Scope of aluminium base bearing alloys

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BEARING materials are special type of materials which carry a moving or rotating component with the least friction or wear. One of the principle difficulties in developing a good bearing material is that two practically conflicting requirements are to be satisfied by a good bearing material. The material must be soft with extremely low shear strength as well as it must be strong enough to support heavy dynamic loads. This is generally achieved either by having a bearing material with a metallurgical structure inherently incorporating both hard and soft constituents; the soft, low melting constituent helping easy running of the moving parts and the hard constituent bearing load, alternatively these might be a strong metal coated with a very thin overlay of soft metal.

In a very large number of general engineering practices where lubricating conditions are relatively poor and service conditions are not very exacting, thick solid bearings are used with a duplex structure. The type of bearing depends on the load, speed and other working conditions in which it is to be used.

Practically in all cases a plain bearing material is a non-ferrous alloy or a mixture. With the development of Reave engineering industries, the amount of bearing metal requirement is increasing at a very fast rate. Until very recently, most common type of 'bushing' and bearing material has been either bronzes, copper and lead mixture and lead or tin base white metals. As such, bearing industries consume large quantities of copper, lead, zinc, tin, indium, silver, etc. Apart from the cost factor of these materials these are not available or produced in India at all or produced in negligibly small quantities and consequently can be termed rare in relation to present day requirement of the industries.

These considerations lead the metallurgists to search for alternative bearing materials with special attention to metals which are more easily available both at the time of emergency and in normal times. Naturally attention was given to aluminium base alloys and from as early as 1936 extensive research has been carried out in various countries for development of aluminium base bearing alloys.

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Work done in other countries

In attempting to develop aluminium base bearing alloys three approaches were followed.

The German work contributed towards the development of aluminium copper alloys and complex aluminium alloys containing lead-antimony, copper, manganese and iron. Most of these developments were for solid (unbacked) type of bearing, containing little or no low melting point constituent.

The development in the United States and Great Britain was to produce alloys strong enough to serve as unbacked bearing but containing a proportion of low melting point constituent to improve its bearing properties. Continued research showed that addition of tin to aluminium up to 25% progressively improved the scuffing resistance of aluminium-tin alloys but its strength properties deteriorated when the tin exceeded 10%. It was also found that elements forming a hard constituent improved wear properties and seizure resistance.

The third approach was to bond a thin layer of the aluminium alloy to a thicker steel backing so that the dimensional behaviour of the composite would be largely determined by that of steel. Such procedure incidentally, was found to overcome the difficulty arising from differential expansion of aluminium alloy bearings—an inherent drawback of aluminium base bearing.

An analysis of behaviour of various alloying elements in aluminium in relation to their influence on bearing properties shows that elements such as tin, cadmium, lead, bismuth and indium provide low melting constituent and thereby improve antiscouring properties of aluminium. On the other hand elements such as nickel, silicon, iron and manganese on alloying with aluminium produce new phases of greater hardness thereby improving wear and seizure resistance. When aluminium alloy bearing is to be used as solid bearing, a strengthening of the aluminium base is needed to prevent objectionable deformation under high bearing loads. The increased resistance is attended by additional elements which strengthen the aluminium matrix through solid solution or precipitation hardening. Copper, magnesium, zinc, or silver produce these effects.

The above considerations indicate in general the line in which the development of aluminium base solid or over-lay bearing has taken place and has also scope for future developmental work.

Any work on development of bearing mrterial has to be based on the knowledge of the conditions a bearing material will be called to fulfil. The most important requirements are that a bearing-shaft combination is to run with minimum wear and friction and has the least mechanical damages arising thereform. In general, these are satisfied when a number of complex combination of strength properties, running properties and corrosion properties are satisfied. The strength properties in case of bearing is characterised by Young's modulus, yield stress in compression, mainly by the operating temperature and resistance to fatigue failure. Of the running properties most important are ability to resist seizure and wear of itself and the opposing member in case of accidental failure of the lubricant film. Further, the bearing material should have the ability to withstand the chemical action of the oil for a prolonged period. If a bearing material satisfy these conditions, it has a good chance of being a satisfactory bearing material, which, then should be confirmed through a large series of mechanical and physical tests as well as service test.

Experimental work

(i) Soft overlay bearing

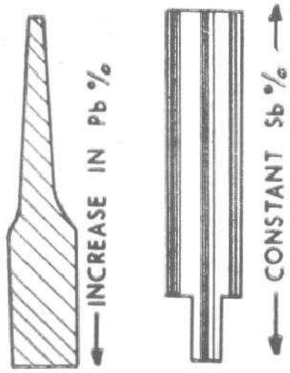
These considerations lead attention to extensive study at the NML on the behaviour of aluminium base bearing with minimum amount of scare and non-indegenous alloying elements. A number of experimental alloys with additions of alloying elements like Cu, Zn, Pb, Sb, Si and small percentages of tin in a few uses were prepared. Preliminary tests revealed that for plain overlay bearing alloy, aluminium base bearing metal with small amounts of Pb and Sb and in some cases on tin as well has got good possibility. Whereas for bushing type of solved bearing aluminium alloy with some zinc and small amount of other alloying elements like Cu, Si, Mg offer good scope.

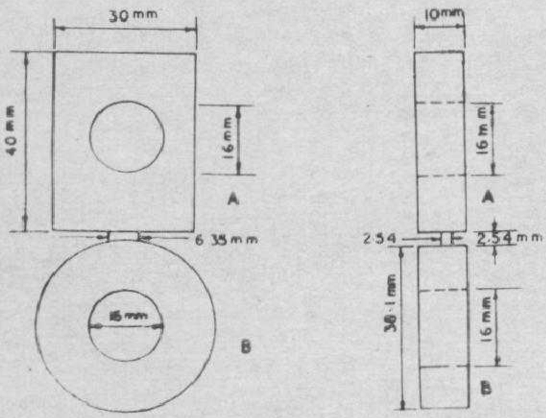
After preliminary work on suitable alloying systems, more experimental heats were made of aluminium-lead-antimony group and aluminium-lead-antimony-copper group for bearing overlay applications. Variations of alloying elements from heat to heat are shown qualitatively in column 2 of Table I. Some of the mechanical properties are also given in Tables I and II.

As referred to earlier, antifriction characteristics are the most important characteristics of bearing metals. As there is no standard test for antifriction properties, the following tests were carried out to determine antifriction properties of the alloys.

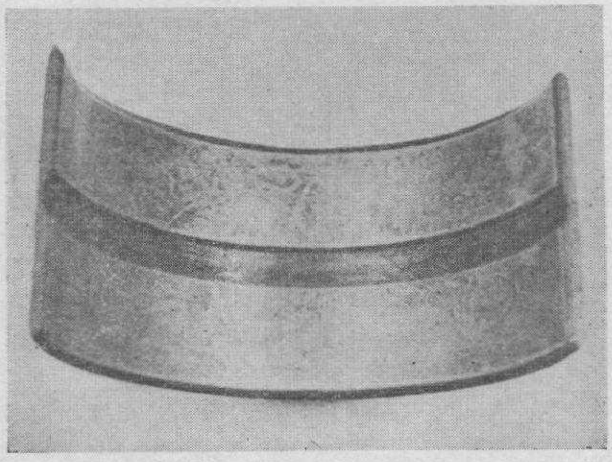
Specimens were prepared from the bearing metal as shown in Fig. 1. The melting disk B $1\frac{1}{2}''$ in diameter representing the shaft was made of steel with a standard hardness of 200 HV. The mating area of the bearing specimen A with B were made small $0{\cdot}25''$, only so that with the available Amsler Wear and Friction testing machine high load up to about 15000 pounds per square

TABLE I Properties of Al-Pb-Sb bearing allops

		Mechanical properties				
Heat No.	Nominal chemical composition Al with varying Pb and Sb per cent (Total Pb–Sb 10%)	Young's modulus $\times 10^6$ lb/sq. in	Ultimate tensile strength T. S. I.	Elongation per cent	Hardness in BHN	Coefficient friction under lubrication
AB2		6·5	7	23	23·5	0·018
AB24		6·7	4·7	12·5	25	0·021–0·025
AB26		—	5	31	24·2	0·018–0·020
AB32		—	5	—	23	0·018
AB33		6·9	5	18·5	27	0·021
AB29		6·7	8·4	12·5	26·5	0·02
White metal (Tin Base)		7·9	—	12·5	24	0·022



1 *Frictions and antiseizing test piece*



2 *Steel backed sleeve bearing with roll clad experimental aluminium alloy*

inch could be applied between A and B. The speed of rotation of the specimen bares 200 per minute. A fixed load was applied between the specimens. During running system was kept under constant lubrication with a suitable lubricating oil. The system was allowed to run several hours under low load so that the matching of the wearing surfaces wear perfect.

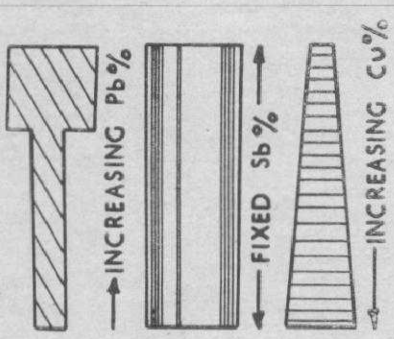
After the initial wear-in period the co-efficient of friction under steady condition was measured at different fixed loads from the reading of the torque dynamometer. The experiment was repeated with a standard white metal bearing. These are recorded in the last column of Tables I and II.

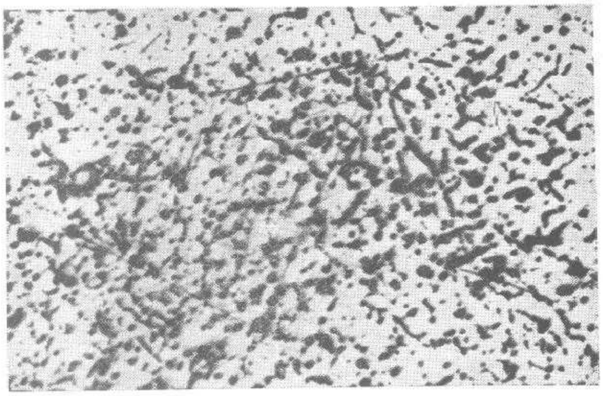
Solid bearing

The characteristics of solid bearing are quite different from that of bearing overlays. By virture of the fact that solid bearings themselves support load, these should be harder. Further such bearings are generally used where either the load is less or the rotation speed is less, that is, in non-critical application. Keeping these in view, it seemed reasonable that the type of overlay bearing alloys which proved to have good frictional characteristics, if strengthened through additions of other alloying elements may be useful to replace solid bearings for diverse applications.

After initial experiments a series of heats was made with addition of zinc and in some case, magnesium, copper. The nominal compositions of a few are given in the Table III below together with some of the mechanical properties and wear and frictional characte-

TABLE II Properties of Al-Pb-Sb-Cu bearing alloys

Heat No.	Nominal chemical composition Al with small percentage of Pb, Sb, Cu singly or jointly (Total of Pb, Sb, Cu 10%)	Mechanical properties: Young's modulus $\times 10^6$ lb/sq. in	Ultimate tensile strength T. S. I.	Elongation per cent	Hardness in BHN	Coefficient of friction under lubrication
AB25		—	6·85	10·23	37	0·023
AB4		7·5	10·1	6·25	43	0·023
AB27		8	10	11	40	0·018
AB30		7·5	—	—	38	0·020
AB23		—	—	—	50	0·042



3 *Microstructure of aluminium base over-lay ; Clad bearing alloy AB41* *×150*

ristics. Comparative values for wear and frictional torque for long period service for some conventional bushing like leaded bronze, phosphor bronze, are also included in the Table IV.

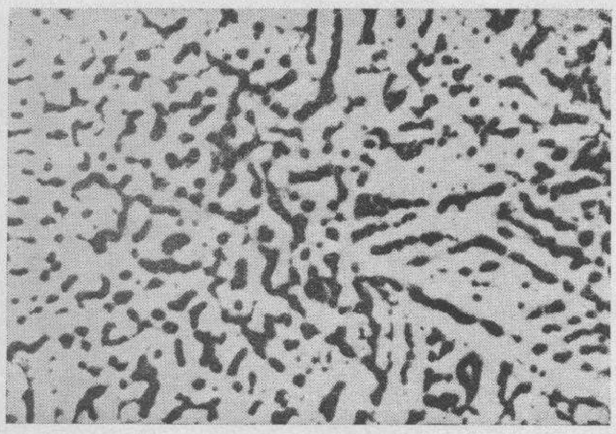
Discussions

Bearing metals are in general characterised by a special type of micro-structure called duplex structure. Though the conventional hypothesis of a hard phase distributed in the matrix of a soft phase or the reverse as a criterion for good bearing material is considered not as correct, basically a good bearing metal does have such structure or such a structure might potentially have good bearing properties. Further, it is known that most convenient method of joining an aluminium base bearing overlay to steel backing is roll cladding process. Aluminium base bearing metal may be amenable to withstand deformation necessary for roll cladding if its microstructure is such as the grains are not completely or nearly completely enveloped by a second phase; as such a microstructure is likely to develop cracks during heavy deformations. Microstructures of some of the bearing metals detailed in Tables I and II are shown in figures. It will be seen that the basic requirement of the suitable type of microstructure for aluminium base bearing overlays are satisfied in most of the cases (Fig. 3). The Young's modulus values shown in the Tables are low and comparable to those of babbit and other conventional overlay bearing alloys. Low Young's modulus value satisfy another important requirement of bearing metal known as conformability, by which it is meant, the ability of the bearing alloy get deformed elastically out of the way of the shaft when there is impact load, so as to have a cushioning effect.

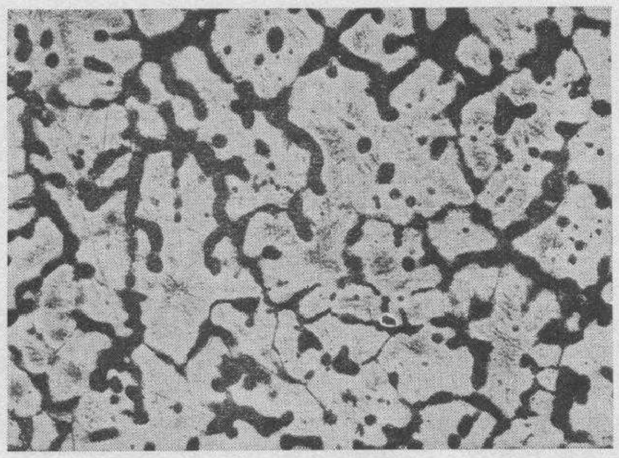
The hardness values are also comparable. Friction measurement under lubricated condition was carried under gradually increased loadings. All of the reported compositions recorded very little change in the coefficient of friction up to a load of 3 000 lb per square inch. After 3 000 lb some of the material started deforming plastically. This however, does not point to any drawback of the experimental alloys as these bearing metals are meant to be suitable for overlays applications in actual use some hard backing like steel is to be used. Under such conditions the load carrying capacity of the bearing is known to improve to a considerable extent. In order to find out whether the material can stand plastic deformation necessary for cladding, forging and rolling experiments were carried out. It was found that in most of the above cases the materials were amenable to deformation Finally tests were carried out by actual cladding of the material to steel strip. Fig. 2 shows the clad bearing alloy in shape of a sleeve bearing.

TABLE III Properties of solid bearing alloys

Heat No.	Nominal chemical composition major Al and zinc with small percentage of Pb, Mg, Cu, Sb	Mechanical properties			
		Ultimate tensile strength T. S. I.	Elongation %	Hardness in BHN	Coefficient of friction under lubrication
AB11		19·5	1·56	136	0·016
AB15		15·11	10	78	0·0247
AB19		21·44	3·12	104	0·03
AB3		25·7	1·56	136	0·04
Gun metal		—	—	74	0·06
Phosphor Bronze		—	—	75	0·09



4a Microstructure of aluminium base bushing type bearing alloy AB3 ×150



4b Microstructure of aluminium base bushing type bearing alloy AB19 ×150

Experiments on solid bearing were carried out with the group of alloys reported in Table III. The comparative tests were carried on some conventional bearings as well. The microstructures of the experimental alloys were found favourable (Figs. 4A and 4B). Other mechanical properties were also comparable. Coefficient of friction of the experimental alloys as well as the conventional alloys given in Table IV would show that the experimental alloys have better frictional properties under identical test conditions. A more revealing picture of the frictional behaviour of various alloys are given by the value of integrated frictional work done in 80 hours run. The experimental aluminium alloys were again much more favourably placed than conventional bushing alloys. The amount of wear in 80 hours run against a standard shaft for the new bearing alloys are much less than conventional solid bearing alloys.

TABLE IV Comparative wear test results of solid bearing alloys

Materials	Weight loss in 80 hours	Integral work done in kgm in 80 hours
Gun Metal (standard bearing)	0·0142 gm	110850
Leaded bronze (standard bearing)	0·0038 gm	106200
Phosphor bronze (standard bearing)	0·0252 gm	132300
AB3	0·0026 gm	57690

The work will be followed by more comprehensive trials of these experimental alloys both as overlay type as well as solid bushing type applications. However from the metallurgical structure as well as the result of all tests carried out uptil now, there is a strong evidence that the group of alloys under investigation has good scope of application as substitute plain bearing alloys both as overlay application as well as solid bearing application. The final test should have to be carried out by replacing conventional bearings in machines with non-critical service conditions at first and finally in machines with more demanding service conditions.

Acknowledgement

Authors' thanks are due to Dr B. R. Nijhawan, Director, National Metallurgical Laboratory, for his permission to publish this paper.

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