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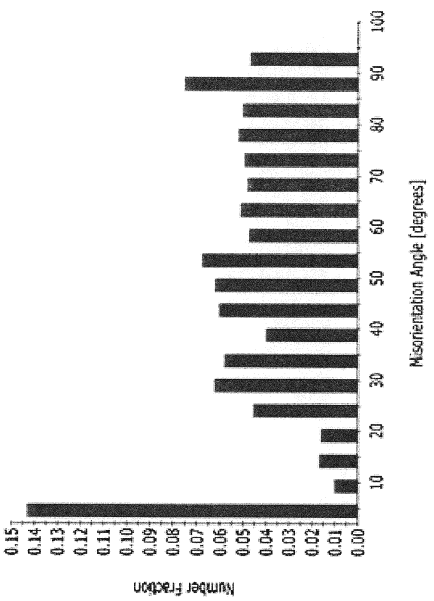
(54) **MAGNESIUM ALLOY SHEET AND MANUFACTURING METHOD THEREFOR**

(57) The present invention relates to a magnesium alloy sheet and a manufacturing method therefor.

An embodiment of the present invention provides a magnesium alloy sheet containing, relative to 100 wt% of the entire magnesium alloy sheet, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities, wherein a volume fraction of bottom crystal grains, relative to 100 vol% of overall crystal grains of the magnesium alloy sheet, is 30% or less, and the bottom crystal grains are crystal grains in a <0001>//C-axis direction.

FIG. 9



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Description

[Technical Field]

[0001] An embodiment of the present invention relates to a magnesium alloy sheet and a manufacturing method therefor.

[Background Art]

[0002] At present, the limitation of carbon dioxide emission and the importance of renewable energy are becoming a hot issue in the international community. Accordingly, lightweight alloys, which are a type of structural materials, are recognized as very attractive research fields.

[0003] In particular, magnesium is the lightest metal with a density of 1.74 g/cm^3 and has various advantages such as vibration absorbing ability and electromagnetic wave shielding ability as compared with other structural materials such as aluminum and steel. Therefore, research of related industry has been actively carried out to utilize magnesium.

[0004] An alloy containing magnesium has been currently applied not only in the field of electronic device but also in the field of vehicle, but it has fundamental problems in corrosion resistance, flame resistance, and formability, and thus there are limitations in expanding the application range thereof.

[0005] In particular, with regard to formability, magnesium has a hexagonal closed packed (HCP) structure, such that a slip system is not enough at room temperature, which makes it difficult to perform a processing process thereof. That is, a large amount of heat is required in a processing process of magnesium, which leads to an increase in the cost of the processing process.

[0006] Meanwhile, among the magnesium alloys, an AZ-based alloy contains aluminum (Al) and zinc (Zn), and corresponds to a commercialized magnesium alloy, because it is inexpensive while securing physical properties of a somewhat appropriate strength and ductile.

[0007] However, the physical properties mentioned above mean only an appropriate level among the magnesium alloys. The strength of the AZ-based alloy is lower than that of aluminum (Al) which is a competitive material.

[0008] Therefore, it is necessary to improve the physical properties such as a low formability and strength of the AZ-based magnesium alloy, but there is a lack of research on this.

[Disclosure]

[Technical Problem]

[0009] The present invention has been made in an effort to provide a magnesium alloy sheet and a manufacturing method therefor.

[0010] Specifically, the present invention is to improve formability of a magnesium sheet by suppressing center segregation consisting of Al-Ca secondary phase particles. Accordingly, the present invention is to provide a magnesium alloy sheet in which Al-Ca secondary phases are dispersed without being segregated in the center of the magnesium alloy sheet.

[0011] In addition, the present invention is to improve a strength of a magnesium alloy sheet by controlling a twinned crystal structure through skin pass rolling while maintaining the formability of the magnesium alloy sheet. Specifically, a strength of a magnesium alloy sheet may be increased while maintaining formability of the magnesium alloy sheet by minimizing a development change in texture of (0001) through skin pass rolling.

[Technical Solution]

[0012] An exemplary embodiment of the present invention provides a magnesium alloy sheet containing, relative to 100 wt% of the entire magnesium alloy sheet, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities, wherein a volume fraction of bottom crystal grains, relative to 100 vol% of overall crystal grains of the magnesium alloy sheet, is 30% or less, and the bottom crystal grains are crystal grains in a <0001>//C-axis direction.

[0013] The magnesium alloy sheet may include Al-Ca secondary phase particles, and a difference in area fraction of the Al-Ca secondary phase particles between a quarter portion (1/4) of a surface of the magnesium alloy sheet and a center portion (1/2) of the surface of the magnesium alloy sheet may be 10% or less.

[0014] Specifically, a ratio of a length of center segregation to a total length of the magnesium alloy sheet in a rolling direction may be less than 5%.

[0015] A ratio of a thickness of the center segregation to a total thickness of the magnesium alloy sheet in a thickness direction may be less than 2.5%. Therefore, in the magnesium alloy sheet, the Al-Ca secondary phase particles may be uniformly distributed without being segregated in the center portion of the magnesium alloy sheet.

[0016] The Al-Ca secondary phase particle may contain, relative to 100 wt% of the entire Al-Ca secondary phase particle, 20.0 to 25.0 wt% of Al, 5.0 to 10.0 wt% of Ca, 0.1 to 0.5 wt% of Mn, 0.5 to 1.0 wt% of Zn, and the balance of Mg and other inevitable impurities.

[0017] An average particle size of the Al-Ca secondary phase particles may be 0.01 to 4 μm.

[0018] 2 to 15 Al-Ca secondary phase particles may be included per area of 100 μm^2 of the magnesium alloy sheet.

[0019] A limiting dome height (LDH) of the magnesium alloy sheet may be 7 mm or more.

[0020] A maximum texture intensity of a (0001) surface of the magnesium alloy sheet may be 1 to 4.

[0021] A yield strength of the magnesium alloy sheet may be 150 to 190 MPa.

[0022] Another exemplary embodiment of the present invention provides a magnesium alloy sheet containing: relative to 100 wt% of the entire magnesium alloy sheet, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities, wherein a volume fraction of a twinned crystal structure, relative to 100 vol% of the entire area of the magnesium alloy sheet, is 35% or less.

[0023] Specifically, the volume fraction of the twinned crystal structure, relative to 100 vol% of the entire area of the magnesium alloy sheet, may be 5 to 35%.

[0024] The magnesium alloy sheet in which a volume fraction of bottom crystal grains, relative to 100 vol% of overall crystal grains of the magnesium alloy sheet, is 30% or less, and the bottom crystal grains are crystal grains in a <0001 >//C-axis direction may be provided.

[0025] A limiting dome height of the magnesium alloy sheet may be 7 mm or more.

[0026] A maximum texture intensity of a (0001) surface of the magnesium alloy sheet may be 1 to 4.

[0027] A yield strength of the magnesium alloy sheet may be 200 to 300 MPa.

[Advantageous Effect]

[0028] In the magnesium alloy sheet according to an embodiment of the present invention, the center segregations consisting of Al-Ca secondary phase particles are dispersed, such that the formability the magnesium sheet may be improved. Accordingly, according to an embodiment of the present invention, it is possible to provide the magnesium alloy sheet in which the Al-Ca secondary phases are dispersed without being segregated in the center of the magnesium alloy sheet. Specifically, it is possible to provide the magnesium alloy sheet in which a difference in area fraction of the Al-Ca secondary phase particles between a quarter portion (1/4) of a surface of the magnesium alloy sheet and a center portion (1/2) of the surface of the magnesium alloy sheet is 10% or less.

[0029] According to an embodiment of the present invention, it is possible to obtain, through skin pass rolling, the magnesium alloy sheet in which an area fraction of a twinned crystal structure, relative to 100% of the entire area of the magnesium alloy sheet, is 35% or less. Specifically, the strength of the magnesium alloy sheet may be improved by controlling the twinned crystal structure while maintaining the formability of the magnesium alloy sheet by minimizing the development of a texture of (0001) through a skin pass process.

[Description of the Drawings]

[0030]

FIG. 1 is a flowchart schematically illustrating a manufacturing method for a magnesium alloy sheet according to an embodiment of the present invention.

FIG. 2 is a photograph obtained by observing a magnesium alloy sheet produced in Example 1a with optical microscopy.

FIG. 3 is a photograph obtained by observing a magnesium alloy sheet produced in Comparative Example 1a with optical microscopy.

FIG. 4 is a photograph obtained by observing the magnesium alloy sheet produced in Example 1a with secondary electron microscopy.

FIG. 5 shows a result of measuring a limiting dome height of the magnesium alloy sheet produced in Example 1a.

FIG. 6 shows a maximum texture intensity of a (0001) surface of Example 1a.

FIG. 7 shows a maximum texture intensity of a (0001) surface of Comparative Example 1a.

FIG. 8 shows a result of electron backscatter diffraction (EBSD) analysis of the magnesium alloy sheet produced in Example 1a.

FIG. 9 is a graph illustrating fractions of crystal orientations of Example 1a.

FIG. 10 is a result of EBSD analysis of a magnesium alloy sheet according to a reduction ratio of skin pass.

FIG. 11 shows a maximum texture intensity of each of (0001) surfaces of Example 2 and Comparative Example 2, depending on a skin pass condition.

[Mode for Invention]

[0031] The advantages and features of the present invention, and methods of accomplishing these will become obvious with reference to the embodiments to be described below in detail along with the accompanying drawings. However, the present invention is not limited to embodiments to be disclosed below, but various forms different from each other may be implemented. The embodiments are merely provided to make the present invention complete and to completely notify those skilled in the art to which the present invention pertains, of the scope of the present invention, and the present invention is only defined by the scope of the claims. The same reference numerals throughout the specification denote the same elements.

[0032] Accordingly, in some embodiments, well-known techniques are not described in detail in order to avoid obscuring the present invention. Unless otherwise defined, all terms (including technical and scientific terms) used in the specification have the same meaning as commonly understood by those skilled in the art to which the present invention pertains. Throughout the present specification, unless explicitly described to the contrary, "comprising" any components will be understood to imply the inclusion of other elements rather than the exclusion of any other elements. In addition, unless explicitly described to the contrary, a singular form includes a plural form.

[0033] A magnesium alloy sheet according to an embodiment of the present invention may contain, relative to 100 wt% of the entire magnesium alloy sheet, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities.

[0034] Hereinafter, the reason for limiting the components and compositions will be described.

[0035] First, aluminum (Al) improves the mechanical properties of the magnesium alloy sheet and castability of a molten metal. When Al is added in an amount of more than 5.0 wt%, the castability may rapidly deteriorate. On the other hand, when Al is added in an amount of less than 2.7 wt%, the mechanical properties of the magnesium alloy sheet may deteriorate. Therefore, a content of Al may be adjusted within the above-mentioned range.

[0036] Zinc (Zn) improves the mechanical properties of the magnesium alloy sheet. When Zn is added in an amount of more than 1.0 wt%, a large number of surface defects or center segregations is generated, and the castability may thus rapidly deteriorate. On the other hand, when Zn is added in an amount of less than 0.75 wt%, the mechanical properties of the magnesium alloy sheet may deteriorate. Therefore, a content of Zn may be adjusted within the above-mentioned range.

[0037] Calcium (Ca) imparts flame resistance to the magnesium alloy sheet. When Ca is added in an amount of more than 1.0 wt%, the castability may rapidly deteriorate due to reduction of fluidity of the molten metal, and the formability of the magnesium alloy sheet may deteriorate due to an increase of the center segregation consisting of an Al-Ca-based intermetallic compound. When Ca is added in an amount of less than 0.1 wt%, the flame resistance may not be sufficiently imparted. Therefore, a content of Ca may be adjusted within the above-mentioned range. More specifically, Ca may be contained in an amount of 0.5 to 0.8 wt%.

[0038] Manganese (Mn) improves the mechanical properties of the magnesium alloy sheet. When Mn is added in an amount of more than 1.0 wt%, a heat dissipation property may deteriorate and uniform distribution control may be difficult. Therefore, a content of Mn may be adjusted within the above-mentioned range.

[0039] The volume fraction of bottom crystal grains, relative to 100 vol% of overall crystal grains of the magnesium alloy sheet may be 30% or less.

[0040] In an embodiment of the present invention, a bottom crystal grain refers to a crystal grain with a bottom orientation. Specifically, magnesium has a hexagonal closed pack (HCP) crystal structure, here, a crystal grain when a C-axis of the crystal structure is parallel to a thickness direction of the sheet refers to a crystal grain with a bottom crystal orientation (that is, bottom crystal grain). Accordingly, in the present specification, the bottom crystal grain may be expressed as a "<0001>//C-axis".

[0041] More specifically, in a case where a fraction of the bottom crystal grains is in the above-mentioned range, a magnesium alloy sheet having an excellent formability may be obtained.

[0042] Specifically, the volume fraction of bottom crystal grains in the <0001>//C-axis direction, relative to 100 vol% of overall crystal grains of the magnesium alloy sheet may be 30% or less. More specifically, the volume fraction of bottom crystal grains in the <0001>HC-axis direction, relative to 100 vol% of overall crystal grains of the magnesium alloy sheet may be 25% or less. Still more specifically, the volume fraction of bottom crystal grains in the <0001>//C-axis direction, relative to 100 vol% of overall crystal grains of the magnesium alloy sheet may be 20% or less. A lower limit of the volume fraction of bottom crystal grains in the <0001>//C-axis may be more than 0%. This means that in a case where the volume fraction of crystal grains in the <0001>//C-axis direction is in any range (more than 0%), the magnesium alloy sheet may be included in the present invention.

[0043] In the magnesium alloy sheet, the fraction of crystal grains in the <0001 >//C-axis direction may be decreased due to an increase of the orientation distribution of crystal grains.

[0044] In a case where the fraction of crystal grains in the <0001>//C-axis direction satisfies the above-mentioned range, the texture intensity of the magnesium alloy sheet is decreased, such that a magnesium alloy sheet having an excellent formability may be obtained.

[0045] The magnesium alloy sheet according to an embodiment of the present invention may include Al-Ca secondary phase particles.

[0046] Specifically, the magnesium alloy sheet according to an embodiment of the present invention may include the Al-Ca secondary phase particles, but may hardly include the center segregation. More specifically, the magnesium alloy sheet according to an embodiment of the present invention may have a form in which the Al-Ca secondary phase particles are uniformly dispersed. The center segregation refers to that Al-Ca secondary phase particles are segregated in the center portion of the magnesium alloy sheet in the thickness direction (ND), and as described above, as the center segregation increases, the formability of the magnesium alloy sheet may deteriorate.

[0047] Accordingly, in the magnesium alloy sheet according to an embodiment of the present invention, a difference in area fraction of the Al-Ca secondary phase particles between a quarter portion (1/4) of a surface of the magnesium alloy sheet and the center portion (1/2) of the surface of the magnesium alloy sheet may be 10% or less. Therefore, the Al-Ca secondary phase particles are entirely and uniformly dispersed without segregation in the center portion of the magnesium alloy sheet, and the formability of the magnesium alloy sheet may thus be improved. Here, the area fraction refers to a fraction with respect to an area of the Al-Ca secondary phase particles per same area of the quarter portion and the center portion.

[0048] More specifically, a ratio of a length of the center segregation to the total length of the magnesium alloy sheet in the rolling direction (RD) may be less than 5%. In addition, a ratio of a thickness of the center segregation to the total thickness of the magnesium alloy sheet in the thickness direction (ND) may be less than 2.5%.

[0049] The above description means that the center segregation is hardly generated, and the above range is a range in which both the length and thickness of the center segregation are decreased as compared to center segregation which is generally generated when Al and Ca are added. Therefore, the formability of the magnesium alloy sheet according to an embodiment of the present invention may be improved.

[0050] The total length of the magnesium sheet may be based on a magnesium sheet with a constant length unit. Specifically, the length unit may be 1,000 to 3,000 μm.

[0051] Specifically, the Al-Ca secondary phase particle may contain, relative to 100 wt% of the entire Al-Ca secondary phase particle, 20.0 to 25.0 wt% of Al, 5.0 to 10.0 wt% of Ca, 0.1 to 0.5 wt% of Mn, 0.5 to 1.0 wt% of Zn, and the balance of Mg and other inevitable impurities.

[0052] In general, in a case where Al and Ca are added to magnesium to from an alloy, center segregation consisting of Al-Ca secondary phase particles is generated, which causes the significant deterioration of the formability of the magnesium alloy sheet. On the other hand, the magnesium alloy sheet according to an embodiment of the present invention may improve the formability of the magnesium sheet by suppressing the generation of the center segregation consisting of Al-Ca secondary phase particles. Specifically, the magnesium alloy sheet in which Al-Ca secondary phase particles are dispersed may be provided.

[0053] An average particle size of the Al-Ca secondary phase particles may be 0.01 to 4 μm. As the average particle size of the Al-Ca secondary phase particles is large, as described above, the formability of the magnesium alloy sheet may deteriorate due to the generation of the center segregation. Within the above-mentioned range of the particle size, the improved formability may be exhibited.

[0054] 2 to 15 Al-Ca secondary phase particles may be included per area of 100 μm^2 of the magnesium alloy sheet. The number of Al-Ca secondary phase particles is in the above-mentioned range, the formability of the magnesium alloy sheet may be improved.

[0055] In an embodiment of the present invention, in order to control the Al-Ca secondary phase particles, composition ranges of Al, Zn, Mn, and Ca, temperature and time conditions during homogenization heat treatment, temperature and rolling ratio during warm-rolling, and the like may be precisely controlled.

[0056] The magnesium alloy sheet according to an embodiment of the present invention includes crystal grains, and an average particle size of the crystal grains may be 5 to 30 μm. Within the above particle size range of the crystal grains, the formability of the magnesium alloy sheet may be improved.

[0057] In addition, a limiting dome height of the magnesium alloy sheet according to an embodiment of the present invention may be 7 mm or more. More preferably, the limiting dome height of the magnesium alloy sheet may be 7 to 10 mm.

[0058] In general, a limiting dome height is utilized as an index for evaluating formability (in particular, pressability) of a material, and as the limiting dome height is increased, the formability of the material is improved.

[0059] A limiting dome height within the above limited range is a significantly higher limiting dome height than that of a magnesium alloy sheet generally known, which caused by an increase in orientation distribution of the crystal grain in the magnesium alloy sheet.

[0060] Therefore, the maximum texture intensity of a (0001) surface of the magnesium alloy sheet may be 1 to 4. In a case where the limiting dome height is out of the above-mentioned range, the formability of the magnesium alloy sheet may deteriorate.

[0061] In addition, a yield strength of the magnesium alloy sheet according to an embodiment of the present invention may be in a range of 150 to 190 MPa.

[0062] In the magnesium alloy sheet according to an embodiment of the present invention, through skin pass in a production step described below, an area fraction of a twinned crystal structure may be 35% or less relative to 100% of the entire area of the magnesium alloy sheet. More specifically, the area fraction of the twinned crystal structure may be 5 to 35%. Still more specifically, the area fraction of the twinned crystal structure may be 5 to 33%. By controlling the fraction of the twinned crystal structure to the above range, the yield strength of the magnesium alloy sheet according to an embodiment of the present invention may be 200 to 300 MPa. This range is considered as an excellent range in the magnesium sheet according to an embodiment of the present invention.

[0063] In addition, a thickness of the magnesium alloy sheet according to an embodiment of the present invention may be 0.4 to 3 mm. The magnesium sheet according to an embodiment of the present invention may be selected depending on properties required in the above thickness range. However, the present invention is not limited to this thickness range.

[0064] FIG. 1 is a flowchart schematically illustrating a manufacturing method for a magnesium alloy sheet according to an embodiment of the present invention. The flowchart of the manufacturing method for a magnesium alloy sheet of FIG. 1 is merely to illustrate the present invention, and the present invention is not limited thereto. Therefore, the manufacturing method for a magnesium alloy sheet may be variously modified.

[0065] A manufacturing method for a magnesium alloy sheet according to an embodiment of the present invention includes: a step (S10) of preparing a cast material by casting a molten metal, the molten metal containing, relative to 100 wt% of the entire molten metal, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities; a step (S20) of subjecting the cast material to homogenization heat treatment; and a step (S30) of subjecting the cast material subjected to the homogenization heat treatment to warm-rolling.

[0066] In addition, the manufacturing method for a magnesium alloy sheet may further include other steps, as necessary.

[0067] First, the step (S10) of preparing a cast material by casting a molten metal may be performed, the molten metal containing, relative to 100 wt% of the entire molten metal, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities.

[0068] The reason for limiting the numeral values of the respective components is the same as that mentioned above, and the repeated description thereof will thus be omitted.

[0069] At this time, as the method (S10) of preparing the cast material, a die casting method, a strip casting method, a billet casting method, a centrifugal casting method, a tilting casting method, a sand casting method, a direct chill casting method, or combination thereof may be used.

[0070] More specifically, a strip casting method may be used. However, the present invention is not limited thereto.

[0071] More specifically, in the step (S10) of preparing the cast material, a rolling force may be 0.2 ton/mm^2 or more. Still more specifically, the rolling force may be 1 ton/mm^2 or more. Still more specifically, the rolling force may be 1.5 ton/mm^2. The cast material is coagulated and a rolling force is simultaneously applied thereto, and at this time, the formability of the magnesium alloy sheet may be improved by adjusting the rolling force to the above range.

[0072] Next, the step (S20) of subjecting the cast material to homogenization heat treatment may be carried out.

[0073] At this time, the heat treatment may be performed at a temperature of 350°C to 500°C for 1 to 28 hours. More specifically, the homogenization heat treatment may be performed for 18 to 28 hours.

[0074] In a temperature range of lower than 350°C, the homogenization heat treatment is not properly performed, and beta phases such as $Mg_{17}Al_{12}$ may not be solid-dissolved in the matrix.

[0075] In a temperature range of higher than 500°C, the beta phases condensed in the cast material may melt, resulting in an occurrence of a fire or formation of holes in the magnesium sheet. Therefore, the homogenization heat treatment may be performed within the above-mentioned temperature range.

[0076] Next, the step (S30) of subjecting the cast material subjected to the homogenization heat treatment to warm-rolling may be carried out.

[0077] At this time, a temperature condition of the warm-rolling may be 150°C to 350°C. In a temperature range of lower than 150°C, a large amount of edge cracks may be generated. In a temperature range of higher than of 500°C, the magnesium alloy sheet may not be appropriate for mass production. Therefore, the warm-rolling may be performed in the above-mentioned temperature range.

[0078] The step of subjecting the cast material subjected to the homogenization heat treatment to warm-rolling may be carried out a plurality of times, and the warm-rolling may be performed at a reduction ratio of 10 to 30% per time. The reduction ratio of the warm-rolling refers to a "value(%)" relative to 100% of the thickness (length(%) of the cast material. By performing warm-rolling a plurality of times, finally, the rolling may be performed until the cast material has a thin thickness of about 0.4 mm.

[0079] At least one time of a step of performing intermediate annealing in the middle of a plurality of times of warm-rolling may be further included. By further including the step of performing intermediate annealing in the middle of a plurality of times of warm-rolling, the formability of the magnesium alloy sheet may be further improved. Specifically, the step of performing intermediate annealing may be carried out at 300 to 500°C for 1 to 10 hours. More specifically, the intermediate annealing step may be carried out at 450 to 500°C. Within the above-mentioned range, the formability of the magnesium alloy sheet may be further improved.

[0080] After the warm-rolling step, the method may further include a step of performing subsequent heat treatment. By including the step of performing subsequent heat treatment, the formability of the magnesium alloy sheet may be further improved. The step of performing subsequent heat treatment may be carried out at 300 to 500°C for 1 to 15 hours. Specifically, the step of performing subsequent heat treatment may be carried out for 1 to 10 hours. Within the above-mentioned range, the formability of the magnesium alloy sheet may be further improved.

[0081] A manufacturing method for a magnesium alloy sheet according to another embodiment of the present invention may include: a step of preparing a cast material by casting a molten metal, the molten metal containing, relative to 100 wt% of the entire molten metal, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities; a step of subjecting the cast material to homogenization heat treatment; a step of preparing a rolled material by subjecting the cast material subjected to the homogenization heat treatment to warm-rolling; a step of subjecting the rolled material to subsequent heat treatment; and a step of producing a magnesium alloy sheet by subjecting the rolled material subjected to the subsequent heat treatment to skin pass.

[0082] First, the step of preparing a cast material by casting a molten metal may be performed, the molten metal containing, relative to 100 wt% of the entire molten metal, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities.

[0083] In the above step, the molten metal may a commercially available AZ31 alloy, AL5083 alloy, or a combination thereof. However, the present invention is not limited thereto.

[0084] More specifically, the molten metal may be prepared in a temperature range of 650 to 750°C. Thereafter, a cast material may be produced by casting the molten metal. At this time, a thickness of the cast material may be 3 to 7 mm.

[0085] At this time, as the method of preparing the cast material, a die casting method, a strip casting method, a billet casting method, a centrifugal casting method, a tilting casting method, a sand casting method, a direct chill casting method, or combination thereof may be used. More specifically, a strip casting method may be used. However, the present invention is not limited thereto.

[0086] More specifically, in the step of preparing the cast material, a rolling force may be 0.2 ton/mm^2 or more. Still more specifically, the rolling force may be 1 ton/mm^2 or more. Still more specifically, the rolling force may be 1.5 ton/mm^2.

[0087] Next, the step of subjecting the cast material to homogenization heat treatment may be carried out.

[0088] More specifically, the step of subjecting the cast material to homogenization heat treatment may include: a primary heat treatment step in a temperature range of 300°C to 400°C; and a secondary heat treatment step in a temperature range of 400°C to 500°C. The temperature ranges of the primary heat treatment step and the secondary heat treatment step may be different from each other.

[0089] Still more specifically, the primary heat treatment step in a temperature range of 300°C to 400°C may be carried out for 5 hours to 20 hours. In addition, the secondary heat treatment step in a temperature range of 400°C to 500°C may be carried out for 5 hours to 20 hours.

[0090] By carrying out the primary heat treatment step in the above temperature range, a Mg-Al-Zn ternary system Pi-phase generated in the casting step may be removed. In a case where the ternary system Pi-phase is present, the subsequent process may be adversely affected. In addition, by carrying out the secondary heat treatment step in the above temperature range, a stress in a slab may be released. Further, the formation of recrystallization of the cast structure may be more actively induced.

[0091] Next, the step of preparing a rolled material by subjecting the cast material subjected to the homogenization heat treatment to warm-rolling may be carried out.

[0092] The cast material subjected to the heat treatment may be rolled to a thickness range of 0.4 to 3 mm through 1 to 15 times of rolling. In addition, the rolling may be performed at 150 to 350°C.

[0093] More specifically, in a case where the rolling temperature is lower than 150°C, a crack on the surface when rolling may be induced, and in a case where the rolling temperature is higher than 350°C, it may not be suitable for actual production facilities. Therefore, the rolling may be performed at 150°C to 350°C.

[0094] Next, a step of subjecting the rolled material to intermediate annealing may be carried out. In the rolling step, when the cast material is rolled a plurality of times, heat treatment may be performed in a temperature range of 300°C to 550°C for 1 hour to 15 hours in an interval between the pass and the pass.

[0095] For example, the intermediate annealing is performed one time after performing the rolling two times, and the rolled material may thus be rolled to the final target thickness. As another example, the intermediate annealing is performed one time after performing the rolling three times, and the rolled material may thus be rolled to the final target thickness. More specifically, in a case where the rolled cast material is annealed in the above temperature range, the stress generated by the rolling may be released. Therefore, the rolling may be performed several times to obtain a desired thickness of the cast material.

[0096] Next, the step of subjecting the rolled material to subsequent heat treatment may be carried out.

[0097] The step of subjecting the cast material to subsequent heat treatment may be carried out at 300 to 500°C for 1 to 15 hours. Specifically, the step of subjecting the cast material to subsequent heat treatment may be carried out for 1 to 10 hours. Within the above-mentioned range, the formability of the magnesium alloy sheet may be further improved.

[0098] Finally, the step of producing a magnesium alloy sheet by subjecting the rolled material subjected to the subsequent heat treatment to skin pass may be carried out.

[0099] More specifically, the skin pass is also referred to as skin pass rolling or temper rolling, which means that a deformation pattern generated in a cold rolled sheet after heat treatment is removed, and cold rolling is performed with a light pressure to improve the strength.

[0100] Therefore, in an embodiment of the present invention, the skin pass may be performed one time in a temperature range of 250°C to 350°C.

[0101] The magnesium alloy sheet produced by performing the skin pass may be rolled at a reduction ratio of 2 to 15% with respect to the thickness of the rolled material. More specifically, the reduction ratio may be related to the skin pass temperature.

[0102] As a specific example, when the skin pass temperature is 250°C, the reduction ratio of the skin pass may be 5 to 15%. At this time, a yield strength may be in a range of 200 to 260 MPa. Further, at this time, a limiting dome height may be in a range of 7.3 to 8.1.

[0103] As a specific example, when the skin pass temperature is 300°C, the reduction ratio of the skin pass may be 5 to 15%. More preferably, the reduction ratio of the skin pass may be 7 to 12%. At this time, a yield strength may be in a range of 200 to 250 MPa. Further, at this time, a limiting dome height may be in a range of 7.3 to 8.1.

[0104] In the present invention, a limit dome height (LDH) is an index for evaluating formability of the sheet, in particular, pressability, and the formability may be measured by measuring a deformed height of a specimen obtained by applying a deformation to the specimen. A high value of the limiting dome height means that the formability of the sheet is excellent.

[0105] More specifically, the skin pass is performed under the conditions of the above temperature and pressure, the development of the texture of (0001) is suppressed, the formability may be secured. That is, in a case where the skin pass is performed under the above conditions, a change of the texture intensity may be minimized and the strength may thus be increased.

[0106] Hereinafter, the present invention will be described in detail with reference to examples. However, the following examples are only to illustrate the present invention, and the contents of the present invention are not limited by the following examples.

Example 1

[0107] A molten metal containing, relative to 100 wt% of the entire molten metal, Al and Ca in amounts as shown in Table 1, 0.8 wt% of Zn, 0.5 wt% of Mn, and the balance of Mg and inevitable impurities was prepared.

[0108] The molten metal was passed between two cooling rolls to prepare a magnesium cast material. At this time, a rolling force of the cooling roll is as shown in Table 1.

[0109] Next, the magnesium cast material was subjected to homogenization heat treatment at 400°C while varying time as shown in Table 1.

[0110] The magnesium cast material subjected to the homogenization heat treatment was subjected to warm-rolling at a temperature of 250°C at a reduction ratio of 15%. Next, the magnesium cast material subjected to the warm-rolling was subjected to intermediate annealing at a temperature as shown in Table 1, and then subjected to warm-rolling again at a temperature of 250°C at a reduction ratio of 15%, thereby producing a magnesium alloy sheet.

Comparative Example 1

[0111] A molten metal containing, relative to 100 wt% of the entire molten metal, Al and Ca in amounts as shown in Table 1, 0.8 wt% of Zn, and the balance of Mg and inevitable impurities was prepared.

[0112] A magnesium alloy sheet was produced in the same manner as that of Example 1, except for the conditions as shown in Table 1.

[Table 1]

	Al content (wt%)	Ca content (wt%)	Casting roll Rolling force (ton/mm^2)	Homogenization Annealing time (hr)	Rolling temperature (C)	Intermediate annealing temperature (C)
Example 1a	3	0.6	1.2	24	250	450
Example 1b	4	0.6	1.2	24	250	450
Example 1c	5	0.6	1	24	250	450
Example 1d	3	0.6	1.2	24	250	300
Example 1e	3	0.6	1.2	24	250	400
Example 1f	3	0.6	1.2	24	250	500
Example 1g	3	0.7	0.2	24	250	500
Example 1h	3	0.7	1.2	24	250	450
Example 1i	3	0.6	1	1	250	400
Comparative Example 1a	3	0.6	0.8	24	250	-
Comparative Example 1b	3	0.7	1.2	24	**400**	250
Comparative Example 1c	3	0.7	1	**48**	250	400
Comparative Example 1d	3	0.7	0.8	24	**100**	400

[0113] In order to compare and evaluate physical properties of the magnesium alloy sheets produced in examples and comparative examples, the following experimental examples were performed.

Experimental Example 1: Observation of Microstructure of Magnesium Alloy Sheet

[0114] Microstructures of the magnesium alloy sheets produced in examples and comparative examples were observed with a scanning electron microscope (SEM).

[0115] The observed results are illustrated in FIGS. 2 to 4 of the present invention.

[0116] FIG. 2 is a photograph obtained by observing a magnesium alloy sheet produced in Example 1a with a scanning electron microscope (SEM). FIG. 3 is a photograph obtained by observing a magnesium alloy sheet produced in Comparative Example 1a with a scanning electron microscope (SEM).

[0117] Specifically, in each of FIGS. 2 and 3, a horizontal direction is a rolling direction (RD) of the magnesium alloy sheet and a vertical direction is a thickness direction (ND) of the magnesium alloy sheet.

[0118] As illustrated in FIG. 2, it can be appreciated that center segregation of the magnesium alloy sheet was hardly generated in Example 1a. Specifically, it can be appreciated that a ratio of a length of the center segregation to the total length of about 2000 μm in the rolling direction in Example 1a was less than 5%.

[0119] On the other hand, as illustrated in FIG. 3, it can be appreciated that, a large amount of center segregation of the magnesium alloy sheet was generated in Comparative Example 1a. Specifically, it can be appreciated that a ratio of a length of the center segregation to the total length of about 2000 μm in the rolling direction in Comparative Example 1a was 5% or more. Further, it was confirmed that, a thickness of the center segregation to the total thickness of about 1200 μm in the thickness direction in Comparative Example 1a was about 30 μm. From this fact, it can be appreciated that a ratio of the thickness of the center segregation to the total thickness of the magnesium alloy sheet in the thickness direction was 2.5%. Therefore, it could be confirmed that a large amount of center segregation was generated in Comparative Example 1a.

[0120] As described above, since the center segregation causes deterioration of formability of the magnesium alloy sheet, as the center segregation is not generated, a magnesium alloy sheet having an excellent formability may be obtained.

[0121] FIG. 4 is a photograph obtained by observing the magnesium alloy sheet produced in Example 1a with secondary electron microscopy.

[0122] The white dots in FIG. 4 are Al-Ca secondary phase particles. More specifically, as a result of analyzing compositions of the white dots in FIG. 4, it was analyzed that the white dots contain 24.61 wt% of Al, 8.75 wt% of Ca, 0.36 wt% of Mn, 0.66 wt% of Zn, and the balance of Mg and other inevitable impurities.

[0123] From this fact, it was confirmed that the magnesium alloy sheet produced in Example 1a includes the Al-Ca secondary phase particles. Specifically, it can be appreciated that 50 Al-Ca secondary phase particles were distributed per area of 1600 μm^2 of the magnesium alloy sheet in FIG. 4.

[0124] As illustrated in FIG. 4, it can be appreciated that the center segregation of the Al-Ca secondary phase particles was not generated in Example 1a, and the Al-Ca secondary phase particles were dispersed. From this fact, as shown in Table 2, it can be appreciated that a limiting dome height of the magnesium alloy sheet produced in Example 1a of the present invention is 9.4 mm, whereas a limiting dome height of the magnesium alloy sheet produced in Comparative Example 1a is 2.5 mm, which shows that the formability of the magnesium alloy sheet produced in Comparative Example 1a is inferior to that of the magnesium alloy sheet produced in Example 1a.

Experimental Example 2: Measurement of Limiting Dome Height of Magnesium Alloy Sheet

[0125] In the present invention, a limit dome height (LDH) is an index for evaluating formability of the sheet, in particular, pressability, and the formability may be measured by measuring a deformed height of a specimen obtained by applying a deformation to the specimen.

[0126] The limiting dome height was measured by inserting each of the magnesium alloy sheets of examples and comparative examples between an upper die and a lower die, and fixing an outer periphery of each specimen with a force of 5 kN. Here, a known press oil was used as a lubricant. Then, a spherical punch having a diameter of 20 mm was used to deform the specimen at a rate of 5 to 10 mm/min, the punch was inserted until each specimen was fractured, and then a deformed height of each specimen at the time of fracturing was measured. That is, the deformed height of the specimen was measured.

[0127] The results are illustrated in FIG. 5 of the present invention.

[0128] FIG. 5 shows a result of measuring a limiting dome height of the magnesium alloy sheet produced in Example 1a.

[0129] As illustrated in FIG. 5, it can be appreciated that the magnesium alloy sheet produced in Example 1a has an excellent formability.

[0130] The results can also be confirmed in Tables 2 and 3.

Experimental Example 3: Analysis of Crystal Orientation of Crystal Grain

[0131] The crystal orientation of crystal grain of each of the magnesium alloy sheets produced in examples and comparative examples were confirmed with an XRD analyzer, and the results are illustrated in FIGS. 6 to 11. Specifically, a texture of the crystal grains obtained by using an XRD pole figure method is illustrated.

[0132] More specifically, the pole figure is represented by stereographic projection of an orientation of an arbitrarily fixed crystal coordinate system onto a coordinate system of the specimen. Still more specifically, poles of the crystal grains with various orientations with respect to a {0001} surface are represented on a standard coordinate system, and a density contour of the poles is drawn according to a pole density distribution, thereby representing the pole figure. At this time, the poles are fixed in a specific lattice direction by Bragg's angle, and a plurality of poles may be represented for a single crystal.

[0133] Accordingly, it can be construed that as a density distribution value of the contour represented by the pole figure method is small, crystal grains with various orientations are distributed, and as the density distribution value is large, a large amount of crystal grains in a <0001>//C-axis direction is distributed.

[0134] The results may be compared through FIGS. 6 and 7 of the present invention.

[0135] FIG. 6 shows a maximum texture intensity of a (0001) surface of Example 1a. FIG. 7 shows a maximum texture intensity of a (0001) surface of Comparative Example 1a.

[0136] Specifically, the maximum texture intensity of each of the (0001) surfaces of FIGS. 6 and 7 is the result obtained by analyzing the crystal orientation of the magnesium alloy sheet with the XRD analyzer as described above.

[0137] As illustrated in FIG. 6, it could be confirmed that the maximum density distribution value (texture intensity) of the (0001) surface in examples was 2.73, which is low, whereas the maximum density distribution value in comparative examples was 12.1, which is high as compared to that of each example.

[0138] That is, since a value of the maximum texture intensity is small, and the contour is widely spread in examples, it can be derived that the crystal grains with various orientations are distributed.

[0139] On the other hand, since a value of the maximum texture intensity is large, and the contour is concentrated in comparative examples, it can be appreciated that a large amount of crystal grains in the <0001 >//C-axis direction is included.

[0140] From the above results, it can be appreciated that the magnesium alloy sheets of examples have a more excellent formability.

[0141] This may be appreciated through FIGS. 8 and 9 of the present invention.

[0142] FIG. 8 shows a result of electron backscatter diffraction (EBSD) analysis of the magnesium alloy sheet produced in Example 1a.

[0143] FIG. 9 is a graph illustrating fractions of crystal orientations of Example 1a.

[0144] First, as illustrated in FIG. 8, the crystal orientation of crystal grain may also be measured by EBSD. More specifically, the crystal orientation of crystal grain may be measured by EBSD by injecting electrons into a specimen through e-electron beam and using inelastic scattering diffraction at the back of the specimen.

[0145] In addition, as illustrated in FIG. 9, crystal grains having a misorientation angle of 20° or less between grains may be bottom crystal grains. Therefore, it was confirmed that the volume fraction of the crystal grains in the <0001>//C-axis direction relative to 100% of the volume fraction of the entire crystal grains was about 18.5%.

[0146] In addition, as illustrated in FIG. 8, it can be appreciated that the crystal grains with various orientations were distributed in various colors, and the crystal grains (red) corresponding to the crystal grains in the <0001 >//C-axis direction could be confirmed with naked eyes from the EBSD results.

[Table 2]

	Size of crystal grain (μm)	Sheet thickness (mm)	Yield strength (MPa)	Limiting dome height (LDH, mm)
Example 1a	19	0.7	164	9.4
Example 1b	7	0.6	161	8.2
Example 1c	6	1	166	8.1
Example 1d	13	1	155	7.5
Example 1e	21	1	157	8
Example 1f	25	1	154	9.9
Example 1g	16	0.7	151	9
Example 1h	15	3	155	9.1
Example 1i	17	1	164	9
Comparative Example 1a	10	0.7	188	2.5
Comparative Example 1b	11	0.6	155	5
Comparative Example 1c	40	1.5	145	5.1
Comparative Example 1d	8	1	166	4.9

[0147] As a result, it was confirmed that in Comparative Examples of 1a to 1d which did not satisfy the conditions of homogenization annealing time, rolling temperature, and intermediate annealing temperature, the formability was inferior to that of each example. In addition, it can be appreciated that a yield strength of each of Comparative Examples of 1a to 1d was inferior to that of each example. In Comparative Example 1c, an average size of the crystal grains was about 40 μm, that is, the formability was relatively excellent as compared to that of the other comparative examples, but a level of the formability was less than that of each example.

Example 2

[0148] A molten metal containing, relative to 100 wt% of the entire molten metal, 3.0 wt% of Al, 0.1 wt% of Zn, 1.0 wt% of Ca, 0.3 wt% of Mn, and the balance of Mg and inevitable impurities was prepared.

[0149] The molten metal was casted to prepare a magnesium cast material.

[0150] The magnesium cast material was subjected to a primary homogenization heat treatment at 350°C for 10 hours. The magnesium cast material subjected to the primary homogenization heat treatment was subjected to a secondary homogenization heat treatment at 450°C for 10 hours.

[0151] A rolled material was prepared by casting the cast material subjected to homogenization heat treatment.
[0152] Thereafter, the rolled material was subjected to subsequent heat treatment at 400°C for 10 hours.
[0153] Finally, a magnesium sheet was produced by subjecting the rolled material subjected to the subsequent heat treatment to skin pass, and the skin pass temperature and reduction ratio are as shown in Table 2.

Comparative Example 2

[0154] A magnesium alloy sheet was produced in the same manner as that of Example 2, except for the conditions of skin pass temperature and reduction ratio.
[0155] In order to compare and evaluate physical properties of the magnesium alloy sheets produced in examples and comparative examples, the following experimental examples were performed
[0156] In addition, an experimental example for measurement of the limiting dome height and analysis of the crystal orientation was carried out, and the experimental method is the same as described above.

Experimental Example 4: Comparison of Physical Properties Depending On Reduction Ratio of Skin Pass and Temperature

[0157]

[Table 3]

	Skin pass temperature (C)	Skin pass Reduction ratio (%)	Yield strength (MPa)	Maximum tensile strength 강도(MPa)	Elongation rate (%)	Limitingdome height (LDH, mm)
Example 2a	250	5	202	257	22	8.1
Example 2b		9	211	254	22	8.0
Example 2c		15	252	272	16	7.3
Comparative Example 2a		22	272	289	8.6	7.0
Comparative Example 2b	300	X DELETEDTEXTS	140	233	23	8-9
Example 2d		7	203	253	22	8
Example 2e		12	247	267	18	7.3
Comparative Example 2c		17	247	272	10	7.3

[0158] As shown in Table 3, as a result of subjecting the magnesium alloys having the same compositions and components as each other, a yield strength was improved without a large change of the formability. More specifically, the formability may be measured by comparing numerical values of an elongation rate and a limiting dome height.
[0159] In addition, the formability may be secured by minimizing the change of the texture, and the change of the texture depending on the reduction ratio of the skin pass may be confirmed through FIG. 10.
[0160] FIG. 10 is a result of EBSD analysis of a magnesium alloy sheet depending on a reduction ratio of skin pass.
[0161] As illustrated in FIG. 10, it can be confirmed that even in a case where the skin pass after rolling was further performed, the crystal grains with various orientations were distributed. In addition, in a case where the rolling was performed in a state in which the reduction ratio of the skin pass was increased, the orientation change of the texture was minimized, and the strength of the magnesium alloy sheet was improved, due to the development of the twinned crystal (black) structure and potential.
[0162] Specifically, it was confirmed that in a case where the reduction ratio of the skin pass is 2 to 6%, the area fraction of the twinned crystal structure, relative to 100% of the entire area of the magnesium alloy, was 15%. It was confirmed that in a case where the reduction ratio of the skin pass is 6 to 15%, the area fraction of the twinned crystal structure, relative to 100% of the entire area of the magnesium alloy, was 30%.
[0163] As described above, due to the twinned crystal structure and potential, the strength of the magnesium alloy sheet may be maintained and the formability of the magnesium alloy sheet may also be improved.

[0164] Therefore, in a case where the rolling is performed by exceeding the reduction ratio of 15% (Comparative Example 2a), the texture of the (0001) surface is developed again, which causes deterioration of the formability of the magnesium alloy sheet.

[0165] FIG. 11 shows a maximum texture intensity of each of (0001) surfaces of Example 2 and Comparative Example 2, depending on a skin pass condition.

[0166] As illustrated in FIG. 11, even in a case where the skin pass was performed, the change of the texture of examples was not large. However, it could be appreciated that in a case where the reduction ratio of the skin pass was excessive as in Comparative Example 2a, the intensity of the texture was largely changed. Therefore, as illustrated in Table 3, it was confirmed that a phenomenon in which an increase effect of the yield strength was excellent, but the elongation rate significantly deteriorated.

[0167] In addition, it was also confirmed that an increase effect of the yield strength depending on the reduction ratio of the skin pass was significantly exhibited as compared to an increase effect of the yield strength depending on the change in skin pass temperature.

[0168] Although the embodiments of the present invention has been described with reference to the accompanying drawings, those skilled in the art will appreciate that various modifications and alterations may be made without departing from the spirit or essential feature of the present invention.

[0169] Therefore, it should be understood that the aforementioned embodiments are illustrative in terms of all aspects and are not limited. The scope of the present invention is defined by the appended claims rather than the detailed description, and all changes or modifications derived from the meaning and scope of the appended claims and their equivalents should be interpreted as falling within the scope of the present invention.

Claims

1. A magnesium alloy sheet comprising: relative to 100 wt% of the entire magnesium alloy sheet, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities,
   wherein a volume fraction of bottom crystal grains is 30% or less relative to 100 vol% of overall crystal grains of the magnesium alloy sheet, and
   wherein the bottom crystal grains are crystal grains in a <0001>//C-axis direction.

2. The magnesium alloy sheet of claim 1, wherein:

   the magnesium alloy sheet comprises Al-Ca secondary phase particles, and
   a difference in area fraction of the Al-Ca secondary phase particles is 10% or less between a quarter portion (1/4) of a surface of the magnesium alloy sheet and a center portion (1/2) of the surface of the magnesium alloy sheet.

3. The magnesium alloy sheet of claim 2, wherein:
   a ratio of a length of center segregation to a total length of the magnesium alloy sheet in a rolling direction is less than 5%.

4. The magnesium alloy sheet of claim 3, wherein:
   a ratio of a thickness of the center segregation to a total thickness of the magnesium alloy sheet in a thickness direction is less than 2.5%.

5. The magnesium alloy sheet of claim 4, wherein:

   a limiting dome height (LDH) of the magnesium alloy sheet is 7 mm or more, and
   a maximum texture intensity of a (0001) surface of the magnesium alloy sheet is 1 to 4.

6. A magnesium alloy sheet comprising: relative to 100 wt% of the entire magnesium alloy sheet, 2.7 to 5.0 wt% of Al, 0.75 to 1.0 wt% of Zn, 0.1 to 1.0 wt% of Ca, 1.0 wt% or less of Mn (excluding 0 wt%), and the balance of Mg and other inevitable impurities,
   wherein a volume fraction of a twinned crystal structure is 35% or less relative to 100 vol% of the entire area of the magnesium alloy sheet.

7. The magnesium alloy sheet of claim 6, wherein:

the volume fraction of the twinned crystal structure, relative to 100 vol% of the entire area of the magnesium alloy sheet, is 5 to 35%.

8. The magnesium alloy sheet of claim 7, wherein:

a volume fraction of bottom crystal grains is 30% or less relative to 100 vol% of overall crystal grains of the magnesium alloy sheet, and
the bottom crystal grains are crystal grains in a <0001 >//C-axis direction.

9. The magnesium alloy sheet of claim 8, wherein:

a limiting dome height of the magnesium alloy sheet is 7 mm or more, and
a maximum texture intensity of a (0001) surface of the magnesium alloy sheet is 1 to 4.

10. The magnesium alloy sheet of claim 9, wherein:
a yield strength of the magnesium alloy sheet is 200 to 300 MPa.

FIG. 1

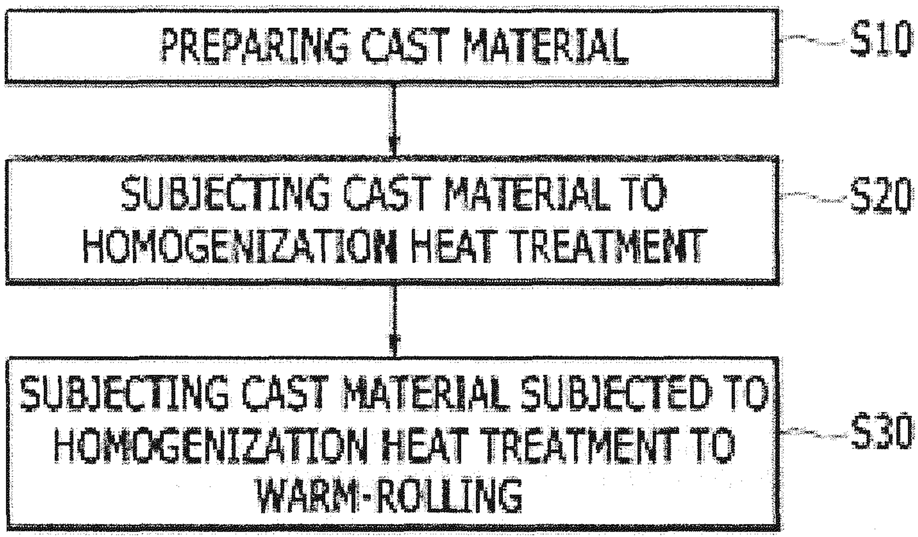

PREPARING CAST MATERIAL
S10
SUBJECTING CAST MATERIAL TO HOMOGENIZATION HEAT TREATMENT
S20
SUBJECTING CAST MATERIAL SUBJECTED TO HOMOGENIZATION HEAT TREATMENT TO WARM-ROLLING
S30

FIG. 2

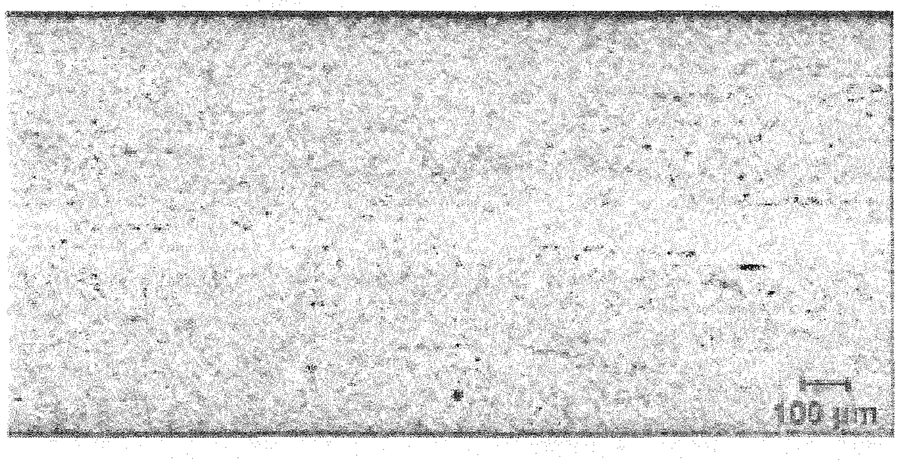

100 μm

FIG. 3

FIG. 4

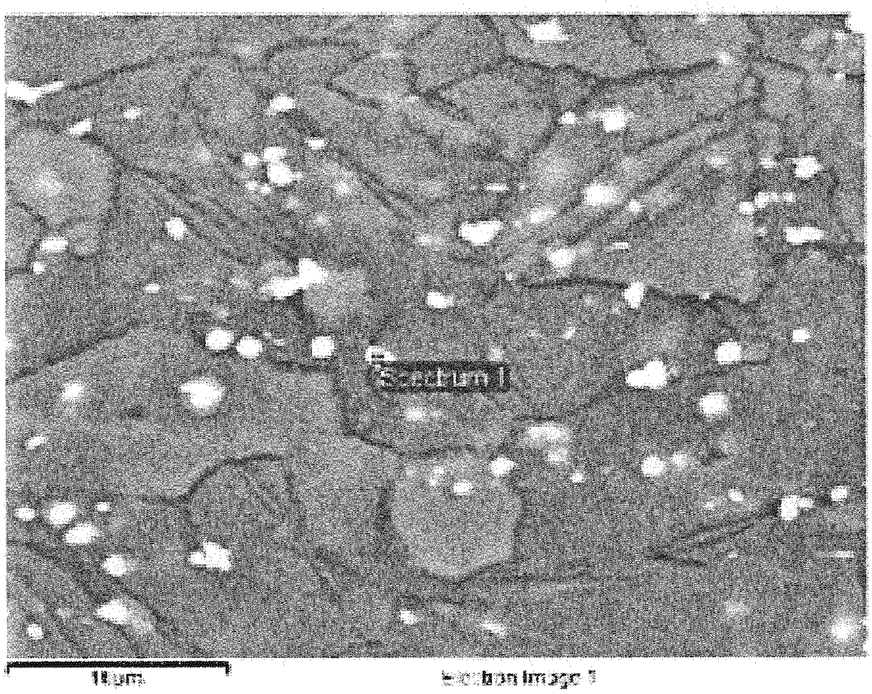


FIG. 5

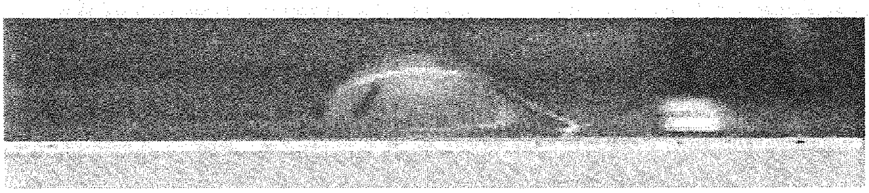
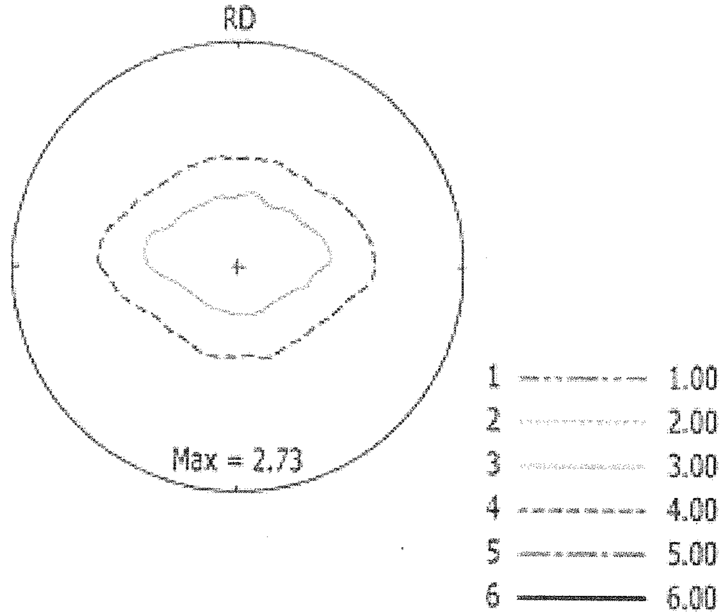


FIG. 6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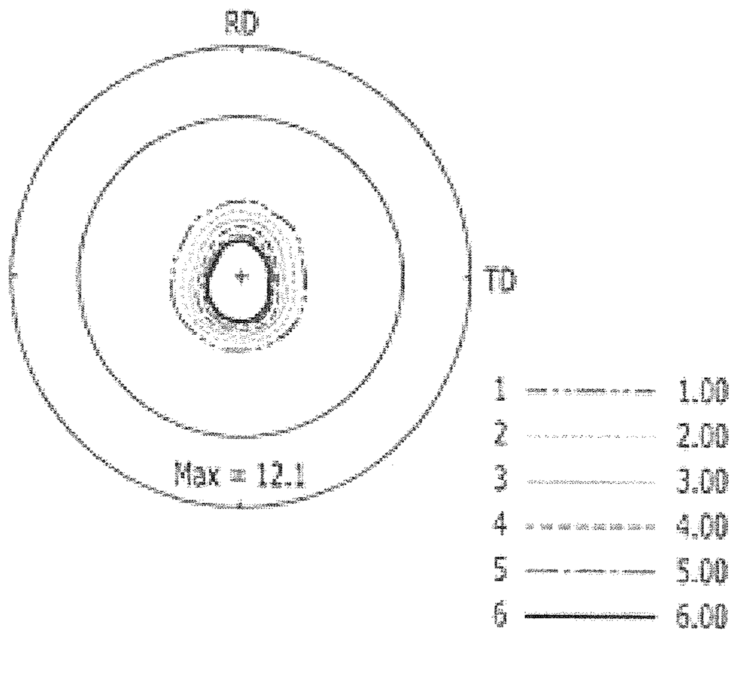
5 5.00
6 6.00

FIG. 7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6 6.00

FIG. 8

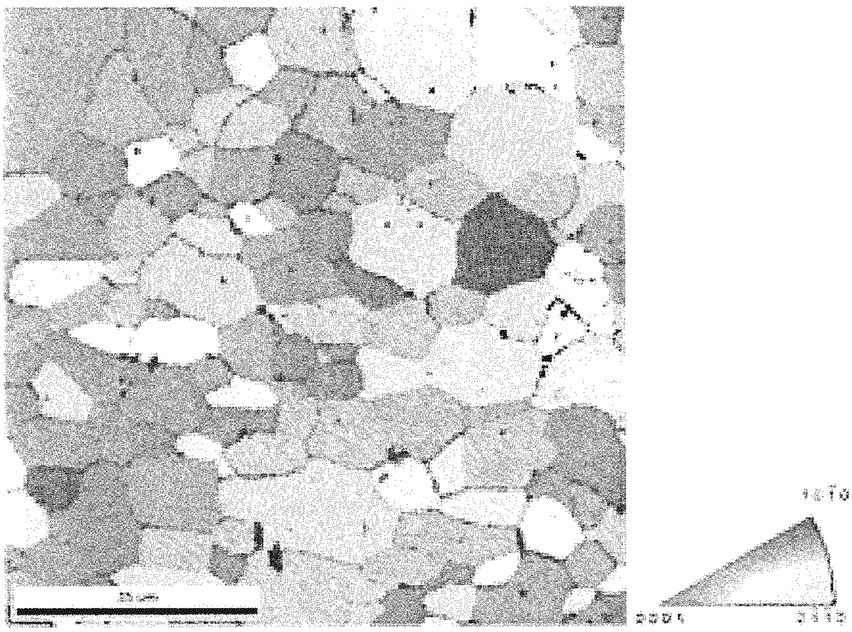
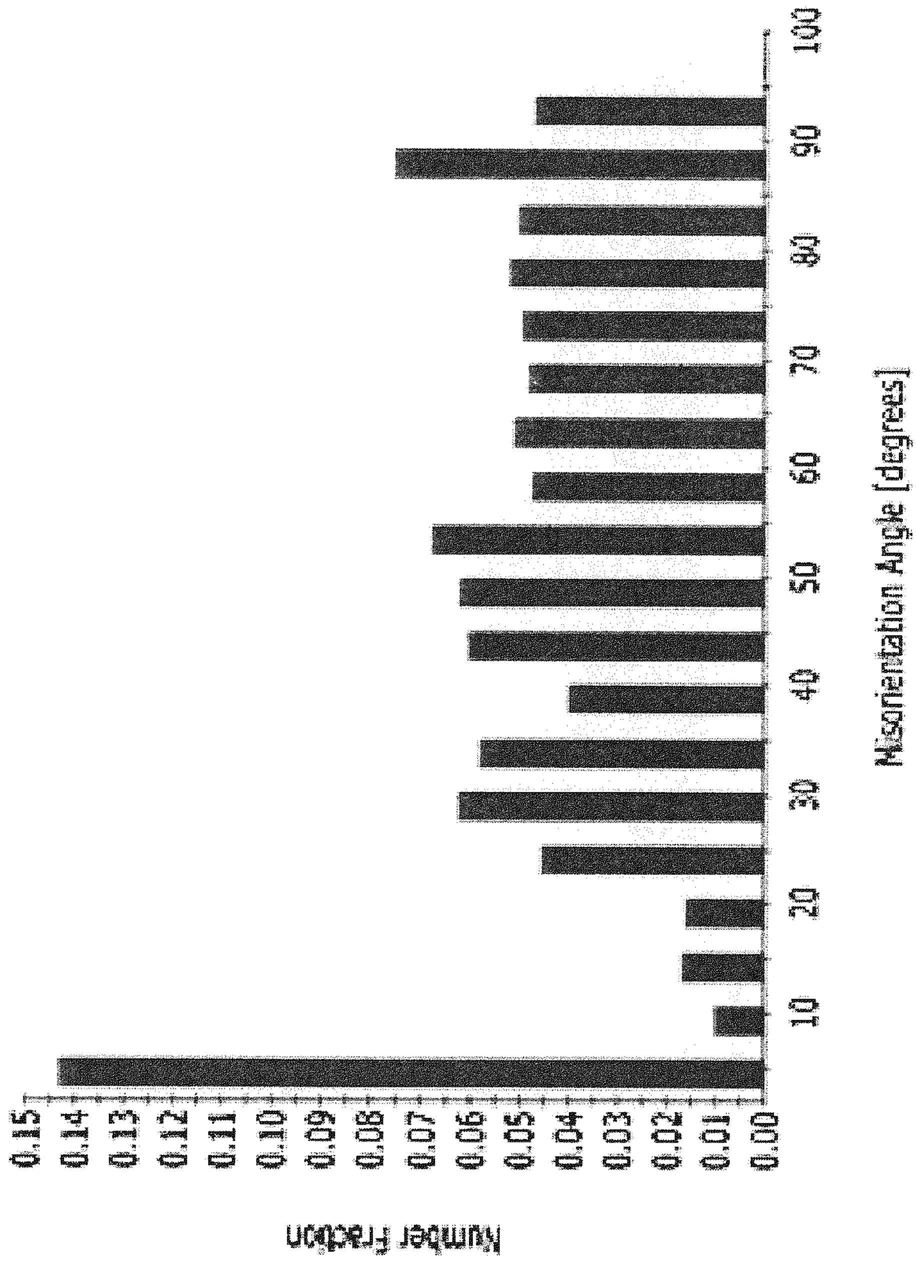


FIG. 9


Number Fraction
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0.13
0.12
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0.10
0.09
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0.05
0.04
0.03
0.02
0.01
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10
20
30
40
50
60
70
80
90
100
Misorientation Angle [degrees]

FIG. 10

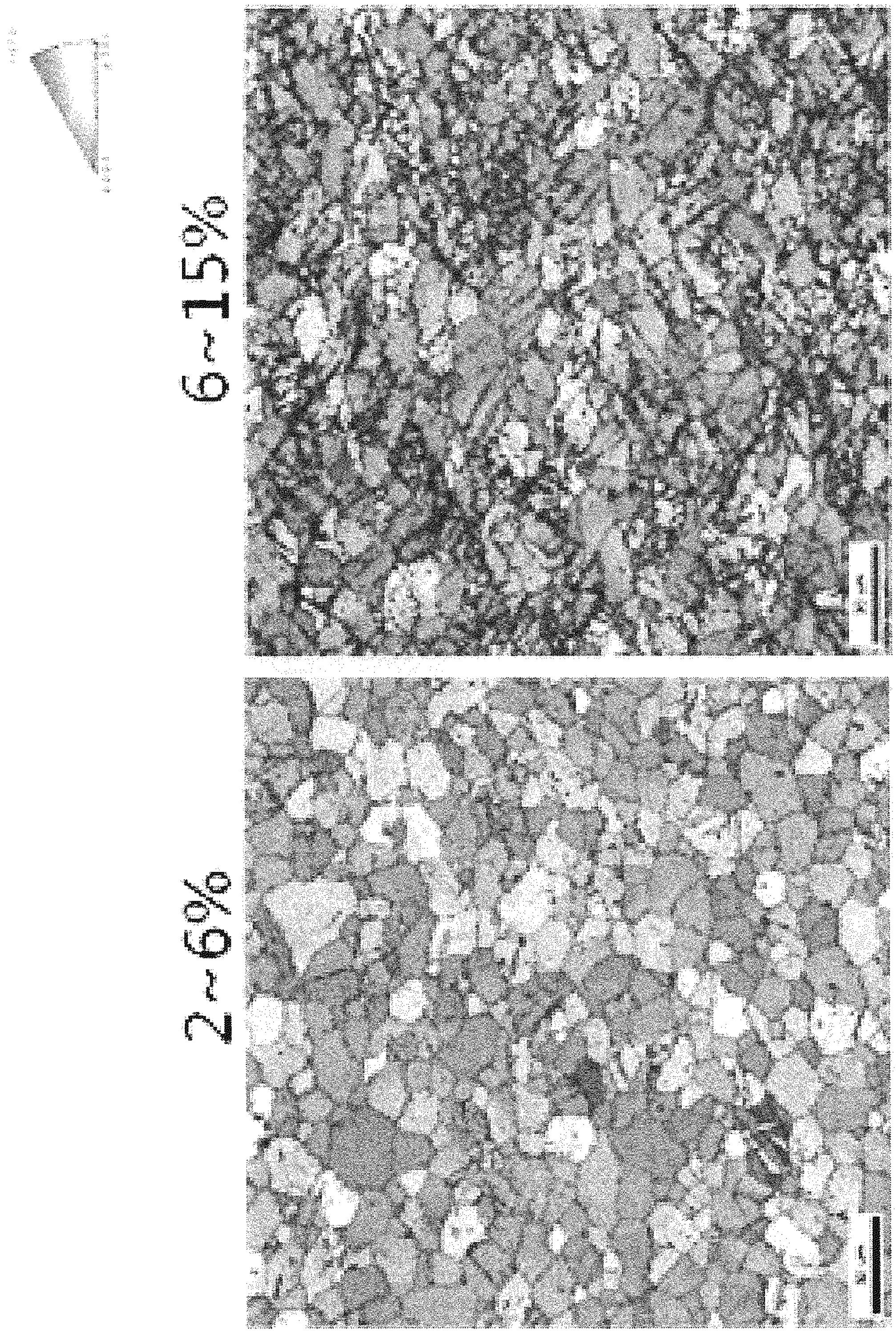
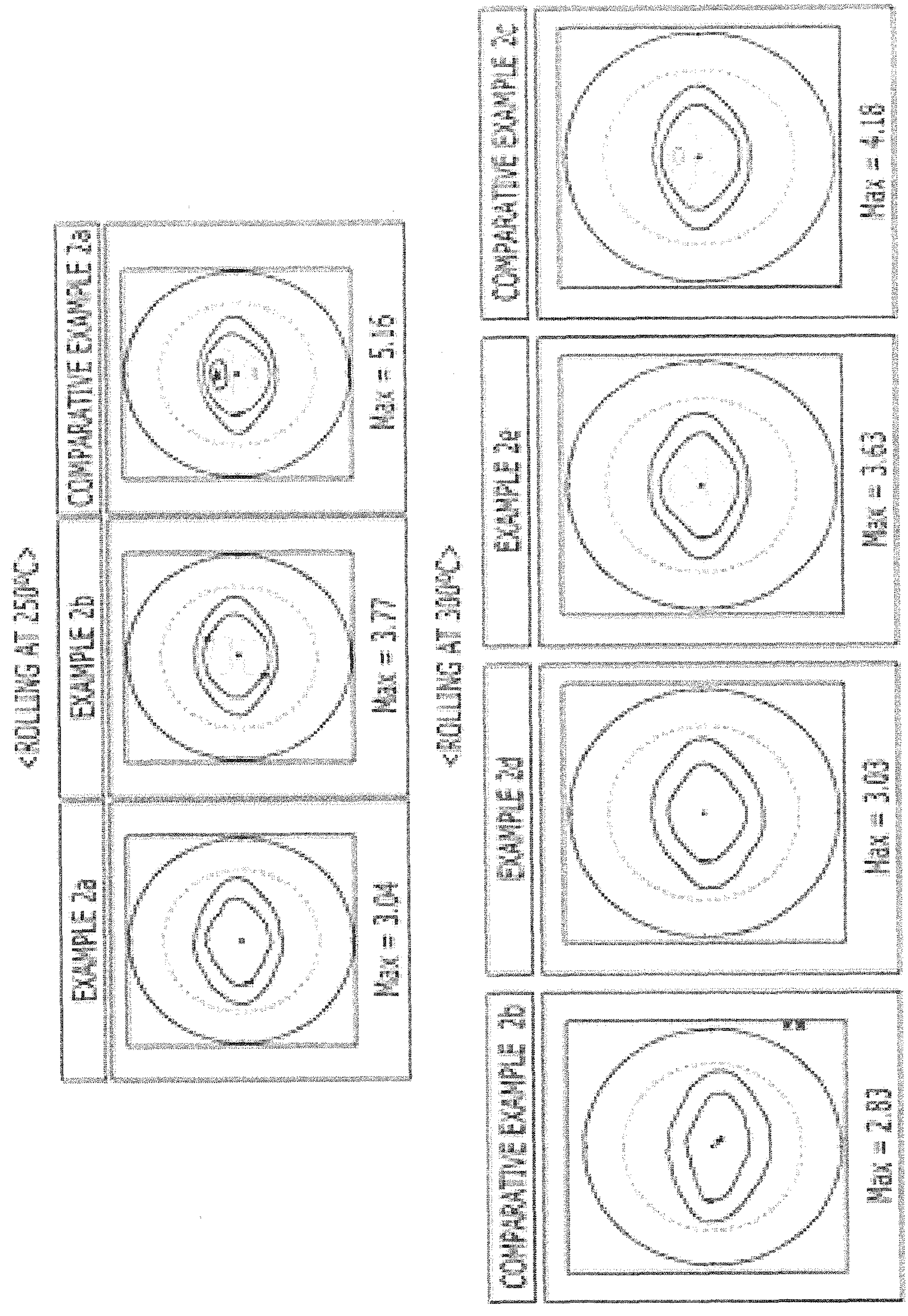


FIG. 11


<ROLLING AT 250°C>
EXAMPLE 2a
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EXAMPLE 2b
Max = 3.77
COMPARATIVE EXAMPLE 2a
Max = 5.16
<ROLLING AT 300°C>
COMPARATIVE EXAMPLE 2b
Max = 2.83
EXAMPLE 2d
Max = 3.03
EXAMPLE 2e
Max = 3.63
COMPARATIVE EXAMPLE 2c
Max = 4.18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2018/007030

A. CLASSIFICATION OF SUBJECT MATTER

C22C 23/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 23/02; B21B 1/42; B21B 3/00; B22D 11/06; B22D 21/04; C22F 1/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: magnesium alloy board, bottom crystal grain, Al-Ca secondary phase, rolling, medium segregation, limiting dome height

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2015-0065418 A (POSCO) 15 June 2015 See paragraphs [0033]-[0060]; claims 1-14; and figures 1-2.	1-10
Y	JP 2010-229467 A (HITACHI METALS LTD.) 14 October 2010 See paragraphs [0010]-[0025]; and claims 1-2.	1-10
A	KR 10-2009-0120194 A (POSTECH ACADEMY-INDUSTRY FOUNDATION) 24 November 2009 See paragraphs [0037]-[0055]; and figures 2-3.	1-10
A	JP 2011-179075 A (NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE & TECHNOLOGY et al.) 15 September 2011 See paragraphs [0019]-[0050]; and claims 1-3.	1-10
PX	KR 10-1751521 B1 (POSCO) 27 June 2017 See paragraphs [0035]-[0036], [0038]-[0040], [0042]-[0044], [0046], [0048]-[0049], [0051]-[0053], [0055]-[0056]; and claims 1-3.	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 OCTOBER 2018 (18.10.2018)	**19 OCTOBER 2018 (19.10.2018)**

Name and mailing address of the ISA/KR	Authorized officer
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