[DESCRIPTION]

[TITLE OF INVENTION]

PRODUCTION METHOD OF ALLOY MEMBER, ALLOY MEMBER, AND PRODUCT USING ALLOY MEMBER

[Technical Field]

[0001]

The present invention relates to a production method of an alloy member produced through an additive manufacturing method, an alloy member obtained through this production method, and a product using the alloy member.

[Background Art]

[0002]

In recent years, high-entropy alloys (HEAs) have been proposed as alloys of a new technical idea different from alloys (for example, alloys obtained by adding trace amounts of plural kinds of sub-component elements to 1 to 3 kinds of main component elements) of technical ideas in the related art. HEAs are defined as alloys consisting of 5 or more kinds of principal metal elements (respectively 5 to 35 atom%), and are known to exhibit characteristics (a) to (d) below. In addition, an alloy concept of a multi-principal element alloy (MPEA) having a plurality of principal elements and allowing existence of multiple phases has also been proposed. In the present application, HEAs and MPEAs are treated as the same concept, and both are collectively referred to as HEAs.

[0003]

Examples of advantages of HEAs include (a) stabilization of a mixed state due to a negative increase in a mixed entropy term in the Gibbs free energy equation, (b) a diffusion delay due to a complex fine structure, (c) a decrease in temperature dependence,

According to the technique of Patent Literature 1, an alloy member having excellent corrosion resistance and mechanical properties such as tensile strength or ductility can be obtained. However, further improvement in hardness is required to apply this alloy member to a severe environment where wear resistance is required.

[0008]

As described above, an objective of the present invention is to provide an alloy member which is produced through an additive manufacturing method using an alloy powder, has excellent corrosion resistance and mechanical properties, and has wear resistance due to further improved hardness, and a production method thereof. In addition, another objective of the present invention is to provide a production method of an alloy member having higher mechanical properties. Furthermore, still another objective of the present invention is to provide a product having excellent corrosion resistance and wear resistance and excellent mechanical properties using this alloy member.

[Solution to Problem]

[0009]

A production method of an alloy member of the present invention is a production method of an alloy member including: an additive manufacturing step of forming a shaped member through an additive manufacturing method using an alloy powder containing elements Co, Cr, Fe, Ni, and Ti each in a range of 5 atom% or more to 35 atom% or less and containing Mo in a range exceeding 0 atom% and 8 atom% or less, the remainder being unavoidable impurities (the shaped member obtained through such a step is regarded as a shaped member A); and an aging heat treatment step of holding the shaped member (shaped member A) obtained through the additive manufacturing step in

a temperature range higher than 500°C and lower than 900°C in a state where a melt solidification structure is provided at least in a surface layer part.

[0010]

A production method of an alloy member according to another aspect of the present invention is a production method of an alloy member including the following steps between the additive manufacturing step and the aging heat treatment step: a solution heat treatment step of heating the shaped member (shaped member A) formed through the additive manufacturing step and holding the shaped member in a temperature range of 1080°C or more to 1180°C or less; a cooling step of cooling the shaped member after the solution heat treatment step (a shaped member obtained through such a step is regarded as a shaped member B); and then a remelting and resolidifying step of melting and solidifying the surface layer part of the shaped member (shaped member B) again (a shaped member obtained through such a step is regarded as a shaped member C).

[0011]

A production method of an alloy member according to still another aspect of the present invention is a production method of an alloy member including the following steps between the additive manufacturing step and the aging heat treatment step: a solution heat treatment step of heating the shaped member (shaped member A) and holding the shaped member in a temperature range of 1080°C or more to 1180°C or less; a cooling step of cooling the shaped member after the solution heat treatment step (a shaped member obtained through such a step is regarded as a shaped member B); and then a surface layer-adding and shaping step of forming a melt solidification layer on the surface layer part of the shaped member (shaped member B) that has undergone the cooling step, through the additive manufacturing method using the alloy powder (a shaped member obtained through such a step is regarded as a shaped member D).

holding time is preferably set to 0.5 hours or longer and 8 hours or shorter and more preferably set to 1 hour or longer and 8 hours or shorter. When the holding time is 0.5 hours or longer, the effect of improving the strength can be obtained. When the holding time is 24 hours or shorter, formation of hexagonal precipitates causing deterioration in corrosion resistance can be inhibited. By the above aging heat treatment, nanoscale ultrafine particles having an average particle diameter of 50 nm or less can be generated in a microcell structure to be described below, thereby improving the strength.

[0042]

A cooling step after the aging heat treatment is not particularly limited. However, there is a possibility that nanoscale ultrafine particles may be excessively generated if the temperature is held near the aging heat treatment temperature for a long period of time. Therefore, the temperature may be cooled to room temperature through air cooling, gas cooling, or the like. In addition, Fig. 4 is merely an example, and the heat treatment pattern can be variously changed. In addition, in the process of raising the temperature in the aging heat treatment, the retention time in an intermediate temperature range at which it is difficult to adjust the precipitation amount can be shortened if the rate of temperature increase is 5°C/minute or higher, which is suitable. The temperature rising rate is preferably 10°C/minute or higher. The upper limit is not particularly limited, but is about 1000°C/minute or lower from the viewpoint of securing temperature uniformity in the shaped member 101, particularly prevention of generation of an overheated part.

[0043]

(Ultrafine Particles)

As described above, in the aging heat treatment of the present invention, ultrafine particles are generated in the microcell structure having an average diameter of

SEM image of (a). The average crystal grain size is an average grain size of 10 crystal grains measured through a cutting method using an SEM image of magnification of 500 times. In addition, although not shown in the SEM image of (a), microcell structures having an average diameter of 10 μm or less are formed inside the structure. It can be stated that, for example, the interval indicated by the arrow in an enlarged image of (b) indicates a diameter of a microcell structure. Moreover, the enrichment of Ti was confirmed in a boundary part 3 of the microcell structure shown by a white bright part in the SEM-EDS image of (b). In addition, in the high-magnification bright-field image of the STEM image of (c), a brighter region indicates the inside of the microcell structure and the boundary part 3 of the microcell structure includes a dislocation 4 shown by a black line having a higher density than the inside of the microcell structure. Accordingly, by confirming the concentration part where more black streaks are gathered compared to the inside of the microcell structure using the STEM image, it is possible to identify that there is a dislocation having a higher surface density than the inside of the structure. In addition, it was confirmed that a precipitate 5 containing an intermetallic compound is formed at the boundary part 3 of another microcell structure. Furthermore, ultrafine particles 6 having an average particle diameter of about 3 nm were confirmed in the high-magnification STEM image of (d). In addition, an element mapping image by STEM-EDX in this region is shown in the upper right of (d), and it was confirmed that the above-described ultrafine particles 6 were particles in which Ni and Ti were concentrated. (e) schematically illustrates a fine structure. As described above, this fine structure has a microcell structure in crystal grains of a surface layer part, and the boundary part 3 of this microcell structure has the black streak-like dislocation 4 having a higher surface density than the inside of the microcell structure. Furthermore, it was

members M1-S and M2-S through additive manufacturing and further performing an aging heat treatment. It was confirmed by TEM and STEM-EDX that minute particles having an average particle diameter of 100 nm or less were formed in the crystal grains inside the alloy members M1-S, M2-S, M1-RM650AG, M1-LD650AG, M2-RM650AG, and M2-LD650AG. Furthermore, it was confirmed by STEM-EDX that more Ni and Ti components were concentrated in the minute particles than in parent phase crystals.

[0066]

[Experiment 4]

(Measurement of Tensile Strength and Breaking Elongation)

M1, M1-S, M1-650AG, M2, M2-S, and M2-650AG were selected from the above-described test pieces, and tensile test pieces (parallel part diameter of 6 mm, length between gauge points of 24 mm) conforming to the standard test (ASTM E8) were produced based on the materials produced through the technique shown above. Tensile tests at room temperature (22°C) were performed at N=3 on the tensile test pieces, and average values of the tensile strength and the breaking elongation were obtained and shown in Table 3. From Table 3, it was confirmed that a tensile strength of 1,100 MPa or more and a breaking elongation of 5% or more were obtained in all of the test pieces. Among these, it was confirmed that a tensile strength of 1,500 MPa or more was obtained from the test pieces of M1-650AG and M2-650AG.

160 Recoater

107 Powder bed (Layered powder)

108 Laser oscillator

109 Laser beam

110 Galvanometer mirror

111 Collection container for unmelted powder

112 2D Slice-shaped solidification layer

101a Shaped member (inside)

101b Shaped member (surface layer)

200 Powder additive manufacturing device

201 Powder supply container

203 Laser beam or electron beam

204 Table

205 base plate

206 Laser head part

303 Shaped member

S10 Raw material powder production step

S30 Additive manufacturing step

S40 Solution heat treatment step

S50 Removal step

S60 Remelting and resolidifying step

S65 Surface layer-adding and shaping step

S70 Aging heat treatment step