

[54] TITANIUM COMPOSITE
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[57] ABSTRACT
A composite article comprised of at least two metallic layers. One of the layers being a metal from the group consisting of titanium and titanium base alloys and another being steel. The steel being a plain carbon steel having up to 1.5% of carbide former present in a carbide former-to-carbon ratio of from 1.5 to 25.

7 Claims, No Drawings

TITANIUM COMPOSITE

The present invention relates to a composite article and more particularly to a composite article comprised of titanium or a titanium base alloy, and plain carbon steel containing a carbide former.

Titanium and titanium base alloys, hereinafter referred to as titanium, are characterized by excellent corrosion resistance and a high strength to weight ratio, and hence, a combination of properties which makes them particularly desirable for a number of applications. For example, their resistance to corrosion in chloride environments makes their use in heat exchangers, air pollution equipment and marine equipment highly beneficial, and their high strength to weight ratio makes their use in aircraft and other structural applications most advantageous. On the other hand, their high cost makes them economically unattractive at the present time.

One way to lessen the costs of parts and equipment made from titanium and to thereby increase its usage is to use it in composites in which a layer of dissimilar and less expensive metal is sandwiched between two layers of titanium or between one layer of titanium and another corrosion resistant metal; e.g. stainless steel. A particularly desirable dissimilar metal would appear to be plain carbon steel. Plain carbon steel is relatively inexpensive and characterized by good mechanical properties. For example, it is a good heat conductor and would not detract from titanium in heat exchanger applications. The use of plain carbon steel is, however, accompanied by potential dangers. Interstitial elements, carbon, oxygen, and nitrogen and particularly carbon, can diffuse from plain carbon steel into titanium and especially into the plain carbon steel-titanium interface, and thereby detrimentally affect its properties, and particularly its ductility. Exemplifying this are hard and brittle titanium carbides which form in titanium metal when carbon is present in amounts of approximately 0.15% and higher.

The present invention overcomes the potential dangers of using plain carbon steel in titanium composites by adding at least one carbide former to the plain carbon steel. Carbide formers, such as titanium and columbium, have a high affinity for oxygen, nitrogen and carbon, and hence substantially preclude their migration from plain carbon steel into titanium. Copending application Ser. No. 000,177, filed Jan. 2, 1970, now Pat. No. 3,693,242 issued Sept. 26, 1972, discusses the use of carbide formers in plain carbon steel-stainless steel composites.

It is accordingly an object of this invention to provide a composite article comprised of titanium or a titanium base alloy, and plain carbon steel containing a carbide former.

The article of the present invention is a composite comprised of at least two metallic layers. One of the layers is a metal from the group consisting of titanium and titanium base alloys and another is steel. The steel is a plain carbon steel having up to 1.5% carbide former present in a carbide former-to-carbon ratio of from 1.5 to 25. The term carbide former refers to one or more of the elements which have a strong affinity for carbon, and preferably to titanium and columbium. The amount of carbide former is limited to 1.5% and preferably to 0.75%, as the benefits obtained from further increases in the level of carbide former are disproportionate with regard to the costs involved.

The ratio of carbide former-to-carbon in the plain carbon steel should be between about 1.5 and 25. This means that the weight percent of carbide forming elements should be between 1.5 and 25 times the weight percent of carbon. A minimum carbide former-to-carbon ratio of at least 1.5 is imposed to insure sufficient carbide former to substantially preclude carbon migration from the plain carbon steel toward and into the titanium and to preclude the formation of enriched carbide areas, which are associated with decreased drawability. Composites formed from plain carbon steel with carbide former-to-carbon ratios of 1.5 to 5 are often preferred as they generally have higher yield strengths than similar composites formed from plain carbon steel with carbide former-to-carbon ratios in excess of 5. On the other hand, composites having carbide former-to-carbon ratios in excess of 5 are often preferred as they are more workable than those having ratios below 5. Yield strengths of the composites decrease and elongations increase with increasing amounts of carbide former. An upper carbide former-to-carbon ratio of 25 is imposed as the grain size of the plain carbon steel can become undesirably large at higher ratios. A maximum carbide former-to-carbon ratio of 15 is often desirable since a range of from 5-15 has proven to provide an optimum combination of drawability and cost.

In a particular embodiment, the article of the present invention is comprised of a layer of titanium, a layer of stainless steel, and a layer of plain carbon steel containing carbide former sandwiched therebetween. Composites of this nature are particularly desirable in applications such as condensor tubes or heat exchanger tubes where the inner surface of the tube which is exposed to hot chloride solutions could be titanium and where the outer surface which is exposed to air or decontaminated water could be stainless steel. In such composites the carbide former substantially precludes carbon migration from the plain carbon steel toward and into both the stainless steel and titanium.

To further minimize carbon migration another embodiment of the invention calls for a layer of barrier metal between the plain carbon steel and titanium. The barrier metal is from the group consisting of nickel, cobalt, palladium, platinum, chromium and copper, as limited by those instances wherein their melting point does not preclude their use. Although no criticality is placed upon the thickness of the barrier metal, layers ranging in thickness from 0.0001 to 0.005 inch are believed to be beneficial.

There are a number of methods for making the article of the present invention. These methods include: (1) pouring molten steel around or between solid shapes of titanium and subsequently hot processing the composite as per normal mill methods for manufacturing titanium products; (2) compacting and sintering titanium powders on and to a steel surface; (3) pressure bonding; e.g. hot roll bonding, of titanium to steel; (4) explosive bonding of titanium to steel; and (5) brazing of titanium to steel. In all these methods care must be taken to provide a nonreactive atmosphere, e.g. an inert atmosphere or a vacuum, to avoid surface contamination of the titanium as it is very reactive with oxygen and nitrogen at elevated temperatures.

The titanium alloy can be an alpha alloy; e.g. 5% Al, 2.5% Sn, balance essentially titanium, an alpha-beta alloy; e.g. 8% manganese, balance essentially titanium, or

a beta alloy; e.g. 3% aluminum, 13% vanadium, 11% chromium, balance essentially titanium. The plain carbon steel and stainless steel can be any of a number of alloys. Respective examples are A.I.S.I. Type C1006 with carbide former, and MF-1 and HWT stainless steels. On page 7 of Volume 1 of the Eighth Edition Metals Handbook, put out by the American Society for Metals, carbon steel is defined as follows:

"Steel containing carbon up to about 2% and other residual quantities of other elements except those added for deoxidation, with silicon usually limited to 0.60% and manganese to about 1.65%. Also termed 'plain carbon steel', 'ordinary steel' and 'straight carbon steel'."

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in connection with specific examples thereof will suggest various other modifications and applications of the same. It is accordingly desired that in construing the breadth of the appended claims they shall not be limited to the specific examples of the invention described herein.

I claim:

1. A composite article comprised of at least two bonded metallic layers: at least one of said metallic layers being a metal from the group consisting of titanium and titanium base alloys; at least one of said metallic layers being steel, said steel consisting essentially of up to 2% carbon, up to 0.6% silicon, up to 1.65% manganese, up to 1.5% carbide former, balance essentially

iron, said carbide former being from the group consisting of titanium and columbium, said carbide former being present in a carbide former-to-carbon ratio of from 1.5 to 25.

2. An article according to claim 1 wherein said carbide former is present in said plain carbon steel in a carbide former-to-carbon ratio of from 1.5 to 5.

3. An article according to claim 1 wherein said plain carbon steel contains up to 0.75% of carbide former.

4. An article according to claim 1 wherein said carbide former is present in said plain carbon steel in a carbide former-to-carbon ratio of from 5 to 15.

5. An article according to claim 1 having at least two layers from the group consisting of titanium and titanium base alloys, and wherein said layer of plain carbon steel is sandwiched between said layers of metal from the group consisting of titanium and titanium base alloys.

6. An article according to claim 1 including a layer of stainless steel, and wherein said layer of plain carbon steel is sandwiched between said layer of stainless steel and said layer of metal from the group consisting of titanium and titanium base alloys.

7. An article according to claim 1 including a layer of third metal between said layer of metal from the group consisting of titanium and titanium base alloys and said layer of plain carbon steel, said layer of third metal being from the group consisting of nickel, cobalt, palladium, platinum, copper and chromium.

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