United States Patent

[11] 3,615,279

[72] Inventor Bennie Ray Ward, Jr.
Chesterfield County, Va.

[21] Appl. No. 720,421
[22] Filed Dec. 4, 1967
[23] Division of Ser. No. 497,554, Oct. 18, 1965, Pat. No. 3,359,142
[45] Patented Oct. 26, 1971
[73] Assignee Reynolds Metals Company
Richmond, Va.

[54] **METAL COMPOSITE HAVING AN ALUMINUM ALLOY LAYER BONDED TO A TITANIUM ALLOY LAYER**

8 Claims, No Drawings

[52] U.S. Cl. 29/197
[51] Int. Cl. B32b 15/00
[50] Field of Search 29/194, 198, 197

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Primary Examiner—Hyland Bizoi
Attorney—Glenn, Palmer, Lyne, Gibbs & Thompson

ABSTRACT: There is disclosed a high-strength metal composite made of at least one layer of heat-treatable aluminous metal bonded to a layer of titanium alloy which is susceptible to strengthening by heating in the temperature range for solution treatment of the aluminous metal. Thus, one heat treatment may be used to simultaneously solution heat-treat the aluminous metal and age the titanium alloy. Specific examples discussed include four types of composites of 2024 and 7075 aluminum alloys with Ti–6A1–4V and Ti–4A1–3Mo–1V titanium alloys.

METAL COMPOSITE HAVING AN ALUMINUM ALLOY LAYER BONDED TO A TITANIUM ALLOY LAYER

This is a division of application Ser. No. 497,554 filed Oct. 18, 1965, now U.S. Pat. No. 3,359,142, Dec. 19, 1967.

This invention relates to novel composites having both titanium and aluminous metal components. More particularly, the invention concerns bonded composites of heat-treatable aluminum base alloys and heat-treatable titanium alloys in the solution heat-treated condition, which possess high resistance to deformation and to corrosion.

Composites of titanium and aluminum find limited application in aircraft structures, especially where lightweight, rigidity, and corrosion resistance are of importance.

In accordance with the present invention there are provided novel composites of aluminum base alloys and heat-treatable titanium alloys which possess the foregoing properties in greater degree than known composites of titanium and aluminum.

The term aluminous metal refers to alloys which contain at least 50 percent aluminum. Aluminum base alloys which may be advantageously employed in accordance with the invention include heat-treatable wrought alloys of the aluminum-copper or the aluminum-zinc-magnesium types, such as copper-bearing alloys 2014, 2017, 2024, and 2025, ranging in copper content from about 3.5 percent to abut 5.0 percent, and zinc-bearing alloys such as 7075 and **7002**, the strength of which is increased by solution heat treatment (810°–990° F.) followed by quenching, and aging.

The aluminum base alloys may be used when clad on at least one side with aluminum, for example alclad 2024 with a 2.5 percent or a 5 percent cladding.

Heat-treatable titanium alloys which are advantageously employed in the composites of the invention include the heat-treatable alloys of titanium with aluminum and vanadium or molybdenum. These may be used in the form of sheet or mesh. They are preferably employed in the solution heat-treated condition, or in the solution heat-treated and aged condition.

Examples of suitable heat-treatable titanium alloys of the type described are titanium alloyed with 6 percent aluminum and 4 percent vanadium, and titanium alloyed with 4 percent aluminum, 3 percent molybdenum and 1 vanadium. These titanium alloys are particularly adapted to bonding with aluminum alloys which are responsive to thermal treatment within approximately the same temperature range as the titanium alloys themselves. The alloys are available as sheet in the cold-rolled or cold-drawn condition. Solution heat treatment of the titanium alloys increases their tensile strength from 110–150 K s.i. to above 180 K s.i. when aged at about 900° F.

In the preparation of the composites of the invention, the sheets of aluminum and of titanium alloy may be of any desired thickness compatible with good bonding, varying from foil gages up to the limit of the processing equipment. Preferred aluminum alloy gages vary, for example, from 0.040 inches to 0.125 inches, while suitable titanium alloy gages may range from 0.02 to 0.05 **inch, inches, all before bonding. These gage ranges are to be considered as illustrative, however, and not as limiting.**

The composites of the invention may be bonded by rolling or by means of suitable adhesives, but rolling is preferred. Bonding is advantageously performed by a rolling operation in which the titanium alloy sheet is maintained substantially at room temperature. The aluminum alloy is preheated to a temperature between about 650° F. and about 1,000° F., depending upon the alloy employed, care being taken to avoid grain boundary melting. A temperature range between about 850° F. and about 950° F. ordinarily is preferred. The time of preheat may vary according to conditions, but generally a period of from 5 to 15 minutes is sufficient to uniformly heat the aluminum to the desired temperature. The time of preheat should, however, be kept to a minumum because of surface oxidation.

The metal-to-metal composites of the invention may be of the binary type, i.e. a single layer of aluminum alloy bonded to a single layer of titanium alloy, or they may be of the sandwich type, such as a layer of aluminum alloy between two layers of titanium alloy. Where alclad alloy is used, the titanium alloy is preferably bonded to the aluminum cladding layer. Also included within the scope of the invention are composites having adjacent multiple thicknesses of one or both of the titanium alloy and aluminous metal components.

In preparing the composites of the invention, the surface of the aluminum or aluminum base alloy is degreased, and is then roughened by wire brushing, sanding, grinding, or like methods, in order to remove any film or tin layer of aluminum oxide which would with bonding. If desired, a chemical dip may also be employed. Similarly, the titanium alloy is subjected to roughening by brushing, or by grinding, to break up any oxide layer.

As mentioned previously, bonding may be by means of an adhesive or by rolling. Where rolling is used, the production of a bond may be effected with a reduction in the thickness of the aluminum alloy sheet from about 30 percent to about 70 percent, and in the titanium alloy sheet from about 10 percent to about 50 percent. Rolling is carried out in conventional equipment, an overall gage reduction of about 50 percent resulting in satisfactory bonding.

After bonding, the composite is subjected, in accordance with the invention, to a thermal treatment by reheating the bonded composite to a temperature between about 850° F., and about 950° F. for a period of from about 30 minutes to about 2 hours or more. This serves to strengthen the titanium alloy and to solution heat-treat the aluminum alloy. The temperature is selected according to the particular alloys involved. Thus, for example, alloy 2024 requires treatment at about 920° F., while alloy 7075 is heated at about 880° F. Followed by a cold water quench, such thermal treatment places the aluminum alloy in T–4 temper condition, while if followed by a cold water quench and precipitation hardening (aging) it places the aluminum alloy in T–6 temper condition.

The following examples serve to illustrate the practice of the invention, but are not to be considered as limiting:

EXAMPLE 1

A composite was prepared from a sheet of annealed alclad 2024 alloy, clad on one side with aluminum, dimensions 6×6 ×0.080 inch, and sheet of Ti–6A1–4V sheet, solution heat treated at 1,650° F. and cold water quenched, dimensions 6×6 ×0.45 inch. Prior to bonding, both pieces were wire brushed on the side to be bonded. The 2024 sheet was heated for 10 minutes at 900° F., and the titanium alloy sheet was maintained at room temperature. The sheets were bonded by rolling in a 4-high mill having work rolls 8 inches in diameter, backup rolls 16 inches, width 18 inches, using a mill setting of –0.010 inches (negative roll gap) to effect an approximately 50 percent reduction. The bonded composite (51 percent 2024, 49 percent Ti–6A1–4V) exhibited the following properties in the as-rolled condition: Tensile strength 117 K s.i., yield strength 98.8 K s.i., percent elongation in 2inch–4. The composite then was heat treated at 910° F. for 2 hours and quenched in cold water.

The composite exhibited longitudinally a tensile strength of 121,900 p.s.i., a yield strength of 109,600 p.s.i., an elongation in 2 inches of 6.5 percent. l

EXAMPLE 2

Proceeding as in example 1, a composite was prepared from a sheet of annealed alclad 2024 alloy, dimensions 6×7×0.080 inches, and a sheet of Ti–4A1–3Mo–1V, dimensions 6×6×0 .032 inches solution heat-treated at 1,650° F. for 15 minutes and cold water quenched. Both pieces were wire brushed on one side before bonding. Prior to bonding the 2024 sheet was heated for 10 minutes at 850° F. while the titanium alloy was kept at room temperature. Bonding was performed using a mill setting of plus 0.010 inch.

The bonded composite (64 percent 2024, 36 percent Ti4A1-3Mo-1V) exhibited the following properties in the as-rolled condition: Tensile strength 93.6 K s.i., yield strength 80.6 K s.i., percent elongation in 2 inches=5.3. Upon heating the composite at 910° F. for various times and quenching in cold water the following properties were obtained:

	T.S. in K s.i.	Y.S. in K s.i.	% El. in 2 in.
1 hour at 910° F.	104.5	—	5.0
2 hours at 910° F.	108.0	89.8	12.0
4 hours at 910° F.	103.0	90.9	4.0
8 hours at 910° F.	110.2	91.4	5.0

EXAMPLE 3

A composite was prepared from a sheet of annealed alclad 7075 alloy, dimensions 6×7×0.080 inch, and a sheet of Ti-6A1-4Mn, dimensions 6×6×0.045 inch, solution heat-treated at 1,650° F. for 30 minutes and cold water quenched. Both pieces were wire brushed on one side before bonding. Prior to bonding the 7075 sheet was heated for 10 minutes at 850° F., while the titanium alloy was kept at room temperature. Bonding was performed using a mill setting of –0.010 inch (negative roll gap).

The bonded composite (50 percent 7075, 50 percent Ti-6A1-4V) exhibited the following properties in the as-rolled condition: Tensile strength 127.1 K s.i., yield strength 111.8 K s.i., percent elongation in 2 inches=6.0. Upon heating the composite at 880° F. for various times, quenching in cold water, incubating for 5 days at room temperature and aging at 250° F. for 24 hours the following properties are obtained:

	T.S. in K s.i.	Y.S. in K s.i.	% El. in 2 in.
1 hour at 880° F.	133.4	102.7	5.0
2 hours at 880° F.	135.0	102.0	6.0
4 hours at 880° F.	131.2	97.2	5.0
8 hours at 880° F.	132.2	100.7	4.0

EXAMPLE 4

A composite was prepared from a sheet of annealed alclad 7075 dimensions 6×7×0.080 inch and a sheet of Ti-4A1-3Mo-1V dimensions 6×6×0.032 inch, solution heat-treated at 1,650° F. for 15 minutes and cold water quenched. Both pieces were wire brushed on one side before bonding. Prior to bonding the 7075 sheet was heated for 10 minutes at 850° F., while the titanium alloy was kept at room temperature. Bonding was performed using a mill setting of 0.010 inch.

The bonded composite (65 percent, 7075, 35 percent Ti4A1-3Mo-1V) exhibited the following properties in the as-rolled condition: Longitudinal tensile strength 98.3 K s.i., yield strength 77.5 K s.i., percent elongation in 2 inches=6; transverse tensile strength 96.7 K s.i., yield strength 71.8 K s.i., percent elongation in 2 inches=15.5.

Upon heating the composite at 880° F. for various times, quenching in cold water, incubating for 5 days at room temperature, and aging at 250° F. for 24 hours the following properties were obtained:

	T.S. in K s.i.	Y.S. in K s.i.	% El. in 2 in.
1 hour at 880° F. Long.	113.3	89.2	—
2 hours at 880° F. Long.	117.5	94.2	6.0
2 hours at 880° F. Trans.	117.6	69.4	10.0
4 hours at 880° F. Long.	118.0	95.0	4.0

What is claimed is:

1. A high-strength metal composite comprising a layer of a wrought heat-treatable copper bearing aluminum base alloy bonded to a layer of a titanium alloy consisting essentially of approximately 6 percent aluminum, 4 percent vanadium, balance substantially titanium.

2. A high-strength metal composite comprising a layer of a wrought heat-treatable zinc bearing aluminum base alloy bonded to a layer of a titanium alloy consisting essentially of approximately 6 percent aluminum, 4 percent vanadium, balance substantially titanium.

3. The composite of claim 1 in which the aluminum base alloy is alloy 2024.

4. The composite of claim 2 in which the aluminum base alloy is alloy 7075.

5. A high-strength metal composite comprising a layer of a wrought heat-treatable copper bearing aluminum base alloy bonded to a layer of a titanium alloy consisting essentially of approximately 4 percent aluminum, 3 percent molybdenum, 1 percent vanadium, balance substantially titanium.

6. A high-strength metal composite comprising a layer of a wrought heat-treatable zinc bearing aluminum base alloy bonded to a layer of a titanium alloy consisting essentially of approximately 4 percent aluminum, 3 percent molybdenum, 1 percent vanadium, balance substantially titanium.

7. The composite of claim 5 in which the aluminum base alloy is alloy 2024.

8. The composite of claim 6 in which the aluminum base alloy is alloy 7075.