PATENT SPECIFICATION

(11) 1 549 610

(21) Application No. 52807/76 (22) Filed 17 Dec 1976 (19)
(31) Convention Application No. 642627 (32) Filed 19 Dec 1975 in
(33) United States of America (US)
(44) Complete Specification Published 1 Aug 1979
(51) INT. CL.^{2} B23K 35/24
(52) Index at Acceptance
B3R 22G 24

1 549 610

(54) COMPOSITE INTERLAYER FOR DIFFUSION BONDING

(71) We, UNITED TECHNOLOGIES CORPORATION, a Corporation organized and existing under the laws of the State of Delaware, United States of America, having a place of business at 1, Financial Plaza, Hartford, Connecticut, 06101, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:–

The present invention relates in general to the art of diffusion bonding and, more particularly, to diffusion bonding of articles utilizing a transient liquid phase in the bonding process.

Transient liquid phase diffusion bonding has been shown to be a very useful method for producing high quality diffusion bonds in the high temperature superalloys, such as those utilized in the manufacture of gas turbine engine hardware. Such bonding is described in detail in the U.S. Patent No. 3,678,570.

The superalloys are recognized as those alloys usually having nickel, cobalt or iron as their base, or some combination thereof exhibiting good high temperature strength and oxidation resistance in environments such as gas turbine engines. Usually, these alloys also contain substantial quantities of chromium and other elements such as aluminum, titanium and the refractory metals.

It is frequently desirable to make certain gas turbine engine components by joining easily fabricable segments together into the desired configurations. However, the limited weldability of many of those superalloys has severely limited the applicability of conventional joining techniques, such as fusion welding, in the production of structural hardware. Further, many components because of their design are simply not adapted to the utilization of fusion welding. Brazing, while offering a number of advantages over fusion welding, has very limited application because of the penalties associated with the relatively low strengths and low melting points of typical brazed joints.

The relative simplicity and reproducibility of the transient liquid phase diffusion bonding technique in the production of high quality bonds in sensitive hardware has led to substantial usage thereof. This is particularly true in the gas turbine engine industry although the invention described herein is obviously not limited thereto.

One key element in the transient liquid phase diffusion bonding technique is the provision between the surfaces to be joined of a thin alloy interlayer. This interlayer melts at a temperature below the melting temperature of the materials being joined, and through diffusion, solidifies at the joining temperature to form a bond. The composition of the interlayer preferably should be tailored to the alloys being joined, particularly with respect to the inclusion therein of those elements whose presence is required in the finished bond area and whose solid state diffusion rates are slow. It is also desirable to exclude from the interlayer alloy those elements which may adversely affect the bonding process or the quality of the finished joint. A melting point depressant (usually boron) is added to reduce the melting point of the interlayer to the desired point.

Since the amount of melting point depressant (boron) added to an interlayer to allow it to sufficiently melt at the bonding temperature also renders it extremely brittle; therefore, unrollable in homogeneous form, other methods of applying such interlayers between the articles to be joined have been devised.

One method of getting the interlayer alloy species between the facing surfaces is through the use of a thin ductile foil of the type described in the U.S. Patent No. 3,753,794. Ductile interlayer foil as described in this.

According to one aspect of the invention there is provided a ductile interlayer, useful for transient liquid phase diffusion bonding of metallic articles, interlayer comprising a melting point depressant or depressants, and a plurality of ductile lamellae, each of said lamellae being free from carbides, aluminides and borides. The melting point depressant is preferably chosen to have a high diffusion coefficient in the articles to be joined so that after the joint is heated above the interlayer melting point, solidification will occur isothermally as the concentration of the melting point depressant in the interlayer is reduced by diffusion into the articles being joined.

In order to ensure proper bonding, and to minimize the total amount of melting point depressant in the finished bond, thin uniform interlayers are required and these are most advantageously produced by rolling to foil form. The current commercial practice is to prepare the interlayer without the melting point depressant, and to subsequently add the melting point depressant (usually boron) to the surfaces of the foil by a diffusion process (boronizing).

The composition of the interlayer is preferably chosen to be as similar as possible to the articles being joined (excluding the melting point depressant) so that the finished bond will be as similar as possible to the parent metal. Unfortunately, in some cases difficulties are encountered in the preparation of interlayers for joining the high strength superalloys because certain combinations of alloy constituents react and severely impair the interlayer material ductility and fabricability.

A majority of nickel base superalloys contain gamma prime as a strengthening agent, which is an intermetallic phase of aluminum and nickel with the approximate formula Ni_3Al (often titanium is substituted in part for the aluminum). Many superalloys contain upwards of 5% aluminum and it would be desirable to produce interlayers with 5% (and greater) aluminum levels. Four percent is generally the upper limit for the production of homogeneous interlayers of complex alloys by rolling, and production is easier and more consistent if the aluminum level is limited to about two percent. Any deviation of the interlayer composition (except melting point depressant) from the alloys being joined can be equalized by extended diffusion heat treatments, but this is not desirable, particularly with the thicker interlayers. Also, aluminum raises the melting point of the interlayer to the point where the interlayer could not be used to join certain alloys. Thus, from both a technical and manufacturing standpoint, it would be desirable to be able to produce interlayers containing relatively high aluminum levels without the penalties of making the foil difficult to roll or raising the melting point excessively.

A similar problem is presented by a combination of carbon with carbide formers such as hafnium, chromium, tantalum, niobium, titanium, zirconium, tungsten, etc., which together with carbon may form brittle carbides. Current practice is to limit the percentage added of these elements in interlayers, but of course, bonds could more closely approximate the composition of the parent metal if greater amounts of these elements could be incorporated into the interlayer.

Each of the lamellae of the interlayer may differ significantly in chemistry from the adjacent lamellae. Each lamella is free from those combinations of elements which cause brittle phases and other problems, thus the lamellar interlayer material is relatively ductile and may be fabricated by rolling. The overall composition of the interlayer (excluding the melting point depressant) is adjusted to be close to the composition of the materials being joined. This concept may be employed in several different ways including the following:

A. Use of two or more separate lamellae, produced by rolling, with adjacent lamellae having distinct chemical compositions. These lamellae may be stacked in sandwich form to produce an interlayer of the desired thickness. Even though only two distinct compositions are required to produce the desired interlayer chemistry, it may be desirable to use several sets of the two lamellae to reduce diffusion distances and shorten the bonding cycle, the time required to produce a homogeneous bond, especially if a thick interlayer is desired.

B. Use of an interlayer as described in A above wherein the separate ductile lamellae have been bonded together, for example by co-rolling, to produce an integral lamellar interlayer material.

C. Use of one or more ductile rolled lamellae with a directly applied lamella on at least one surface of the rolled interlayer. The last-mentioned lamella would usually be metallic, but might contain nonmetallic elements such as boron. For example an electroless plating scheme could be used to apply a nickel boron alloy to the two surfaces of the interlayer, and the or each rolled lamella could be a (ductile) nickel-chromium-aluminum alloy. The same comments made above with reference to ductility of surface layers also apply to this embodiment.

In the above schemes boron would normally be used as the melting point depressant, although other depressants might be used. The boron could be applied by conventional boronizing; by vapor deposition, either pure boron or a boron metallic mixture; or by electroless plating, for example of a nickel boron alloy or nickel-cobalt-boron alloy. Other elements include aluminum which is desirable for precipitation strengthening and might be supplied in pure form, as part of a ductile alloy, or by various vapor deposition methods. Chromium is desirable since it lowers the melting point of some alloy interlayers, and because it increases the oxidation and corrosion resistance of the bond region; chromium might be applied as part of a ductile alloy or by plating or vapor deposition. Various refractory and carbide former elements such as W, Mo, Zr and Hf are desirable for high strength and creep resistance; these materials may also be applied as part of a ductile alloy or by plating and/or vapor deposition. In general these elements (except boron) would be desirable in substantially the same concentration as in the base alloy, and sufficient melting point additions would be used to depress the melting point as desired.

Another embodiment of the invention which should be discussed is an embodiment in which not all of the interlayer parts melt. For example the refractory metals such as tungsten are present in many superalloys and would be desirable in the interlayer but for the fact that they act to increase the interlayer melting point. It is desirable that bonding be performed at a low temperature so that minimal metallurgical changes occur in the articles being bonded. If a three lamellae interlayer were utilized with the central alloy lamella containing tungsten and the outer parts being fabricated from a Ni–15% Cr-3.5% B alloy melting point 1054°C), the transient liquid phase diffusion bonding process could be performed at a temperature just slightly in excess of 1054°C. The tungsten free portions of the interlayer would melt at this temperature, and, although the tungsten containing layer would not melt it would be partially dissolved by the melted layers and permit satisfactory bonding. The invention excludes the arrangement of one unitary interlayer containing all of the tungsten in which the process temperature required would be much greater.

Another embodiment involves the preparation of interlayers for wide gap bonding in which a lamellar interlayer is utilized to provide elements such as aluminum, titanium, carbon and the refractory metals within the bond area so that homogeneous bonds can be developed with only short diffusion times. For example, one of the interlayer lamellae might have a composition close to that of the parent metal.

Although the invention has been shown and described with respect to a preferred embodiment thereof, it should be understood by those skilled in the art that various changes and omissions in the form and detail thereof may be made therein without departing from the scope of the invention.

WHAT WE CLAIM IS:–

1. A ductile interlayer, useful for transient liquid phase diffusion bonding of metallic articles, interlayer comprising a melting point depressant or depressants, and a plurality of ductile lamellae, each of said lamellae being free from carbides, aluminides and borides.

2. Interlayer according to claim 1 wherein no single lamella contains both carbon and a material chosen from the group consisting of hafnium, chromium, tantalum, niobium, titanium, zirconium and tungsten and mixtures thereof.

3. Interlayer according to claim 1 or claim 2 wherein the lamellae are bonded together to form a unitary interlayer.

4. Interlayer according to any one of claims 1 to 3 wherein at least one of the lamellae melts at a lower temperature than would an alloy containing all the components of the lamellar interlayer.

5. A process for producing the ductile lamellar interlayer of any one of the claims 1 to 4 containing a melt depressant useful in the transient liquid phase diffusion bonding of metallic articles comprises the steps of providing a plurality of ductile lamellae and bonding the lamellae together by co-rolling to produce a unitary ductile interlayer.

6. A process for producing the ductile lamellar interlayer of claim 1 useful in the transient liquid phase bonding of metallic articles, the overall interlayer containing a melting point depressant and combinations of elements which form carbides, aluminides or borides, the process comprising the steps of: providing a ductile lamellar substrate, with each ductile lamella being free from said carbides, aluminides and borides, and depositing at least one adherent coating on the surface of the lamellar substrate.

7. Process for bonding metallic articles of predetermined composition, using the transient liquid phase bonding process with the melting point depressant containing interlayer of anyone of the claims 1 to 4 comprising the steps of:

a. depositing at least one coating to the surfaces to be joined.

b. providing a ductile interlayer with the composition of the interlayer being different from the composition of the coating and with the overall composition of the interlayer and the coating (excluding the melting point depressant) being similar to the composition of the articles to be joined.

c. placing the interlayer between the

coated surfaces to be joined, and maintaining the surfaces to be joined in close contact,

d. heating the articles to be joined and the interlayer to a temperature above the interlayer melting point but below the melting point of the articles being joined.

e. maintaining the articles to be joined at a substantially constant temperature until solidification occurs as a result of diffusion of the melting point depressant away from the joint.

8. Process according to claim 6 or claim 7 wherein the coating deposition process involves electroplating.

9. Process according to claim 6 or claim 7 wherein the coating deposition process involves electroless plating.

10. Process according to claim 6 or claim 7 wherein the coating deposition process involves vapor deposition.

11. A ductile interlayer, useful for transient liquid phase diffusion bonding of metallic articles as hereinbefore described.

12. A process for producing a ductile lamellar interlayer as hereinbefore described.

13. A process for bonding metallic articles using the transient liquid phase diffusion bonding process as hereinbefore described.

ARTHUR R. DAVIES
Chartered Patent Agents,
27, Imperial Square,
Cheltenham.
– and –
115, High Holborn,
London. W.C.1.
Agents for the Applicants.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1979.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.