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(54) **HIGHLY MOLDED MAGNESIUM ALLOY SHEET AND METHOD FOR MANUFACTURING SAME**

(57) The present invention relates to a high-formed magnesium alloy sheet and a method of manufacturing the same.
One embodiment of the present invention provides a magnesium alloy sheet comprising:
3.0 wt% or less (excluding 0 wt%) of Zn, 1.5 wt% or less (excluding 0 wt%) of Ca, 1.0 wt% or less (excluding 0 wt%) of Mn, balance of Mg and inevitable impurities, for a total of 100 wt%, wherein, the magnesium alloy sheet further comprises 0.3 wt% or less of Al, based on 100 wt% of the entire magnesium alloy sheet, and the magnesium alloy sheet satisfies the following formulas (1) and (2):

$[Zn]/[Ca] \leq 4.0$ ----- formula (1)

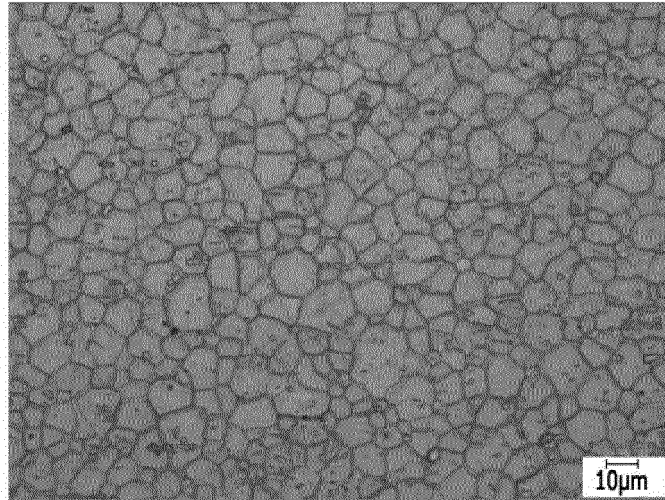
$[Zn] + [Ca] > [Mn]$ formula (2)

[Zn], [Ca], and [Mn] refer to weight percent of each component.

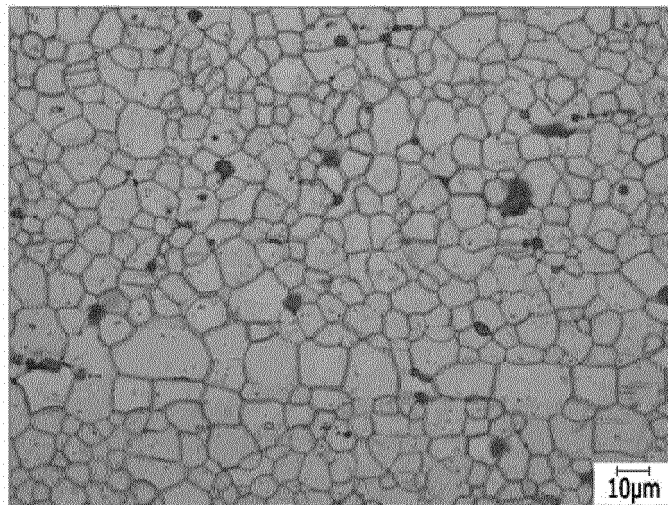
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【Fig 1】

Microstructure Comparison (x500)



Example 2



Comparative Example 2

Description

[Technical Field]

5 **[0001]** The present invention relates to a high-formed magnesium alloy sheet and a method of manufacturing the same.

[Background of the Invention]

10 **[0002]** In recent years, light weight (gram, gram) marketing has been actively performed in mobile and IT fields. More specifically, as the functions of the mobile device field become diversified, the product weight is required to be lighter. As a result, there is an increasing interest in magnesium sheet having excellent non-strength (strength against density).

15 **[0003]** The density of magnesium is 1.74 g/cm³, which is the lightest metal among the structural metals including aluminum and steel. In addition, it is a metal that is attracting attention in mobile and IT fields because of its excellent vibration absorbing ability and electromagnetic wave shielding ability. In addition, in the automobile field, studies are being actively carried out in advanced countries including Europe to reduce the weight of the vehicle body due to the regulation of fuel economy and performance, and magnesium is being reported as a substitute metal. However, since magnesium is expensive compared to competitive materials such as aluminum and stainless steel, its application to magnesium is limited to only some parts that are required to be lightweight.

20 **[0004]** In addition, magnesium is difficult to form at room temperature due to hexagonal close packing (HCP). Since the warm forming process is essential for the application of the product, the investment cost of the mold/heating device for the warm forming becomes large. In addition, it is deteriorated the productivity due to sticking, scratching between the mold and the material, and delay time for heating. Therefore, not only the price of the magnesium material, but also the processing cost of the magnesium alloy is more expensive than the competitive material.

25 **[0005]** On the basis of this, a magnesium alloy for improving room temperature moldability has been developed. However, a lithium alloy or a rare earth element having a high value is added, or the manufacturing process is complicated.

[Description of the Invention]

[Problem to Solve]

30 **[0006]** An embodiment of the present invention is to provide a high-formed magnesium alloy sheet and a method of manufacturing the same by controlling the composition range of the Zn, Ca, and Mn components of the magnesium alloy sheet and the relationship of the components.

35 **[0007]** Specifically, the present invention provides a magnesium alloy sheet excellent in moldability by controlling the Mg-Ca based secondary phase through the composition of the alloy and the manufacturing conditions.

[Solution to the Problem]

40 **[0008]** A magnesium alloy sheet of one embodiment of the invention may include 3.0 wt% or less (excluding 0 wt%) of Zn, 1.5 wt% or less (excluding 0 wt%) of Ca, 1.0 wt% or less (excluding 0 wt%) of Mn, balance of Mg and inevitable impurities, for a total of 100 wt%, wherein, the magnesium alloy sheet further comprises 0.3 wt% or less of Al, based on 100 wt% of the entire magnesium alloy sheet.

[0009] The magnesium alloy sheet may satisfy the following formulas (1) and (2):

45
$$[Zn]/[Ca] \leq 4.0 \text{-----} \quad \text{formula (1)}$$

$$[Zn] + [Ca] > [Mn] \text{-----} \quad \text{formula (2)}$$

[Zn], [Ca], and [Mn] refer to weight percent of each component.

50 **[0010]** A maximum texture intensity based on the {0001} plane of the magnesium alloy sheet may be 1 to 4.

[0011] The magnesium alloy sheet can have 7 to 10 mm of Limit Dome Height (LDH).

[0012] The magnesium alloy sheet may include crystal grain having an average particle size of 1 to 20 μm .

[0013] The magnesium alloy sheet may include a Mg-Ca based secondary phase, and the average particle size of the secondary phase is 30 μm or less.

55 **[0014]** Otherwise, the magnesium alloy sheet can include 1 to 20 secondary phases per 100 μm^2 of the magnesium alloy sheet area.

[0015] A method of manufacturing a magnesium alloy sheet of one embodiment of the invention may include: preparing a cast material by casting a molten alloy comprising 3.0 wt% or less (excluding 0 wt%) of Zn, 1.5 wt% or less (excluding

0 wt%) of Ca, 1.0 wt% or less (excluding 0 wt%) of Mn, balance of Mg and inevitable impurities, for a total of 100 wt%; subjecting the cast material to homogenizing heat treatment; preparing a rolled material by subjecting the homogenizing heat treated cast material to hot rolling; and final annealing the rolled material.

[0016] Wherein, the molten alloy can further include 0.3 wt% or less of Al, based on 100 wt% of the entire molten alloy, and the magnesium alloy sheet satisfies the following formulas (1) and (2).

$$[\text{Zn}]/[\text{Ca}] \leq 4.0 \text{-----} \quad \text{formula (1)}$$

$$[\text{Zn}] + [\text{Ca}] > [\text{Mn}] \text{-----} \quad \text{formula (2)}$$

[Zn], [Ca], and [Mn] refer to weight percent of each component.

[0017] In the step of final annealing the rolled material, a temperature range may be from 200 to 500°C. The step of the final annealing the rolled material may be conducted for less than 5 hours (excluding 0 hours).

[Effect]

[0018] According to an embodiment of the present invention, the composition range of the Zn, Ca, and Mn components of the magnesium alloy sheet and the relationship of the above components can be controlled to provide a magnesium alloy sheet of high molding.

[0019] Specifically, it is possible to provide a magnesium alloy sheet excellent in strength and room temperature moldability by controlling the Mg-Ca based secondary phase.

[Brief Description of Drawings]

[0020]

Fig. 1 is a photograph of the microstructure of the magnesium alloy sheet of Example 2 and Comparative Example 2 observed with an optical microscope.

Fig. 2 shows the results of analysis of the secondary phase components of Example 2 and Comparative Example 2 by SEM-EDS.

Fig. 3 shows the results of analysis of the {0001} planes of Example 2 and Comparative Example 3 by the XRD pole diagram and EBSD.

[Detailed Description of the Invention]

[0021] The advantages and features of the present invention and the manner of achieving them will become apparent with reference to the embodiments described in detail below with the accompanying drawings. However, it is to be understood that the present invention is not limited to the disclosed embodiments, but may be embodied in many different forms, and these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the scope of the invention to a person skilled in the art, and the present invention is only defined by the scope of the claims. Same reference numerals refer to same elements throughout the specification.

[0022] Thus, in some embodiments, well-known techniques are not specifically described to avoid an ambiguous interpretation of the present invention. Unless defined otherwise, all terms (including technical and scientific terms) used herein may be used in a sense commonly understood by a person skilled in the art. Further, through the specification, unless explicitly described to the contrary, the word "comprise" and variations such as "comprises" or "comprising" will be understood to imply the inclusion of stated elements but not the exclusion of any other elements. Also, singular forms comprise plural forms unless noted otherwise.

[0023] One embodiment of the present invention provides a magnesium alloy sheet including: 3.0 wt% or less (excluding 0 wt%) of Zn, 1.5 wt% or less (excluding 0 wt%) of Ca, 1.0 wt% or less (excluding 0 wt%) of Mn, balance of Mg and inevitable impurities, for a total of 100 wt%.

[0024] The magnesium alloy sheet can further include 0.3 wt% or less of Al, based on 100 wt% of the entire magnesium alloy sheet.

[0025] The composition range of the aluminum component may be such that it is added at an impurity level as compared with essential additive elements such as zinc, calcium, and manganese in the magnesium alloy sheet according to one embodiment of the present invention.

[0026] The reason for limiting the component and composition of the magnesium alloy sheet according to one embodiment of the present invention will be described in detail.

[0027] Zn may include 3.0 wt% or less, but 0 wt% is excluded.

[0028] More specifically, Zn may be 0.5 to 3.0 wt%.

[0029] More specifically, when zinc is added, such as calcium, it may segregate in the grain boundary and the twin crystal phase to contribute to the generation and growth of the non-bottom grain recrystallized grains. As a result, softening phenomenon of the non-bottom surface is brought about, and the slip of the non-bottom surface is activated to improve the formability of the sheet material. Therefore, when it is added in an amount less than 0.5% by weight, it may be difficult to ensure moldability.

[0030] However, if it is added in an amount exceeding 3.0% by weight, it may be bonded with magnesium and calcium to form additional intermetallic compounds, which may adversely affect the moldability. Further, when casting, sticking occurs more deeply and molding may be difficult. Accordingly, when zinc is contained in the above range, an effect of improving moldability at room temperature can be expected.

[0031] Ca may contain up to 1.5% by weight, but excluding 0% by weight.

[0032] More specifically, Ca may be 0.1 to 1.5% by weight.

[0033] More specifically, calcium, like zinc, may be segregated in grain boundaries and twin crystal phase to contribute to the production and growth of non-bottom recrystallized grains. As a result, softening phenomenon of the non-bottom surface is brought about, and the slip of the non-bottom surface is activated to improve the formability of the sheet. Therefore, when it is added in an amount of less than 0.1% by weight, it is difficult to secure moldability.

[0034] However, the addition of more than 1.5% by weight reduces the fluidity of the molten alloy and lowers the casting property, so that the productivity may be reduced, cracks may be generated at the time of rolling, and the rolling property of the plate material may be deteriorated. Accordingly, when calcium is contained in the above range in the present invention, an effect of improving the room temperature moldability can be expected within a range that does not inhibit the casting and rolling property.

[0035] Mn may include not more than 1.0 wt%, but not 0 wt%.

[0036] More specifically, manganese acts as a recrystallization nucleation site to generate fine grains, and then to suppress grain growth, thereby providing fine and uniform grains. Therefore, in the method of manufacturing a magnesium alloy sheet, which is another embodiment of the present invention described later, it is possible to provide fine crystal grains in the homogenizing heat treatment step, and finely control the crystal grains of the final magnesium alloy sheet.

[0037] Accordingly, when the manganese is contained in the range as described above, the crystal grains of the homogenizing heat treated sheet are finely formed, and defects such as abnormal crystal growth in the hot rolling step, orange peel due to shear band and surface cracks can be prevented. Therefore, the rolling property can be improved. In addition, when manganese is contained in the above range, impurities such as iron (Fe) and silicon (Si) can be controlled to provide excellent corrosion resistance.

[0038] Therefore, a sheet having fine crystal grains can be produced through addition of manganese, so that both the strength and the formability can be excellent.

[0039] The magnesium alloy sheet satisfies the following formulas (1) and (2).

$$[\text{Zn}]/[\text{Ca}] \leq 4.0 \text{-----} \quad \text{formula (1)}$$

$$[\text{Zn}] + [\text{Ca}] > [\text{Mn}] \text{-----} \quad \text{formula (2)}$$

[Zn], [Ca], and [Mn] refer to weight percent of each component.

[0040] More specifically, the formula (1) may be 3 or less.

[0041] It may be possible to prevent the secondary phase coarsening generated by further limiting the composition ratios of Zn and Ca components as well as the composition ratios as in the above formula (1), and realized the desired high strength and high molding properties.

[0042] Specifically, the magnesium alloy sheet can satisfy the formula (2) ($[\text{Zn}] + [\text{Ca}] > [\text{Mn}]$). Concretely, when the sum of the Zn and Ca composition is equal to or smaller than the composition of Mn, the rolling property and the formability may be deteriorated.

[0043] The magnesium alloy sheet satisfying the above-described components and composition ranges may include a Mg-Ca based secondary phase. At this time, the average particle size of the secondary phase may be 30 μm or less. Specifically, it may be 25 μm or less. Specifically, it may be 20 μm or less.

[0044] The average particle size in this specification means the average diameter of the spherical substance present in the unit of measurement. If the material is a non-spherical material, it can be calculated by approximating the non-spherical material to the spherical shape.

[0045] That is, the range of the secondary phase size is significantly smaller than that of the secondary phase of the general magnesium alloy sheet.

[0046] When the average particle size of the secondary phase exceeds 30 μm , the moldability of the alloy material may be lowered.

[0047] As will be described later, this can be visually confirmed through the drawings.

[0048] The magnesium alloy sheet can include 1 to 20 secondary phases per 100 μm^2 of the magnesium alloy sheet area.

[0049] When the number of the secondary phases is the same as above, the strength and moldability of the magnesium alloy sheet can be excellent.

[0050] The magnesium alloy sheet may include crystal grains having an average particle diameter of 1 to 20 μm .

[0051] By controlling the component and composition of the aforementioned magnesium alloy sheet, it is possible to obtain the crystal grain size in the above range. More specifically, when the grain size of the magnesium alloy sheet is in the above range, the strength can be excellent.

[0052] The maximum texture intensity based on the {0001} plane of the magnesium alloy sheet may be 1 to 4.

[0053] As the texture intensity of the magnesium alloy sheet is in the above range, crystal grains of various orientations can be distributed. Accordingly, since the fraction of the bottom grain (<0001>//C-axis orientation) is small, a magnesium alloy sheet having excellent formability can be provided.

[0054] In the present specification, the bottom crystal grain means a crystal grain having a bottom orientation. Specifically, magnesium has an HCP (Hexagonal Closed Pack) crystal structure. At this time, when the C axis of the crystal structure is parallel to the thickness direction of the sheet, the crystal grains is referred to as crystal grains having a bottom crystal orientation (that is, bottom crystal grains). Therefore, in the present specification, the bottom grain can also be expressed as "<0001>//C axis".

[0055] Specifically, the smaller the maximum texture intensity with respect to the {0001} plane of the magnesium alloy sheet, the more crystal grains of various orientations are distributed. Further, as the crystal grains of various orientations are distributed and the fraction of the bottom surface crystal grains is lower, a magnesium alloy sheet having excellent formability can be obtained.

[0056] Therefore, the magnesium alloy sheet according to an embodiment of the present invention has a texture intensity of 1 to 4 based on the {0001} plane, so that the moldability can be excellent.

[0057] The Erichsen value of the magnesium alloy sheet at room temperature may be 7 to 10 mm.

[0058] In this specification, the Erichsen value means an experimental value derived from the Ericsson test at room temperature. More specifically, the Erichsen value refers to the height at which the sheet is deformed until a fracture occurs, when the sheet is deformed into a cup shape.

[0059] Therefore, the room temperature moldability can be compared through the Erichsen value.

[0060] The yield strength of the magnesium alloy sheet may be 170 MPa or more. Specifically, it may be 170 to 220 MPa.

[0061] Also, the tensile strength of the magnesium alloy sheet may be 240 MPa or more. Specifically, it may be 240 to 300 MPa.

[0062] The elongation of the magnesium alloy sheet may be 20% or more. Specifically, it may be 20 to 30%.

[0063] However, the present invention is not limited thereto. Specifically, the yield strength, the tensile strength, and the elongation are preferably as good as possible, and the magnesium alloy sheet according to one embodiment of the present invention can realize mechanical properties at least the minimum value.

[0064] In addition, the strength and elongation of the magnesium alloy sheet according to one embodiment of the present invention are excellent in strength and elongation as compared with the conventional case in which an additional element is added to the AZ-based magnesium alloy.

[0065] Thus, by controlling the component and composition of the magnesium alloy sheet as described above, it is possible to provide a magnesium alloy sheet excellent in both strength and moldability.

[0066] A method of manufacturing a magnesium alloy sheet of one embodiment of the invention may include: preparing a cast material by casting a molten alloy comprising 3.0 wt% or less (excluding 0 wt%) of Zn, 1.5 wt% or less (excluding 0 wt%) of Ca, 1.0 wt% or less (excluding 0 wt%) of Mn, balance of Mg and inevitable impurities, for a total of 100 wt% (S10); subjecting the cast material to homogenizing heat treatment (S20); preparing a rolled material by subjecting the homogenizing heat treated cast material to hot rolling (S30); and final annealing the rolled material (S40).

[0067] First, a step of preparing a cast material by casting a molten alloy comprising 3.0 wt% or less (excluding 0 wt%) of Zn, 1.5 wt% or less (excluding 0 wt%) of Ca, 1.0 wt% or less (excluding 0 wt%) of Mn, balance of Mg and inevitable impurities, for a total of 100 wt% (S10) can be performed.

[0068] It may further contain less than 0.3% by weight of Al relative to 100% by weight of the entire magnesium molten alloy.

[0069] Specifically, the magnesium molten alloy can satisfy the following formulas (1) and (2).

$$[\text{Zn}]/[\text{Ca}] \leq 4.0 \text{-----} \quad \text{formula (1)}$$

$$[\text{Zn}] + [\text{Ca}] > [\text{Mn}] \text{-----} \quad \text{formula (2)}$$

[Zn], [Ca], and [Mn] refer to weight percent of each component.

[0070] The reason for limiting the component and the composition range of the molten alloy is the same as the reason

for limiting the component and the composition range of the magnesium alloy sheet described above, so that the description is omitted.

[0071] More specifically, the molten alloy can be cast by gravity casting, continuous casting, strip casting (thin sheet casting), sand casting, vacuum casting, centrifugal casting, die casting, or thixo molding.

[0072] However, the present invention is not limited thereto, and any method capable of producing a cast material is possible.

[0073] Thereafter, a step (S20) of subjecting the cast material to homogenizing heat treatment can be performed.

[0074] Specifically, it can be carried out at 300 to 500 °C.

[0075] More specifically, it may be carried out for 5 to 30 hours.

[0076] More specifically, overheating can be prevented by homogenizing the cast material in the temperature and time range, and the microstructure and segregation of the cast material can be sufficiently homogenizing heated.

[0077] Thereafter, the step (S30) of preparing a rolled material by subjecting the homogenizing heat treated cast material to hot rolling may be performed.

[0078] Specifically, hot rolling can be performed in a temperature range of 150 to 400 °C.

[0079] More specifically, in the case of hot rolling at less than 150 °C, a large amount of surface scattering type cracks or edge cracks may occur.

[0080] On the other hand, when hot rolling is performed at a temperature higher than 400 °C, there may be occurred a problem of equipment such as the necessity of changing the component of the equipment to a heat resistant material for rolling at a high temperature. As a result, problems such as an increase in process cost and a decrease in productivity are caused, and mass production of the magnesium alloy sheet may be difficult.

[0081] In addition, the cast material may be hot rolled once or twice at a reduction ratio of not more than 40% (excluding 0%) per rolling.

[0082] The homogenizing heat treated cast material can be hot rolled by using a hot rolling mill.

[0083] When the cast material is hot-rolled twice or more, an intermediate annealing may be performed at least once between hot rolling. The intermediate annealing may be performed at a temperature range of 300 to 500 °C

[0084] The intermediate annealing may be performed for 5 hours or less (excluding 0 hours).

[0085] More specifically, if the temperature and time range are not satisfied, the stress of the hardened tissue is not sufficiently solved by the cumulative rolling reduction, and the annealing process may not be performed properly. Further, the abnormal crystal grains can grow due to excessive annealing.

[0086] Further, the thickness of the rolled material that is hot-rolled at least twice may be 2.0 mm or less.

[0087] Thereafter, a step (S40) of final annealing the rolled material can be carried out.

[0088] Concretely, it can be carried out at 200 to 500 °C.

[0089] More specifically, it can be carried out for not more than 5 hours (excluding 0 hours).

[0090] More specifically, by finally annealing the rolled material in the temperature and time range, the magnesium alloy sheet produced can secure the desired formability at room temperature.

[0091] Hereinafter, the embodiment will be described in detail. The following examples are illustrative of the present invention only and are not intended to limit the scope of the present invention.

Examples and Comparative Examples

[0092] As shown in the following Table 1, when the range according to one embodiment of the present invention is satisfied, it is classified as an invention material. Meanwhile, when the range according to one embodiment of the present invention is not satisfied, it is classified as a comparative material.

[0093] Then, using the inventive material and the comparative material shown in Table 1, a magnesium alloy plate material was produced under the following conditions.

[0094] First, an alloyed molten metal of an inventive material and a comparative material was cast to produce a cast material.

[0095] Thereafter, the cast material was subjected to homogenizing heat treatment at 330 to 450 °C for 16 hours.

[0096] The homogenizing heat treated cast material was rolled at 300 °C at a reduction ratio of 10 to 20% to prepare a rolled material. At this time, intermediate annealing was performed at 450 °C for 0.5 to 1 hour.

[0097] Finally, the rolled material was subjected to final annealing as shown in Table 2 below to produce a magnesium alloy sheet.

[Table 1]

Classification	Alloy	Al	Zn	Ca	Mn	formula (1) Zn+ Ca>Mn	formula (2) Zn/Ca
Example 1	Mg-1.0Zn-0.6Ca-0.3Mn	-	1.07	0.61	0.35	○	1.75

(continued)

Classification	Alloy	Al	Zn	Ca	Mn	formula (1) Zn+ Ca>Mn	formula (2) Zn/Ca
Example 2	Mg-1.5Zn-0.6Ca-0.3Mn	-	1.55	0.60	0.35	○	2.58
Example 3	Mg-2.0Zn-0.6Ca-0.3Mn	-	2.23	0.59	0.31	○	3.77
C-Example 1	Mg-0.3Zn-0.2Ca-1.2Mn	-	0.38	0.22	1.26	X	1.73
C-Example 2	Mg-3.0Zn-0.6Ca-0.3Mn	-	3.04	0.55	0.32	○	5.52
C-Example 3	Mg-3.0Al-1.0Zn(AZ31)	2.98	0.79	-	0.33	○	-
C-Example 4	Mg-3.0Al-0.6Ca-1.0Zn	2.98	0.79	0.65	0.33	○	1.22
C-Example 5	Mg-2.0Zn-0.1Ca-0.3Mn	-	2.09	0.11	0.32	○	20

[0098] As a result, Table 2 shows mechanical properties of the magnesium alloy sheet according to Examples and Comparative Examples and Erichsen's values at room temperature.

[0099] The Ericsson values measurement method is as follows.

[0100] Specifically, a magnesium alloy sheet having a size of 50 to 60 mm in each of the width and the length was used, and a lubricant was used on the surface of the sheet to reduce the friction between the sheet and the spherical punch.

[0101] At this time, the temperature of the die and the spherical punch was set at room temperature.

[0102] More specifically, after inserting the magnesium alloy sheet between the upper die and the lower die, the outer peripheral portion of the sheet was fixed with a force of 10 kN. Thereafter, the sheet was deformed at a rate of 5 mm/min using a spherical punch having a diameter of 20 mm. Thereafter, the punch was inserted until the sheet was broken, and then the deformation height of the sheet was measured at the time of breaking.

[0103] The deformation height of the plate measured in this way is called the Erichsen value or the limit dome height (LDH).

[Table 2]

species	Classification	Final annealing temperature and time	Yield strength (MPa)	tensile strength (MPa)	Elongation (%)	Erichsen value (mm)
Invention material 1	Example 1	400 °C, 30 min	174	246	23.1	8.3
Invention material 2	Example 2	400 °C, 30 min	185	254	22.2	9.0
Invention material 3	Example 3	400 °C, 30 min	191	263	20.9	8.1
Comparative material 1	C-Example 1	400 °C, 30 min	125	208	23.4	5.5
Comparative material 2	C-Example 2	400 °C, 30 min	173	253	19.1	6.9
Comparative material 3	C-Example 3	350 °C, 30 min	165	257	24.5	3.5
Comparative material 4	C-Example 4	400 °C, 30 min	151	251	19.6	7.4

(continued)

species	Classification	Final annealing temperature and time	Yield strength (MPa)	tensile strength (MPa)	Elongation (%)	Erichsen value (mm)
Comparative material 5	C-Example 5	400 °C, 30 min	152	237	22.6	7.1

[0104] As a result, it can be seen that Examples 1 to 3 have a much higher Erichsen value than the Comparative Examples. Specifically, it can be seen that the present example has a yield strength of 170 MPa or more, a tensile strength of 240 MPa or more, an elongation of 20% or more, and a room temperature Erichsen value of 7 mm or more.

[0105] Specifically, the comparative examples which satisfy the range of the composition of Zn, Ca, and Mn according to one embodiment of the present invention, but do not satisfy both the formula $[Zn] + [Ca] > [Mn]$ and the formula $[Zn]/[Ca] \leq 4.0$, can be confirmed that there is an effect of heating strength and formability.

[0106] These characteristics can also be confirmed through the drawings.

[0107] Fig. 1 is a photograph of the microstructure of the magnesium alloy sheet of Example 2 and Comparative Example 2 observed with an optical microscope.

[0108] As a result, comparing the microstructures of Example 2 and Comparative Example 2 in which the final annealing conditions were the same and the components of the alloy were different, the secondary phase in the form of agglomerated black in Comparative Example 2 is more than Example 2. It can be seen with the naked eye.

[0109] In addition, in the case of Comparative Example 2 using Comparative Material 2 having a higher Zn content than Example 2 using Invention Material 2, it can be seen that the size of the secondary phase is coarse.

[0110] As described above, the coarse secondary phase adversely affects the moldability.

[0111] As a result, as shown in Table 2, the Erichsen value of Comparative Example 2 is 6.9 mm, while the Erichsen value of Example 2 is 9.0 mm, indicating that the moldability of this embodiment is better.

[0112] Further, when the content of Zn is added in an amount exceeding 3% by weight, the crystal grains can be locally coarsened as in Comparative Example 2. As a result, mechanical properties and moldability may be deteriorated.

[0113] Fig. 2 shows the results of analysis of the secondary phase components of Example 2 and Comparative Example 2 by SEM-EDS.

[0114] When a sample is irradiated with a certain wavelength using a SEM-EDS analyzer, a peak may appear at a value corresponding to the energy of the material. At this time, component analysis can be derived from the wavelengths shown.

[0115] Specifically, it can be seen that a secondary phase (dark gray spherical shape) is finely dispersed in an EDS (Energy Dispersive Spectroscopy) photograph of a scanning electron microscope (SEM) of Example 2. As a result of analyzing the secondary phase component of Example 2, it can be seen that it is a Mg-Ca secondary phase. At this time, the size of the secondary phase was about 20 μm or less.

[0116] On the other hand, the secondary phase (white) of the microstructure of Comparative Example 2 in which the content of Zn exceeded 3.0 wt% was confirmed. However, as a result of analyzing the secondary phase component of Comparative Example 2, it can be seen that the secondary phase is a Ca-Mg-Zn three-atom system.

[0117] In other words, in Example 2, as a result of the content ratio of Zn and Ca and the content ratio of Zn/Ca satisfying all the ranges defined in the embodiment of the present invention, it was also confirmed that the formation of the secondary phase of the Mg-Ca two-atom system is more easy than the secondary phase of Ca-Mg-Zn three-atom system.

[0118] Further, as can be seen from Fig. 2, the secondary phase of Comparative Example 2 in which the Zn content is excessive is larger than that of the secondary phase of Example 2.

[0119] On the other hand, in Example 2 of the present application, the Mg-Ca based secondary phase is finely dispersed and distributed at a level of 20 μm or less, thereby contributing to improvement of the strength and moldability of the magnesium alloy sheet.

[0120] Fig. 3 shows the results of analysis of the {0001} planes of Example 2 and Comparative Example 3 by the XRD pole diagram and EBSD.

[0121] Specifically, Fig. 3 shows the texture according to the crystal orientation of the crystal grains by using the XRD pole figure method and EBSD (Electron Backscatter Diffraction) method.

[0122] The EBSD can inject electrons into the specimen through the e-electron beam and measure the crystal orientation of the grains using inelastic scattering diffraction at the back of the specimen.

[0123] The pole figure is a stereo projection of the direction of the arbitrarily fixed crystal coordinate system in the specimen coordinate system. More specifically, the poles for the {0001} planes of the crystal grains of various orientations can be displayed in the reference coordinate system, and the poles can be represented by plotting density contours

according to the poles density distribution. At this time, the poles are fixed in a specific lattice direction by the Bragg angle, and a plurality of poles can be displayed for a single crystal.

[0124] Therefore, the numerical representation of the density distribution values of the contour lines indicated by the poling method can be referred to as the texture intensity for the {0001} plane.

[0125] Accordingly, as the texture intensity becomes smaller, crystal grains of various orientations are distributed. As the texture intensity becomes larger, it can be interpreted that the crystal grains of <0001>//C axis orientation are distributed much.

[0126] First, as shown in Fig. 3, it can be seen that the grain size of the grain in Example 2 is as fine as 1 to 20 μm as compared with that of Comparative Example 3.

[0127] In addition, the maximum texture intensity of the {0001} plane of Example 2 was 2.46. It is significantly lower than that of Comparative Example 3 with a maximum texture intensity of 12.11. From this, it can be interpreted that the crystal grains of various orientations are distributed in Example 2 of the present invention, whereas the crystal grains (bottom crystal grains) of the <0001>//C axis orientation are distributed much in Comparative Example 3.

[0128] From this, it can be seen that the embodiment has better moldability because the fraction of the bottom surface crystal grain is smaller than that of the comparative example.

[0129] Although the embodiments of the present invention have been described with reference to the accompanying drawings, it will be understood by a person skilled in the art may understand that it may be carried out in different and concrete forms without changing the technical idea or fundamental feature of the present invention.

[0130] Therefore, it is to be understood that the above-mentioned examples or embodiments are illustrative in all aspects and not limitative. 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 claims and their equivalents should be interpreted as being included in the scope of the present invention.

Claims

1. A magnesium alloy sheet comprising:

3.0 wt% or less (excluding 0 wt%) of Zn, 1.5 wt% or less (excluding 0 wt%) of Ca, 1.0 wt% or less (excluding 0 wt%) of Mn, balance of Mg and inevitable impurities, for a total of 100 wt%,
wherein, the magnesium alloy sheet further comprises 0.3 wt% or less of Al, based on 100 wt% of the entire magnesium alloy sheet, and
the magnesium alloy sheet satisfies the following formulas (1) and (2):

$$[\text{Zn}]/[\text{Ca}] \leq 4.0 \text{-----} \quad \text{formula (1)}$$

$$[\text{Zn}] + [\text{Ca}] > [\text{Mn}] \quad \text{formula (2)}$$

[Zn], [Ca], and [Mn] refer to weight percent of each component.

2. The magnesium alloy sheet of Claim 1,
wherein, a maximum texture intensity based on the {0001} plane of the magnesium alloy sheet is 1 to 4.

3. The magnesium alloy sheet of Claim 1,
wherein, the magnesium alloy sheet has 7 to 10 mm of Limit Dome Height (LDH).

4. The magnesium alloy sheet of Claim 1,
wherein, the magnesium alloy sheet has 170 MPa or more of yield strength.

5. The magnesium alloy sheet of Claim 1,
wherein, the magnesium alloy sheet has 240 MPa or more of tensile strength.

6. The magnesium alloy sheet of Claim 1,
wherein, the magnesium alloy sheet has 20% or more of elongation percentage.

7. The magnesium alloy sheet of Claim 1,
wherein, the magnesium alloy sheet comprises crystal grain having an average particle size of 1 to 20 μm .

8. The magnesium alloy sheet of Claim 1,
wherein, the magnesium alloy sheet comprises a Mg-Ca based secondary phase, and
the average particle size of the secondary phase is 30 μm or less.

9. The magnesium alloy sheet of Claim 1,
wherein the magnesium alloy sheet comprises 1 to 20 secondary phases per 100 μm^2 of the magnesium alloy sheet
area.

10. A method of manufacturing a magnesium alloy sheet comprising:

preparing a cast material by casting a molten alloy comprising 3.0 wt% or less (excluding 0 wt%) of Zn, 1.5 wt%
or less (excluding 0 wt%) of Ca, 1.0 wt% or less (excluding 0 wt%) of Mn, balance of Mg and inevitable impurities,
for a total of 100 wt%;

subjecting the cast material to homogenizing heat treatment;

preparing a rolled material by subjecting the homogenizing heat treated cast material to hot rolling; and
final annealing the rolled material;

wherein, the molten alloy further comprises 0.3 wt% or less of Al, based on 100 wt% of the entire molten alloy, and
the magnesium alloy sheet satisfies the following formulas (1) and (2):

$$[\text{Zn}]/[\text{Ca}] \leq 4.0 \quad \text{formula (1)}$$

$$[\text{Zn}] + [\text{Ca}] > [\text{Mn}] \quad \text{formula (2)}$$

[Zn], [Ca], and [Mn] refer to weight percent of each component.

11. The method of Claim 10,
wherein, in the step of final annealing the rolled material,
a temperature range is from 200 to 500°C.

12. The method of Claim 11,
wherein, a step of the final annealing the rolled material is conducted for less than 5 hours (excluding 0 hours).

13. The method of Claim 10,
wherein, in a step of the subjecting the cast material to homogenizing heat treatment;
a temperature range is from 300 to 500°C.

14. The method of Claim 13,
wherein, a step of the subjecting the cast material to homogenizing heat treatment is conducted for 5 hours to 30 hours.

15. The method of Claim 10,
wherein, in a step of preparing a rolled material by subjecting the homogenizing heat treated cast material to hot rolling,
a temperature range is from 150 to 400°C.

16. The method of Claim 15,
wherein, the step of preparing a rolled material by subjecting the homogenizing heat treated cast material to hot rolling,
the cast material is rolled once or twice at a reduction ratio of not more than 40% (excluding 0%) per rolling.

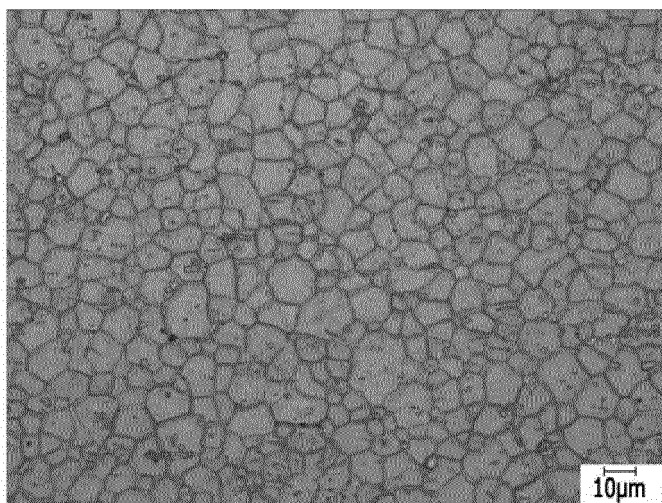
17. The method of Claim 16,
wherein, the step of preparing a rolled material by subjecting the homogenizing heat treated cast material to hot rolling,
the cast material is hot-rolled twice or more, and
an intermediate annealing is performed at least once between hot rolling.

18. The method of Claim 17,
the intermediate annealing is performed at a temperature range of 300 to 500 °C

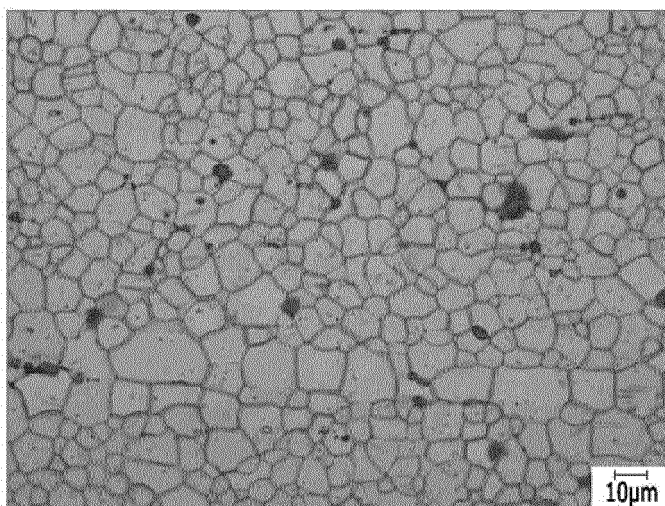
19. The method of Claim 18,
the intermediate annealing is performed for 5 hours or less (excluding 0 hours).

【Fig 1】

Microstructure Comparison (x500)

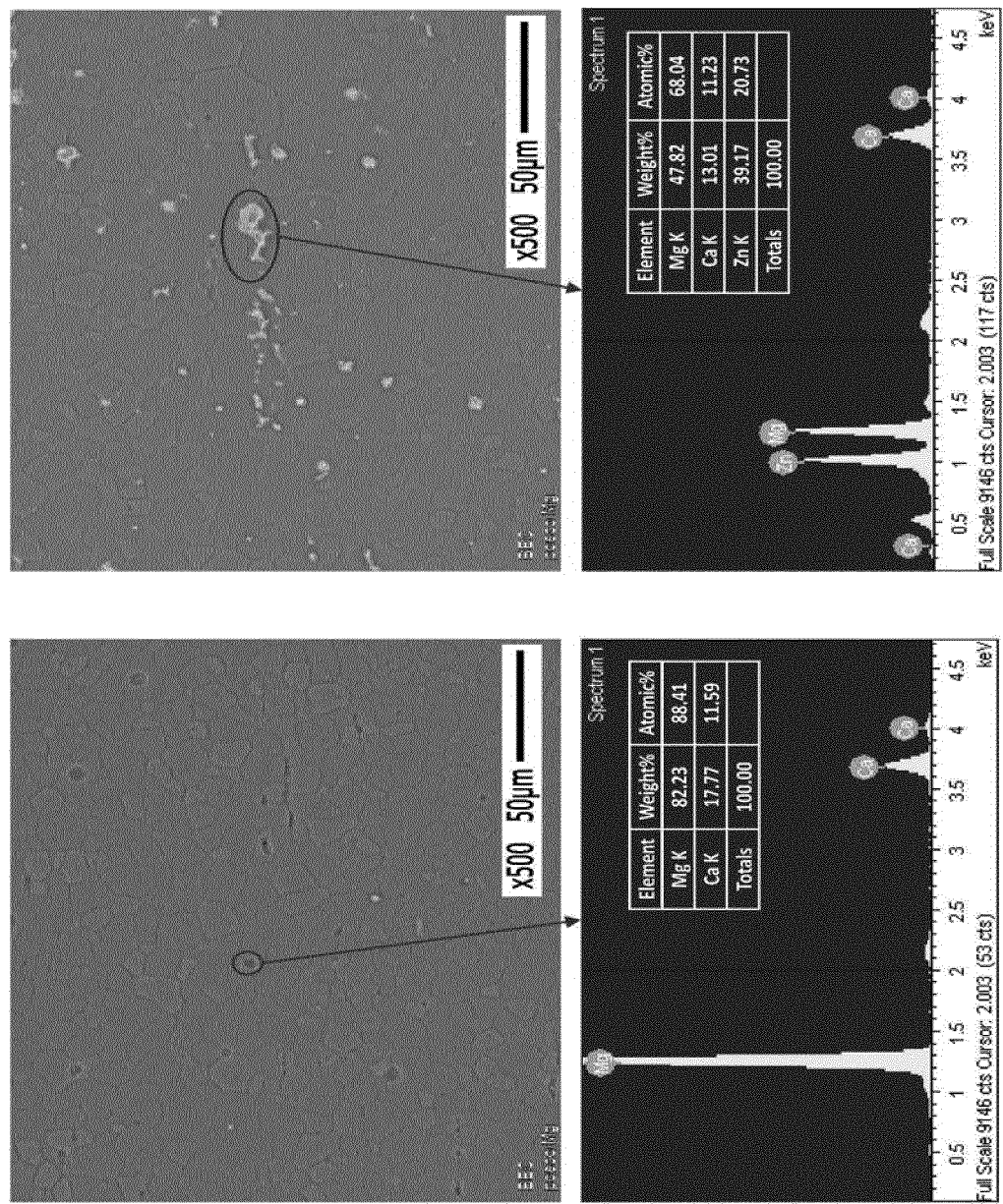


Example 2

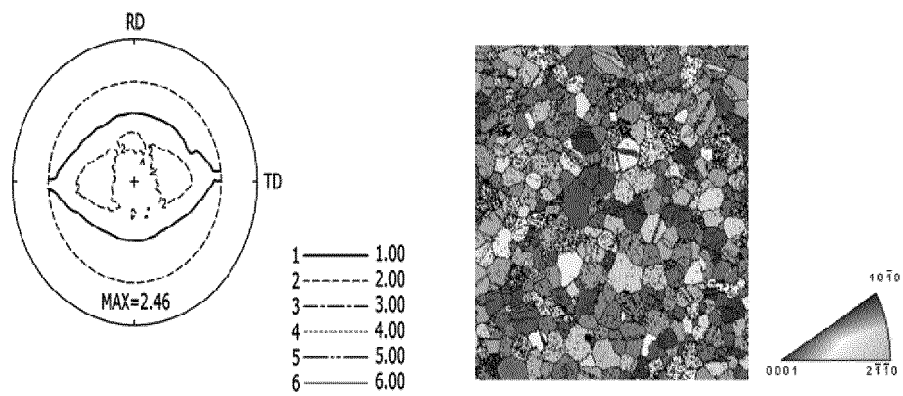


Comparative Example 2

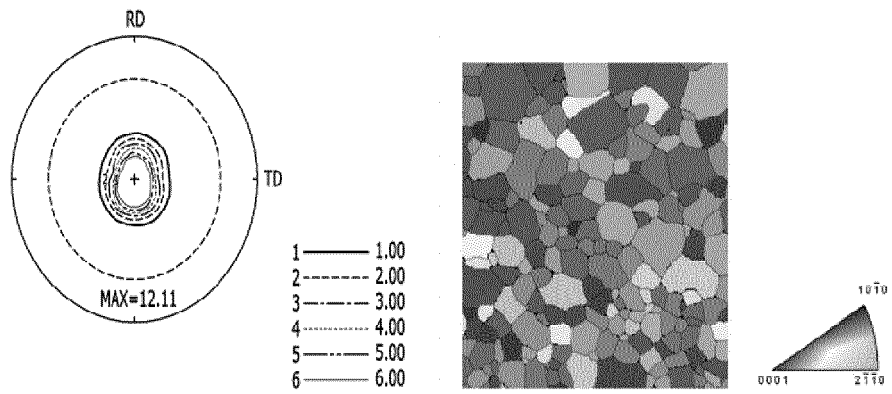
【Fig 2】



【Fig 3】



Example 2



Comparative Example 3