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METHOD OF BONDING ALUMINUM ALLOYS TO STEEL

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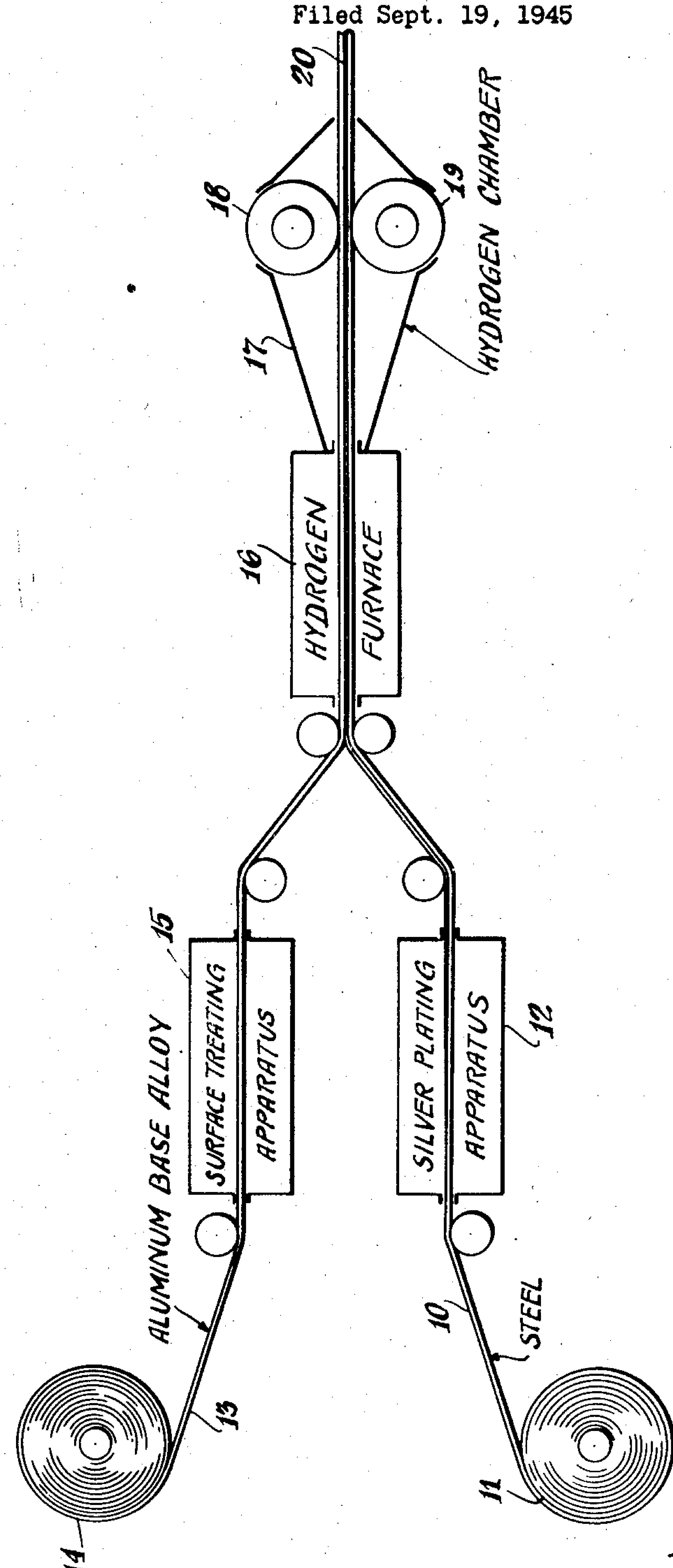

INVENTORS
William E. Lynch
Robert M. Strain
BY Chester F. Carlson
ATTORNEY

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METHOD OF BONDING ALUMINUM ALLOYS TO STEEL

William E. Lynch and Robert M. Strain, Indianapolis, Ind., assignors to P. R. Mallory & Co., Inc., Indianapolis, Ind., a corporation of Delaware

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This invention relates to the art of bonding aluminum alloys to iron group base metals, and, more particularly, to a method of bonding aluminum alloys having good bearing properties to steel.

It is an object of the invention to improve methods of bonding aluminum base materials to metals of the iron group.

It is another object of the invention to provide a novel and improved method of bonding aluminum alloys having good bearing properties to iron base metals, particularly steel, whereby a strong, fatigue-resistant and permanent bond is obtained.

The invention also contemplates a bearing of improved character comprising a steel backing member, a lining constituted of an aluminum alloy having good antifriction properties, and a silver interlayer bonding the backing member and the lining together.

Other and further objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawing which is a diagrammatic illustration of an apparatus for carrying the method of the invention into practice.

The present application is related to co-pending applications Serial Nos. 557,703, 579,992, and 607,993 of Franz R. Hensel, filed October 7, 1944, February 27, 1945, and July 31, 1945, respectively. In the above-entitled co-pending applications there is disclosed that a strong, ductile and fatigue-resistant bond may be obtained between a layer of iron group metal and a layer of aluminum base metal by providing a bonding layer between the two metals. One method of making overlay metals of the described character comprises coating a layer of silver on the surface of the iron group metal, cleaning the surface of the aluminum base metal, and then bonding the layers together by the application of heat and pressure. The preferred method of applying the silver to the iron group metal is electroplating, although other methods may also be employed such as silver vapor deposition, pressure bonding, or fusion bonding. The clean silver-coated surface of the iron group metal and the cleaned surface of the aluminum base metal are then placed in contact and heated in a non-oxidizing atmosphere to a temperature which may be in the range of 350° to 550° C. and the two sheets are then placed between pressure rolls or other pressure applying means to complete the bond.

Experience has demonstrated that the foregoing procedure provides an excellent bond be-

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tween the iron base metal and the aluminum base metal and that such bond will remain unaffected by subsequent mechanical forming or moderate heating of the bimetal. Certain difficulties, however, have been experienced when applying this procedure to bonding aluminum alloys of specific characteristics to a steel or similar iron base metal backing. Such difficulties were particularly accentuated when it was attempted to bond aluminum alloys having good bearing properties to steel. Aluminum bearing alloys generally comprise a number of various alloying elements such as silicon, cadmium, tin, copper, nickel, and the like. For example, a typical aluminum base bearing alloy having excellent antifriction properties consists of aluminum 85 to 96½%, silicon up to 10%, and cadmium up to 5%, the preferred composition consisting of 4% silicon, 4% cadmium, and the balance aluminum. Another typical aluminum base bearing alloy consists of 6.5% tin, 2.5% silicon, 1% copper, 0.5% nickel, the balance aluminum. When it was attempted to bond these aluminum base bearing alloys to a steel backing, it was found that the bond formed was relatively weak and that it did not stand up under the conditions present in forming and operating the bearing.

An investigation directed to this problem revealed that the difficulty was due to the presence of the alloying ingredients of the aluminum base bearing metal in the bonding regions. Thus, for example, it was found that during the preheating process the silicon contained in the alloys would seriously interfere with the formation of the aluminum-silver alloy in the interlayer. The other alloying ingredients, particularly those of low melting points, such as tin and cadmium, would be fused during the preheating process and would likewise interfere with the formation of a good and strong bond. Since aluminum bearing alloys having good bearing properties have only relatively low mechanical strength and have to be reinforced with a strong backing layer, this situation seriously interfered with the practical and commercial use of these otherwise excellent bearing materials.

It has now been discovered that the outstanding problem may be solved in a remarkably simple manner by removing the alloying ingredients from the bonding surface of the aluminum base alloys. The cleaning treatments heretofore employed preliminary to the bonding process and generally comprising a hot alkaline dip did not accomplish this result and, as a matter of fact, aggravated the situation by dissolving some of the aluminum from the alloy and thereby increasing the silicon content in the bonding surface. This difficulty is completely eliminated in accordance with the principles of the present invention by following the hot alkaline dip with a treatment with strong mineral acids, capable of dissolving practically all of the alloying ingredients, including the silicon, from the bonding surface. In this manner, the bonding surface of the aluminum base alloys will be converted into a surface consisting of substantially pure aluminum which will readily bond to the silver bonding layer previously provided on the steel backing. It has been found that a mixture of nitric and hydrofluoric acids provides particularly good results.

The invention will be best understood by referring to the drawing in which there is diagrammatically illustrated a preferred form of apparatus for carrying the method of invention into practice. A strip of steel sheet **10** is unwound from roll **11** and passes through a cleaning and electroplating apparatus **12** which applies first a copper strike or any other suitable metal strike capable of producing a good bond to steel and then a layer of silver plate to one surface of the steel strip. The thickness of said silver layer may be between 0.000025″ and 0.001″, best results being obtained with a silver deposit having a thickness in the order of 0.0001″. A strip **13** constituted of a suitable aluminum base alloy is simultaneously unwound from roll **14** and passes through a chemical cleaning and treating apparatus **15** to clean and to prepare at least one of its surfaces in such a manner that the alloying ingredients of aluminum are dissolved therefrom and a subsequently pure aluminum surface is provided. The silver-plated steel strip **10** and the clean and pretreated aluminum alloy strip **13** are then brought together with the silver-plated face of the steel in contact with the cleaned and pretreated face of the aluminum alloy and led through a hydrogen furnace **16** which heats them to pressure bonding temperature in a hydrogen atmosphere. The preheating temperature may be between 350° and 550° C., the preferred preheating temperature being in the order of 500° C. The contiguous strips emerge from the furnace through a hydrogen chamber **17** and then pass between pressure rolls **18** and **19** which apply sufficient pressure to cause at least some reduction of the strips and bonding the silver surface of the steel with the pretreated surface of the aluminum, thus completing the bimetal strip **20**, which emerges from the apparatus. It has been found that in order to obtain a strong and fatigue-resistant bond, it is desirable to adjust the rolling pressure to such a value as to produce at least 10% and up to about 30% reduction of the strips.

In order to give to those skilled in the art a better understanding of the invention, the following illustrative example may be given:

EXAMPLE

A steel strip is provided with an electrodeposited coating of silver having a thickness in the order of 0.0001″ by one of the methods disclosed in the co-pending applications referred to in the foregoing. A suitable method is the following:

Silver plating on steel

For an adherent plate of silver on steel, surface condition is of prime importance. The ideal surface is a chemically clean mirror finish.

To plate on a rolled steel surface:

1. Degrease in an organic solvent
2. Electro-clean anodically.

A phosphate or silicate cleaner may be used, such as "Anodex" or "Oakite #90."

Cleaner	60 grams per liter
Temperature	just below boiling
Current density	40 to 50 A. S. F.

3. Rinse
4. Sulfuric acid dip:
   10% acid by volume.
   Time—1 minute.
5. Rinse
6. Copper flash:

Solution—

Copper cyanide	oz./gal	1.4–2.0
Free sodium cyanide		.8–1.1
Potassium hydroxide		4.5–5
Tri-sodium phosphate		2
Copper anodes:		
Temperature	°F	170–175
Current density	A. S. F	45
Time	minutes	2

7. Rinse
8. Sodium cyanide dip:
   40 grams per liter.
   40 sec.
9. Silver strike:

Solution—

Silver cyanide	grams per liter	2.25–2.5
Potassium cyanide	do	160–175
Potassium carbonate		15
Temperature	°F	90–95
Current density	A. S. F	30
Time	seconds	20

10. Silver plate:

Solution—

Silver cyanide	grams per liter	36
Total potassium cyanide		52
Potassium carbonate		38
Temperature	°C	30
Current density	A. S. F	15

Brightener of the carbon disulfide type may be used.

At this current density, silver will be deposited at the rate of .0001″ in 3.5 minutes.

The aluminum alloy must also be carefully cleaned and prepared by using for instance the following method:

Preparation of the aluminum alloy surface

1. Degrease with a suitable volatile solvent.
2. Dip in hot alkaline solution, such as 5% to 20% sodium hydroxide solution at 50° to 80° C. for 20 to 60 seconds.
3. Rinse thoroughly.
4. Acid dip for 10 to 60 seconds at 15° to 35° C.

The type of acid dip employed is determined by the composition of the aluminum base alloy. For example, for 99.8% aluminum or for an alloy known as 2S aluminum and consisting of 99.0% aluminum, and for other alloys free from silicon, the acid dip may comprise 20% to 100% by volume 40° Bé. nitric acid. For alloys containing silicon, such as the aforesaid aluminum base bearing alloy consisting of 92% aluminum, 4% silicon and 4% cadmium, or the aluminum base bearing alloy consisting of 89.5% aluminum, 2.5% silicon, 6.5% tin, 1% copper, and 0.5% nickel, the acid dip may comprise one volume of hydrofluoric acid (48% to 52%) and one to four volumes 40° Bé. nitric acid.

5. Rinse thoroughly and dry with a blast of clean air, or in an oven at elevated temperature.

The foregoing chemical treatment, which is a combination of alkaline and acid dips, removes all the surface impurities and dissolves all of the alloying ingredients of the aluminum base alloy from the treated surface thereby providing a clean bonding surface consisting of substantially pure aluminum.

Bonding

The silver-plated steel strip and the pretreated strip of aluminum base alloy are preheated in a suitable non-oxidizing or reducing atmosphere to a temperature in the order of 500° C. so that the silver coating of the steel strip is in contact with the clean surface of the strip of aluminum base alloy, constituted of substantially pure aluminum. The strips are now passed between a pair of rolls to cause a reduction of at least 10% and bonding of the strips to produce a bimetal of desired characteristics.

The method of the invention eliminates the detrimental effect of the alloying ingredients of aluminum base alloys upon the bond strength. Silicon, if present in the bonding surface, prevents the formation of a strong bond. In the case of aluminum-tin alloys, the removal of tin from the bonding surface is very important because of the low melting point of the tin which is 232° C. Since the bonding process is generally carried out at temperatures between 450° to 550° C., the tin particles in the aluminum alloy are in a molten condition thereby segregating within the bond and decreasing the strength of the bond.

The same is true in the case of cadmium. Aluminum and cadmium are substantially insoluble in each other and at temperatures above 321° C. two phases are present, namely aluminum and liquid cadmium. Therefore, the pressure applied during rolling would force any free cadmium near to the bonding surface into the bonding layer thereby creating a cadmium-silver phase which would have a deleterious effect on the bond strength.

It will be noted that the present invention provides a number of important advantages. Thus, the method of the invention makes it possible to provide a composite strip comprising a layer of an aluminum alloy having excellent antifriction properties and relatively low mechanical strength which is reinforced by means of a steel backing having high mechanical strength. The bond between the aluminum base bearing alloy and the steel is of such character as to stand up under all conditions encountered in the manufacture and applications of aluminum base bearings.

It is also to be observed that the method of the invention is very simple and may be carried out quickly, efficiently and at a low cost for the manufacture of aluminum alloy-steel bimetals or aluminum alloy-steel bearing blanks on a quantity production scale.

Although the present invention has been described in connection with a few preferred embodiments thereof, variations and modifications may be resorted to by those skilled in the art without departing from the principles of the invention. All of these variations and modifications are considered to be within the true spirit and scope of the present invention, as disclosed in the foregoing description and defined by the appended claims.

What is claimed is:

1. The method of making aluminum alloy-steel overlay metal from strips of aluminum alloy and steel which comprises electroplating a silver deposit having a thickness not exceeding 0.001'' on one face of the steel strip, subjecting the face of the aluminum alloy strip first to an alkaline and then to an acid treatment to remove therefrom impurities and the ingredients alloyed with the aluminum base thereby to provide thereon a bonding surface of substantially pure aluminum, preheating both of said strips in a non-oxidizing atmosphere to raise their temperature to a welding temperature in the range between 350° and 550° C. and appreciably below the melting point of silver, and passing said strips between pressure rolls with the surface of the said silver deposit in contact with the said bonding surface of pure aluminum to weld said strips together.

2. The continuous method of making aluminum alloy-steel overlay metal from strips of aluminum alloy and steel which comprises passing the steel strip through a silver plating bath to deposit a silver coating thereon having a thickness not exceeding 0.001'', passing the aluminum alloy strip through an alkaline and through an acid treating bath to remove from the surface thereof impurities and the ingredients alloyed with the aluminum and to provide thereon a bonding surface substantially constituted of pure aluminum, passing both of said strips through a furnace containing a non-oxidizing atmosphere to raise the temperature of said strips to a welding temperature in the range between 350° C. and 550° C., and then applying rolling pressure to said preheated strips with the silver coating on one strip in contact with the pure aluminum surface of the other thereby to cause reduction of the strips by at least 10% and welding of said strips together.

3. The method of making overlay metal from strips of iron base metal and of an aluminum alloy containing silicon which comprises electrodepositing a coating of silver having a thickness not exceeding 0.001'' on said strip of iron base metal, subjecting the aluminum alloy strip to an alkaline cleaning treatment, treating said cleaned aluminum alloy strip with a mixture of strong mineral acids including hydrofluoric acid to dissolve from the surface thereof the silicon and other alloying ingredients and to provide thereon a bonding surface of unalloyed aluminum, preheating said strips in a reducing atmosphere to a bonding temperature in the range between 350° and 550° C., placing said preheated strips in contact with the silver coating in face to face position with the said bonding surface of unalloyed aluminum, and then passing said strips between a pair of bonding rolls to cause bonding and at least some reduction thereof.

4. The method of making an overlay metal from a strip of high-strength iron base metal and a strip of aluminum alloy having good antifriction properties and containing alloying ingredients such as silicon, cadmium, tin, copper, nickel, and the like, which comprises electrodepositing a thin coating of silver on said strip of iron base metal, subjecting the aluminum alloy strip to a preliminary cleaning treatment in a hot alkaline solution, subjecting the pretreated aluminum alloy strip to a supplementary cleaning treatment in a mixture of nitric and hydrofluoric acids to dissolve from the surface thereof the silicon and other alloying ingredients and to provide thereon a clean bonding surface of pure aluminum, preheating said strips in a non-oxidizing atmosphere to the bonding tempera-

ture of silver, placing said preheated strips in contact with the silver coating facing the bonding surface of pure aluminum, and then passing said strips between a pair of rolls to cause at least some reduction and strong bonding of the strips together.

5. The method of making bearing blanks from a strip of steel and a strip of aluminum base bearing alloy containing about 4% of silicon and about 4% of cadmium which comprises electrodepositing a thin coating of silver on said strip of steel, subjecting the aluminum alloy strip to a preliminary cleaning treatment in a hot alkaline solution, subjecting the pretreated aluminum alloy strip to a supplementary cleaning treatment in a mixture of nitric and hydrofluoric acids to dissolve from the surface thereof the silicon and cadmium and also the residual impurities thereby providing thereon a clean bonding surface of pure aluminum, preheating said strips in a reducing atmosphere to the bonding temperature of silver, placing said preheated strips in contact with each other with the silver coating facing the bonding surface of pure aluminum, and then passing said strips between a pair of rolls to cause bonding of the strips together into a reinforced composite bearing blank strip.

6. The method of making bearing blanks from a strip of steel and a strip of aluminum base bearing alloy containing about 6.5% tin, about 2.5% silicon, about 1% copper, and about 0.5% nickel, which comprises electrodepositing a thin coating of silver on said strip of steel, subjecting the aluminum alloy strip to a preliminary cleaning treatment in a hot alkaline solution, subjecting the pretreated aluminum alloy strip to a supplementary cleaning treatment in a mixture of nitric and hydrofluoric acids to dissolve from the surface thereof the alloying ingredients and the residual impurities thereby providing thereon a clean bonding surface of pure aluminum, preheating said strips in a reducing atmosphere to the bonding temperature of silver, placing said preheated strips in face to face position with the silver coating opposite to the bonding surface of pure aluminum, and then passing said strips between a pair of rolls to cause bonding of the individual strips together into a reinforced composite bearing blank strip.

7. The method of making a reinforced composite bearing strip from a strip of steel and a strip of aluminum bearing alloy containing alloying ingredients selected from the group consisting of silicon, cadmium, tin, copper and nickel, which comprises electrodepositing a coating of silver having a thickness of about 0.000025'' to

about 0.001'' on said steel strip, subjecting the aluminum alloy strip to a preliminary cleaning treatment in a hot alkaline solution, subjecting the pretreated aluminum alloy strip to a supplementary cleaning treatment in a mixture of nitric and hydrofluoric acids to dissolve from the surface thereof the residual impurities and the alloying ingredients and to provide thereon a clean bonding surface of pure aluminum, preheating said strips in a reducing atmosphere to a temperature of about 450° to about 550° C., placing said preheated strips together with the silver coating facing the bonding surface of pure aluminum, and then passing said strips between a pair of rolls to cause reduction of about 10% to about 30% and bonding of said strips together.

WILLIAM E. LYNCH.
ROBERT M. STRAIN.

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