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PROCESS FOR IMPROVING THE WORKABILITY OF TITANIUM ALLOYS

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The present invention relates to a process for improving the workability (deformability) of titanium alloys.

The hot working, for example, the forging, rolling and extrusion of titanium alloys, requires relatively high forces which increase as the temperature of working increases. For example, with increasing quantities of aluminum in such alloys the resistance to deformation increases to such an extent that very high working temperatures are required, as with lower temperatures they cannot be worked with the power available or tend to crack. For this reason, titanium alloys containing over 6% of Al could not be used upon a commercial scale.

Pure titanium is very strongly embrittled at room temperature by the presence of hydrogen therein and many titanium alloys are embrittled at room temperatures by the presence therein of only very small quantities of hydrogen. The embrittlement causes a lowered impact resistance.

While it was previously believed that hydrogen only has deleterious effects in titanium alloys, it was unexpectedly found according to the invention that the hot workability of titanium alloys is improved thereby. For example, when a titanium alloy, whose workability is to be improved so that, for example, it can be worked at lower temperatures without difficulty, is melted in the presence of hydrogen it takes up hydrogen and the resulting hydrogen containing alloy is much more easily hot worked than the hydrogen free alloy. In order to obtain good mechanical properties in the hot worked product, it is generally necessary to remove the hydrogen therefrom after the hot working has been completed.

The quantity of hydrogen required to improve the hot workability of the titanium alloys depends upon the composition of the individual alloy. In general, however, the quantity required lies between 0.01 and 1% by weight. Alloys which are especially difficult to work in general will only take up limited quantities of hydrogen and in such alloys as much hydrogen is incorporated therein as is soluble therein. Alloys which are easier to work often have a larger affinity for hydrogen so that in such instances less hydrogen is incorporated therein to improve their hot workability than corresponds to its maximum solubility.

The provess according to the invention is especially well suited for titanium alloys which preponderantly contain alpha-titanium mixed crystals, whether in oriented or unoriented form. Aluminum, tin, indium, gallium, oxygen, nitrogen, carbon and other elements come into consideration as alpha-stabilizers. Increasing quantities of these elements cause a deterioration in the hot working properties of titanium alloys. The addition of hydrogen stabilizes the beta-phase of the titanium alloy at the hot working temperature and the hot working properties are improved thereby.

The process according to the invention is particularly advantageous for titanium alloys containing over 6% of aluminum which have been rendered workable at elevated temperatures by the incorporation of hydrogen therein.

The hydrogen can be incorporated in the titanium alloys in numerous ways. The simplest method is to melt down the titanium alloy in a hydrogen atmosphere. The hydrogen take up can be increased by the use of superatmospheric pressures. In view of the hydrogen taken up by the alloy the pressure can drop below the starting pressure. On the other hand, it can also be advantageous to melt down the alloy right from the start at subatmospheric pressures and if necessary supplementing the hydrogen in the gas chamber above the alloy. It is not necessary to melt down the alloy in a pure hydrogen atmosphere and, for example, a hydrogen containing inert gas, such as argon, can be employed in order to maintain a uniform and stable arc. Hydrogen mixtures containing 25–50% of hydrogen have provided stable arcs at normal pressure and currents of 150 to 350 amperes and permitted hydrogen to be taken up by the alloy.

It is also possible in incorporate hydrogen in the titanium alloy or to increase its hydrogen content by heating the workpiece in which the hydrogen is to be incorporated at temperatures below its melting point in hydrogen or a hydrogen containing inert gas. It has, for example, been found especially advantageous to heat workpieces whose surfaces have been freed of oxygen first to temperatures of about 900° C. in a hydrogen containing atmosphere and then to lower the temperature slowly.

The process according to the invention is illustrated by the following examples:

Example 1

A titanium alloy containing 8% of aluminum was melted down in an atmosphere of 75% argon and 25% hydrogen at atmospheric pressure in an arc and then allowed to solidify again. The resulting alloy contained 0.061% of hydrogen. A sample thereof was forged at 950° C. with a single stroke of a 400 kg. forging hammer. A 65% deformation with only small surface cracks was attained. When a further sample was additionally heated to 900° C. in hydrogen and permitted to cool in the oven, the hydrogen content increased to 0.505%. Its deformability under the same conditions increased to 78% without crack formation.

After the deformation the hydrogen content of the forged samples was reduced to below 0.002% by heating to 1000° C. in high vacuum. A corresponding sample which did not contain hydrogen was destroyed by forging under the same conditions.

Example 2

A titanium alloy containing 13% of aluminum was treated with hydrogen as described in Example 1. When it was melted down it took up to 0.05% of hydrogen and at a 65% deformation it exhibited somewhat greater crack formation than the sample containing 8% of aluminum prepared under the same conditions. The alloy by additional heating in hydrogen took up 0.24% of hydrogen and the alloy was then able to be deformed 69% with only slight crack formation. In this instance again a sample of the alloy which did not contain hydrogen was totally destroyed when forged.

Example 3

A titanium alloy containing 8% of aluminum and 3% of indium which could not be hot worked was melted down in a hydrogen containing argon atmosphere and then heated in a hydrogen atmosphere to 900° C. to provide a 0.16% hydrogen content therein. This hydrogen containing alloy could then be forged well at

950° C. This alloy possesses especially good creep properties.

Example 4

A sheet of a 10% Al 90% Ti alloy 6.5 mm. thick was heated at 900° C. under hydrogen until it had taken up 1% by weight of hydrogen. The resulting sheet could then be hot rolled at temperatures over 750° C. down to a thickness of 0.8 mm. without even the smallest crack formation. Hot rolling of the same sheet but without incorporation of hydrogen therein was impossible under the same rolling conditions. Marked edge cracks occurred even in the first passes and these covered more than ⅓ of the width of the sheet when it only had been reduced to a thickness of 1.5 mm.

In the same manner, the incorporation of hydrogen in titanium alloys facilitates their deformation in an extrusion press. Intermediate anneals can be carried between the individual working operations without any substantial loss of the hydrogen incorporated in the alloys.

We claim:

1. In a process for hot working of titanium alloys, the steps which comprise incorporating 0.05% to 1% of hydrogen in such alloys and hot working such hydrogen containing alloys.

2. In a process for hot working of titanium alloys which predominantly contain alpha-titanium mixed crystals, the steps which comprise incorporating 0.05% to 1% of hydrogen in such alloys and hot working such hydrogen containing alloys.

3. The process of claim 2 in which said titanium alloy contains over 6% of aluminum.

4. The process of claim 1 in which said alloy is melted down under a hydrogen containing atmosphere to incorporate the hydrogen therein.

5. The process of claim 1 in which said alloy is heated in a hydrogen containing atmosphere to incorporate the hydrogen therein.

6. The process of claim 1 in which said alloy is melted down under an atmosphere containing at least 25% of hydrogen to incorporate the hydrogen therein.

7. The process of claim 1 in which said alloy is heated in an atmosphere containing at least 25% of hydrogen to incorporate the hydrogen therein.

References Cited in the file of this patent

Handbook on Titanium, by Heinrich K. Adenstedt, pages I–3–9, August 1954, Wright Air Development Center.