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(54) Aluminium alloy sheet for bottle cans superior in high-temperature properties

(57) An aluminum alloy sheet for bottle cans superior in high-temperature properties, the aluminum alloy sheet comprising the following composition: Mn 0.7-1.5% (mass %, also in the following), Mg 0.8-1.7%, Fe 0.1-0.7%, Si 0.05-0.5%, Cu 0.1-0.6%, with the remainder being Al and inevitable impurities, and comprising a crystal structure elongated in a rolling direction and with an aspect ratio of crystal grains of 3 or more as determined through an examination from above of a part located at the center in the through-thickness direction, wherein an average particle size of 0.5 μm or larger dispersed particles in the aluminum alloy sheet is 5 μm or smaller, and ΔT indicative of a solid-liquid coexistence temperature range between liquid and solid phases of aluminum is 40˚C or less.

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Description

Technical Field

[0001] The present invention relates to an aluminum alloy sheet for bottle cans (blank for bottle cans) which even when reduced in thickness to 0.2 mm or less (about 120-130 μm in a thickness-reduced central portion of a can body) and heat-treated at a high temperature as a can body material of a bottle can (beverage can), exhibits little deterioration in strength, can ensure a high strength and is difficult to be deformed, thus having high-temperature properties. As the aluminum alloy sheet as referred to herein, reference will be made below to a rolled sheet (cold rolled sheet) as an example which has been rolled through hot rolling and cold rolling. It is applicable widely to aluminum alloy sheets, including this type of cold rolled sheets. The aluminum alloy will hereinafter be referred to also as Al alloy.

Background Art

[0002] As aluminum beverage cans, 2-piece aluminum cans fabricated by seaming a can body and a can lid (can end) are popular. The can body is fabricated by subjecting a cold rolled aluminum sheet to DI (deep drawing and ironing), followed by trimming into a predetermined size, subsequent degreasing and washing, further, painting, printing, baking, and subsequent necking and flanging of can body edge portions.

[0003] As the cold rolled sheet for can body, hard sheets of, for example, JIS3004 alloy and 3104 alloy , which are Al-Mg-Mn alloys, have heretofore been widely used. The JIS3004 alloy and 3104 alloy are superior in ironing and exhibit a relatively good formability even when subjected to cold molding at a high draft in order to enhance the strength and are therefore considered suitable as DI can body materials.

[0004] On the other hand, in the case of a bottle can, an aluminum alloy sheet formed on both surfaces thereof with thermoplastic resin coating layers and with lubricant applied thereto is punched to obtain a blank, the blank is then subjected to deep drawing into a cup shape, then this cup-like molding is subjected to again deep drawing and stretching or ironing (DI working) to form a bottomed cylindrical can having a body portion of reduced diameter and thickness. Then, the bottom side of the can is subjected to deep drawing plural times to form a shoulder portion and an unopened mouth portion, followed by washing and trimming, subsequent printing and coating for the can body portion, further, opening the mounting portion, forming a curled portion and a screw portion (threading/curling), subsequent neck-in working and flanging, and sealing a separately-formed can lid by a seamer to afford a bottle can (see Patent Literature 1).

[0005] Thus, in the case of a 2-piece can, after an aluminum alloy sheet is subjected to substrate treatment (e.g., chromate treatment), it is coated with resin (application of resin or film laminate), then is punched into a circular blank, followed by forming into a cup, subjected deep drawing and ironing, further, printing, coating, necking, and trimming.

[0006] In the case of a bottle can with a threaded mouth portion, an aluminum alloy sheet is subjected to substrate treatment (e.g., chromate treatment), followed by resin coating (application of resin or film laminate), subsequent punching into a circular blank, forming into a cup, deep drawing and ironing, trimming, printing, coating, threading/curling, and subsequent neck flanging.

[0007] Just after DI, the bottle can body is usually in a substantially true circular form in its horizontal section. However, at the time of printing/coating and heat treatment for improving the adhesion of laminate film, the can body is heated to a temperature of 200˚C or higher.

[0008] At this time, the can body itself is in a state in which it is reduced in thickness from the original 0.3 to 0.4 mm or so as a cold rolled sheet thickness to 0.2 mm or less. Therefore, when the can body is heat-treated at such a high temperature as exceeds 200˚C, it is released from its work strain and residual stress induced during DI and softens thermally.

[0009] On this regard, in the case of a material which softens easily, the degree of softening is marked, with the result that the strength and hardness of the can are deteriorated markedly, thus giving rise to the problem that a sufficient can strength can $_{\text{no longer}}$ be ensured.

[0010] Besides, since the degree of softening becomes non-uniform in the circumferential direction of the can, a cross section of the can body is not a true circle as formed, but is deformed elliptically, thus giving rise to the problem that the can body shape becomes non-uniform.

[0011] Recently, due to a demand for reduction of the can weight, the aluminum can thickness is at the level of 0.2 mm or less and is becoming more and more small. At the same time, the aforesaid phenomena caused by thermal softening such as lowering in strength and hardness of the can body and non-uniforming in shape of the can body are becoming more and more marked.

[0012] Recently, moreover, from the standpoint of improving the productivity of cans, the foregoing printing/coating and heat treatment for improving the adhesion of laminate film are becoming more and more high in temperature and speed like, for example, 290˚C × 20 seconds. Such a tendency also promote the lowering in strength and hardness of the can body and non-uniforming of the shape thereof caused by the aforesaid thermal softening.

[0013] If the thickness of the can body is increased in an effort to prevent lowering in strength and deformation of the can body caused by thermal softening, an increase of the can weight results, while if the strength of the aluminum material itself is increased without increasing the sheet thickness, there occurs an inconvenience such as breakage during the foregoing ironing work. Thus, with only such selection of can material and method as in the prior art, it is impossible to cope with the problem in question.

[0014] Against the non-uniforming in shape of the can body caused by the foregoing thermal softening there has so far been proposed an aluminum alloy sheet for DI can capable of preventing thermal deformation during painting and heat treatment and affording a DI can high in true circularity (Patent Literature 2). The composition of such proposed aluminum alloy sheet for DI can is as follows: Mn 0.5-1.3 mass %, Mg 0.5-1.3 mass %, Cu 0.1-0.3 mass %, Fe 0.2-0.6 mass %, Si 0.1-0.5 mass %. When heat treatment is performed at a baking temperature T(˚C) of 230˚ to 270˚C for 20 minutes, it is intended to diminish a change ΔTS in tensile strength before and after the heat treatment.

[0015] In addition, also as to controlling the structure for improving the formability into a can, a large number of proposals have heretofore been made. For example, it has been proposed to control the amount of solute Mn and crystal grain diameter of a hot rolled sheet within respective predetermined ranges, thereby making the earing rate of the hot rolled sheet stably to -3% to 6%, then subject the sheet to cold rolling without going through intermediate annealing, thereby making the earing rate of the resulting cold rolled sheet stably to 0% to 2% (Patent Literature 3).

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2001-162344 (whole $_{test)}$
Patent Literature 2: Japanese Unexamined Patent Application Publication No. 2003-277865 (whole $_{text)}$
Patent Literature 3: Japanese Unexamined Patent Application Publication No. 2003-342657 (whole text)

Disclosure of the Invention

Problem to be Solved by the Invention

[0016] By only controlling the metallurgical factors on the structure of aluminum alloy sheets for stabilizing the earing rate such as controlling the amount of solute Mn and crystal grain diameter, which has so far been conducted, it is impossible to prevent thermal deformation during coating and heat treatment.

[0017] Likewise, by only controlling the aluminum alloy composition, including Mn, Mg, Cu, Fe and Si, a large limit is encountered in suppressing the lowering in strength and deformation of the can body caused by the foregoing thermal softening.

[0018] More particularly, the method proposed in Patent Literature 2 may be effective for its prescribed or presumed heat treatment of 230-270˚C $\times$ 20 minutes. However, as noted above, against such a higher temperature and shorter time heat treatment as 290˚C $\times$ 20 seconds, since the heat treatment temperature is higher and the can body thickness is smaller, it is impossible to prevent lowering in strength and deformation of the can body caused by thermal softening.

[0019] The present invention has been accomplished in view of such problems. On the premise that satisfactory formability in DI, etc. is to be ensured, it is an object of the present invention to provide an aluminum alloy sheet for bottle can capable of preventing thermal deformation during coating and heat treatment, securing can strength after heat treatment, affording a bottle can high in true circularity, and being superior in high-temperature properties.

Means for Solving the Problems

[0020] For achieving the above-mentioned object, in a first aspect of the present invention there is provided an aluminum alloy sheet for bottle cans superior in high-temperature properties, the aluminum alloy sheet comprising the following composition: Mn 0.7-1.5% (mass %, also in the following), Mg 0.8-1.7%, Fe 0.1-0.7%, Si 0.05-0.5%, Cu 0.1-0.6%, with the remainder being Al and inevitable impurities, and comprising a crystal structure elongated in a rolling direction and with an average aspect ratio of crystal grains of 3 or more as determined through an examination from above of a part located at the center in the through-thickness direction, wherein the amount of solute Cu is 0.05-0.3%, which means the amount of Cu in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol and the amount of solute Mg is 0.75-1.6%, which means the amount of solute Mg separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol.

[0021] As to a DI can body of a bottle can, as noted above, a further reduction of thickness is desired mainly for the purpose of reducing the manufacturing cost and weight. For attaining the thickness reduction it is necessary that the strength of the cold rolled aluminum alloy sheet as the material be made high so as to not cause a lowering of buckling strength. For achieving the thickness reduction it is also strongly desired that the earing rate in DI be low. If the earing rate in DI is made low, it is possible to increase the yield in DI and further possible to prevent the breakage of the can body caused by edge cutting of the can body.

[0022] Heretofore, as noted above, in order to highly stabilize the earing rate, there has publicly been known a method

wherein metallurgical factors of the structure of the cold rolled aluminum alloy sheet as the DI bottle can body material are controlled. Typical of such controls are crystal grain size microsizing control, controlling the number and size of a compound such as Mg_2Si, microscopic segregation suppression for added elements, controlling the amount of solute alloy elements such as Mn, and cube orientation control.

[0023] However, a technique for controlling metallurgical factors of the structure of the rolled aluminum alloy sheet in order to prevent thermal deformation in coating and heat treatment, which is to be attained in the present invention, has not substantially been proposed yet. This is because metallurgical factors of the structure correlated with thermal deformation in coating and heat treatment have not been made clear yet. Moreover, by merely controlling various known metallurgical factors of the structures for stabilizing the earing rate as referred to above, it is impossible to prevent thermal deformation in coating and heat treatment.

[0024] On the other hand, according to the present invention it has been found out that among various metallurgical factors of the structure, the form of crystal grain and the amount of solute Cu and that of solute Mg in the structure are correlated with the can strength after heat treatment and thermal deformation in coating and heat treatment.

[0025] Since such metallurgical factors of the structure do not obstruct the stabilization of the earing rate but rather act to stabilize the earing rate, it is possible to secure can strength after heat treatment and suppress thermal deformation in coating and heat treatment and then secure formability in DI, etc. In other words, it is possible to obtain an aluminum alloy sheet capable of securing can strength after heat treatment and suppressing thermal deformation in coating and heat treatment and then securing formability in DI, etc.

[0026] By controlling each individual crystal grain of the aluminum alloy sheet not into an equiaxed grain but into an elongated structure in the rolling direction with an average aspect ratio of 2 or more, it is possible to suppress thermal deformation in coating and heat treatment and secure can strength after heat treatment, thus possible to cope with a high-speed heat treatment performed at a higher temperature for a shorter time.

[0027] In the present invention, in addition to the above crystal grain shape control, the amount of solute Cu and that of solute Mg in the structure are controlled to respective optimum ranges.

[0028] The amount of solute Cu and that of solute Mg exert a great influence on anti-softening property in high-temperature heat treatment. Therefore, by securing both such Cu and Mg quantities present in a solid solution form it is possible to improve the anti-softening property in high-temperature heat treatment and suppress elliptic deformation. Besides, the amount of solute Mg exerts a great influence on the strength property after high-temperature heat treatment, so by securing the amount of solute Mg it is possible to also secure strength after high-temperature heat treatment.

[0029] Controlling the amount of other alloy elements, e.g., Mn, present in a solid solution form in the prior art described above makes contribution to improving the formability in DI, etc. such as lowering the earing rate of the cold rolled sheet. However, in point of suppressing thermal deformation in coating and heat treatment and securing can strength after heat treatment, which are to be attained in the present invention, such solid solution quantity control for other alloy elements is much less effective than controlling both Cu and Mg solid solution quantities. Thus, even if the amount of other alloy elements as Mn present in a solid solution form are ensured, thermal deformation during coating and heat treatment is not suppressed and it is impossible to secure can strength after heat treatment.

[0030] It is the first object of the present invention to suppress thermal deformation in coating and heat treatment and make it possible to secure can strength after heat treatment in connection with a high-speed heat treatment performed at a higher temperature for a shorter time by controlling each individual crystal grain of the aluminum alloy sheet not to an equiaxed grain but to an elongated structure in the rolling direction with an average aspect ratio of 3 or more. In the present invention, in order to further ensure this effect, there is made control so as to suppress anisotropy in the structure. More specifically, among tensile strengths in 0˚, 45˚ and 90˚ directions relative to the rolling direction, the difference between the maximum and the minimum value is 25 MPa or less, and among n values obtained by tensile tests in 0˚, 45˚ and 90˚ directions relative to the rolling direction, the difference between the maximum and the minimum value is 0.3 or less.

Thus, in a second aspect of the present invention there is provided an aluminum alloy sheet for bottle cans superior in high-temperature properties, the aluminum alloy sheet comprising the following composition: Mn 0.7-1.5% (mass %, also in the following), Mg 0.8-1.7%, Fe 0.1-0.7%, Si 0.05-0.5%, Cu 0.1-0.6%, with the remainder being Al and inevitable impurities, and having a structure elongated in a rolling direction and with an average aspect ratio of crystal grains of 3 or more as determined through an examination from above of a part located at the center in the through-thickness direction, wherein among tensile strengths in 0˚, 45˚ and 90˚ directions relative to the rolling direction, the difference between maximum and minimum values is 25 MPa or less, and among n values obtained by tensile tests in 0˚, 45˚ and 90˚ directions relative to the rolling direction, the difference between maximum and minimum values is 0.03 or less.

[0031] According to the second aspect of the present invention, in a conventional aluminum alloy sheet manufacturing process involving hot rolling and cold rolling, when a hot rolled sheet is cold rolled to the final sheet thickness by performing intermediate annealing (intermediate annealing), the draft in cold rolling inevitably becomes high, with consequent occurrence of anisotropy in strength, and there occurs a difference of about 30 MPa or more among tensile strengths in 0˚, 45˚ and 90˚ directions relative to the rolling direction. As the anisotropy in strength becomes higher, the internal

stress after cupping and ironing becomes non-uniform in the circumferential direction, so that the degree of recovery becomes non-uniform and elliptic deformation is apt to occur during printing/painting and heat treatment performed for improving the adhesion of laminate film. It is for this reason that thermal deformation in coating and heat treatment cannot be prevented when the conventional hot rolling and cold rolling are performed.

[0032] Also in the case where a hot rolled sheet is cold rolled directly to the final sheet thickness without going through intermediate annealing, the draft in cold rolling inevitably becomes high and there easily occurs anisotropy in strength. Consequently, there occurs a difference among tensile strengths in 0˚, 45˚ and 90˚ directions relative to the rolling direction and hence elliptic deformation is apt to occur. It is for this reason that thermal deformation in coating and heat treatment cannot be prevented in the conventional intermediate annealing-free cold rolling.

[0033] On the other hand, in the present invention, even when not the conventional cold rolling involving interpass (halfway in cold rolling) intermediate annealing but cold rolling is performed directly to the final sheet thickness without intermediate annealing of a hot rolled sheet, the foregoing thermal deformation in coating and heat treatment is suppressed and can strength after heat treatment can be secured.

[0034] Further, in the present invention, as noted above, crystal grains of the cold rolled aluminum sheet are controlled not to equiaxed grains but to an elongated structure in the rolling direction with an average aspect ratio of 3 or more, whereby thermal deformation in coating and heat treatment is suppressed and can strength after heat treatment can be secured in connection with a high-speed heat treatment performed at a higher temperature for a shorter time. In the present invention, for further ensuring this effect, dispersed grains in the structure are controlled. More specifically, an average grain size of dispersed grains is controlled as fine as 5 μm or less and ΔT, which represents a solid-liquid coexistence temperature range between liquid and solid phases of aluminum, is set at 40˚C or less.

[0035] The larger the solid-liquid coexistence temperature range ΔT, the larger the solid-liquid coexistence temperature range in a component system of both dispersed grains of Al (Fe, Mn)-based intermetallic compounds and the liquid phase of aluminum. That is, the component system is apt to undergo a change of crystal phase depending on casting conditions and the form thereof is apt to scattered, and the structure obtained permits easy formation of coarse compound grains.

[0036] Conversely, the smaller the solid-liquid coexistence temperature range ΔT, the smaller the solid-liquid coexistence temperature range in a component system of both dispersed particles and the liquid phase of aluminum. It can be said that in this structure the variations in production of stable and metastable phases of the intermetallic compound are small and compound grains are fine particles.

Brief Description of the Drawings

[0037]

[Fig. 1] is a developed view of a cup formed by DI of a blank.
[Fig. 2] is a schematic phase diagram showing ΔT defined in the present invention.
[Fig. 3] is a calculation phase diagram for determining ΔT by calculation.

Best Mode for Carrying Out the Invention

(Composition of Cold Rolled Al Alloy Sheet)

[0038] First, a preferred chemical components composition (unit: mass %) of the cold rolled Al alloy sheet according to the present invention will be described together with the reason for limitation of each element.

[0039] The composition of the cold rolled aluminum sheet for bottle can superior in high-temperature properties according to the present invention is as follows: Mn 0.7-1.5%, Mg 0.8-1.7%, Fe 0.1-0.7%, Si 0.05-0.5%, Cu 0.1-0.6%, with the remainder being Al and inevitable impurities.

[0040] In the present invention it is preferable to design the components balance of main constituent elements (Mn, Mg, Fe, Cu, Si) in such a manner that the required amount of solute Mg and that of solute Cu can be ensured. By making such a design, not only fine and stable crystals are formed, but also it is possible to make control so as to afford a structure of an optimum Cu or Mg solid solution quantity.

Mn: 0.7-1.5%

[0041] Mn is an effective element contributing to improvement of not only strength but also formability. Particularly, since the can body material (cold rolled sheet) used in the present invention is subjected to ironing in DI, Mn is an extremely important element.

[0042] More particularly, Mn affords various Mn-based intermetallic compounds, e.g., Al-Fe-Mn-Si-based intermetallic

compounds (α phase). The more appropriately dispersed the α ase, the more can be improved the ironing workability. In ironing an aluminum sheet, there usually is employed an emulsion type lubricant. But if the amount of the aforesaid α phase is small, even if an emulsion type lubricant is used, the lubricity becomes deficient, with a consequent fear of occurrence of an appearance defect such as rubbed scratch or seizure called galling. Thus, Mn is an indispensable element also for formation of α phase to prevent a surface defect in ironing.

[0043] If the content of Mn is too low, the above effect will not be exhibited. Therefore, the content of Mn is 0.7% or more, preferably 0.8% or more, more preferably 0.85% or more, still more preferably 0.9% or more.

[0044] On the other hand, if the content of Mn is too high, a giant metallic compound, $MnAl_6$, will be formed as a primary crystal, with consequent deterioration of formability. Therefore, the upper limit of the Mn content is set at 1.5%, preferably 1.3%, more preferably 1.1%, still more preferably 1.0%.

(Mn Solid Solution Quantity)

[0045] As noted above, by combining with cold rolling free of intermediate annealing, the amount of solute Mn in the cold rolled aluminum sheet contributes to improving the formability in DI, etc. such as lowering of the earing rate of the cold rolled sheet. Therefore, in order to improve the formability in DI, etc., it is preferable to set the amount of solute Mn at 0.12-0.38%, which means the amount of Mn (total amount of both dissolved Mn quantity and the amount of Mn contained in a precipitate of 0.2 μm or less in particle size) in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol. If the amount of solute Mn is less than 0.12%, there will be no effect of improving the formability in DI, etc., while if the amount of solute Mn exceeds 0.38%, the work hardening in cold rolling will become excessive and rather the formability in DI, etc. is very likely to be deteriorated.

Mg: 0.8-1.7%

[0046] Mg is effective in that it can improve its strength by solid solution hardening. Further, by using it in combination with Cu, as will be described later, it is possible to prevent softening of the can body material (cold rolled sheet) of the present invention at the time of final annealing (also called finish annealing, e.g., annealing at a temperature of about 100˚ to 150˚C for about 1 to 2 hours) and subsequent forming into a can and baking. More particularly, in the presence of both Mg and Cu, it is possible to ensure the required amount of solute Cu at the stage of fabrication of a hot rolled sheet, and since Al-Cu-Mg is precipitated at the time of baking, it is possible to suppress softening during baking.

[0047] If the content of Mg is too low, it is impossible to ensure the required amount of solute Mg and the effect of improving the anti-softening property in high-temperature heat treatment is not exhibited. Therefore, the content of Mg is set at 0.8% or more, preferably 0.9% or more, more preferably 1.0% or more.

[0048] On the other hand, if the content of Mg is too much, work hardening is apt to occur and hence the formability is deteriorated. Therefore, the upper limit of the Mg content is set at 1.7%, preferably 1.6%, more preferably 1.35%.

[0049] The content of Mg also exerts an influence on the amount of Mn precipitated and the amount of solute Mn. More particularly, the higher the Mg content, the more suppressed the amount of Al-Fe-Mn-Si-based intermetallic compounds (α phase) precipitated, so that the amount of solute Mn is apt to become large. It is preferable to determine the content of Mg in relation to the amount of solute Mn.

(Sum of Mg Solid Solution Quantity and the amount of Mg contained in Fine Precipitate of 0.2 μm or less)

[0050] The sum of the amount of solute Mg and the amount of Mg contained in a fine precipitate of 0.2 μm or less, like the sum of the amount of solute Cu and the amount of Cu contained in a fine precipitate of 0.2 μm or less, exerts a great influence on the anti-softening property in high-temperature heat treatment. Heretofore there has been the patent of Patent Literature 3 which defines both Mn and Cu solid solution quantities for the purpose of eliminating variations in the earing rate and stabilizing the same rate. However, in order to suppress elliptic deformation after can heating in intermediate annealing, the conventional control if applied alone is insufficient. It is necessary to also control the state of solid solution and precipitation of Mg. As a result of detailed investigation about the state of presence of Mg it turned out that not only Mg was present as a solid solution and a fine precipitate like that so far mentioned but also it was dissolved in a coarse Al-Fe-Si- or Al-Mn-Fe-Si-based precipitate and that if the amount thereof is large, the amount of dissolved Mg and that of Mg contained in fine precipitate become smaller and elliptic deformation is apt to occur. The amount of solute Mg exerts a great influence also on the strength property after high-temperature heat treatment. In the present invention, therefore, both Cu and Mg solid solution quantities required are ensured to not only improve the anti-softening property in high-temperature heat treatment but also ensure the required strength after high-temperature heat treatment.

[0051] Accordingly, in the present invention, the Mg solid solution quantity is set at 0.75-1.6% as the content of Mg (the'total quantity of both dissolved Mg quantity and the amount of Mg contained in a precipitate of 0.2 μm in particle

size) in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol.

[0052] Mg present in a coarse precipitate exceeding 0.2 μm in particle size rather deteriorates the anti-softening property in high-temperature heat treatment and the strength property after the same treatment. Thus, ensuring the required amount of solute Mg also leads to restricting the presence of a coarse precipitate exceeding 0.2 μm in particle size.

[0053] Not only Mg actually dissolved, but also Mg contained in a precipitate of 0.2 μm or less in particle size, like dissolved Mg, also improves the anti-softening property in high-temperature heat treatment and ensures the required strength after the same treatment. In the present invention, therefore, the total amount of both dissolved Mg quantity and the amount of Mg contained in a precipitate of 0.2 μm or less in particle size is defined to be the dissolved Mg quantity. Accordingly, the dissolved Mg quantity is defined as the amount of Mg contained in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol.

[0054] If the dissolved Mg quantity is less than 0.75%, the anti-softening property in high-temperature heat treatment will become insufficient and deformation of the can will not be suppressed; besides, the strength after high-temperature heat treatment will be deteriorated.

[0055] On the other hand, even if the dissolved Mg quantity exceeds 1.6%, the work hardening in cold rolling will become excessive, rather resulting in deterioration of formability in DI, etc.

Fe: 0.1-0.7%

[0056] Fe has a function of microsizing crystal grains and produces the foregoing Al-Fe-Mn-Si-based intermetallic compound (α phase), thus contributing to the improvement of formability. Moreover, Fe is useful also in point of promoting the crystallization and precipitation of Mn and controlling the amount of solute Mn in aluminum base and the state of dispersion of Mn-based intermetallic compounds (e.g., the aforesaid α phase). On the other hand, if the content of Fe is too high in the presence of Mn, a giant intermetallic compound as a primary crystal is apt to be produced, with consequent fear of formability being impaired.

[0057] Thus, the content of Fe can be set in accordance with the content of Mn and the mass ratio of Fe to Mn (Fe/Mn) is, for example, in the range of 0.1 to 0.7, preferably 0.2 to 0.6, more preferably 0.3 to 0.5.

[0058] In the case where the content of Mn falls under the above range, a lower-limit content of Fe is 0.1% or more, preferably 0.2% or more, more preferably 0.3% or more, while an upper-limit content of Fe is 0.7% or less, preferably 0.6% or less, more preferably 0.5% or less.

Si: 0.05-0.5%

[0059] Si produces Al-Fe-Mn-Si-based intermetallic compounds (α phase) and controls the state of dispersion Mn-based intermetallic compounds, thus being a useful element. The more appropriate the distribution of α phase, the more can be improved formability.

[0060] Accordingly, the content of Si is 0.05% or more, preferably 0.1% or more, more preferably 0.2% or more. On the other hand, if the Si content is too high, the material will become too hard due to age hardening, resulting in formability being deteriorated. Therefore, an upper-limit Si content is set at 0.5%, preferably 0.45%, more preferably 0.4%.

Cu: 0.1-0.6%

[0061] When performing baking in fabrication of the cold rolled sheet into a can, Al-Cu-Mg precipitates, and when Cu is used in combination with Mg, softening can be suppressed by the action of both dissolved Mg and dissolved Cu. Therefore, a lower-limit content of Cu is set at 0.1% or more, preferably 0.15% or more, more preferably 0.2% or more. On the other hand, if the Cu content is too high, hardening proceeds to an excessive degree although age hardening is attained easily, so that the formability is deteriorated and so is corrosion resistance. Accordingly, an upper-limit content of Cu is set at 0.6%, preferably 0.5%, more preferably 0.35%.

[0062] As other examples of strength improving element exhibiting the same effect as Cu there are mentioned Cr and Zn. Thus, Cr and/or Zn may be used selectively in addition to Cu.

(Sum of Cu Solid Solution Quantity and the amount of Cu contained in Fine Precipitate of 0.2 μm or less)

[0063] The sum of the amount of solute Cu and the amount of Cu contained in a fine precipitate of 0.2 μm or less, like the sum of the amount of solute Mg and the amount of Mg contained in a precipitate of 0.2 μm or less, exerts a great influence on the anti-softening property in high-temperature heat treatment.

[0064] In the present invention, the Cu content (total quantity of both dissolved Cu quantity and the amount of Cu

contained in a precipitate of 0.2 μm or less in particle size) in a solution separated from a precipitate exceeding. 0.2 μm in particle size by the extracted residue method using hot phenol is set at 0.05-0.3%.

[0065] Cu present in a coarse precipitate exceeding 0.2 μm in particle size rather deteriorates the anti-softening property in high-temperature heat treatment and the strength property after the same treatment. Therefore, ensuring the required dissolved Cu quantity also leads to restricting the formation of a coarse precipitate exceeding 0.2 μm in particle size.

[0066] Not only Cu actually dissolved but also Cu contained in a precipitate of 0.2 μm or less in particle size, like dissolved Cu, also improves the anti-softening property in high-temperature heat treatment and ensures the required strength after the same treatment. In the present invention, therefore, the total amount of both dissolved Cu quantity and the amount of Cu contained in a precipitate of 0.2 μm or less in particle size is defined to be the dissolved Cu quantity. Accordingly, the dissolved Cu quantity is defined as the amount of Cu contained in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol.

[0067] If the dissolved Cu quantity is less than 0.05%, the anti-softening property in high-temperature heat treatment will become insufficient and deformation of the can will not be suppressed; besides, the strength after high-temperature heat treatment will be deteriorated.

[0068] On the other hand, even if the dissolved Cu quantity exceeds 0.3%, the work hardening in cold rolling will become excessive, rather resulting in deterioration of formability in DI, etc. and deterioration of corrosion resistance.

Cr: 0.001-0.3%

[0069] For exhibiting the strength improving effect, the content of Cr is set at 0.001% or more, preferably 0.002% or more. On the other hand, if the Cr content is too high, a giant product will be formed by crystallization, with consequent deterioration of formability. Therefore, an upper limit of the Cr content is set at 0.3%, preferably 0.25%.

Zn: 0.05-1.0%

[0070] In the presence of Zn, there occurs age precipitation of Al-Mg-Zn particles, whereby the strength can be improved. For exhibition of this effect, the content of Zn is set at 0.05% or more, preferably 0.06% or more. On the other hand, a too high content of Zn will result in deterioration of corrosion resistance. Therefore,an upper limit of the Zn content is set at 0.5%, preferably 0.45%.

Ti: 0.005-0.2%

[0071] Ti is a crystal grain microsizing element. When this effect is to be exhibited, Ti is used selectively. In this case, the content of Ti is set at 0.005% or more, preferably 0.01% or more, more preferably 0.015% or more. If the Ti content is too high, giant Al-Ti-based intermetallic compounds will be formed by crystallization and impair the formability. Therefore, an upper limit of the Ti content is set at 0.2%, preferably 0.1%, more preferably 0.05%.

[0072] Ti may be used alone or in combination with a very small amount of B. A combined use thereof with B will further improve the crystal grain microsizing effect. Therefore, the content of B in a selective use thereof is set at 0.0001% or more, preferably 0.0005% or more, more preferably 0.0008% or more. On the other hand, a too high content of B will result in formation of coarse Ti-B particles and deterioration of formability. An upper limit of the B content is set at 0.05%, preferably 0.01%, more preferably 0.005%.

[0073] The balance other than the elements described above consists of inevitable impurities. In order not to impair the sheet properties described above, it is preferable that the content of such impurities be as low as possible. But their contents up to approximately the upper-limit values of elements in 3000 series aluminum alloys defined in JIS are acceptable insofar as they do not impair the above properties.

(Structure of Cold Rolled Al Alloy Sheet)

[0074] The following description is now provided about the structure of cold rolled A1 alloy sheet of the present invention.

(Average Aspect Ratio of Crystal Grain)

[0075] As noted above, by making each individual crystal grain of the cold rolled aluminum alloy sheet into not the ordinary equiaxed grain but an elongated crystal grain in the rolling direction with an average aspect ratio of 3 or more, thermal deformation in coating and heat treatment is suppressed and the required can strength after heat treatment can be ensured in connection with high-speed heat treatment at a higher temperature for a shorter time.

[0076] That is, by making each individual crystal grain of the cold rolled aluminum alloy sheet into an elongated grain

in the rolling direction, it is possible to impart ironing processability to the sheet and ensure the formability in DI, etc. and further possible to ensure the required can strength after heat treatment under the above components' composition and the state and texture of solid solution and precipitation to be described later. As a result, thermal deformation in coating and heat treatment is also suppressed.

[0077] If the average aspect ratio of crystal grains is less than 3, there is no great difference from the ordinary equiaxed grains and the foregoing effect is not attained to a satisfactory extent, so that it is impossible to suppress thermal deformation in painting and heat treatment and ensure the required can strength after heat treatment. In this point, the larger the extension in the rolling direction of crystal grains, the better. More preferably, an average aspect ratio of crystal grains is 3.1 or more.

[0078] Without intermediate annealing, the aspect ratio of each individual crystal grain depends on the crystal structure of the hot rolled sheet, as well as the draft in cold rolling and the cold rolling temperature. In this point, an upper limit of the average aspect ratio of crystal grains is determined from a capacity limit of the manufacturing process for making the crystal groins into the elongated grains, including hot rolling and cold rolling. Its level is 6 or so.

(Method for Measuring Average Aspect Ratio)

[0079] An average aspect ratio of crystal grains is measured through an observation (polarization observation) from above of a part located at the center in the through-thickness direction. A rolled upper surface of the central part in the thickness direction of the sheet after thermal refining (before forming the bottle can) is examined by polarization observation after mechanical polishing, electrolytic polishing and anodic oxidation using barker's liquid.

[0080] When the crystal structure is examined by polarization observation from the upper surface side of the central part in the thickness direction of the sheet, there occurs black-white difference due to the difference in crystal orientation. In this observation, with respect to crystal grains in a visual field permitting clear observation of the contour, both maximum length in the rolling direction and maximum length in the sheet width direction of each individual crystal grain are measured. In this case, (maximum length in the rolling direction)/ (maximum length in the sheet width direction) of each individual crystal grain is calculated as an aspect ratio. Through observation using an optical microscope of 100 magnifications, the number of crystal grains to be subjected to measurement is determined to be 100 grains and a mean value of aspect ratios of those crystal grains is determined as an average aspect ratio of crystal grains.

(Suppressing Anisotropy)

[0081] In the present invention, even when the hot rolled sheet is subjected to cold rolling directly up to the final sheet thickness without going through intermediate annealing in order to attain the thus-defined average aspect ratio of crystal grains and improve the formability of the sheet into a can and the strength thereof, the foregoing thermal deformation in coating and heat treatment is suppressed and the required can strength after heat treatment is ensured.

[0082] To this end, in the present invention, not only the above crystal grain control is made, but also a control is made so as to suppress anisotropy in the structure. For this anisotropy control, two anisotropy indices, which are tensile strength and n value, are used selectively.

[0083] In connection with the tensile strength as one anisotropy index, when the tensile strength becomes more and more anisotropic, as noted above, an internal stress after cupping and ironing becomes non-uniform in the circumferential direction and the degree of recovery becomes non-uniform in printing/coating and during heat treatment performed for improving the adhesion of laminate film, with the result that elliptic deformation is apt to occur.

[0084] For diminishing the anisotropy of the tensile strength, the difference between maximum and minimum values among tensile strengths in 0˚, 45˚ and 90˚ directions relative to the rolling direction is made as small as possible. More specifically, this difference is reduced to 25 MPa or less, preferably 20 MPa or less.

[0085] In addition to the above tensile strength, anisotropy in the rolling direction of a work hardening index, i.e., n value, is also important. If the anisotropy of n value is large, even if the anisotropy of the tensile strength referred to above is small (even if it is within the prescribed range), an internal stress induced by cupping and ironing becomes non-uniform in the circumferential direction, and the degree of recovery becomes non-uniform in printing/coating and when heat treatment is performed for improving the adhesion of laminate film, resulting in elliptic deformation being apt to occur.

[0086] Therefore, in order to diminish the anisotropy of n value, the difference between maximum and minimum values among n values in 0˚, 45˚ and 90˚ directions relative to the rolling direction of the aluminum alloy sheet is made as small as possible. More specifically, this difference is set at 0.03 or less, preferably 0.028 or less, more preferably 0.025 or less, still more preferably 0.02 or less, and still more preferably 0.015 or less.

[0087] If the aluminum alloy sheet has one or both of the anisotropic indices, there will occur the foregoing thermal deformation in coating and heat treatment even if the foregoing crystal grain control is made, although the can formability may not be influenced. More particularly, if the difference between maximum and minimum values among the foregoing

tensile strengths exceeds 25 MPa and/or if the difference between maximum and minimum values among the foregoing n values exceeds 0.03, there will occur the foregoing thermal deformation in coating and heat treatment.

(Anisotropy Suppressing Method)

[0088] Even when the hot rolled sheet is subjected to cold rolling without intermediate annealing, hot rolling conditions are controlled in order to satisfy both anisotropic indices. More specifically, hot finish rolling is performed by a tandem rolling mill equipped with three to six rolling stands and the coil winding tension in those final stands is made relatively high to increase the forward slip of the rolled sheet.

[0089] In this connection, an average coil winding tension in the final stands is made as high as possible in excess of at least 20 MPa. If an average coil winding tension is 20 MPa or less, crystal grains such as cube orientation are apt to be formed, and when cold rolling is performed without intermediate annealing, the sheet anisotropy becomes conspicuous. An ordinary average coil winding tension is in the range of 5 to 10 MPa.

[0090] A description will now be given also about controlling dispersed particles in the cold rolled aluminum alloy structure. In the present invention, as noted above, in order to ensure the exhibition of the effect of the foregoing elongated crystal grains, an average particle size of dispersed particles in this structure is controlled. More specifically, in the observation of particles of 0.5 μm or more, an average particle size of dispersed particles is microsized to 5 μm or less and ΔT which represents the liquid-solid phase coexistence temperature range of aluminum is set at 40˚C or lower.

(Average Particle Size of Dispersed Particles)

[0091] Dispersed particles in the cold rolled aluminum alloy structure are various intermetallic compound particles, including the foregoing Al-Fe-Mn-Si-based intermetallic compounds (α phase). In this case, the finer the average particle size of the dispersed particles, the better.

[0092] If the proportion of coarse dispersed particles (precipitated compounds) exceeding 5 μm in average particle size increases, they are apt to become the nucleus of recovery and recrystallization, so that softening at a high temperature becomes conspicuous and there easily occur elliptic deformation and a lowering of strength in high-temperature heat treatment. As a result, the aforesaid effect of the elongated crystal grains is offset.

[0093] In the present invention, therefore, an average particle size of dispersed particles in the observation of 0.5 μm or larger particles is set at 5 μm or less, preferably 4.5 μm or less.

[0094] It is assumed that the dispersed particles to be analyzed have a size (barycentric diameter) of 0.5 μm or more. This is because the presence of particles of 0.5 μm or larger exerts a great influence on the anti-softening property as noted above, while particles smaller than 0.5μ m are little influential. Moreover, dispersed particles smaller than 0.5 μm are difficult to be observed and measurement variations in this measurement become large. Therefore, such small particles are excluded from the measurement range defined in the present invention.

(Measurement of Average Particle Size)

[0095] An average particle size of dispersed particles in the observation of particles of 0.5 μm or more is determined using a scanning electron microscope (SEM) for the sheet structure. More specifically, a test piece of an upper rolled surface of a central sheet portion is mirror-polished and the structure of the polished surface is observed in ten visual fields each about 200 μm by about 150 μm in size through an SEM (e.g., Model S4500 FE-SEM: Field Emission Scanning Electron Microscopy, a product of Hitachi, Ltd.) having 500 or 1000 magnifications.

[0096] In this case, for observing the dispersed particle phase (intermetallic compound phase) clearly, the observation is made by observing a reflected electron image. A black image indicates Al and different contrasts make the dispersed particle phase clear. The dispersed particles are traced and an average size (mean value of barycentric diameters) of the dispersed particles is determined using Image-ProPlus (a product of MEDIACYBERNETICS Co.) as software for image analysis. The number of measured dispersed particles is 200 or more as a total in the above ten-visual field structure observation and calculation was made using a mean value.

(Solid-Liquid Coexistence Temperature Range ΔT)

[0097] Fig. 2 is a schematic phase diagram of Al-Mg-Mn-based alloy, showing schematically a relation among a liquidus line of aluminum, a solidus line of aluminum, and the crystallization temperature of AlMn- and Al(Fe,Mn)-based compounds as main crystals. In Fig. 2, the temperature range (temperature difference) between the Al liquidus and solidus lines corresponds to the solid-liquid coexistence temperature range ΔT as referred to herein.

[0098] There is a tendency that the wider (longer) the ΔT of a component system, variations in production between stable and metastable phases of the intermetallic compound become larger, depending on solidifying and cooling con-

ditions in casting. In this state of structure, elements other than the constituent elements of the intermetallic compounds are forcibly dissolved in those crystals. Therefore, at the stage of the bottle can body, softening at a high temperature becomes conspicuous and elliptic deformation and a lowering of strength are apt to occur in high-temperature heat treatment. Accordingly, as is the case with coarsening in average particle size of dispersed particles, the effect of the foregoing elongated crystal grain is offset.

[0099] Moreover, the wider (larger) the ΔT of a component system, the more easily is formed a coarse compound particle distribution because intermetallic compounds grow rapidly in liquid phase. As a result, it becomes impossible to microsize the average particle size of dispersed particles defined above. Consequently, as explained above in connection with the dispersed particles, coarse particles become the nucleus of recovery and recrystallization and softening of the bottle can body in heat treatment become more conspicuous, so that elliptic deformation is apt to occur. Further, the presence itself of a coarse compound is apt to be a cause of defect of the can surface.

[0100] Strictly speaking, in connection with ΔT, there is a method for defining the range of crystallization temperature of Al-Mn-based intermetallic compounds and that of the solid phase temperature of Al, as noted above. However, in the Al alloy system according to the present invention, the melting point of the Al alloy system and the crystallization temperature of Al-Mn-based compounds exhibit a change of only about 4˚ to 7˚ and thus cannot be an exact index. For this reason, there was used the range (temperature difference) between the Al liquid phase temperature and the Al solid phase temperature, which can be an exact index, with a sufficient difference (margin) found in ΔT in point of measurement evaluation.

[0101] The narrower (smaller) the ΔT (solid-liquid coexistence temperature range), the smaller the solid-liquid coexistence temperature range between dispersed particles and aluminum liquid phase in the component system concerned, and the smaller the variations in the production of stable phase and metastable phase in intermetallic compounds and the finer the compound particles. Consequently, at the stage of the bottle can body, the anti-softening property at high temperatures is enhanced and it is possible to suppress elliptic deformation and a lowering of strength in high-temperature heat treatment.

[0102] As will be seen in Examples to be described later, as ΔT becomes larger, the average particle size of dispersed particles increases as well. Particularly, when the value of ΔT exceeds 40˚C, the average particle size of dispersed particles shows a coarsening tendency, Thus, the smaller the value of ΔT in the range of not higher than 40˚C, the better. More preferably, the value of ΔT is 38˚C or less, still more preferably 36˚C or less, and still more preferably 34˚C or less.

(Calculation of Solid-Liquid Coexistence Temperature Range ΔT)

[0103] The value of ΔT is calculated by measuring the melting point and solid phase temperature of a cold rolled aluminum sheet (test piece) concerned by differential thermal analysis and thereby calculating the temperature range ΔT in which the liquid phase of aluminum is existent. In the range related to the aluminum alloy system according to the present invention, the melting point lies in the range of approximately 645˚ to 660˚C and a change detected at a temperature of approximately 600˚ to 630˚C is the solid phase temperature.

[0104] Tests were conducted using, for example, TG/DTA (TGD7000) manufactured by ULVAC-RIKO, Inc. and under the following conditions:

Heat pattern: RT ~ 700˚C ~ RT: 10˚C/min
Atmosphere: Ar (100 ml/min)
Sample weight: about 500 mg
Reference: Alumina powder
Sample container: Alumina (Macro type 8 × 10 mm)

[0105] As a method other than differential thermal analysis, ΔT may be determined from a calculation phase diagram, but the method using differential thermal analysis is more accurate. However, ΔT determined by a thermodynamic equilibrium phase diagram calculation is useful in case of making alloy design beforehand so that the value of ΔT becomes 40˚C or less. Fig. 3 illustrates ΔT in a calculation phase diagram of C alloy according to an Example of the present invention which is described in Table 7 to be shown later.

(Control of ΔT)

[0106] The control of ΔT is basically made by designing the balance of the main constituent elements (Mn, Mg, Fe, Cu, Si) in the present invention in such a manner that the solid-liquid coexistence temperature range ΔT of aluminum becomes 40˚C or less. According to a general trend of the alloy elements (components), as to Mn and Fe, the value of ΔT becomes larger as the content thereof increases or decreases from a median in the defined content range. As to Mg, Cu and Si, the value of ΔT tends to become larger as their contents increase. Within the contents' ranges defined

in the present invention, generally, the lower the contents of these alloy elements, the smaller the value of ΔT.

[0107] However, in order for the cold rolled aluminum alloy sheet for bottle cans to satisfy the required strength and formability, it is difficult to simply decrease the respective contents of the main constituent elements.

[0108] Further, the crystallization temperature of Al (Fe, Mn)-based intermetallic compound varies depending on multi-element components, including the foregoing other selective added elements and impurity elements. Therefore, the value of ΔT also varies largely depending on such other selective added elements and impurity elements.

[0109] Particularly, the proportion of can material scraps in molten material used as can material has been increasing every year in comparison with base metal and the proportion of inevitable impurity elements present other than basic component elements is increasing. Examples of such inevitable impurity elements are Zr, Bi, Sn, Ga, V, Co, Ni, Ca, Mo, Be, Pb, and W. The total (total amount) of contents of these elements has heretofore been 0.01% or less, but with the recent increase of the scrap proportion, it is now 0.015% or more, or 0.02% or more, as the case may be it is 0.05% or 0.1% or more, as inevitable impurities.

[0110] Consequently, even assuming that the amounts of the main constituent elements and the amounts of the selective added elements remains the same, if the total amount of the impurity elements exceeds 0.01%, the value of ΔT is influenced thereby and varies greatly. The degree of such influence differs depending on the kind of alloying elements; besides, in a multi-component system, the solid-liquid coexistence temperature range varies also depending on interaction of the constituent components. Therefore, in the case where the amount of such inevitable impurity elements becomes large, with a mere control of the content range and the balance of basic components (e.g., Mg/Mn ratio), it is very difficult to make a components design for making the solid-liquid coexistence temperature range into an optimal range, because of complicatedness of the component system.

[0111] For this reason, when controlling the value of ΔT, first there is made design of components balance with respect to the main constituent elements (Mn, Mg, Fe, Cu, Si) and selective added elements in the present invention and there is made alloy design so as to satisfy the strength and formability required of the cold rolled aluminum alloy sheet for bottle cans.

[0112] Then, for calculating the liquid phase temperature and solid phase temperature, there is made such a thermodynamic equilibrium phase diagram calculation as shown in Fig. 2 and the alloy design is modified so that the solid-liquid coexistence temperature range ΔT of aluminum becomes 40˚C or less. Thereafter, it is necessary to make a trial manufacture and check beforehand whether the solid-liquid coexistence temperature range ΔT of aluminum becomes 40˚C or less under mass-productive manufacturing conditions to be described later.

(Manufacturing Method)

[0113] The cold rolled aluminum sheet of the present invention can be manufactured without greatly changing the conventional soaking, hot rolling and cold rolling processes. However, in order to attain the structure defined in the present invention and ensure the basic material properties (earing rate and strength), as well as formability and ironing processability, without impairing them, it is necessary to limit each of the above individual processes to an optimal condition range and combine those processes.

(Soaking Condition)

[0114] The soaking temperature is set at 550-650˚C. If the soaking temperature is too low, it will take too much time for soaking, resulting in productivity being deteriorated, while if the soaking temperature is too high, there occurs swelling on ingot surface. Therefore, the soaking temperature is set to a temperature falling under the above range. A preferred soaking temperature range is in the range of 580˚C (especially 590˚C) to 615˚C (especially 610˚C) .

[0115] The shorter the soaking time (homogenizing time), the better insofar as the ingot can be homogenized. For example, the soaking time is preferably 12 hours or less, more preferably 6 hours or less. However, if the soaking temperature is set at 550˚C or higher, the soaking time is required to be 6 hours or more. Likewise, if the soaking temperature is set at 580˚C or higher, the soaking time is required to be 5 hours or more, and if the soaking temperature is set at 590˚C or higher, the soaking time is required to be 4 hours or more.

[0116] The soaking treatment may be done dividedly in plural stages. In the soaking treatment, control of the heating speed, of the soaking temperature (homogenizing temperature) and of the cooling speed may be done in any stage. Such control may be done in all the stages, but is preferably done at least in the first stage.

[0117] In the case where the temperature of the first soaking treatment is set to a temperature falling under the above range, the temperatures of the second and subsequent soaking treatments are in many cases set lower than the temperature of the first soaking treatment. For example, the temperatures of the second and subsequent soaking treatments are set lower by about 10˚ to 100˚C, preferably about 50˚ to 100˚C, as compared with the temperature of the first soaking treatment.

(Hot Rolling Start Condition)

[0118] After end of the soaking process, the ingot may be once cooled, then re-heated and thereafter subjected to rough hot rolling, or without cooling to excess, it may be subjected directly to rough hot rolling. In case of subjecting the ingot directly to rough hot rolling without excessive cooling, the sum of the amount of solute Cu and the amount of Cu contained in a fine precipitate of 0.2 μm or less can be easily set at a value in the range of 0.05% to 0.3%, which means the amount of Cu in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol, and the sum of the amount of solute Mg and the amount of Mg contained in a fine precipitate of 0.2 μm or less can be easily set at a value in the range of 0.75% to 1.6%, which means the amount of solute Mg separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol. Moreover, it is possible to utilize self-heat generation of the ingot after the'soaking process, whereby not only the production time and heat energy can be saved, but also it is possible to diminish the number density of alloy elements' precipitates and hence possible to diminish the earing rate.

[0119] In case of once cooling the ingot and re-heating it, it is preferable to perform rapid heating at a rate of 30˚C/hr or higher. By this rapid heating it is possible to suppress dissolving of Mg and Cu to the coarse compounds so far produced or precipitation at the interface of coarse precipitates, whereby the sum of the amount of solute Cu and the amount of Cu contained in a fine precipitate of 0.2 μm or less in particle size can be easily set at a value in the range of 0.05% to 0.3%, which means the amount of Cu in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol, and the sum of the amount of solute Mg and the amount of Mg contained in a fine precipitate of 0.2 μm or less in particle size can be easily set at a value in the range of 0.75% to 1.6%, which means the amount of solute Mg separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol. Moreover, it is possible to prevent an excessive increase in the number density of alloying elements' precipitates.

(Rough Hot Rolling Condition)

[0120] When performing hot rolling dividedly into rough rolling and finish rolling and in a continuous manner, if the end temperature in rough hot rolling is too low, the rolling temperature will become low in the next finish hot rolling and an edge crack becomes easier to occur. Moreover, if the end temperature in rough hot rolling becomes too low, the self heat required for recrystallization after finish rolling is apt to become deficient, so that the crystal grain diameter becomes too small. Therefore, it is preferable that the end temperature in rough hot rolling be set at 420˚C or higher, more preferably a temperature in the range of 430˚C (especially 440˚C) to 470˚C (especially 460˚C) .

[0121] In order to ensure the end temperature in rough hot rolling of 420˚ to 480˚C it is preferable that the start temperature in rough hot rolling be set at, for example, about 490˚ to 550˚C, more preferably about 495˚ to 540˚C, still more preferably about 500˚ to 530˚C. As long as the said start temperature is kept at a temperature of 550˚C or lower, it is also possible to prevent surface oxidation of the hot rolled sheet. Further, it is possible to prevent coarsening of recrystallized grains and hence possible to further enhance the formability.

[0122] It is preferable that the aluminum alloy sheet having gone through the rough hot rolling process be subjected to finish hot rolling rapidly, for example continuously, whereby it is possible to prevent recovery of the strain accumulated in rough hot rolling and hence possible to enhance the strength of the cold rolled sheet to be obtained subsequently. It is preferable that the aluminum alloy sheet after the end of rough hot rolling be subjected to finish hot rolling for example within 5 minutes, preferably within 3 minutes.

(Finish Hot Rolling Condition)

[0123] It is preferable that the end temperature in finish hot rolling be set at 310˚ to 350˚C. The finish hot rolling process is a process for finishing the cold rolled alloy sheet to predetermined dimensions, and since the structure after the end of rolling becomes a recrystallized structure due to self-heat generation, the end temperature in finish hot rolling exerts an influence on the recrystallized structure. By setting the end temperature in finish hot rolling at 310˚C or higher, in combination with the cold rolling condition which follows, the final sheet structure can be made into an elongated structure in the rolling direction with an aspect ratio of 3 or more and it is possible to ensure both Cu and Mg solid solution quantities defined in the present invention. If the end temperature in finish hot rolling is lower than 310˚C, it is difficult to attain the above structure in the present invention even if the draft in cooling rolling in the subsequent cold rolling process is set large.

[0124] On the other hand, if the end temperature in finish hot rolling exceeds 350˚C, it will be impossible to make the final sheet structure into an elongated structure in the rolling direction and the desired amount of solute Mg cannot be ensured. Accordingly, a lower limit of the end temperature in finish hot rolling is set at 310˚C or higher, preferably 320˚C or higher, while an upper limit thereof is set at 350˚C or lower, preferably 340˚C or lower.

(Type of Finish Hot Rolling Mill)

[0125] As a finish hot rolling mill there is used a tandem hot rolling mill equipped with three or more stands. By setting the number of stands at three or more it is possible to diminish the draft per stand and accumulate strain while ensuring surface properties of the hot rolled sheet, so that it is possible to further enhance the strength of the cold rolled sheet and that of its DI-formed product.

(Total Draft in Finish Hot Rolling)

[0126] It is preferable that the total draft in finish hot rolling be set at 80% or more. By setting the total draft at 80% or more, in combination with cold rolling to be described later, the final sheet structure can be easily made into an elongated structure in the rolling direction with an average aspect ratio of 3 or more. It is also possible to enhance the strength of the cold rolled sheet and its DI-formed product.

(Thickness of Hot Rolled Sheet)

[0127] It is preferable that the thickness of the alloy sheet after hot (finish) rolling be about 1.8 to 3 mm. By setting the sheet thickness at 1.8 mm or more it is possible to prevent worsening (e.g., seizure or roughening) of surface properties of the hot rolled sheet and the sheet thickness profile. On the other hand, by setting the sheet thickness at 3 mm or less it is possible to prevent the draft from becoming too high when fabricating the cold rolled sheet (the sheet thickness is usually about 0.28 to 0.35 mm) and hence possible to suppress the earing rate after DI.

[0128] In the hot rolled sheet obtained in the above manner, the amount of solute Cu and that of solute Mg are in a controlled state to the respective optimum ranges, so that the average earing rate is controlled to its predetermined range. Therefore, it is possible to effect cold rolling without intermediate annealing and make the average earing rate of the cold rolled sheet as small as 0% to 3.5%. Moreover, by combination with cold rolling to be described later, the final sheet structure can be made into an elongated structure in the rolling direction with an average aspect ratio of crystal grains of 3 or more and the sum of the amount of solute Cu and the amount of Cu contained in a fine precipitate of 0.2 μm or less in particle size can be easily set at 0.05-0.3%, which means the amount of Cu in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol, likewise, the sum of the amount of solute Mg and the amount of Mg in a fine precipitate of 0.2 μm or less in particle size can be easily set at 0.75-1.6%, which means the amount of solute Mg separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol.

(Cold Rolling)

[0129] In the cold rolling process, rolling is performed directly through plural number of passes without intermediate annealing and it is preferable that the total draft be 77-90%. By making the total draft 77% or more without intermediate annealing, the final sheet structure can be made into an elongated structure in the rolling direction with an average aspect ratio of crystal grains of 3 or more and the sum of the amount of solute Cu and the amount of Cu contained in a fine precipitate of 0.2 μm or less in particle size can be easily set at 0.05-0.3%, which means the amount of Cu in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol, likewise, the sum of the amount of solute Mg and the amount of Mg present in a fine precipitate of 0.2 μm or less can be set at 0.75-1.6%, which means the amount of solute Mg separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol. Besides, it is possible to secure compressive strength of the can. In the case where intermediate annealing is performed or where the total draft is low, the crystal grains are apt to become equiaxed grains and the final sheet structure is difficult to become an elongated structure in the rolling direction with an average aspect ratio of crystal grains of 3 or more.

[0130] On the other hand, if the draft exceeds 90%, although the average aspect ratio of crystal grains can be made large, the plus earing in DI becomes too large and the strength becomes too high, so a cupping crack or a can bottom crack is very likely to occur during DI.

[0131] The sheet thickness after cold rolling is set at about 0.28-0.35 mm in view of formability thereof into a bottle can.

[0132] In the cold rolling process it is preferable to' use a tandem rolling mill with two or more stages of rolling stands arranged in series. By using such a tandem rolling mill, in comparison with a single rolling mill having one stage of rolling stand and wherein cold rolling to a predetermined sheet thickness is performed by repeated pass (sheet pass), a smaller number of pass suffices even at the same total draft in cold rolling and it is possible to increase the draft in one pass.

[0133] Thus, the final sheet structure can be made more easily into an elongated structure in the rolling direction with an average aspect ratio of crystal grains of 3 or more.

[0134] Moreover, in comparison with the conventional cold rolling process using a single rolling mill wherein finish

annealing is performed after the cold rolling, it is possible to let recovery occur continuously at a lower temperature and produce subgrains. However, the rolling mill to be used is not limited to the tandem rolling mill insofar as the rolling mill adopted can cause recovery in cold rolling and produce subgrains sufficiently.

[0135] In cold rolling using a tandem rolling mill, the amount of heat generated in one pass is large because the draft in one pass is high. In the case where the amount of heat generated becomes too large, the amount of precipitates of Cu and Mg produced, especially the amount of precipitates at the boundary of coarse precipitates, increases due to strain introduction and heat generation in cold rolling. Consequently, there is the possibility that it will be impossible to ensure the required amount of solute Cu and that of solute Mg and the required amount of a fine precipitate.

[0136] Accordingly, in cold rolling using a tandem rolling mill, when the temperature of the aluminum alloy sheet rises to the greatest extent just after cold rolling in the cold rolling process, it is preferable to cool the aluminum alloy sheet forcibly so as to prevent the aluminum alloy sheet temperature after cold rolling from rising to a level exceeding 200˚C.

[0137] As means for cooling the aluminum alloy sheet forcibly in cold rolling it is preferable to adopt cooling means such that water-free rolling oil used commonly is changed into an emulsion type such as water-soluble oil or lubricant and an aqueous solution of the emulsion is used to strengthen the cooling performance without deteriorating the lubricating performance.

[0138] After cold rolling, finish annealing (final annealing) may be done at a temperature lower than the recrystallization temperature, if necessary. Finish annealing results in recovery of the structure and improvement of both DI formability and can bottom formability. It is preferable that the finish annealing temperature be, for example, about 100-150˚C, more preferably 115-150˚C. By setting the temperature at 100˚C or higher, it is possible to effect a satisfactory recovery of the structure. On the other hand, by setting the temperature at 150˚C or lower, it is possible to prevent excessive precipitation of dissolved elements and further enhance the DI formability and flange formability.

[0139] It is preferable that the finish annealing time be 4 hours or less (especially about 1 to 3 hours). By avoiding too long annealing it is possible to prevent excessive precipitation of dissolved elements and further enhance the DI formability.

[0140] However, in cold rolling using the foregoing tandem rolling mill, finish annealing is basically not required because it is possible to let recovery occur at a lower temperature and continuously and product subgrains.

[0141] The present invention will be described below more concretely by way of Examples, but the present invention is not limited by the following Examples and changes may be made appropriately within the scope conforming to the above and following gists of the present invention, which changes are all included in the technical scope of the present invention.

Example 1

[0142] Using aluminum metal alone as a melting raw material and using molten metal of Al alloy components in A to N shown in Table 1 below, ingots each 600 mm thick by 2100 mm wide were produced by the DC casting method. In Table 1, the element content indicated by "-" represents that it is below the detection limit.

[0143] As shown in Table 1, in both working examples and comparative examples, the ingots contained inevitable impurity elements Zr, Bi, Sn, Ga, V, Co, Ni, Ca, Mo, Be, Pb and W in total contents of 0.01% or less as the total amount of other elements.

[0144] The ingots were each subjected to a soaking treatment in accordance with the conditions shown in Table 2. The soaking treatment was conducted twice. That is, after the first soaking treatment, each ingot was cooled to room temperature at a cooling speed shown in Table 2, followed by re-heating to effect the second soaking treatment. The heating speed as a first soaking condition indicates a heating speed in the temperature range from 300˚C to the highest temperature which temperature range substantially exerts an influence on properties. The cooling speed as a first soaking condition indicates a cooling speed in the temperature range from the highest temperature to 300˚C which temperature range substantially exerts an influence on properties. After this soaking treatment, rough hot rolling was performed using a reversing rough hot rolling mill having one stand, followed by finish hot rolling using a tandem hot rolling mill having four stands. The finish hot rolling was started within three minutes after the end of rough hot rolling.

In this way there were obtained hot rolled aluminum alloy sheets 2 to 2.5 mm in thickness as a common condition after finish hot rolling.

[0145] The hot rolled sheets were then subjected to cold rolling by only one pass with use of a tandem rolling mill having two stages of rolling stands without intermediate annealing to afford sheets (cold rolled sheets) for bottle can body 0.3 mm in final thickness as a common condition. In the cold rolling by the tandem rolling mill, the aluminum sheets were cooled forcibly using an aqueous emulsion so as to prevent the aluminum sheet temperature just after cold rolling from rising to a temperature exceeding 250˚C. Finish annealing (final annealing) after this cold rolling was not conducted.

[0146] In only comparative example 10, two passes were performed in a single rolling mill having one stage of rolling stand and intermediate annealing of 150˚C × 1 hour was performed between the first and the second pass for comparison purpose although the total draft in cold rolling was the same.

[0147] A test piece was sampled from each sheet (coil) for bottle can body after cold rolling and the structure thereof was checked. More particularly, an average aspect ratio of crystal grains and the amount of solute Cu and that of solute Mg were checked by the methods described above, the results of which are shown in Table 3.

[0148] For determining high temperature properties of the test piece, hardness and 0.2% proof stress of the test piece surface at room temperature, as well as hardness and 0.2% proof stress of the test piece surface in 290˚C × 20 sec. heat treatment of the test piece, were measured and a change in hardness (hardness reduction) ΔHv (Hv) of the test piece before and after the heat treatment was determined. Further, an elliptic deformation quantity upon bake-hardening of the can body after forming was measured. These results are also shown in Table 3.

(Measurement of 0.2% Proof Stress)

[0149] Tensile test for measuring 0.2% proof stress was conducted in accordance with JIS Z 2201 and, as the test piece shape, there was used the shape of JIS No. 5 test piece. The test piece was obtained in such a manner that its longitudinal direction was coincident with the rolling direction. Crosshead speed was 5 mm/min and a constant speed was adopted until breakage of the test piece.

(Hardness Measurement)

[0150] Each cold rolled sheet sample was measured for hardness at four positions under the application of 100 g load by means of a micro Vickers hardness tester and a mean value of the measured values was used as the hardness value.

(Evaluation of Elliptic Deformation)

[0151] For evaluation of elliptic deformation, as will be described later, a bottle can body obtained by DI of the above sheet for a bottle can body was washed and then baked under the condition that the bodily temperature of the can should reach 300˚C in 30 seconds, then the degree of elliptic deformation was checked. For checking the degree of elliptic deformation, the diameter of the mouth portion of the bottle can body was checked successively in the circumferential direction, then an amount obtained by subtracting the minimum diameter from the maximum diameter was determined as an elliptic deformation quantity (mm), and evaluation was made using a mean value from N = 10 cans. In the case where the elliptic deformation quantity is 4 mm or less, it was evaluated that the elliptic deformability came up to a passing point. If the elliptic deformation quantity exceeds 4 mm, there will occur defects such as falling-down and jam during conveyance and necking as post-steps in the can manufacturing process, thus making continuous and efficient manufacture of cans difficult.

[0152] Further, as formability which the sheet for bottle can body should satisfy basically, both earing rate and DI formability (the number of times of cracking in forming) were measured and evaluated, the results of which are also shown in Table 3.

(Earing Rate)

[0153] For checking the earing rate, a blank was sampled from the sheet for a bottle can body and lubricating oil (Nalco 147, a product of D.A. Stuart Co.) was applied thereto, then the blank was subjected to 40% deep drawing test and formed into a cup for investigation, using an Erichsen tester. The test was performed under the following conditions: blank dia. 66.7 mm, punch dia. 40 mm, R of the die-side shoulder portion 2.0 mm, punch shoulder R 3.0 mm, blank holder pressure 400 kgf.

[0154] Mountain-valley shapes formed in eight directions (0˚, 45˚, 90˚, 135˚, 180˚, 225˚, 270˚ and 315˚ directions, assuming that the rolling direction is 0˚) in the peripheral edge portion of the opening of the cup thus obtained were measured and an average earing rate was calculated.

[0155] An average earing rate calculating method will now be described with reference to Fig. 1. Fig. 1 is a developed view of the cup formed by DI of the sheet for a bottle can body. In this developed view, earing heights (T1, T2, T3, T4, designated minus earings) created in 0˚, 90˚, 180˚ and 270˚ directions, assuming that the rolling direction is 0˚, are measured and likewise earing heights (Y1, Y2, Y3, Y4, designated plus earings) created in 45˚, 135˚, 225˚ and 315˚ directions are measured. The heights Y1 to Y4 and T1 to T4 are from the bottom of the cup. From the measured values, an average earing rate is calculated in accordance with the following equation:

$$\text{Average Earing Rate (\%)} = [\{(Y1+Y2+Y3+Y4)-(T1+T2+T3+T4)\}/\{1/2\times(Y1+Y2+Y3+Y4+T1+T2+T3+T4)\}]\times 100$$

[0156] In the cold rolled sheet according to the present invention, when the average earing rate is set at near 0, the development of the four plug earings (Y1 to Y4) and the two minus earings (T2 and T4 in Fig. 1) in 90˚ and 270˚ directions are suppressed, but the development of the two minus earings (T1 and T3 in Fig. 1) in 0˚ and 180˚ directions are difficult to be suppressed. Even if the absolute value of the average earing rate is merely made small, for example when the average earing rate is set at - 2% to 2% (2% or less in absolute value), the minus earings (T1 and T3 in Fig. 1) are not suppressed to a satisfactory extent even if the average earing rate is not less than -2% and less than 0%, so that the blank holder pressure in deep drawing is concentrated on the two minus earings (T1 and T3 in Fig. 1), causing edge rise and edge crack, which are inconvenient to the manufacture. On the other hand, when the average earing rate is set at 0-2% (plus side), it is possible to prevent breakage of the can body caused by edge crack because the remaining two minus earings (T1 and T3 in Fig. 1) can also be suppressed to a satisfactory extent. In the present invention, the range of +0% to +3.5% is defined to be an allowable range.

(DI Formability)

[0157] A blank 156 mm in diameter was punched from the above sheet for bottle can body (sheet thickness 0.3 mm). Using the blank, a cup having a diameter of 92 mm was formed and then subjected to re-deep drawing, ironing and trimming, whereby DI can bodies for bottle can (inside diameter 66 mm, height 170 mm, side wall thickness 103 μm, side wall tip thickness 165 μm, final third ironing rate 40%) were fabricated at a can manufacturing speed of 300 cans/min. The number of body-cracked cans per 50,000 formed cans was determined and DI formability was evaluated. The evaluation was made in accordance with the following criterion. ◎: no cracked can (extremely good), O: one cracked can or less (good), Δ: two to four cracked cans (generally good), X: more than five cracked cans (bad).

[0158] As is apparent from Table 3, working examples 1 to 6 have compositions according to the present invention, average aspect ratios of crystal grains therein are 3 or more, Cu solid solution quantities as determined in the foregoing manner are in the range of 0.05% to 0.3%, and Mg solid solution quantities are in the range of 0.75% to 1.6%.

[0159] Thus, in working examples 1 to 6, as is seen from Table 3, after heat treatment at 290˚C for 20 seconds (after bake-hardening), the hardness change ΔHv is 30 Hv or less, 0.2% proof stress is 210 MPa or more, there is little lowering of hardness and strength, and high-temperature properties are excellent.

[0160] Working examples 1 to 6 are superior also in earing rate and DI formability. Thus, it is seen that the improvement of high-temperature properties in the present invention does not impair the formability which the sheet for bottle can body should satisfy basically.

[0161] On the other hand, in comparative examples 7 to 10, conditions for soaking and hot rolling do not fall under the foregoing preferred conditions, although the compositions adopted therein fall under those defined in the present invention, so that any of the average aspect ratio of crystal grains, the amount of solute Cu and that of solute Mg deviates from the range defined in the present invention. As a result, in comparison with the foregoing working examples, a lowering of hardness and that of strength are marked and high-temperature properties are inferior.

[0162] In comparative example 7, the second soaking temperature is too low, and the end temperature in finish hot rolling is too low. In comparative example 8, the end temperature in finish hot rolling is too low. In comparative example 9, the end temperature in finish hot rolling is too low. In comparative example 10, the rolling mill used is a single cold rolling mill and intermediate annealing was performed halfway of cold rolling.

[0163] Comparative examples 11 to 20 follow preferred manufacturing conditions. However, alloy compositions used therein deviate from those defined in the present invention. As a result, in comparison with the foregoing Examples of the present invention, a lowering of hardness and that of strength are marked and high-temperature properties are inferior. Formability is also low.

[0164] From the above results, critical meanings of the conditions defined in the first invention can be understood.

[0165]

TABLE 1

Example	Symbol	Al Alloy Chemical Components (mass %, provided B is in ppm, balance Al)									
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	B	Total amount of other elements *
Working Examples	A	0.26	0.44	0.22	1.04	1.25	-	-	-	-	0.005
	B	0.25	0.44	0.22	1.03	1.22	0.03	0.19	0.03	0	0.005
	C	0.24	0.42	0.19	0.91	0.92	0.03	0.2	0.02	10	0.007
	D	0.31	0.45	0.10	1.32	1.01	-	-	0.02	10	0.01
Comparative Examples	E	0.35	0.50	0.2	1.6	1.05	-	-	0.01	40	0.007
	F	0.35	0.51	0.2	0.6	1.04	-	-	0.01	40	0.007
	G	0.20	0.31	0.3	1.0	1.8	-	-	0.03	30	0.005
	H	0.20	0.31	0.3	1.0	0.7	-	-	0.03	30	0.005
	I	0.30	0.45	0.7	1.07	0.95	-	-	0.02	30	0.005
	J	0.30	0.46	0.03	1.06	0.93	-	-	0.02	30	0.005
	K	0.03	0.51	0.4	0.96	1.02	-	-	0.03	30	0.005
	L	0.6	0.50	0.4	0.95	1.03	-	-	0.03	30	0.005
	M	0.4	0.05	0.35	1.2	1.25	-	-	0.02	30	0.005
	N	0.4	0.80	0.34	1.21	1.24	-	-	0.02	30	0.005
* Total amount of other elements (Zr, Bi, Sn, Ga, V, Co, Ni, Ca, Mo, Be, Pb, and W)											

[0166]

TABLE 2

Example	Symbol	Al Alloy Symbol	1 st Soaking				2nd Soaking		Rough Hot Rolling		Finish Hot Rolling			Cold Rolling		
			Heating Speed (˚C/hr)	Soaking Temp. (˚C)	Holding Time (hr)	Cooling Speed (˚C/hr)	Soaking Temp. (˚C)	Holding Time (hr)	Start Temp. (˚C)	End Temp. (˚C)	Total Working Ratio (%)	End Temp. (˚C)	Sheet Thickness (mm)	Type of Rolling Mill	Draft (%)	Final Sheet Thickness (mm)
Working Examples	1	A	25	610	6	30	510	7	505	450	94	339	2.5	Tandem	88	0.3
	2	A	18	610	6	40	510	15	510	430	94	342	2.5	Tandem	88	0.3
	3	A	23	610	4	40	510	10	500	425	94	321	2	Tandem	88	0.3
	4	B	21	610	4	45	550	8	550	440	94	333	2.5	Tandem	88	0.3
	5	B	19	590	6	45	510	9	505	430	94	349	2.5	Tandem	88	0.3
	6	C	15	610	6	30	550	10	540	465	94	320	2	Tandem	85	0.3
Comparative Examples	7	A	40	610	10	40	450	6	440	410	94	302	2.5	Tandem	88	0.3
	8	C	40	610	10	40	530	4	530	490	94	360	2.5	Tandem	88	0.3
	9	A	40	610	8	40	500	8	495	380	90	291	2.5	Tandem	88	0.3
	10	D	40	610	8	40	500	8	490	420	94	332	2	Single	85	0.3
	11	E	40	610	8	40	500	8	499	465	94	339	2.5	Tandem	88	0.3
	12	F	40	610	8	40	500	8	489	447	94	334	2.5	Tandem	88	0.3
	13	G	40	610	8	40	500	8	478	440	94	331	2.5	Tandem	88	0.3
	14	H	40	610	8	40	500	8	494	485	94	319	2.5	Tandem	88	0.3
	15	I	40	610	8	40	500	8	496	469	94	312	2.5	Tandem	88	0.3
	16	J	40	610	8	40	500	8	472	465	94	325	2.5	Tandem	88	0.3
	17	K	40	610	8	40	500	8	500	472	94	303	2.5	Tandem	88	0.3
	18	L	40	610	8	40	500	8	485	445	94	325	2.5	Tandem	88	0.3
	19	M	40	610	8	40	500	8	494	463	94	330	2.5	Tandem	88	0.3
	20	N	40	610	8	40	500	8	495	420	94	327	2.5	Tandem	88	0.3

[0167]

TABLE 3

Example	Symbol	Al Alloy Symbol	Al Alloy Sheet Structure				Al Alloy Sheet High-temp. Properties							Al Alloy Sheet Formability		
			Average aspect ratio	Cu Solid Solution Quantity (%)	Mg Solid Solution Quantity (%)	Mn Solid Solution Quantity (%)	AS Hardness (Hv)	AB Hardness (Hv)	Hardness Reduction (ΔHv)	AS 0.2% Proof Stress (MPa)	AB 0.2% Proof Stress (MPa)	0.2% Proof Stress Reduction (ΔMPa)	Elliptic Deformation (mm)	Earing Rate (%)	Number of times of cracking occurrence in DI (times/ 50,000 cans)	Formability Evaluation
Working Examples	1	A	4.5	0.15	0.15	0.32	99	81	18	303	225	78	2.0	+3.0	1	○
	2	A	5.0	0.12	1.0	0.29	103	80	23	310	230	80	1.0	+1.0	0	◎
	3	A	3.5	0.09	1.05	0.36	95	78	17	302	227	75	1.0	+2.0	0	◎
	4	B	5.2	0.10	1.2	0.27	100	85	25	302	225	79	1.5	+1.0	0	◎
	5	B	5.5	0.07	1.0	0.20	99	85	13	296	220	76	1.8	+2.0	0	◎
	6	C	4.5	0.06	0.79	0.15	95	83	12	291	229	62	2.1	+2.2	1	○
Comparative Examples	7	A	4.0	0.03	0.7	0.1	105	73	32	316	212	104	5.1	+4.0	8	×
	8	C	4.1	0.1	0.95	0.2	103	73	30	301	225	76	4.8	-1.0	4	△
	9	A	4.3	0.05	0.71	0.21	106	76	30	311	210	101	4.5	+2.0	4	△
	10	D	2.5	0.08	0.98	0.15	105	71	34	318	220	98	5.1	+2.0	1	○
	11	E	6.5	0.06	0.78	0.45	121	75	46	325	224	101	5.1	+4.1	7	×
	12	F	4.8	0.05	0.8	0.09	92	71	21	285	202	83	4.5	+0.5	6	×
	13	G	5.7	0.15	1.7	0.21	120	76	44	335	230	105	5.0	-1.5	10	×
	14	H	4.8	0.13	0.6	0.22	95	73	22	295	210	85	4.8	-0.5	9	×
	15	I	5.0	0.4	0.85	0.28	110	74	36	315	220	95	5.5	+3.9	7	×
	16	J	4.8	0.01	0.79	0.30	100	71	29	303	211	92	4.2	+2.0	7	×
	17	K	3.9	0.25	0.88	0.36	95	72	22	290	203	97	4.5	-1.0	5	×
	18	L	3.7	0.28	0.90	0.33	106	71	35	304	222	82	5.0	+2.7	6	×
	19	M	3.4	0.23	1.05	0.28	98	72	26	287	201	86	5.1	-0.5	8	×
	20	N	4.1	0.25	1.08	0.25	105	75	30	312	223	89	5.0	-3.5	5	×

Example 2

[0168] Using aluminum metal alone as a melting raw material and using molten metal of alloy components in A.to N shown in Table 4 below, ingots each 600 mm thick by 2100 mm wide were produced by the DC casting method. In Table 4, the element content indicated by "-" represents that it is below the detection limit.

[0169] As shown in Table 4, in both working examples and comparative example, the ingots contained inevitable impurity elements Zr, Bi, Sn, Ga, V, Co, Ni, Ca, Mo, Be, Pb and W in total contents of 0.03% or more as the total amount of other elements.

[0170] The ingots were each subjected to a soaking treatment in accordance with the conditions shown in Table 5. The soaking treatment was conducted twice. That is, after the first soaking treatment, the ingot was cooled to room temperature at a cooling speed shown in Table 5, followed by re-heating to effect the second soaking treatment. The heating speed as a first soaking condition indicates a heating speed in the temperature range from 300˚C to the highest temperature which temperature range substantially exerts an influence on properties. The cooling speed as a first soaking condition indicates a cooling speed in the temperature range from the highest temperature to 300˚C which temperature range substantially exerts an influence on properties. After this soaking treatment, rough hot rolling was performed using a reversing rough hot rolling mill having one stand, followed by finish hot rolling using a tandem hot rolling mill having four stands. The finish hot rolling was started within three minutes after the end of rough hot rolling, and for controlling the foregoing anisotropic index, an average winding tension was controlled as in Table 5. In this way there were obtained hot rolled aluminum alloy sheets 2 to 2.5 mm in thickness as a common condition after finish hot rolling.

[0171] The hot rolled sheets were then subjected to cold rolling by only one pass with use of a tandem rolling mill having two stages of rolling stands without intermediate annealing to afford sheets (cold rolled sheets) for bottle can body 0.3 mm in final thickness as a common condition. In the cold rolling by the tandem rolling mill, the temperature of each aluminum sheet just after cold rolling was controlled to 130-200˚C. Finish annealing (final annealing) after this cold rolling was not conducted.

[0172] In only comparative example 110, two passes were performed in a single rolling mill having one stage of rolling stand and intermediate annealing of 150˚C × 1 hour was performed between the first and the second pass for comparison purpose although the total draft in cold rolling was the same.

[0173] A test piece was sampled from each sheet (coil) for a bottle can body after cold rolling and the structure thereof was checked. More particularly, an average aspect ratio of crystal grains and tensile properties were checked. These results are shown in Table 6.

[0174] For determining high temperature properties of the test piece, hardness and 0.2% proof stress of the test piece surface at room temperature, as well as hardness and 0.2% proof stress of the test piece surface in 290˚C × 20 sec. heat treatment of the test piece, were measured and a change in hardness (hardness reduction) ΔHv(Hv) of the test piece surface before and after this heat treatment was determined. Tensile test was conducted under the following conditions and in 0˚ direction relative to the rolling direction. Further, an elliptic deformation quantity upon bake-hardening of the can body after forming was measured. These results are also shown in Table 6.

(Anisotropy Measurement by Tensile Test)

[0175] Tensile test of each test piece was conducted in accordance with JIS Z 2201 and, as the test piece shape, there was used the shape of JIS No. 5 test piece. Crosshead speed was 5 mm/min and a constant speed was adopted until breakage of the test piece. In this case, there were provided test pieces whose longitudinal directions were 0˚, 45˚ and 90˚ directions respectively relative to the rolling direction and tensile strength and n value of each of the test pieces were determined. There were determined a difference (MPa) between maximum and minimum values of tensile strength and a difference between maximum and minimum values of the n values (strain quantities in the range of between 2% and 4%). Mean values in the above directions of both tensile strength and n values were also determined.

(Hardness Measurement)

[0176] Each cold rolled sheet sample was measured for hardness at four positions under the application of 100 g load and a mean value of the measured values was used as the hardness value.

(Evaluation of Elliptic Deformation)

[0177] For evaluation of elliptic deformation, as will be described later, a bottle can body obtained by DI of the above sheet for a bottle can body was washed and then baked under the condition that the bodily temperature of the can should reach 300˚C in 30 seconds, then the degree of elliptic deformation was checked. For checking the degree of elliptic deformation, the diameter of the mouth portion of the bottle can body was checked successively in the circum-

ferential direction, then an amount obtained by subtracting the minimum value from the maximum value was determined as an elliptic deformation quantity (mm), and evaluation was made using a mean value from N = 10 cans. In the case where the elliptic deformation quantity is 4 mm or less, it was evaluated that the elliptic deformability came up to a passing point. If the elliptic deformation quantity exceeds 4 mm, there will occur defects such as falling-down and jam during conveyance and necking as post-steps in the can manufacturing process, thus making continuous and efficient manufacture of cans difficult.

[0178] Further, as formability which the sheet for bottle can body should satisfy basically, both earing rate and DI formability (the number of times of cracking in forming) were measured and evaluated, the results of which are also shown in Table 6.

(Earing Rate)

[0179] For checking the earing rate, in the same way as in Example 1, a blank was sampled from the sheet for bottle can body and lubricating oil (Nalco 147, a product of D.A. Stuart Co.) was applied thereto, then the blank was subjected to 40% deep drawing test and formed into a cup for investigation, using an Erichsen tester. The test was performed under the same conditions as in Example 1 and an average earing rate was calculated.

(DI Formability)

[0180] In the same manner as in Example 1 the number of body-cracked cans per 50,000 formed cans was determined and DI formability was evaluated. The evaluation was made in accordance with the following criterion. ◎: no cracked can (extremely good), ○: one cracked can or less (good), Δ: two to four cracked cans (generally good), X: more than five cracked cans (bad).

[0181] As is apparent from Table 6, working examples 101 to 106 have compositions according to the present invention, average aspect ratios of crystal grains therein are 3 ore more, the difference between maximum and minimum values in tensile strength in 0˚, 45˚ and 90˚ directions relative to the rolling direction is 25 MPa or less, and the difference between maximum and minimum values among n values obtained by tensile tests in 0˚, 45˚ and 90˚ directions relative to the rolling direction is 0.03 or less. Thus, the structures obtained in these working examples are less anisotropic.

[0182] In working examples 101 to 106, as is seen from Table 6, after heat treatment at 290˚C for 20 seconds (after bake-hardening), the hardness change ΔHV is 30 Hv or less, 0.2% proof stress is 215 MPa or more, there is little lowering of hardness and strength, and high-temperature properties are excellent.

[0183] Working examples 101 to 106 are superior also in earing rate and DI formability. Thus, it is seen that the improvement of high-temperature properties in the present invention does not impair the formability which the sheet for a bottle can body should satisfy basically.

[0184] From the above results, critical meanings of the conditions defined in the second invention can be understood.

[0185]

TABLE 4

Example	Symbol	Al Alloy Chemical Components (mass %, provided B is in ppm, balance Al)									
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	B	Total amount of other elements *
Working Examples	A	0.27	0.45	0.23	1.03	1.23	-	-	-	-	0.03
	B	0.27	0.46	0.19	1.02	1.22	0.03	0.19	0.03	0	0.03
	C	0.26	0.43	0.21	0.94	0.94	0.03	0.2	0.02	10	0.04
	D	0.33	0.44	0.11	1.31	1.00	-	-	0.02	10	0.05

(continued)

Example	Symbol	Al Alloy Chemical Components (mass %, provided B is in ppm, balance Al)									
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	B	Total amount of other elements *
Comparative Examples	E	0.41	0.51	0.41	1.6	1.01	-	-	0.01	40	0.04
	F	0.22	0.45	0.26	0.6	1.01	-	-	0.01	40	0.04
	G	0.13	0.25	0.31	1.01	1.80	-	-	0.03	30	0.03
	H	0.12	0.23	0.33	1.02	0.70	-	-	0.03	30	0.03
	I	0.31	0.47	0.71	1.11	0.96	-	-	0.02	30	0.03
	J	0.14	0.43	0.03	1.05	0.95	-	-	0.02	30	0.03
	K	0.03	0.52	0.42	0.92	1.05	-	-	0.03	30	0.03
	L	0.61	0.42	0.41	0.96	1.04	-	-	0.03	30	0.03
	M	0.34	0.05	0.36	1.21	1.15	-	-	0.02	30	0.03
	N	0.25	0.8	0.33	0.99	1.21	-	-	0.02	30	0.03
* Total amount of other elements (Zr, Bi, Sn, Ga, V, Co, Ni, Ca, Mo, Be, Pb, and W)											

[0186]

TABLE 5

Example	Symbol	Al Alloy Symbol	1st Soaking				2nd Soaking		Rough Hot Rolling		Finish Hot Rolling				Cold Rolling			
			Heating Speed (˚C/hr)	Soaking Temp. (˚C)	Holding Time (hr)	Cooling Speed (˚C/hr)	Soaking Temp. (˚C)	Holding Time (hr)	Start Temp. (˚C)	End Temp. (˚C)	Total Working Ratio (%)	End Temp. (˚C)	Average Winding Tension (MPa)	Sheet Thickness (mm)	Type of Rolling Mil	Draft (%)	Sheet Temp. just after Cold Rolling (˚C)	Final Sheet Thickness (mm)
Working Examples	101	A	25	610	6	40	510	7	503	460	94	341	22	2.5	Tandem	88	147	0.3
	102	A	23	610	6	35	510	15	512	440	94	341	25	2.5	Tandem	88	163	0.3
	103	A	25	610	4	45	510	10	500	450	94	320	30	2.5	Tandem	88	148	0.3
	104	B	24	610	6	50	550	4	545	480	94	332	20	2.5	Tandem	88	145	0.3
	105	B	22	590	8	40	510	7	505	466	94	350	25	2.5	Tandem	88	140	0.3
	106	C	16	610	4	35	550	10	543	460	94	321	25	2.5	Tandem	88	150	0.3
Comparative Examples	107	A	40	610	10	40	510	6	503	435	94	320	10	2.5	Tandem	88	153	0.3
	108	C	40	610	9	40	530	4	491	430	94	300	20	2.5	Tandem	88	149	0.3
	109	A	40	610	8	40	500	8	491	388	90	360	15	2.5	Tandem	88	155	0.3
	110	D	40	610	8	40	500	8	495	460	94	333	20	2.5	Tandem	85	80	0.3
	111	E	40	610	8	40	500	8	490	470	94	341	20	2.5	Tandem	88	149	0.3
	112	F	40	610	8	40	500	8	490	454	94	333	20	2.5	Tandem	88	133	0.3
	113	G	40	610	8	40	500	8	490	454	94	335	20	2.5	Tandem	88	149	0.3
	114	H	40	610	8	40	500	8	494	488	94	321	20	2.5	Tandem	88	151	0.3
	115	I	40	610	8	40	500	8	495	460	94	314	20	2.5	Tandem	88	155	0.3
	116	J	40	610	8	40	500	8	488	459	94	324	20	2.5	Tandem	88	141	0.3
	117	K	40	610	8	40	500	8	498	462	94	302	20	2.5	Tandem	88	153	0.3
	118	L	40	610	8	40	500	8	482	453	94	322	20	2.5	Tandem	88	149	0.3
	119	M	40	610	8	40	500	8	491	450	94	328	20	2.5	Tandem	88	153	0.3
	120	N	40	610	8	40	500	8	495	420	94	320	20	2.5	Tandem	88	141	0.3

[0187]

TABLE 6

Example	Symbol	Al Alloy Symbol	Al Alloy Sheet Structure					Al Alloy Sheet High-temp. Properties							Al Alloy Sheet Formability		
			Average aspect ratio	Average Tensile Strength (MPa)	Anisotropy of Tensile Strength *1	Mean n Value	Anisotropy of n Value *2	AS Hardness (Hv)	AB Hardness (Hv)	Hardness Reduction (ΔHv)	AS 0.2% Proof Stress (MPa)	AB 0.2% Proof Stress (MPa)	0.2% Proof Stress Reduction (ΔMPa)	Elliptic Deformation (mm)	Earing Rate (%)	Number of times of cracking occurrence In DI (times/ 50,000 cans)	Formability Evaluation
Working Examples	101	A	4.7	320	15	0.07	0.01	98	82	16	294	224	70	1.0	+2.0	0	◎
	102	A	5.1	330	17	0.072	0.015	99	81	18	296	228	68	1.1	+1.1	0	◎
	103	A	3.7	320	20	0.074	0.02	100	79	21	301	225	76	1.2	+2.0	0	◎
	104	B	5.0	326	15	0.076	0.01	99	86	13	288	224	64	1.8	+1.1	0	◎
	105	B	5.6	322	10	0.078	0.004	98	86	12	295	223	72	1.4	+2.2	0	◎
	106	C	4.7	319	11	0.080	0.006	96	85	11	290	226	64	2.0	+2.0	0	◎

(continued)

Example	Symb ol	Al Alloy Symbol	Al Alloy Sheet Structure					Al Alloy Sheet High-temp. Properties							Al Alloy Sheet Formability		
			Average aspect ratio	Average Tensile Strength (MPa)	Anisotropy of Tensile Strength *1	Mean n Value	Anisotropy of n Value *2	AS Hard ness (Hv)	AB Hard ness (Hv)	Hardness Reduction (ΔHv)	AS 0.2% Proof Stress (MPa)	AB 0.2% Proof Stress (MPa)	0.2% Proof Stress Reduction (ΔMPa)	Elliptic Deformation (mm)	Earin g Rate (%)	Number of times of cracking occurrence In DI (times/ 50,000 cans)	Formability Evaluation
Comparative Examples	107	A	4.1	322	30	0.075	0.035	103	72	31	299	212	77	4.9	+4.1	6	×
	108	C	4.3	326	21	0.072	0.032	101	72	29	301	225	76	4.5	-1.0	3	△
	109	A	4.6	325	35	0.070	0.035	98	70	28	290	210	80	4.0	+3.9	2	△
	110	D	2.2	328	28	0.078	0.030	104	70	34	308	220	88	5.3	+2.2	1	○
	111	E	6.3	330	30	0.076	0.030	116	73	43	315	224	91	5.0	+4.2	6	×
	112	F	4.6	320	27	0.069	0.032	93	70	23	275	202	73	4.7	+0.6	5	×
	113	G	5.5	340	31	0.072	0.032	110	73	47	325	230	95	4.9	-1.7	9	×
	114	H	4.5	315	32	0.079	0.033	93	71	22	285	210	75	4.7	-0.6	8	×
	115	I	5.2	325	32	0.080	0.025	105	72	33	305	220	85	5.4	+3.8	8	×
	116	J	4.9	322	32	0.070	0.029	99	70	29	293	211	82	4.1	+1.8	8	×
	117	K	4.0	310	33	0.078	0.024	94	71	23	280	203	87	4.7	-1.1	6	×
	118	L	3.6	325	31	0.068	0.020	100	70	30	294	222	72	4.9	+2.8	7	×
	119	M	3.7	311	31	0.071	0.033	94	69	25	277	201	76	5.3	-0.6	7	×
	120	N	4.0	330	30	0.075	0.035	100	72	28	302	223	79	4.9	+3.7	5	×

*1...Anisotropy of Tensile Strength: Difference between maximum and minimum values of tensile strength in 0°, 45° and 90° directions relative to the rolling direction.
*2...Anisotropy of n Value: Difference between maximum and minimum values among n values obtained by tensile tests in 0°, 45° and 90° directions relative to the rolling direction.

Example 3

[0188] Using aluminum metal alone as a melting raw material and using molten metal of alloy components in A to N shown in Table 7 below, ingots each 600 mm thick by 2100 mm wide were produced by the DC casting method. In Table 7, the element content indicated by "-" represents that it is below the detection limit.

[0189] As shown in Table 7, in both working examples and comparative examples, the ingots contained inevitable impurity elements Zr, Bi, Sn, Ga, V, Co, Ni, Ca, Mo, Be, Pb and W in total contents of 0.03% or less as the total amount of other elements.

[0190] Therefore, first an alloying design satisfying strength and formability required of the cold rolled aluminum alloy sheet for a bottle can was made by designing balance of main constituent elements (Mn, Mg, Fe, Cu, Si) and selective added elements. Thereafter, a thermodynamic equilibrium phase diagram calculation in each example was made to effect control of ΔT, thereby calculating the solid-liquid coexistence temperature range ΔT of aluminum to make an alloying design or modification. There were obtained such actual aluminum alloy components' compositions in A to N as shown in Table 7.

[0191] Ingots of the said compositions were subjected to a soaking treatment in accordance with the conditions shown in Table 8. The soaking treatment was conducted twice. More specifically, after the first soaking treatment, each ingot was cooled to room temperature at a cooling speed shown in Table 8, followed by re-heating to effect the second soaking treatment.

[0192] The heating speed as a first soaking condition indicates a heating speed in the temperature range from 300˚C to the highest temperature which temperature range substantially exerts an influence on properties. The cooling speed as a first soaking condition indicates a cooling speed in the temperature range from the highest temperature to 300˚C which temperature range substantially exerts an influence on properties. After this soaking treatment, rough hot rolling was performed using a reversing rough hot rolling mill having one stand, followed by finish hot rolling using a tandem hot rolling mill having four stands. The finish hot rolling was started within three minutes after the end of rough hot rolling. In this way there were obtained hot rolled aluminum alloy sheets 2.5 mm in thickness as a common condition after finish hot rolling.

[0193] The hot rolled sheets were then subjected to cold rolling by only one pass with use of a tandem rolling mill having two stages of rolling stands without intermediate annealing to afford sheets (cold rolled sheets) for bottle can body 0.3 mm in final thickness as a common condition. In the cold rolling by the tandem rolling mill, the aluminum sheets were cooled forcibly using an aqueous emulsion so as to prevent the aluminum sheet temperature just after cold rolling from rising to a temperature exceeding 250˚C. Finish annealing (final annealing) after this cold rolling was not conducted.

[0194] In only comparative example 210, two passes were performed in a single rolling mill having one stage of rolling stand and intermediate annealing of 150˚C $\times$ 1 hour was performed between the first and the second pass for comparison purpose although the total draft in cold rolling was the same.

[0195] A test piece was sampled from each sheet (coil) for a bottle can body after cold rolling and the structure thereof was checked. More particularly, an average aspect ratio of crystal grains, an average size (central part in the through-thickness direction) of intermetallic compounds of 0.5 μm or more, and the solid-liquid coexistence temperature range ΔT, were checked by differential thermal analysis, the results of which are shown in Table 9.

[0196] For determining high temperature properties of the test piece, hardness and 0.2% proof stress of the test piece surface at room temperature, as well as hardness and 0.2% proof stress of the test piece surface in 290˚C $\times$ 20 sec. heat treatment of the test piece, were measured and a change in hardness (hardness reduction) ΔHv (Hv) of the test piece before and after the heat treatment was determined. Further, an elliptic deformation quantity upon bake-hardening of the can body after forming was measured. These results are also shown in Table 9.

(Measurement of 0.2% Proof Stress)

[0197] Tensile test for measuring 0.2% proof stress was conducted in the same way as in Example 1 and in accordance with JIS Z 2201 and, as the test piece shape, there was used the shape of JIS No. 5 test piece. The test piece was obtained in such a manner that its longitudinal direction was coincident with the rolling direction. Crosshead speed was 5 mm/min and a constant speed was adopted until breakage of the test piece.

(Hardness Measurement)

[0198] Each cold rolled sheet sample was measured for hardness at four positions under the application of 100 g load by means of a micro Vickers hardness tester and a mean value of the measured values was used as the hardness value.

(Evaluation of Elliptic Deformation)

[0199] As will be described later, evaluation of elliptic deformation was made in the same way as in Example 1.

[0200] Further, as formability which the sheet for bottle can body should satisfy basically, both earing rate and DI formability (the number of times of cracking in forming) were measured and evaluated, the results of which are also shown in Table 9.

(Earing Rate)

[0201] For checking the earing rate, as in Example 1, a blank was sampled from the sheet for bottle can body and lubricating oil (Nalco 147, a product of D.A. Stuart Co.) was applied thereto, then the blank was subjected to 40% deep drawing test and formed into a cup for investigation, using an Erichsen tester. The test was performed under the following conditions: blank dia. 66.7 mm, punch dia. 40 mm, R of the die-side shoulder portion 2.0 mm, punch shoulder R 3.0 mm, blank holder pressure 400 kgf.

[0202] Mountain-valley shapes formed in eight directions (0˚, 45˚, 90˚, 135˚, 180˚, 225˚, 270˚ and 315˚ directions, assuming that the rolling direction is 0˚) in the peripheral edge portion of the opening of the cup thus obtained were measured and an average earing rate was calculated.

[0203] How to calculate the earing rate is as described in Example 1.

(DI Formability)

[0204] In the same way as in Example 1 the number of body-cracked cans per 50,000 formed cans was determined and DI formability was evaluated. The evaluation was made in accordance with the following criterion. ◎: no cracked can (extremely good), ○: one cracked can or less (good), △: two to four cracked cans (generally good), X: more than five cracked cans (bad).

[0205] As is apparent from Table 9, working examples 201 to 206 have compositions according to the present invention and have structures such that an average particle size of 0.5 μm or larger dispersed particles with an aspect ratio of crystal grains of 3 or more is 5 μm or less, and solid-liquid coexistence temperature range ΔT of aluminum is 40˚ or lower.

[0206] Thus, in working examples 201 to 206, as is seen from Table 9, after heat treatment at 290˚C for 20 seconds (after bake-hardening), the hardness change ΔHv is 30 Hv or less, 0.2% proof stress is 270 MPa or more, there is little lowering of hardness and strength, and high-temperature properties are excellent.

[0207] Working examples 201 to 206 are superior also in earing rate and DI formability. Thus, it is seen that the improvement of high-temperature properties in the present invention does not impair the formability which the sheet for bottle can body should satisfy basically.

[0208] On the other hand, in comparative examples 207 to 210, conditions for soaking and hot rolling do not fall under the foregoing preferred conditions, although the compositions adopted therein fall under those defined in the present invention, so that any of the average aspect ratio of crystal grains, the average particle size of dispersed grains 0.5 μm or more in particle size, and ΔT, deviates from the range defined in the present invention. As a result, in comparison with the foregoing working examples, a lowering of hardness and that of strength are marked and high-temperature properties are inferior.

[0209] In comparative example 207, the second soaking temperature is too low and so is the end temperature in finish hot rolling. In comparative example 208, the end temperature in finish hot rolling is too low. In comparative example 209, the end temperature in finish hot rolling is too low. In comparative example 210, intermediate annealing was performed halfway of cold rolling.

[0210] Comparative examples 211 to 220 follow preferred manufacturing conditions. However, alloy compositions used therein deviate from those defined in the present invention. As a result, any of the average aspect ratio of crystal grains, the average particle size of 0.5 μm or larger dispersed particles, and ΔT, deviates from the range defined in the present invention. Consequently, in comparison with the working examples, a lowering of hardness and that of strength are marked and high-temperature properties are inferior. Formability is also low.

[0211] From the above results, critical meanings of the conditions defined in the present invention can be understood.

[0212]

TABLE 7

Example	Symbol	Al Alloy Chemical Components (mass %, provided B is in ppm, balance Al)									
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	B	Total amount of other elements *
Working Examples	A	0.25	0.44	0.21	1.05	1.2	-	-	-	-	0.03
	B	0.26	0.44	0.21	1.04	1.21	0.03	0.19	0.03	0	0.03
	C	0.25	0.42	0.2	0.9	0.9	0.03	0.2	0.02	10	0.04
	D	0.3	0.45	0.1	1.3	1	-	-	0.02	10	0.05
Comparative Examples	E	0.4	0.5	0.4	1.6	1	-	-	0.01	40	0.04
	F	0.2	0.4	0.2	0.6	1	-	-	0.01	40	0.04
	G	0.1	0.2	0.3	1	1.8	-	-	0.03	30	0.03
	H	0.1	0.2	0.3	1	0.7	-	-	0.03	30	0.03
	I	0.3	0.4	0.7	1.1	0.9	-	-	0.02	30	0.03
	J	0.12	0.45	0.03	1.05	0.97	-	-	0.02	30	0.03
	K	0.03	0.5	0.4	0.9	1	-	-	0.03	30	0.03
	L	0.6	0.4	0.4	0.95	1.05	-	-	0.03	30	0.03
	M	0.3	0.05	0.35	1.2	1.1	-	-	0.02	30	0.03
	N	0.2	0.8	0.33	0.99	1.2	-	-	0.02	30	0.03
* Total amount of other elements (Zr, Bi, Sn, Ga, V, Co, Ni, Ca, Mo, Be, Pb, and W)											

[0213]

TABLE 8

Example	Symbol	Al Alloy Symbol	1st Soaking				2nd Soaking		Rough Hot Rolling		Finish Hot Rolling			Cold Rolling		
			Heating Speed (˚C/hr)	Soaking Temp. (˚C)	Holding Time (hr)	Cooling Speed (˚C/hr)	Soaking Temp. (˚C)	Holding Time (hr)	Start Temp. (˚C)	End Temp. (˚C)	Total Working Ratio (%)	End Temp. (˚C)	Sheet Thickness (mm)	Type of Rolling Mill	Draft (%)	Final Sheet Thickness (mm)
Working Examples	201	A	21	610	6	40	510	7	505	460	92	341	2.5	Tandem	88	0.3
	202	A	20	610	8	35	510	15	510	440	92	341	2.5	Tandem	88	0.3
	203	A	25	610	4	45	510	10	500	450	92	320	2.5	Tandem	88	0.3
	204	B	22	610	6	50	510	4	510	470	92	332	2.5	Tandem	88	0.3
	205	B	20	590	8	40	550	7	550	480	92	340	2.5	Tandem	88	0.3
	206	C	15	610	6	35	510	10	510	460	92	321	2.5	Tandem	88	0.3
Comparative Examples	207	A	40	610	10	40	450	6	450	401	92	300	2.5	Tandem	88	0.3
	208	C	40	610	9	40	530	4	490	430	92	300	2.5	Tandem	88	0.3
	209	A	40	610	8	40	500	8	490	330	88	290	2.5	Tandem	88	0.3
	210	D	40	610	8	40	500	8	498	450	92	333	2.5	Tandem	88	0.3
	211	E	40	610	8	40	500	8	500	460	92	341	2.5	Tandem	88	0.3
	212	F	40	610	8	40	500	8	488	444	92	333	2.5	Tandem	88	0.3
	213	G	40	610	8	40	500	8	476	443	92	335	2.5	Tandem	88	0.3
	214	H	40	610	8	40	500	8	497	487	92	321	2.5	Tandem	88	0.3
	215	I	40	610	8	40	500	8	499	467	92	314	2.5	Tandem	88	0.3
	216	J	40	610	8	40	500	8	476	460	92	324	2.5	Tandem	88	0.3
	217	K	40	610	8	40	500	8	501	470	92	302	2.5	Tandem	88	0.3
	218	L	40	610	8	40	500	8	480	443	92	322	2.5	Tandem	88	0.3
	219	M	40	610	8	40	500	8	490	460	92	329	2.5	Tandem	88	0.3
	220	N	40	610	8	40	500	8	495	470	92	325	2.5	Tandem	88	0.3

[0214]

TABLE 9

Example	Symbol	Al Alloy Symbol	Al Alloy Sheet Structure			Al Alloy Sheet High-temp. Properties							Al Alloy Sheet Formability		
			Average aspect ratio	Average Particle Size of Dispersion Particles (μm)	ΔT (˚C)	AS Hardness (Hv)	AB Hardness (Hv)	Hardness Reduction (ΔHv)	AS 0.2% Proof Stress (MPa)	AB 0.2% Proof Stress (MPa)	0.2% Proof Stress Reduction (ΔMPa)	Elliptic Deformation (mm)	Earing Rate (%)	Number of times of cracking occurrence in DI (times/ 50,000	Formability Evaluation
Working Examples	201	A	4.1 1	4.3	36	98	75	23	300	220	80	3.1	+3.2	cans) 1	○
	202	A	3.9	4.8	36	105	77	28	310	225	88	1.9	+1.5	1	○
	203	A	3.8	4.3	36	98	80	18	300	230	70	2.0	+1,9	0	◎
	204	B	5.5	3.8	33	103	88	25	300	222	78	2.8	+2	0	◎
	205	B	5.4	3.8	33	100	82	28	297	220	77	1.5	+3	1	○
	206	C	4.1	3.6	27	95	80	15	290	230	60	1.1	+1.9	0	◎
Comparative Examples	207	A	3.9	4.4	36	107	74	33	315	210	95	4.5	+3.7	7	×
	208	C	4.2	3.7	27	105	75	30	300	213	87	5.0	+4.3	3	△
	209	A	4.2	4.0	36	106	75	31	310	211	89	4.3	+2.5	4	△
	210	D	2.7	4.8	39	105	70	35	320	210	110	5.0	+1.8	1	O
	211	E	6.3	5.4	43	120	75	45	325	212	113	6.0	+4	8	×
	212	F	4.5	3.7	32	90	70	20	280	200	80	5.0	+1	7	×
	213	G	5.5	5.8	47	125	77	48	330	213	117	5.0	-1	9	×
	214	H	5.0	4.0	33	95	72	23	290	205	85	5.0	-1	8	×
	215	I	4.8	5.5	44	110	75	35	320	210	110	5.3	+3.8	6	×
	216	J	4.7	3.5	30	100	70	30	300	210	90	4.5	+2.0	5	×
	217	K	4.0	3.6	31	95	71	24	285	200	85	5.2	-1.0	6	×
	218	L	3.8	5.9	45	105	70	35	305	212	93	5.2	+2.6	5	×
	219	M	3.5	4.8	38	95	70	25	285	200	85	5.2	-0.5	7	×
	220	N	4.0	3.5	30	110	74	31	315	215	100	5.0	+3.3	5	×

Industrial Applicability

[0215] According to the present invention, as set forth above, it is possible to provide a cold rolled aluminum alloy sheet for a bottle can which, on the premise that formability in DI, etc. is to be secured, even in a high-speed heat treatment performed at a higher temperature for a shorter time, can be prevented from being thermally deformed in coating and heat treatment, can ensure required can strength after heat treatment, and can afford a bottle can high in true circularity, and which has excellent high-temperature properties. Thus, the cold rolled aluminum alloy sheet of the present invention is suitable for such applications as require strict properties while retaining formability intact.

1. An aluminum alloy sheet for bottle cans superior in high-temperature properties, the aluminum alloy sheet comprising the following composition: Mn 0.7-1.5% (mass %, also in the following), Mg 0.8-1.7%, Fe 0.1-0.7%, Si 0.05-0.5%, Cu 0.1-0.6%, with the remainder being Al and inevitable impurities, and comprising a crystal structure elongated in a rolling direction and with an average aspect ratio of crystal grains of 3 or more as determined through an examination from above of a part located at the center in the through-thickness direction, wherein the amount of solute Cu is 0.05-0.3%, which means the amount of Cu in a solution separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol, and the amount of solute Mg is 0.75-1.6%, which means the amount of solute Mg separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol.

2. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to item 1, wherein the difference between a maximum value and a minimum value of tensile strength in 0˚, 45˚ and 90˚ directions relative to the rolling direction is 25 MPa or less and the difference between a maximum value and a minimum value of n values obtained by tensile tests in 0˚, 45˚ and 90˚ directions relative to the rolling direction is 0.03 or less.

3. An aluminum alloy sheet for bottle cans superior in high-temperature properties, wherein an average particle size of 0.5 μm or larger dispersed particles in the aluminum alloy sheet is 5 μm or smaller, and ΔT indicative of a solid-liquid coexistence temperature range between liquid and solid phases of aluminum is 40˚C or less.

4. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to any of items 1 to 3, further comprising 0.001-0.3% of Cr and/or 0.05-1.0% of Zr.

5. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to any of items 1 to 4, further comprising 0.005-0.2% of Ti alone or in combination with 0.0001-0.05% of B.

6. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to any of items 1 to 3, wherein the amount of solute Mn is 0.12-0.38%, which means the amount of solute^{Mn} separated from a precipitate exceeding 0.2 μm in particle size by the extracted residue method using hot phenol.

7. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to any of items 1 to 6, wherein when the aluminum alloy sheet is subjected to a heat treatment at 290˚C for 20' seconds, a change in hardness, ΔHv, of the aluminum alloy sheet before and after the heat treatment is 30 Hv or less, and 0.2% proof stress of the aluminum alloy sheet after the heat treatment is 215 MPa or more.

8. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to any of items 1 to 7, which is a cold rolled aluminum alloy sheet obtained by subjecting a hot rolled aluminum alloy sheet to cold rolling up to a final sheet without intermediate annealing.

9. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to any of items 1 to 8, wherein when the aluminum alloy sheet is subjected to a heat treatment at 290˚C for 20 seconds, a change in hardness, ΔHv, of the aluminum alloy sheet before and after the heat treatment is 30 Hv or less, and 0.2% proof stress of the aluminum alloy sheet after the heat treatment is 215 MPa or more.

10. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to any of items 1 to 9, which is a cold rolled aluminum alloy sheet obtained by subjecting a hot rolled aluminum alloy sheet to cold rolling up to a final sheet without intermediate annealing.

11. An aluminum alloy sheet for bottle cans superior in high-temperature properties, the aluminum alloy sheet comprising the following composition: Mn 0.7-1.5% (mass %, also in the following), Mg 0.8-1.7%, Fe 0.1-0.7%, Si

0.05-0.5%, Cu 0.1-0.6%, with the remainder being Al and inevitable impurities, and comprising a crystal structure elongated in a rolling direction and with an average aspect ratio of crystal grains of 3 or more as determined through an examination from above of a part located at the center in the through-thickness direction, wherein the difference between a maximum value and a minimum value of tensile strength in 0˚, 45˚ and 90˚ directions relative to the rolling direction is 25 MPa or less, and a difference between a maximum value and a minimum value of n values obtained by tensile tests in 0˚, 45˚ and 90˚ directions relative to the rolling direction is 0.03 or less.

12. An aluminum alloy sheet for bottle cans superior in high-temperature properties, the aluminum alloy sheet comprising the following composition: Mn 0.7-1.5% (mass %, also in the following), Mg 0.8-1.7%, Fe 0.1-0.7%, Si 0.05-0.5%, Cu 0.1-0.6%, with the remainder being Al and inevitable impurities, and comprising a crystal structure elongated in a rolling direction and with an aspect ratio of crystal grains of 3 or more as determined through an examination from above of a part located at the center in the through-thickness direction, wherein an average particle size of 0.5 μm or larger dispersed particles in the aluminum alloy sheet is 5 μm or smaller, and ΔT indicative of a solid-liquid coexistence temperature range between liquid and solid phases of aluminum is 40˚C or less.

13. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to items 11 or claim 12, further comprising 0.001-0.3% of Cr and/or 0.05-1.0% of Zn.

14. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to any of items 11 to 13, further comprising 0.005-0.2% of Ti alone or in combination with 0.0001-0.05% of B.

Claims

1. An aluminum alloy sheet for bottle cans superior in high-temperature properties, the aluminum alloy sheet comprising the following composition: Mn 0.7-1.5% (mass %, also in the following), Mg 0.8-1.7%, Fe 0.1-0.7%, Si 0.05-0.5%, Cu 0.1-0.6%, with the remainder being Al and inevitable impurities, and comprising a crystal structure elongated in a rolling direction and with an aspect ratio of crystal grains of 3 or more as determined through an examination from above of a part located at the center in the through-thickness direction, wherein an average particle size of 0.5 μm or larger dispersed particles in the aluminum alloy sheet is 5 μm or smaller, and ΔT indicative of a solid-liquid coexistence temperature range between liquid and solid phases of aluminum is 40˚C or less.

2. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to claim 1, further comprising 0.001-0.3% of Cr and/or 0.05-1.0% of Zn.

3. An aluminum alloy sheet for bottle cans superior in high-temperature properties according to claim 1 or 2, further comprising 0.005-0.2% of Ti alone or in combination with 0.0001-0.05% of B.

FIG.1

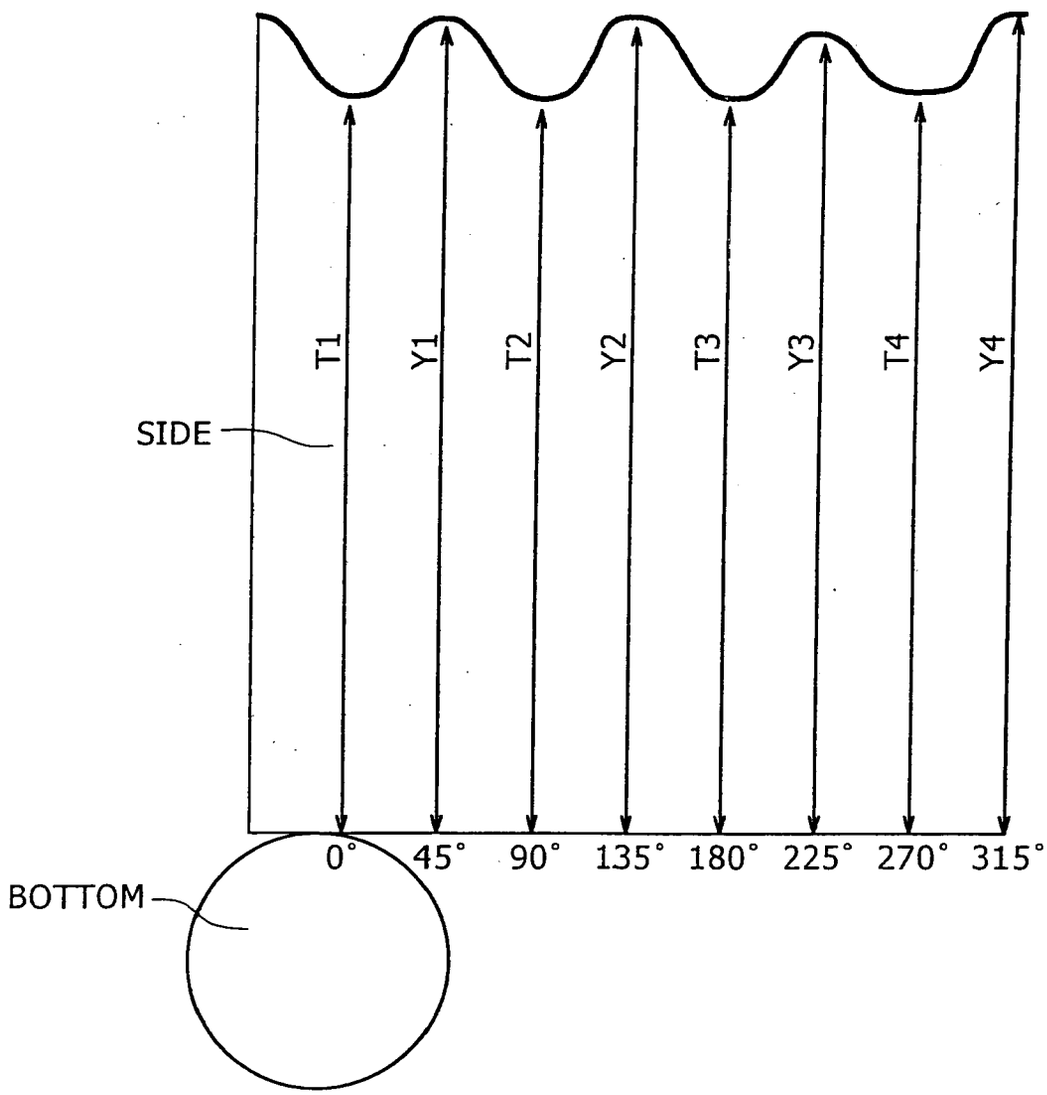


FIG. 2

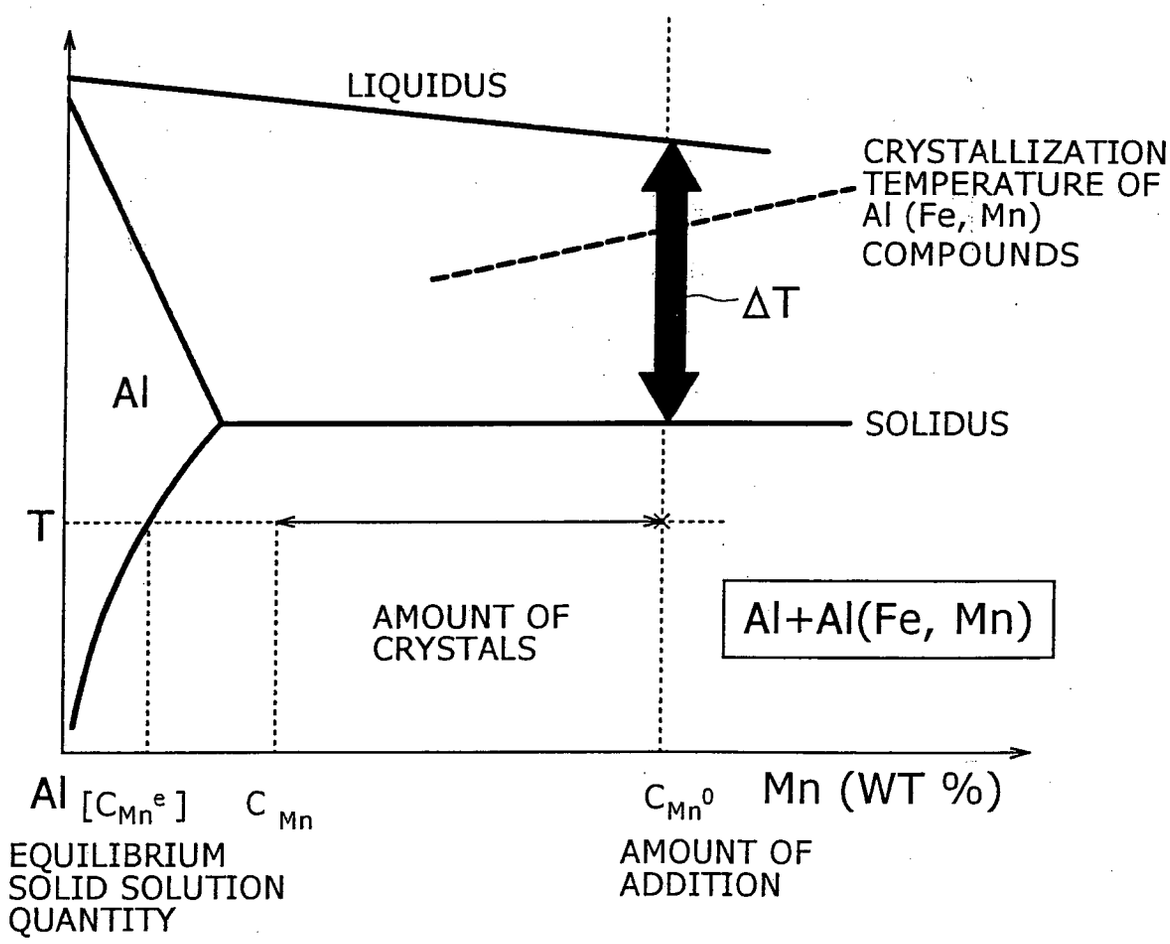
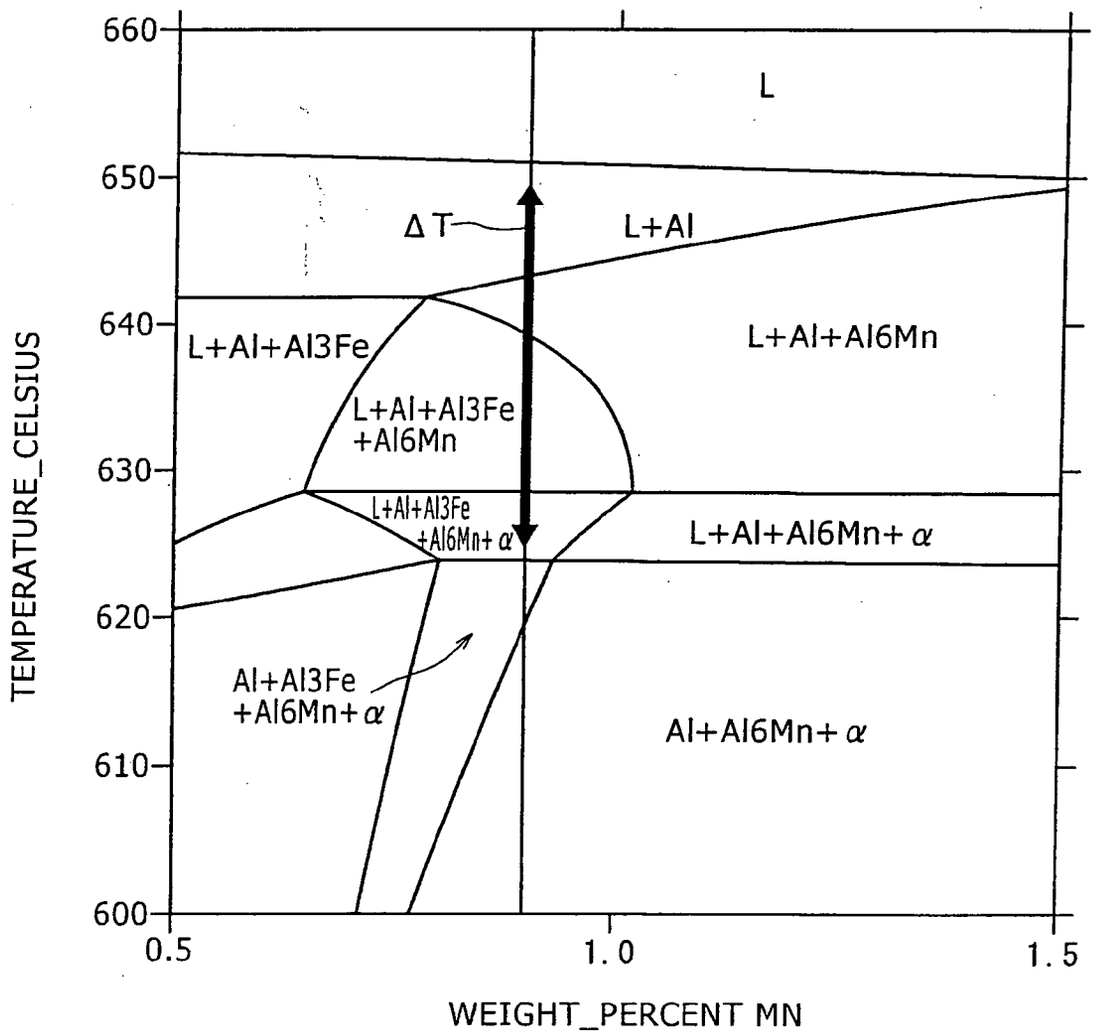

LIQUIDUS
CRYSTALLIZATION TEMPERATURE OF Al (Fe, Mn) COMPOUNDS
ΔT
Al
SOLIDUS
T
AMOUNT OF CRYSTALS
Al+Al(Fe, Mn)
Al [C_Mn^e]
C_Mn
C_Mn^0
Mn (WT %)
EQUILIBRIUM SOLID SOLUTION QUANTITY
AMOUNT OF ADDITION

FIG. 3


660
650
640
630
620
610
600
TEMPERATURE_CELSIUS
0.5
1.0
1.5
WEIGHT_PERCENT MN
L
ΔT
L+Al
L+Al+Al3Fe
L+Al+Al6Mn
L+Al+Al3Fe
+Al6Mn
L+Al+Al3Fe
+Al6Mn+α
L+Al+Al6Mn+α
Al+Al3Fe
+Al6Mn+α
Al+Al6Mn+α

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EUROPEAN SEARCH REPORT

Application Number
EP 10 01 0378

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	JP 10 310837 A (FURUKAWA ELECTRIC CO LTD) 24 November 1998 (1998-11-24) * abstract * -----	1-3	
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TECHNICAL FIELDS SEARCHED (IPC)

C22C
C22F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	24 November 2010	Patton, Guy

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24-11-2010

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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