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M. F. MILLER ET AL

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ALUMINUM-LEAD BASED ALLOYS AND METHOD OF PREPARATION

Original Filed March 16, 1966

3 Sheets-Sheet 1

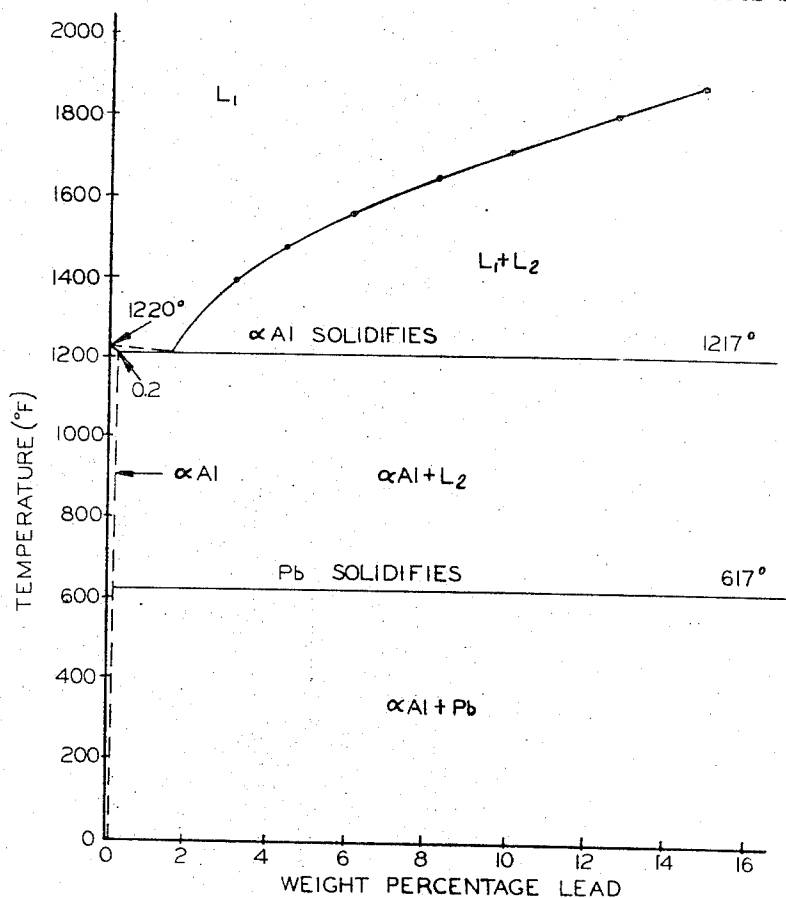


Fig. 1

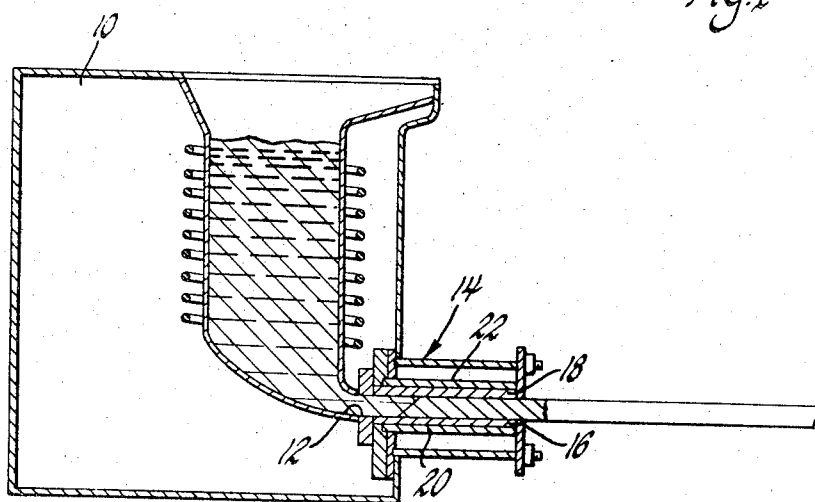


Fig. 2

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3 Sheets-Sheet 2

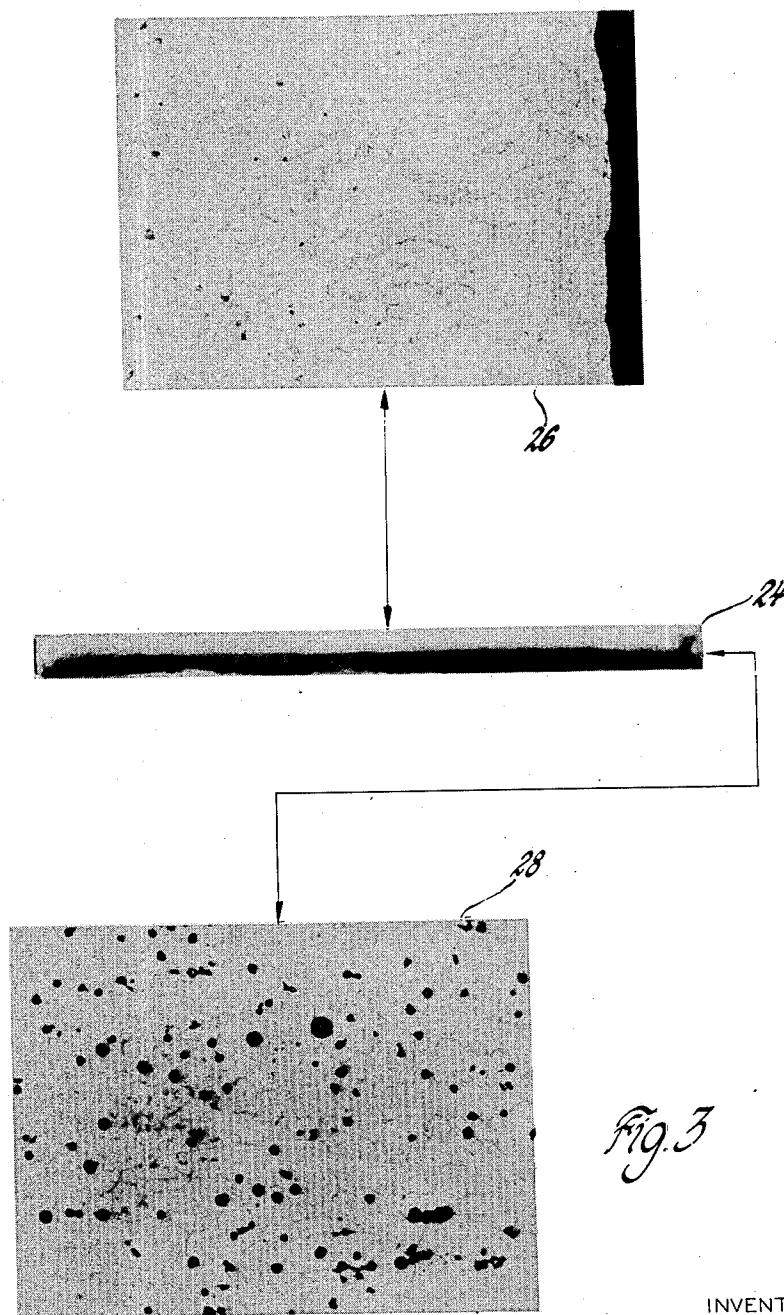


Fig. 3

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3 Sheets-Sheet 3

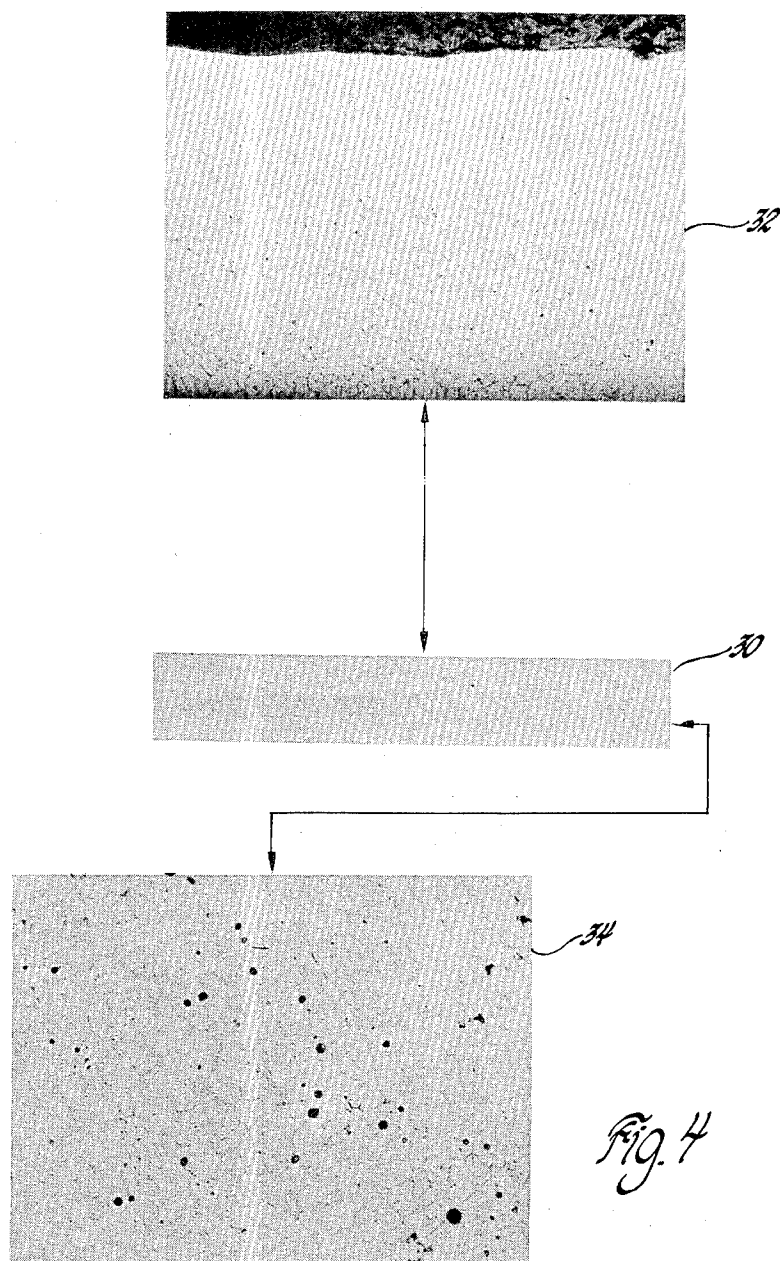


Fig. 4

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ALUMINUM-LEAD BASED ALLOYS AND METHOD OF PREPARATION

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Original application Mar. 16, 1966, Ser. No. 534,768, now
Patent No. 3,410,331, dated Nov. 12, 1968. Divided and
this application June 17, 1968, Ser. No. 737,520
Int. Cl. B32b 15/00; F16c 33/12; C22c 21/00
U.S. Cl. 29—191.2

4 Claims

ABSTRACT OF THE DISCLOSURE

An aluminum-lead based bearing alloy and a method of its preparation is disclosed. In a preferred embodiment a cast strip is formed comprising a major portion of aluminum, a minor portion of lead, and other suitable alloying constituents. The lead is present as fine discrete particles in the aluminum matrix and distributed therein such that the concentration of lead increases in a direction from one surface of the strip to the other.

This is a division of S.N. 534,768 filed Mar. 16, 1966, now U.S. Pat. No. 3,410,331, issued Nov. 12, 1968.

This invention relates to the preparation of aluminum-based bearing alloys. More particularly, it relates to a method of casting an aluminum-based bearing alloy containing lead, wherein the lead becomes dispersed as fine discrete particles in the aluminum phase of the cast article.

While many aluminum-based compositions are known to have suitable strength and fatigue resistance for use as bearing surfaces, some may not be utilized in direct contact with ferrous metal because of the tendency of aluminum to adhere to the ferrous metal thereby causing scoring or seizing. Aluminum alloys which are suitable for use as bearings in other respects may be plated with a thin layer of copper, lead and tin to improve score resistance. However, this plating step significantly increases the cost of the bearing and makes it less competitive with other bearing materials.

It is known that by combining a suitable amount of lead with aluminum the expensive overplating step may be eliminated in the preparation of a score-resistant bearing. However, the solubility of lead in aluminum is relatively low and it has proven difficult to obtain a satisfactory dispersion of lead in high-lead content aluminum alloys on a production basis. Moreover, it is common to bond the aluminum bearing material to a steel backing for many applications and the presence of lead in the aluminum adversely affects this bonding process. In other words, while an increase in the lead concentration improves the inherent bearing properties of an aluminum-based alloy, at the same time it causes processing difficulties. These difficulties have proved prohibitive to the use of high-lead content aluminum bearing alloys, at least within the capabilities of the prior art. As the various processes for the manufacture of bearing alloys and bearings are very competitive, a process which readily facilitates the use of high lead concentrations and thus permits the elimination of the old overplating step is extremely valuable.

It is an object of this invention to provide a cast article comprised of an aluminum-based alloy containing substantial amounts of lead present as a fine dispersion of discrete particles which are distributed throughout the aluminum-rich phase in a predetermined manner. It is a further object of this invention to provide a relatively thin cast strip of an aluminum-based bearing alloy

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wherein this aluminum casting contains a dispersion of fine discrete particles of lead. This cast strip is further characterized by a gradient in the lead concentration across its thickness, the concentration of lead increasing from a minimum value at one surface to a maximum value at or near the opposite surface.

Moreover, it is an object of this invention to provide a method of preparing such cast articles.

More specifically, it is an object of this invention to provide a process of preparing a homogeneous melt of aluminum, lead and other suitable alloying constituents and of cooling this melt while applying a net force such that upon solidification a casting is obtained in which the lead is dispersed as fine particles in a concentration gradient that increases from a minimum at one surface to a maximum at or near an opposite surface.

These and other objects and advantages are accomplished in accordance with our invention by heating and thoroughly mixing aluminum and other suitable alloying constituents, including lead, to obtain a complete, substantially homogeneous solution. It is important that during heating the molten bath be thoroughly mixed in a manner such that the molten lead is dissolved in the molten aluminum when a suitable temperature is reached. The molten solution is then poured into, or through, a mold and cooled therein at a rate such that the lead which precipitates from the molten aluminum is trapped in the solidifying aluminum in the form of a fine dispersion of discrete particles. While cooling, the molten mass is subjected to a suitable force, such as centrifugal force or gravitational force, that is operative to cause the precipitating lead to flow or migrate in the direction of such force whereupon a concentration gradient of the dispersed lead particles is obtained in the final casting.

Other objects and advantages will be apparent to one skilled in the art in view of the detailed description of our invention which follows. Throughout this description reference will be made to the drawings and photographs in which:

FIG. 1 is a portion of the aluminum-lead phase diagram up to about 16% by weight lead;

FIG. 2 is a schematic representation of an apparatus suitable for the continuous casting of our bearing alloy in accordance with one embodiment of our invention;

FIG. 3 is comprised of a radiograph and two photographs illustrating the dispersion of lead in an aluminum-based casting prepared in accordance with our invention;

FIG. 4 is similar to FIG. 3 except that it depicts the lead dispersion in a different casting of different composition.

A wide variety of lead containing aluminum-based alloys may be cast in accordance with our process. Aluminum-based compositions containing at least as high as 15% lead by weight may be prepared by our method. In general, however, average lead compositions of 10% by weight or less are suitable for good bearing performance. This is particularly true when other beneficial alloying constituents are included.

It is known that silicon can be added to somewhat reduce the amount of lead required to obtain a score-resistant surface. Up to about 5% to 6% silicon by weight advantageously may be added without adversely affecting the castability of the alloy. Cadmium is also useful in this respect, generally up to about 4% by weight. Tin, 0.1 to 5% by weight, frequently is added to aluminum-lead alloys to minimize lead corrosion. One tenth to five percent by weight of copper, silver, magnesium, manganese, nickel and/or chromium may suitably be added to strengthen and harden the aluminum-based alloy. The preferred structure for these bearing materials is a dispersion of fine particles of lead dis-

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tributed in a predetermined pattern throughout the aluminum-rich phase. Tin, if added, tends to remain in or migrate to the lead, thus providing corrosion resistance. Cadmium will also tend to concentrate in the lead. Although these aluminum-lead alloys would find particular utility in precision insert bearings where they would be bonded to a steel backing, it is to be recognized that the utility of our method is not limited to producing such products.

Aluminum alloys containing substantial amounts of lead are not readily prepared. The cause of the difficulty becomes apparent from a study of the phase diagram of FIG. 1 and a knowledge of the relative specific gravities of molten aluminum and lead. FIG. 1 was prepared from data published by L. W. Kempf and K. R. Van Horn in Trans. AIME, volume 133 (1939) pp. 81-94. As shown in FIG. 1 when the lead concentration in aluminum is increased above about 1½% by weight, it is not possible to form a single liquid phase at the fusion temperature of the alpha aluminum. This means that no matter how completely solid aluminum and lead may be mixed prior to melting, two liquid phases will be present at least until the liquids are heated to a temperature substantially above the melting point of aluminum. Since the density of lead is four times that of aluminum, there is a strong tendency for the molten lead and aluminum phases to completely separate before the two liquids can be heated to a temperature region of mutual solubility. It is difficult to overcome this tendency by mechanically stirring the liquids to obtain a complete solution, particularly when large amounts of material are used.

In accordance with our process, this material is preferably mixed in the molten state by subjecting it to an inductive electromagnetic field of a suitable frequency. This type of mixing has proved to be extremely useful in preventing premature separation of the molten lead and aluminum phases. Of course the melting and mixing could readily be accomplished simultaneously in an induction-type furnace. Under the influence of the high frequency alternating current, the two phases are completely and thoroughly mixed so that by heating to the temperature region of mutual solubility for a given composition, as indicated in FIG. 1, a complete solution is readily obtained. In our experience, the difference between alloy compositions obtained by melting by induction means and by melting by other means coupled with vigorous mechanical stirring is markedly significant. With induction heating and stirring the composition of the melt accurately reflects the quantities of starting materials charged. However, despite the most vigorous mechanical stirring coupled with convection heating, there is, frequently, a large variation in the lead content of the molten aluminum with respect to the quantity of lead initially charged. Normally this variation increases as the size of the melt increases. This factor heretofore has restricted the preparation of such alloys on a large scale basis.

The steps in the casting of the molten alloy by our process are critical in obtaining the desired cast product. The rate of cooling must be closely controlled to produce a casting in which the lead is dispersed as fine discrete particles in a manner such that the lead concentration increases steadily across the thickness of the casting from a minimum value at one surface to a maximum at or near the opposite surface. This concentration gradient is obtained by subjecting the metal to a force in the desired direction of the gradient at the same time the molten material is being cooled for solidification.

Again referring to FIG. 1, in the case of lead concentration greater than 1.52%, it can be seen that as molten metal L_1 is cooled below the temperature region of mutual solubility, molten lead L_2 will commence to separate from the aluminum-rich phase L_1 . As the temperature is further decreased more and more lead L_2 (it is

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believed that L_2 is substantially all lead) separates from L_1 . Thus, the lead content of L_1 is gradually depleted until a temperature of approximately 1217° F. is reached. At this temperature alpha aluminum solidifies and more L_2 is rejected. Because of the relatively large amount of aluminum this last quantity of molten lead is trapped as soon as it separates and cannot readily be shifted to a different portion of the solid mass. Thus, it is virtually impossible to obtain a lead concentration in any portion of a casting less than about 1½% when the overall lead concentration in the original melt was greater than this value. This is true despite the fact that alpha aluminum contains a maximum of about 0.2% lead in solid solution.

However, when a batch of this two-component system is in the temperature range at which L_1 and L_2 can co-exist, a force, such as a gravitational force or centrifugal force, may be used to redistribute the respective liquid phases in a predetermined manner until the alpha aluminum solidifies to retard further mobility of the molten lead L_2 . Thus, under the influence of such a force, the more dense lead phase L_2 tends to migrate in the direction of the force thereby displacing the less dense aluminum-rich phase. If the rate of cooling is relatively low the separation of L_1 and L_2 will be substantially complete and the lead phase will be present primarily as a massive layer rather than a dispersion of small particles except of course for the lead that is rejected only upon solidification of the alpha aluminum. Conversely, when the molten material is rapidly chilled or quenched the lead phase is randomly dispersed as fine particles in the solid; but there is no apparent gradient in lead concentration. The desired cooling rate in accordance with our process lies between these extremes and must be determined with a particular casting and mold configuration in mind. Of course it is realized that the above discussion has been directed to an aluminum-lead system. However, in accordance with our invention the addition of small amounts of the other constituents identified above does not substantially change the overall phenomena which has been described.

An important utilization of our process is in the casting of lead-aluminum alloys for the manufacture of bearings. In this application, it is preferable to have a lead-rich bearing surface and a lead-poor surface which may be bonded to a steel backing. With this end use in mind, it is of particular interest to obtain a bearing surface with a lead concentration significantly greater than the average lead concentration in the alloy and the other surface with lead content significantly less than the average lead concentration in the alloy. In some embodiments the lead may be depleted to about 1.5% by weight from the lead-poor side of the casting. Furthermore, in general it is preferable that the change in concentration be more or less gradual and uniform so that there is no abrupt change in properties throughout the cross section of the material. Moreover, since the bearing surfaces are normally rather thin it is to be expected that this alloy would preferably be cast in relatively thin sections, strips or bands regardless of whether the casting operation is accomplished using centrifugal force or the force of gravity. We have found it preferable in the casting of bearing alloys by our process to limit the thickness of the casting to 1" or less.

A few general comments may first be made concerning factors which control or influence the character of the lead gradient obtained during casting, before dealing with specific examples. These factors are all related to the rate of cooling and the force applied. In general, the smaller the force and the greater the rate of cooling the smaller the gradient that will be obtained in lead concentration from one surface to the opposite surface. At the opposite extreme, the greater the force and the lower the rate of cooling the greater will be the gradient in the concentration across the thickness of the casting. As a practical matter, the only way the force can be varied is to cast centrifugally. Also of importance in affecting the gradient of lead

concentration is the pouring temperature of the molten alloy. We have found it preferable to pour the metal at a temperature about 100° F. above the lowest temperature of mutual solubility. This value can be estimated from FIG. 1 for a given lead-aluminum composition. Of course, it may be modified somewhat by the presence of other alloying constituents. Of particular importance in this phase of the process is the temperature of the mold. The initial temperature of the mold, together with any supplemental cooling means of disposing of the heat which is transferred to the mold, determines the length of time that the aluminum phase remains molten which in turn limits the migration of the lead.

Reference to the specific examples will further serve to illustrate our method of preparing high-lead content aluminum bearing alloys.

minute. Cooling water was pumped through the top copper plate 22 at a rate of approximately 2.85 gallons per minute. This water entered at a temperature of 79° F. and exited at a temperature of 120° F. Water was pumped through the bottom copper plate 20 at a rate of 3¼ gallons per minute, it entered at the temperature of 79° F. and exited at a temperature of 115° F. The thickness of the graphite upper and lower portions of the mold 16 and 18 was ¾ of an inch.

Samples of the cast strip for analysis were taken at various depths across the thickness and at various spots along the length of the strip. The results of the analyses are summarized in Table 1. The values are percentages by weight of the respective components at the particular locations.

TABLE 1.—ANALYSES OF CAST STRIP ¾" THICK (BY WEIGHT)

Component	Nominal overall alloy concentration, by wt.	Distance from top of strip, in.	Distance from end of strip in feet			
			2', percent	6', percent	12', percent	18', percent
Silicon.....	3.8	¾	3.73	3.76	3.91	3.98
Tin.....	0.45	¾	0.47	0.43	0.45	0.46
Lead.....	6.0	¾	3.10	1.82	1.67	1.99
		¾	4.19	2.80	2.13	2.23
		¾	6.08	6.94	6.28	7.47
		¾	6.18	7.52	8.64	10.67
Cadmium.....	1.1	¾	1.05	1.03	0.98	1.07
		¾	1.08	1.01	1.00	1.02
		¾	1.16	1.18	1.13	1.19
		¾	1.18	1.20	1.21	1.28
Manganese.....	0.25	¾	0.25	0.25	0.25	0.26
Aluminum.....	Balance	¾				

EXAMPLE I

Forty-five pounds of an alloy comprised by weight of 3.8% silicon, 0.45% tin, 6.0% lead, 1.1% cadmium, 0.25% manganese and the balance substantially all aluminum was prepared by first melting the aluminum and the other constituents, with the exception of the lead, in an induction furnace. Lead was added subsequently with further heating until a complete solution had been obtained. A clay-graphite crucible was used in conjunction with a 100 kilowatt, 3,000 cycle per second power source. Lead was not added until the aluminum melt temperature had exceeded about 1250° F. As stated above, preferably the lead-containing melt is then superheated to a temperature of about 100° F. above the upper limit of the bi-liquid range. As seen in FIG. 1, at 6% lead this temperature is approximately 1650° F. The melt was heated to 1700° F. This superheating is necessary so that the material may be poured without having the lead phase L₂ prematurely separate from the molten aluminum upon entering the mold.

As shown in FIG. 2, an induction melting or holding furnace may be integrally associated with a casting mold in accordance with our invention, and this device was used to cast the above-specified 45# melt. By this casting mode a strip of lead-aluminum alloy may be continuously formed. In general, the length of the strip is limited only by the amount of molten metal. The liquid aluminum-base lead-containing alloy specified above was prepared in an induction furnace 10 in accordance with the procedure outlined. When a substantially homogeneous melt had been obtained, material was allowed to flow out through a hole 12 in a side of the furnace and through a horizontally disposed water-cooled mold 14. In this example, a cast strip ¾" thick x 5¼" wide by 18.3' long was formed. The mold 14 was comprised of a flat horizontally disposed bottom portion 16 and a flat horizontally disposed to portion 18 and straight vertically disposed side portions (not shown) to contain the molten metal. In general, the mold walls were formed of graphite. The top 18 and bottom 16 portions of the graphite mold were backed with copper plates 20 and 22 containing passages (not shown) for cooling water. The mold was 9" long and the cast strip was advanced at a rate of 26" per

As shown by the data in the table, the lead concentration varied substantially from the top of the strip to the bottom. At the top of the strip the lead concentration was only slightly above the minimum value which can be obtained in a casting procedure of this sort. It will also be observed that the percentage of lead in the bottom of the strip, particularly the bottom third, was substantially above the average lead concentration in the alloy. Electron probe analysis of the material indicated that there was a tendency for the tin and cadmium to concentrate in the lead. To some extent this is shown in the cadmium analysis where its concentration does increase slightly in the lower part of the strip. The presence of tin and cadmium in the lead improve the score-resistant properties of the bearing surface and, in addition, the tin serves to minimize lead corrosion. The silicon and manganese concentrations were not found to vary in any substantial manner throughout the cross section. The chemical analysis also indicated that the casting process has to proceed for a brief period before the temperature of the mold stabilizes to the point at which the concentrations of the several components at various locations stabilized. In this continuous mode of casting it is believed that the longer the cast strip the more stable and reproducible will be the concentration gradient of the lead.

In addition to the chemical analysis, FIG. 3 also illustrates how the lead particles are dispersed and distributed across the cast strip. In FIG. 3, 24 is a radiograph of the cross section. The dark areas indicate the presence of lead, which is not transparent to X-rays. Twenty-six and 28 are photomicrographs at a magnification of 100X, 26 being representative of the top surface of the strip and 28 of a point ½ up from the bottom of the strip. The reason for interest in a photograph at this latter point is that in the manufacture of precision insert bearings it is normal practice to remove approximately ½ the thickness of the aluminum-based bearing surface to bring the bearing within dimensional tolerances. Therefore, in this example we are particularly interested in data revealing lead dispersion at this point of the casting.

The lead concentration at the top portion of the casting in the neighborhood of 1.5% to 2% lead is tolerable for roll bonding to a steel backing.

It is apparent from this example that the gradient of the lead in gravity casting is controlled by adjusting the temperature and flow rate of water through the cooling passages of the mold and the rate of withdrawal of the solidified strip from the mold. These conditions must be determined experimentally for each different embodiment in accordance with the general principles set forth herein.

EXAMPLE II

By following essentially the same procedure as set forth in Example I, a cast strip 3/4" thick x 4 1/8" wide by 10' long was cast. This strip was formed from a 45# melt having an overall concentration, by weight, of about 4.0% silicon, 0.45% tin, 2.5% lead, 1.0% cadmium and the balance substantially all aluminum. This melt was poured at a temperature of about 1500° F. Again samples were taken at various points along the strip and at selected levels across the thickness of the strip for chemical analysis. The results of the chemical analyses are summarized in Table 2. Again, the values are percentages by weight of the respective components at the particular locations.

TABLE 2.—ANALYSES OF CAST STRIP 3/4" THICK (BY WEIGHT)

Component	Nominal overall concentration, percent by wt.	Distance from top of strip, in.	Distance from end of strip in feet		
			1', percent	5', percent	10', percent
Silicon.....	4.0	3/16	4.04	4.04	4.27
Tin.....	0.45	1/16	0.48	0.33	0.37
		3/16	0.45	0.38	0.31
		5/16	0.46	0.47	0.34
		11/16	0.46	0.41	0.50
Lead.....	2.5	1/16	2.12	1.52	1.62
		3/16	2.29	1.86	1.69
		5/16	2.52	2.65	2.58
		11/16	2.43	2.38	2.19
Cadmium.....	1.10	1/16	1.12	1.13	1.09
		3/16	1.15	1.12	1.08
		5/16	1.17	1.14	1.10
		11/16	1.14	1.17	1.12
Aluminum.....	Balance				

In this run the mold 14 was again 9" long. The graphite upper and lower plates 16 and 18 were each 1/2" thick. The casting progressed at a rate of 15" per minute. Cooling water at 80° F. was pumped through the upper copper plate 22 at a rate of approximately 2.6 gallons per minute. The temperature of the water leaving the top copper plate 22 was 130° F. Water at 80° F. was pumped through the bottom copper plate 20 at a rate of about 3.15 gallons per minute the temperature of the water leaving the bottom portion of the mold was 120° F.

In FIG. 4, 30 is a radiograph of a cross section of the cast strip in which the dark areas indicate the relative concentration of lead. Thirty-two and 34 are photomicrographs at a 100 fold magnification. Thirty-two is a photomicrograph taken of a specimen prepared from the top surface of the strip and 34 is a photomicrograph which was prepared from a specimen taken at a point 1/3 the distance up from the bottom of the strip. In both FIGS. 3 and 4 at 28 and 34 it will be observed that the lead is present as fine discrete substantially spherical particles. The diameter of the particles is in the neighborhood of 0.001 inch.

Sheets of lead-aluminum based alloys 1/4" to 3/4" thick have been gravity cast in molds of the type described in these two examples and it is apparent that even thinner strips could be cast by our process. These sheets have been subsequently rolled to a thickness of about 0.050" thick without destroying the lead concentration gradient. In insert bearing manufacture the low lead side of the sheet is subsequently clad to a steel backing and, after various other processing steps recognized in the art of fabricating steel-backed aluminum-based precision insert bearings, about 1/3 the thickness of the aluminum strip is removed by broaching at the bearing surface to bring the article within dimensional tolerances. An excellent bear-

ing surface is thus provided which requires no overlating for score resistance.

EXAMPLE III

Our bearing alloy has also been prepared by centrifugal casting techniques. A mold was machined from steel tubing which had a 12" ID and a finished wall thickness of 1 1/8". To obtain maximum heat transfer no coatings were used on the mold surface. With a steel mold of this mass sufficient cooling is obtained even though the mold is preheated to a temperature between 300–500° F. A melt was prepared which was comprised by weight of 5% lead, 3% silicon and the balance aluminum. It was prepared as in the induction furnace described above in Example I. In this experiment the mold had been preheated to 500° F. and was rotated at 330 r.p.m. A casting 3/4" thick was obtained and 1/8" was machined off the outer surface before samples for analysis were taken at various depths. The lead concentration in the outer surface of the casting was 9.2% and in the inner surface about 2.8%. The concentration of other alloying ele-

ments soluble in the molten aluminum were not found to vary significantly across the thickness of the casting. The lead gradient is drastically affected by mold speed, pouring temperature and cast thickness. If a less steep gradient is desired, the speed of rotation of the mold may be described and the thickness of the casting reduced.

Cylinders of aluminum-lead alloy having wall thicknesses up to 1" can be sectioned and reduced by rolling to sheet as thin as 0.050" with the desired lead gradient maintained between opposite faces. Thus, adequate lead content at the wear surface of a final rolled product may be provided from melts of lower lead composition allowing appreciably lower melting and casting temperatures and the attendant benefits of a narrower two-phase liquid region.

Thus, there are several aspects of our process which are critical in order that the cast product has lead present in a finely dispersed form increasing in concentration in a given direction through the casting. Initially, a melt must be prepared which is substantially homogenous. This may be accomplished for example, by melting in an induction furnace of the type described above. Second, the cooling rate must be such during casting that an imposed force, centrifugal or gravitational, has time to cause the separating lead to migrate through the molten and solidifying aluminum so that the desired lead concentration gradient is obtained. At the same time the cooling must be sufficiently rapid so the lead is trapped in finely defined form and no large globules are obtained which structurally weaken the casting.

While our invention has been described in terms of certain preferred embodiments, it is apparent that other forms could be adopted by one skilled in the art and therefore our invention should be considered limited only by the scope of the following claims.

We claim:

1. A cast strip of length substantially greater than its width or thickness and having two major opposed surfaces and comprising by weight about 1-15% lead, 0-6% silicon, 0-4% cadmium, 0-5% tin, a total of from 0-5% of at least one metal taken from the group consisting of copper, silver, magnesium, manganese, nickel and chromium, and the balance substantially all aluminum, said lead being present in the aluminum as discrete particles which are dispersed such that the concentration of lead increases steadily in a direction from one of said surfaces to the other.

2. A cast strip of length substantially greater than its width or thickness having two major opposed surfaces and consisting essentially by weight of 1-10% lead, 0.1-6% silicon, 0.1-4% cadmium, 0.1-5% tin; a total of from 0.1-5% of at least one metal taken from the group consisting of copper, silver, magnesium, manganese, nickel and chromium; and aluminum, said lead being present in the aluminum as discrete particles which are dispersed such that the concentration of lead increases steadily in a direction from one of said surfaces to the other.

3. A bearing comprised of an aluminum-based surface layer and a ferrous metal backing layer integrally bonded to said surface layer, said surface layer being comprised of a major portion of an aluminum alloy and a minor portion of lead, said lead being present in the aluminum as discrete particles which are dispersed such that there is a gradient in the concentration of lead from a maximum

value at the bearing surface of said surface layer to a minimum value at the opposite surface of said surface layer which is integrally bonded to said ferrous metal backing.

4. A bearing comprised of an aluminum-containing surface layer and a ferrous metal backing integrally bonded to said surface layer, said layer consisting essentially by weight of 1-10% lead, 0.1-6% silicon, 0.1-4% cadmium, 0.1-5% tin, a total of from 0.1-5% of at least one metal taken from the group consisting of copper, silver, magnesium, manganese, nickel and chromium, and aluminum, said lead being present in the aluminum as discrete particles wherein said particles are dispersed such that there is a gradient in the concentration of lead from a maximum value at the bearing surface of said layer to a minimum value at the opposite surface of said layer which is integrally bonded to said ferrous metal backing.

References Cited

UNITED STATES PATENTS

3,104,135	9/1963	Morrison et al.	-----	308—237
3,221,392	12/1965	Gould et al.	-----	29—149.5
3,432,293	3/1969	Michael et al.	-----	75—138

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