

Method for Welding Dissimilar Metals

Field of the Invention

[0001] The present invention relates to a method of welding two dissimilar metals. In particular, the present invention relates to a method for welding two dissimilar metals using Gas Tungsten Arc Welding.

Background

[0002] Titanium (Ti) is one metal that has an exceptional corrosion resistance and desirable mechanical properties. However, it is a costly practice to use mere pure titanium to manufacture any equipment. In many instances, it is advantageous both technically and economically to join titanium with other metals, such as stainless steel, so as to lower cost of titanium. Titanium cladding on stainless steel substrate construction offers not only a significant cost reduction, but also a superior durability in comparison to pure titanium equipment.

[0003] Methods of conventional non-fusion welding like mechanical joining, friction welding, explosive cladding, and soldering have been investigated to join such dissimilar metals. Explosive cladding, one method of non-fusion welding, has deemed to be the only method available for fabricating raw materials of Ti-clad steel nowadays. Friction welding between titanium and steel by introducing interlayer metals of vanadium and copper has been found successful. While the integrity and stability of friction welding joint is acceptable, the method of friction welding itself is restricted by the particular configuration of the metals to be welded. The method of friction welding thus might not be applicable for welding a wide range of dissimilar metals.

[0004] Besides non-fusion welding, fusion welding is also applicable for joining titanium and stainless steel. Nevertheless, fusion welding, such as arc welding, of dissimilar metals has always associated with shortcomings due to the nature of the metals. For example, while joining titanium to stainless steel, the metallurgical incompatibility between titanium and iron in stainless steel leads to the formation of brittle intermetallic phase between titanium and iron. Furthermore, different thermal expansion characteristic between titanium and stainless steel has been found to cause cracks developed by large tensile stress produced from cooling action after welding. These shortcomings therefore affect the quality of the joints integrity between titanium and stainless steel.

[0005] To overcome problems associated with above shortcomings, intermediates metals can be introduced into the intermediate joint between two dissimilar metals. US Patent Publication No. 2010233501 discloses a method for joining two dissimilar metals by introducing an adapter in the intermediate position between the two dissimilar metals using a fusion welding process. The adapter is formed by a first and second metal, in which the first and second metals are manufactured from dissimilar metals that are similar to the dissimilar metals to be welded, respectively.

[0006] While many methods of joining dissimilar metals are known, there is a need to improve methods for satisfactorily joining two dissimilar metals. Therefore, the feasibility of Gas Tungsten Arc Welding for welding two dissimilar metals, such as, titanium and stainless steel by introducing bi-filler rods as intermediates, in which the bi-filler rods are not similar to the welded metals, is disclosed.

Summary

[0007] The present invention relates to a method for joining two dissimilar base metals, i.e. titanium and stainless steel, by Gas Tungsten Arc welding via V-butt joint with root gap. In the present invention, two intermediates metal, vanadium and aluminum bronze, are introduced as bi-filler rods between the two dissimilar base metals.

[0008] To weld the base metals together, a welding current is applied so that an arc welding is formed between tungsten electrode and the base metal portions. As the arc welding is formed, the two filler rods are fed into the gap present between the titanium and the stainless steel, hence sealing the gap between the titanium and the stainless steel. The vanadium is fed onto the titanium side, while the aluminum bronze is fed onto the stainless steel side. In this way, a sound weldment of titanium and stainless steel will be achieved. The tensile strength of the joint between the titanium and stainless steel with bi-filler rods of vanadium and aluminum bronze is satisfactory while compared to the tensile strength of the joint between the titanium and stainless steel with single filler rod of vanadium.

[0009] The present invention also discloses a method for joining titanium and carbon steel, by Gas Tungsten Arc welding via V-butt joint with root gap. Similarly, two intermediates metal, vanadium and aluminum bronze, are introduced as bi-filler rods and a sound weldment between the titanium and the carbon steel is achieved.

Brief Description of the Drawings

[0010] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

[0011] **Fig. 1** is a schematic view showing V-butt joint design adopted for welding of the present invention;

[0012] Fig. 2 is a schematic view showing V-butt joint design for welding Ti Gr. 2 and stainless steel 316L in accordance with one embodiment of the present invention;

[0013] Fig. 3 illustrates a sound weldment Ti Gr.2 and stainless steel 316 L in accordance with yet one embodiment of the present invention;

[0014] Fig. 4 is a schematic view showing V-butt joint design for welding Ti Gr. 2 and stainless steel 316L in another preferred embodiment of the present invention; and

[0015] Fig. 5 is a schematic view showing V-butt joint design for welding Ti Gr. 2 and carbon steel in accordance with another preferred embodiment of the present invention.

Detailed Description

[0016] The following descriptions of a number of specific and alternative embodiments are provided to understand the inventive features of the present invention. It shall be apparent to one skilled in the art, however that this invention may be practiced without such specific details. Some of the details may not be described in length so as to not obscure the invention. For ease of reference, common reference numerals will be used throughout the figures when referring to same or similar features common to the figures.

[0017] The present invention provides a method of Gas Tungsten Arc welding with V-butt joint for joining titanium base metal portion with stainless steel base metal portion. In the arc welding process of the present invention, two intermediates filler rods, vanadium and aluminum bronze, are introduced between the titanium base metal and the stainless steel base metal. This method provides sound weld between these two dissimilar base metals.

[0018] It is known that vanadium has better compatibility with titanium rather than with stainless steel that a contact between vanadium and stainless steel leads to formation of

embrittle intermediate and thus fracturing the joint between vanadium and stainless steel. Additionally, vanadium has a better compatibility with aluminum bronze rather than with stainless steel. Because of these metallurgical compatibility reasons, in this present invention, vanadium filler rod will be fed onto the titanium base side and aluminum bronze filler rod will be fed onto the stainless steel base side, while vanadium and aluminum bronze will be overlapping to each other. With this configuration, a sound weldment will be achieved.

[0019] Fig. 1 illustrates a schematic drawing of V-butt joint design adopted for Gas Tungsten Arc Welding between two base metals of titanium 101 and stainless steel 102 by using intermediate filler rods of pure vanadium wire 103 and aluminum bronze 104 according to one embodiment of the present invention. Both of the base metals 101, 102 are one side beveled. A root gap 105 is present between both base metals 101, 102, and the intermediate bi-filler rods of vanadium wire 103 and aluminum bronze 104 will be used to seal the root gap 105. Due to the metallurgical compatibility, the vanadium wire 103 is fed onto the titanium side 101, while the aluminum bronze 104 is fed onto the stainless steel 102 side.

[0020] The present invention will now be further described by means of welding two dissimilar metals of commercially pure Ti Gr.2 (99% pure) and stainless steel 316 L (62%~72% Ferrous content).

[0021] Fig. 2 illustrates the schematic drawing of V butt joint design for welding Ti Gr.2 (99% pure) 201 and stainless steel 316 L 202 (62%~72% Ferrous content) via Gas Tungsten Arc Welding. In one embodiment of the present invention, the Ti Gr. 2 201 is in the dimension of 150*300*10 mm, while the stainless steel 316 L 202 is in the dimension of 150*300*10 mm. Commercially pure vanadium wire (99.9% pure), 2.5 mm in diameter, and aluminum bronze (~9% aluminum alloying), 2.4 mm in diameter, are co-used as bi-filler rods of 203 and 204 respectively.

[0022] Prior to welding, both base metals **201**, **202** and bi-filler rods **203**, **204** are carefully cleaned with acetone. The base metals **201**, **202** are then one side beveled at an angle range of 32° and 38°, and most preferably at an angle of 35°. Subsequently, vanadium is buttered on the beveled side of the Ti Gr. 2 **201** base metal with the thickness of 2.5~3.5 mm, forming a vanadium-buttered Ti Gr. 2 **205**. Next, the vanadium-buttered Ti Gr. 2 **205** is arranged with the stainless steel 316 L **202** such that a root gap **206** of 3.2 ± 1.6 mm is provided between the vanadium-buttered Ti Gr. 2 **205** and the stainless steel 316 L **202**. Clamp is used to fix the base metals **202**, **205** and maintain the root gap **206** between the base metals **202**, **205**. A welding current is then applied between tungsten electrode of the arc and the base metals **202**, **205**, forming an arc welding. Subsequently, the bi-filler rods are fed into the root gap **206** between the base metals **202**, **205** hence sealing the root gap **206** and joining the base metals **202**, **205** together. The vanadium filler rod **203** is fed onto the vanadium-buttered Ti Gr.2 **205** side and the aluminum bronze filler rod **204** is fed onto the stainless steel **202** side during the welding process. The vanadium-buttered zone **207** of the vanadium-buttered Ti Gr. 2 **205** prevents the Ti Gr.2 **201** from contact with the aluminum bronze filler rod **204**. It is highly undesired to have the aluminium bronze filler rod **204** being in contact with the vanadium-buttered Ti Gr. 2 **205** since titanium has limited solubility with aluminum.

[0023] In one embodiment of the present invention, the optimum welding condition for performing Gas Tungsten Arc welding is obtained at 8~12 Volt, 86~125 Ampere at a travel speed of 30~120 mm/min with Argon cover gas flow of 15~25 L/min.

[0024] Fig. 3 illustrates a sound weldment **301** with thickness of 10 mm which is formed between the Ti Gr.2 **201** and the stainless steel 316 L **202** according to one embodiment of the present invention. There are five characteristic zones that are formed during welding, they are stainless steel 316 L **202** zone, fusion zone **302** of aluminum bronze filler rod, fusion zone **303**

of vanadium filler rod, vanadium buttered zone **207**, and Ti Gr.2 **201** zone. To test the strength and ductility of the weldment **301** between the Ti Gr.2 **201** and the stainless steel 316 L **202**, tensile test is carried out. Two samples **T1**, **T2** of weldment **301** between the Ti Gr.2 **201** and the stainless steel 316 L **202** are run for tensile test. The details of prepared samples **T1**, **T2** and test results are depicted in the table below.

Specimen No.	T1	T2
Measured Thickness (mm)	9.49	9.59
Measured Width (mm)	19.07	19.05
Effective Area (mm ²)	180.97	182.69
Ultimate Tensile Load (KN)	50.96	53.88
Ultimate Tensile Stress (N/mm ²)	282	295
Location of Failure	Broke at Buttering Weld	Broke at Buttering Weld
Type of Failure	Brittle Failure	Brittle Failure

[0025] A satisfactory tensile strength is obtained from the weldment **301** between the Ti Gr.2 **201** and the stainless steel 316 L **202**, and the value of the tensile strength is 282 MPa. The break point of the weldment **301** is occurring at the vanadium-buttered zone **207**, indicating that the vanadium-buttered zone **207**, instead of the fusion region **302**, **303** or the heat affected region, is the weakest point within the weldment **301**. Although the break point of the weldment **301** is occurring at vanadium-buttered zone **207**, in which the zone **207** mainly comprises of vanadium only, the tensile strength of the weldment **301** (282 MPa) is larger than the tensile strength of the pure vanadium itself (245 MPa). This occurs because vanadium and aluminum bronze is forming intercross layers **305**, which found in the weld pool. The intercross **305** layers facilitate diffusion and alloying effect in the weldment **301** and therefore, improve the mechanical property of the weldment **301**.

[0026] Fig. 4 illustrates schematic drawing of V butt joint design for welding Ti Gr.2 (99% pure) 401 and stainless steel 316 L 402 (62%~72% Ferrous content) via Gas Tungsten Arc Welding according to another embodiment of the present invention. The Ti Gr. 2 401 is in the dimension of 150*300*10 mm, while the stainless steel 316 L 402 is in the dimension of 150*300*10 mm. Both of base metals 401, 402 are one side partially beveled by the thickness of 5 mm that the remaining thickness of 5 mm of the base metals 401, 402 is not beveled. The base metals 401, 402 are aligned prior to welding with a zero root gap 405 present between the base metals 401, 402. During welding, the vanadium filler rod and aluminum bronze 403, 404 are fed into gap 406 between the beveled sides of the base metals. A sound weldment with the thickness of 5 mm is formed between the base metals 401, 402.

[0027] Fig. 5 illustrates a schematic drawing of V-butt joint design adopted for Gas Tungsten Arc Welding between two base metals of Ti Gr. 2 501 and carbon steel 502 by using intermediate filler rods of pure vanadium wire 503 and aluminum bronze 504 according to one embodiment of the present invention. Both of the base metals are one side beveled and vanadium is buttered on the beveled side of titanium base metal 501, forming a vanadium-buttered titanium 505. A root gap 506 is present between the vanadium buttered titanium 505 and the carbon steel 502 in which the root gap 506 will be sealed with the bi-filler rods 503, 504. The filler rod of vanadium 503 is fed onto the buttered titanium 505 side and the filler rod of aluminum bronze 504 is fed onto the carbon steel 502 side during the welding process. The vanadium-buttered zone 507 prevents the aluminum bronze 504 to come in contact with the Ti Gr. 2 501.

[0028] The above description illustrates various embodiments of the present invention along with examples of how aspects of the present invention may be implemented. While specific embodiments have been described and illustrated it is understood that many changes,

modifications, variations and combinations thereof could be made to the present invention without departing from the scope of the present invention. The above examples, embodiments, instructions semantics, and drawings should not be deemed to be the only embodiments, and are presented to illustrate the flexibility and advantages of the present invention as defined by the following claims:

Claims

1. A method of joining titanium base metal portion and stainless steel base metal portion using Gas Tungsten Arc welding with V butt joint welding type, the method comprising the steps of:
 - (a) applying a welding current such that an arc welding is formed between the tungsten electrode of the arc and said base metal portions; and
 - (b) introducing two intermediates filler rods of vanadium wire and aluminum bronze to the arc welding such that said filler rods are fed into the weld area between said base metal portions, and joins said base metal portions, wherein the vanadium filler rod is placed adjacent to said titanium base metal portion and the aluminum bronze filler rod is placed adjacent to said stainless steel base metal portion, and the two intermediates filler rods are placed adjacent to each other.
2. The method of claim 1, wherein the welding current is set at 8~12 Volt, 86~125 Ampere at a travel speed of 30~120 mm/min with Argon cover gas flow of 15~25 L/min.
3. The method of claim 1, wherein said titanium base metal portion contains a titanium content of at least 99.34% by weight and said stainless steel base metal portion contains a ferrous content of 62~72%.
4. The method of claim 1, wherein the vanadium filler rod contains 99.9% pure vanadium and the aluminum bronze filler rod contains ~9% aluminum alloying.
5. The method of claim 1, wherein a root gap is formed in V butt joint between said titanium and said stainless steel base metal portions, and said root gap is ranging between 1.6 mm to 4.8 mm.

6. The method of claim 5, wherein the root gap is 3.2 mm.
7. The method of claim 1, wherein both of the base metals are beveled at an angle range of $32^{\circ}\sim 38^{\circ}$ at one side thereof.
8. The method of claim 1, wherein both of base metals are beveled at angle of 35° at one side thereof.
9. The method of claim 1, wherein vanadium is buttered on the titanium beveled side prior to welding.
10. The method of claim 9, wherein the thickness of the vanadium buttered zone at the titanium beveled side is 2.5~3.5 mm.
11. The method of claim 1, wherein the V butt joint between said titanium and stainless steel base metal portions has no root gap.
12. A filler rod component for joining dissimilar metals, the filler rod comprising:
 - (1) 99.9% pure vanadium; and
 - (2) 8.5%~11.0% aluminum bronze.
13. A method of joining titanium base metal portion and carbon steel base metal portion using Gas Tungsten Arc welding with V butt joint welding type, the method comprising the steps of:
 - (a) applying a welding current such that an arc welding is formed between the tungsten electrode of the arc and said base metal portions; and

(b) introducing two intermediates filler rods of vanadium wire and aluminum bronze to the arc welding such that said filler rods are fed into the weld area between said base metal portions, and joins said base metal portions, wherein the vanadium filler rod is placed adjacent to said titanium base metal portion and the aluminum bronze filler rod is placed adjacent to said carbon steel base metal portion, and the two intermediates filler rods are placed adjacent to each other.

14. The method of claim 13, wherein the welding current is set at 8~12 Volt, 86~125 Ampere at a travel speed of 30~120 mm/min with Argon cover gas flow of 15~25 L/min.

15. The method of claim 13, wherein the vanadium filler rod contains 99.9% pure vanadium and the aluminum bronze filler rod contains ~9% aluminum alloying.

16. The method of claim 13, wherein a root gap presents in V butt joint between said titanium and stainless steel base metal portions, said root gap has a distance in a range of 1.6 mm to 4.8 mm.

17. The method of claim 13, wherein both of base metals are beveled at an angle range of 32°~38° at one side thereof.

18. The method of claim 13, wherein vanadium is buttered on the titanium beveled side prior to welding.