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METHOD OF MAKING ALUMINUM CLAD STEEL

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Fig. 1

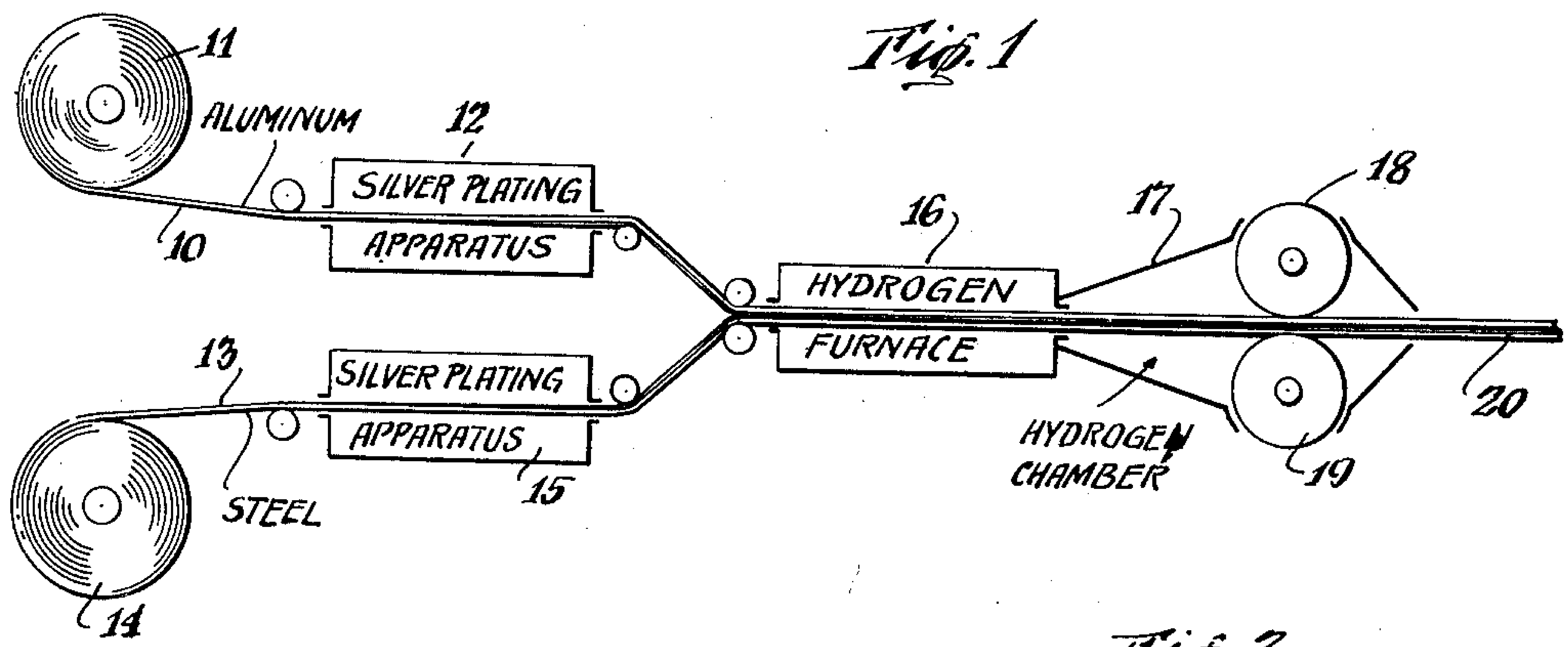


Fig. 2

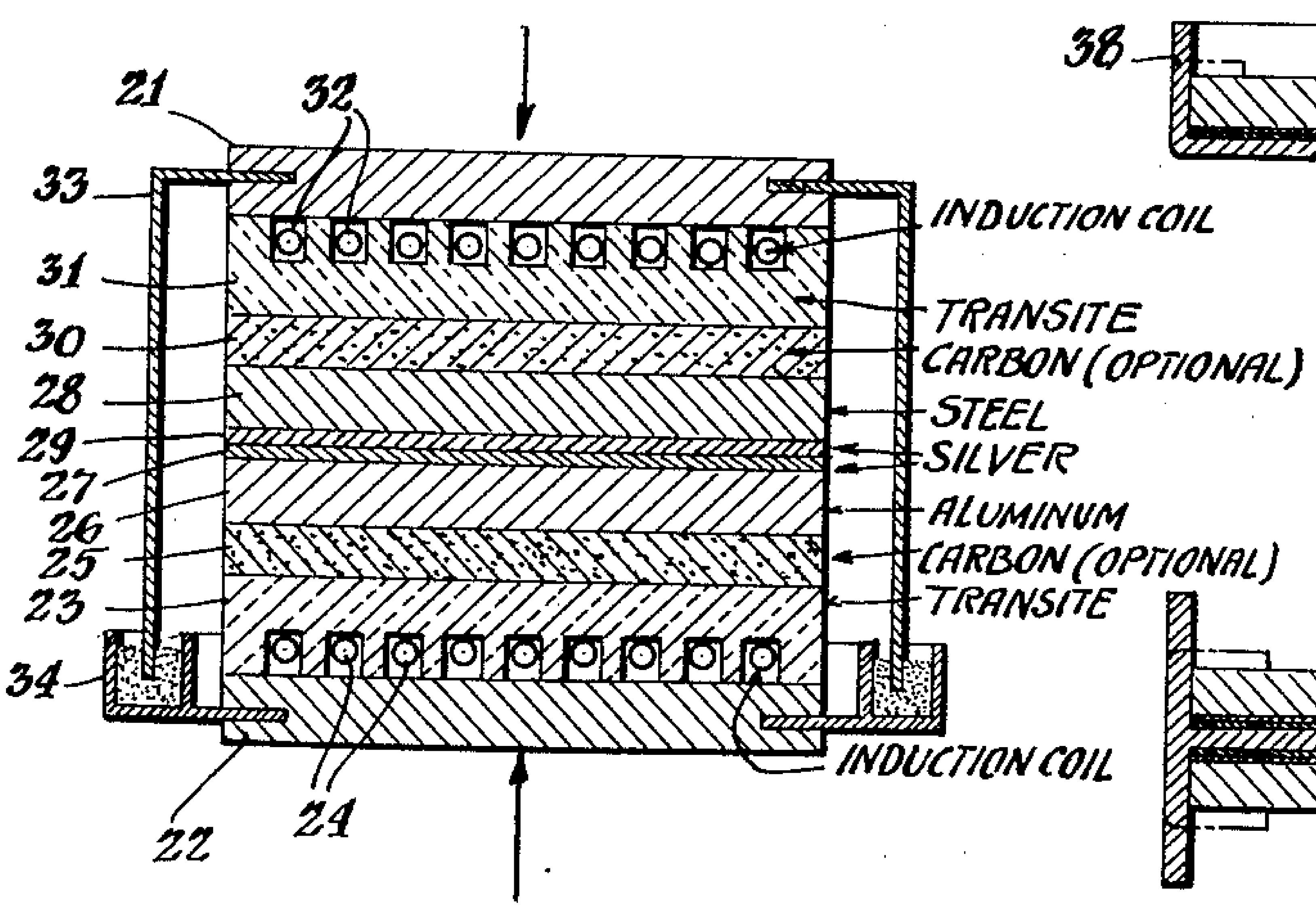


Fig. 3

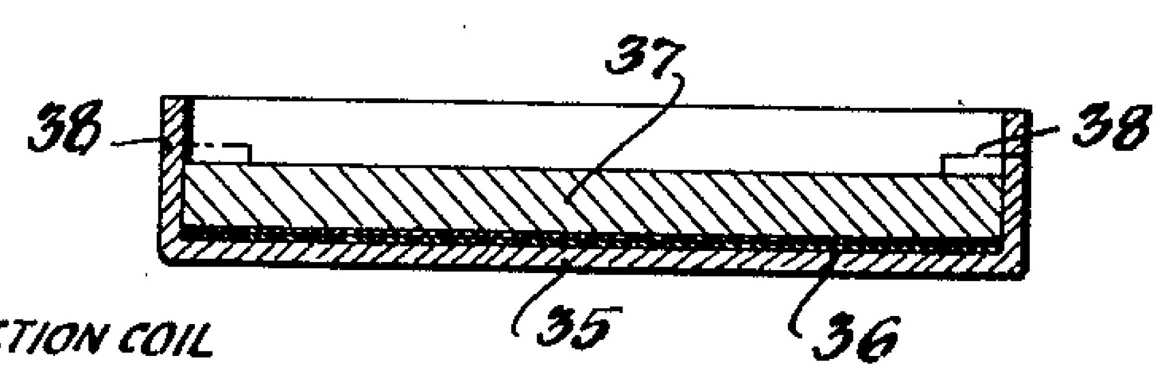


Fig. 4

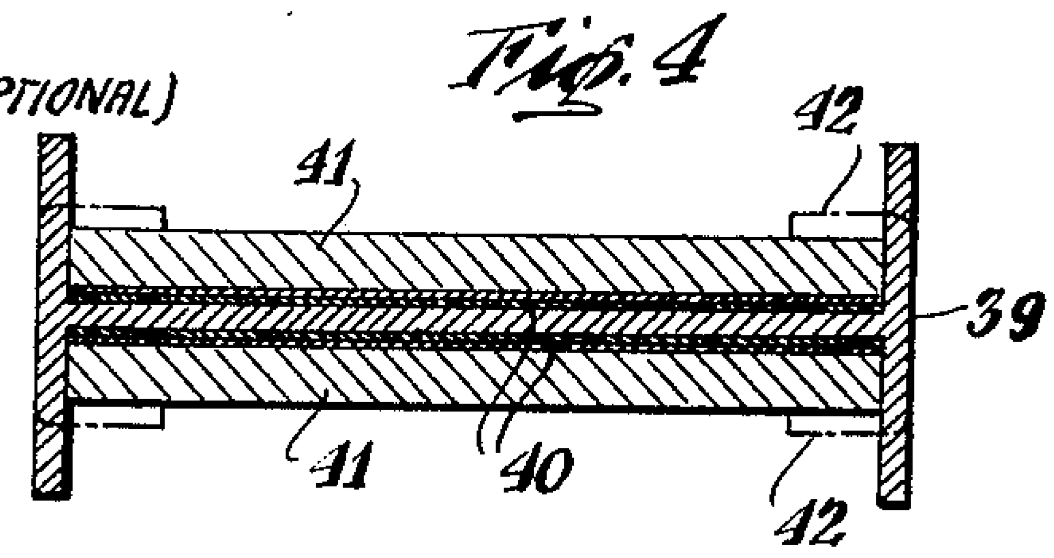
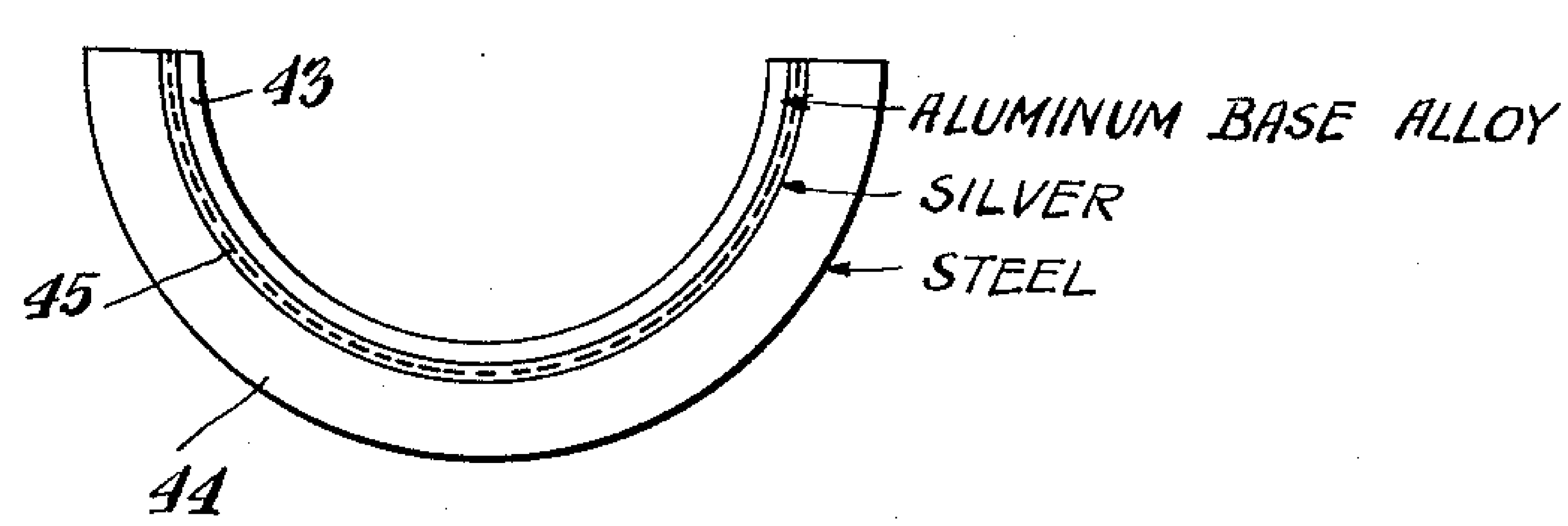


Fig. 5



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METHOD OF MAKING ALUMINUM CLAD STEEL

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2 Claims. (Cl. 29—189)

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This invention relates to overlay metals of aluminum bonded to an iron group metal, and particularly to aluminum-steel overlay metal and its manufacture, and to aluminum-lined bearings.

An object of the present invention is to improve aluminum overlay metal and the methods of making it and to improve aluminum lined bearings.

Other objects of the invention will be apparent from the description and claims.

In the drawings:

Figure 1 is a diagrammatic illustration of a process for making aluminum-steel overlay metal;

Figure 2 is a sectional elevation illustrating another method of bonding aluminum to steel;

Figures 3 and 4 illustrate in cross-section assemblies for use in preparing aluminum-steel overlay metal; and

Figure 5 illustrates an aluminum lined bearing half shell embodying features of the present invention.

A number of methods of producing aluminum clad steel have been tried heretofore. One method comprises dipping steel into a bath of molten aluminum. This method results in only a very thin superficial layer which adheres to the steel by the formation of an iron-aluminum compound which is extremely brittle. Another method comprises the rolling together of a thin aluminum foil and steel. Again the bonding action is based on the formation of the brittle iron-aluminum compound which will fracture in bending and which has a very low fatigue strength. It has also been suggested that a layer of zinc be interposed between the aluminum and steel to avoid the brittle iron-aluminum layer. This layer does not prevent the brittleness altogether and is characterized by low melting point and low strength.

The present invention overcomes all the objections of the prior methods and provides a strong, ductile fatigue resistant bond. This is accomplished by providing a silver bonding layer between the aluminum and steel.

The preferred method of making the overlay metal comprises bonding a layer of silver to the steel surface and another layer of silver to the aluminum surface and then bonding the layers together by heat and pressure.

The preferred method of applying the silver to the steel and to the aluminum is electroplating although other methods may also be employed such as silver vapor deposition, pressure bonding or fusion bonding. It is essential that the silver adhere tightly to the steel and therefore the surface of the steel must be carefully prepared to receive the silver layer by cleaning, sand blasting, pickling and bright annealing if necessary.

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The silver layer may be deposited by conventional electroplating methods. 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		45 A. S. F.
Time	minutes	2

7. Rinse.
8. Sodium cyanide dip:
   40 oz./gal.
   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		30 A. S. F.
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		15 A. S. F.

Brightener of the carbondisulfide type may be used.

At this current density, silver will be deposited at the rate of .0001'' in 2.5 minutes.

In the experimental work a plate .001'' thick was deposited.

The aluminum must also be carefully cleaned and prepared to receive the silver deposit by using for instance the following method:

Silver plating on aluminum

In plating on aluminum the time required for anodizing and modification is dependent on the grade of aluminum and the nature of the alloy. The following flow sheet applies to pure aluminum.

1. Degrease with organic solvent.
2. Polish lightly with a mild abrasive.
3. Etch in sodium cyanide:

Solution—

Sodium cyanide	grams per liter	60
Time	minutes	5

4. Anodize:

Solution—

Oxalic acid .... grams per liter .. 30

A. C. current:

Voltage—10 v. at start—raised to 50 v.

Time—10 minutes.

An alkali metal carbonate-chromate may be used in anodizing.

5. Modify anodic film:

Solution—

Sodium cyanide as above

Time—5 minutes.

The modifying treatment may be either basic or acidic, using sodium cyanide or a dilute solution of hydro-fluoric acid.

6. Rinse.
7. Nickel plate:

Solution: (Watt's type)

Nickel sulfate	grams per liter	330
Nickel chloride	do	30
Boric acid	do	30
Hydrogen peroxide to prevent gassing.		
Temperature	°F	140
Current density		25–50 A. S. F.

At 25 A. S. F., nickel will be deposited at the rate of .0001'' in 5 minutes. An .0002 plate was deposited.

Any type of nickel bath may be used.

8. Rinse.
9. Sodium cyanide dip.
10. Silver strike—as in steel.
11. Silver plate—as in steel.

In the experimental work a silver plate of .001'' was deposited.

The clean silver coated surfaces of the steel and aluminum are then placed in contact and heated in a non-oxidizing atmosphere to a temperature which may be in the range of 350 to 500° C. and the two sheets are then pressed between pressure rolls, platens or other pressure applying means to complete the bond.

I have found that two clean silver surfaces can be welded together at low temperatures provided a sufficiently high pressure is applied. It can be stated that this phenomenon is a matter of cold welding. This is entirely different from the usual methods of pressure bonding where it becomes necessary to heat the parts close to their melting points. This type of cold welding is

particularly useful in this invention where the cladding material is aluminum having a low melting point. Metals such as copper are undesirable because pressure bonding could only be accomplished at temperatures which are considerably above the melting of the aluminum or the aluminum alloy.

Referring to Figure 1 a process of making silver-steel overlay metal is illustrated diagrammatically. A strip of steel sheet **13** is unwound from roll **14** and passes through a cleaning and electroplating apparatus **15** which applies a layer of silver to one surface of the steel strip. An aluminum strip **10** is simultaneously unwound from roll **11** and passes through a cleaning and electroplating apparatus **12** to apply a layer of silver to one surface. The two silver plated strips **10** and **13** are then brought together with the silver plated faces in contact and led through a hydrogen furnace **16** which heats them to pressure bonding temperature in a hydrogen atmosphere. 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 bond the silver surfaces together thus completing the bimetal strip **20** which emerges from the process.

According to another method of carrying out the bonding process the silver coated sheets of aluminum and steel are placed between pressure plates of a hydraulic press while being simultaneously heated in a reducing atmosphere. Figure 2 shows an arrangement suitable for this method comprising pressure plates **21** and **22** of a hydraulic press between which is interposed a stack comprising the following elements: first a Transite plate **23** against pressure plate **22** carrying an induction coil **24** disposed in suitable groovings in the plate. Above the Transite plate are stacked a carbon plate **25**, the aluminum sheet **26** coated with silver layer **27**, steel plate **28** coated with silver layer **29** in contact with silver layer **27**, carbon plate **30** and upper Transite plate **31**, grooved to carry induction coil **32**. A hood **33** operating in a sand seal **34** encloses the stack and permits the assembly to be enveloped in hydrogen. High frequency currents through induction coils **24** and **32** heat up the carbon plates **25** and **30** and the aluminum and steel layers until the pressure bonding temperature is reached. Pressure is applied either simultaneously or subsequently by pressure plates **21** and **22** to complete the bond between the two silver surfaces. If relatively thick aluminum and steel layers are used, the bonded slab may subsequently be rolled down to a suitable thickness for the use contemplated.

In some cases the carbon plates **25** and **30** may be eliminated in the assembly described and the aluminum and steel plates heated directly by the induction coils. The plates may also be heated by a hydrogen flame or by substituting heating coils for the induction coils **24** and **32**. In this case the heating coils are mounted as closely to the aluminum and steel plates as possible.

Another suitable method consists in stacking a number of bimetal assemblies on top of each other into a furnace operating in a non-oxidizing atmosphere. Hydraulic or mechanical means are provided to move the bottom of the furnace against the bimetal stacks thereby exerting sufficient pressure to cause "cold" welding of the silver faces to each other.

It is sometimes desirable, especially where subsequent reductions are to be made, to place the aluminum slab into a recess in the steel. The recess may be formed by a machining operation or by use of a prerolled steel section such as a U or I section. The steel recess may be electroplated with silver or coated with silver by other methods and the aluminum slab which has been carefully cleaned and coated with silver and then placed in the recess after which the assembly is heated and rolled in a reducing atmosphere to complete the bond.

If the side walls of the steel section are tightly crimped over the coated aluminum to force the latter into intimate contact with the coated steel, it will not always be necessary to roll the assembly in a reducing atmosphere as sufficient pressure will be maintained between the surfaces to substantially exclude oxidizing gases prior to bonding. The higher expansion coefficient of aluminum also promotes a tight joint.

Figure 3 shows a steel U section **35** lined with a silver layer **36** and enclosing a slab of aluminum **37** to be bonded to the silver plated steel surface. The edges of the steel are crimped over at **38** to substantially seal the joint preparatory to rolling.

Figure 4 shows an assembly using a steel I section **39** both grooves of which are plated with silver layers **40** after which aluminum slabs **41** are inserted and the edges **42** of the steel flanges are turned over on top of the aluminum slabs.

After bonding, the assemblies are rolled down to the desired thickness, the flanges on the steel members preventing the spreading of the more plastic aluminum during rolling and thus maintaining the same ratio of aluminum to steel as the overall thickness is reduced.

While the thickness of the silver bonding layers may vary considerably, it is preferred for most applications that the total thickness of silver between the aluminum and steel amount to between .0003″ to .006″. Thus where both the aluminum and steel surfaces are plated with silver prior to bonding, each layer of silver may be within the range .00015 to .003″. If the bonded overlay metal is subsequently reduced by rolling, the thickness of the silver layer will of course also be reduced in the finished bimetal.

Silver offers several advantages in the making of aluminum-steel overlay metals as described herein. The silver bonds readily to both aluminum and steel and while the metallurgical characteristics of this excellent bond are not completely understood, it is believed that the bonds consist of a combination of fine silver, silver-aluminum alloys and silver-iron alloys. Since silver welds readily to itself at relatively low temperatures such as 350 to 500° C. the bonding can be produced without the detrimental effects of overheating the aluminum.

Various steels may be used in forming the overlay metal such as ductile carbon or alloy steels in addition to low carbon steel. Commercial aluminum or aluminum base alloys may be used for the aluminum component.

Austenitic steels such as nickel, nickel manganese, nickel chromium compositions may also be used having a coefficient of expansion matching the coefficient of the aluminum or aluminum alloy, or in some cases the steel may be selected to match the coefficient of the silver layer.

In place of steel, ductile nickel and cobalt base alloys may be used, such as Monel metal, and the standard nickel-manganese alloys, such as A, B, C and D nickel.

Figure 5 shows another embodiment of the invention wherein a case and silver coated aluminum alloy bearing lining half shell **43** is pressed into a silver coated half shell backing **44**. The lining is bonded to the backing by simultaneously applying heat and pressure between suitably formed dies in a reducing atmosphere. The two silver coatings weld together into a single bonding layer **45**.

The term "aluminum" in the claims is intended to include aluminum base alloys.

While specific embodiments of the invention have been described, it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. The continuous method of making aluminum-steel overlay metal from layers of aluminum and steel which comprises cleaning the bonding surfaces of the aluminum and steel layers, coating the cleaned surfaces of both said layers with layers of silver having thicknesses not over .003″, placing said layers of aluminum and steel together with the silver coatings in contact, preheating the layers in a non-oxidizing atmosphere to a temperature below the melting point of silver and between about 350° and about 500° C., and hot rolling said preheated layers to reduce the thickness of the layers and to permanently bond the layers together.

2. The continuous method of making an aluminum-lined steel-backed bearing which comprises cleaning the bonding surfaces of an aluminum lining and of a steel backing layer, passing the said layers through individual silver plating baths to deposit thereon coatings of silver having thicknesses not over .003″, placing said layers together with the silver coatings in contact, preheating the layers in a non-oxidizing atmosphere to a temperature below the melting point of silver and between about 350° and 500° C., and hot rolling said preheated layers to reduce the thickness of the layers and to permanently bond the layers together.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
625,117	Martin	May 16, 1899
673,126	Martin	Apr. 30, 1901
685,758	Griffith	Nov. 5, 1901
757,852	Wachwitz	Apr. 19, 1904
894,163	Monnot	July 21, 1908
894,164	Monnot	July 21, 1908
909,924	Monnot	Jan. 19, 1909
929,778	Monnot	Aug. 3, 1909
1,156,169	Monnot	Oct. 12, 1915
1,554,097	Jordan	Sept. 15, 1925
1,731,790	Payne	Oct. 15, 1929
1,792,377	Jordan	Feb. 10, 1931
1,850,997	Assmann	Mar. 29, 1932
2,094,483	Weder	Sept. 28, 1937
2,171,040	Merritt	Aug. 29, 1939
2,266,276	Schluchter	Dec. 16, 1941
2,266,319	Hobbs	Dec. 16, 1941
2,269,523	Deutsch	Jan. 13, 1942
2,277,023	Steiner	Nov. 17, 1942
2,289,572	Underwood	July 14, 1942
2,294,404	Hensel	Sept. 1, 1942

(Other references on following page)

UNITED STATES PATENTS

Number	Name	Date
2,317,150	Barklie	Apr. 27, 1943
2,366,168	Bakarian	Jan. 2, 1945
2,484,118	Reynolds	Oct. 11, 1949

FOREIGN PATENTS

Number	Country	Date
26,375	Great Britain	1903
29,577	Great Britain	1897
545,023	Great Britain	May 7, 1942

OTHER REFERENCES

P. 130, Aviation, Jan. 1927, pub. by the Gardner Pub. Co., Inc. Copy in Aviation, vol. 22, Library P.O. T1, 501, A8.

Pp. 188, 189, 271, 272, Silver in Industry (1940) by Lawrence Addicks, Reinhold Pub. Corp., 330 West 42nd St., New York, N.Y. (Copy in Div. 14.)