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PRODUCTION OF TITANIUM-BASE ALLOY

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This invention relates to an improved method of producing titanium-base alloys. More particularly, this invention relates to a method of producing titanium-aluminum-tin alloys exhibiting greater workability at elevated temperatures.

Titanium-aluminum-tin alloys have been developed primarily for use in the form of sheets at elevated temperatures on aircraft and missiles. These essentially single-phase alloys combine high strength at elevated temperatures with the excellent welding properties characteristic of alpha-type titanium-base alloys.

The subject alloys are commonly produced by adding elemental tin and aluminum to a base of titanium sponge. Such alloys will hereinafter be termed "elemental-addition alloys." Experience, however, has shown that alloys fabricated in the above manner begin to experience hot-shortness to such an extent, at temperatures of 1750° F. that hot working above these temperatures is prohibited. At approximately 1750° F., the hot-shortness phenomenon is manifested by pronounced edge-cracking. Hot shortness does not prevail above 1900° F., but hot working above this temperature is precluded by the prevalence of excessive oxidation and grain growth. As a consequence, it was previously necessary to work alloys, fabricated in the above described manner, at a temperature below 1750° F., and working could not be continued below 1675° F. because the material stiffened due to loss of heat. These restrictions allowed less than a 75° F. working temperature range for alloys produced by elemental-addition methods.

It is an object of the present invention to provide a process whereby titanium-base aluminum-tin alloys are produced which exhibit greater workability at normal rolling temperatures than alloys fabricated by previous methods, without encountering detrimental hot shortness.

Other objects will be apparent from the remaining disclosure.

The objects of the present invention are achieved by fusing titanium sponge and a titanium master-alloy containing aluminum and tin in sufficient amounts to produce a final titanium-base aluminum-tin alloy of the required composition. As employed herein, the term "master-alloy" designates an alloy containing 30 to 70 weight percent titanium and the remainder aluminum and tin in a ratio of 2 parts aluminum to 1 part tin and incidental impurities. The "master-alloy" must also contain a sufficient amount of aluminum and tin such that the final alloy, upon dilution by the titanium sponge, will have the desired ratio of constituents. The term "master-addition alloys" is hereinafter used to refer to alloys fabricated as described immediately above. The employment of a titanium master-alloy as the vehicle to introduce aluminum and tin into the titanium sponge in contrast to the previously employed method of adding elemental aluminum and tin to a titanium sponge, has enabled the production of a final alloy which exhibits greater workability over the normal temperature ranges of hot working for the subject alloys, and has raised the temperature level at which hot shortness becomes detrimental during hot-working operations on the alloy.

In elemental-addition alloys, the tin component of the alloy has decided tendencies to segregate in the grain boundaries of the final alloy rather than remaining in

solid solution in the titanium base-metal lattice along with its counterpart aluminum. This phenomenon gives rise to hot-shortness. The homogeneity of the final alloy is increased by employing the master-addition method. The increased homogeneity causes an increase in ductility over the normal hot working temperature and thereby decreases the tendency for the hot shortness phenomenon to set in at any given temperature level.

This improvement in the titanium alloy field involves a seemingly simple step but it is imperative that the improvement be viewed in its proper perspective.

In the hot-working art, the prime factors attributing to the overall process cost are the intermediate heating cost and the rolling machine power costs. The increase in ductility afforded by the present invention greatly decreases overall process costs since hot-working operations can be conducted over a wider temperature range without encountering hot-shortness.

To compare the present product with the previous product, tensile tests were conducted at several temperatures to investigate the effect on the ductility of alloys produced by the present and previous methods of fabrication. The data and results are shown in Table I.

The method of fabrication is as follows:

A blend simulating the elemental-addition method of titanium alloy production was prepared by mixing aluminum, 20 mesh by down, tin 20 mesh by down; and titanium sponge of Brinell hardness No. 113 in proportions of 92.5% titanium, 5% aluminum, 2.5% tin.

A blend simulating the master-addition method of the present invention was prepared by mixing a titanium master-alloy analyzing 20% tin, 40% aluminum, 40% titanium with titanium sponge of Brinell hardness No. 113.

Two, two-inch consumable electrodes were fabricated by pressing the above two blends. The pressed electrodes were then melted under high vacuum using direct current, straight polarity, to form two four-inch diameter ingots of 92.5% titanium, —5% aluminum —2.5% tin alloys, one from each starting blend.

Standard 0.25 inch diameter tensile specimens were prepared from each of the above produced ingots and short time, elevated-temperature tensile tests were conducted. The elongation results are listed in Table I. An increase in elongation and percent reduction in area (R.A.) indicates an increase in ductility. An increase in percent reduction in area (percent R.A.) is generally considered a better measure of a decrease in hot-shortness tendency than an increase in percent elongation.

TABLE I

Elevated Temperature Tensile Testing—Standard 0.25-Inch Diameter Tensile Specimens

ELEMENTAL-ADDITION ALLOY

Temp. (° F.)	U.T.S. (p.s.i.)	Percent Elong. (in 1″)	Percent R.A.
1,700	7,640	76	69
1,750	6,930	32	47
1,800	5,210	54	48
1,850	3,510	68	73
1,900	2,870	59	80

MASTER-ADDITION ALLOY

1,650	9,580	80	92
1,700	8,010	78	90
1,750	7,600	90	88
1,800	5,710	126	79
1,850	3,810	104	95
1,900	2,480	76	99
1,950	1,560	90	99

It is readily apparent from the above example that ductility over the normal range of rolling temperatures for titanium-aluminum-tin alloys is greatly increased. The increased ductility can be directly correlated to the homogeneity of the product as shown in Table II. The elemental addition alloy exhibited much less homogeneity in aluminum and tin content than did the master-addition alloy.

TABLE II

Ingot Analysis

Master-addition alloys		Sample point	Elemental-addition alloys	
Aluminum, percent	Tin, percent		Aluminum, percent	Tin, percent
5.66	2.74	Outside, top	5.10	2.47
4.95	2.51	Outside, center	4.35	1.58
4.58	2.35	Outside, bottom	4.24	1.53
5.59	2.77	Center, top	5.12	2.67
5.46	2.69	Center, center	4.85	2.20
4.91	2.44	Center, bottom	4.37	1.69

In the above example, 92.5 weight percent titanium, 5 weight percent aluminum, 2.5 weight percent tin alloy was tested. The process of the present invention may be utilized to produce titanium-aluminum-tin alloys with the single restriction being that the master alloy used in the process must contain 30 to 70 weight percent titanium, remainder aluminum and tin, wherein the weight percent ratio of aluminum to tin is about 2 to 1 and incidental impurities.

We claim:

1. In processes for the production of titanium-base aluminum-tin alloys by fusion of the necessary elements to form said titanium-base aluminum-tin alloy, in combination therewith the improvement comprising fusing a mixture of a titanium-base aluminum-tin master alloy, said master alloy consisting essentially of 30–70 weight percent titanium and the remainder aluminum and tin in a ratio of about 2 to 1 and incidental impurities, together with elemental titanium to form a final titanium-base aluminum-tin alloy which exhibits greater ductility over the normal range of hot-working temperatures.

2. In processes for the production of titanium-base aluminum-tin alloys by fusion of the necessary elements to form said titanium-base aluminum tin alloy, in combination therewith the improvement comprising preparing a mixture of titanium master-alloy, said master alloy consisting essentially of 30–70 weight percent titanium and the remainder aluminum and tin in a ratio of about 2 to 1 and incidental impurities, together with elemental titanium; pressing said mixture into an electrode; and arc-melting said electrode to form a final titanium-base aluminum-tin alloy which exhibits greater ductility over the normal range of hot-working temperatures.

3. In processes for the production of titanium-base aluminum-tin alloys by fusion of the necessary elements to form said titanium-base aluminum-tin alloy, in combination therewith the improvement comprising preparing a mixture of titanium master-alloy, consisting essentially of 20 weight percent tin–40 weight percent aluminum–40 weight percent titanium, together with titanium sponge, wherein the weights of said titanium master-alloy and said titanium sponge are in the proper proportion to form a final alloy analyzing 5 weight percent aluminum–2.5 weight percent tin and 92.5 weight percent titanium; pressing said mixture into an electrode; and arc-melting said electrode to form said final alloy.

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