

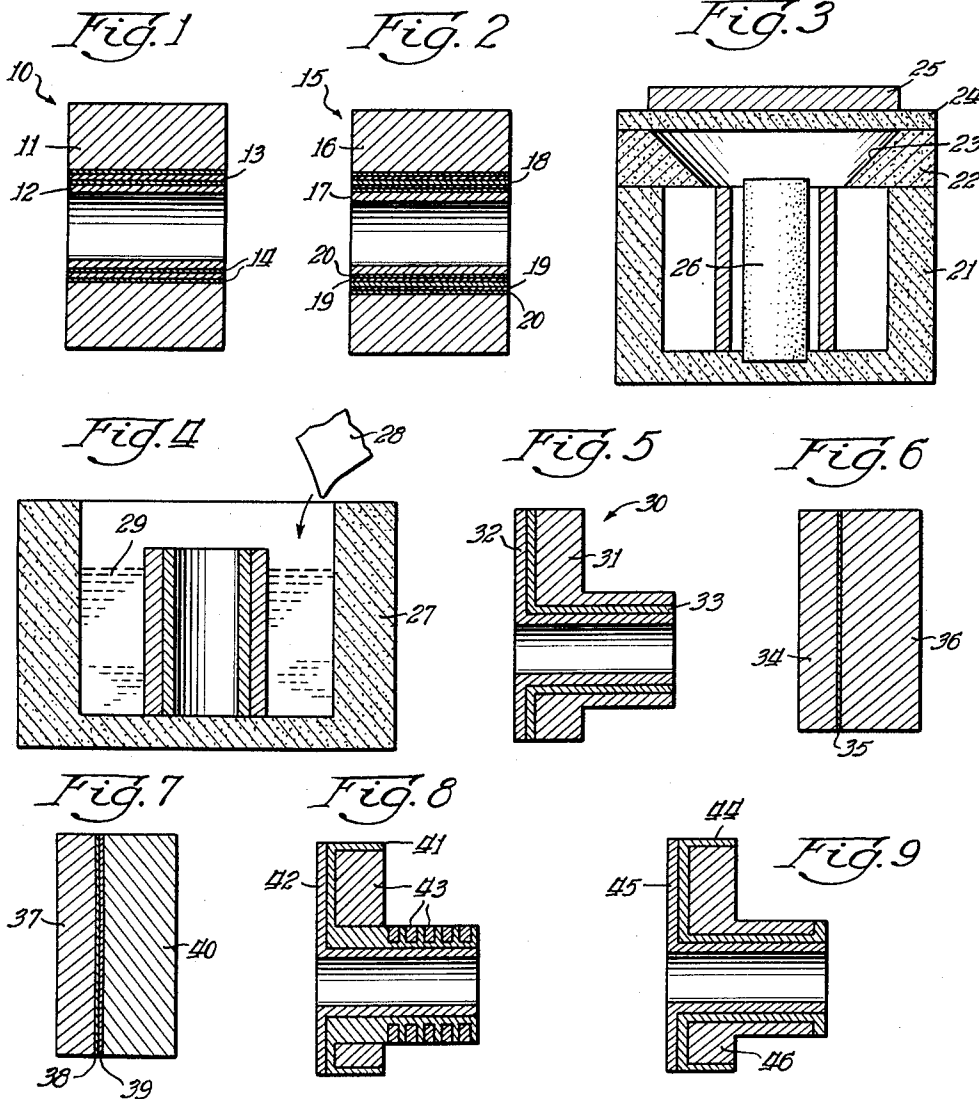
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COMPOSITE BONDED ARTICLE

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2,916,337

COMPOSITE BONDED ARTICLE

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This invention relates to processes of bonding metals and to the articles so produced. More particularly, my invention relates to the processes of bonding metals and alloys possessing good bearing properties to stainless steels, aluminum or aluminum alloys to stainless steels, and the combination of the two.

Articles produced in accordance with the teachings of my invention are advantageous for use as bearings, pump bushings, and the like, and are characterized by desirable features found necessary in the environment in which these articles are used.

It is well known that metals, such as copper, copper alloys having a high lead content, silver, and silver alloys provide excellent bearing surfaces which are superior to those provided by other well known metals and alloys; stainless steels are non-corrosive and do not warp or distort under high temperature and high load conditions; and aluminum has a high heat conductivity and possesses great strength per unit weight. Since copper, copper alloys, silver and silver alloys alone will distort or warp under high heat and load conditions; aluminum, while providing an acceptable bearing surface is inferior to copper, copper alloys, silver or silver alloys; and steel is heavy, offers a relatively poor bearing surface and does not conduct heat as rapidly as aluminum, it is necessary to bond one metal or alloy to the other to take advantage of the desirable characteristics and properties of these metals and alloys in the aforementioned articles.

The bonding of copper, copper alloys, silver or silver alloys directly to aluminum to obtain the combination of a superior bearing surface and a light weight structure has proven to be unsatisfactory, since a complex copper-aluminum or silver-aluminum alloy is formed at the interface resulting in a brittle bond quite susceptible to shock. The bonding of copper or copper alloys directly to steel, resulting in a structure having a good bearing surface supported so as not to distort or warp under high heat and load conditions is not satisfactory because of the properties of copper and copper alloys upon heating to a bonding temperature. At the bonding temperature, the low melting component of copper alloys begins to sweat out of solution with the copper to form a brittle bond with austenitic and martensitic types of stainless steel, which bond is susceptible to cracking. On the other hand, silver and silver alloys will not bond directly to steel or iron alloys. The bonding of aluminum or aluminum alloys directly to steel, while combining the desirable properties of strength, lightness in weight and high heat conductivity is not satisfactory because a complex aluminum-iron alloy is formed at the interface resulting in a brittle, non-ductile bond.

It has been found that the undesirable reactions in joining the various metals and/or the non-joinability of the various metals may be successfully overcome by a preliminary treating of the steel prior to the bonding operation. Broadly, this treating comprises the usual degreasing and etching of the metal, plus the application of a metallic coating or plate, or coatings or platings

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thereon, which avoids the formation of the complex alloys at the interface, or allows the metal or alloy to bond thereto. In addition to the above, structures constructed in accordance with my processes are useful in relatively high temperature installations, for example, in a range of approximately 800° F.

Therefore, the principal object of my invention is the provision of improved processes for bonding dissimilar metals and alloys.

Another object of my invention is the provision of improved processes for bonding copper, copper alloys, silver or silver alloys to stainless steel.

Another and still further object of my invention is the provision of improved processes for bonding aluminum or aluminum alloys to stainless steel.

A still further object of my invention is the provision of improved processes for producing copper, a copper alloy, silver, or a silver alloy-to stainless steel-to-aluminum bonds.

Still a further object of my invention is the provision of improved processes for producing strong, light weight, metallic bonds useful in relatively high temperature applications.

Another and still further object of my invention is the provision of structures incorporating improved bonds between dissimilar metals and alloys.

Still another object of my invention is the provision of structures constructed with bonds between stainless steel, copper, copper alloys, silver or silver alloys and/or aluminum.

Still another and further object of my invention is the provision of a strong, light weight bearing or pump bushing or the like, useful in relatively high temperature installations.

Another and still further object of my invention is the provision of an improved pump bearing having a good bearing surface, a strong, rigid backing member and having the ability to dissipate heat rapidly.

These and other objects and features of my invention will become apparent from the following description when taken with the accompanying drawing in which:

Figure 1 is a cross-sectional illustration of a bearing member produced in accordance with the teachings of one embodiment of my invention;

Figure 2 is a cross-sectional illustration of a bearing member produced in accordance with the teachings of a second embodiment of my invention;

Figure 3 is a cross-sectional illustration showing a treated stainless steel part within a substantially pure carbon mold useful in bonding copper, a copper alloy, silver or a silver alloy to the steel part;

Figure 4 is a partial cross-sectional illustration of a mold showing a steel part having a bearing layer thereon positioned therein, and which mold is employed for casting aluminum or an aluminum alloy onto the steel part;

Figure 5 is a cross-sectional illustration showing the general arrangement of a pump bushing constructed in accordance with the teachings of my invention;

Figure 6 is a cross-sectional illustration showing a bond between stainless steel, copper, a copper alloy, silver, a silver alloy, aluminum or an aluminum alloy and constructed in accordance with the teachings of one embodiment of my invention;

Figure 7 is a cross-sectional illustration similar to Figure 6 and showing a structure constructed in accordance with the teachings of a second embodiment of my invention;

Figure 8 is a cross-sectional illustration of a pump bushing having a high heat conductivity constructed in accordance with the teachings of my invention; and

Figure 9 is a cross-sectional illustration similar to Fig-

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ure 8 and showing another embodiment of a pump bushing having a high heat conductivity.

Broadly, my novel process comprises the preparation of a stainless steel part for bonding, and may include a bonding of a layer of copper, a copper alloy, silver or a silver alloy to one side thereof, or the casting of aluminum or an aluminum alloy to one side thereof, or the bonding of a layer of copper, a copper alloy, silver or a silver alloy to one side and the casting of aluminum or an aluminum alloy onto the other side thereof.

The stainless steel part used in my bonding method may be any type stainless steel, however, the type of stainless steel used in practice is 303 or 440 stainless. The chemical composition of 303 stainless steel is as follows:

Chemical element:	Percent
Carbon	0.15 max.
Chromium	17.0-19.0.
Nickel	8.00-10.00.
Phosphorus	0.07 min.
Sulphur	0.07 min.
Selenium	0.07 min.
Zirconium	0.60 max.
Molybdenum	0.60 max.
Manganese	2.00 max.
Silicon	1.00 max.

The chemical composition of 440 stainless steel is as follows:

Chemical element:	Percent
Carbon	0.60-1.20.
Manganese	1.00 max.
Silicon	1.00 max.
Phosphorus	.04 max.
Sulphur	.03 max.
Chromium	16.0-18.0.
Molybdenum	.75 max.

The stainless steel part is degreased, etched and provided with a preliminary overall coating of copper, or copper-tin, or nickel, so as to provide a surface to which the other metals, namely, copper, copper alloys, silver, silver alloys, aluminum and aluminum alloys will wet and readily bond without the formation of complex alloys, such as those previously described. I provide two alternate procedures for the preparation of the stainless steel part, as follows:

Procedure I

- (1) Degrease.
- (2) Etch in concentrated nitric acid.
- (3) Rinse in cold water.
- (4) Etch in an acid-salt mixture (13 ozs. gal. H_2SO_4 , 13 ozs. per gal. Rochelle salts), until the entire surface is etched to a black color at a temperature of 180° to 200° F.
- (5) Rinse in cold water.
- (6) Dip in HCl (1:1) for 30 seconds.
- (7) Rinse in cold water.
- (8) Nickel plate to a thickness of 0.0005 to 0.001 inch in ammonium chloride bath at 10 to 15 amp./sq. ft. current density.
- (9) Rinse in cold water.
- (10) Air dry.

Procedure II

- (1) Degrease.
- (2) Etch in concentrated nitric acid.
- (3) Rinse in cold water.
- (4) Immerse in an acid-salt solution (13 ozs. per gal. H_2SO_4 , 13 ozs. per gal. Rochelle salts) at a temperature of 175° to 200° F. for 1 to 7 minutes or until the surface is a black color.
- (5) Rinse in cold water.
- (6) Dip in HCl (1:1).
- (7) Rinse in cold water.

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(8) Copper clean in a bath containing an electro cleaner (6 ozs. per gal.), such as a conventional, commercial caustic cleaner and copper cyanide (2.5 ozs. per gal.) at a temperature of 175° to 200° F. The stainless steel is made the cathode and allowed to be copper cleaned until the entire surface is thoroughly plated with a copper deposit, usually on the order of 0.0005 inch in thickness.

(9) Rinse in cold water.

(10) Plate with copper, or copper-tin (usually 90% copper, 10% tin), or nickel to a thickness of 0.0005 to 0.001 inch.

If, after treatment, according to the foregoing procedures, it is desired to bond the steel to copper, a copper alloy, silver or a silver alloy, a treated steel shape is placed within a carbon mold of the general type described in the copending United States application of Fike and Pilous, Serial No. 531,010, and the metal or alloy is placed over, around, or within the treated steel shape. As will be obvious, the particular procedure followed will depend on the article being produced, which may have a facing, an external layer or an internal layer bonded thereto. The alloy may be in the form of a preform or a compress of powdered metal or alloy, a cast metal or alloy slug, or metal or alloy shot.

One copper alloy which produces excellent results has a composition of 20% to 30% lead, 1% to 6% tin, 0.25% to 1% (maximum) nickel and the remainder copper. This, as will be obvious, is a high lead content bronze. The preform or compress of this alloy may be formed of powdered bronze alloy, a mixture of pure metals, or powdered scrap bronze material. With regard to the copper, silver or silver alloy, the particular metal or alloy may be prepared in a similar manner to the copper alloy described. It is, of course, to be understood that the copper alloy is disclosed merely as an example and that other, similar copper alloys may be employed, as well as pure copper, pure silver and various silver alloys without changing the broad process. Each of these metals and alloys produces a bond with the steel having the desired physical characteristics.

As in the aforementioned copending application, the mold used in the process of bonding the steel part to the metal or alloy is constructed of substantially pure carbon, for example, carbon having a purity of 95% to 100%. The mold is so shaped to receive the particular shaped part being bonded, and is provided with an enlarged space or cavity above the part receiving cavity. A proper closure member, also constructed of the same purity carbon is placed over the mold and is retained in position by means of a weight, if necessary or desirable.

Since it is desirable to bond the steel and copper, copper alloy, silver or silver alloy in a non-oxidizing atmosphere, so as to prevent the oxidation of the metals which would produce a flakey, weak bond, the carbon mold burns under high temperatures, such as those temperatures employed for the bonding operation, and produces carbon dioxide, which gas is retained within the mold and around the article being produced. Thus, the bonding, thus described, is accomplished in a reducing atmosphere.

After the parts to be bonded are properly placed within the mold, the cover placed thereover, the mold is placed within a furnace and its temperature is raised to a temperature on the order of 1950° to 2000° F., at which temperature copper, the copper alloy, silver or the silver alloy becomes slushy or molten, wets the treated steel and bonds thereto. This action occurs in about 15 minutes after the mold and its contents reaches the aforementioned bonding temperature. The steel shape is not adversely affected at the bonding temperature; however, there is an alloying at the interface between the coating or coatings thereon and the molten material being bonded thereto.

The mold and its bonded structure is then removed from the furnace and allowed to cool to a temperature slightly below the melting temperature of the copper or silver,

or the major component of the alloy, i.e., copper or silver, if alloys thereof are being used. After the assembly has been cooled within the mold, it is removed therefrom and subjected to a cooling stream of water or is quenched rapidly, so that the freezing of the bonded layer begins at the interface and travels therethrough. Such treatment results in a layer having the desired characteristics for its ultimate use.

If it is desired to bond aluminum or an aluminum alloy to a treated steel part, the steel part is placed within the cavity of a complementary shaped, substantially pure carbon mold, having a purity of 95% to 100%. The mold need only be a chambered one of carbon for this process.

With the steel part placed in the cavity of the mold, molten aluminum or an aluminum alloy is cast onto the treated steel part and forms a bond therewith. The casting temperature is of the order of 1200° to 1300° F. As with the prior described bonding process, the casting temperature does not adversely affect the steel part.

To form an article having an aluminum portion, an intermediate steel backing portion and a facing portion of copper, a copper alloy, silver or a silver alloy, it is only necessary to combine and follow the previously described procedures. For example, the bearing metal or alloy layer is bonded to one side of the treated steel part and aluminum or an aluminum alloy is cast onto the other side of the steel part. However, precautions must be taken when casting the aluminum or aluminum alloy portion to prevent the aluminum or aluminum alloy from contacting and bonding to or alloying with the bearing layer. This is accomplished by completely isolating the bearing layer from the molten aluminum or aluminum alloy. If such precautions are not taken, complex aluminum alloys would be formed with the bearing material which are susceptible to shock because of brittleness; this would defeat the proposed uses of the final product.

The melting points of the metals constituting the steel-bearing layer bonded shape being above the casting temperature of the aluminum or the aluminum alloy, it will be obvious that the casting will have no adverse effects on the coatings on the steel other than to bond thereto, or the bond between the steel and the bearing layer.

When the desired assembly is completed, whether it be steel to copper, steel to a copper alloy, steel to silver, steel to a silver alloy, steel to aluminum, steel to an aluminum alloy, or aluminum or aluminum alloy to steel to copper, a copper alloy, silver or a silver alloy, the structure must be machined to its final dimensions.

Referring now to the drawing, and in particular to Figure 1, there is illustrated a bearing member 10 constructed in accordance with the teachings of Procedure I, previously described, and which comprises an aluminum or aluminum alloy portion 11, a bearing sleeve 12 of copper, a copper alloy, silver or a silver alloy, an intermediate backing stainless steel part 13 and a nickel coating 14 on the steel part 13 and bonded to the sleeve 12.

Figure 2 illustrates a bearing member 15 constructed in accordance with Procedure II, previously described, and which comprises an aluminum or aluminum alloy portion 16, a bearing sleeve 17 of copper, a copper alloy, silver or a silver alloy, an intermediate stainless steel backing portion 18, and coatings 19 and 20 between the steel and bearing sleeve and the steel and aluminum. The coating 19 is of copper and the coating 20 may be of copper, copper-tin alloy or nickel.

Figure 3 illustrates the mold constructed of substantially pure carbon in which the copper, copper alloy, silver or silver alloy bearing sleeve is bonded to the treated steel part. The mold comprises a lower portion 21 having a central cavity therein, an intermediate portion 22 having an enlarged opening 23, previously described, and a cover member 24. A weight 25 may be used to retain the mold parts in their proper assembly. The lower portion 21 of the mold is provided with a cen-

tral opening to receive a core 26 constructed of carbon having the same purity as the mold. Such a core is useful when bonding an internal bearing layer to the backing member. However, when it is desired to bond an external layer, the cavity within the mold is of approximately the diameter required.

The treated steel part is placed around the core and the bearing layer preform, slug or shot is placed within the treated steel part and around the core, so that upon heating to the aforementioned bonding temperature, the metal or alloy constituting the bearing layer will melt, fill the space between the treated steel part and the core, bond to the steel part, and form the bearing sleeve.

Figure 4 represents a mold 27 of substantially pure carbon to receive in its center a treated steel part or a steel bearing layer assembly produced in the mold of Figure 3, and into which molten aluminum or aluminum alloy is cast from a ladle 28, the aluminum or aluminum alloy being identified at 29.

Figure 5 represents a pump bushing 30 constructed by either of the two methods described and which comprises an aluminum portion 31, bearing surfaces 32 of copper, a copper alloy, silver or a silver alloy, and an intermediate treated steel part 33. For the sake of clarity, the coatings illustrated in Figure 1 or in Figure 2 are not shown, it being understood that the steel may be treated by either of the two procedures previously set forth.

Figure 6 illustrates a structure, the steel portion 34 of which is treated in accordance with Procedure I and which comprises a steel part 34, a nickel coating 35 and a layer 36 bonded thereto, which layer may be either copper, a copper alloy, silver, a silver alloy, aluminum or an aluminum alloy.

Figure 7 illustrates a structure in which the steel part has been treated according to Procedure II. There is shown the steel part 37, a preliminary copper coating 38, a plating 39 which may be copper, copper-tin or nickel and the metal 40 bonded thereto, which may be copper, a copper alloy, silver, a silver alloy, aluminum or an aluminum alloy.

Figure 8 represents a cross-sectional illustration of a pump bushing constructed in accordance with either of the two procedures set forth. There is shown a steel backing member 41, a bearing surface 42 which may be copper, a copper alloy, silver or a silver alloy, and aluminum or aluminum alloy 43 which has a high heat conductivity, and the aluminum or aluminum alloy is so placed to conduct heat rapidly away from the bearing surfaces.

Figure 9 is an illustration similar to that of Figure 8 and shows a pump bushing comprising a steel backing portion 44, a bearing layer 45 which may be of copper, a copper alloy, silver or a silver alloy and an aluminum or aluminum alloy insert portion 46.

In each of the structures illustrated in Figure 8 and Figure 9, the aluminum has the ability of conducting heat rapidly away from the bearing surfaces and this high heat conductivity allows the bearing to be run at temperatures in excess of the melting points of components of alloys used for the bearing layers, so as not to destroy the bearing layer during high temperature use.

While I have described my invention in connection with certain specific embodiments thereof, it is to be understood that this is by way of illustration and not by way of limitation and the scope of my invention is defined solely by the appended claims which should be construed as broadly as the prior art will permit.

I claim:

1. A metallic bonded article comprising, a backing member of aluminum or aluminum alloy, a facing member of a metal selected from the group consisting of copper and silver and their alloys, and an intermediate member of stainless steel.

2. A metallic bonded article comprising, a backing member of aluminum or aluminum alloy, a facing member of metal selected from the group consisting of copper

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and silver and their alloys, and an intermediate member of stainless steel, said stainless steel being provided with at least one coating of metal selected from the group consisting of copper, nickel, and an alloy of copper and tin.

3. A bearing comprising, a backing member of aluminum or aluminum alloy, a bearing facing of a metal selected from the group consisting of copper and silver and their alloys, and an intermediate member of stainless steel.

4. A bearing comprising, a backing member of aluminum or aluminum alloy, a bearing facing member of a metal selected from the group consisting of copper and silver and their alloys, and an intermediate member of stainless steel, said stainless steel being provided with at least one coating of metal selected from the group consisting of copper, nickel, and an alloy of copper and tin.

5. A pump bushing comprising, a backing member of aluminum or aluminum alloy, a facing member of a metal selected from the group consisting of copper and silver and their alloys, and an intermediate member of stainless steel.

6. A pump bushing comprising, a backing member of aluminum or aluminum alloy, a facing member of a metal selected from the group consisting of copper and silver and their alloys, and an intermediate member of stainless steel, said stainless steel being provided with at least one

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coating of metal selected from the group consisting of copper, nickel, and an alloy of copper and tin.

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