TA20 BACKGROUND / TC18, TC21 AND TC6 WELDING | ENGLISH TRANSLATION

Welding wire for high-strength two-phase titanium alloys

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Scope of this reference

English translation of the published Chinese patent disclosure. This is not a certified translation, purchase specification, material certificate, qualified production procedure or guarantee of supplied properties. Results and benefits are statements of the original disclosure. The original Chinese publication controls.

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Translation notes

TA20 is discussed as the existing comparison wire. The newly claimed Al-Mo-V-Zr-Nb-Hf wire is a different alloy, not TA20. The source notation CΠ2 is transliterated here as SPT-2. The source calls the alloy system Ti-Al-Mo-V-Zr-Nb-RE although its specified addition is Hf; that wording is retained. The abstract contains an apparent extra Al before Ti; the unambiguous Ti, Zr and Hf wording used in the description and claims is followed. Alloy compositions and reported weld results are source statements, not guaranteed properties of supplied material.

Bibliographic information

Application: 200610057574.8; filed 16 March 2006. Earlier application publication: CN1814395A, 9 August 2006. Grant publication: CN100393473C, 11 June 2008. This translation includes the abstract, complete technical description, both examples and all nine claims. No source tables or drawings are present.

Abstract

The invention concerns welding wire suitable for welding various high-strength two-phase titanium alloys. Its alloy composition, in weight percent, is Al 3.0-5.0, Mo 1.5-3.0, V 1.5-3.0, Zr 1.0-2.0, Nb 3.0-5.0, Hf 0.1-0.3, balance Ti. In preparing filler material or welding wire, Ti, Zr and Hf are added as grade 0 sponge, and Al, Mo, V and Nb as aluminium-based master alloys. The ingot is melted at least three times in a vacuum consumable-electrode arc furnace, followed by forging, annealing and drawing.

Description - technical field

The invention concerns welding wire suitable for welding various high-strength two-phase titanium alloys.

Background

At the time of the original publication, SPT-2 welding wire, with a molybdenum equivalent close to 2.2, was generally selected in China for welding medium- and high-strength titanium alloys. Its domestically produced designation is TA20. Its composition, in weight percent, is Al 3.5-4.5, V 2.5-3.5, Zr 1.0-2.0, balance Ti. It can produce welded joints with good mechanical properties in medium-strength titanium alloys. For high-strength titanium alloys, however, its relatively low alloy content cannot ensure the required joint strength; this tendency becomes more pronounced in multipass welding. To address this issue, the invention develops a multicomponent Ti-Al-Mo-V-Zr-Nb-RE welding wire with a molybdenum equivalent of 4.0-6.0, intended to produce joints with satisfactory strength, ductility and toughness in high-strength two-phase titanium alloys.

Disclosure of the invention

The objective is to provide welding wire for a range of high-strength two-phase titanium alloys. The specified composition, in weight percent, is Al 3.0-5.0, Mo 1.5-3.0, V 1.5-3.0, Zr 1.0-2.0, Nb 3.0-5.0, Hf 0.1-0.3, balance Ti.

(1) Add Ti, Zr and Hf as grade 0 sponge, and Al, Mo, V and Nb as aluminium-based master alloys.

(2) Melt the ingot at least three times in a vacuum consumable-electrode arc furnace to ensure compositional homogeneity.

(3) Remove the shrinkage cavity and turn off the ingot surface, then perform breakdown forging at 1100 ± 10°C with a holding time of 60 min.

(4) Open-die forge the breakdown-forged stock into bars at 950 ± 10°C, holding for 30-60 min. Shorten the holding time as the stock cross-section decreases.

(5) Anneal the open-die-forged bars at 700 ± 10°C for 60 min and air cool to relieve stress and homogenise the microstructure. Then hot roll to small bars.

(6) Draw the hot-rolled small bars on wire-drawing equipment. Repeatedly anneal at 700 ± 10°C for 20 min followed by air cooling during drawing to remove work hardening, until the required wire size is obtained. Wire-cut hot-rolled foil or strip to the shape and size required for filler material.

Before use, vacuum-dehydrogenate the wire or filler material because hydrogen strongly affects titanium mechanical properties, especially impact toughness. Pickle in an aqueous HF + HNO3 solution, dry thoroughly in an oven for at least 3 h, then degas in a vacuum furnace at 800 ± 10°C for 180 min and furnace cool.

The invention is applicable to welding various high-strength two-phase titanium alloys. Tests reported under the same heat-treatment schedule gave the following results. For TC18, with tensile strength close to 1200 MPa and nominal composition Ti-5Al-4.75Mo-4.75V-1Cr-1Fe, joint strength reached 100% and impact toughness 97% of the parent material. For TC21, with tensile strength above 1200 MPa and nominal composition Ti-6Al-2Sn-2Zr-2.5Mo-1.7Cr-2Nb-0.1Si, joint strength reached 100% and impact toughness 95% of the parent material. For TC6, with tensile strength close to 1100 MPa and nominal composition Ti-6Al-2.5Mo-1.5Cr-0.5Fe-0.3Si, joint strength reached 110% and impact toughness 80% of the parent material. The alloy can also be made into foil or strip as filler for these welds.

Detailed implementation

Select an alloy containing, in weight percent, Al 3.0-5.0, Mo 1.5-3.0, V 1.5-3.0, Zr 1.0-2.0, Nb 3.0-5.0, Hf 0.1-0.3, balance Ti. Prepare the wire as follows:

(1) Add Ti, Zr and Hf as grade 0 sponge, and Al, Mo, V and Nb as aluminium-based master alloys.

(2) Melt the ingot at least three times in a vacuum consumable-electrode arc furnace to ensure compositional homogeneity.

(3) Remove the shrinkage cavity and turn off the ingot surface, then perform breakdown forging at 1100 ± 10°C with a holding time of 60 min.

(4) Open-die forge the breakdown-forged stock into 14 mm diameter bars at 950 ± 10°C, holding for 30-60 min. Shorten the holding time as the stock cross-section decreases.

(5) Anneal the open-die-forged bars at 700 ± 10°C for 60 min and air cool to relieve stress and homogenise the microstructure. Then hot roll to small bars, foil or strip.

(6) Draw the hot-rolled small bars on wire-drawing equipment. Repeatedly anneal at 700 ± 10°C for 20 min followed by air cooling during drawing to remove work hardening, until the required wire size is obtained. Wire-cut the hot-rolled foil or strip to the required filler shape and dimensions.

(7) Before use, vacuum-dehydrogenate the wire or filler material because hydrogen strongly affects titanium mechanical properties, especially impact toughness. Pickle in an aqueous HF + HNO3 solution, dry thoroughly in an oven for at least 3 h, then degas in a vacuum furnace at 800 ± 10°C for 180 min and furnace cool.

Example 1 - welding wire

Select the following composition, in weight percent: Al 5.0, Mo 1.5, V 3.0, Zr 2.0, Nb 3.0, Hf 0.1, balance Ti.

(1) Add Ti, Zr and Hf as grade 0 sponge, and Al, Mo, V and Nb as aluminium-based master alloys.

(2) Melt the ingot at least three times in a vacuum consumable-electrode arc furnace to ensure compositional homogeneity.

(3) Remove the shrinkage cavity and turn off the ingot surface, then perform breakdown forging at 1100 ± 10°C with a holding time of 60 min.

(4) Open-die forge the breakdown-forged stock into small bars at 950 ± 10°C, holding for 30-60 min. Shorten the holding time as the stock cross-section decreases.

(5) Anneal the open-die-forged bars at 700 ± 10°C for 60 min and air cool to relieve stress and homogenise the microstructure. Then hot roll the bars to the target size.

(6) Draw the hot-rolled small bars on wire-drawing equipment. Repeatedly anneal at 700 ± 10°C for 20 min followed by air cooling during drawing to remove work hardening, until the required wire size is obtained.

(7) Before use, vacuum-dehydrogenate the wire or filler material because hydrogen strongly affects titanium mechanical properties, especially impact toughness. Pickle in an aqueous HF + HNO3 solution, dry thoroughly in an oven for at least 3 h, then degas in a vacuum furnace at 800 ± 10°C for 180 min and furnace cool.

Example 2 - filler material

Select the following composition, in weight percent: Al 3.0, Mo 3.0, V 1.5, Zr 1.0, Nb 5.0, Hf 0.3, balance Ti.

(1) Add Ti, Zr and Hf as grade 0 sponge, and Al, Mo, V and Nb as aluminium-based master alloys.

(2) Melt the ingot at least three times in a vacuum consumable-electrode arc furnace to ensure compositional homogeneity.

(3) Remove the shrinkage cavity and turn off the ingot surface, then perform breakdown forging at 1100 ± 10°C with a holding time of 60 min.

(4) Open-die forge the breakdown-forged stock into small bars at 950 ± 10°C, holding for 30-60 min. Shorten the holding time as the stock cross-section decreases.

(5) Anneal the open-die-forged bars at 700 ± 10°C for 60 min and air cool to relieve stress and homogenise the microstructure. Then hot roll the bars to strip.

(6) Wire-cut the strip to the required shape and dimensions. Use it as filler material that transfers into the weld during fusion welding of high-strength two-phase titanium alloys.

(7) Before use, vacuum-dehydrogenate the wire or filler material because hydrogen strongly affects titanium mechanical properties, especially impact toughness. Pickle in an aqueous HF + HNO3 solution, dry thoroughly in an oven for at least 3 h, then degas in a vacuum furnace at 800 ± 10°C for 180 min and furnace cool.

Claims

1. Welding wire for high-strength two-phase titanium alloys, having the following composition in weight percent: Al 3.0-5.0, Mo 1.5-3.0, V 1.5-3.0, Zr 1.0-2.0, Nb 3.0-5.0, Hf 0.1-0.3, balance Ti; prepared by the following method:

(1) Add Ti, Zr and Hf as grade 0 sponge, and Al, Mo, V and Nb as aluminium-based master alloys.

(2) Melt the ingot at least three times in a vacuum consumable-electrode arc furnace to ensure compositional homogeneity.

(3) Remove the shrinkage cavity and turn off the ingot surface, then perform breakdown forging at 1100 ± 10°C with a holding time of 60 min.

(4) Open-die forge the breakdown-forged stock into bars at 950 ± 10°C, holding for 30-60 min. Shorten the holding time as the stock cross-section decreases.

(5) Anneal the open-die-forged bars at 700 ± 10°C for 60 min and air cool to relieve stress and homogenise the microstructure. Then hot roll to small bars, foil or strip.

(6) Draw the hot-rolled small bars on wire-drawing equipment. Repeatedly anneal at 700 ± 10°C for 20 min followed by air cooling during drawing to remove work hardening, until the required wire size is obtained. Wire-cut the hot-rolled foil or strip to the required shape and size of the filler material.

2. The wire of claim 1 is vacuum-dehydrogenated before use: pickle and oven-dry the wire thoroughly, then degas it in a vacuum furnace. The pickling solution is aqueous HF + HNO3. The vacuum-dehydrogenation schedule is 800 ± 10°C for 180 min, followed by furnace cooling.

3. The wire of claim 1 has the following alloy composition, in weight percent: Al 4.0, Mo 2.0, V 2.0, Zr 1.5, Nb 4.0, Hf 0.2, balance Ti.

4. The wire of claim 1 has the following alloy composition, in weight percent: Al 3.0, Mo 1.5, V 1.5, Zr 1.5, Nb 3.0, Hf 0.3, balance Ti.

5. The wire of claim 1 has the following alloy composition, in weight percent: Al 4.0, Mo 3.0, V 2.0, Zr 1.5, Nb 5.0, Hf 0.15, balance Ti.

6. The wire of claim 1 has the following alloy composition, in weight percent: Al 5.0, Mo 2.5, V 2.2, Zr 1.5, Nb 4.0, Hf 0.2, balance Ti.

7. The wire of claim 1 has the following alloy composition, in weight percent: Al 3.0, Mo 2.0, V 1.8, Zr 1.5, Nb 4.0, Hf 0.2, balance Ti.

8. The wire of claim 1 has the following alloy composition, in weight percent: Al 4.5, Mo 2.5, V 2.5, Zr 1.5, Nb 4.5, Hf 0.15, balance Ti.

9. The wire alloy of claim 1 can be processed into foil or strip for use as filler material when welding various high-strength two-phase titanium alloys.