United States Patent

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[73] Assignee **The United States of America as represented by the Secretary of the Navy**

[54] **METHOD OF FORMING BIMETALLIC TRANSITION JOINTS**
7 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **29/471.1,** 29/474.3, 29/480, 29/481
[51] **Int. Cl.** **B23k 31/02**
[50] **Fieldof Search** 29/474.3, 473.3, 472.3, 471.7, 471.1, 4.75, 473.5, 480,481, 422.3

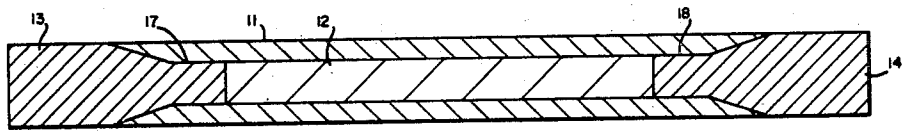
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ABSTRACT: Transition joints formed of dissimilar metals, such as stainless steel and aluminum, are produced by assembling an aluminum rod and two stainless steel plugs coaxially within a stainless cylinder with the plugs positioned at each end of the rod. Both plugs are welded to the cylinder and the assembly is then heated and subjected to reduction by rotary swagging thus forming a metallurgical bond of the two metals. The assembly may be machined into tubular joints by standard techniques.



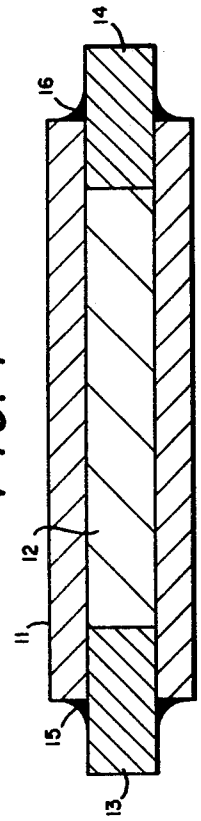


FIG. 1

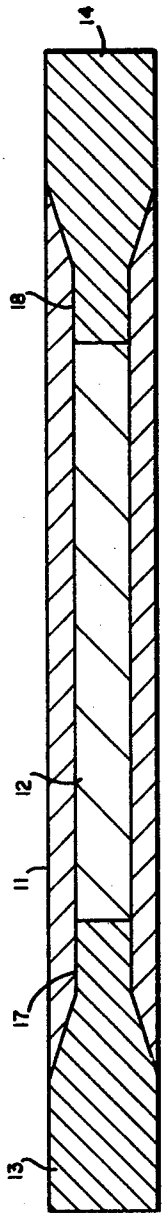


FIG. 2

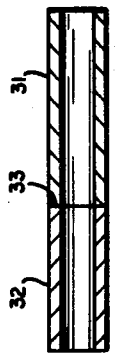


FIG. 3B

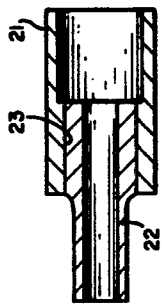


FIG. 3A

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BY ATTORNEYS

METHOD OF FORMING BIMETALLIC TRANSITION JOINTS

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention relates generally to metal working and more particularly to a method of fabricating a gas impervious tubular connection between two dissimilar metals which do not readily lend themselves to coupling by conventional techniques such as welding.

Certain metals do not lend themselves to being welded together by conventional techniques and therefore, it has been the practice in the past to join such dissimilar metals by means of mechanical devices such as flarings, farrels, flanges, and O-ring-type fittings. Couplings fabricated by these techniques do not perform satisfactorily under all operating conditions, particularly in those situations where the coupling is subjected to cryogenic temperatures. When exposed to cryogenic temperatures, the differential expansion of the dissimilar metals will often cause metal-to-metal seals to fracture and leak, the O-rings become glass hard and thereby lose the effectiveness of the seal, and organic sealants such epoxies will become hard and fracture easily with slight vibrations. Since conventional mechanical couplings consistently fail when subjected to cryogenic temperatures, the method of this invention was conceived for joining together dissimilar metals in a manner to provide a gas pervious tubular coupling suitable for operation over wide temperature ranges including cryogenic temperatures while maintaining the gastight integrity of the system.

SUMMARY OF THE INVENTION

The general purpose of the present invention is to provide a method for forming bimetallic transition joints which embraces all of the advantages of previous methods and yet possesses none of the aforedescribed advantages. To attain this, the present invention contemplates the assembly of an aluminum rod and two stainless steel plugs within a close fitting stainless steel cylinder, the plugs being positioned at each end of the aluminum rod and in coaxial alignment therewith. Each stainless steel plug is then welded to the stainless steel cylinder to thereby enclose the aluminum rod in a gastight envelope of stainless steel. The assembly is then heated and subjected to a reduction by rotary swagging which causes the aluminum and stainless steel to grow together at their interface and form a sound metallurgical bond therebetween. Upon cooling, the assembly may be machined by conventional techniques to produce tubular transition joints having a sound metallurgical bond between the two metals forming the joint. Transition joints formed in accordance with the method of this invention have been found to remain impervious to gas and thus prevent leaks even when operated over wide temperature differentials including cryogenic temperatures.

OBJECTS OF THE INVENTION

It is therefore an object of the present invention to provide a method of forming improved transition joints for use in the coupling of dissimilar metals.

Another object of the present invention is to provide an improved metallurgical bond between dissimilar metals having substantially different coefficients of thermal expansion.

A further object of the present invention is to provide a method of fabricating an improved tubular transition joint having a sound metallurgical bond between the two metals forming the joint and being free of gas leakage over wide ranges of temperature operation.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings wherein:

FIG. 1 illustrates a longitudinal cross-sectional view of the starting stock materials assembled for treatment.

FIG. 2 illustrates a longitudinal cross-sectional view of the assembly after it has been subjected to heat treatment and reduction by rotary swagging

Figs. 3A and 3B illustrate two types of tubular transition joints which may be machined from the assembly shown in FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to Fig. 1, the starting materials necessary for carrying out the method of this invention are shown in their assembled form. These starting materials include a stainless cylinder **11**, and aluminum rod **12**, and two stainless steel plugs **13** and **14**. As shown, the aluminum rod is inserted within the stainless cylinder and a stainless plug is partially received within each end of the cylinder at opposed ends of the aluminum rod. Prior to assembly, these four parts are carefully machined for an accurate fit; the stainless steel cylinder being prepared by sizing its inner diameter to a smooth round bore by means of honing while the aluminum plug and the stainless steel plugs are prepared by turning their outer diameters to a smooth round surface which may be for example 0.001 inch smaller than the inner diameter of the cylinder. Such machining eliminates surface irregularities on the parts and assures a close fit of all parts in the assembly.

For optimum results, it is also desirable to thoroughly clean the four parts prior to assembly. The cleaning of the stainless steel parts may be accomplished by dipping these parts in trichloroethylene to achieve a vapor degrease, drying, dipping these parts in an alkaline solution, drying, dipping these parts in an acid solution such as a mixture of nitric acid and hydrofluoric acid, drying, dipping in cold water rinse and drying by blowing air on the parts. Cleaning of the aluminum parts may be accomplished by dipping the aluminum rod in trichloroethylene for vapor degrease, drying, dipping in alkali solution and subjecting to a cold water rinse, dipping the rod into an acid solution such as dilute nitric acid and subjecting to a cold water rinse, dipping the rod into a zincate solution and subjecting to a cold water rinse, repeating the acid dip and cold water rinse and then repeating the zincate dip and cold water rinse and finally drying the parts by blowing air on the rod. Cleaning the parts in this manner will remove surface contaminations, will eliminate the absorbed and adsorbed gases on the surfaces of the parts and will remove the oxide coating which is otherwise present on these parts. The cleaning steps eliminate the contaminating coatings which might otherwise inhibit the formation of the metallurgical bond between the metals which is desired to be achieved.

After the parts have been cleaned and assembled in the manner shown in Fig. 1, the stainless steel rod **13** is welded to the stainless steel cylinder **11** in a manner to produce a continuous annular weld joint **15** at the juncture of the end of the stainless steel rod with the plug. Similarly, a second annular weld joint **16** is produced at the juncture of plug **14** with the other end of the cylinder **11**. Welding stainless steel parts in the manner described serves to completely enclose the aluminum rod **12** within a continuous stainless steel jacket or envelope.

The welded assembly is then heated to a point above the recrystalization temperature, but below the lowest melting point of any metal in the assembly and subjected to a reduction in cross-sectional area. This reduction is preferably accomplished by means of rotary swagging which produces very high internal pressures in the assembly. These high internal pressures in the assembly. These high internal pressures, ac-

companied by flexing of the tube walls during the rotary swagging operation, produces a very good metallurgical bond throughout the areas of contact of the aluminum with the stainless steel. It has been found that excellent metallurgical bonds of the dissimilar metals are produced by a 50 percent reduction of cross-sectional area, although lesser amounts of reduction of cross- will produce satisfactory results. Although iron, which is a constituent of stainless steel, and aluminum are two metals which chemically react to produce an intermetallic compound which has brittle characteristics, such a compound has not been detected in the bonds produces in accordance with this method even though theoretically such a layer should exist.

The quality of the metallurgical bond between the dissimilar metals produced by the method of this invention is enhanced by the particular arrangement of parts and assembly of parts which enables all entrapped air which might be present between the outer diameter of the aluminum plug and the inner diameter of the stainless steel cylinder to be displaced from this area. Any air present at the interface of the aluminum and stainless steel parts is permitted to be displaced from the interfacial area toward the welded areas **15** and **16** by the pressures exerted thereon during the swagging operation. The temperature and pressure conditions during the swagging operation are not sufficient to produce a bond between the stainless steel plugs and the stainless steel cylinder, which would require much higher temperature and pressure. Thus WHATEVER AIR IS PRESENT IN THE ASSEMBLY IS PERMITTED TO COLLECT IN THE STAINLESS STEEL TO STAINLESS STEEL INTERFACE AREAS -& AND -* WHILE THE METALLURGICAL BOND OF THE ALUMINUM TO STAINLESS STEEL IS BEING CREATED. The chromium oxide layer on the stainless steel cylinder is believed to give up its oxygen by denying it oxygen, i.e., removing the air at the aluminum and stainless steel interface, thus preventing an oxide layer from inhibiting the metallurgical bond which is being produced. Since the temperatures employed in the method of this invention are well below the melting point of any of the metals being worked, the intermetallic layer is kept very thin.

Referring now to FIG. 3A, there is shown a bimetallic transition manufactured from the assembly shown in FIG. 2. This transition joint is formed by cutting away the stainless steel plugs **13** and **14** from the swaged assembly shown in FIG. 2, making a transverse cut through the assembly at a point midway between the ends of the aluminum rod, drilling an axial bore throughout the length of the remaining workpiece, milling off the stainless steel layer from the left end of the workpiece along a portion which is less than one-half the length of the workpiece, and drilling out the aluminum from the right end of the workpiece to a depth less than one-half the length of the workpiece, to thus produce a transition joint having a tubular aluminum section **22** joined to a tubular stainless steel section **21** by means of a lap joint **23** in which area the stainless steel and aluminum overlap and are metallurgically bonded together.

Referring now to FIG. 3B, there is shown a transition joint formed by an aluminum section **32** and a stainless steel section **31** joined together by a butt joint **33**. This transition joint is formed by making a transverse cut through the assembly at a point along the length of the aluminum rod **12**. The remaining workpiece is then milled down to the final diameter of the aluminum rod **12** thus removing the stainless steel layer including the welds **15** and **16**. Then by forming an axial bore throughout the length of the workpiece, the transition joint shown in FIG. 3B is produced with the aluminum and stainless steel tubular sections metallurgically bonded together by a butt joint.

From the foregoing, it will be apparent that applicant has provided a new and improved method of producing improved tubular transition joints formed of dissimilar metals which cannot be welded together by conventional techniques. By practicing the method hereinabove described, dissimilar metals may be joined together by a metallurgical bond to form tubular transition joints which will remain free from gas leakage when operated over extreme ranges of temperature variation, including cryogenic temperatures. Moreover, the method of this invention may be practiced with relatively inexpensive equipment commonly found in most machine shops.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that the invention may be practiced otherwise than as specifically described. For example, transition joints may be manufactured in large quantities in accordance with the method of this invention by merely utilizing a longer stainless steel cylinder **11** within which are alternately positioned a plurality of aluminum and stainless steel rods in the area between the stainless steel plugs **13** and **14** which are welded to the cylinder.

What is claimed and desired to be secured by letters patent of the United States is:

1. A method of joining two metals having different coefficients of thermal expansion comprising:
- positioning a rod formed of a first metal within a cylinder which is formed of a second metal and is longer than said rod,
- positioning first and second plugs formed of said second metal at least partially within opposed ends of said cylinder and in abutting contact with said rod,
- welding each plug to said cylinder, and forming a metallurgical bond between said two metals by heating the assembled rod, plugs and cylinder, and
- reducing the cross-sectional area of said assembly by 10 to 50 percent, severing said first and second plugs and a portion of said rod and said cylinder to form a workpiece comprising the remaining portion of said rod and said cylinder.

2. The method of claim **1** wherein:
- the reducing step is performed by rotary swagging until the desired amount of reduction is achieved.

3. The method of claim **2** wherein:
- the rods and plugs are machined to smooth close fitting surfaces prior to assembly.

4. The method of claim **2** wherein the welding step includes:
- making a continuous annular weld around each plug to join the plugs to the cylinder.

5. The method of claim **3** wherein the welding step includes:
- making a continuous annular weld around each plug at a position thereon which is spaced from the rod.

6. A method of joining two metals having different coefficients of thermal expansion comprising:
- positioning a rod formed of a first metal within a cylinder which is formed of a second metal and is longer than said rod,
- positioning first and second plugs formed of said second metal at least partially within opposed ends of said cylinder and in abutting contact with said rod,
- welding each plug to said cylinder, and
- forming a metallurgical bond between said two metals by heating the assembled rod, plugs and cylinder, and
- reducing the cross-sectional area of said assembly by 10 to 50 percent,
- cooling the assembly subsequent to the rotary swagging
- cutting away the original cylinder and the outer portion of the plugs so that the final diameter of the assembly is reduced to the final diameter of the rod,
- drilling an axial bore throughout the length of the assembly, and
- transversely cutting the drilled assembly at a position between the ends of the rod portion to thereby form two tubular transition joints each having tubular sections of dissimilar metals joined together by a metallurgical bond at a butt joint.

7. A method of joining two metals having different coefficients of thermal expansion comprising:

positioning a rod formed of a first metal within a cylinder which is formed of a second metal and is longer than said rod,

positioning first and second plugs formed of said second metal at least partially within opposed ends of said cylinder and in abutting contact with said rod,

welding each plug to said cylinder, and

forming a metallurgical bond between said two metals by heating the assembled rod, plugs and cylinder, and

reducing the cross-sectional area of said assembly by 10 to 50 percent,

cooling the assembly subsequent to rotary swagging

transversely cutting the assembly near the midpoint of the rod to make two sections,

drilling an axial bore in one end of each section to a depth and diameter so as to remove all of the rod along a portion thereof less than one-half the length of the section,

cutting away the second metal from the outer diameter of the other end of each section along a portion thereof which is less than one-half the length of the section and,

drilling an axial bore through the sections to form two transition joints each having two tubular sections of dissimilar metals joined together by a lapjoint at which is formed a metallurgical bond.