

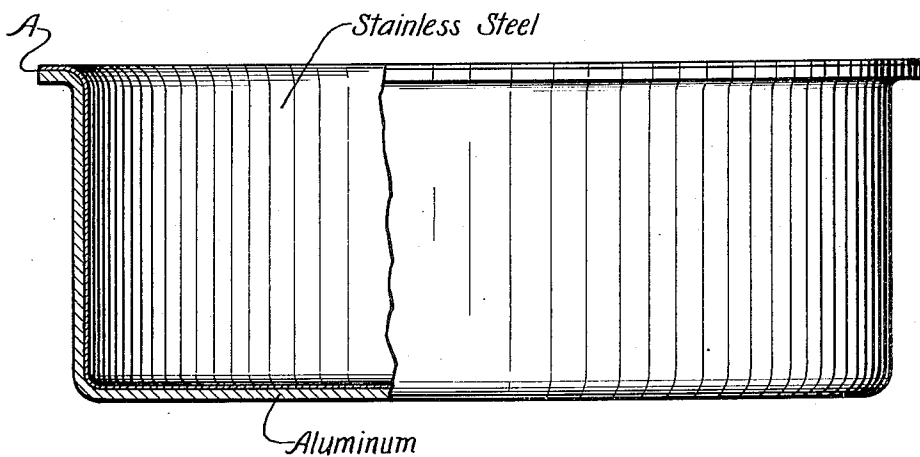
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COMPOSITE SHEET METAL BODY AND METHOD OF PRODUCING THE SAME

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COMPOSITE SHEET METAL BODY AND
METHOD OF PRODUCING THE SAME

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This invention relates to the production of composite metal bodies. It particularly concerns the production of a composite metal body of aluminum and stainless steel.

5 In the past various attempts have been made to join the surfaces of iron and aluminum sheets to form a composite metal body possessing the desirable qualities of each metal. These meth-
10 ods, which in general consisted in placing the two sheets in juxtaposition and repeatedly rolling them together with or without the applica-
15 tion of heat, have met with some degree of success but have never attained wide application. The group of steel alloys known as stainless steels, as
20 contrasted with ordinary steels, have not heretofore been successfully joined with aluminum because of difficulties arising from the inherent
25 qualities of these alloys. Stainless steels are more resistant to deformation than iron or low carbon or mild steel. There is an absence of any sub-
30 stantial amount of diffusion between stainless steels and aluminum surfaces when brought into intimate contact under heat and pressure which
35 is not true in the similar case with iron or mild steel. Moreover, when heated, stainless steels exhibit a tendency to form a surface oxide film
40 which increases the difficulty of securing a metal-to-metal contact. The difficulty of reconciling the higher annealing temperature of a ferrous
45 metal with the low melting point of aluminum during the simultaneous working of the two is accentuated in the case of stainless steels.

It is an object of the present invention to provide a composite metal body of aluminum and stainless steel, the component parts of which are
50 firmly and tenaciously bonded together, and more particularly to provide a method of securing such a firm, tenacious bond between aluminum and stainless steel surfaces. A further object is to
55 provide a method of producing a composite sheet metal body of aluminum and stainless steel wherein the aluminum is characterized by its fine grain structure. Another object is to produce a composite sheet metal article composed of stainless steel and fine-grained aluminum without sacrificing the characteristic properties of either metal.

By our invention we have provided a method of securing a firm and tenacious bond between
50 aluminum and stainless steel surfaces, consisting in a combination of working and heating steps during which the aluminum element is brought into intimate contact with the surface of the stainless steel element. It has been found that
55 by cleaning the surfaces to be joined, bringing

them into close contact, heating to a temperature of between 600 and 900° F., and then exerting a continuous pressure sufficient to produce a substantial flow of aluminum, a satisfactory preliminary bond may be formed. By means of a fur-
5 ther heating or annealing treatment at or somewhat above the recrystallization temperature of the aluminum, the strength of this preliminary bond may be greatly increased. It has been
10 found that the preliminary bond is of sufficient strength to allow, if desired a step of metal working such as shaping by drawing, before the bond
15 is perfected by further heating. It has also been found that the aluminum portion of such a composite metal may be softened by heating to a
20 temperature somewhat below the temperature of recrystallization of the aluminum to expedite working of the composite metal, either before or after heating at the higher temperature to perfect the bond, without affecting either the bond
25 between the metals or other characteristics of aluminum, such as grain refinement.

The mechanical properties of these composite metal bodies may be made to approach those of stainless steel by forming a body consisting prin-
30 cipally of stainless steel and a thin surface of aluminum, or the mechanical properties may be made to more closely resemble those of aluminum by forming a composite of a thick layer of alu-
35 minium and a thin layer of stainless steel. Of paramount interest among these useful composite metals is one composed of two layers, one a relatively thick layer of aluminum and the
40 other a relatively thin layer of stainless steel. This composite metal is useful in the production of cooking utensils. A utensil produced from
45 such a composite metal, the aluminum surface forming the exterior surface and the stainless steel the interior surface, retains the principal advantages of aluminum, that is, light weight
50 and high heat conductivity, and possesses, in addition, the advantages of stainless steel as an interior surface, that is, high hardness and resistance to staining. The heat distribution throughout the body of such utensil is very uni-
55 form on account of the thick aluminum body portion, and resistance to heat flow through the interior stainless steel layer and through the bond between the layers of metal has been found to be practically negligible owing to its thinness and the intimate contact with the aluminum.

In the practice of this invention it has been found necessary to consider the individual characteristics of the metals forming the composite metal to secure the most advantageous results.

Stainless steel is not appreciably affected during this working and heating process, except to be hardened if the pressure used to reduce the thickness becomes great enough to cause an appreciable reduction of the steel layer. The temperatures used to treat the aluminum are not sufficiently high to have any appreciable softening effect upon the stainless steel portion, and it is practicable to draw this metal only in a relatively soft condition. The ductility of the stainless steel decreases as the metal is cold-worked, as by a reduction in its thickness, and this loss of ductility increases rapidly as the amount of cold work is increased. It has been determined in general that the amount of work put in the annealed stainless steel portion of an aluminum and stainless steel composite by a reduction of 50 per cent in thickness, or over, is sufficient to work-harden the stainless steel above the point that it can be satisfactorily drawn. However, after the bond has been improved by annealing, such a composite may be further reduced in thickness, if desired, by rolling. At or somewhat below a 50 per cent reduction of the composite metal, articles requiring a relatively small amount of working may be formed without difficulty. For the purpose of forming articles such as cooking utensils requiring a deep drawing operation, a composite sheet preliminarily joined during a reduction in thickness of 15 to 20 per cent, with a corresponding reduction in the thickness of the stainless steel, is preferred. Aluminum, on the other hand, tends to form a coarse crystalline structure if annealed at or above the temperature of recrystallization when the amount of cold work is much below an amount equivalent to about a 30 per cent reduction in thickness. Therefore, if a coarse crystalline structure is not desirable in the finished article, it is preferable, in forming a composite metal which is to be subsequently shaped, that a small reduction in the thickness of the aluminum layer be made in the joining process, such as would correspond to from 15 to 20 per cent reduction of the composite metal, and that sufficient working in the drawing process to increase the total cold work in the aluminum layer to an amount equivalent to a 30 per cent or more reduction in thickness be interposed between the bonding and heat-treatment to attain a fine-grained aluminum layer in the finished article. In the production of sheet or other articles which require no work in shaping or forming, or in case the work is to be done subsequent to heating, the reduction of the composite sheet must amount to 30 per cent or more in the joining operation, if a fine-grained aluminum is to be attained in the fully bonded product.

The terms cold-rolling and cold-working as herein employed signify deformation of the metal below the temperature of recrystallization. For the purpose of defining the present invention the amount of cold work performed on the metal is expressed throughout the specification and claims in terms of reduction in thickness as effected by cold-working. When the deformation of the metal is accomplished other than by cold-rolling, as by drawing, for example, or by cold pressing or other means, the measure of the amount of cold work performed obviously cannot be expressed directly in terms of reduction in thickness of the metal, since other factors may be involved, such as bending. In the press drawing operation the working of the metal may or may not be quite severe according to the shape

of the dies and such other considerations as are familiar to those skilled in the art to which the present invention appertains. It will be understood that for any given metal working operation there can be found a point at which the amount of cold work performed is substantially equivalent to that occasioned by a stated percentage of reduction in thickness by cold-rolling. Hence, reference will be had to percentage reduction in thickness by cold-rolling or an equivalent amount of cold work as produced by drawing or other working of the metal.

A composite sheet of aluminum and stainless steel made in accordance with our invention possesses a strong ductile bond between the two metals. This bond, we have found, possesses sufficient ductility to withstand severe drawing operations without a separation between the two metals. Under some conditions, as in the Ericksen cupping test, for example, it has been discovered that the sheet may be actually fractured without a failure of the bond. The Ericksen test, which is described in a number of technical publications, comprises clamping the sheet metal to be tested between a die having a circular opening of 27 mm. diameter and an annular internally threaded holder having an externally threaded rotatable tool mounted therein and co-axially aligned with the circular opening in the die. The end of the tool which comes in contact with the sheet metal, and which has sloping sides and a round nose with an end radius of 10 mm., is forced against the specimen by rotating the threaded tool in the holder, the rotation thus being transformed into a forward motion of the tool. A cup is thus formed in the specimen which becomes deeper as the tool is advanced, until a fracture occurs in the metal. The depth of the cup, registered in millimeters, at the time that the break in the metal first appears, is taken as a measure of the ductility of the material. In order to ascertain the ductility of the bond in the case of composite sheets, the cupping test need only be carried to the point where a rupture occurs in the bond between the two metals. Such resistance to separation is indicative of a high shear strength of the composite sheet. This tenacity of bond between the two metals is of particular importance in making drawn articles since there is little or no danger of separation between the two metals even up to the point of fracture of the sheet, a point that would be obviously avoided in commercial operations. For this reason, we consider that our composite sheet is capable of taking a deep draw. This term, deep draw, here refers to the capacity of the sheet to take a draw where the depth of the depression is at least 25% of the minimum transverse dimension of the depression as measured across the said depression in the plane of the original undrawn sheet which in the case of a circular depression would be the diameter of the depression or cup.

In making such draws, the composite sheet undergoes some reduction in thickness but the reduction is not uniform over the entire surface of the sheet since the greatest deformation occurs at the sharp bends. Because the deformation is thus localized, it becomes necessary for commercial purposes to have a material that can withstand both slight and severe working operations. We have found that the ductility of our composite sheet, especially the bond, permits a wide latitude in the severity of the drawing

operations, and it is therefore adapted to the manufacture of a wide variety of articles.

Throughout this specification and the appended claims the term "aluminum" is intended to include not only the unalloyed metal but also all alloys of aluminum containing an aluminum content of 75 per cent or more. Among the aluminum alloys applicable to this process the following are given as examples:

10 Aluminum of commercial purity having an aluminum content of 99.20 per cent or more.
Aluminum of commercial purity alloyed with 1.25 per cent manganese.

15 Aluminum of commercial purity alloyed with 4 per cent copper, 0.5 per cent manganese, 0.5 per cent magnesium.

Aluminum of commercial purity alloyed with 4.5 per cent copper, 0.8 per cent silicon, 0.8 per cent manganese.

20 It has been found desirable to use aluminum alloys containing less than 0.5 per cent magnesium.

Likewise, by the term "stainless steel" is meant all alloys of steel, chromium and nickel generally known under this term, that is, steel alloys containing up to 30 per cent chromium and up to about 12 per cent nickel. The carbon content of stainless steel is usually about 0.1 to 0.4 per cent or less, and other metals such as titanium or silicon are sometimes present in small amounts. By virtue of these alloying elements and the heat-treatment, the metal has properties quite different from those of ordinary steel. Notable among these new properties is its resistance to corrosion or staining. Of the stainless steels, the preferred alloy is one containing 18 per cent chromium and 8 per cent nickel due to its good stain-resisting properties and workability.

In the preferred practice of this invention the aluminum and stainless steel surfaces to be joined, for example an aluminum alloy sheet containing 1.25 per cent manganese and an 18 per cent chromium-8 per cent nickel stainless steel sheet in annealed condition, are cleaned of grease as by washing with a solvent, and any loose material lightly attached to the surface removed. In some cases it may be found desirable to roughen the surfaces. The cleaning and roughening operations may be effected simultaneously by chemical etching. It is customary to etch the stainless steel surface on account of its extreme hardness, and to otherwise clean and/or scratch-brush the aluminum surface.

The sheets with the roughened surfaces are placed in close contact with each other and heated to a temperature of 800° F. The sheets may, of course, be heated separately if desired. This temperature may be varied from 600° to 900° F., but should not be below 600° F. The time of heating after the desired temperature has been attained is not important. After prolonged heating, unless the freshly cleaned surfaces are adequately protected, a film of oxide will form which is detrimental to the subsequent joining operation. Oxidation of the prepared surfaces may be easily controlled by extending the outer sheets of metal and welding the edges together to form an envelope, which can be sheared off after rolling, or by placing the sheets with the prepared surfaces in contact and applying pressure to the pack during heating, or by simply heating the contacting sheets rapidly to the desired temperature and removing immediately from the heat, employing, for example, a heating period of ten minutes.

75 This pack, at a temperature of 600° to 900° F.,

and preferably from 800° to 850° F., is subjected to a pressure sufficient to cause the softer aluminum to flow into the minute crevices of the surface of the harder stainless steel, which forms a temporary bond of considerable strength. The pressure is preferably applied by means of pressure rolls. The pack is passed through the rolls but once, as the bond is fully formed at the first pass and tends to be destroyed by further rolling due to the crawling of the aluminum over the harder stainless steel surface. The pressure is preferably sufficient to cause at least a 5 per cent reduction in the thickness of the composite metal. When rolls are used to effect this preliminary joining, it has been found desirable to form a pack of sheets to be joined in such a manner that a similar metal surface will be presented to each roll; otherwise, the rolling action may be uneven. This may be accomplished in the case of joining a sheet of aluminum and a sheet of stainless steel by rolling two pairs of sheets with the stainless steel sheets in contact in the center and the aluminum sheets in contact with the rolls. The same result may be attained by rolling a single sheet of stainless steel with a single sheet of aluminum, and at the same time applying a small tension to the composite sheet coming from the rolls, tending to draw it through the rolls. It is desirable to fasten the ends of the sheets which are to enter the rolls by welding or riveting through the pack.

After the composite metal is preliminarily bonded and, if desired, subjected to a drawing step, it is heated up to or above the temperature of recrystallization of aluminum, or from 600° to 900° F., for a short time. The preferred temperature is 750° F. While the strength of the joint between the two metals which have been reduced in thickness an amount of 5 per cent or more will, after heating to from 600° to 900° F., be found to be greatly improved, the joint between the metals which have been reduced more than 5 per cent in thickness, or which have received further cold-working, as by the subsequent drawing operation, will be found after heat-treatment to possess even greater strength. Contrary to processes joining metal surfaces depending upon the ready diffusion of metal between the contacting surfaces, the bonding action of this invention is not improved by a prolonged heating, fifteen minutes to one hour being sufficient.

In case it is desired to interpose a drawing or forming step between the preliminary bonding and the subsequent heat-treating steps, the preliminarily bonded composite sheet can be drawn to an extent which will not destroy the bond. The operation of drawing proceeds without difficulty, as, contrary to additional rolling in the joining operation, there is no tearing or separating of the two layers under ordinary conditions. It will be understood that in some cases the preliminary bond may not possess sufficient strength to allow the completion of the drawing operations contemplated, and in such cases it may be desirable to perfect the bond by heating before drawing, or between successive drawing steps. Often it is desirable to form the preliminarily bonded composite article except for one step of working, for example beading of a pan edge, complete the bond, and subsequently complete the working operation. It will be understood that if the preliminary bond is once ruptured it cannot be improved by further heating.

In drawing these composite metals, the operation, except in the case of shallow articles, is

customarily accomplished in a series of small drawing steps. In the case of forming or working composites of a relatively thick layer of aluminum and a thin layer of stainless steel, if work-hardening occurs during the drawing process, the metal may be softened by heating to a temperature below the recrystallization temperature of aluminum, preferably about 400° F. This softening treatment does not affect the temper of the stainless steel, or the nature of the bond, or any subsequent improvement or strengthening of the bond by annealing at higher temperatures, but it does soften the aluminum portion and may be repeated as often as desired between successive steps of the forming operation.

The method of producing a bond between aluminum and stainless steel surfaces is applicable to the production of composite metals composed of more than two layers, and useful multi-layer composite metals may be produced consisting of two or more layers of aluminum and/or two or more layers of stainless steel.

A more complete understanding of the production of this novel composite metal and its application to the fabrication of various articles may be had by reference to the drawing and to the detailed description given hereinbelow.

The drawing shows a pan in partial section to illustrate, in exaggerated form, the composite metal sheet from which it is formed. The aluminum section shows a fine grain structure. The thin layer of stainless steel is firmly bonded to the thick aluminum layer along the contacting surfaces A.

The process of manufacture of this pan from sheets of the two metals forming the composite sheet was as follows:

A sheet of aluminum of commercial purity containing 99.2 per cent aluminum, with the balance impurities ordinarily occurring, consisting of iron, silicon, and copper, having an approximate thickness of .046 inch was scratch-brushed to form a clean, rough surface and the roughened surface placed in contact with the surface of an annealed stainless steel sheet of .006 inch thickness, which contained, in addition to iron, about 18 per cent chromium and 8 per cent nickel, said sheet having been etched with a solution of nitric and hydrofluoric acids. The pack was placed in the furnace and heated to 800° F. for a period of 30 minutes. The pack was then removed and immediately passed once through pressure rolls set to give 20 per cent reduction in thickness of the aluminum section of the composite pack. A circular disc was cut from the composite sheet, which had a total thickness of 0.040 inch, and placed in a drawing press with the stainless steel surface facing the punch, in order that the finished utensil would possess an aluminum exterior and a stainless steel interior. The pan was formed in three drawing operations, and was then heated to a temperature of 650° F. for a period of 20 minutes. The pan was then ready for finishing. The aluminum surface, after this treatment, was found by test to consist of a smooth, fine-grained aluminum, firmly bonded to the hard stainless steel interior.

To show the remarkable efficiency in heat conductivity of this composite metal utensil, the above pan was placed on a uniformly heated hot plate beside a solid aluminum sheet pan of equal thickness and size. A liter of water was placed in each container. The water in the two pans reached the boiling temperature simultaneously, showing that neither the contact joint between

the two layers of the composite metal nor the greater resistance to heat flow of the stainless steel portion had any appreciable effect on the heat conductivity of the composite metal when compared to solid aluminum.

This application is a continuation-in-part of our copending application, Serial No. 728,228, for Composite sheet metal body and method of producing the same, filed May 31, 1934.

Now having described in accurate detail our invention and shown how it may be carried out, what we claim is:

1. The method of joining aluminum and stainless steel sheets, comprising heating said sheets in contact with each other to a temperature of about 600 to 900° F, subjecting said heated contacting sheets to a continuous pressure to produce at least a 5 per cent reduction in the combined thickness of the sheets, and afterwards reheating the joined sheets to a temperature of about 600 to 900° F.

2. The method of joining aluminum and stainless steel sheets, comprising cleaning and roughening a surface of the sheets to be joined, heating said sheets with the roughened surfaces in contact with each other to a temperature of from 800 to 850° F., subjecting said heated contacting sheets to a single pass through pressure rolls sufficient to produce at least a 5 per cent reduction in the combined thickness of the sheets, and afterwards reheating the composite sheet to a temperature of about 750° F.

3. The method of joining aluminum and stainless steel sheets, comprising cleaning and roughening a surface of the sheets to be joined, heating said sheets with the roughened surfaces in contact with each other to a temperature of from 800 to 850° F., subjecting said heated contacting sheets to a single pass through pressure rolls sufficient to produce at least a 15 to 20 per cent reduction in the combined thickness of the sheets, and afterwards reheating the composite sheet to a temperature of 750° F.

4. In the method of producing drawn composite metal articles from aluminum and annealed stainless steel sheets, the steps comprising heating said sheets in contact to a temperature of from 600 to 900° F., subjecting said contacting sheets to a continuous pressure sufficient to produce substantial flow, drawing the preliminarily bonded composite metal, and heating to at least the temperature of recrystallization of the aluminum.

5. In the method of producing drawn composite metal articles from aluminum and annealed stainless steel sheets, the steps comprising heating said sheets in contact to a temperature of from 600 to 900° F., subjecting said contacting sheets to a continuous pressure sufficient to produce substantial flow, drawing the preliminarily bonded composite metal, heating to at least the temperature of recrystallization of the aluminum, and working the fully bonded metal.

6. In the method of producing drawn composite metal articles from aluminum and annealed stainless steel sheets, the steps comprising heating said sheets in contact to a temperature of from 600 to 900° F., subjecting said contacting sheets to a continuous pressure sufficient to produce substantial flow, drawing the preliminarily bonded composite metal, heating to at least the temperature of recrystallization of the aluminum, and drawing the fully bonded metal.

7. In the method of producing drawn composite metal articles from aluminum and annealed

stainless steel sheets, the steps comprising heating said sheets in contact to a temperature of from 800 to 850° F., rolling said contacting sheets to effect a 15 to 20 per cent reduction of the combined thickness of the sheets, drawing the preliminarily bonded composite metal, and heating to 750° F.

8. In the method of producing drawn composite metal articles from aluminum and annealed stainless steel sheets, the steps comprising heating said sheets in contact to a temperature of from 600 to 900° F., subjecting said contacting sheets to a continuous pressure to effect substantial flow, drawing the preliminarily bonded metal, heating to a temperature below the temperature of recrystallization of the aluminum, drawing to shape, and heating to at least the temperature of recrystallization of the aluminum.

9. In the method of producing a composite sheet metal article, the body of which consists of a layer of fine-grained aluminum and a layer of stainless steel firmly bonded together, the steps comprising heating said sheets to a temperature of 600 to 900° F., subjecting said sheets placed in contact to a pressure sufficient to cause a 5 per cent reduction of the combined thickness of the sheets, drawing the thus preliminarily bonded composite metal to simultaneously shape and produce an amount of cold work equivalent to a reduction in thickness of at least 25 per cent by rolling, and heating to at least the temperature of recrystallization of the aluminum.

10. In the method of producing a composite sheet metal article, the body of which consists of a layer of fine-grained aluminum and a layer of stainless steel firmly bonded together, the steps comprising heating said sheets to a temperature of 800 to 850° F., subjecting said sheets placed in contact to a pressure sufficient to cause a 15 to 20 per cent reduction of the combined thickness of the sheets, drawing the thus preliminarily bonded composite metal to simultaneously shape and produce an amount of cold work equivalent to a reduction in thickness of at least 10 to 15 per cent by rolling, and heating to at least the temperature of recrystallization of the aluminum.

11. The method of joining aluminum and stainless steel sheets comprising heating said sheets in contact with each other to between 600 and 900° F., subjecting said contacting sheets to a pressure sufficient to cause a substantial flow of the aluminum, and then reheating the composite body to between 600 and 900° F.

12. The method of producing a composite sheet of fine grained aluminum firmly bonded to stainless steel comprising heating sheets of said metals in contact with each other to between 600 and 900° F., subjecting said contacting sheets to a pressure sufficient to cause at least a 30 per cent reduction in thickness of the aluminum sheet, and subsequently reheating the composite sheet to between 600 and 900° F.

13. As an article of manufacture, a composite sheet of aluminum and stainless steel capable of being drawn to a depth of at least 25 per cent of the minimum transverse dimension of the drawn portion as measured in the plane of the original undrawn sheet, said sheet being characterized by a continuous, firm, intimate, and ductile bond between the two metals over their entire contacting surfaces, said bond being independent of any intervening third material, and capable of retaining said properties when fractured by the Ericksen cupping test.

14. As an article of manufacture, a hollow, drawn composite sheet metal utensil having an inner surface of stainless steel and an outer surface of aluminum, said utensil being drawn to a depth of at least 25 per cent of the drawn portion, as measured across the minimum transverse dimension in the plane of the original undrawn sheet, and being drawn from a composite sheet of said metals bonded together over their entire contacting surfaces, said bond being continuous, firm, intimate and ductile, and independent of any intervening third material, and capable of retaining said properties when said composite sheet is fractured by the Ericksen cupping test.

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