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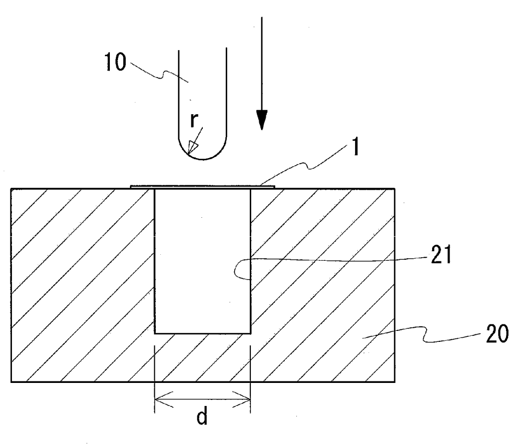
(54) **MAGNESIUM ALLOY PLATE**

(57) A magnesium alloy sheet having high impact resistance at low temperature, a magnesium alloy structural member using this sheet, and a method for producing a magnesium alloy sheet are provided. The magnesium alloy sheet is composed of a magnesium alloy containing Al and Mn. When a region from a surface of the alloy sheet to 30% of the thickness of the alloy sheet in a thickness direction of the magnesium alloy sheet is defined as a surface region and when a 50 μm^2 subregion is arbitrarily selected from this surface region, the number of grains that are crystallized phases containing both Al and Mn is 15 or less. The maximum diameter of each of the crystallized phases is 0.1 to 1 μm and the mass ratio Al/Mn of Al to Mn is 2 to 5. This magnesium alloy sheet has high impact resistance since it contains crystallized phases that are small in size and in amount contained and cause breaking and the like, and exhibits good mechanical properties even in a low-temperature environment.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a magnesium alloy sheet suitable as a material for housings and various parts, a magnesium alloy structural member using the alloy sheet, and a method for producing a magnesium alloy sheet. In particular, it relates to a magnesium alloy sheet and a magnesium alloy structural member having high impact resistance at low temperature.

Background Art

[0002] Magnesium alloys containing magnesium and various additive elements are increasingly employed as materials for housings of mobile electronic devices such as cellular phones and laptop computers, and automobile parts.

[0003] Since magnesium alloys have a hexagonal crystalline structure (hexagonal close-packed (hcp) structure) and has low plastic formability at ordinary temperature, magnesium alloy structural members such as the housings described above are mainly formed of cast materials by a die casting method or a thixomolding method. Recently, studies have been made to form the housing by press-forming a sheet composed of an AZ31 alloy according to American Society for Testing and Materials (ASTM) standard. Patent literature 1 proposes a rolled sheet composed of an alloy equivalent to AZ91 alloy of the ASTM standard, the rolled sheet having good press formability.

Citation List

Patent Literature

[0004]

PTL 1: Japanese Unexamined Patent Application Publication No. 2007-098470

Summary of Invention

Technical Problem

[0005] Since magnesium alloys are light-weight and exhibit good specific strength and specific rigidity, they are desirably used in not only an ordinary temperature environment at about 0˚C to 30˚C but also below-zero cold districts and refrigeration rooms. However, the mechanical properties of magnesium alloys in such low-temperature environments have not been fully investigated.

[0006] Cast materials of magnesium alloys are inferior to rolled materials of magnesium alloys and press-formed structural members in terms of strength. The inventors of the present invention have also found that the structural members formed by press-forming an AZ31 alloy also has insufficient strength and low impact resistance in a low-temperature environment.

[0007] In contrast, rolled sheets composed of AZ91 alloys described in patent literature 1 and structural members formed by press-forming these rolled sheets have a higher strength than the sheet composed of AZ31 alloys and pressed structural members composed of AZ31 alloys. However, the inventors have conducted studies and found that the rolled sheets composed of AZ91 alloys and structural members formed by plastic-forming, such as press-forming, the rolled sheets sometimes lack sufficient impact resistance in a low-temperature environment.

[0008] One of the objects of the present invention is to provide a magnesium alloy structural member having high impact resistance even in a low-temperature environment and a magnesium alloy sheet suitable as a material for this structural member. Another object of the present invention is to provide a method for producing the magnesium alloy sheet of the present invention.

Solution to Problem

[0009] The inventors have produced magnesium alloy sheets under various conditions, subjected the resulting sheets to plastic-forming such as press-forming to prepare magnesium alloy structural members, and investigated the impact resistance (dent resistance) and mechanical properties of these magnesium alloy sheets and structural members in a low-temperature environment. As a result, they have found that a magnesium alloy sheet that has high dent resistance contains few crystallized phases having a particular composition that are small in size. A magnesium alloy structural member obtained from the magnesium alloy sheet that contains few crystallized phases having a particular composition that are small in size also has high dent resistance, and as with the sheet of the material, the structural member also contains few crystallized phases having a particular composition that are small in size. They have also found that in order to control the number and the maximum diameter of the crystallized phases, i.e., reduce the number of the crystallized phases and the number of coarse crystallized phases, in producing the magnesium alloy sheet, it is preferable to conduct continuous casting and roll the resulting cast sheet under particular conditions. The present invention has been made on the basis of these findings.

[0010] The magnesium alloy sheet of the present invention is composed of a magnesium alloy containing Al and Mn. When a region from a surface of the alloy sheet to 30% of the thickness of the alloy sheet in a thickness direction of the magnesium alloy sheet is defined as a surface region and when a 50 μm^2 sub-region is arbitrarily selected from this surface region, the number of grains that are crystallized phases containing both Al and Mn and having a maximum diameter of 0.1 to 1 μm is 15 or less. Furthermore, in the grains of the crystallized phases, the mass ratio Al/Mn of Al to Mn is 2 to 5.

[0011] The magnesium alloy sheet of the present invention having a particular structure can be produced by, for example, a production method of the invention below. The method for producing a magnesium alloy sheet according to the present invention includes a casting step and a rolling step below:

Casting step: step of casting a magnesium alloy containing Al and Mn into a sheet.
Rolling step: step of rolling the cast sheet obtained by the casting step.
In particular, the casting is conducted by a twin-roll continuous casting process at a roll temperature of 100˚C or less and the thickness of the cast sheet is 5 mm or less.

[0012] A magnesium alloy structural member of the present invention is produced by subjecting the magnesium alloy sheet of the present invention to plastic forming such as press forming. This structural member also has the same structure as the magnesium alloy sheet of the present invention, i.e., when a 50 μm^2 sub-region is arbitrarily selected from the surface region, the number of grains that are crystallized phases of a particular size and a particular composition is 15 or less.

[0013] According to a continuous casting process such as a twin-roll continuous casting process capable of performing rapid solidification, the amounts of oxides and segregates can be reduced, generation of coarse crystallized phases can be suppressed, and fine crystallized phases can be formed. In particular, according to the production method of the present invention, the cooling rate is sufficiently increased by adjusting the roll temperature and the thickness of the cast sheet in the above-described particular ranges, and thus the generation of the crystallized phases itself can be suppressed. Accordingly, the structure of a surface-side region of a sheet susceptible to impact can be turned into a structure containing few fine crystallized phases. Presumably since the size and the amount of the crystallized phases are small, the decrease in the amount of dissolved Al in the matrix caused by coarse crystallized phases or large amounts of crystallized phases is suppressed, and the degradation of solution hardening associated with the decrease in Al content is suppressed. Moreover, rapid solidification gives a cast sheet having a fine structure with a small average crystal grain diameter. Such a cast sheet contains few coarse crystallized phases that serve as starting points of breaking and deformation and thus has high plastic formability such as rolling. When the cast sheet is rolled, strength and elongation can be improved.

[0014] Thus, the invention alloy sheet obtained by the production method described above has a reduced amount of coarse crystallized phases and few crystallized phases. In particular, the structure contains a reduced amount of coarse crystallized phases in a surface-side region susceptible to impact and has a structure in which a minute amount of and more preferably substantially no fine crystallized phases are present, and thus breaking and cracking do not readily occur even when an impact is applied by, for example, dropping. Since the amount of the crystallized phases is small, the decrease in dissolved Al content can be suppressed, a high strength can be maintained due to presence of a sufficient amount of dissolved Al, and the strength can be further enhanced by rolling. Accordingly, the invention alloy sheet is resistance to denting even when an impact is applied and exhibits high impact resistance not only at room temperature (about 20˚C) but also in a low-temperature environment below 0˚C. The invention alloy sheet having the particular structure also has good plastic formability and can be easily subjected to press-forming, for example. The invention alloy structural member obtained thereby also has a structure in which crystallized phases are small in size and in amount in a surface-side region particularly susceptible to impact as with the invention alloy sheet. Accordingly, the invention alloy structural member also has good mechanical properties such as strength and elongation in a low-temperature environment and exhibits high impact resistance.

[0015] The present invention will now be described in detail.

<<Composition>>

[0016] Examples of the magnesium alloy constituting the invention magnesium alloy sheet and the invention magnesium alloy structural member include those having various compositions and containing at least Al and Mn as additive elements (balance being Mg and impurities). An example of the additive element other than Al and Mn is at least one element selected from Zn, Si, Ca, Sr, Y, Cu, Ag, Ce, Zr, and rare earth elements (excluding Y and Ce). In particular, 5% to 12% by mass of Al and 0.1% to 2.0% by mass of Mn are preferably contained. When Al and Mn are contained in these ranges, not only mechanical properties such as strength and elongation is improved but also corrosion resistance is improved. However, if the contents of these elements are excessively large, a decrease in plastic formability results. The contents of the additive elements other than Al and Mn are, for example, Zn: 0.2 to 7.0% by mass, Si: 0.2 to 1.0% by mass, Ca: 0.2 to 6.0% by mass, Sr: 0.2 to 7.0% by mass, Y: 1.0 to 6.0% by mass, Cu: 0.2 to 3.0% by mass, Ag: 0.5 to 3.0% by mass, Ce: 0.05 to 1.0% by mass, Zr: 0.1 to 1.0% by mass, and RE (rare earth element (excluding Y and Ce)): 1.0 to 3.5% by mass. When these elements are contained in addition to Al and Mn, the mechanical properties can be further enhanced. Examples of the compositions of the alloy containing Al, Mn, and at least one of these elements in amounts in the above-described ranges include AZ series alloys (Mg-Al-Zn series alloys, Zn: 0.2 to 1.5% by mass) and AM series alloys (Mg-Al-Mn series alloys, Mn: 0.15 to 0.5% by mass) of the ASTM standard. In particular, the amount of Al contained (hereinafter referred to as the "Al content") is preferably large since the mechanical properties and corrosion resistance improve with the increase in Al content, and the Al content is more preferably 5.8% by mass or more and 10% by mass or less. Preferable examples of the magnesium alloys having an Al content of 5.8% to 10% by mass include Mg-Al-Zn series alloys such as AZ61 alloys, AZ80 alloys, AZ81 alloys, and AZ91 alloys, and Mg-Al-Mn series alloys such as AM60 alloys and AM100 alloys. In particular, AZ91 alloys having an Al content of 8.3 to 9.5% by mass have superior corrosion resistance and mechanical properties such as strength and plastic deformation resistance compared to other Mg-Al series alloys.

<<Modes of magnesium alloy sheet and magnesium alloy structural member>>

[0017] The invention alloy sheet has a first surface and a second surface that are a pair of surfaces opposing each other. These two surfaces are typically in parallel with each other and usually serve as a front surface and a back surface during the use. The first and second surfaces may be flat or curved. The distance between the first and second surfaces is the thickness of the magnesium alloy sheet. The invention alloy sheet is obtained by rolling a cast sheet having a thickness of 5 mm or less as described above; thus, the thickness of the invention alloy sheet is less than 5 mm. In particular, because the invention alloy sheet is plastically formed, such as press-formed and used as a material for thin, light-weight housings and various structural members, the thickness of the alloy sheet is about 0.3 mm to 3 mm and preferably 0.5 mm to 2.0 mm. The alloy sheet exhibits a high strength when the thickness is large within this range, and becomes suitable for use in thin, light-weight housings etc., when the thickness is small. The thickness of the magnesium alloy sheet obtained as a final product may be selected by controlling the casting conditions and rolling conditions in accordance with the desired usage.

[0018] Representative examples of the shape of the invention alloy structural member include various shapes formed by subjecting the magnesium alloy sheet to plastic forming such as press-forming, e.g., a square-bracket-shaped or box-shaped member having a bottom portion and a side wall portion extending upward from the bottom portion. The thickness of the magnesium alloy structural member in a flat portion not substantially subjected to deformation caused by plastic forming such as press-forming is substantially the same as that of the magnesium alloy sheet used as the material, and the structure thereof is also about the same. In other words, the surface region satisfies that the number of Al-Mn crystallized phases having a maximum diameter of 0.1 to 1 μm is 15 or less per 50 μm^2.

[0019] Examples of the invention alloy sheet include a rolled sheet prepared by rolling a cast material and a treated sheet prepared by subjecting the rolled sheet to a heat treatment, a leveling process, a polishing process, or the like. The invention alloy structural member may be a structural member prepared by subjecting the alloy sheet to plastic forming such as press-forming and those subjected to a heat treatment or a polishing process after the plastic forming. The rolled sheet, the treated sheet, and the alloy structural member may be further provided with an anticorrosion layer of a coating layer.

<<Mechanical properties>>

[0020] The invention alloys sheet and the invention alloy structural member have good mechanical properties such as strength and elongation even in a low-temperature environment and are resistant to dent upon impact such as dropping. For example, in a tensile test at -30˚C, the invention alloy sheet and the invention alloy structure member in a flat portion (a portion substantially the same as the sheet of the material) not substantially subjected to deformation (e.g., deformation by drawing) caused by plastic forming such as press-forming exhibit a tensile strength of 350 MPa or more, a 0.2% proof stress of 280 MPa or more, and an elongation of 2% or more.

<<Structure>>

<Crystallized phases>

[0021] When a sub-region is arbitrarily selected from a surface-side region of the invention alloy sheet and the structure thereof is observed, the structure includes substantially no coarse crystallized phases but includes minute amounts of fine crystallized phases. In particular, in a direction of the thickness of the alloy sheet, a region from the surface of the alloy sheet to 30% of the thickness of the alloy sheet is defined as a surface region, a 50 μm^2 sub-region is arbitrarily selected from this surface region, and the grain diameters of all the crystallized phases found in one sub-region are measured. When the maximum diameter is measured from each crystallized phases, the number of fine crystallized phases having a maximum diameter of 0.1 μm to 1 μm in the sub-region is 15 or less. Preferably, only the crystallized phases having a maximum diameter of 0.5 μm or less are present. When coarse crystallized phases larger than 1 μm are present, the coarse crystallized phases can serve as starting points for breaking upon impact such as dropping. Thus, breaking and cracking easily occur and the impact resistance is low. Even when the crystallized phases have a maximum diameter of 1 μm or less, when more than 15 such impurities are present in 50 μm^2, the number of starting points for breaking and cracking increases, resulting in a decrease in strength and impact resistance. The impact resistance tends to be high when the number of crystallized phases having a maximum diameter of 0.1 to 1 μm is small. The number if preferably 10 or less and ideally zero. The crystallized phases contain both Al and Mn. The detail for measuring the maximum diameter is described below. Note that in the present invention, presence of superfine crystallized phases which are not likely to cause breaking, i.e., crystallized phases having a maximum diameter less than 0.1 μm, is allowable. However, the precipitated impurities are preferably absent.

<Average crystal grain diameter>

[0022] An example of the invention alloy sheet is one having a microstructure with a small average crystal grain diameter, i.e., 20 μm or less. As described above, a cast sheet having a microstructure is obtained by continuous casting under particular conditions, and a rolled sheet having the microstructure described above can be prepared by rolling the cast sheet under particular conditions. The invention alloy sheet having such a microstructure exhibits good mechanical properties such as strength and elongation, and an enhanced impact resistance even in a low-temperature environment. The invention magnesium alloy structural member made of a magnesium alloy sheet having the microstructure or a treated sheet prepared by correcting, such as leveling, the rolled sheet can also have a microstructure having an average crystal grain diameter of 20 μm or less and exhibit high impact resistance. More preferably, the average crystal grain diameter is 0.1 μm to 10 μm.

[Production method]

<<Casting>>

[0023] In the invention production method, a twin-roll continuous casting process is employed. In this casting, the temperature of the rolls used as a die is adjusted to 100˚C or less and the thickness of the cast sheet obtained thereby is adjusted to 5 mm or less. By decreasing the thickness of the cast sheet and the roll temperature, generation of crystallized phases caused by rapid solidification is suppressed and a cast sheet containing fewer crystallized phases that are small in size can be obtained. The roll temperature is adjusted to 100˚C or less by using rolls that can be subjected to forced cooling such as water-cooling. The lower the roll temperature and the thinner the cast sheet, the faster the cooling rate and more suppressed is the generation of the crystallized phases. Accordingly, the roll temperature is more preferably 60˚C or less and the thickness of the cast sheet is more preferably 4.0 mm or less. This casting step (including cooling step) is preferably conducted in an inert gas atmosphere to prevent oxidation of the magnesium alloy.

<<Rolling>>

[0024] The rolling conditions are, for example, the temperature of heating the material: 200˚C to 400˚C, the temperature of heating the rolling rolls: 150˚C to 300˚C, and a reduction per pass: 5% to 50%. A plurality of passes of rolling may be conducted to adjust the thickness to a desired value. The controlled rolling disclosed in patent literature 1 may also be employed. When the cast material is rolled, the structure can be converted to a rolled structure from a metal structure formed by casting. Furthermore, by conducting the rolling, a microstructure having an average crystal grain diameter of 20 μm or less can be easily formed, internal and surface defects such as segregation, shrinkage cavities, and pores generated by casting can be reduced, and a rolled sheet with an excellent surface texture can be obtained. The strength and the corrosion resistance of the resulting rolled sheet can be further enhanced by conducting a final heat treatment after final rolling whereby a fine recrystallized structure having an average crystal grain diameter of 20 μm or less is formed.

<<Plastic forming>>

[0025] The invention alloy structural member is obtained by subjecting the rolled sheet (including a heat-treated rolled sheet) to plastic forming, such as press-forming (including blanking), deep-drawing, forging, blowing, or bending, into a desired shape. The plastic forming can suppress the structure of the rolled sheet from turning into a coarse recrystallized structure and reduce deterioration of the mechanical properties and corrosion resistance if the plastic forming is conducted in a warm process at 200˚C to 280˚C. A heat treatment or an anticorrosion treatment may be performed or a coating layer may be formed after the plastic forming.

Advantageous Effects of Invention

[0026] The invention magnesium alloy sheet and the invention magnesium alloy structural member have high impact resistance in a low-temperature environment. The invention method for producing a magnesium alloy sheet can produce the magnesium alloy sheet of the invention.

Brief Description of Drawings

[0027]

[Fig. 1] Figure 1 is a schematic diagram illustrating an impact test.

Description of Embodiments

[0028] Embodiments of the present invention will now be described.

[Test Example 1]

[0029] Ingots (commercially available products) composed of magnesium alloys shown in Table I were used to produce magnesium alloy sheets and magnesium alloy structural members (housings) under various conditions. The structure of the resulting magnesium alloy sheets and magnesium alloy structural members was observed and a tensile test (low temperature) and an impact test (low temperature) were conducted. The production conditions were as follows.

(Condition A: Twin-roll casting → rolling)

[0030] Each of the ingots of magnesium alloys is heated to 700˚C in an inert atmosphere to prepare molten metal, and the molten metal is used to form a plurality of cast sheets each 4.0 mm (< 5 mm) in thickness by a twin-roll continuous casting process in the inert atmosphere. This casting is conducted while cooling the rolls so that the roll temperature is 60˚C (< 100˚C). Each of the resulting cast sheets is used as a material and rolled a plurality of times at a material heating temperature of 200˚C to 400˚C, a rolling roll heating temperature of 150˚C to 300˚C, and a reduction ratio per pass of 5% to 50% until the thickness of the material is 0.6 mm so as to prepare a rolled sheet. The resulting rolled sheets (magnesium alloy sheets) are used as samples (sheets). The resulting rolled sheets are subjected to a rectangular cup drawing at a heating temperature of 250˚C to prepare a box having a square-bracket-shaped cross-section. This box (magnesium alloy structural member) is used as a sample (housing).

[0031] A heat treatment (solution treatment) or aging treatment may be performed after the casting to homogenize the structure, an intermediate heat treatment may be performed during the rolling, or a final heat treatment may be performed after the final rolling. The rolled sheet may be subjected to a leveling process or a polishing process to improve the flatness by correction or may be polished to make the surface smooth. These also apply to Text Example 2 described below.

(Condition B: Die casting)

[0032] A commercially available die-cast product is used (box having a square-bracket-shaped cross-section, thickness of the bottom portion: 0.6 mm)

(Condition C: Commercially available sheet)

[0033] A commercially available sheet (thickness: 0.6 mm) composed of an AZ31 alloy is used.

(Condition D: Commercially available housing)

[0034] A box (commercially available product) having a square-bracket-shaped cross-section (thickness of the bottom portion: 0.6 mm) prepared by subjecting a sheet (thickness: 0.6 mm) composed of an AZ31 alloy to a rectangular cup drawing is used.

<<Structural observation>>

[0035] For each of the obtained samples, the metal structure was observed as below to study crystallized phases. The sample (sheet) is cut in the thickness direction, and the section is observed with a transmission electron microscope (20,000 magnification). In this observed image, a region from the surface of the sample (sheet) to 30% (0.6 mm × 30% = 0.18 mm) of the thickness of the sample (sheet) in the thickness direction of the sample (sheet) is defined as a surface region. Five 50 μm^2 sub-regions are arbitrarily selected from the surface region, and the size of all crystallized phases present in each of each sub-regions is measured. Identification of the crystallized phases is conducted on the basis of the composition. After mirror-polishing the section, for example, the composition of the grains present in the section is determined by qualitative analysis and semiquantitative analysis such as energy dispersive X-ray spectroscopy (EDX), and grains containing Al and Mg are identified as crystallized phases. For each of the crystallized phases containing Al and Mn, the ratio Al/Mn of the mass of the Al to the mass of Mn is measured. The Al/Mn was 2 to 5 in all Samples 1-1 and 1-2. For each of the grains of the crystallized phases in the section, parallel lines are drawn in the section and the maximum value of the lengths of each grain traversing the straight lines is determined to be the maximum diameter of that grain. The number of crystallized phases having a maximum diameter of 0.1 μm to 1 μm is defined to be the number of crystallized phases in the sub-region. The average number of the five sub-regions is defined to be the number of the crystallized phases in this sample per 50 μm^2. For a sample (housing), a bottom portion, which is a flat portion not subjected to drawing deformation in the sample, is cut in the sheet thickness direction, and the section is observed as with the sample (sheet) above to count the number of crystallized phases per 50 μm^2. When coarse crystallized phases having a maximum diameter exceeding 5 μm are observed in the observed image, the area of the sub-region is changed to 200 μm^2 and the maximum diameter of the crystallized phases in this 200 μm^2 and the number of the crystallized phases per 200 μm^2 are measured. The shape of each sub-region may be any as long as the area satisfies the description above, but a rectangular shape (typically square) is easy to use. The measurement results are shown in Table I.

<<Tensile test (low temperature)>>

[0036] A Japanese Industrial Standard (JIS) 13B sheet specimen (JIS Z 2201 (1998)) was taken from each sample (thickness: 0.6 mm) and subjected to a tensile test in accordance with a metal material tensile test method of JIS Z 2241 (1998). In the test, the gage distance GL is set to 50 mm for the sample (sheet) and to 15 mm for the sample (housing). For all samples, the test temperature was set to -30˚C and the tensile velocity was set to 5 mm/min to conduct the tensile test to determine the tensile strength (MPa), the 0.2% proof stress (MPa), and the elongation (%) (number of evaluation: n = 1 in all cases). The results are shown in Table I. Note that, for the sample (housing), a specimen for the tensile test and a specimen for the impact test described below are prepared by cutting the bottom portion of the sample, which is a flat portion not subjected to drawing deformation.

<<Impact test (low temperature)>>

[0037] A 30 mm × 30 mm sheet piece is cut out from each sample and used as a specimen. In this test, as shown in Fig. 1, a support table 20 having a circular hole 21 having a diameter d of 20 mm in a horizontal surface was prepared. The depth of the circular hole 21 was large enough to allow insertion of a circular cylinder rod 10. A specimen 1 was placed to cover the circular hole 21 and a ceramic circular cylinder rod 10 having a weight of 100 g and a tip r of 5 mm was arranged at a position with a height of 200 mm from the specimen 1 so that the center axis of the specimen 1 and the center axis of the circular hole 21 were coaxial. The circular cylinder rod 10 was allowed to freely drop from the position (height of 200 mm) described above toward the specimen 1 and the amount of dent of the specimen 1 is measured. The amount of dent (mm) was measured by drawing a straight line connecting two opposing sides of the specimen 1 and measuring the distance from the straight line to a portion that had dented most with a point micrometer. The impact test was conducted in a low-temperature environment at -30˚C. The results are shown in Table I. The rating ○ is given for samples with an amount of dent of 0.5 mm or less and the rating X is given for samples with an amount of dent of more than 0.5 mm. For samples in which the amount of dent could not be measured due to breaking, "Breaking" is indicated. For samples in which cracking occurred, "Crack" is indicated. The thickness of the 30 mm × 30 mm specimen prepared from the sample (housing) was measured at four arbitrary points. The thickness (thickness of the specimen: 0.6 mm) was equal to the thickness (0.6 mm) of the sheet of the material at all positions.

[0038]

[Table I]

Sample No.	Alloy component	Production condition	Sample shape	Al-Mn crystallized impurities		Tensile test			Impact test
				Maximum diameter (μm)	Grains/50 μm^2 (*: Grains/200 μm^2)	Tensile strength (MPa)	0.2% proof stress (MPa)	Elongation (%)	Amount of dent (mm)
1-1	AZ91	A	Sheet	0.4 μm	11	408	369	2.3	○ (0.5)
1-2	AZ91	A	Housing	0.3 μm	10	381	300	5.7	○ (0.5)
101	AZ91	B	Housing	15 μm	1*	203	192	0.2	X (Breaking)
102	AZ31	C	Sheet	13 μm	1*	319	261	15.0	X (0.9)
103	AZ31	D	Housing	11 μm	1*	296	225	16.5	X (0.9)

[0039] As shown in Table I, magnesium alloy sheets and magnesium alloy structural members in which the number of Al-Mn crystallized phases having a maximum diameter of 0.1 to 1 μm per 50 μm^2 arbitrarily selected from the surface region is 15 or less, the amount of dent is small and the impact resistance is high even in a low-temperature environment at -30˚C compared to cast materials and expanded materials (AZ31 alloys) having the same composition. The reason therefor is presumably that the mechanical properties such as tensile strength and elongation were excellent even in a low-temperature environment. In particular, according to this test, Samples 1-1 and 1-2 having high impact resistance contain only crystallized phases having a maximum diameter of 0.5 μm or less. Al-Mn crystallized phases having a maximum diameter more than 1μm were not observed form Samples 1-1 and 1-2 having high impact resistance and can be considered substantially absent at least in the surface region. In contrast, samples of commercially available products not produced under the particular casting conditions contained coarse crystallized phases in the surface region, and breaking presumably occurred easily due to the presence of such coarse crystallized phases. It has also been found that a magnesium alloy structural member having high impact resistance can be obtained by conducting plastic forming such as press forming on a magnesium alloy sheet containing 15 or less of Al-Mn crystallized phases having a maximum diameter of 0.1 to 1μm in 50 μm^2 arbitrarily selected from the surface region.

[Test Example 2]

[0040] Ingots (commercially available products) composed of magnesium alloys shown in Table II were used to produce magnesium alloy sheets and magnesium alloy structural members (housings) under various conditions. The structure of the resulting magnesium alloy sheets and magnesium alloy structural members was observed and the impact test (low temperature) was performed as in Test Example 1. The results are shown in Table II.

[0041] As for the production condition "Casting → rolling", the casting is conducted by a twin-roll continuous casting process and the conditions of the roll temperature and the thickness of the cast sheet are set as shown in Table II. Rolling is conducted under the same rolling conditions as Test Example 1. However, in this test, the total length of time the material is retained in the temperature range of 150˚C to 250˚C is adjusted to 45 minutes or 90 minutes by adjusting the time of heating the material, the rolling velocity, the cooling rate during the rolling, etc. Note that in Test Example 1, this total length of time is set to about 60 minutes. In Table II, the shape "Sheet" indicates that the sample is a rolled sheet (magnesium alloy sheet) and "Housing" indicates that the sample is a box (magnesium alloy structural member) produced from the rolled sheet under the same conditions as Test Example 1.

[0042] Regarding the production conditions, "Condition B", "Condition C", and "Condition D" are the same as Condition B (Die casting), Condition C (Commercially available sheet), and Condition D (Commercially available housing) of Test Example 1. Regarding the production condition "Casting → rolling", a commercially available extruded material is prepared and rolled under the same conditions as the production condition, "Casting → rolling". The resulting rolled sheet is used as a sample (sheet), and a box-shape sample (housing) is produced from this rolled sheet under the same conditions as "Casting → rolling".

[0043]

[Table II]

Sample No:	Alloy component	Production condition	Sample shape	Casting condition		Al-Mn crystallized impurities		Impact test
				Roll temperature (˚C)	Thickness (mm)	Maximum diameter (μm)	Grains/ 50μm^2 (*:grains/ 200 μm^2)	Amount of dent (mm)
2-1	AZ91	Casting → rolling	Sheet	25˚C	4 mm	0.3 μm	8	○ (0.4)
2-2	AZ91	Casting → rolling	Box	25˚C	4 mm	0.3 μm	7	○ (0.4)
2-3	AZ91	Casting → rolling	Sheet	60˚C	2 mm	0.3 μm	7	○ (0.4)
2-4	AZ91	Casting → rolling	Box	60˚C	2 mm	0.3 μm	7	○ (0.4)

(continued)

Sample No:	Alloy component	Production condition	Sample shape	Casting condition		Al-Mn crystallized impurities		Impact test
				Roll temperature (˚C)	Thickness (mm)	Maximum diameter (μm)	Grains/ 50μm^2 (*:grains/ 200 μm^2)	Amount of dent (mm)
2-5	AZ91	Castings → rolling	Sheet	60˚C	4 mm	0.4 μm	11	○ (0.5)
2-6	AZ91	Casting → rolling	Box	60˚C	4 mm	0.3 μm	10	○ (0.5)
201	AZ91	Casting → rolling	Sheet	60˚C	6 mm	3.5 μm	4	× (Crack)
202	AZ91	Casting → rolling	Box	60˚C	6 mm	3.5 μm	4	× (Crack)
203	AZ91	Casting → rolling	Sheet	120˚C	4 mm	1.1 μm	16	× (crack)
204	AZ91	Casting → rolling	Box	120˚C	4 mm	1.1 μm	16	× (Crack)
205	AZ91	Condition B	Box	-	-	15 μm	1*	× (Breaking)
206	AZ31	Condition C	Sheet	-	-	13 μm	1*	× (0.9)
207	AZ31	Condition D	Box	-	-	11 μm	1*	× (0.9)
208	AZ91	Casting → rolling	Sheet	-	-	7 μm	2*	× (Breaking)
209	AZ91	Casting → rolling	Box	-	-	6 μm	2*	× (Breaking)
210	AZ91	Casting → rolling	Sheet	-	-	8 μm	2*	× (Breaking)
211	AZ91	Casting → rolling	Box	-	-	7 μm	2*	× (Breaking)

[0044] Table II shows that magnesium alloy sheets and magnesium alloy structural members containing 15 or less of Al-Mn crystallized phases having a maximum diameter of 0.1 to 1 μm per 50 μm^2 arbitrarily selected from the surface region can be obtained by rolling cast sheets cast by a twin-roll continuous casting process at a roll temperature of 100˚C or less to a cast sheet thickness of 5 mm or less. In contrast, coarse crystallized phases will occur unless the particular coasting conditions are observed. Furthermore, the results show that as with Test Example 1, the magnesium alloy sheets and magnesium alloy structural members containing 15 or less of Al-Mn crystallized phases having a maximum diameter of 0.1 to 1 μm per 50 μm^2 arbitrarily selected from the surface region exhibit high impact resistance even in a low-temperature environment of -30˚C. The Al/Mn was measured in all Samples 2-1 to 2-6 and was all 2 to 5.

[0045] Furthermore, the test has found that (1) when the thickness of the cast materials prepared is the same, the amount of crystallized phases can be reduced by decreasing the roll temperature; and (2) when the roll temperature is the same, the amount of crystallized phases can be reduced by decreasing the thickness of the cast material prepared.

[0046] It should be understood that the embodiments described above are subject various modification without departing from the scope of the present invention and the scope of the present invention is not limited by the structures described above. For example, the composition of the magnesium alloy, the thickness of the sheet after casting and after rolling, the roll temperature during casting, etc., may be modified as needed. The obtained rolled sheet or pressed structural member may be subjected to anticorrosion treatment or coated with a coating layer.

Industrial Applicability

[0047] Since the invention magnesium alloy structural member has high impact resistance in a low-temperature environment, it is suitable for use in various housings and parts used in low-temperature environment. The invention magnesium alloy sheet is suitable for use as a structural material of the invention magnesium alloy structural member. The invention method for producing a magnesium alloy sheet is suitable for use in production of the invention magnesium alloy sheet.
According to the present invention,.

Reference Signs List

[0048]

1 specimen
10 circular cylindrical rod
20 support table
21 circular hole

Claims

1. A magnesium alloy sheet comprising a magnesium alloy containing Al and Mn, wherein when a region from a surface of the alloy sheet to 30% of the thickness of the alloy sheet in a thickness direction of the magnesium alloy sheet is defined as a surface region and when a 50 μm^2 sub-region is arbitrarily selected from this surface region, the number of grains that are crystallized phases containing both Al and Mn and having a maximum diameter of 0.1 to 1 μm is 15 or less, and
in the grains of the crystallized phases, the mass ratio Al/Mn of Al to Mn is 2 to 5.

2. The magnesium alloy sheet according to Claim 1, wherein the magnesium alloy contains 5% by mass to 12% by mass of Al and 0.1% by mass to 2.0% by mass of Mn.

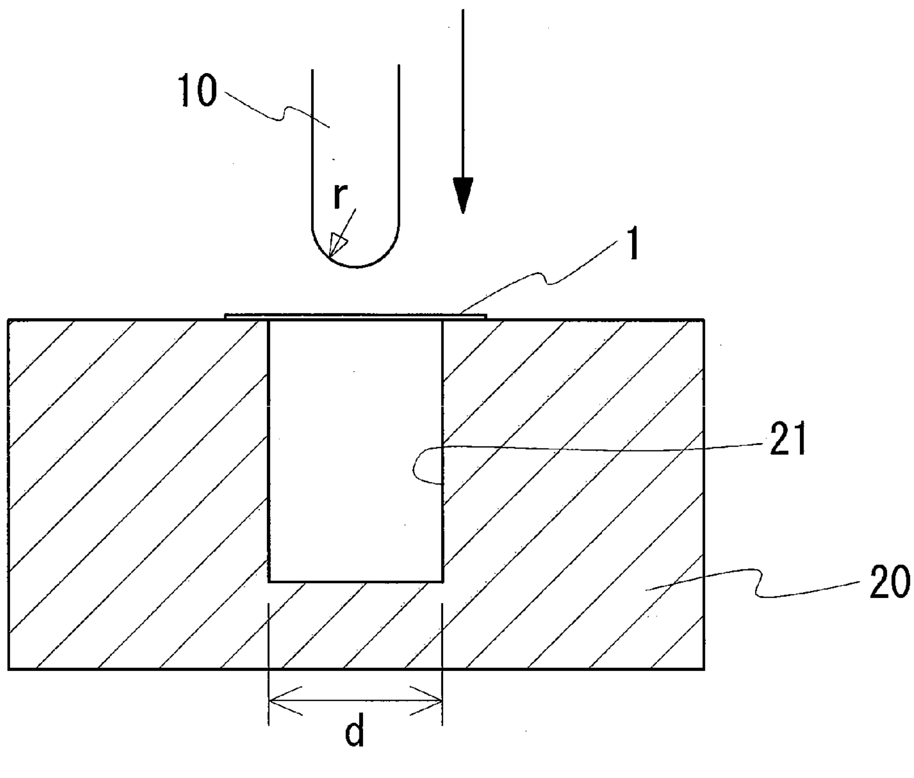
3. The magnesium alloy sheet according to Claim 1 or 2, wherein the magnesium alloy further contains at least one element selected from Zn, Si, Ca, Sr, Y, Cu, Ag, Ce, Zr, and rare earth elements (excluding Y and Ce).

4. A magnesium alloy structural member produced by plastic-forming the magnesium alloy sheet according to any one of Claims 1 to 3.

5. A method for making a magnesium alloy sheet, comprising:

 a casting step of casting a magnesium alloy containing Al and Mn into a sheet, and
 a rolling step of rolling the cast sheet obtained by the casting step,
 wherein the casting is conducted by a twin-roll continuous casting process at a roll temperature of 100˚C or less and the thickness of the cast sheet is 5 mm or less.

FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/059710

A. CLASSIFICATION OF SUBJECT MATTER
C22C23/02(2006.01)i, *B21B1/46*(2006.01)i, *B21B3/00*(2006.01)i, *C22F1/06*(2006.01)i, *C22F1/00*(2006.01)n

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)
C22C23/00-23/06, B21B1/46, B21B3/00, C22F1/06, C22F1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009-007606 A (Mitsubishi Aluminum Co., Ltd.), 15 January 2009 (15.01.2009), claims 1 to 3; paragraphs [0005], [0011], [0012], [0029], [0034], [0036] (Family: none)	1-5
X	JP 2009-120883 A (Mitsubishi Aluminum Co., Ltd.), 04 June 2009 (04.06.2009), claims 1 to 6; paragraphs [0002], [0009], [0025] to [0027], [0031], [0032] (Family: none)	1-5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
07 September, 2010 (07.09.10)	21 September, 2010 (21.09.10)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

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PCT/JP2010/059710

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2008-308703 A (Mitsubishi Aluminum Co., Ltd.), 25 December 2008 (25.12.2008), claims 1 to 4; paragraphs [0011] to [0016], [0027]; table 1, examples 2 to 5 (Family: none)	1-5
X	JP 2008-163402 A (Mitsubishi Aluminum Co., Ltd.), 17 July 2008 (17.07.2008), claim 1; paragraphs [0010], [0012], [0016] to [0018]; table 1, alloy 2 (Family: none)	1-5
X	JP 2006-144043 A (Mitsubishi Aluminum Co., Ltd.), 08 June 2006 (08.06.2006), claims 1, 3; paragraphs [0012], [0018] to [0022], [0027] (Family: none)	1-5
X	JP 2006-144059 A (Mitsubishi Aluminum Co., Ltd.), 08 June 2006 (08.06.2006), claims 1, 2; paragraphs [0018], [0025] (Family: none)	1-5
X	JP 2006-144062 A (Mitsubishi Aluminum Co., Ltd.), 08 June 2006 (08.06.2006), claim 1; paragraphs [0013], [0018] (Family: none)	1-5
X	WO 2009/001516 A1 (Sumitomo Electric Industries, Ltd.), 31 December 2008 (31.12.2008), paragraphs [0027], [0045], [0080]; table 5, sample no.17 & EP 002169089 A1 & CN 101688270 A & KR 10-2010-0027152 A	1-5
X	JP 2006-144044 A (Mitsubishi Aluminum Co., Ltd.), 08 June 2006 (08.06.2006), claim 1; paragraphs [0019], [0025] (Family: none)	1,3-5
X	JP 06-256883 A (Kobe Steel, Ltd.), 13 September 1994 (13.09.1994), claims 1, 2; paragraphs [0020], [0034] (Family: none)	1-4

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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