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(54) **Manufacturing method for heat resistant aluminium alloy shaped products, heat resistant aluminium alloy shaped products, and forming apparatus for heat resistant aluminium alloy shaped products**

(57) A manufacturing method for heat resistant aluminium alloy shaped products forms a shaped product by performing hot extrusion of a material (billet) made of a heat resistant aluminium alloy. The hot extrusion is per-

formed causing a temperature of the shaped product immediately after the hot extrusion to fall within a range between 350°C and below 550°C.

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a manufacturing method for heat resistant aluminium alloy shaped products, heat resistant aluminium alloy shaped products, and forming apparatus for heat resistant aluminium alloy shaped products.

2. Description of the Related Art

[0002] Conventionally, heat resistant aluminium alloy materials having superior high temperature toughness, wear resistance, and high temperature fatigue property ("fatigue resistance," hereinbelow) are known (see Patent Publication 1 (Japanese Unexamined Patent Application Publication No. 2006-104561), for example).

[0003] Patent Publication 1 describes suitable use of such heat resistant aluminium alloy materials for mechanical components ("components" includes "parts," hereinbelow), such as vehicle components and engine components, for which heat resistance and lightweight property are required, and the mechanical components are formed through the step of a hot extrusion process from the heat resistant aluminium alloy materials.

[0004] However, although heat resistant aluminium alloy materials equivalent to those disclosed in Patent Publication 1 were actually subjected to hot extrusion process, surface cracking occurred on materials depending on processing conditions.

SUMMARY OF THE INVENTION

[0005] The present invention is made to solve problems such as described above, and an object of the invention is to form well-shaped heat resistant aluminium alloy shaped products by hot extrusion while suppressing surface cracking.

[0006] As a consequence of an extensive research and study conducted to achieve the object of the present invention, the inventor discovered that surface cracking can be suppressed when hot extrusion is performed so that the shaped product temperature immediately after extrusion falls within a predetermined temperature range.

Accordingly, one aspect of the present invention provides a manufacturing method for heat resistant aluminium alloy shaped products, wherein a shaped product is formed by hot extrusion of a material made of a heat resistant aluminium alloy. The hot extrusion is performed causing a temperature of the shaped product immediately after the hot extrusion to fall within a range between 350°C and below 550°C.

[0007] By the hot extrusion thus performed causing the temperature of the shaped product immediately after

the hot extrusion to fall within the range between 350°C and below 550°C, well-shaped heat resistant aluminium alloy shaped products can be formed by hot extrusion while suppressing surface cracking.

[0008] According to the aspect of the present invention, there is further provided a heat resistant aluminium alloy shaped product manufactured by the manufacturing method described above. For the shaped product, surface cracking can be suppressed during the manufacture, and properties such as superior high temperature toughness, wear resistance, and fatigue resistance, can be obtained.

[0009] Preferably, in the manufacturing method for heat resistant aluminium alloy shaped products, the hot extrusion of the material is performed by using a forming apparatus including a plurality of entry side ports, a single merge portion fluidly connected to the plurality of entry side ports, and a die including a shaping space fluidly connected to the merge portion. In this case, the forming apparatus performs a process including the steps of dividing the compressively loaded material into parts of the material through the plurality of entry side ports, directing the parts of the material passed through the plurality of entry side ports to be merged and welded to one another, and extruding the shaped product having a hollow cross-sectional shape from the shaping space, wherein a ratio of the size of a cross-sectional area of the material prior to compressive loading thereof into the die to the size of a cross-sectional area of the shaped product is 11 or greater, the cross sectional area of the material and the cross sectional area of the shaped product being perpendicular to an extrusion direction.

[0010] As a consequence of the extensive research and study, the inventor discovered the following. Reference is now made to a case where, as described above, a material to be compressive loaded into the die is divided into parts of the material through the plurality of entry side ports, the parts of the material passed through the plurality of entry side ports are merged and welded to one another, and the shaped product having a hollow cross-sectional shape is extruded from the shaping space. In this case, the ratio of the size of a cross-sectional area of the material prior to compressive loading thereof into the die to the size of a cross-sectional area of the shaped product is set to 11 or greater, wherein the cross sectional area of the material and the cross sectional area of the shaped product are perpendicular to an extrusion direction. Thereby, a strength (tensile strength) as high as 90% or more ("at least 90%," hereinbelow) of the strength of a non-weld portion of the shaped product can be imparted to a weld portion between the parts of the material passed through the respective entry side ports.

The level that the weld portion has the strength as high as at least 90% of the strength of the non-weld portion can be construed as a level not having a significant difference between the weld portion and the non-weld portion, as fluctuations in the strengths of the respective weld

portion and non-weld portion are taken into account. As such, it can be construed that the weld portion and the non-weld portion have substantially the same strength, so that the strength of the entirety of the hollow shaped product can be caused to be close to a uniform level. Consequently, unlike a case where the strength of a weld portion is lower than the strength of a non-weld portion, such a case where the weld portion fails earlier than the non-weld portion when a load is applied can be prevented.

[0011] The heat resistant aluminium alloy shaped product according to the aspect of the present invention is manufactured in accordance with the manufacturing method described above. In the manufacturing method, the ratio of the size of the cross-sectional area of the material prior to compressive loading thereof into the die to the size of the cross-sectional area of the shaped product is set to 11 or greater, the cross sectional area of the material and the cross sectional area of the shaped product being perpendicular to the extrusion direction. The shaped product includes the weld portion between the parts of the material passed through the respective entry side ports, and the non-weld portion other than the weld portion. The weld portion has the strength as high as at least 90% of the non-weld portion.

[0012] As described above, in the heat resistant aluminium alloy shaped product, the weld portion has the strength as high as at least 90% of the non-weld portion. The level that the weld portion has the strength as high as at least 90% of the strength of the non-weld portion can be construed as the level not having the significant difference between the weld portion and the non-weld portion, as fluctuations in the strengths of the respective weld portion and non-weld portion are taken into account. As such, it can be construed that the weld portion and the non-weld portion have substantially the same strength, so that the strength of the entirety of the hollow shaped product can be caused to be close to a uniform level. Consequently, unlike the case where the strength of the weld portion is lower than the strength of the non-weld portion, such a case where the weld portion fails earlier than the non-weld portion when a load is applied can be prevented.

[0013] A forming apparatus for heat resistant aluminium alloy shaped products, according to the aspect of the present invention is used, as a prerequisite condition, for the above-described manufacturing method for shaped products. In the manufacturing method, the ratio of the size of the cross-sectional area of the material prior to compressive loading thereof into the die to the size of the cross-sectional area of the shaped product is set to 11 or greater, wherein the cross sectional area of the material and the cross sectional area of the shaped product are perpendicular to an extrusion direction. The forming apparatus includes a container including a bore hole into which the material prior to the hot extrusion is loaded; a plurality of entry side ports fluidly connected to the bore hole; a single merge portion fluidly connected to the plu-

ality of entry side ports; a die including a shaping space fluidly connected to the merge portion; and a stem for compressing the material present in the bore hole to compressively load the material into the die. In the forming apparatus, a ratio of the size of a cross-sectional area of the bore hole of the container to the size of a cross-sectional area of the shaping space is set to 11 or greater, wherein the cross sectional area of the bore hole and the cross sectional area of the shaping space are perpendicular to an extrusion direction.

[0014] Thus, in the forming apparatus, the ratio of the size of the cross-sectional area of the bore hole of the container to the size of the cross-sectional area of the shaping space is set to 11 or greater, wherein the cross sectional area of the bore hole and the cross sectional area of the shaping space are perpendicular to the extrusion direction. Accordingly, the ratio of the size of the cross-sectional area of the material prior to compressive loading thereof into the die to the size of the cross-sectional area of the shaped product can be set to 11 or greater, wherein the cross sectional area of the material and the cross sectional area of the shaped product are perpendicular to an extrusion direction. Thereby, the strength as high as 90% or more ("at least 90%," hereinbelow) of the strength of the non-weld portion of the shaped product can be imparted to the weld portion, so that the strength of the entirety of the shaped product can be caused to be close to a uniform level. Consequently, unlike a case where the strength of a weld portion is lower than the strength of a non-weld portion, such a case where the weld portion fails earlier than the non-weld portion when a load is applied can be prevented. As described above, the aspect of the present invention can form well-shaped heat resistant aluminium alloy shaped products by hot extrusion while suppressing surface cracking.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] In the accompanying drawings:

FIG. 1 is an explanatory view of a manufacturing process for heat resistant aluminium alloy shaped products in accordance with a first embodiment of the present invention;

FIG. 2 is a correlation diagram showing the correlation between an immediate post-extrusion shaped product temperature and shaped-material surface cracking in the manufacturing process of the first embodiment;

FIG. 3 is an explanatory view of a manufacturing process of a heat resistant aluminium alloy hollow shaped product in accordance with a second embodiment of the present invention;

FIG. 4 is a view showing the state where the hollow shaped product is extruded by a forming apparatus used in the manufacturing process shown in FIG. 3; FIG. 5 is a perspective view showing the shape of

the material in the forming apparatus in accordance with the second embodiment;

FIG. 6 is an explanatory view of a sampling method for sampling (cutting) a test specimen for tensile strength testing from the hollow shaped product; and FIG. 7 is a correlation diagram showing the correlation between weld portions of the hollow shaped product and the tensile strength.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Embodiments of the present invention will be described in detail with reference to the accompanying drawings.

(First Embodiment)

[0017] FIG. 1 shows a manufacturing process for heat resistant aluminium alloy shaped products in accordance with a first embodiment of the present invention. A heat resistant aluminium alloy used in the manufacturing process is a material that has a superior high temperature toughness, wear resistance, and fatigue resistance at a temperature of nearly 300°C. The heat resistant aluminium alloy contains an aluminium-base alloy structure composed of about 50% to about 90% intermetallic compound phase in terms of the volume fraction (vf) and a metal matrix formed as the balance. Further, the heat resistant aluminium alloy has a composition that contains three elements selected from Cr, Fe, Ti, Mn, V, and Si as elements that forms the intermetallic compound phase, in which a total content of the selected three elements is in the range of about 15 mass % to about 50 mass %.

[0018] Preferably, the intermetallic compound phase has a composition containing about 5 mass % to about 30 mass % Cr, about 1 mass % to about 20 mass % Fe, and about 1 mass % to about 15 mass % Ti, and is any one of Al-Cr, Al-Fe, and Al-Ti systems or types. According to the configuration described above, the high temperature fatigue property of the heat resistant aluminium alloy can be even more improved.

[0019] In the manufacturing process according to the first embodiment, a shaped product 2 is formed by hot extrusion of a billet 1 (material) formed of the heat resistant aluminium alloy described above. In this case, the billet 1 to be used for processing is formed by a so-called "spray forming process." In the spray forming process, the heat resistant aluminium alloy, which has the above-described composition, is melted by being heated up to the range between 1250°C and 1600°C, and is cooled at a cooling rate of 100°C/h. When being cooled down to a range between 900°C and 1200°C, spraying of the heat resistant aluminium alloy in the melted state is started. Then, particulate matter of the sprayed heat resistant aluminium alloy is deposited, thereby to create a pre-form. Then, HIP (hot isostatic pressing) processing is per-

formed on the pre-form in a sealed vacuum vessel, whereby the billet 1 is created. The HIP processing is processing that exerts the pressure of a high pressure gas at high temperature on such a pre-form, thereby to perform defect removal from the pre-form. The billet 1 to be thus created is formed in a round columnar shape.

[0020] In the manufacturing process according to the first embodiment, hot extrusion is performed by loading the billet 1 into a forming apparatus 10. The forming apparatus 10 used for hot extrusion includes a container 12, a stem 14, and a die 16.

[0021] The container 12 has a bore hole 12a into which the billet 1 is loaded. The bore hole 12a extends along the extrusion direction of the billet 1, and has a circular cross section perpendicular to the extrusion direction. In the bore hole 12a, the stem 14 is driven by a drive mechanism (not shown) to be extendable or retractable (or, reciprocable) along the extrusion direction. The die 16 is disposed in an end portion of the bore hole 12a in the extrusion direction (right direction as viewed on FIG. 1). The die 16 has a shaping opening 16a into which the billet 1 compressed from the bore hole 12a flows. The billet 1 present in the bore hole 12a is compressed by the stem 14, thereby to extrude the solid shaped product 2 corresponding to the shape of the shaping opening 16a of the die 16. In the manufacturing process according to the first embodiment, shaped products 2 having various shapes, such as planar and angled columnar shaped products 2 shown in FIG. 1, can be formed.

[0022] In the hot extrusion according to the first embodiment, the hot extrusion is performed so that the shaped product 2 temperature immediately after the extrusion from the forming apparatus 10 falls within in the range between 350°C and below 550°C. When the heat resistant aluminium alloy material was actually subjected to hot extrusion, cracking occurred on the surfaces of extruded shaped products in some cases. In order to solve the problems of such surface cracking, the inventor focused attention on the temperature of the material during the hot extrusion. Then, the inventor conducted experimentation to investigate the correlation between the surface cracking occurring on the shaped product 2 and the temperature of the shaped product 2 immediately after the hot extrusion.

[0023] In the experimentation, a plurality of shaped products 2 were formed in the manner that a ratio of the size of a cross-sectional area of the respective billet 1 in the bore hole 12a to the size of a cross-sectional area of the respective shaped product 2 is varied in a range of between 14.5 and 65.5, in which the respective cross-sectional areas of the billet 1 and shaped product 2 are perpendicular to the extrusion direction. The above-described ratio hereinbelow is referred to as an "extrusion ratio." Then, the temperature of the respective shaped product 2 immediately after the hot extrusion from the forming apparatus 10 was measured, and whether cracking occurred on the surface of the respective shaped product 2 was observed. The result of the experimenta-

tion is shown in FIG. 2.

[0024] As seen from FIG. 2, in hot extrusion causing the temperature of the respective shaped product 2 immediately after the hot extrusion to reach 550°C, well-shaped shaped products was not able to be formed as surface cracking occurred on the respective shaped products 2. However, in hot extrusion causing the temperature of the respective shaped product 2 immediately after the hot extrusion to be below 550°C, well-shaped shaped products 2 were able to be formed without surface cracking. In hot extrusion causing the temperature of a shaped product 2 immediately after the hot extrusion to be below 350°C, deformability of the billet 1 is excessively low, therefore making it difficult to extrude the shaped product 2 from the forming apparatus 10. Consequently, it was known that surface cracking can be suppressed and hence a well-shaped shaped product 2 of the heat resistant aluminium alloy can be formed by performing the hot extrusion causing the temperature of the shaped product 2 immediately after the hot extrusion to fall within the range of range between 350°C and below 550°C.

[0025] The temperature of the shaped product 2 immediately after the hot extrusion varies depending upon factors, such as the temperature of the billet 1 prior to loading thereof into the bore hole 12a of the container 12, the amount of heat loss from the billet 1, the temperature of the container 12, and processing heat occurring during the extrusion. Nevertheless, however, the temperature of a shaped product 2 immediately after the hot extrusion can be adjusted by adjusting a heating temperature of a billet 1 prior to loading thereof into the bore hole 12a of the container 12. More specifically, the temperature of a shaped product 2 immediately after the hot extrusion is once actually measured. As a result, when the temperature of the shaped product 2 is higher than the 550°C, the heating temperature of a corresponding billet 1 is reduced. Thus, hot extrusion is performed to set a temperature condition, and the heating temperature of a billet 1 is adjusted in accordance with the temperature of a corresponding shaped product 2 immediately after the hot extrusion. Thereby, the temperature of the shaped product 2 immediately after the hot extrusion can easily be adjusted to fall within the range between 350°C and below 550°C.

[0026] As described above, according to the first embodiment, surface cracking can be suppressed and hence a well-shaped shaped product 2 of the heat resistant aluminium alloy can be formed by performing the hot extrusion causing the temperature of the shaped product 2 immediately after the hot extrusion to fall within the range of range between 350°C and below 550°C.

[0027] Further, for the heat resistant aluminium alloy shaped product 2 manufactured by the manufacturing method according to the first embodiment, superior high temperature toughness, wear resistance, and fatigue resistance can be obtained.

(Second Embodiment)

[0028] A second embodiment of the present invention will be described herebelow.

5 The manufacturing method for heat resistant aluminium alloy shaped products is different from the manufacturing method according to the first embodiment in that, as shown in FIG. 3, shaped products 22, respectively, having hollow cross sectional shapes (which hereinbelow will be referred to as "hollow shaped product 22a") are continually extruded.

10 FIG. 3 shows the manufacturing process according to the second embodiment. The manufacturing method according to the second embodiment is capable of forming hollow shaped products 22 of various shapes correspondingly to the shapes of shaping spaces S. The hollow shaped products 22 include, for example, a rectangularly columnar hollow shaped product 22a and a hollow shaped product 22c of a shape in which a space inside a rectangular column is partitioned by a partition wall into two spaces formed along the long-side direction. However, the second embodiment will be described herebelow with reference to the case of forming the rectangularly columnar hollow shaped product 22a.

15 **[0029]** Similarly as in the first embodiment, in the second embodiment, a billet 1 formed by a spray forming process from heat resistant aluminium alloy is loaded in to a forming apparatus 30, and is subjected to hot extrusion, thereby to form the hollow shaped product 22a. The forming apparatus 30 includes a container 32, a stem 32, a die 36, and a die holder 38. The configurations of the container 32 and the stem 34 are similar to those of the container 12 and the stem 14, respectively, in the first embodiment.

20 **[0030]** The die holder 38 is disposed in an end portion in the extrusion direction of the billet 1 in alignment with the container 32, and is fixedly attached in the position. The die holder 38 has a holding opening 38a through-formed along the extrusion direction of the billet 1, and the die 36 is fitted therein to be held by the holding opening 38a.

25 **[0031]** The die 36 includes male and female dies 40 and 41. The male and female dies 40 and 41 are provided in that order along the extrusion direction of the billet 1, in which the male die 40 is fitted or coupled into the female die 41. With reference to FIG. 4, the male die 40 has a plurality of entry ports 40a (entry side ports) through-formed along the extrusion direction. The plurality of entry ports 40a are fluidly connected to the bore hole 32a of the container 32. The billet 1 compressed by the stem 34 from the bore hole 32a of the container 32 is divided through the respective entry ports 40a into parts 1a of the material (see FIG. 5), and the parts 1a of the material, which have been divided through the respective entry

30 35 40 45 50 55

ports 40a, are compressively loaded for extrusion. The male die 40 further has a protruding portion 40b protruding along the extrusion direction of the billet 1. An end portion of the protruding portion 40b on the side of the female die 41 has a rectangular cross sectional plane perpendicular to the extrusion direction in correspondence to an interior space of the hollow shaped product 22a.

[0032] The female die 41 includes a single merge portion 41a fluidly connected to the plurality of entry ports 40a of the male die 40, and a forming opening 41b fluidly connected to the merge portion 41a. The merge portion 41a of the merge portion 41a causes fluid communication between the entry ports 40a and the forming opening 41b. The shaping opening 41b has a cross sectional plane perpendicular to the extrusion direction in correspondence to the peripheral shape of the hollow shaped product 22a. The protruding portion 40b of the male die 40 is inserted into the shaping opening 41b in the state where a clearance exists between the protruding portion 40b and an inner wall surface of the shaping opening 41b. By the protruding portion 40b of the male die 40 and the inner wall surface of the shaping opening 41b of the female die 41, the shaping space S (see FIG. 3) having a rectangular frame shape corresponding to the rectangularly columnar shape of the hollow shaped product 22a. The shaping space S is fluidly connected to the merge portion 41a.

[0033] In the configuration thus formed, the billet 1 is compressively loaded by the stem 34 into the respective entry ports 40a from the bore hole 32a of the container 32 and is divided therethrough into the parts 1a of the material (see FIG. 5). In this state, the parts 1a of the material flow out of the respective entry ports 40a. Then, the parts 1a of the material flowed past the respective entry ports 40a are merged and welded to one another in the merge portion 41a, whereby an integral material 1b is formed (see FIG. 5). The material 1b is extruded through the shaping space S (see FIG. 3), whereby the rectangularly columnar hollow shaped product 22a is formed. Similarly as in the manufacturing method according to the first embodiment, in the manufacturing method according to the second embodiment, the heating temperature of the billet 1 prior to loading thereof into the bore hole 32a of the container 32 is adjusted, thereby to perform hot extrusion causing the temperature of the hollow shaped product 22 immediately after the hot extrusion to fall within the range between 350°C and below 550°C.

[0034] For the hot extrusion according to the second embodiment, the extrusion ratio is set to 11 or greater. More specifically, the ratio of the size of a cross-sectional area of the billet 1 prior to compressive loading thereof into the die 36 (i.e., in the state where the billet 1 present inside the bore hole 32a of the container 32) to the size of a cross-sectional area of the hollow shaped product 22a is set to 11 or greater, in which the respective cross-sectional areas of the billet 1 and hollow shaped product

22a are perpendicular to the extrusion direction. The size of the cross sectional area of the hollow shaped product 22a perpendicular to the extrusion direction corresponds to the size of the cross sectional area of the shaping space S perpendicular to the extrusion direction. In addition, the size of the cross sectional area, which is perpendicular to the extrusion direction, of the billet 1 prior to loading thereof into the die 36 corresponds to the size of the cross sectional area of the bore hole 32a perpendicular to the extrusion direction. As such, in design stages, setting is made so that the extrusion ratio is 11 or greater. More specifically, in the stage of design of the die 36, the size of the cross sectional area of the shaping space S is adjusted by adjusting the outside diameter of the protruding portion 40b of the male die 40 and the inside diameter of the shaping opening 41b of the shaping opening 41b. In addition, in the stage of the container 32, the size of the cross sectional area of the bore hole 32a is adjusted by adjusting the diameter of the bore hole 32a.

[0035] The interior of the hollow shaped product 22a includes weld portions 22d of the parts 1a of the material passed through the respective entry ports 40a, and non-weld portions 22e other than the weld portions 22d (see FIG. 5). The weld portions 22d are disposed in respective angular portions of the hollow shaped product 22a, and are formed in the entirety of the hollow shaped product 22a in the extrusion direction. In many cases, portions corresponding to the weld portions 22d are inferior in strength to portions corresponding to the non-weld portions 22e. If the strength of a weld portion 22d is excessively lower than the strength of a non-weld portions 22e, the weld portion 22d can fail earlier than the non-weld portion when a load is applied during the use of the hollow shaped product 22a. In order to suppress reduction in the strength of the weld portions 22d, the inventor focused attention on the extrusion ratio in the hot extrusion, and carried out experimentation to investigate the correlation between the strength of the weld portions 22d and the extrusion ratio.

[0036] In the experimentation, a plurality of hollow shaped products 22a of the type shown in FIG. 6, in each of which a weld portion 22d is formed in a central portion with respect to the width direction. In this case, hot extrusion was performed similarly as in the manufacturing process so that the hollow shaped product 22a immediately after the hot extrusion is 530°C, and the plurality of hollow, shaped products 22a were formed by varying the extrusion ratio.

With reference to FIG. 6, respective test pieces 50 were sampled (cut) from respective hollow shaped products 22a including the weld portions 22d, and were subjected to tensile strength testing. In the tensile strength testing, tensile forces along opposite directions were applied to the end portions of the test piece 50 positioned on both sides thereof with the weld portion 22d located therebetween until the test piece 50 is broken, in which the maximum strength was measured. The tensile strength testing was performed in the state of the test piece 50 heated

at 300°C. The testing was performed on three test pieces 50 in units of the condition of each extrusion ratio, and average values of the results were calculated. The results are shown in FIG. 7. In FIG. 7, the strength of the weld portion 22d is shown in terms of the rate (%) with respect to the tensile strength of the non-weld portions 22e.

[0037] It can be known from FIG. 7, in the hollow shaped product 22a manufactured in accordance with the extrusion ratio set to the 11 or greater, the weld portion 22d has a tensile strength as high as 90% or more ("at least 90%," hereinbelow) of the tensile strength of the non-weld portion 22e. The level that the weld portion 22d has the tensile strength as high as at least 90% of the tensile strength of the non-weld portion 22e can be construed as a level not having a significant difference between the weld portion 22d and the non-weld portion 22e, as fluctuations in the strengths of the respective weld portion 22d and non-weld portion 22e are taken into account.

In comparison to the above, it can be known from FIG. 7 that in the hollow shaped product 22a manufactured in accordance with the extrusion ratio set to 7, the tensile strength of the weld portion 22d is only about 50% of the tensile strength of the weld portion 22d. That is, it can be known that, in the case of the aforementioned extrusion ratio, the tensile strength of the weld portion 22d is significantly low, compared to the tensile strength of the non-weld portion 22e. Thus, it was known that the tensile strength of the weld portion 22d of the hollow shaped product 22a can be increased to be substantially the same as that of the non-weld portion 22e of the hollow shaped product 22a in accordance with the extrusion ratio set to 11 or greater.

[0038] As described above, also in the second embodiment, the hot extrusion is performed causing the hollow shaped material 22 immediately after the hot extrusion to fall within the range between 350°C and below 550°C. Consequently, similar effects to those in the first embodiment can be obtained in that surface cracking can be suppressed and hence a well-shaped hollow shaped product 22 of the heat resistant aluminium alloy can be formed.

[0039] Further, according to the second embodiment, the ratio (extrusion ratio) of the size of the cross-sectional area, which is perpendicular to the extrusion direction, of the billet 1 prior to compressive loading thereof into the die 36 to the size of a cross-sectional area, perpendicular to the extrusion direction, of the hollow shaped product 22a is 11 or greater. Thereby, the tensile strength as high as at least 90% of the tensile strength of the non-weld portion 22e of the hollow shaped product 22a, that is, substantially the same tensile strength as the tensile strength of the non-weld portion 22e, can be imparted to the weld portion 22d of the hollow shaped product 22a. As such, the strength of the entirety of the hollow shaped product 22a can be caused to be close to a uniform level. Consequently, unlike the case where the strength of the weld portion 22d is lower than the strength of the non-

weld portion 22e, such a case where the weld portion 22d fails earlier than the non-weld portion when a load is applied can be prevented.

[0040] The embodiments are disclosed above by way of examples in all respects and should not be construed to be restrictive. The scope of the present invention is not defined by description of the embodiments, but is defined only by the appended claims. Further, it is to be understood that definitions or meanings equivalent to those in the claims and all modifications and/or alterations within the scope defined therein are included in the present invention.

[0041] For example, in the second embodiment, the die 36 including the separately configured the male die 40 and the female die 41 is used. However, there are no limitations to this type, but a die formed from integrated female dies 40 and 41 may be used.

[0042] Further, the second embodiment has been described with reference to the case where the hollow shaped products 22 having the hollow cross sectional shapes are formed, but there are no limitations thereto. For example, a shaped product having a shape in which an opening is formed along the extrusion direction in a part of the shaped product (such as the hollow shaped product 22), and a shaped product including a hollow cross sectional shape portion only in a partial region may be formed.

It should be understood by those skilled in the art that various modifications, combinations, sub-combinations, and alternations may occur depending on the design requirements and other factors insofar as they are within the scope and spirit of the appended claims or the equivalents thereof.

Claims

1. A manufacturing method for heat resistant aluminium alloy shaped products, wherein:

a shaped product is formed by hot extrusion of a material made of a heat resistant aluminium alloy; and
the hot extrusion is performed causing a temperature of the shaped product immediately after the hot extrusion to fall within a range between 350°C and below 550°C.

2. A heat resistant aluminium alloy shaped product manufactured by the manufacturing method as claimed in claim 1.

3. The manufacturing method for heat resistant aluminium alloy shaped products, as claimed in claim 1, wherein:

the hot extrusion of the material is performed by using a forming apparatus including a plurality

of entry side ports, a single merge portion fluidly connected to the plurality of entry side ports, and a die including a shaping space fluidly connected to the merge portion;
 the forming apparatus performs a process including the steps of
 dividing the loaded material to be compressive loaded into the die into parts of the material through the plurality of entry side ports,
 directing the parts of the material passed through the plurality of entry side ports to be merged and welded to one another, and
 extruding the shaped product having a hollow cross-sectional shape from the shaping space, wherein a ratio of the size of a cross-sectional area of the material prior to compressive loading thereof into the die to the size of a cross-sectional area of the shaped product is set to 11 or greater, the cross sectional area of the material and the cross sectional area of the shaped product being perpendicular to an extrusion direction.

4. A shaped product manufactured by the manufacturing method as claimed in claim 3, the shaped product including
 a weld portion between parts of material passed through the respective entry side ports, and
 non-weld portion other than the weld portion, wherein the weld portion has the strength as high as at least 90% of the non-weld portion.
5. A forming apparatus for use in the manufacturing method for heat resistant aluminium alloy shaped products, as claimed in claim 3, the forming apparatus comprising:

a container including a bore hole into which the material prior to the hot extrusion is loaded;
 a plurality of entry side ports fluidly connected to the bore hole;
 a single merge portion fluidly connected to the plurality of entry side ports;
 a die including a shaping space fluidly connected to the merge portion; and
 a stem for compressing the material present in the bore hole to compressively load the material into the die,
 wherein a ratio of the size of a cross-sectional area of the bore hole of the container to the size of a cross-sectional area of the shaping space is set to 11 or greater, the cross sectional area of the bore hole and the cross sectional area of the shaping space being perpendicular to an extrusion direction.

FIG. 1

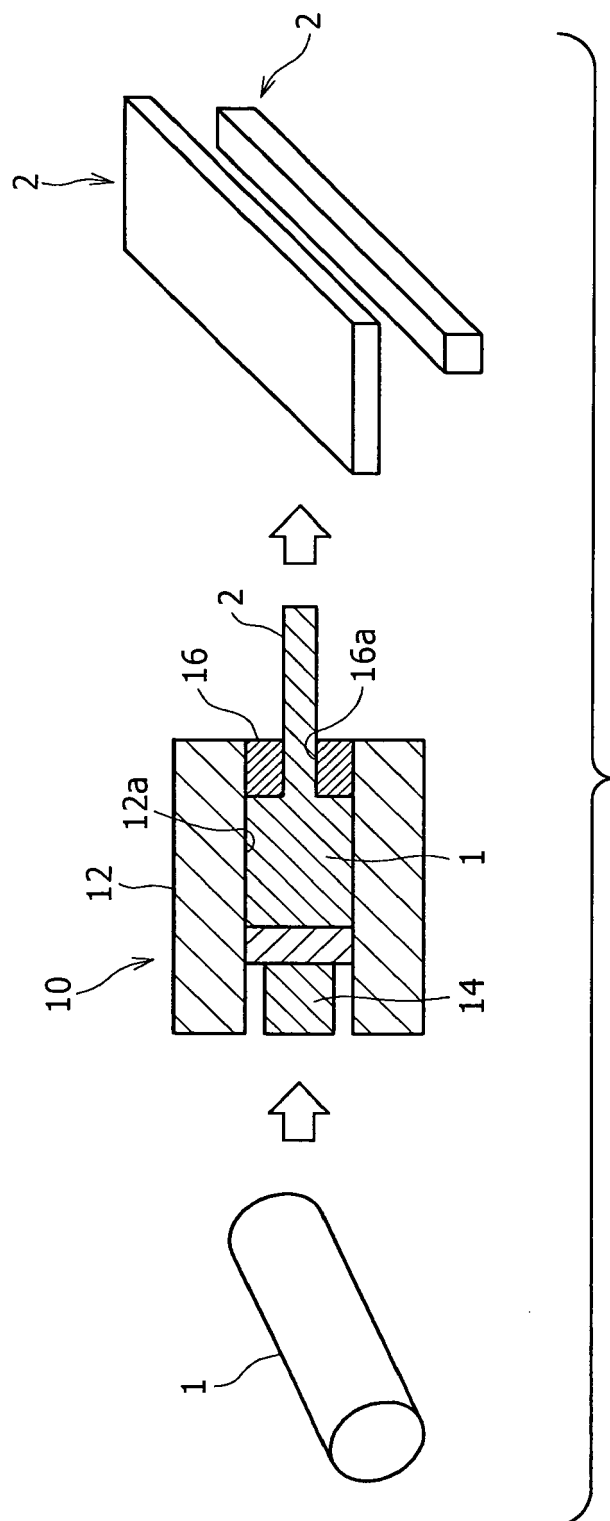


FIG. 2

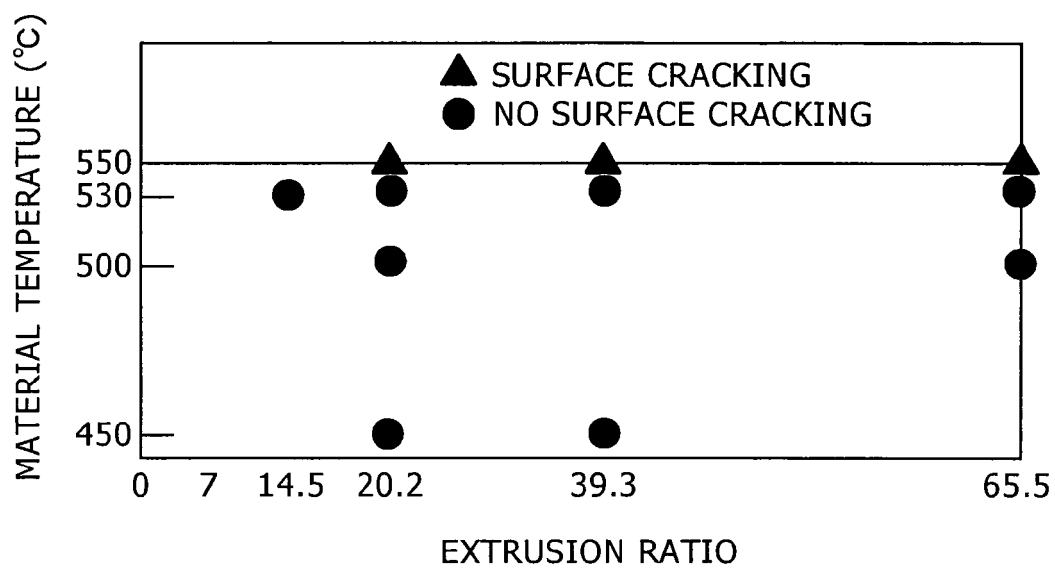


FIG. 3

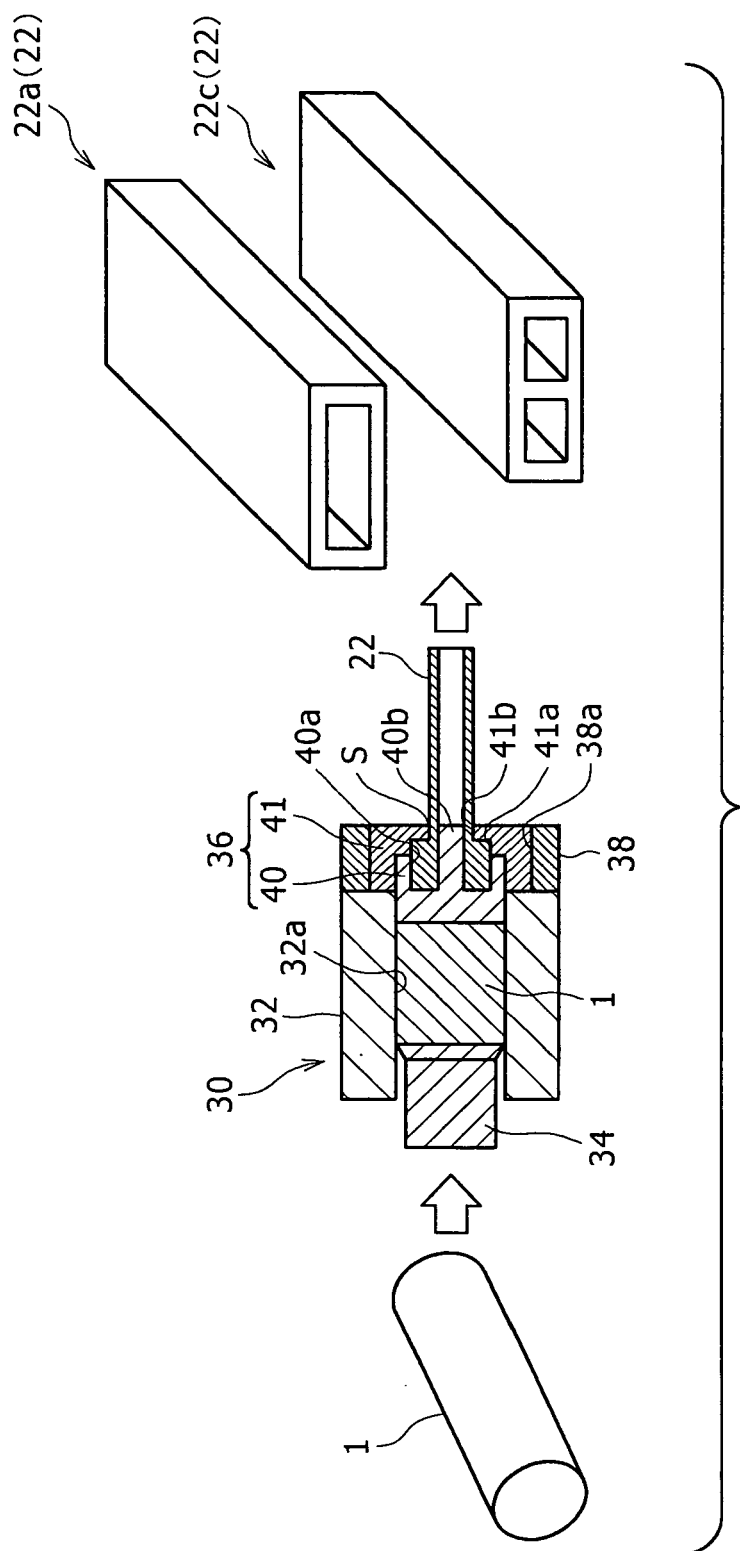


FIG. 4

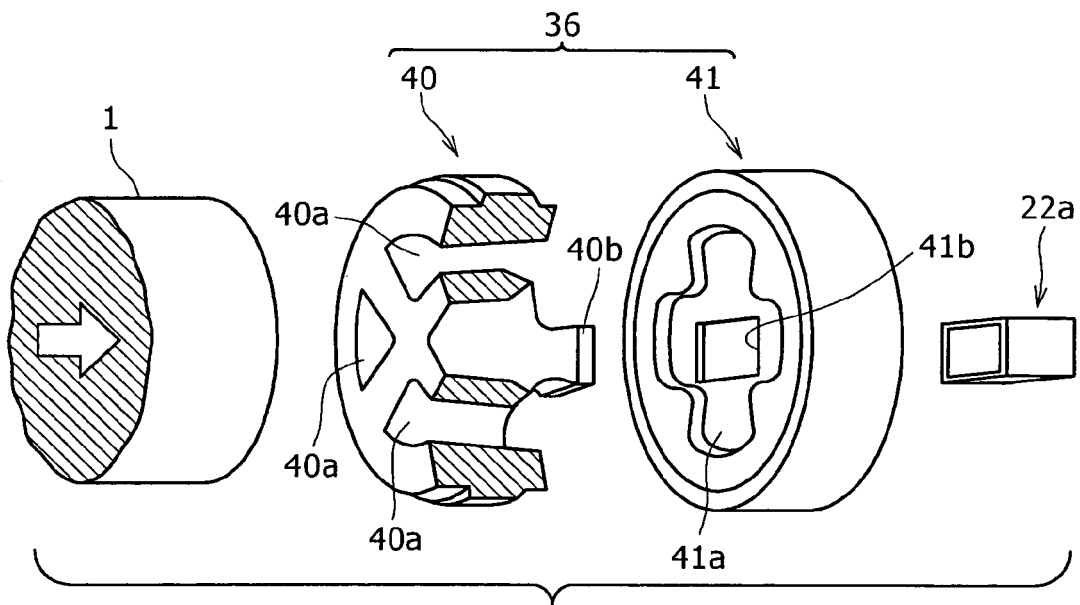


FIG. 5

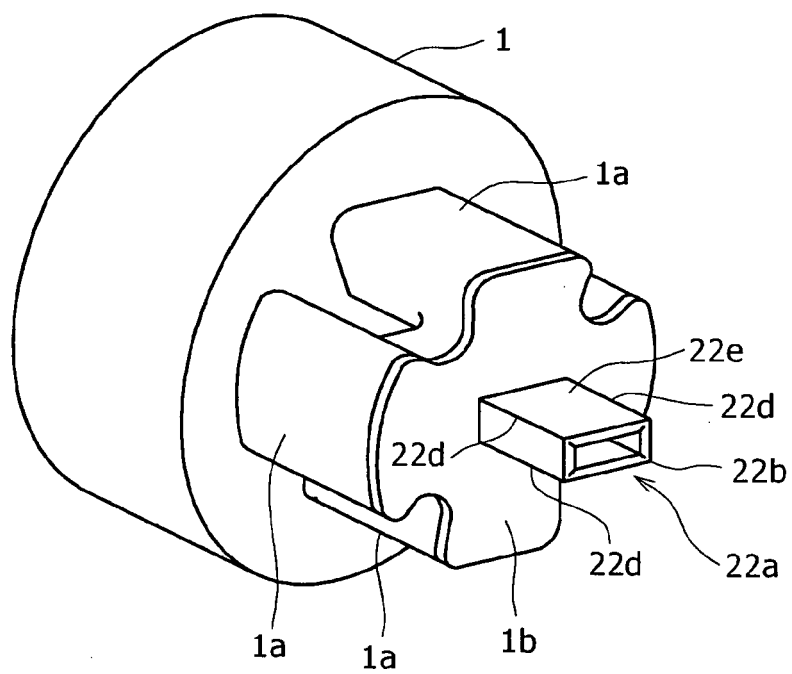


FIG. 6

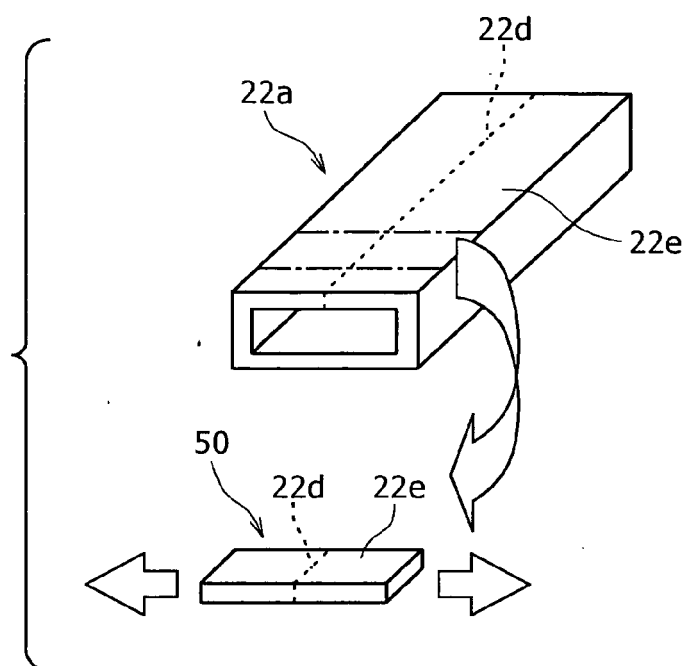
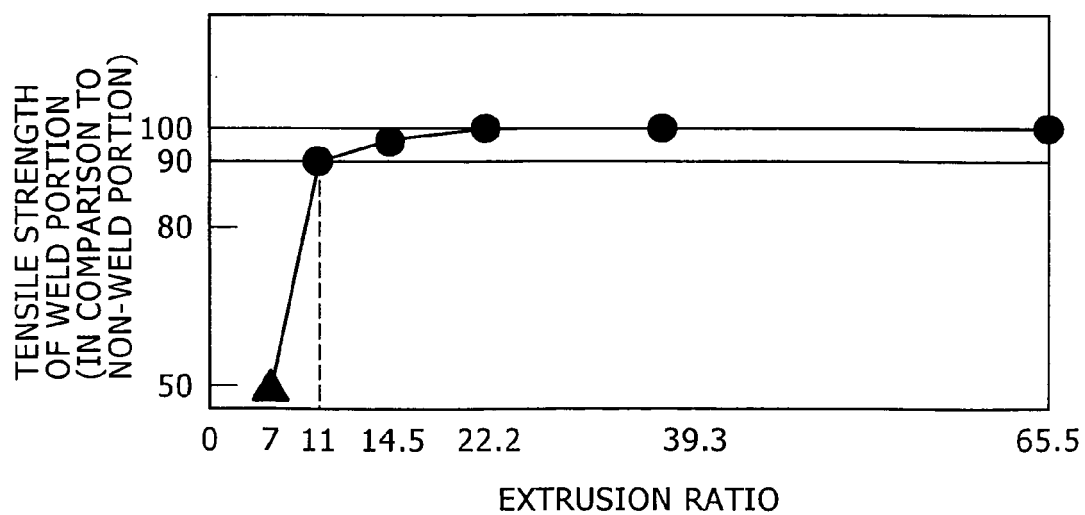


FIG. 7





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EUROPEAN SEARCH REPORT

Application Number
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