EXPLOSIVE SPOT JOINING OF METALS

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The invention is an apparatus and method for wire splicing using an explosive joining process. The apparatus consists of a prebend, U-shaped strap of metal that slides over prepositioned wires. A standoff means separates the wires from the strap before joining. An adhesive means holds two ribbon explosives in position centered over the U-shaped strap. A detonating means connects to the ribbon explosives. The process involves spreading strands of each wire to be joined into a flat plane. The process then requires alternating each strand in alignment to form a mesh-like arrangement with an overlapped area. The strap slides over the strands of the wires, and the standoff means is positioned between the two surfaces. The detonating means then initiates the ribbon explosives that drive the strap to accomplish a high velocity, angular collision between the mating surfaces. This collision creates surface melts and collision bonding resulting in electron-sharing linkups.

30 Claims, 2 Drawing Sheets
EXPLOSIVE SPOT JOINING OF METALS

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA Contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, as amended, Public Law 85-568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention generally relates to metal fusion bonding using explosive energy. More specifically, the invention is an apparatus and method for explosively joining, i.e., welding and cladding, metals of similar or dissimilar composition in small-areas or "spots," whereby a sealing bulkhead prevents contamination of the surfaces of the metals to be joined.

2. Description of the Related Art

Since the 1960s, metal bond fusion using explosive energy, or "explosive joining," has been developed to provide an efficient and versatile means of bonding metals which are otherwise difficult or impossible to weld and/or clad by conventional, non-explosive means. In particular, explosive joining is uniquely and especially suitable for joining metals of dissimilar metallurgical composition whose melting points are incompatible with conventional welding; for joining thin sheets of metal or metal wiring which might be damaged by the heat of conventional welding; for joining metals in areas made inaccessible by bulky conventional welding equipment, e.g., the assembly of structures in space; and for joining metals, e.g., titanium or aluminum, which require time and a high degree of skill to weld due to the unique physical properties of the metals.

The explosive joining process produces a high velocity, angular collision between the surfaces of the metal components to be joined which causes the formation of interatomic, electron-sharing linkups at the point of contact between the metal components. Upon detonation of the explosives, the metal components to be joined are impelled together with sufficient force to produce metallurgical bonds which are impossible to achieve by any other known process. This process is comparatively simple and can be performed by relatively unskilled personnel. Consequently, explosive joining is particularly useful in its unique applications and relative simplicity.

Previous methods of explosive joining have addressed incorporating an inverted "V" standoff interface on one or a plurality of metal components to be joined, in order to maximize bonding efficiency. For example, U.S. Pat. No. 4,708,280 by Bement describes an inverted "V" standoff, machined into the outer surface of either or both of the metal tubes to be joined, as an alternate to the preferred embodiment. Hence, the Bement patent reveals art which purports to limit use to joining two metal tubes.

Previous methods of explosive joining also have addressed problems associated with degradation of the bonding surface, i.e., the surface bond area, between the metal components to be joined. Such degradation typically results after the initial detonation of the explosives when very-fine, high-density particles contained in the explosives invade the standoff space between the metal components to be joined before the explosive energy has propagated through the metal components to initiate the angular collisions between the metal components. For example, U.S. Pat. No. 5,318,213 by Strickland et al. addresses one aspect of surface degradation, i.e., "air burning," by shielding the metal components to be joined in an "envelope made of deformable material." Typically, air burning is manifested when very-fine, high-density solid particles from the explosives, e.g., carbon, which became airborne after the initial detonation, ignite. Thus, the Strickland patent reveals art which embodies a means of minimizing surface bond degradation caused by very-fine, airborne particles which ignite in the air space between the metal components to be joined.

SUMMARY OF THE INVENTION

The present invention is an apparatus and process for explosively joining a plurality of metal components of similar or dissimilar composition.

An object of the present invention is to provide a means of explosively joining a plurality of metal components, wherein an inverted "V" standoff interface is machined onto or formed into a plurality of metal components to be joined, to maximize bonding efficiency.

Another object of the present invention is to provide a means of explosively joining a plurality of metal components, wherein a sealing bulkhead is employed, to minimize contamination of the bonding surface, and, hence, a degradation in the size and strength of the bond area.

A further object of the present invention is to provide a means of explosively joining a plurality of metal components which minimizes the amount of explosive required.

Still another object of the present invention is to provide a means of explosively joining a plurality of metal components which reduces damaging pressure waves, noise nuisance, and damage to surrounding structures.

The present invention attains the foregoing and additional objects by providing an apparatus and process for joining metal components using explosive energy. While this process is specifically applicable to explosive cladding and welding of metals, its application is not limited to those two embodiments. Similarly, this process is particularly useful for joining metal components in small areas or "spots;" however, its application is not limited to explosive "spot" welding. A "spot" is therein defined as a bond area that is at least twice the thickness of the thinnest metal component being joined, in any direction of the surface bonded.

The apparatus consists of a plurality of small metal components to be joined and ribbon explosives. A standoff means, consisting of an inverted "V" standoff interface machined onto or formed into a plurality of the metal components, separates the metal bonding surfaces prior to detonation and is designed to provide maximum joining efficiency. A sealing means protects the integrity of the bonding surface using a sealing bulkhead which prevents surface contamination by high-velocity particles released by the detonation. An adhesive means holds a ribbon explosive in position on each metal component. A detonating means initiates the ribbon explosives.

The process involves placing the metal components to be joined in any desired orientation. When the metal components are joined with their axes generally perpendicular to each other, a tab joint is created. When the metal components are joined along the same axes, i.e., parallel, to each other, a splice joint is created.

For a splice joint, an inverted "V" standoff is machined onto or formed into a "host" metal component at any desired location. A "host" metal component is herein defined as a metal component into which either an inverted "V" standoff,
or a sealing bulkhead, or a combination of the two, is machined or formed. The tip of the inverted "V" is oriented along the same axis of the "host" metal component and generally perpendicular to the axis of the other metal components. A sealing bulkhead is also machined onto or formed into the same "host" metal component so that it is oriented generally perpendicular to the "host" metal component and therefore along the same axis as the other metal components. The sealing bulkhead is located nearest to the point of initiation of the explosives so that the explosive energy impacts the sealing bulkhead before impacting other portions of the metal components to be joined.

For a tab joint, an inverted "V" standoff is machined onto or formed into a "host" metal component at any desired location. The tip of the "V" is oriented along the same axis as the "host" metal component. A sealing bulkhead is machined onto the "host" metal component so that the sealing bulkhead is located generally perpendicular to the axis of the "host." The sealing bulkhead is located nearest to the point of initiation of the explosives so that the explosive energy impacts the sealing bulkhead before impacting other portions of the metal components to be joined.

For either joint type, ribbon explosives, or, alternately, unconfined strips of explosives, are fashioned and bonded to the outermost surface of the metal components to be joined. An adhesive means, e.g., double-backed tape, affixes the ribbon explosives, or, alternately, unconfined strips of explosives, to the metal components. A detonating means is mated to the ribbon explosives so that the propagation direction of the detonation initially impacts the sealing bulkhead. The detonating means is then ignited to effect an explosive joining of the metal components.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a cross-sectional view of a "host" metal component for a splice joint with an inverted "V" interface detail; FIG. 2 is a plan view of a "host" metal component for a splice joint with a sealing bulkhead detail; FIG. 3 is a cross-sectional view of the splice jointing process comprising two metal components whose common axes are parallel to one another; FIG. 4 is a plan view of the splice jointing process comprising two metal components whose common axes are parallel to one another; FIG. 5 is a cross-sectional view of a "host" metal component for a tab joint with an inverted "V" interface detail; FIG. 6 is a plan view of a "host" metal component for a tab joint with a sealing bulkhead detail; FIG. 7 is a cross-sectional view of the tab jointing process comprising two metal components whose axes are generally perpendicular to one another; and FIG. 8 is a plan view of the tab jointing process comprising two metal components whose axes are generally perpendicular to one another.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

The present invention involves physical processes for explosively joining a plurality of similar or dissimilar metal components to form a splice joint or a tab joint, depicted in plan view in FIGS. 4 and 8, respectively.

Referring to FIGS. 1 and 2, which, respectively, depict cross-sectional and plan views of a "host" metal component for a splice joint 20, a preferred embodiment of a "host" metal component 10 comprises a strip of metal approximately 0.125 inches in thickness 14 and 0.50 in. in width 16. An inverted "V" interface 12 is machined or formed onto the "host" metal component 10 as a standoff means to separate the "host" metal component 10 from the receiving metal component 11, to maximize the efficiency of the high velocity, angular collision necessary to effect the explosive joint. The inverted "V" interface 12 should be machined or formed onto the "host" metal component 10 at an approximate angle between 3 and 10 degrees from the horizontal with the tip of the inverted "V" interface 12 oriented generally perpendicular to the axis of the "host" metal component 10. The length of the inverted "V" interface 12 should be such that the tip of the inverted "V" interface 12 is positioned along the receiving metal component 11 at the midpoint of the desired splice joint 20 location.

As shown in the completed assembly of FIGS. 3 and 4, a preferred embodiment of the present invention for a splice joint 20 comprises a "host" metal component 10 and a receiving metal component 11 which are placed one atop the other along their common axis 18. The orientation of the "host" metal component 10 and the receiving metal component 11 should be such that the tip of the inverted "V" interface 12 is positioned along the receiving metal component 11 at the midpoint of the desired splice joint 20 location.

Referring to FIGS. 5 and 6, which, respectively, depict cross-sectional and plan views of a "host" metal component 30 for a tab joint 40. As for the splice joint described above, a preferred embodiment of a "host" metal component 30 comprises a strip of metal approximately 0.125 inches in thickness 34 and 0.50 in. in width 36. An inverted "V" interface 32 is machined or formed onto the "host" metal component 30 as a standoff means to separate the "host" metal component 30 from the receiving metal component 31, to maximize the efficiency of the high velocity, angular collision necessary to effect the explosive joint. The inverted "V" interface 32 should be machined or formed onto the "host" metal component 30 at an approximate angle between 3 and 10 degrees from the horizontal with the tip of the inverted "V" interface 32 oriented generally along the axis 38 of the "host" metal component 30. The length of the inverted "V" interface 32 should be such that the tip of the inverted "V" interface 32 is positioned along the receiving metal component 31 at an approximate angle between 3 and 10 degrees from the horizontal with the tip of the inverted "V" interface 32 approximately one-half the total length of the desired bond length 40. A sealing bulkhead 33 is also machined or formed onto the "host" metal component 30 to provide a sealing means, to minimize contamination of the bonded surface between the "host" metal component 30 and the receiving metal component 31. The sealing bulkhead 33 could be any practical thickness. The length of the sealing bulkhead 33 should be such that it extends slightly beyond each leg 37 of the inverted "V" interface 12.

As shown in the completed assembly of FIGS. 7 and 8, a preferred embodiment of the present invention for a tab joint 20 comprises a "host" metal component 50 and a receiving metal component 60 which are placed one atop the other along their common axis 58. The orientation of the "host" metal component 50 and the receiving metal component 60 should be such that the tip of the inverted "V" interface 12 is positioned along the receiving metal component 60 at the midpoint of the desired splice joint 20 location.
An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

2. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the composition of the metal components is metallurgically dissimilar.

3. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the standoff means is positioned on at least one of the metal components.

4. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned along a common axis to form a splice joint.

5. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

6. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

7. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

8. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

9. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

10. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

11. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

12. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

13. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

14. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

15. An apparatus for explosively joining a plurality of metal components as in claim 1 wherein the metal components are positioned perpendicularly to one another to form a tab joint.

16. A process for explosively joining a plurality of metal components at a bonding surface, comprising:

(a) a detonating means initiating the ribbon explosives.

(b) a detonating means initiating the ribbon explosives.

(c) a detonating means initiating the ribbon explosives.

(d) an adhesive means holding the ribbon explosive in any desired position on at least one of the metal components.

(e) a detonating means initiating the ribbon explosives.

(f) an adhesive means holding the ribbon explosive in any desired position on at least one of the metal components.

(g) a detonating means initiating the ribbon explosives.

(h) a detonating means initiating the ribbon explosives.

(i) a detonating means initiating the ribbon explosives.

(j) an adhesive means holding the ribbon explosive in any desired position on at least one of the metal components.

(k) a detonating means initiating the ribbon explosives.

(l) a detonating means initiating the ribbon explosives.
(a) machining or forming at least one metal component at intended areas to be joined, to provide a standoff means;
(b) machining or forming at least one metal component at intended areas to be joined, to provide a sealing means;
(c) placing ribbon explosives on at least one metal component at intended areas to be joined;
(d) bonding ribbon explosives to at least one metal component with an adhesive means;
(e) mating the ribbon explosives to a detonating means so that the ribbon explosives can be properly initiated;
(f) positioning the metal components over one another at the intended joining area;
(g) initiating the ribbon explosives with the detonating means to allow the ribbon explosives to drive the metal components together to effect a bonded explosive joint.

18. A process for explosively joining a plurality of metal components as in claim 16 wherein the composition of the metal components is metallurgically dissimilar.

19. A process for explosively joining a plurality of metal components as in claim 16 wherein the composition of the metal components is metallurgically similar.

20. A process for explosively joining a plurality of metal components as in claim 16 wherein the metal components are positioned along a common axis in step (f), to form a splice joint.

21. A process for explosively joining a plurality of metal components as in claim 16 wherein the standoff means in step (a) consists of an inverted "V" interface.

22. A process for explosively joining a plurality of metal components as in claim 21 wherein the inverted "V" interface is machined or formed along a common axis as the host metal component, to form a splice joint.

23. A process for explosively joining a plurality of metal components as in claim 22 wherein the inverted "V" interface is machined or formed generally perpendicular to the axis of the host metal component, to form a tab joint.

24. A process for explosively joining a plurality of metal components as in claim 22 wherein the inverted "V" interface is machined or formed along a common axis as the host metal component, at a point nearest to a point whence initiation of the explosives occurs, to form a splice joint.

25. A process for explosively joining a plurality of metal components as in claim 16 wherein the sealing means in step (b) consists of bulkhead.

26. A process for explosively joining a plurality of metal components as in claim 25 wherein the sealing bulkhead is machined or formed generally perpendicular to the axis of the host metal components, at a point nearest to a point whence initiation of the explosives occurs, to form a tab joint.

27. A process for explosively joining a plurality of metal components as in claim 25 wherein the sealing bulkhead is machined or formed generally perpendicular to the axis of the host metal components, at a point nearest to a point whence initiation of the explosives occurs, to form a tab joint.

28. A process for explosively joining a plurality of metal components as in claim 16 wherein joining of the metal components is confined to a small area or spot.

29. A process for explosively joining a plurality of metal components as in claim 28 wherein joining of the metal components is confined to a small area or spot which has a minimum bonded width of 0.10 inches.

30. A process for explosively joining a plurality of metal components as in claim 28 wherein joining of the metal components is confined to a small area or spot which has an explosive footprint area to size of bond area ratio no greater than 8.

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