TOTALLY CONFINED EXPLOSIVE WELDING


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A simple means for eliminating the noise and debris of explosive welding techniques by totally enclosing and applying the explosive pressure through the wall of the enclosure.
TOTALLY CONFINED EXPLOSIVE WELDING

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the U.S. Government and may be manufactured and used by or for the Government for Governmental purposes without the payment of any royalties thereon or therefor.

This is a division of application Ser. No. 289,048, filed 9/14/72, now U.S. Pat. No. 3,797,098.

BACKGROUND OF THE INVENTION

This invention relates generally to explosive welding techniques and specifically to a method of bonding materials which are difficult to weld by more conventional means. It is particularly useful for thin materials which are not suited to the process of welding, and for large structures which require complex and expensive equipment to obtain uniform welds by conventional means.

The method of confined explosive welding retains all the benefits of the original technique. It is capable of welding materials that are normally extremely difficult; it can weld very thin materials such as those used on aircraft and spacecraft; it requires very little tooling so that the cost of the confined technique is competitive, and the confined welding technique is anticipated in the aircraft industry and in extra-terrestrial applications. It is viewed as particularly applicable to the fabrication of space stations in orbit. Despite its advantages and the fact that the technique has been under development for more than twenty years, it has seen relatively little industrial use.

This may be because of the psychological effects of the noise and scattering of debris from the explosion. While such phenomena are relatively minor when a small amount of explosive is used, they do present some safety hazard and create a reluctance to use the use of this otherwise valuable technique. This same explosive debris presents another problem in some applications. In high vacuum, space and other applications which require close control of potential contaminants, the explosive welding technique presents the problem of scattering debris into areas where it causes undesirable contamination. The present invention solves these problems without adding significantly to the complexity or cost of the basic technique.

SUMMARY OF THE INVENTION

The present invention is a method and associated apparatus for confining the undesirable byproducts and limiting the noise of explosive welding, the use of which has been limited because of such phenomena. The apparatus is comprised of a simple enclosure into which the explosive is placed and within which the explosion occurs. Due to the shape of the enclosure, the placement of the explosive within it, and the manner in which the enclosure is placed upon the material to be welded, the force of the explosion is transmitted to the proposed bond area.

In one example of a seam bonded by explosive welding, flattened steel tubing is used as an enclosure. This is attached to the weld material by the use of masking tape; just as the explosive itself is attached in unconfined explosive welding. The preformed explosive is slipped into the tubing along with a strip of silicone rubber which holds the explosive against the flattened side of the tubing which is adjacent to the proposed weld area. The explosion is initiated electrically by a commercially available detonator which threads into a fitting welded to the end fitting of the tubing. The noise generated is no more than the rattle of metal, whereas an unconfined explosion creates noise comparable to that of a very close shotgun firing. The residue from unconfined explosive welding contains carbon, portions of the explosive sheathing material, and masking tape. Such residue is completely contained when the confined technique is used so that the use of such a bonding method becomes practical even in the restricted environment of a space station.

The method of confined explosive bonding retains all the benefits of the original technique. It is capable of welding materials that are normally extremely difficult; it can weld very thin materials such as those used on aircraft and spacecraft; it requires very little tooling so that it may be used in remote installations or on large structures; and its simplicity allows performance by unskilled labor. Because of these original benefits, the totally confined explosive welding method eliminates the major remaining problems involved in the process, those of noise and debris, with no significant sacrifice of simplicity.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the apparatus for confining the explosive showing a typical cross section;

FIG. 2 is an axial cross-sectional view of the detonator adapter assembly;

FIG. 3 is an end view of the detonator adapter assembly; and

FIG. 4 is an axial cross-sectional view of the closed end fitting.

DETAILED DESCRIPTION OF THE INVENTION

The embodiment of the invention selected for illustration as shown in FIGS. 1 and 2 is one used for seam welding. FIG. 1 shows a typical cross-sectional view perpendicular to the planes of sheet materials 12 and 14 to be welded and to the centerline of the proposed bond area.
area 10 at which they will be joined. Upper sheet 14 is
0.040 inch thick aluminum; and while lower sheet 12 is
0.25 inch aluminum in this example, it should be under-
stood that these materials may be either the same or
different thicknesses. Lower sheet 12 is placed upon
anvil 11 which supports the work, furnishes reactive
force during the explosion, and absorbs excess shock
waves. Separators 13 made of aluminum 0.010 inch
thick, are placed on either side of proposed bond area 10
and are located through the inner clearance so that they
will not interfere with the subsequent bonding. Separa-
tion is required in the explosive welding process so that
a velocity may be imparted to one or both of the pieces
to be welded. This velocity is a basic requirement for
the explosive welding process so that the collision be-
tween the workpieces strips the mating surfaces clean
and metallurgically bonds them together. In the ar-
arrangement shown in FIG. 1, the velocity is imparted to
upper sheet material 14 by the force generated by the
detonation of explosive 17. This force is transmitted
through the wall of the steel tubing of infrangible enclo-
sure 16 and the silicone grease 15 which is placed be-
tween the lower flattened side of tubing 16 and the
upper surface of the material to be bonded 14. Grease 15
is used to assure that no voids exist between tubing 16
and workpiece 14 and that the explosive pressure is
efficiently transmitted to the material to be welded.
Explosive 17 is completely contained within steel tub-
ing 16 and its appropriate end fittings. This containment
prevents any products of the explosion from reaching
the surrounding environment and virtually eliminates
the noise of the explosion. Infrangible enclosure 16 used
in the arrangement shown in FIG. 1, is a steel tubing and
may be formed from type 347 alloy. It is .85 inch on
the longest dimension of its cross section and is .30
inch high. The wall thickness is 0.030 inch and the di-
mension of the flat surface is 0.5 inch. Infrangible enclo-
sure 16 is attached to upper sheet 14 by the use of strips
19 of conventional masking tape.
Explosive 17 used in the specific embodiment shown
is a linear ribbon constructed of lead shoted RDX
explosive. It is available with explosive loads of 7 to 25
grams per foot but in the specific example 15 grains per
foot is used. Its size is 0.025 inch thick by 0.315 inch
wide overall. It may safely be cut to length with a scis-
sors. The use of an enclosure to contain the byproducts
of the explosion and reduce noise is in no way limited to
either the specific explosive or the specific enclosure
described herein. However, it should be understood
that the enclosure must be selected to contain the explo-
sion without rupture while the explosive should be
selected with consideration of materials and thicknesses
to be welded.

The silicone filler strip 18 is slipped into steel tubing
16 along the explosive 17. Together they are sized to
form a snug but not tight fit within tubing 16. Filler strip
18 holds explosive 17 in contact with the flattened side
of steel tubing 16 during preparation. When the explo-
sion occurs filler strip 18 attenuates and diffuses that
force which is directed away from weld area 10 so that
no rupture occurs in the topside of tubing 16. The sili-
cone rubber filler strip 18 also contributes to the re-
duction of the noise from the operation.

FIGS. 2 and 3 illustrate the detonator adapter assem-
bly which is used in conjunction with the configuration
of FIG. 1 to accomplish total enclosure of the explosive.
Because of the shock pressures generated by the explo-
sion such fittings must be structurally strong and con-
tain pressure seals at all joints. This is accomplished in
the illustrated assembly by attaching steel enclosure
tube 16 to steel end housing 21 at weld joint 22 by weld-
1ng prior to setting up the explosive welding operation.
The commercially available detonator cartridge 26 is
screwed into end housing 21 by means of threads 27 and
tightened against O-ring 28 to complete the pressure
seal to the interior of the explosive enclosure extension
31 drilled into the center of housing 21.

The aluminum restraining adapters 23 and 24 are
added to the assembly to prevent the explosive shock
from fracturing enclosure tube 16 at weld joint 22. The
explosion is initiated by supplying current to electrical
pins 29 which detonates charge 30, in turn detonating
explosive 17. The explosive detonates along its length at
a finite velocity of the order of 26,000 ft/sec. As this
detonation wave passes weld joint 22 between end
housing 21 and tubing 16 the stress created by the shock
wave on the unsupported tubing would be such as to
rupture the tubing at the weld. Upper restraining
adapter 23 is attached to end housing 21 by bolt 32,
while lower restraining adapter 24 is attached to end
housing 21 by bolt 33. Together the restraining adapters
23 and 24 completely surround tubing 16 and support it
in all directions. This support decreases as the distance
from the end housing increases because of the tapered
construction of the restraining adapters. Upper restrain-
ning adapter 23 provides restraint which at end housing
21 approaches the same degree of restraint afforded by
the end housing while at the other end the adapter is
tapered to approach the strength of only the unsup-
ported tubing 16. Lower restraining adapter 24 fur-
nishes restraint approaching that of the end housing at
one end, but is tapered such that at the other end it
approximates the restraint provided to tubing 16 by the
work piece 14. The surface of the tubing 16 against
which explosive 17 acts, in this example the lower sur-
face, must be supported in some manner for the entire
length of the explosive in order to prevent a disconti-
nuity at the work piece which would accentuate the stress
on the tubing and cause rupture. The upper surface of
the tubing does not require such backing since the shock
from the explosive is damped by the silicone rubber
filler material 18 and there is no backing material along
the total tubing length.

FIG. 4 shows the closed end fitting used at the end of
the tubing opposite from the detonator. It comprises a
simple end cap 36 drilled to fit outside tubing 16. The
tubing is inserted into cap 36 and welded at 35. Tubing
16 rests on support 37 for its length not supported by the
weld pieces to meet the requirements for shock re-
straint. However, when tubing 16 is made long enough
in the section that contains no explosive 17, the shock
wave is reduced to a level that requires no support.
Such a modification is valuable where the welding is
done in confined quarters and it is desirable to place the
det end fitting elsewhere.

While the benefits of explosive welding are most
apparent in longseam welding, neither the prior tech-
nique nor the invention described herein is limited to
such a configuration. Any operation which previously
used explosive welding can benefit from the enclosing
of the explosive so as to limit the noise and debris. In
spot-welding, as another example, small containers can
be constructed which enclose the charge used for each
spot.

Another variation of the technique prescribed by this
invention is the use of two enclosures to contain the
A dual explosive charge used when a second charge is substituted for anvil 11 in the prior example. The confinement technique is also effective in its simplest form when no silicone grease as shown by 15 in FIG. 1 is used. In such an option only a slight loss of efficiency of transmission of explosive force may be experienced if the surfaces of tubing 16 and workpiece 14 do not mate exactly. The silicone rubber filler material 18 provides for other variations. In one case, it may be entirely removed and the absence of attenuation of the explosive force counteracted by strengthening the enclosure, shaping the enclosure, or minimizing the charge of explosive. The filler material may also be shaped and made of a material such that it will actually reflect the force back in the direction of the bond thereby increasing the force available from a given charge. Such a variation is shown in FIG. 3 in which filler material 38 has a triangular undercut 39. The enclosure may likewise be constructed so as to deflect the forces back to the work area to accomplish a similar increase in effective force.

It is to be understood that the forms of the invention herein shown are merely preferred embodiments. Various changes may be made in shape, size and the arrangement of parts; equivalent means may be substituted for those illustrated and described; and certain features may be used independently from other features without departing from the spirit and scope of the invention as defined in the following claims. For example, the enclosure shown is constructed from flattened steel tubing. Other shapes and materials may be used where the parts to be welded and the explosive used make them more effective or economical.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An apparatus for limiting the disturbing noise and hazardous debris of an explosive bonding procedure while transmitting the explosive pressure to the area to be bonding comprising:
   - an infrangible enclosure means removably attached to one of the members to be bonded at the point directly opposite the bond area;
   - explosive means completely confined inside the infrangible enclosure means at a point of close proximity to the member to be bonded;
   - detonating means attached to said explosive means to initiate the explosive within the infrangible enclosure means;
   - the balance of the infrangible enclosure means not occupied by the explosive being filled with a material which attenuates and diffuses the explosive pressure not directed toward the bond area, said material also serving to position and retain the explosive;
   - the infrangible enclosure means being flattened steel tubing with end fittings which seal off the ends of the tubing;
   - the explosive means being lead-sheathed RDX explosive;
   - the detonating means being an electrically operated detonator cartridge which screws into threads in an end fitting and furnishes a sure means; and
   - the filler material being silicone rubber.

2. An apparatus for limiting the disturbing noise and hazardous debris of an explosive bonding procedure while transmitting the explosive pressure to the area to be bonding comprising:
   - infrangible enclosure means removably attached to one of the members to be bonded at the point directly opposite the bond area;
   - explosive means completely confined inside the infrangible enclosure means at a point of close proximity to the member to be bonded;
   - detonating means attached to said explosive means to initiate the explosive within the infrangible enclosure means;
   - the balance of the enclosure not occupied by explosive filled with a shaped material which directs the explosive pressure toward the bond area.

3. An apparatus for limiting the disturbing noise and hazardous debris of an explosive bonding procedure while transmitting the explosive pressure to the area to be bonding comprising:
   - a detonator adapter which accommodates commercially available detonators by variation in its structural strength as a function of its length from the end of the explosive enclosure controls the expansion of the enclosure by the explosive force such that the enclosure at no point experiences a discontinuity in expansion which causes rupture;
   - said detonator adapter having an end housing with a central aperture adapted to receive a portion of the infrangible explosive enclosure to form an extension to and close the infrangible explosive enclosure, said housing being connected to the explosive enclosure;
   - said detonator adapter also having an upper adapter fastened to said end housing at the end opposite said detonator, shaped so that it fits tightly against said infrangible explosive enclosure and furnishes a varying support to said infrangible enclosure, such support decreasing with distance from the end housing; and
   - said detonator adapter further having a lower adapter fastened to said end housing at the end opposite the detonator shaped so that it fits tightly against said infrangible explosive enclosure and said upper adapter to form a variable strength support member on all sides of the infrangible explosive enclosure.

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