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CLADDING PROCESS

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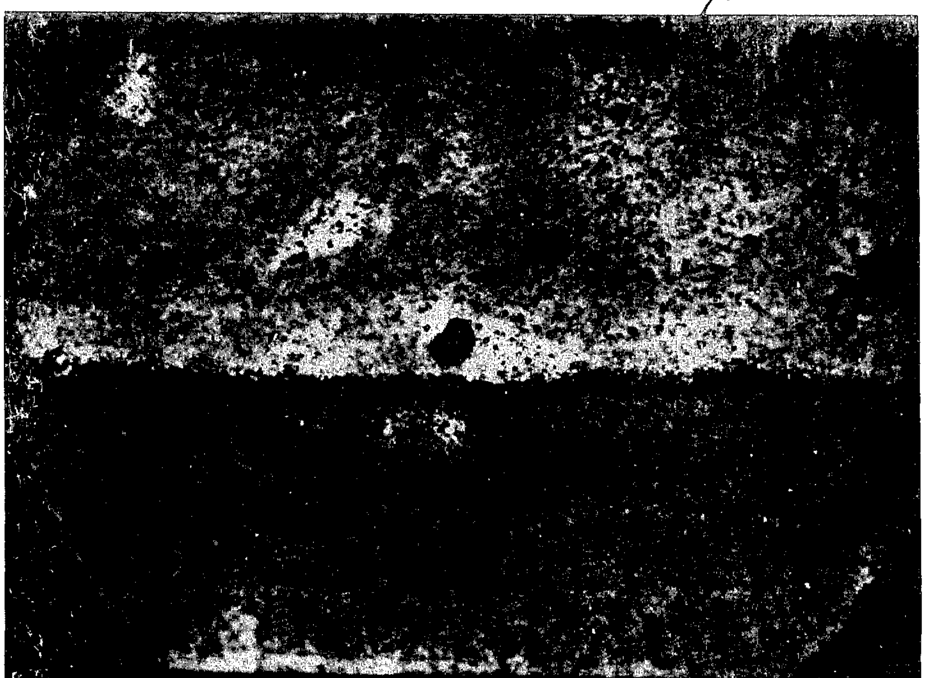

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CLADDING PROCESS

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This invention deals with a process of producing integral metallic structural elements or members which have a metal-containing core and one surface layer on each side of said core and in which said surface layers consist of a metal different from that of the core.

For many purposes corrodible metals have to be used on account of some other properties that are desirable or necessary. Such corrodible metals then are advantageously protected by surface layers such as coatings, platings, or claddings with a less corrodible metal, this especially when they are to be used under corrosion-causing conditions. In most of such instances it is important that a firm and durable bond is obtained between the surface metal and the core. This is necessary, for instance, if a final member of good heat conductivity and of great shape and dimensional stability is needed. Another reason for a complete bond between core and cladding is the desirability of avoiding leaks through which the corrosive means could penetrate to the core whereby the purpose of such surface layers would be defeated.

Clad elements of the nature just described are being used, for instance, in the construction of aircraft engines. Control rods for neutronic reactors also frequently consist of a core of corrodible material, such as cadmium or boron, and therefore have to be clad with a noncorrodible protective metal. The uranium fuel elements of a great many types of neutronic reactors require cladding, and zirconium metal, for instance, has been used satisfactorily for this purpose; it protects the uranium against corrosion by the coolant and also prevents the spread of fission products. Also in the case of fuel elements the bond between the cladding material and the core must be of high quality so that their heat conductivity during service and durability are satisfactory.

Clad elements or articles of the types just described have been made heretofore by stacking strips or pieces of the core material between a top plate and a bottom plate of the cladding metal; welding the edges of the assembly thus formed, preferably with the interior evacuated; then enclosing the assembly in a steel rolling box to prevent the access of air; and finally roll-bonding the assembly with sufficient rolling pressure to reduce the thickness of the assembly. Usually a reduction by about 90% was considered necessary to obtain a sufficiently firm bond.

The articles obtained by this procedure previously used, however, lacked homogeneity on account of the discontinuous character of the bonds in the interfaces. Moreover, on account of the high degree of reduction required, these conventional processes are rather tedious and it is also difficult to produce the predetermined dimensions of the final article with the preciseness required. The core of the final unit, due to the high degree of reduction produced, frequently has a faulty location so that an unreasonably high proportion of the products had to be rejected. The necessity of using rolling boxes, which have to be discarded after each use, also makes the process costly.

Clad articles have also been made by a seal-welding step without a reduction of the dimensions; reduction or other fabrication processes were then applied in a separate, subsequent operation. These subsequent fabrication steps, however, often impaired or destroyed the bond produced.

It is an object of this invention to provide a process of bonding protective metal layers to a metal-containing core whereby the disadvantages outlined above are overcome.

It is another object of this invention to provide a process of bonding protective metal layers to a metal-containing core which is characterized by greater simplicity.

It is another object of this invention to provide a process of bonding protective metal layers to a metal-containing core in which bonding and reduction to predetermined dimensions and desired heat treatment are carried out in one step simultaneously.

It is still another object of this invention to provide a process of bonding protective metal layers to a metal-containing core in which a relatively small degree of reduction is necessary to obtain a durable bond.

It is still another object of this invention to provide a process of bonding protective metal layers to a metal-containing core in which a smooth and continuous bond is obtained between core and plate metals and an integral end product is obtained.

It is another object of this invention to provide a process of bonding protective metal layers to a metal-containing core by which a complete seal of the core is accomplished, said seal being impervious to water or other corrosive media.

It is a further object of this invention to provide a process of bonding protective metal layers to a metal-containing core by which predetermined dimensions of the article can be reached with a high degree of precision, so that the proportion of articles that have to be rejected upon examination is reduced.

It is still another object of this invention to provide a process of bonding protective metal layers to a metal-containing core for which relatively low rolling power and short duration of heating are necessary.

It is also an object of this invention to provide a process of bonding protective metal layers to a metal-containing core in which no rolling boxes are needed.

It is finally also an object of this invention to provide a process of bonding protective metal layers to a metal-containing core which can be carried out automatically and by remote control so that it can be applied to the cladding of radioactive materials.

The objects of this invention are accomplished by stacking a metal-containing core element between two metal plate elements so as to form a sandwich-like assembly, the thickness of the three elements of the assembly exceeding the final thickness desired of the clad article by between 10 and 30%; and resistance-welding by applying mechanical pressure and electrical current simultaneously and intermittently through the entire thickness of the assembly in a limited amount sufficient to cause bonding, but insufficient to cause melting, said pressure and current being applied over the entire surface area of the assembly, whereby a smooth, continuous bond between the entire area of the adjoining interfaces of said elements is accomplished and an integral unit is formed.

The process need not be carried out while excluding air and the use of rolling boxes is therefore not necessary. Likewise, preheating of the assembly is not required.

Depending upon the use intended of the final article, the cladding plates may have the same length as the core. If the ends of the core are also to be protected, an arrangement has been found advantageous that comprises placing a strip of cladding material of the same thickness as the core around, and in contact with, the four side walls of the core in a picture frame-like manner and then arranging bottom and top plates of cladding material so as to cover both the core and the frame. Resistance-welding then not only firmly bonds the core to the top and bottom plates, but simultaneously unites the frame to the plates and to the core. By this a completely clad unit is obtained.

Of course, instead of having two protective plates, the process can also be used for bonding only one surface plate to a metal piece, or a plurality of cladding plates may be applied.

Machining of the core or the plates prior to bonding is not necessary and conventional surface cleaning is entirely satisfactory. However, in the case of the bonding of zirconium plates to a uranium core, pretreatment of the core by electro-polishing and of the zirconium plates by dipping into a mixture of nitric and hydrofluoric acids was found advantageous. In the case that the core material is extremely reactive, a preliminary step of inert-arc welding under pressure in a hydraulic press was found advisable to prevent the ingress of air during the resistance seam-welding process of this invention; however, this pretreatment is optional.

A conventional resistance seam welder equipped with a brake to permit the use of intermittent drive was found satisfactory; a 100-kva. unit was used in all instances and in the example given below. However, the current capacity may be varied according to the materials and dimensions of the articles to be produced. The electrodes were wheel-shaped and simultaneously served as the immediate means for applying the pressure; in most instances they were made of pure copper. The contour of their contacting face was flat. One of the wheel electrodes was run above the sandwich assembly in contact with the top surface, while the second electrode ran below the assembly in contact with the bottom surface. By this arrangement, the electric current flowed from one electrode transversely through the entire thickness of the sandwich assembly to the other electrode. The wheels were provided with means for external cooling. While in many cases the width of the electrodes was sufficient to bond the entire areas of the interfaces in one single pass, two or three wheels are necessary in other instances where the article to be produced is wider than the wheels.

The degree of pressure exerted by the electrodes on the assembly affects the amount of contact resistance which in turn has a bearing on the temperature obtained in the assembly during welding. The higher the pressure is, the lower is the resistance and also the lower the temperature. Thus, by adjusting the pressure and also the time of pressure application, the bonding conditions can be adjusted to those necessary for each individual material. Usually it is preferable to use the elevated temperature for as short a time as possible in order to avoid melting of any of the materials, including that of the electrode. Apart from this the temperature may be adjusted so that the bonding step simultaneously accomplishes any heat treatment desired.

In the case of cladding uranium with zirconium and the use of pure copper as the electrode material, the pressure should be chosen so that a reduction of between 10 and 30% is obtained. This pressure in the case of zirconium cladding and copper electrodes is critical. A lower pressure, it was found, reduces the contact and thus increases the resistance; to much heat is then created and a eutectic forms between the copper of the wheel and the zirconium of the cladding plate and melts. Formation and melting of the eutectic impairs not only the surface of the finished article, but also ruins the electrodes so that they are not reusable. If the pressure is higher than that which causes a 30% reduction, the dimensions cannot be obtained with the predetermined preciseness.

The voltage of the current used, too, may be adjusted to the characteristcs of the metals to be bonded. Such variations, however, can be easily and empirically determined by anybody skilled in the art.

All of the bonded articles produced by the process of this invention were tested as the firmness of the bond. This was done by first filing the end surface parallelly thereto and thereafter applying the file in an angle in an attempt to pry or peel off the plated layer. In all instances the protective surface plates remained firmly bonded to the core when the filing test was applied.

Various materials can be clad by the process of this invention. Cores of uranium and of uranium alloys, for instance, can be clad with zirconium, titanium, molybdenum and vanadium metals by the process of this invention. Likewise, a core of a zirconium alloy containing 4% of uranium and 1.5% of tin and having a thickness of 0.040 inch has been satisfactorily clad with zirconium metal layers having a thickness of 0.010 inch. Another combination bonded by the process of this invention was a core of so-called nickel-silver (55% by weight of copper, 27% zinc and 18% nickel) clad with Monel metal (67% nickel, 30% copper, 1.4% iron and 1% manganese), or the same core clad with iron.

Example

An example is now being given of the process of this invention as applied to the cladding of a uranium core with zirconium. The core had a rectangular cross section; its dimensions were ½" x 0.040" x 5.5". The cladding consisted of a top place, a bottom plate, two side strips and two end strips. The top and bottom plate each was 0.010" x 6" x 1", the side strips were 0.040" x 0.25" x 6", and the two end strips were 0.040" x 0.25" x 0.5". The dimensions of the assembly were 0.060" x 1" x 6". The uranium core had been electropolished, and the cladding elements had been surface-activated by immersion in a nitric acid-hydrofluoric acid mixture. The assembly was bonded by welding it in a 200-kva. three-phase resistance seam welder with a transformer connected in parallel; the welder operated at a primary potential of 440 volts. The electrode wheels were made of pure copper, had a width of 1.5" and a diameter of 9"; their face contour was flat. Welding was carried out intermittently using a pressure of about 500 lbs. The phase shift setting was at 84% and heating and cooling time of each cycle lasted 1/60 second and 1/10 second, respectively. The actual motor speed was 21"/min. The reduction brought about was about 10%.

In the attached drawing a photomicrograph of the zirconium-clad uranium is shown after it had been anodically etched at a current density of 30 ma./cm.^{2} in a solution consisting of 5 parts by weight of orthophosphoric acid, 5 parts of ethylene glycol and 8 parts of a 95% ethanol. The smoothness, continuity and homogeneity of the bond are evident from this micrograph.

It will be understood that this invention is not to be limited to the details given herein but that it may be modified within the scope of the appended claims.

What is claimed is:

1. A process of security and uniformly bonding a uranium-metal-containing core directly to a cladding metal of the group consisting of zirconium, titanium, molybdenum and vanadium, comprising placing a strip of cladding metal of the same thickness as that of the core around said core in a picture-frame manner; placing said framed core between a bottom plate and a top plate of cladding metal to form a sandwich-like assembly consisting of said core, cladding strip, and bottom and top plates, said plates being large enough to cover both core and frame; and moving a rolling pressure and at the same time an intermittent electrical potential along the entire length of said assembly from opposite sides, whereby pressure and potential are applied through the entire thickness and over the entire width of the assembly, the assembly being allowed to cool between each pressure-electricity application whereby melting of the

metals is avoided, a continuous bond between core, strip and plates is formed and the thickness of the assembly is reduced.

2. A process of cladding a 0.04-inch thick rectangular uranium core with zirconium metal, comprising placing two side strips of zirconium and two end strips of zirconium along the sides of said core whereby a frame is formed around said core, said strips having the same thickness as said core; covering the bottom and top of said core plus the edge of the frame with a bottom and a top plate of zirconium each of which has a thickness of 0.01 inch; moving a rolling pressure of 500 pounds and an intermittent electrical potential of 440 volts along the entire length of said assembly from opposite sides, whereby pressure and potential are applied through the entire thickness and over the entire width of the assembly consisting of core, frame, bottom and top plates, said rolling pressure being moved along the length of the assembly at a speed of 21 inches per minute, said electrical potential being applied for 1/60 of a second and

interrupted for 1/10 of a second in each cycle, whereby a secure bond between cladding frame and plates is formed without any of the metals reaching melting temperature.

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