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Short communication

# A study on tribological behaviour of tin-based bearing material in dry sliding

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**Abstract**

In this study, we investigated the tribological behaviour of two different tin-based bearing materials in dry sliding conditions. One of these alloys with low Sb content (7%) is known as SAE 12 and is widely used in the automotive industry and the other with high Sb content (20%) is a Sn–Sb–Cu alloy. Wear and friction characteristics were determined with respect to sliding distance, sliding speed and bearing load, using a Tecquipment HFN type 5 journal bearing test equipment. Hardness measurements were carried out to determine the effect of the increase in Sb content and its impact on tribological properties. Light microscopy is used to understand the tribological events in these two different bearing materials.

Thus, the purpose of this study is to investigate the tribological properties of tin-based bearing alloys with different compositions, used especially in heavy industrial service conditions. Tests were carried out in dry sliding conditions, since despite the presence of lubricant film, under heavy service conditions dry sliding may occur from time to time, causing local wear. As a result of local wear, bearing materials and bearing may be out of their tolerance limits in their early life time.


*Keywords:* Tin-based materials; Tribology; Dry sliding

## 1. Introduction

Many materials have been tried as bearing components. In 1839, Babbitt patented a Sn–Sb–Cu alloy for use in journal bearings. White metal is now widely used as a material for sliding bearings operating under oil lubrication, for example, bearing for general industrial use, marine use and automotive use. One of the most heavy duty applications of thrust bearings is in hydroelectric power stations for support of the shaft, carrying hydraulic turbine and electric generator. White metal can be fundamentally classified into two types. One has lead as its main component, the other tin. A bearing works in a stabilised manner when a proper film thickness is formed and maintained between shaft and bearing. However, under unacceptably high loads and shaft revolution speeds, or improper lubricating conditions, a bearing is often damaged when a sufficient thickness of the oil film is not formed between shaft and bearing. Under these conditions, shaft and white metal make partial contact with each other during the sliding wear process. This condition is called boundary lubrication [1–4].

Lead and tin white metal alloys are commonly the first choice for bearing materials in offering superior compatibility with steel shafts, their ability (due to their softness) to embed foreign particles, and their unique ability to adapt to misalignment by mild wiping on initial run-in as enabled by their low melting points. Table 1 covers representative physical properties of typical Babbitt compositions [2].

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Table 1
Physical properties of babbitte alloys (tin-based white metals)

| | Tin-base | | |
|---|---|---|---|
| *Designation* | | | |
| ASTM B23 | – | 2 | 3 |
| SAE | 11 | 12 | – |
| *Nominal composition* (%) | | | |
| Tin | 87 | 89 | 84 |
| Lead | | | |
| Antimony | 7 | 7.5 | 8 |
| Copper | 6 | 3.5 | 8 |
| Arsenic | | | |
| Specific gravity | 7.4 | 7.39 | 7.45 |
| Melting point (°C) | 240 | 241 | 240 |
| Complete liquefaction (°C) | 400 | 354 | 422 |
| *Brinell hardness* | 26 | 24 | 27 |
| Ultimate tensile strength (MPa) | 90 | 77 | – |
| Compressive yield strength (MPa) | 45 | 42 | – |
| *Approximate strength retained at* | | | |
| 100 °C | 49 | 52 | 52 |
| 150 °C | 23 | 24 | 24 |
| 200 °C | 5 | 7 | 7 |

Despite their higher cost, tin babbitts are often used in preference to lead babbitts for their excellent corrosion resistance, easy bonding, and less tendency towards segregation. SAE 12 (ASTM Grade 2) is widely used in industrial and automotive bearings. SAE 11 and ASTM Grade 3 also find extensive industrial use [2–5]. Table 2 shows the characteristics of widely used bearing materials [5].

The babbitts are among the most widely used materials for hydrodynamically lubricated bearings. Babbitts are either tin or lead-based alloys having excellent embeddability and conformability characteristics. They are unsurpassed in compatibility and thus prevent shaft scoring [6–9].

Tin Babbitt alloys commonly contain about 3–8% copper and 5–8% antimony. Within a soft solution matrix antimony in tin, small, hard $Cu_6Sn_5$ copper–tin intermetallic particles are dispersed. Increasing copper increases the proportion of $Cu_6Sn_5$ needles or stars in the microstructure. An increase in antimony above 7.5% results in antimony–tin cubes. Hardness and tensile strength increase with greater copper and antimony content, while ductility decreases. Low antimony (3–7%) and low copper content (2–4%) provide maximum resistance to fatigue cracking. Since these low-alloy compositions are relatively soft and weak, a compromise is often made with fatigue resistance and compressive strength [1,2].

Table 2
Characteristics of widely used bearing materials

| Physical property | Significance of property in service | Characteristics of widely used materials | | |
|---|---|---|---|---|
| | | White metals | Copper-base alloys | Aluminium-base alloys |
| Fatigue strength | To sustain imposed dynamic loadings at operating temperature | Adequate for many applications, but falls rapidly with rise of temperature | Wide range of strength available by selection of composition | Similar to copper-base alloys by appropriate selection of composition |
| Compressive strength | To support uni-directional loading without extrusion or dimensional change | As above | As above | As above |
| Embeddability | To tolerate and embed foreign matter in lubricant, so minimising journal wear | Excellent-unequalled by any other bearing materials | Inferior to white metals. Softer weaker alloys with low melting point constituent, e.g., lead; superior to harder stronger alloys in this category. These properties can be enhanced by provision of overlay, e.g., lead–tin or lead–indium, on bearing surface where appropriate | Inferior to white metals. Alloys with high content of low melting point constituent, e.g., tin or cadmium; superior in these properties to copper-base alloys of equivalent strength. Overlays may be provided in appropriate cases to enhance these properties |
| Conformability | To tolerate some misalignment or journal deflection under load | | | |
| Compatibility | To tolerate momentary boundary lubrication or metal-to-metal contact without seizure | | | |
| Corrosion resistance | To resist attack by acidic oil oxidation products or water or coolant in lubricant | Tin-base white metals excellent in the absence of sea water. Lead-base white metals attacked by acidic products | Lead constituent, if present, susceptible to attack. Resistance enhanced by lead–tin or lead–tin–copper overlay | Good. No evidence of attack of aluminium-rich matrix even by alkaline high-additive oils |