

(19)



(11)

EP 1 935 998 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:

25.06.2008 Bulletin 2008/26

(51) Int Cl.:

C22C 21/06^(2006.01) B21C 37/15^(2006.01)

(21) Application number: **05783336.0**

(86) International application number:

PCT/JP2005/017083

(22) Date of filing: **09.09.2005**

(87) International publication number:

WO 2007/029343 (15.03.2007 Gazette 2007/11)

(84) Designated Contracting States:

**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI
SK TR**

(71) Applicants:

- **Furukawa-Sky Aluminum Corporation**
Tokyo 130-0013 (JP)
- **HONDA GIKEN KOGYO KABUSHIKI KAISHA**
Minato-ku,
Tokyo 107-8556 (JP)

(72) Inventors:

- **KASHIWAZAKI, Kazuhisa**
Tokyo 130-0013 (JP)
- **SHOJI, Ryo**
Tokyo 130-0013 (JP)

• **UENO, Seizo**

Tokyo 130-0013 (JP)

• **AKIYAMA, Hiroshi**

Wako-shi

Saitama 351-0193 (JP)

• **SHIOTSUKI, Katsuhiko**

Wako-shi

Saitama 351-0193 (JP)

• **HORI, Izuru**

Wako-shi

Saitama 321-3395 (JP)

• **UKENA, Toshiyasu**

Tokyo 100-8071 (JP)

(74) Representative: **Forstmeyer, Dietmar et al**

BOETERS & LIECK

Oberanger 32

80331 München (DE)

(54) **ALUMINUM ALLOY TUBE AND ALUMINUM ALLOY STRUCTURAL MEMBER FOR AUTOMOBILE USING THE SAME**

(57) An Al-Mg-based aluminum alloy pipe for hot working, having an alloy composition having from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe, and from 0.25% by mass to 0.35% by mass of Cr, with the balance being

inevitable impurities and Al, wherein an area ratio of cavities after hot working is 2.3% or less; and an aluminum alloy structural member for automobile using the same.

EP 1 935 998 A1

Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to an aluminum alloy pipe and an aluminum alloy structural member for automobile using the same.

BACKGROUND ART

10 **[0002]** Automobile parts have been required to be light-weight in recent years. For attaining the above, cast and die-cast articles of an aluminum alloy have been used in place of parts manufactured by welding and assembling a plurality of steel sheets or steel pipes by pressing or bending. However, it is difficult to manufacture thin articles of cast or die-cast aluminum alloys having a relatively larger size, and the effect of making weight lighter is not sufficient. Since the cast and die-cast articles have low toughness as compared with draw materials such as extruded materials or sheets, and the articles are not completely appropriate for the parts required to have toughness.

15 **[0003]** On the other hand, as an example for using a drawn material, forming a part having a complex shape by combining bending, crushing and hydroforming (hydrostatic bulge forming) an aluminum alloy pipe has been attempted. For example, methods for obtaining a hollow aluminum member having a desired shape have been proposed by combining bending and hydrostatic bulge forming (JP-A-6-226339 ("JP-A" means unexamined published Japanese patent application)) and by combining crushing and hydrostatic bulge forming (JP-A-11-104751). However, since the above-mentioned methods are based on cold working, it was a problem that the material is cracked when it is worked into a complex shape.

20 **[0004]** Thus, hot working has become to draw attention in recent years. However, a convention aluminum alloy pipe has the following problems that fatigue strength may be decreased due to coarsening of crystal grains, fluctuations of tensile strength and fatigue strength may be increased due to generation of cavities, and the thickness of the pipe wall may be locally decreased. In particular, cavities are conspicuously generated by working such as expanding the aluminum alloy pipe by hot working at a temperature of 350°C or higher, and characteristics of the material is deteriorated.

25 **[0005]** Therefore, it has been strongly desired to provide an aluminum alloy pipe for hot working suitable for working into a member having a specified shape, with maintaining a required mechanical strength, such as the structural member for automobile. Al-Mg-based alloys described in JIS 5052 and JIS 5154 are examples of the conventional alloys being relatively excellent in strength and workability. However, these conventional alloys are not satisfactory for applying hot working, since they cause problems, such as decrease of tensile strength and fatigue strength due to coarsening of crystal grains and generation of cavities, as well as reduction of local pipe wall thickness.

35 DISCLOSURE OF INVENTION

[0006] An object of the present invention is to provide an aluminum alloy pipe favorable for manufacturing a member by hot working, which is required to have a specified shape while a required strength is maintained, such as an automobile structural member. Another object of the present invention is to provide an automobile structural member which has higher reliability and lower fluctuations of strength and fatigue strength, using the aluminum alloy pipe.

40 **[0007]** The inventors of the present invention have found, through intensive studies on an aluminum alloy pipe for hot working, that, when an aluminum alloy contains a predetermined amount of Mg, the content of Cr is correlated with coarsening of crystal grains occurring in the hot working process and the coarsening of the crystal grains results in decrease of tensile strength and fatigue strength. Further, the inventors have found that the content of Cr and the amounts of Si and Fe as inevitable impurities are correlated with the amount of cavities occurring in the hot working process, and the cavities causes wider fluctuation of tensile strength and wider fluctuation and the decrease of fatigue strength, and further local decrease of the thickness of the pipe.

45 **[0008]** In other words, the crystal grains are coarsened by hot working when the content of Cr is too small. When the content of Cr and the amounts of Si and Fe as inevitable impurities are too large, on the other hand, the size and distribution density of intermetallic compounds are so increased that the amount of cavities generated by hot working are increased.

50 **[0009]** Thus, the inventors of the present invention found that the crystal grains can be prevented from being coarsened by hot working by limiting the amounts of Cr, Si and Fe in specific ranges in the aluminum alloy pipe while the amount of cavities generated by hot working can be reduced.

55 **[0010]** According to the present invention, there is provided the following means:

(1) An Al-Mg-based aluminum alloy pipe for hot working, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg (magnesium), 0.25% by mass or less of Si (silicon), 0.35% by mass or less of Fe (iron), and

from 0.25% by mass to 0.35% by mass of Cr (chromium), with the balance being inevitable impurities and Al (aluminum), wherein an area ratio of cavities after hot working is 2.3% or less;

(2) An Al-Mg-based aluminum alloy pipe for hot working, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein an area ratio of cavities after hot working is 1.0% or less;

(3) An Al-Mg-based aluminum alloy pipe for hot working, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein an area ratio of cavities after hot working is 2.3% or less, and a minimum pipe wall thickness of the pipe after pipe expanding by hot working is 83% or more of an average thickness of the pipe wall thickness;

(4) An Al-Mg-based aluminum alloy pipe for hot working, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein the area ratio of cavities after hot working is 1.0% or less, and a minimum pipe wall thickness of the pipe after pipe expanding by hot working is 90% or more of an average thickness of the pipe wall thickness;

(5) An Al-Mg-based aluminum alloy pipe for hot working, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe, and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein an area ratio of cavities after hot working is 2.3% or less, a minimum pipe wall thickness of the pipe after pipe expanding by hot working is 83% or more of an average thickness of the pipe wall thickness, and a crystal grain diameter after hot working of the aluminum alloy pipe is 300 μm or less;

(6) An Al-Mg-based aluminum alloy pipe for hot working, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein an area ratio of cavities after hot working is 1.0% or less, a minimum thickness of the pipe after pipe expanding by hot working is 90% or more of an average thickness of the pipe wall thickness, and a crystal grain diameter after hot working of the aluminum alloy pipe is 300 μm or less;

(7) An Al-Mg-based aluminum alloy pipe obtained by hot working the Al-Mg-based aluminum alloy pipe for hot working according to any one of (1) to (6), which has a tensile strength from 175 to 235 MPa and a proof stress from 70 to 95 MPa;

(8) An automobile structural member made of an aluminum alloy, obtained by hot working an Al-Mg-based aluminum alloy pipe, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein an area ratio of cavities after hot working is 2.3% or less, a crystal grain diameter after hot working of the aluminum alloy pipe is 300 μm or less, a minimum pipe wall thickness of the pipe after pipe expanding by hot working is 83% or more of an average thickness of the pipe wall thickness, and a tensile strength is from 175 to 235 MPa and a proof stress is from 70 to 95 MPa after hot working of the aluminum alloy tube, respectively;

(9) An automobile structural member made of an aluminum alloy, obtained by hot working an Al-Mg-based aluminum alloy pipe, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein an area ratio of cavities after hot working is 1.0% or less, a crystal grain diameter after hot working of the aluminum alloy pipe is 300 μm or less, a minimum pipe wall thickness of the pipe after pipe expanding by hot working is 90% or more of an average thickness of the pipe wall thickness, and a tensile strength is from 175 to 235 MPa and a proof stress is from 70 to 95 MPa after hot working of the aluminum alloy tube, respectively;

(10) An aluminum alloy automobile structural member using the Al-Mg-based aluminum alloy pipe for hot working according to any one of (1) to (6) after hot working, wherein a tensile strength is from 175 to 235 MPa and a proof stress is 70 to 95 MPa after the hot working, respectively, and wherein fluctuations of the tensile strength and proof stress are 10 MPa or less, respectively.

(11) An aluminum alloy automobile structural member using the Al-Mg-based aluminum alloy pipe for hot working according to any one of (1) to (6) after extrusion followed by hot working, wherein a fatigue strength upon 1×10^7 times after hot working is 70 MPa or more, and a fluctuation of the fatigue strength upon 1×10^7 times after hot working is 20 MPa or less;

(12) An aluminum alloy automobile structural member using the Al-Mg-based aluminum alloy pipe for hot working according to any one of (1) to (6) after hot working, wherein a tensile strength is from 175 to 235 MPa and a proof stress is from 70 to 95 MPa after the hot working, respectively, fluctuations of the tensile strength and proof stress

are 10 MPa or less, respectively, and a fatigue strength upon 1×10^7 times after hot working is 70 MPa or more, and a fluctuation of the fatigue strength upon 1×10^7 times after hot working is 20 MPa or less; and
 (13) A structural member for motor bicycles or four-wheel automobiles, made of the aluminum alloy according to any one of (10) to (12).

[0011] The Al-Mg-based aluminum alloy pipe of the present invention can prevent coarsening of the crystal grains after hot working with lower generations of cavities, while required strength for the automobile structural member is maintained. According to the aluminum alloy pipe, it is possible to provide an automobile structural member having small fluctuation of properties while required tensile strength, proof stress and fatigue strength are maintained after hot working, and to improve reliability of the automobile structural member.

[0012] Other and further features and advantages of the invention will appear more fully from the following description, appropriately referring to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

Fig. 1(a) is a front view schematically illustrating an expansion die, and Fig. 1 (b) is a cross section along the line A-A in Fig. 1 (a).

Figs. 2(a), 2(b), 2(c) and 2(d) schematically illustrate an example of the pipe expanding process.

Fig. 3(a) is a front view schematically illustrating a round pipe (alloy pipe) obtained by expanding of the pipe, and Fig. 3(b) is a cross section along the line B-B in Fig. 3(a).

Fig. 4 schematically illustrates sampling positions of the round pipe shown in Figs. 3(a) and 3(b).

Fig. 5 is a perspective view schematically illustrating the positions for measuring the pipe wall thickness of the round pipe shown in Figs. 3(a) and 3(b).

Fig. 6(a) is a front view of the die for forming a trapezoidal pipe of the alloy, and Fig. 6(b) is a cross section along the line C-C in Fig. 6(a).

Fig. 7(a) schematically illustrates a trapezoidal pipe formed by hot working by the process in Figs. 6(a) and 6(b), and Fig. 7(b) is a cross section along the line D-D in Fig. 7(a).

BEST MODE FOR CARRYING OUT THE INVENTION

[0014] The present invention will be described in detail below.

[0015] A specified amount of Mg is added to a material in order to attain desired mechanical strength for the automobile structural member. Cr is added for suppressing coarsening of crystal grains from occurring during hot working. The amounts of Cr, Si and Fe are defined for reducing the size and distribution density of intermetallic compounds that serve as cause of cavities during hot working.

[0016] Thus, it is possible to provide an extruded pipe of the aluminum alloy suitable for manufacturing a member required to have a complex shape, while a required strength of the material for the automobile structural member is obtained. The composition of the aluminum alloy used for the aluminum alloy pipe of the present invention will be described in detail below.

[0017] While Mg improves the strength of the alloy by solid solution strengthening, 2.5% by mass or more of Mg should be added for ensuring strength necessary for the automobile structural member. However, when the amount of addition of Mg exceeds 2.8% by mass, hot deformation resistance increases to make working difficult while stress-corrosion cracking is liable to occur. Accordingly, the content of Mg is from 2.5% by mass to 2.8% by mass.

[0018] Cr is an element that improves the strength of the base alloy while crystal grains are suppressed from being coarsened by hot working. While an amount of addition of 2.5% by mass or more of Cr is necessary for suppressing crystal grains from being coarsened by hot working. However, when Cr exceeding 0.35% by mass is added, coarse intermetallic compounds of Al-Cr-based alloys are crystallized and toughness and fatigue characteristics of the material are largely deteriorated.

[0019] Si and Fe are impurity elements inevitably mingled from starting materials such as ground metals and scraps of aluminum in most cases, and form cause of cavities by hot working by forming intermetallic compounds such as Al-Fe, Al-Fe-Si and Mg-Si-based compounds. However, the size and distribution density of the intermetallic compound are reduced to enable the cavities to be suppressed from being generated by hot working, when the contents of Si and Fe are suppressed to be 0.25% by mass or less and 0.35% by mass or less, respectively.

[0020] In the present invention at least one of the elements selected from Ti and B is preferably added in a minute amount to the composition of the Al alloy.

[0021] Ti is an element usually added for industrial manufacture of billets by casting, since it has various advantages

such as an effect for fining the cast structure, an effect for preventing cracks from being generated in the ingot, an effect for improving workability of hot working, and an effect for homogenizing mechanical properties of the product. The fining effect becomes insufficient when the amount of addition of Ti is too small, while toughness and fatigue characteristics are largely deteriorated due to crystallization of coarse intermetallic compounds when the amount of addition is too large. Accordingly, the amount of addition of Ti is preferably suppressed in the range from 0.001 % by mass to 0.2% by mass. While B may be added alone, it is preferable to add B and Ti together since the effect for fining the cast structure is more enhanced. The content of B is preferably 0.02% by mass or less.

[0022] As inevitable impurities mingled from the aluminum ingot and scraps other than Si and Fe, the contents of Mn, Cu and Zn are 0.10% by mass or less, respectively, and permissible contents of the other inevitable impurities are 0.05% by mass or less.

[0023] The ingot of the aluminum alloy having the above-mentioned composition is extruded to a predetermined size after a homogenization, and is molded into an extruded pipe. The extruded pipe is directly used, or is subjected to annealing, if necessary. In the present invention, a drawn pipe after cold working is also used for the aluminum alloy pipe to be subjected to hot working. The drawn pipe manufactured by cold working is directly used, or is subjected to annealing, if necessary.

[0024] Since the crystal grains are coarsened in hot working thereafter when the working rate by cold working is small, a working rate by cold working of at least 20% is necessary.

[0025] Hot working of the aluminum alloy pipe of the present invention may be applied by a conventional pipe expanding method using the die heated at a temperature from 380 to 550°C, preferably from 420 to 530°C. The methods described in following examples are used for defining the characteristics of the tube after hot working.

[0026] The pipe expanding method is able to form the aluminum alloy pipe into round pipes, rectangular pipes such as square or trapezoidal pipes and into complex shapes by partially combining these shapes by introducing air under pressure, and thus alloy pipes having various three-dimensional shapes are obtained. Accordingly, the aluminum alloy tube of the present invention is not restricted to apply for structural members such as the automobile structural member, but is applicable to members for motor bicycles, four-wheel automobiles and the like that require such working method.

[0027] A fluctuation of the pipe wall thickness caused during pipe expanding of the aluminum alloy pipe by hot working is related to the abundance ratio of cavities, and the pipe wall thickness is reduced at the parts containing many cavities. When the area ratio of the cavity is large, the strength of the portion containing many cavities is locally reduced. As a result, stress is concentrated at the portion having a high cavity area ratio, and a pipe wall thickness of the portion rapidly decreases to consequently increase a fluctuation of the pipe wall thickness. The portion where the thickness is reduced may serve as cause of fatigue breaking that finally causes fatigue breaking. Furthermore, localization of the cavity itself may be a cause of fluctuations of the strength and fatigue strength of the material.

[0028] Accordingly, it is preferable to suppress the amount of the cavity to be low. In the aluminum alloy pipe of the present invention, the area ratio of the cavity is suppressed to be 2.3% or less (preferably 1.0% or less) by defining the contents of Cr, Fe and Si as described above. Consequently, a fluctuation of the pipe wall thickness is reduced to permit the minimum pipe wall thickness to be 83% or more (preferably 90% or more) of the average pipe wall thickness. It is also possible to suppress fluctuations of the strength of the material and fatigue strength, and to provide Al-Mg-based alloy pipes preferable for hot working, automobile structural member made of the aluminum alloy, and the like.

[0029] When the crystal grain diameter of the aluminum alloy pipe after hot working (In the present invention, the grain diameter refers to an average value obtained by a line intersection method for measuring the diameter in two directions in the direction of the pipe wall thickness and in the direction of the circumference, unless otherwise stated) is too large, the fatigue strength is so extremely reduced that the alloy is not suitable for using as the automobile structural member. The fatigue strength required for the automobile structural member is satisfied by suppressing the crystal grain diameter to be 300 μm or less.

[0030] While the strength of the aluminum alloy pipe after hot working is mainly determined by the amount of Mg, the tensile stress is determined in the range from 175 to 235 MPa (preferably from 185 to 225 MPa), and the proof stress is determined in the range from 70 to 95 MPa (preferably from 75 to 90 MPa) considering the balance between the strength and workability of hot working. The strength is insufficient for use as the automobile structural member when the tensile strength is 175 MPa or less or the proof stress is 70 MPa or less, while workability of hot working becomes poor when the tensile strength exceeds 235 MPa or the proof stress exceeds 95 MPa.

[0031] Fluctuations of the tensile strength and proof stress after hot working are correlated to the abundance ratio of the cavity, and a smaller amount of the cavity reduces the fluctuation (in the present invention, fluctuation refers to the difference of the minimum value and maximum value of the measured values at least at four points, unless otherwise stated). Accordingly, in the material within the scope of the present invention, the fluctuation of the tensile strength can be suppressed to be 10 MPa or less, the fluctuation of the proof stress can be suppressed to be 10 MPa or less, and the fluctuation of the fatigue strength can be suppressed to be 20 MPa or less by suppressing the amount of the cavity.

[0032] The present invention will be described in more detail based on examples given below, but the invention is not meant to be limited by these.

EXAMPLES

<Manufacture of Aluminum Extruded pipe and Test>

5 (Examples of Manufacture)

[0033] The alloy having the composition shown in Table 1 was melted and cast into a billet with a diameter of 260 mm, which was homogenized at 530°C for 4 hours. The billet was heated at 480°C, extruded at an extrusion rate of 5 m/minute, and formed into a round pipe with an outer diameter of 95 mm and a pipe wall thickness of 3.5 mm. This round pipe (outer diameter 95 mm, pipe wall thickness 3.5 mm) was cut into a length of 300 mm, and the piece of the round pipe was heated at 500°C and was inserted into a die heated at 500°C as shown in Figs. 1(a) and 1(b). Fig. 1(a) is a front view of the die 1. Die 1 has a pipe insertion part 2. A division part is shown by the reference numeral 1 a in Fig. 1(a). Fig. 1(b) shows a cross section of the die.

[0034] Then, the alloy pipe (round pipe) was inserted into the die shown in Figs. 1(a) and 1(b), and was expanded by the steps described in Figs. 2(a), 2(b), 2(c) and 2(d). After inserting a pipe 3 made of an alloy A to D, K or L, respectively, as shown in Fig. 2(a), the pipe was held between the dies 1 as shown in Fig. 2(b). After sealing both ends of the die with a seal mold 4, the pipe 3 was expanded by hot working as shown in Fig. 2(c) by applying a pneumatic pressure of 1.5 MPa through an air induction inlet 5 to mold into an alloy pipe (round pipe) 6 (example). Each alloy pipes made of an alloy E to J, M or N, respectively, was also molded for comparative (comparative example).

[0035] While pieces for various test were sampled from the periphery of the expanded tube, the degree of strain of each test piece at the sampling position was about 27%. Many cavities are generated by hot expansion of the pipe as compared with uniaxial tension processing under high temperature. As a result, the influence of the cavity becomes more clear. Each of outer diameters of the alloy pipe after hot working was as shown in Figs. 3(a) and 3(b) (Fig. 3(a) denote a front view and Fig. 3(b) denotes a cross section), and the time required for working was about 5 seconds.

25 (Measurement of cavity area ratio)

[0036] A test piece for observing the micro-texture (20 mm × 20 mm) was cut from a surface perpendicular to the extrusion or draw direction of the extruded pipe or drawn pipe at the position 6a of the alloy pipe 6 obtained by hot working as shown in Fig. 4. The surface of the test piece was polished, and five fields of view were photographed with a magnification of 100 with an optical microscope. The photographic image was analyzed to measure the cavity area ratios, and an average of the measured values is shown in Table 2 as the cavity area ratio (%).

[0037] Local reduction of the pipe wall thickness occurs when the cavity area ratio exceeds 2.3%, and a fluctuation of the pipe wall thickness increases.

35 (Measurement of crystal grain diameter)

[0038] A test piece for observing the micro-texture (20 mm × 20 mm) was cut from the position 6a of the material after hot working as shown in Fig. 4, and the crystal grain diameter was measured from five fields of vision of the photograph taken with a magnification of 100 with an optical microscope. The crystal grain diameter was measured in two directions of the direction of thickness and the circumference direction using an intersection method, and an average of the values was calculated. The average value of the five fields of vision is shown in Table 2.

[0039] The fatigue strength decreases when the crystal grain diameter exceeds 300 μm. In addition, when the crystal grain diameter exceeds 300 μm, the surface of the aluminum alloy pipe after hot working is roughened and appearance of the product is impaired while the fatigue strength is decreased and secondary workability of the product is deteriorated.

(Tensile test)

[0040] A JIS No. 12 test piece was cut from the position 6b of the pipe after hot working in a longitudinal direction as shown in Fig. 4, and the test piece was subjected to a tensile test according to JIS Z2241. The results are shown in Table 2.

[0041] Workability during hot working fluctuates when the tensile strength is less than 175 MPa or the proof stress is less than 70 MPa, while reliability decreases when the alloy is formed into an aluminum alloy pipe for hot working.

55 (Stress-corrosion cracking)

[0042] A test piece was cut from the position 6b of the pipe after hot working as shown in Fig. 4, and was subjected to a stress-corrosion cracking test according to JIS H8711. Generation of cracks was observed by alternate immersion for 30 days.

[0043] The sample in which cracks are generated within 30 days in the alternate immersion test is likely to generate stress-corrosion cracks when used. The sample showing no generation of cracks is denoted by "o", while the sample showing the generation of cracks is denoted by "×" in Table 2.

5 (Measurement of pipe wall thickness)

[0044] The pipe wall thickness of each of three test pieces was measured at each 8 points with a uniform distance of 45° by taking the minimum thickness portion (the position 6c for measuring the pipe wall thickness) as a reference position along the circumference in the perspective view (Fig. 5) of the alloy pipe 6 after hot working, and the results of measurement are shown in Table 3. The minimum value and average value of the pipe wall thickness were calculated, and the results are shown in Table 2.

[0045] The ratio (%) of the average pipe wall thickness to the minimum pipe wall thickness is defined as a ratio of a pipe wall thickness. Fluctuations of the tensile strength and fatigue strength increase when the ratio of the pipe wall thickness is 83% or less.

15 <Manufacture of automobile structural member and test>

(Example of manufacture)

20 **[0046]** The alloy having the composition shown in Table 1 was melted and cast into a billet with a diameter of 260 mm, and was homogenized at 530°C for 4 hours. The billet was heated at 480°C and, after extruding into an extruded pipe having a predetermined size at an extrusion rate of 5 m/minutes, the pipe was drawn at a cold working ratio of 35% to manufacture a round pipe with an outer diameter of 95 mm and a pipe wall thickness of 3.5 mm.

25 **[0047]** The drawn round pipe (outer diameter 95 mm, pipe wall thickness 3.5 mm) manufactured as described above was cut into a piece with a length of 300 mm, and the piece of the round pipe was heated at 500°C. The piece was inserted into an insertion part 11 of the die 10 heated at 500°C as shown in Figs. 6(a) and 6(b), and both ends of the die were sealed by the same procedure as shown in Figs. 2(a) to 2(d). The reference numeral 10a in Fig. 6(a) shows the dividing position of the die. The pipe was subjected to hot working for forming a trapezoidal pipe (a pipe worked into a trapezoid shape) 12 by applying a pneumatic pressure of 1.5 MPa in the pipe by the same procedure shown in Figs. 30 2(a) to 2(d). The time required for working was about 5 seconds. Each of automobile structural members made of the alloy A to D, K or L, respectively, was molded (examples). Each of members made of the alloy E to J, M or N, respectively, was also molded for comparison (comparative examples).

35 **[0048]** The front view (i.e. view from the surface P) of the trapezoidal pipe and cross section thereof are as shown in Figs. 7(a) and 7(b). While the cross section of the automobile structural member is not specifically restricted to the trapezoid shape and may be various shapes. In this example, a die for working the article into the trapezoid shape was used as a representative example. The cavity area ratio was measured for all the faces of P, Q, R and S surfaces according to the method described below, the crystal grain diameter was observed only on P face where the crystal grain is liable to be coarse, and the tensile characteristics and fatigue characteristics were measured only on P face where the stress is most likely concentrated by forming into automobile parts.

40 (Measurement of cavity area ratio)

45 **[0049]** Test pieces (20 mm × 20 mm) for observing the micro-texture were cut from a surface perpendicular to the extrusion or draw direction of the pipe at the position 12a shown in Fig 7(a), on each surface of P, Q, R and S surfaces of the hot-worked material for the automobile parts as shown in Fig. 7(b). After polishing the surface of the test piece, five fields of vision of each surface were photographed with an optical microscope. The cavity area ratios were measured with respect to the five fields of vision on each observation surfaces P, Q, R and S using an image analyzer. The average cavity area ratios are shown in Table 4.

50 **[0050]** A fluctuation of the pipe wall thickness increases when the area ratio of generation of the cavity exceeds 2.3% (even at one position on any one of the observation faces P, Q, R and S) to cause local reduction of the pipe wall thickness and decrease of the tensile strength and fatigue strength.

(Measurement of crystal grain diameter)

55 **[0051]** A test piece (20 mm × 20 mm) for observing the micro-texture was cut from the position 12a of P-surface of a hot-worked material for automobile parts as shown in Figs. 7(a) and 7(b) in two directions of the direction of the pipe wall thickness and direction along the circumference. The test piece was photographed with a magnification of 100 with an optical microscope to determine the crystal grain diameter. The results of observation on five fields of vision are

EP 1 935 998 A1

shown in Table 5 as the results of measurement of the average grain diameter.

[0052] The fatigue strength decreases when the crystal grain diameter exceeds 300 μm . The sample with a crystal grain diameter of 300 μm or less is shown by "○" and the sample with the crystal grain diameter exceeding 300 μm is shown by "×" in Table 4.

5

(Tensile strength test)

[0053] JIS No. 5 sample pieces were cut from the position 12b on P-surface of the hot-worked material for the automobile part in the longitudinal directions as shown in Figs. 7(a) and 7(b), and each sample was subjected to the tensile strength test according to JIS Z2241. The results are shown in Table 5.

10

[0054] Workability by hot working fluctuates when the tensile strength, proof stress and fluctuations thereof are out of the ranges from 175 to 235 MPa, from 70 to 95 MPa and 10 MPa or less, respectively, while reliability of the material decreases when it is used for the automobile member. The sample with a tensile strength in the range from 175 to 235 MPa, proof stress in the range from 70 to 95 MPa and fluctuations thereof in the range of 10 MPa or less is shown by "o", and the sample out of the above-mentioned ranges is shown by "x" in Table 4.

15

(Fatigue strength)

[0055] JIS No. 1 sample pieces were cut from the position 12b on P-surface of the hot-worked material for automobile parts in the longitudinal directions as shown in Figs. 7(a) and 7(b), and each sample was subjected to the plane bend fatigue test according to JIS Z2275 to determine the fatigue strength upon 1×10^7 times of bending. The results are shown in Table 6.

20

[0056] The sample with fatigue strength of less than 70 MPa or fluctuation thereof of exceeding 20 MPa is of problem with respect to the service life and safety of parts, and reliability for use as the automobile structural member or automobile parts decreases. The sample with the fatigue strength of 70 MPa or more and fluctuation thereof of 20 MPa or less is shown by "o", while the sample out of the above-mentioned ranges is shown by "x" in Table 4.

25

(Stress-corrosion cracking test)

[0057] Sample pieces were cut from the position 12b on P-surface of the hot worked material for automobile parts as shown in Figs. 7(a) and 7(b), and the sample was subjected to the stress-corrosion cracking test according to JIS H8711. Generation of cracking was observed from the alternate immersion test for 30 days.

30

[0058] The sample that generates cracking within 30 days in the alternate immersion test is liable to generate stress-corrosion cracking in practical uses. The sample with no generation of cracking is shown by "o", while the sample that generates cracking is shown by "x" in Table 4.

35

Table 1: Alloy composition (% by mass)

Alloy No.	Mg	Cr	Si	Fe	Mn	Cu	Ti	Al
A	2.8	0.28	0.23	0.33	0.01	0.01	0.01	Balance
B	2.6	0.28	0.23	0.20	0.01	0.01	0.01	Balance
C	2.5	0.28	0.14	0.34	0.01	0.01	0.01	Balance
D	2.6	0.29	0.14	0.19	0.01	0.01	0.01	Balance
E	3.2	0.3	0.2	0.25	0.02	0.01	0.02	Balance
F	2.8	0.45	0.2	0.25	0.02	0.01	0.02	Balance
G	2.6	0.28	0.35	0.2	0.02	0.01	0.02	Balance
H	2.6	0.28	0.2	0.45	0.02	0.01	0.02	Balance
I	2.3	0.27	0.15	0.2	0.01	0.01	0.01	Balance
J	2.7	0.21	0.21	0.26	0.01	0.01	0.01	Balance
K	2.7	0.3	0.24	0.33	0.08	0.08	0.02	Balance
L	2.8	0.35	0.25	0.35	0.1	0.09	0.03	Balance
M	2.8	0.34	0.25	0.49	0.09	0.08	0.03	Balance

40

45

50

55

EP 1 935 998 A1

(continued)

Alloy No.	Mg	Cr	Si	Fe	Mn	Cu	Ti	Al
N	3.2	0.35	0.39	0.35	0.1	0.09	0.03	Balance

Table 2 Evaluation results of aluminum extruded pipes

Alloy No.	Cavity area ratio (%)	Crystal grain diameter (μm)	Tensile strength (MPa)	Proof stress (MPa)	Stress-corrosion cracking	Ratio of pipe wall thickness (%) (the results of measurements are shown in table 3)			Total evaluation
						First sample	Second sample	Third sample	
A	0.9	80	220	85	○	92.2	91.7	92.2	○○
B	0.8	73	198	80	○	93.7	94.1	93.8	○○
C	0.7	76	183	72	○	96.5	96.1	96.8	○○
D	0.5	75	196	79	○	98.9	99.2	98.9	○○
E	0.8	75	245	98	×	94.0	93.8	94.2	×
F	1.7	75	231	91	○	87.3	87.0	87.3	○
G	1.4	73	202	82	○	88.1	88.2	88.1	○
H	1.5	74	199	81	○	88.1	87.9	88.2	○
I	0.5	85	171	68	○	99.2	99.3	99.0	×
J	0.7	320	203	83	○	96.6	96.4	96.3	×
K	2.1	70	226	91	○	84	84.3	84.4	○
L	2.3	68	229	95	○	83.4	83.2	83.0	○
M	2.7	78	231	94	○	81.8	82.2	81.5	×
N	3.0	72	247	99	×	80.2	80.9	81.3	×

Table 3 Evaluation results of aluminum extruded pipes (data of pipe wall thickness)

Alloy No.	No. of measurement	Thickness for every measuring positions (mm)								Minimum thickness (mm)	Average thickness (mm)	Ratio of thickness (%)
		1	2	3	4	5	6	7	8			
A	1	2.39	2.46	2.59	2.70	2.77	2.73	2.60	2.50	2.39	2.59	92.2
	2	2.38	2.48	2.63	2.68	2.76	2.75	2.59	2.49	2.38	2.60	91.7
	3	2.39	2.49	2.59	2.68	2.77	2.75	2.60	2.47	2.39	2.59	92.2
B	1	2.45	2.53	2.57	2.74	2.75	2.70	2.61	2.56	2.45	2.61	93.7
	2	2.46	2.54	2.58	2.73	2.74	2.70	2.61	2.55	2.46	2.61	94.1
	3	2.46	2.51	2.57	2.76	2.76	2.71	2.64	2.56	2.46	2.62	93.8
C	1	2.52	2.58	2.63	2.67	2.70	2.63	2.59	2.57	2.52	2.61	96.5
	2	2.51	2.59	2.62	2.67	2.71	2.61	2.60	2.58	2.51	2.61	96.1
	3	2.53	2.60	2.62	2.65	2.71	2.62	2.60	2.58	2.53	2.61	96.8
D	1	2.58	2.59	2.61	2.63	2.63	2.62	2.61	2.59	2.58	2.61	98.9
	2	2.59	2.60	2.62	2.62	2.64	2.62	2.60	2.60	2.59	2.61	99.2
	3	2.58	2.60	2.62	2.62	2.63	2.63	2.60	2.60	2.58	2.61	98.9
E	1	2.43	2.50	2.59	2.71	2.76	2.63	2.58	2.49	2.43	2.59	94.0
	2	2.43	2.52	2.58	2.72	2.76	2.64	2.57	2.50	2.43	2.59	93.8
	3	2.44	2.50	2.59	2.72	2.75	2.65	2.58	2.50	2.44	2.59	94.2
F	1	2.26	2.43	2.62	2.73	2.79	2.76	2.69	2.42	2.26	2.59	87.3
	2	2.25	2.42	2.64	2.75	2.77	2.75	2.68	2.43	2.25	2.59	87.0
	3	2.26	2.42	2.64	2.74	2.78	2.75	2.69	2.42	2.26	2.59	87.3
G	1	2.29	2.44	2.68	2.75	2.77	2.75	2.67	2.44	2.29	2.60	88.1
	2	2.29	2.44	2.69	2.74	2.76	2.73	2.66	2.45	2.29	2.60	88.2
	3	2.28	2.43	2.67	2.73	2.76	2.73	2.66	2.45	2.28	2.59	88.1
H	1	2.28	2.42	2.64	2.75	2.77	2.74	2.67	2.44	2.28	2.59	88.1
	2	2.27	2.41	2.65	2.74	2.76	2.73	2.66	2.45	2.27	2.58	87.9
	3	2.28	2.41	2.64	2.73	2.76	2.74	2.66	2.45	2.28	2.58	88.2

5
10
15
20
25
30
35
40
45
50
55

(continued)

Alloy No.	No. of measurement	Thickness for every measuring positions (mm)								Minimum thickness (mm)	Average thickness (mm)	Ratio of thickness (%)
		1	2	3	4	5	6	7	8			
I	1	2.59	2.60	2.61	2.62	2.64	2.62	2.60	2.60	2.59	2.61	99.2
	2	2.58	2.60	2.62	2.62	2.63	2.63	2.60	2.59	2.59	2.61	99.3
	3	2.58	2.59	2.61	2.62	2.63	2.62	2.60	2.59	2.58	2.61	99.0
J	1	2.52	2.57	2.62	2.66	2.69	2.64	2.60	2.58	2.52	2.61	96.6
	2	2.51	2.58	2.61	2.65	2.70	2.62	2.59	2.57	2.51	2.60	96.4
	3	2.51	2.57	2.61	2.66	2.71	2.62	2.60	2.57	2.51	2.61	96.3
K	1	2.17	2.47	2.65	2.71	2.78	2.75	2.62	2.52	2.17	2.58	84.0
	2	2.18	2.47	2.65	2.73	2.78	2.73	2.64	2.50	2.18	2.59	84.3
	3	2.18	2.48	2.68	2.73	2.76	2.73	2.62	2.51	2.18	2.58	84.4
L	1	2.16	2.35	2.62	2.78	2.86	2.88	2.72	2.34	2.16	2.59	83.4
	2	2.15	2.36	2.60	2.76	2.89	2.85	2.70	2.37	2.15	2.59	83.2
	3	2.15	2.34	2.63	2.80	2.87	2.88	2.71	2.35	2.15	2.59	83.0
M	1	2.12	2.41	2.69	2.86	2.88	2.79	2.64	2.34	2.12	2.59	81.8
	2	2.13	2.40	2.66	2.87	2.90	2.80	2.62	2.35	2.13	2.59	82.2
	3	2.11	2.39	2.67	2.86	2.91	2.82	2.64	2.32	2.11	2.59	81.5
N	1	2.08	2.32	2.68	2.88	2.95	2.85	2.67	2.32	2.08	2.59	80.2
	2	2.09	2.31	2.67	2.85	2.92	2.84	2.70	2.30	2.09	2.59	80.9
	3	2.11	2.33	2.68	2.85	2.90	2.86	2.70	2.33	2.11	2.60	81.3

EP 1 935 998 A1

Table 4 Evaluation results of automobile structural members

Alloy No.	Cavity area ratio (%)				Crystal grain diameter (μm)	Tensile strength (MPa)	Proof stress (MPa)	Fatigue strength (MPa)	Stress-corrosion cracking	Total evaluation
	P	Q	R	S						
A	0.9	0.4	0.7	0.2	○	○	○	○	○	○
B	0.8	0.4	0.6	0.2	○	○	○	○	○	○
C	0.8	0.3	0.4	0.2	○	○	○	○	○	○
D	0.7	0.3	0.4	0.1	○	○	○	○	○	○
E	0.8	0.4	0.5	0.3	○	×	×	○	×	×
F	1.8	1.0	1.3	0.4	○	×	×	×	○	×
G	1.5	0.8	1.0	0.4	○	×	×	×	○	×
H	1.5	0.7	1.1	0.4	○	×	×	×	○	×
I	0.6	0.3	0.3	0.1	○	×	×	○	○	×
J	0.8	0.4	0.4	0.2	×	○	○	×	○	×
K	2.2	1.1	1.5	0.5	○	○	○	○	○	○
L	2.3	1.2	1.6	0.6	○	○	○	○	○	○
M	2.8	1.4	2.0	0.7	○	○	○	○	○	×
N	3.1	1.6	2.2	0.8	○	○	○	○	×	×

Table 5 Evaluation results of automobile structural members (data of crystal grain diameter, tensile strength and proof stress)

Alloy No.	Crystal grain diameter (μm)	Tensile strength (MPa)					Proof stress (MPa)						
		First	Second	Third	Fourth	Average value	Fluctuation	First	Second	Third	Fourth	Average value	Fluctuation
A	83	218	220	218	222	220	4	83	86	84	87	85	3
B	70	197	200	199	202	200	5	78	83	82	84	82	4
C	73	180	183	183	185	183	5	71	74	73	76	74	4
D	74	194	197	196	200	197	6	77	80	79	82	80	4
E	78	245	247	247	249	247	4	96	99	98	100	98	4
F	72	218	230	226	233	227	15	81	87	83	93	86	12
G	73	193	203	200	206	201	13	72	78	75	83	77	11
H	78	191	201	197	205	199	14	71	78	74	82	76	11
I	88	170	172	172	173	172	3	67	68	68	69	68	2
J	330	200	202	202	203	202	3	79	80	80	81	80	3
K	72	227	225	221	226	225	6	94	93	90	92	92	4
L	70	231	230	228	225	229	6	96	95	95	92	95	4
M	82	223	225	231	236	229	13	87	89	93	98	92	11
N	76	240	249	234	244	242	15	95	100	89	97	95	11

Table 6 Evaluation results of automobile structural members (data of fatigue strength)

Alloy No.	Fatigue strength (MPa)					
	First	Second	Third	Fourth	Average value	Fluctuation
A	87	96	91	99	93	12
B	83	93	88	96	90	13
C	75	85	79	88	82	13
D	80	90	85	94	87	14
E	99	110	106	115	108	16
F	84	97	89	107	94	23
G	75	91	84	98	87	23
H	74	89	83	96	86	22
I	67	74	72	78	73	11
J	58	67	63	73	65	15
K	104	100	97	90	98	14.0
L	94	99	102	107	101	13.0
M	98	77	82	102	89	25.0
N	101	117	91	108	104	26.0

(Total evaluation - extruded pipe)

[0059] The tests of the aluminum extruded pipes and the results shown in Tables 1 to 3 are summarized below.

[0060] Each of the pipes of alloy A to D, K and L has the cavity area ratio of 2.3% or less and the ratio of the pipe wall thickness 83% or more, without coarsening of the crystal grain. Accordingly, the pipes maintain the required tensile strength as the aluminum alloy for the automobile structural member, and no stress-corrosion cracking occurs (evaluated as "o" in the total evaluation in Table 2). Among these pipes, those of alloy A to D have the cavity area ratio of 1.0 or less and the thickness ratio of 90% or more (evaluated as "oo" in total evaluation in Table 2).

[0061] While all of the cavity area ratio, crystal grain diameter, tensile strength, proof stress and local reduction of the pipe wall thickness are satisfied in the pipe of alloy E, the stress-corrosion cracking occurs due to high content of Mg. The pipe of alloy I does not satisfy the required tensile strength as an aluminum alloy pipe for the automobile structural member since the content of Mg is small. The crystal grain is coarsened in the pipe of alloy J due to a small content of Cr. Generation of the cavity is high in the pipes of alloy M and N due to high contents of Fe and Si, respectively, and the pipe wall thickness are locally reduced, respectively (reduction of the ratio of pipe wall thickness) (evaluated as "x" in the total evaluation in Table 2).

(Total evaluation - automobile structural member)

[0062] The test results of the structural members for automobile shown in Tables 4 to 6 are summarized below.

[0063] Each of the structural members of alloy A to D, K and L has the cavity area ratio of 2.3% or less and the ratio of the pipe wall thickness of 83% or more. The crystal grain is not coarsened, the member has the required tensile strength for the automobile structural member with small fluctuation of the tensile strength, and the required fatigue strength is ensured (evaluated as "o" in the total evaluation in Table 4).

[0064] The member of alloy E satisfies all of the cavity area ratio, crystal grain diameter, average of the tensile strength and fluctuation thereof, average of the proof stress and the fluctuation thereof, and average of the fatigue strength and the fluctuation thereof. However, the stress-corrosion cracking occurs due to high content of Mg. The member of alloy I does not satisfy the required tensile strength for the automobile structural member due to small content of Mg. The crystal grain is coarsened in the member of alloy J due to small content of Cr. Generation of the cavity is high in the members of alloys M and N due to high contents of Fe and Si, respectively, and fluctuations of the tensile strength, proof stress and fatigue strength are large. The stress-corrosion cracking occurs in the member of alloy N due to a larger content of Mg (evaluated as "x" in the total evaluation in Table 4).

INDUSTRIAL APPLICABILITY

[0065] The aluminum alloy pipe of the present invention is suitable for working into members required to have relatively complex shapes while required strength is maintained such as structural member for automobile.

[0066] Hot working of the aluminum alloy pipe permits highly reliable members having complex shapes that are impossible to form by cold or warm working and having a small fluctuation of mechanical characteristics to be manufactured. Examples of such member include structural members for automobiles and structural members for motorcycles and four-wheel automobiles.

[0067] Having described our invention as related to the present embodiments, it is our intention that the invention not be limited by any of the details of the description, unless otherwise specified, but rather be construed broadly within its spirit and scope as set out in the accompanying claims.

Claims

1. An Al-Mg-based aluminum alloy pipe for hot working, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe, and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein an area ratio of cavities after hot working is 2.3% or less.
2. The Al-Mg-based aluminum alloy pipe for hot working according to Claim 1, wherein the area ratio of cavities after hot working is 1.0% or less.
3. The Al-Mg-based aluminum alloy pipe for hot working according to Claim 1, wherein a minimum pipe wall thickness of the pipe after pipe expanding by hot working is 83% or more of an average thickness of the pipe wall thickness.
4. The Al-Mg-based aluminum alloy pipe for hot working according to Claim 2, wherein a minimum pipe wall thickness of the pipe after pipe expanding by hot working is 90% or more of the average thickness of the pipe wall thickness.
5. The Al-Mg-based aluminum alloy pipe for hot working according to Claim 3, wherein a crystal grain diameter after hot working of the aluminum alloy pipe is 300 μm or less.
6. The Al-Mg-based aluminum alloy pipe for hot working according to Claim 4, wherein a crystal grain diameter after hot working of the aluminum alloy pipe is 300 μm or less.
7. An Al-Mg-based aluminum alloy pipe obtained by hot working the Al-Mg-based aluminum alloy pipe for hot working according to any one of Claims 1 to 6, which has a tensile strength from 175 to 235 MPa and a proof stress from 70 to 95 MPa.
8. An automobile structural member made of an aluminum alloy, obtained by hot working an Al-Mg-based aluminum alloy pipe, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe, and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein an area ratio of cavities after hot working is 2.3% or less, a crystal grain diameter after hot working of the aluminum alloy pipe is 300 μm or less, a minimum pipe wall thickness of the pipe after pipe expanding by hot working is 83% or more of an average thickness of the pipe wall thickness, and a tensile strength is from 175 to 235 MPa and a proof stress is from 70 to 95 MPa after hot working of the aluminum alloy tube, respectively.
9. An automobile structural member made of an aluminum alloy, obtained by hot working an Al-Mg-based aluminum alloy pipe, having an alloy composition comprising from 2.5% by mass to 2.8% by mass of Mg, 0.25% by mass or less of Si, 0.35% by mass or less of Fe, and from 0.25% by mass to 0.35% by mass of Cr, with the balance being inevitable impurities and Al, wherein an area ratio of cavities after hot working is 1.0% or less, a crystal grain diameter after hot working of the aluminum alloy pipe is 300 μm or less, a minimum pipe wall thickness of the pipe after pipe expanding by hot working is 90% or more of an average thickness of the pipe wall thickness, and a tensile strength is from 175 to 235 MP and a proof stress is from 70 to 95 MPa after hot working of the aluminum alloy tube, respectively.
10. An aluminum alloy automobile structural member using the Al-Mg-based aluminum alloy pipe for hot working according to any one of Claims 1 to 6 after hot working, wherein a tensile strength is from 175 to 235 MPa and a proof

EP 1 935 998 A1

stress is from 70 to 95 MPa after the hot working, respectively, and wherein fluctuations of the tensile strength and proof stress are 10 MPa or less, respectively.

- 5
11. An aluminum alloy automobile structural member using the Al-Mg-based aluminum alloy pipe for hot working according to any one of Claims 1 to 6 after extrusion followed by hot working, wherein a fatigue strength upon 1×10^7 times after hot working is 70 MPa or more, and a fluctuation of the fatigue strength upon 1×10^7 times after hot working is 20 MPa or less.
- 10
12. An aluminum alloy automobile structural member using the Al-Mg-based aluminum alloy pipe for hot working according to any one of Claims 1 to 6 after hot working, wherein a tensile strength is from 175 to 235 MPa and a proof stress is from 70 to 95 MPa after the hot working, respectively, fluctuations of the tensile strength and proof stress are 10 MPa or less, respectively, a fatigue strength upon 1×10^7 times after hot working is 70 MPa or more, and a fluctuation of the fatigue strength upon 1×10^7 times after hot working is 20 MPa or less.
- 15
13. A structural member for motor bicycles or four-wheel automobiles made of the aluminum alloy according to any one of Claims 10 to 12.

20

25

30

35

40

45

50

55

Fig. 1(a)

Fig. 1(b)

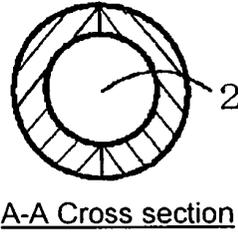
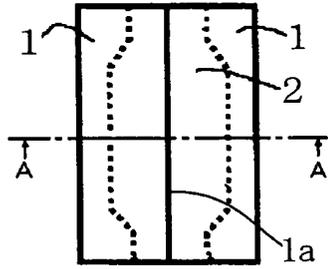
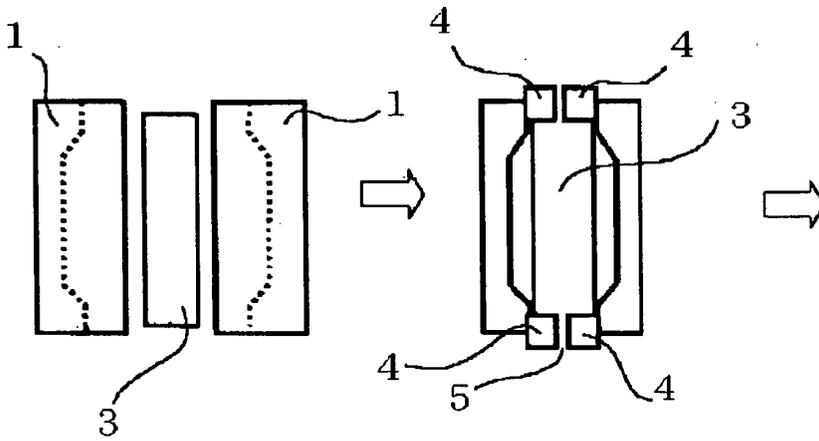
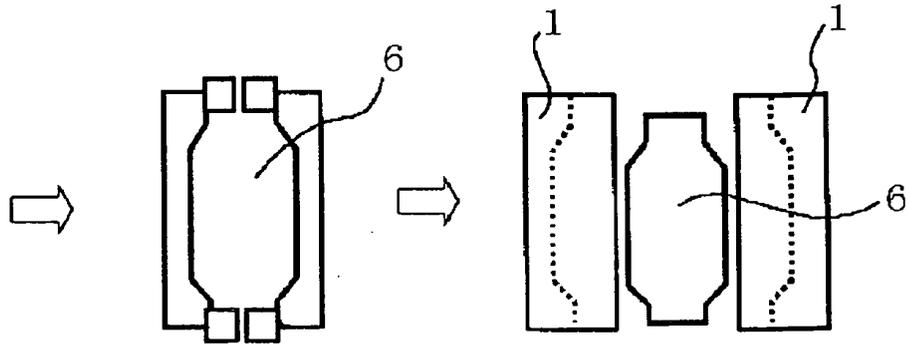


Fig. 2(a)

Fig. 2(b)



Before introducing air
(before expanding the tube)



After introducing air
(after expanding the tube)

Fig. 2(c)

Fig. 2(d)

Fig. 3(a)

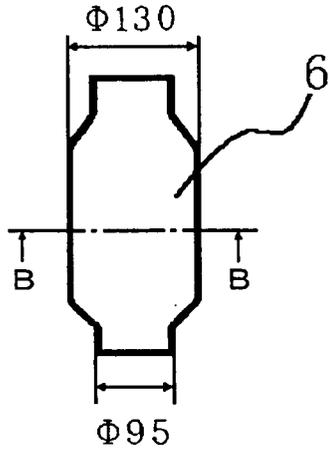


Fig. 3(b)

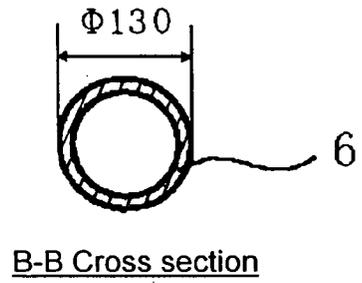


Fig. 4

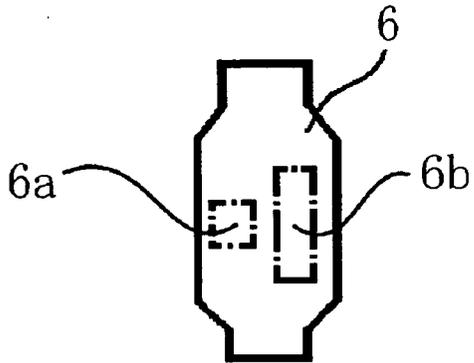


Fig. 5

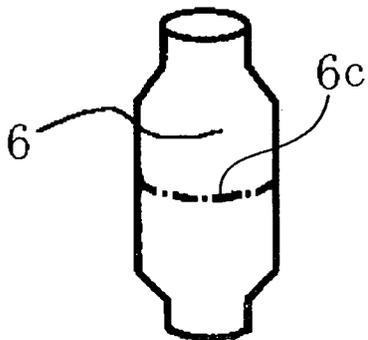


Fig. 6(a)

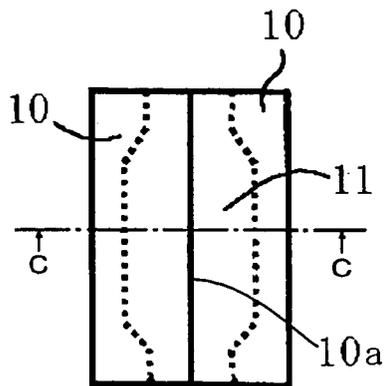


Fig. 6(b)

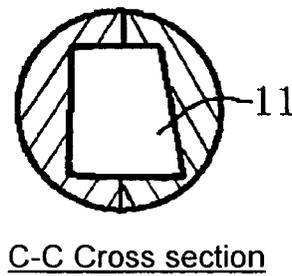


Fig. 7(a)

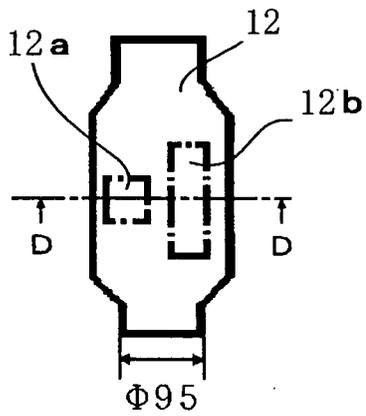
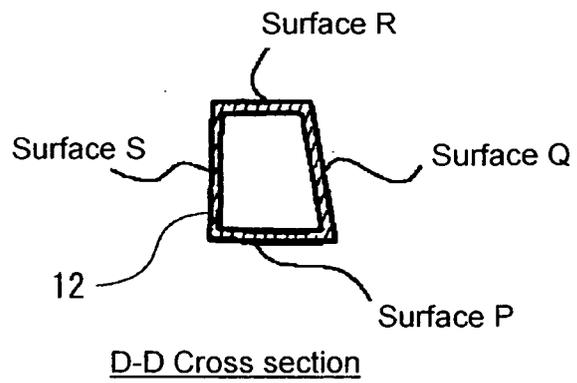


Fig. 7(b)



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/017083

A. CLASSIFICATION OF SUBJECT MATTER <i>C22C21/06</i> (2006.01) , <i>B21C37/15</i> (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) <i>C22C21/06</i> (2006.01) , <i>B21C37/15</i> (2006.01)		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2005 Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E, X	JP 2005-325444 A (Furukawa Sukai Kabushiki Kaisha), 24 November, 2005 (24.11.05), Claims (Family: none)	1-13
Y	JP 2003-301230 A (The Furukawa Electric Co., Ltd.), 24 October, 2003 (24.10.03), Claims; Par. Nos. [0001], [0031], [0073]; Tables 1, 2; Alloy No.D & US 2003-164207 A1 & CN 1436869 A & CA 2417573 A1 & EP 1338664 A1	1-13
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 16 November, 2005 (16.11.05)	Date of mailing of the international search report 29 November, 2005 (29.11.05)	
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer	
Facsimile No.	Telephone No.	

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/017083

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 7-305131 A (Honda Motor Co., Ltd.), 21 November, 1995 (21.11.95), Claims; Par. Nos. [0021], [0052], [0073]; Table 3 & US 6261391 B1	1-13
Y	JP 2004-43966 A (Toyo Seikan Kaisha, Ltd.), 12 February, 2004 (12.02.04), Claims; Par. Nos. [0006], [0007] (Family: none)	3-6, 8, 9
Y	JP 2002-120024 A (Nippon Steel Corp.), 23 April, 2002 (23.04.02), Claims; Par. No. [0016] (Family: none)	10

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 6226339 A [0003]
- JP 11104751 A [0003]