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ALUMINUM-STEEL COMPOSITES

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ABSTRACT OF THE DISCLOSURE

Composites of aluminum and steel are disclosed which are resistant to intermetallic formation. The composites are characterized by the aluminum component containing from 0.5 to 2.5% silicon and the steel component containing free or soluble nitrogen in an amount from 0.001 to 0.05%. The composite results in a synergistic system exhibiting remarkable resistance to intermetallic formation when the composite is annealed.

BACKGROUND OF THE INVENTION

Composites of aluminum and steel find extensive use in industry. For example, they are useful in the electronics industry, in underground cable sheathing, and in areas where the aluminum component provides oxidation and corrosion protection for the steel component.

A great many of the areas of use for this type of composite require an annealing operation in order to soften the composite for forming. During the annealing operation, there is a strong tendency for interdiffusion to occur between the aluminum component and the steel component and form a brittle intermetallic compound. The brittle intermetallic compound which forms significantly reduces the bond strength and, hence, significantly limits the usefulness of the resultant composite.

It would naturally be highly desirable to substantially eliminate this brittle layer. The elimination of the brittle intermetallic compound would greatly extend the usefulness of aluminum-steel composites and would extend the number of products which could be made therefrom. Elimination of the brittle layer would greatly minimize the cost and care currently required to keep the intermetallic layer at acceptable levels.

Art processes have been suggested to minimize intermetallic formation. For example, U.S. Pat. 2,965,963 contemplates the use of soluble or active nitrogen in order to reduce intermetallic formation. However, this patent does not completely eliminate intermetallic formation. Also, this teaching often causes processing difficulties. In order to soften the steel component, the procedure requires annealing at temperatures that tend to form some intermetallics.

In general, art processes do not completely eliminate intermetallic formation and often limit the annealing time and temperature. This frequently results in a product with reduced intermetallic formation but a product that is not softened completely thereby causing subsequent processing problems.

Accordingly, it is a principal object of the present invention to provide novel aluminum-steel composites.

It is an additional and principal object of the present invention to provide aluminum-steel composites which eliminate the problem of intermetallic compound formation between the aluminum and steel components.

Further objects and advantages of the present invention will appear from the ensuing discussion.

SUMMARY OF THE INVENTION

In accordance with the present invention it has now been found that the foregoing objects and advantages may

be readily achieved and a composite provided which overcomes art disadvantages.

The composite of the present invention consists essentially of an aluminum component and a steel component. The aluminum component contains silicon in an amount from 0.5 to 2.5%. The steel component contains free or soluble nitrogen in an amount from 0.001 to 0.050% and also has a carbon content of from 0.01 to 1%.

The composites of the present invention readily overcome the disadvantages of the art and have been found to exhibit remarkable resistance to intermetallic compound formation when annealed. It is believed that a synergistic system exists when the silicon is added to the aluminum component and the free or soluble nitrogen is added to the steel component which system virtually eliminates intermetallic compound formation.

The composites of the present invention overcome previous processing difficulties. Due to the lack of intermetallic formation, the material can be softened at elevated temperature and allows attainment of optimum properties in the composite, especially in the steel component and especially good ductility.

DETAILED DESCRIPTION

As indicated hereinabove, any aluminum alloy may be employed which contains the requisite quantity of silicon, namely from 0.5 to 2.5% and preferably from 1 to 2%. Thus, for example, the aluminum alloy may contain other alloying additions as desired or conventional impurities. Representative alloying additions which may be readily employed are the following materials in the following amounts: boron, up to 1%; copper, up to 3%; zinc, up to 4%; magnesium, up to 5%; iron, up to 3%; and manganese, up to 2%.

The steel component should contain carbon in an amount from 0.01 to 1%. Preferably, the steel component is a low carbon steel containing 0.15% carbon max. Other materials which are readily contemplated in the steel component are, for example, aluminum, vanadium, boron, titanium and niobium. Elements which are preferential nitride formers should be avoided.

As indicated hereinabove, the composite of the present invention requires that the steel component contain free or soluble nitrogen in an amount from 0.001 to 0.050%. By free or soluble nitrogen it is meant that nitrogen be present in the steel component in the amounts listed in dissolved or uncombined form. That is, if the nitrogen is in the form of nitrides or other nitrogen containing compounds, these stable nitrides are not considered free or soluble nitrogen.

The composite may be prepared in any desired manner. A particularly preferred method of preparing the composite involves rolling the components together in direct face-to-face contact in order to form an integral firmly bonded composite as disclosed in, for example, U.S. Pats. 3,462,827 and 3,462,828. Any desired method of forming the composite may, however, be readily employed.

The present invention will be more readily apparent from a consideration of the following illustrative examples.

Example I

A composite was prepared wherein the aluminum component was an aluminum base alloy containing: 1.25% silicon; 0.35% iron; 0.012% magnesium; 0.004% copper; and 0.007% manganese. The steel component was a 1010 low carbon steel containing 0.1% carbon, 0.5% manganese, 0.04% phosphorus and 0.05% sulfur and which contained free or soluble nitrogen in an amount of about 0.003%.

Prior to bonding, the aluminum component had a thickness of 0.010" and the steel component had a thickness

of 0.042". The aluminum component was annealed at 650° F. for 1 hour prior to bonding and the steel component was used in the as-received or annealed condition. The components were degreased, washed, rinsed, dried and wire brushed prior to bonding. A 2" wide x 10" long strip of the aluminum component was folded over the appropriate 2" wide x 5" long strip of the steel component and the resultant assembly was given a 55 to 60% single pass cold reduction which resulted in a firmly bonded composite. The resultant composite was then rolled to the desired gage of 0.010".

Samples of the resultant composite were annealed at 1050° F. for 1 hour. Additional samples were annealed at 1050° F. for 16 hours. The resultant samples were metallographically examined at a magnification of 1000× for evidence of an intermetallic layer at the interface. The result was that no intermetallic layer could be observed on either sample due to the combined or synergistic effect of the silicon in the aluminum component and the free or soluble nitrogen in the steel component.

Example II

Example I was repeated except that the aluminum component was a high purity aluminum (99.99%). The steel component was the same as in Example I. The composite was prepared in the same manner as Example I and the resultant material was given a 1 hour anneal at 1050° F. The metallographic examination of the resultant material showed a 2 to 10 micron thick intermetallic layer at the interface.

Example III

Example I was repeated with the exception that the steel component was an aluminum killed 1010 steel which contained 0.0047% nitrogen which existed as aluminum nitride particles. The composite was prepared in the same manner as Example I and the resultant composite was annealed for 1 hour at 1050° F. Metallographic examination showed an intermetallic layer in excess of 20 microns between the aluminum and steel components and the components split apart due to the thickness and brittle material of the intermetallic layer.

Example IV

Example I was repeated with an aluminum alloy containing: magnesium, 0.9%; silicon, 0.65%; iron, 0.2%;

copper, 0.03%; zinc, 1.00%; boron, 0.022% and manganese, 0.03%. Once again, no intermetallic layer could be observed in the resultant product.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. An aluminum-steel composite free from intermetallic compound formation wherein the aluminum component is an aluminum base alloy containing silicon in an amount from 0.5 to 2.5% and wherein the steel component contains free nitrogen in an amount from 0.001 to 0.050% and has a carbon content of from 0.01 to 1%.

2. A composite according to claim 1 wherein said aluminum component contains silicon in an amount from 1 to 2%.

3. A composite according to claim 1 wherein the steel component is a low carbon steel containing 0.15% max. carbon.

4. A composite according to claim 1 in the annealed condition.

5. A composite according to claim 1 wherein the aluminum component contains boron up to 1.0%, copper up to 3.0%, zinc up to 4.0%, magnesium up to 5.0%, iron up to 3.0% and manganese up to 2.0%.

References Cited

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