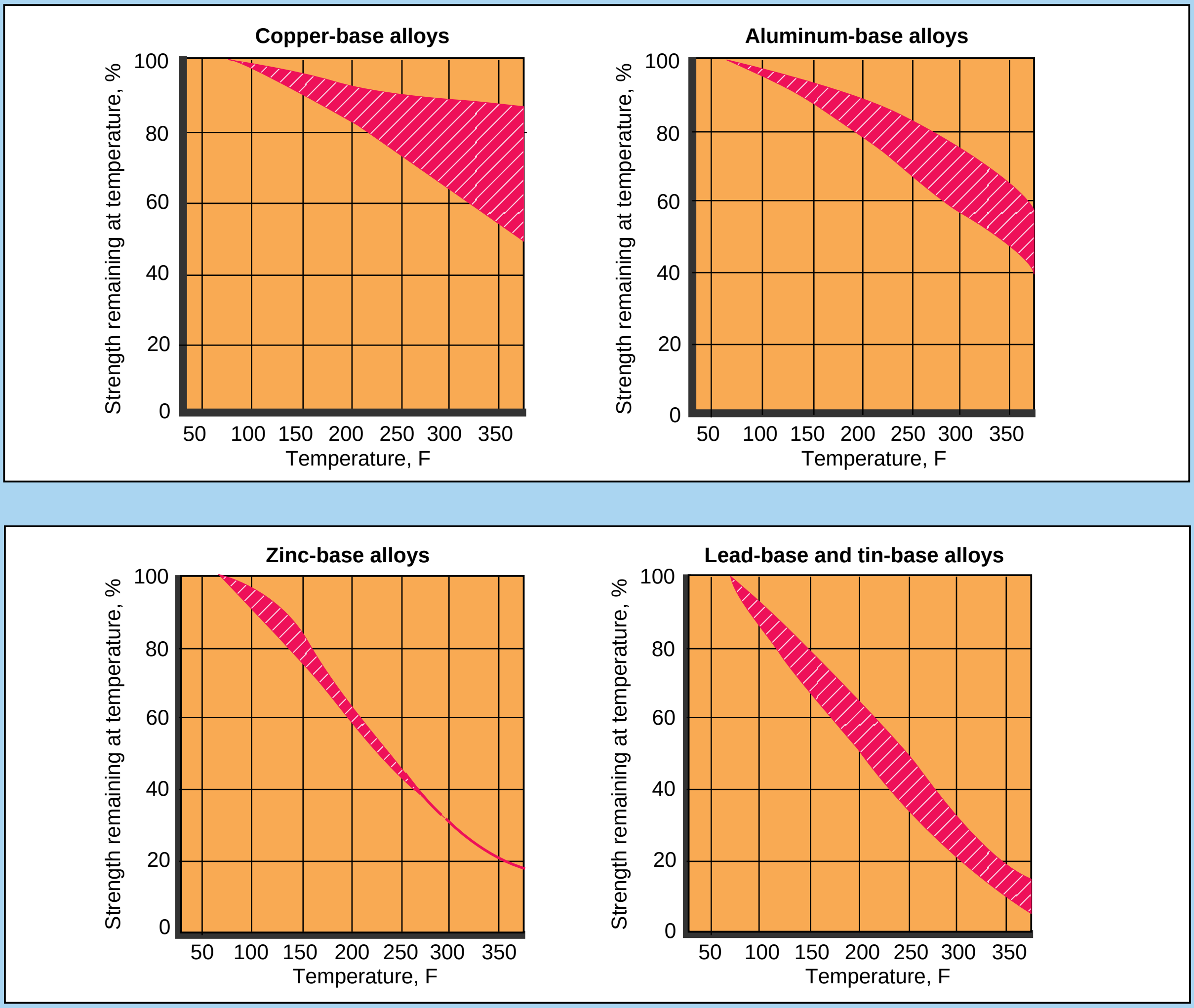


Figure 5 — Graduated strength in two-layer and three-layer bearing material constructions. Strength values are approximate compressive yield strength levels.



Commercially pure lead is susceptible to corrosion by fatty acids. Lead-base and copper-lead bearing alloys can corrode severely in acidic lubricating oils. Tin additions to lead above about 5% protect effectively against this kind of corrosion. Thus, tin is used extensively in lead-base bearing alloys. Acidic oils that contain sulfur attack copper and lead. This is of special concern with copper-lead and leaded bronze bearing alloys. A surface layer of a lead alloy containing tin, or a tin alloy, can provide effective protection. As long as the corrosion-resistant surface layer is intact, corrosion can't damage the underlying copper-lead alloy.

Tin and aluminum bearing alloys are substantially impervious to corrosion by oil-oxidation products. They are used extensively where the potential for lubricating-oil corrosion is high. Although lubricating-oil oxidation and contamination are the most common causes of bearing corrosion, there are others. They include seawater, animal and vegetable oils, and corrosive gases.

Figure 6 — Strength retention in bearing alloys at elevated temperatures for copper-base alloys, aluminum-base alloys, zinc-base alloys, and lead-base and tin-base alloys.

When you select and specify a bearing material for a given application, consider the anticipated service conditions and the corrosion potentials these conditions may involve.

Thermal effects. When selecting a bearing material, it is important to consider the reduced mechanical strength of bearing liner materials at high temperature. Fatigue strength, compressive yield strength, and hardness decrease significantly with increasing temperature. The softening curves in Figure 6 show lead and tin-base bearing alloys are most severely limited; copper alloys, least.

Load capacity. For a bearing material, load capacity is the maximum unit pressure at which the material can operate without excessive friction or wear damage. Capacity ratings published for designer guidance are usually upper limits, which may be safely used only with very good lubricant-film integrity, counterface finish, mechanical alignment, and temperature control.

In cyclic load service (such as in crankshaft bearings), fatigue strength is the primary limit to load capacity. For steady loads, capacity depends more on compressive yield strength, reflected in indentation hardness. In all situations, material strength at operating temperature governs. Thus, successful operation of sliding bearings depends on temperature and its control.

You may find load-capacity ratings useful as references, but you must recognize them as imprecise and somewhat judgmental approximations. They are not guaranteed or directly measurable. ■