METHOD FOR THE BORATION OF TITANIUM AND TITANIUM ALLOYS

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Field of Search .................. C23f 7/00

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ABSTRACT

Metals, especially titanium and titanium alloys, are borated with a borating agent prepared by annealing amorphous boron at a temperature between 850°C and 1,300°C in an inert gas, especially a noble gas. The boration is best accomplished by packing the metal into the borating agent and heating it to a temperature between 900°C and 1,400°C while passing a noble gas through the borating agent. Activators and inert substances can be added to the borating agents.

5 Claims, No Drawings
METHOD FOR THE BORATION OF TITANIUM AND TITANIUM ALLOYS

BACKGROUND OF THE INVENTION

1. Field of the Invention
This invention relates to a borating agent as well as a method for the boration of metals, especially titanium and titanium alloys. The invention furthermore concerns work pieces made of titanium or titanium alloys which are borated according to this method.

2. Description of the Prior Art
The extensive use of titanium and titanium alloys is thus far prevented, among other things, by the fact that there are no suitable methods known which are practical for increasing the hardness and wear-and-tear resistance of the surface of work pieces made of titanium and titanium alloys, without at the same time impairing the positive properties of the titanium (high strength-weight ratio, good toughness, and good corrosion properties).

The invention accordingly is intended to propose a novel borating agent as well as a method for the boration of metals, especially titanium and titanium alloys, which, through the indiffusion of boron considerably improves the hardness and wear-and-tear resistance of the surfaces of work pieces, especially made of titanium and titanium alloys, without impairing the above-described favorable properties of the work material.

SUMMARY OF THE INVENTION

The borating agent according to the invention consists of a boron source, for example, a material containing boron, as a boron donor under a noble gas, especially argon (the very purest argon), the boron here being amorphous and being annealed and then again cooled down.

DETAILED DESCRIPTION OF THE INVENTION

The borating agent from the above-described boron source when used is best provided with additives, more specifically, with suitable activators, especially alkali-, alkaline-earth-, or ammonium-halides, for example, ammonium chloride, ammonium fluoride, barium fluoride, sodium bromide, and the like. This activator has the effect that the hardness layer, made with the borating agent according to the invention, comes out thicker on the working material treated.

Furthermore, according to the invention, an inert substance, in other words, a substance that does not participate in the reaction, is added to the borating agent. The following are particularly suitable for this purpose: aluminum oxide, magnesium oxide, zirconium oxide, beryllium oxide, and other stable oxides, but also talc, asbestos, and the like can be used. Such inert substances keep the borating agent in a disintegrated, gas-permeable state also during boration and make it easier to take the borated work pieces out of the borating agent after boration.

If, according to another embodiment of the invention, a noble gas, especially argon, is conducted through the borating agent during the boration of the work pieces, the inert substances facilitate the passage of the noble gas.

Borated work pieces, according to the invention, made of titanium or titanium alloys, are provided with a surface layer which possesses a surface hardness of 3,000–3,500 HV kg/mm². In the experiments that were conducted, this hardness was measured in the known manner according to Vickers with a stress of 500 g. The thickness of this hardened surface layer is between 0.004 and 0.1 mm. It was furthermore ascertained that the hardened surface layer, made according to the invention, consists of the titanium borides TiB₂ and TiB₃. This layer is hard and wear-and-tear proof, without the base working material — that is, the titanium or titanium alloy — being made brittle due to the admission of oxygen, nitrogen, or hydrogen.

In detail, we proceed as follows in making the boron source, a component of the borating agent: amorphous boron is annealed between 850°C and 1,100°C for a period of about 1–3 hours, with simultaneous constant conduction therethrough of a noble gas, especially argon (purest argon) and is then cooled, accompanied by further through-conduction of a noble gas, down to about room temperature. During this process, the amorphous boron is in a container that is sealed against the entry of air and against the entry of foreign gases; this container is provided with a feeder line and an evacuation line for the noble gas.

The boron source can readily be used as a borating agent without any further additives.

It is advantageous, however, to add the above-described substances, that is, an inert substance as a diluent, as well as an activator. Optimum conditions are obtained when the borating agent contains about 18–40 percent of amorphous boron, treated in accordance with this invention, 60–80 percent of the inert substance, and 2–8 percent of the activator.

Boration with the borating agent according to this invention is best accomplished by packing the work piece to be treated into the borating agent in a suitable vessel and heating it to a temperature between 900° and 1,400°C in an oven. During boration, the noble gas, especially argon (purest argon), is constantly conducted through the borating agent. For this purpose the vessel is closed off against the entry of air and other foreign gases and it is provided with an inlet and an outlet for the noble gas. The duration of the boration is at least 3 hours. This is followed by a slow cooling of the working material.

EXAMPLE I

1 kg of amorphous boron was annealed for 2 hours, accompanied by the conduction therethrough of argon, at a temperature of 1,000°C. This was followed by cooling over a period of 3 hours, accompanied by further conduction therethrough of argon, down to about room temperature. This boron source was then used as the borating agent for a work piece of pure titanium.

The work piece was packed in the treated amorphous boron powder and was borated for a period of 15 hours at a temperature of 1,000°C. During boration, the argon was conducted through the borating agent. The work piece thus treated had a hard surface layer with a thickness of 0.04 mm and a hardness of 3,000–3,500 HV kg/mm².

EXAMPLE II

950 g of amorphous boron was treated as described in Example I above, in other words, it was annealed. 50 g of barium fluoride was then admixed as an activator into the amorphous boron which had been cooled down to room temperature. Afterward, boration was
performed over a period of 5 hours on a work piece of pure titanium, accompanied by the conduction of argon through the borating agent, at a temperature of 1,300°C. The layer thus produced on the work piece had a thickness of 0.07 mm with a hardness of 3,000–3,500 HV kg/mm².

EXAMPLE III

300 g of amorphous boron was once again treated as described in Example I above. After cooling, 600 g of aluminum oxide was added to the boron powder as an inert substance, along with 30 g of ammonium chloride as an activator which was likewise mixed in. With the borating agent thus produced, a work piece, made of a titanium alloy TiAl₇V₄, was borated, more specifically, for a period of 5 hours, while argon was being conducted through the borating agent, as well as at a temperature of 1,200°C. The layer produced here had a thickness of 0.08 mm with a hardness of 3,000–3,500 HV kg/mm².

What is claimed is:

1. A method for borating a titanium metal workpiece which comprises:
   contacting said titanium metal workpiece with a borating agent at a temperature of between 900° and 1400° C., for a period of at least 3 hours while simultaneously conducting a substantially pure noble gas through the borating agent, during boration,
   said borating agent being prepared by a method which comprises:
   annealing amorphous boron at a temperature of between 850° and 1100°C., for a period ranging from about 1 to 3 hours, while simultaneously passing a substantially pure noble gas therethrough, and subsequently, cooling said boron while simultaneously passing a substantially pure noble gas therethrough.

2. The method of claim 1 wherein said noble gas is argon.

3. The method of claim 1, wherein an activator is added to said borating agent, said activator being a member selected from the group consisting of an alkali metal halide, an alkaline earth metal halide, and an ammonium halide.

4. The method of claim 3, wherein said activator is a member selected from the group consisting of ammonium chloride, ammonium fluoride, barium fluoride and sodium bromide.

5. The method of claim 1, wherein an inert substance is added to said borating agent, said inert substance being a member selected from the group consisting of aluminum oxide, magnesium oxide, zirconium oxide, beryllium oxide, talc and asbestos.

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