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2,813,332

PROCESS OF PREPARING COMPOSITE METAL PRODUCTS

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Fig. 1.

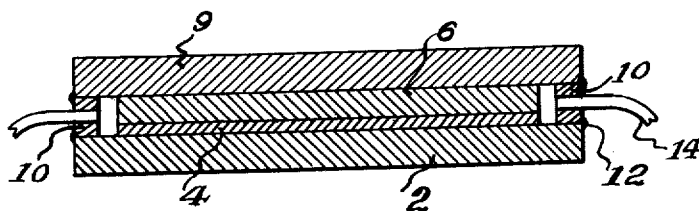
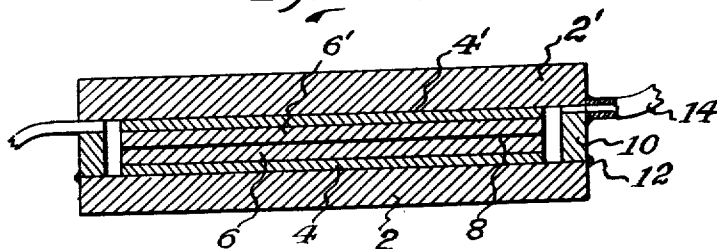


Fig. 2.



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PROCESS OF PREPARING COMPOSITE METAL PRODUCTS

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2 Claims. (Cl. 29—471.5)

This invention is a continuation in part of my previously filed application Serial No. 334,827, now Patent Number 2,786,265, also entitled Process of Preparing Composite Metal Products.

Generally, this invention relates to an improved process for producing a composite metal product, namely a titanium clad metal such as titanium clad steel. My previous application broadly involved the steps of forming a pack of metal slabs or pieces including a base layer of steel, or other metal, a titanium cladding layer of pure or alloy form, an intermediate layer of an iron-chromium alloy, and thereafter subjecting the pack to two successive heat and pressure treatments. The principal novelty in forming this pack is in the use of the iron chromium alloy as a barrier layer and in the double heating and pressure steps, these features being emphasized in Serial No. 334,827, now Patent Number 2,786,265.

It has now been found that it is possible, under some circumstances, to clad metal plate, sheet, strip or foil with titanium of commercially pure or alloy form by a solid phase bonding process which does not involve the double heating steps of my previous invention but, instead, involves the features of utilizing an iron-chromium alloy and a single heating step within a certain range, followed by sufficient pressure reduction of the pack, thereby producing a clad product having a shear strength and durability in the order of that set forth in my copending application.

It is to be understood that the disclosure of my copending application forms a part of the disclosure of this application but that this invention relates to a simplified process for producing a similar clad product.

As is well known, titanium of the pure and alloy types have excellent resistance to corrosion in many different and varied media and, therefore, titanium is a valuable metal for the construction of various equipment and structure adapted to be subjected to or exposed to such corrosive media. In utilizing titanium for such structures, it is often desirable to provide composites or laminates consisting of a corrosion resisting metal bonded to one or both sides of another metal. There are several reasons for this, one being for economy, as where, for example, expensive stainless steels are clad to cheaper carbon or alloy steel. Another reason for using titanium clad instead of pure titanium is that often structures require not only the corrosion resistance properties, but special strength properties which necessitate the use of another type of metal. Furthermore, in some instances, corrosion resistance is required on the exterior of a certain type of structure while the interior does not necessitate this and, here again, a clad product is desirable. These are only a few of the many reasons why titanium clad to steel or the like is a valuable product.

Most of the common structural and corrosion resisting metals such as carbon steel, stainless steel, nickel and nickel base alloys, heat resisting alloys, copper, copper base alloys, aluminum alloys, aluminum, silver, lead, etc., may be bonded to each other simply and readily to ob-

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tain useful clads for particular purposes but heretofore this has not been true in connection with pure titanium or titanium base alloys. As set forth in my copending application, cladding of titanium or titanium base alloys to metal such as steel has not heretofore been particularly successful due to certain metallurgical and chemical properties of titanium present during such a cladding process which involves hot rolling or forming or the like. These properties are (1) the extreme reactivity of titanium with nearly all the common atmospheric and industrial gases such as oxygen, nitrogen, hydrogen, water vapor, carbon dioxide, carbon monoxide, hydrocarbons, ammonia, etc., particularly at elevated temperatures; and (2) the extremely rapid rate of diffusion between titanium and most other common structural and corrosion-resisting metals, and the existence of weak and brittle inter-metallic or intermediate phases in the alloy systems of titanium and such other metals. Due to this combination of characteristics films or scales are formed on titanium surfaces particularly at temperatures upwards of about 1300° F. by reaction with the atmosphere and many other gases and such gases are also dissolved rapidly by the titanium to form hard and brittle alloys. Both of these effects can prevent forming strong and useful bonds between titanium and other metals by rolling, forging, pressing or swaging. Another result of the aforementioned properties of titanium is that during the hot-working operation of bonding, weak alloys will form as the result of diffusion between titanium and such common metals as iron, copper, nickel, silver and many alloys, and the bond between titanium and the other metal may thereby be actually so weakened as to render the composite unusable for certain purposes.

It is the principal object of the present invention to provide a process for producing a titanium clad metal wherein the above difficulties are greatly mitigated or overcome due to certain critical steps of the process.

Another object of this invention is to provide improvements in the process of cladding a metal with titanium.

Still another object of this invention is the provision of improved pack rolling procedures for satisfactorily cladding steel and other metals with titanium of pure or alloy form and wherein the procedures are simple and economical.

Other objects will become apparent upon referring to the accompanying drawing, wherein:

Figure 1 is a sectional view of a multiple pack, and

Figure 2 is a sectional view of another type of pack.

Referring to the drawings somewhat in detail, backing or base layers of steel or other metals, for example, metals to which steel can be readily clad, such as copper, nickel and the alloy thereof, are represented by 2 or 2'. The iron-chromium layer is shown at 4 or 4', the titanium layer by 6 or 6', a parting composition by 8, the spacer members by 10, a metal cover plate used in one form of the invention by 9, the inlet means for circulating an inert gas by 14 and welds 12. Hereinafter a specific example of the process of this invention will be provided and this example will refer to the pack of Figure 2. However, the process is clearly adapted for use in connection with the pack of Figure 1 where a single clad product results instead of in connection with Figure 2 which results in the formation of two clad products, and this should be especially understood by reference to my copending case.

The objects of the present invention are realized by forming a pack including a base layer of steel, or other metal, a titanium-clad layer of pure or alloy form, and an intermediate or barrier layer of an iron-chromium alloy. After usual conditioning steps, the pack is heated to a temperature preferably within the range of 1450° F. to 1650° F. and for a length of time in the order of one-half to one and one-half hours per inch of pack thickness. The iron-chromium alloy, which may be separate or pre-

clad to another metal as long as the other metal easily bonds to the base metal and the iron chromium abuts the titanium layer, preferably contains from about eleven to thirty percent chromium. If a piece of pure iron-chromium is employed, the surfaces engaging the base layer should be electroplated to facilitate bonding. In any event, it is to be assumed that the bond between the barrier and base layers is satisfactory. After the heating step, the pack is subjected to conventional pack rolling treatments whereby reduction of the pack in the order of a ratio of 4 to 1 occurs. By the use of the iron-chromium alloy, and by heating within the temperature range specified and reducing the pack by at least a 4 to 1 ratio, the resulting titanium bond will have a shear strength in the order of twenty thousand to forty thousand p. s. i. and of the order set forth in my copending application. Accordingly, the resultant clad product is of sufficient strength for many uses, and it may be hot formed without decreasing the effectiveness of the metallic bond. Therefore, this resultant product, which retains satisfactory bond strength even when reheated, is produced by a process which overcomes the peculiar properties of titanium that are usually involved during the cladding of titanium to steel or the like.

The present process, therefore, may preferably be employed to provide a titanium-clad product having the characteristics emphasized in this application and my copending application when the reduction of the pack consisting of the base layer of steel or the like, an intermediate layer containing solely an iron-chromium alloy or a pre-cladding of the latter on another metal and a titanium layer of pure or alloy form is at a minimum of about 4 to 1. The maximum or lower limit of reduction is not critical but depends on factors such as practicability and rolling practice. When the pack reduction is less than the four to one ratio, it would be advisable to include the double heating step and process of application Serial No. 334,827. A ratio of less than 4 to 1 is most likely to occur in commercially producing clad plates, $\frac{3}{16}$ " in thickness or greater, instead of clad sheets, strips or foils, $\frac{3}{16}$ " thickness or less. It can be seen that the amount of reduction during the rolling or pressure step is important as this increases the chances of the metals adhering and often eliminates the need for the double heating, especially in connection with sheet metals.

Of course, it is always possible to produce a titanium-clad product using the process of my copending application and this is true whether the metal sheets are greater or less than $\frac{3}{16}$ ". Also, if the facilities are available for fabricating and rolling thick packs, then it would be possible to produce an acceptable titanium-clad product in any thickness with the present process. In the event facilities aren't available, thick clad plates, for example, $\frac{3}{16}$ " or greater probably should be produced in accordance with the process of my copending application. Of course, in connection with the process of this invention and my copending application, the novel features of utilizing an iron-chromium alloy, of heating to within a certain temperature range while maintaining a flow of argon or helium gas through the pack and reducing by rolling or the like are essential in connection with both processes.

An example of the process of the present invention for manufacturing two titanium-clad steel sheets, strips or plates is as follows:

Two A-201 steel pieces 2 and 2' of approximate size are cleaned by polishing or pickling or the like as are two sheets, plates or strips 4 and 4' of type 405 stainless steel clad and two pure titanium sheets 6 and 6'. One layer 4 is placed on the clean side of steel surface 2 with the iron-chromium alloy side up. Thereafter, the titanium sheet 6 is placed on piece 4 and on top of the titanium layer 6 is placed a refractory material 8, such as a graphite suspension, to separate the titanium 6', piece 4' and layer 2' placed thereabove. The material 8 separates the titanium layers and the pack will appear as shown in Figure 2

with appropriate spacer bars 10, welds 12 and means 14 for gaseous flushing.

The pack is then placed in a furnace and heated to a temperature in the range of 1200° F. to 1850° F. and preferably between 1450° F. and 1650° F. and during this heating period, which preferably should be from one-half to one and one-half hours per inch of pack thickness, a flow of argon or helium gas is maintained through the pack by passage through means 14. The pack is then removed from the furnace, and pressure is applied by conventional rolling procedures until the pack is reduced to a minimum ratio of 4 to 1. Following this, the necessary trimming and separation of the two titanium-clad sheets, plates or strips take place and each titanium-clad product has a shear strength as previously described in the order of twenty thousand to forty thousand p. s. i. and may be reheated for, as an example, hot forming without decreasing the effectiveness of the metallic bond. The temperature range mentioned and particularly the range of 1450° F. to 1650° F. is critical and important because such is necessary to dissolve surface contaminants during rolling. On the other hand, if the temperature is too high, excessive or detrimental alloying will occur. Also, the temperature depends to a certain degree on the amount of reduction and could vary accordingly; although it should usually be maintained within the stated range.

In connection with the iron-chromium alloy, the alloy preferably is of the type having the range of between eleven to thirty percent chromium. The reason for the use of the iron-chromium alloy between the titanium and backing metal is that detrimental alloys are formed less rapidly between iron-chromium and titanium than between titanium and iron, titanium and nickel, titanium and copper, etc. as the iron-chromium alloy is metallurgically compatible with titanium. Accordingly, one of the principal features of this invention is in the use of the iron-chromium alloy in combination with heating, while flushing with gas such as argon or helium, within a certain temperature range and reducing to a minimum ratio. The second heating step within a critical temperature range, this being set forth in my copending application, may be employed and included in the combination and is a novel step usually necessary where the reduction of the pack is not at least 4 to 1.

The success of bonding titanium to the iron-chromium layer depends upon getting good metal-to-metal contact, heat and pressure. To get good metal-to-metal contact, all film, such as oxides, must be avoided. Titanium is a highly reactive metal and forms films very rapidly at elevated temperatures, which is why the pack is flushed with inert gas during heating. But even the gas flushing does not completely prevent film formation and in addition, titanium dissolves the film forming gases to give a superficial brittle alloy surface. Thus, at the time when the titanium in the pack has been heated and is just ready to be rolled, the surface has a very thin layer of brittle alloy of oxygen, nitrogen or hydrogen and also an actual film of oxide or nitride. If the titanium is not elongated and reduced enough by rolling at the critical temperature range mentioned or is not hot for a long enough time during rolling, the film and alloy will prevent, even with the use of the iron-chromium barrier layer, a strong bond. The ordinary rolling practice for hot rolled plate, strip and sheet and cold rolled strip and sheet would provide plenty of deformation and so would the rolling schedule for most clad assemblies, which are usually four to one minimum; that is, the reduction and deformation would be sufficient in combination with the temperature range, heating time and use of the iron-chromium alloy as the barrier layer to provide the strong bond desired and prevent any defects or weakening heretofore present due to the film formation and alloying.

As in my application Serial No. 334,827, now Patent Number 2,786,265, titanium alloys may be used as the

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cladding layer and in this connection reference is made to said application.

Heretofore, as in application Serial No. 334,827, now Patent Number 2,786,265, it has been stated that heating of the pack should be done in an inert gas protective atmosphere. However, the main function of such flushing is to prevent, or greatly minimize the gaseous or other reactions, with titanium, such as those previously enumerated. Accordingly, instead of flushing with an inert gas, such as helium or argon, it is within the scope of this invention to utilize in lieu thereof a vacuum arrangement or a tight seal of conventional type to prevent or considerably mitigate gaseous reaction generally.

It is to be understood that various modifications may be made in the invention as described herein without deviating from the scope and spirit thereof as defined in the appended claims.

I claim:

1. The process of making composite metal plates having corrosion-resistant facings which includes forming a pack in which a pair of corrosion-resistant metal sheets are arranged in face to face relation and sandwiched between two metal slabs, one of said sheets being composed of substantially pure titanium and the other being composed of an alloy of iron and chromium only, and wherein said alloy contains from approximately eleven percent to approximately thirty percent chromium, extending the edges of said slabs beyond the edges of said sheets to form a continuous outwardly-opening recess around the edges of said pack, hermetically sealing the open side of said recess to form a gas tight chamber adjacent the edges of said sheets, providing said pack with means to convey a gas to and from said chamber, heating said pack to a

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temperature between 1450° F. and 1650° F. for a period of between one-half and one and one-half hours per inch of pack thickness while maintaining a flow of an inert gas through said chamber to reduce the formation of oxide film in said pack, said subjecting said pack to a pressure sufficient to effect a reduction in its thickness of at least four to one and a bonding of said titanium sheet to one of said slabs with the alloy sheet between them, said slabs being formed of steel, and the pressure on the pack being effected by a rolling step.

2. A process as defined in claim 1, wherein a second pair of corrosion-resistant sheets identical in composition to said first pair is arranged between said first pair and one of said slabs with the titanium sheets arranged in juxtaposition.

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