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METHOD OF UNITING METALS

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1 Claim. (Cl. 113—112)

This invention relates to a method of uniting or bonding together separate bodies of metal or two portions of the same body of metal by means of another metal employed as a uniting or bonding metal and wherein the metal of one or both of the two bodies and the uniting or bonding metal rapidly alloy with each other, especially when subjected to heat. This application is a continuation in part of application Serial No. 417,405, filed October 31, 1941, which is itself a continuation in part of application Serial No. 391,595, filed May 2, 1941.

A difficult problem is presented in the making of a joint between metal bodies or uniting or bonding the metal bodies where the metal used as the bonding medium very readily and rapidly alloys with the metal of one or both of the bodies. On the other hand, the employment of metals having such rapidly alloying characteristics is often desirable and often necessary to the production of a desired article. For example, metals having corrosion resisting characteristics should be used where resistance to corrosion is a necessary characteristic in the finished article and yet the corrosion resisting metals of the desired type may not be usable as they cannot be satisfactorily bonded together or united by the methods heretofore known. Requirements other than resistance to corrosion may dictate the use of various metals.

A number of metal combinations fall within the classification contemplated herein. The term "metal combination" is used with reference to the metal in one or more of the bodies which are to be united and the metal used as the bonding medium. In these metal combinations the body metal is the one with the higher melting temperature and the bonding metal is the one with the lower melting temperature. Among the metal combinations are these: body metal of a copper-nickel alloy, such as Monel metal, and a bonding metal of copper; body metal of nickel and bonding metal of copper; body metal of silver and bonding metal of lead; body metal of platinum and bonding metal of gold; body metal of copper and bonding metal of bismuth; body metal of gold and bonding metal of silver; body metal of nickel and bonding metal of gold.

Alloys of the above metal combinations may be united by the method herein described where the alloys are such that the combination of metals present the problem of the rapid alloying at temperatures above the melting temperature of the bonding metal. In all instances the body

comprised of the metal in the combination may be united to a body of another metal.

In accordance with the invention the surface of at least one of the bodies is provided with a coating of the bonding metal. The two bodies are then placed together in interfacial relationship with the coating lying between the bodies and constituting one of the interfaces. Where the metal of the coating and the metal of at least one of the bodies readily and rapidly alloy with each other, the metal of the coating may be completely absorbed and alloyed into the metal of the body while in a solid state, particularly when subjected to heat. In such a case, there is a complete failure to establish a bond. Once the coating metal is rendered molten, the alloying of the coating and metal of the body or bodies alloy together with increased rapidity.

The situation is a dynamic one in that once the coating metal is rendered molten there is a rapid alloying of the coating metal and the body metal resulting in an ever increasing melting point of the alloy so formed and requiring an increase in temperature to maintain a molten state. The bonding metal employed should have a melting point lower than that of the bodies to be united. If the temperature is not increased after the bonding metal becomes molten the alloying of the bonding metal with the body metal results in the formation of an alloy which freezes as its melting point reaches or exceeds the existing temperature. This prevents the proper flowing or migration of the bonding metal and an incomplete bonding process and the failure to unite the interfaces of the bodies or portions thereof.

Accordingly, the invention contemplates and provides a method wherein the rate of increase in the temperature to which the metal bodies and the metal bonding medium are subjected, in the range above the melting point of the bonding metal and below the maximum temperature attained, is such that the increasing temperature is higher than the increasing freezing point. Thus, it may be said that the average rate of increase in the temperature is greater than the average rate of elevation of the freezing point of the alloy which is being formed by the alloying of the bonding metal and the metal of one or both of the bodies. The rate does not have to be uniform throughout the range so long as the temperature is maintained above the freezing point of the forming alloy. Also, the invention contemplates and provides a method wherein the temperature is increased with such rapidity,

throughout the temperature range below the melting point of the bonding metal, as to prevent complete alloying of the bonding metal with the body metal in a solid state. To these ends, it is preferable that the metals be heated by generation of heat within the metals as distinguished from the heating of the metals by radiation, although furnaces may be developed, such as the radiant tube furnace, which will provide a sufficient temperature gradient to effect heat transfer to the metals in a manner sufficient for the purpose. The work is preferably heated by the electrical resistance method or the electrical inductance method.

An example of the invention may be given with reference to the combination of the metal known as Monel and copper, wherein at least one of the bodies comprises Monel metal and the bonding medium comprises copper. As is well known, Monel is a metal having about 67% to 70% of nickel and the remainder of copper, except for impurities which may include a small percentage of iron. Monel metal has a number of favorable characteristics which are better than characteristics of other copper-nickel alloys, such as high yield strength, ultimate strength, working ability, corrosion resisting characteristics, etc. If these characteristics are to be maintained, then the bond or joint should have copper-nickel percentages proximating those of the Monel metal.

In this example, a thin coating of copper was applied to the surface of the bodies although the copper may be applied to the surface of but one body. By the employment of a small amount of copper the Monel metal is not made overly rich with copper and the provision of a homogeneous structure is facilitated. The amount of copper coated on the body surface was within the range of about .15 to .5 ounce for two square feet of surface. The copper was and is preferably applied by electro-deposition. The surfaces were then placed in interfacial relationship with the copper coating constituting one or both interfaces. The metals, or work, as the metals may be called, were now heated. This was accomplished by electrical induction, and in other cases, by electrical resistance. The temperature of the work was raised from room temperature to copper melting temperature in about one-half a second. This substantially prevents the alloying of the copper and the nickel in the Monel body while the copper is in a solid state. After the melting temperature of copper was attained the molten condition was maintained for about two seconds, and then the raising of the temperature was discontinued to cause solidification.

As soon as the copper becomes molten, however, the rate of the alloying of the copper and the nickel in the Monel metal increases rapidly and, as the resultant alloy becomes enriched in nickel its freezing point raises and there would be a solidification except for an important step in the process. This step resides in the heating of the bodies to raise the temperature thereof to a temperature between the melting temperature of the copper and the melting temperature of either body at an average rate of temperature increase in the range from the melting temperature of the copper to the maximum temperature attained, which is greater than the rate of elevation of the freezing point of the alloy formed by the alloying of the copper and the Monel metal. Thus, the alloying metals at the interfaces are maintained in a molten state during the time of

rising temperature and then the raising of temperature is discontinued to cause solidification.

In considering this example, further, the temperature at which the Monel metal begins to get soft or mushy is about 1315° C. whereas the copper melting temperature is 1084° C. It will be seen, therefore, that it is essential not to subject the work to a temperature that would melt the bodies and yet the temperature to which the work is subjected must be considerably higher than copper melting temperature due to the dynamic nature of the situation. In this example, it is preferable to heat the work to a point safely below 1315° C., or say about 1300° C. However, it has been found that a satisfactory bond can be made where the temperature is in the vicinity of 1225° C. With this arrangement the copper and the Monel are so alloyed with each other, that according to the best available tests which can be made at present, the copper-nickel proportion at the bond or joint are within about 2% of that of the original Monel metal. The resultant article is, as a result, substantially seamless as there is a substantially homogeneous structure throughout the united bodies and across the bond or joint. The term "copper" used herein with reference to the bonding or sealing metal is to be construed to cover commercial copper or cuprous metal or brazing brasses or bronzes.

The metals of the other combinations are treated in the same manner as the copper-nickel alloy and copper combination is treated, with due regard, however, to the differences in melting temperatures. The nickel and copper combination may be satisfactorily handled to unite the nickel body to another body by employing the same temperatures and timing given in the above example for the copper-nickel alloy and copper combination. The lead melts at a relatively low temperature, namely, 621° F. relative to the silver which has a melting point of 1761° F. so that there is quite a large temperature range in this combination. In the platinum and gold combination there is also a substantial range of temperature from the melting temperature of gold which is 1945° F. to that of platinum which is 3224° F. A large temperature range is also present in the copper and bismuth combination since bismuth melts at 520° F., as against copper which melts at 1981° F. The range lessens in the nickel and gold combination, lying between the melting temperature of gold, namely, 1945° F. and the melting temperature of nickel 2650° F. A relatively small range occurs in the gold and silver combination, namely, between 1761° F. and 1945° F. In treating any of these combinations, the rate of temperature increase, above the melting temperature of the bonding metal, exceeds the rate of elevation of the freezing point of the forming alloy, so as to maintain a molten state up to the point of the maximum temperature attained, which necessarily, is sufficiently below the melting temperature of the metal body in question so as not to melt the body or the alloy thereof.

I claim:

The method of uniting two metal bodies by the employment of a bonding metal wherein, at least one of the metal bodies is selected from the group consisting of silver, platinum, copper, gold, and nickel and wherein the bonding metal is selected respectively from the group consisting of lead, gold, bismuth, silver and gold, and, wherein each body has a melting temperature higher than that of the bonding metal, which

comprises placing a coating of the bonding metal on a surface of at least one of the bodies, disposing the bodies, while in a solid state, in interfacial relationship with the coating of bonding metal constituting one of the interfacial surfaces, heating the bodies to raise the temperature thereof to a temperature between the melting temperature of the bonding metal and the melting temperature of either body at an average rate of temperature increase, in the range from the melting temperature of the bonding metal to the maximum temperature attained, which is

greater than the rate of elevation of the freezing point of the alloy formed adjacent the interfaces by the alloying of the bonding metal and the metal of said first mentioned one body, whereby to maintain the alloying metals adjacent the interfaces in a molten state during the time of rising temperature and then discontinuing the raising of the temperature of the bodies to cause solidification of the alloyed metals with all of the bonding metal alloyed with the metal bodies.

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