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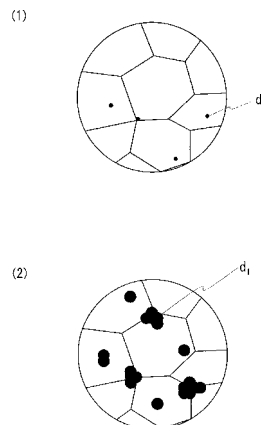
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(54) **FORMED PRODUCT OF MAGNESIUM ALLOY AND MAGNESIUM ALLOY SHEET**

(57) A formed product of a magnesium alloy having excellent impact resistance and a magnesium alloy sheet suitable as a material for the formed product are provided. The formed product is produced by press-forming a magnesium alloy sheet having an Al content of 7% by mass to 12% by mass and has a flat portion that is not subjected to drawing deformation. In a metal texture in a cross section of the flat portion in the thickness direction, the number of coarse intermetallic compound ($Mg_{17}Al_{12}$) particles having a particle size of 5 μm or more present in a surface area region extending from a surface of the flat portion to a position one-third of the thickness from the surface in the thickness direction is five or less. The formed product has a texture in which the number of coarse precipitations d_1 is small and in which fine precipitations d_0 are dispersed. The formed product is less likely to be dented even when impacted because of dispersion strengthening owing to the fine precipitations and

solid-solution strengthening owing to Al that sufficiently forms a solid solution.

FIG. 1



Description

Technical Field

5 **[0001]** The present invention relates to a magnesium alloy sheet suitable as a material for, for example, housings of mobile electronic devices and relates to a formed product of a magnesium alloy, the formed product being produced by press forming. In particular, the present invention relates to a formed product of a magnesium alloy having excellent impact resistance.

10 Background Art

[0002] Resins, such as acrylonitrile butadiene styrene (ABS) copolymer resins and polycarbonate (PC) resins, and metals, such as aluminium alloys and stainless steel (SUS), have been used as housing materials for mobile electronic devices, such as cellular phones and notebook personal computers.

15 **[0003]** Magnesium alloys, which are lightweight and excellent in specific strength and specific rigidity, have recently been studied as housing materials described above. Housings of magnesium alloys are mainly formed of cast materials produced by die casting and thixomolding. Press formed sheets of wrought magnesium alloys typified by the AZ31 alloy according to American Society for Testing and Materials (ASTM) standards are being used. In Patent Literature 1, the press forming of an AZ91 alloy according to ASTM standards is studied.

20 **[0004]** Thin, lightweight housings have recently been required. Metals generally have higher impact resistance than resins and are less likely to be broken. It is easy to reduce the thickness of metals. Aluminium alloys, however, have poor plastic deformation resistance and deform quite readily by an impact, such as falling. Stainless steel is not easily broken or deformed but is heavy.

25 Citation List

Patent Literature

[0005]

30

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

Summary of Invention

35 Technical Problem

[0006] Magnesium alloys has excellent plastic deformation resistance compared with aluminium alloys, and are very light compared with stainless steel. However, cast materials of magnesium alloys have a strength inferior to those of press-formed bodies of magnesium alloys. Furthermore, it is difficult to produce the cast materials having thin walls. Press-formed bodies of the AZ31 alloy also have an insufficient strength.

40 **[0007]** In the case where a rolled sheet of the AZ91 alloy as described in Patent Literature 1 is subjected to press forming, the resulting formed product has a higher strength than a press-formed body of the AZ31 alloy. However, the inventors have investigated and have found that an Al content as high as 7% by mass can cause nonuniformity in the impact resistance of material sheets and press-formed bodies obtained by forming the material sheets.

45 **[0008]** Accordingly, it is an object of the present invention to provide a formed product of a magnesium alloy having excellent impact resistance. It is another object of the present invention to provide a magnesium alloy sheet suitable for the production of a formed product of a magnesium alloy, the formed product having excellent impact resistance. Solution to Problem

50 **[0009]** The inventors have produced material sheets of a magnesium alloys each having an Al content of 7% by mass or more by various production methods. Press-formed bodies of the resulting sheets were produced and examined for the impact resistance (dent resistance). It was found that a press-formed body with good dent resistance has small particles composed of an intermetallic compound (precipitations), such as $Mg_{17}Al_{12}$, and a small number of coarse particles. So, a production method for controlling the maximum particle size and the number of the particles having the maximum particle size, i.e., a production method for reducing coarse precipitations, was studied. The total time that a sheet is held in a specific temperature range mainly in a rolling step is reduced compared with that in the related art. This resulted in a magnesium alloy sheet having a small number of coarse precipitations. Furthermore, a press-formed body produced by press-forming the magnesium alloy sheet has excellent impact resistance. These findings have led to the completion of the present invention.

[0010] According to the present invention, a formed product of a magnesium alloy is produced by press-forming a sheet composed of a magnesium alloy having an Al content of 7% by mass to 12% by mass. The formed product has a flat portion that is not subjected to drawing deformation. In a metal texture in a cross section of the flat portion in the thickness direction, when fields of observation specified below are set, the number of coarse particles of an intermetallic compound present in each of the fields of observation is five or less.

[0011] Furthermore, according to the present invention, a magnesium alloy sheet is used for press forming and is composed of a magnesium alloy having an Al content of 7% by mass to 12% by mass, in which the number of coarse particles of an intermetallic compound present in each of fields of observation specified below is five or less.

[0012] In the metal texture of a cross section of the flat portion or the magnesium alloy sheet in the thickness direction, when a region extending from a surface of the flat portion or a surface of the sheet to a position one-third of the thickness from the surface in the thickness direction is defined as a surface area region, any two $100\ \mu\text{m} \times 100\ \mu\text{m}$ areas in the surface area region are set to the fields of observation.

The term "coarse particles" indicates particles composed of an intermetallic compound containing Al and Mg and each having a particle size of $5\ \mu\text{m}$ or more.

The term "particle size" indicates the diameter of a circle having an area equivalent to the area of the cross section of the particle.

Note that the intermetallic compound present in the cross section may be identified by measuring the composition and the structure of the particles using an energy dispersive x-ray spectrometer (EDS), X-ray diffraction, and so forth.

[0013] The alloy sheet having the specific texture according to the present invention may be produced by, for example, a production method including steps described below.

A preparation step: A cast sheet composed of a magnesium alloy having an Al content of 7% to 12% by mass and produced by a continuous casting process is prepared.

A solution heat treatment step: The cast sheet is subjected to solution heat treatment at 350°C or higher.

A rolling step: The resulting sheet material that has been subjected to the solution heat treatment is subjected to rolling.

In particular, in a cooling substep from the holding temperature of the solution heat treatment, the cooling rate is $0.1^\circ\text{C}/\text{sec}$ or more in a temperature range of 350°C to 250°C . In the rolling step, the total time that the sheet material, which is a workpiece, is held in a temperature range of 250°C to 350°C is within 60 minutes.

[0014] As described above, in the cooling process in the solution heat treatment (that is, immediately before rolling) and the rolling step, the minimization of the length of the time that the sheet is held at a specific temperature range (250°C to 350°C) in which precipitations are precipitated and liable to grow to form coarse particles reduces the number of coarse particles, thereby yielding a texture in which fine precipitations d_0 are dispersed as illustrated in part (1) of Fig. 1.

[0015] Conventionally, rolling is performed multiple times (multipass) at an appropriate working ratio (rolling reduction) in such a manner that a desired thickness is achieved, as illustrated in part (2) of Fig. 2 (each pass is represented by "rolling n" ($n = 1, 2, \dots$) in Fig. 2). Here, heating a workpiece (a cast sheet or a rolled sheet before subjecting the final rolling) to 250°C or higher results in higher plastic formability. So, in the rolling step, preferably, the workpiece is heated and subjected to warm rolling or hot rolling in at least the early stage (rough rolling) of the rolling. However, in particular, for a magnesium alloy having an Al content as high as 7% by mass or more, heating the magnesium alloy to 250°C or higher is liable to cause the growth of precipitations of, for example, an intermetallic compound to form coarse particles. Furthermore, in the cooling process in the solution heat treatment step, when the magnesium alloy passes through the temperature range of 250°C to 350°C , precipitations are liable to coarsen.

[0016] Conventionally, the total time that a workpiece is held in the temperature range of 250°C to 350°C immediately before and during a rolling step has not been well studied. The inventors have studied on the total time and have found as follows: For a magnesium alloy having an Al content of 7% to 12% by mass, in the case where the total holding time in the foregoing temperature range exceeds 1 hour in at least the rolling step, a texture containing coarse precipitations d_1 each having a particle size of $5\ \mu\text{m}$ or more is formed, as illustrated in part (2) of Fig. 1. In contrast, in the case where the total holding time in the foregoing temperature range is within 1 hour in the rolling step, it is possible to reduce the coarse precipitations. Furthermore, only in the rolling step, in the case where the cooling rate in the solution heat treatment is increased in addition to the fact that the total holding time in the foregoing temperature range is within 1 hour, the formation of coarse precipitations is more effectively inhibited. In particular, the sum of the total holding time in the foregoing temperature range in the rolling step and the holding time in the foregoing temperature range in the cooling process in the solution heat treatment step is preferably within 1 hour.

[0017] The alloy sheet of the present invention has a small number of coarse precipitations in the surface area region and has a texture in which very fine precipitations are dispersed (part (1) of Fig. 1). Since the alloy sheet of the present invention has a small number of coarse precipitations, it is believed that a reduction in the amount of Al that forms a solid solution in a matrix (Mg) due to the presence of a large number of coarse precipitations is small and that a reduction in solid-solution strengthening due to the reduction in the Al content is small. Thus, the alloy sheet of the present invention is less likely to be dented even when impacted and has excellent impact resistance because of improvement in the rigidity of the sheet itself as a result of dispersion strengthening owing to the dispersion of precipitations and because

of maintaining the strength owing to the prevention of the reduction in the amount of Al that forms a solid solution. Furthermore, the alloy sheet of the present invention having a small number of coarse precipitations also has excellent plastic formability and can be easily subjected to press forming.

[0018] The alloy sheet of the present invention obtained by the control of the holding time in the specific temperature range mainly in the rolling step as described above is subjected to press forming to produce a formed product of the present invention. In the case of using the alloy sheet of the present invention, the texture constituting the alloy sheet of the present invention and having a small number of coarse precipitations is generally maintained in a portion (flat portion) of the formed product of the present invention where the degree of deformation due to press forming is low.

[0019] That is, the formed product of the present invention also has a texture which has a small number of coarse precipitations in a surface area region and in which very fine precipitations are dispersed. Thus, the formed product of the present invention has excellent impact resistance and is less likely to be dented because of dispersion strengthening owing to the dispersion of fine precipitations and because of solid-solution strengthening owing to Al that sufficiently forms a solid solution, as described above.

[0020] The present invention will be described in more detail below.

«Composition»

[0021] Magnesium alloys include ones having various compositions and each containing Mg and an additive element (remainder: Mg and impurities). The sheet and the formed product of the present invention are composed of a Mg-Al-based alloy containing at least 7% by mass to 12% by mass Al serving as an additive element. The additive element other than Al is at least one element selected from Zn, Mn, Si, Ca, Sr, Y, Cu, Ag, and rare-earth elements (except Y). In the case where the element is contained, the proportion thereof is in the range of 0.01 % by mass to 10% by mass and preferably 0.1% by mass to 5% by mass. More specific examples of the Mg-Al-based alloy include AZ-based alloys (Mg-Al-Zn-based alloys, Zn: 0.2% to 1.5% by mass), AM-based alloys (Mg-Al-Mn-based alloys, Mn: 0.15% to 0.5% by mass), and Mg-Al-RE (rare-earth element)-based alloys according to ASTM standards. In particular, Mg-Al-based alloys containing 8.3% to 9.5% by mass Al and 0.5% to 1.5% by mass Zn, typically, an AZ91 alloy, have excellent mechanical properties, such as corrosion resistance, strength, and plastic deformation resistance, compared with other Mg-Al-based alloys, such as the AZ31 alloy.

«Thickness of Magnesium Alloy Sheet »

[0022] The alloy sheet of the present invention is subjected to press forming, such as bending and drawing, and is used as a material for a thin, lightweight component, such as a housing. For a housing produced by press forming, in order to achieve a small thickness of a portion of the housing where the thickness is not changed substantially by deformation during plastic forming (a flat portion of the formed product of the present invention), the alloy sheet of the present invention preferably has a thickness of 2.0 mm or less, particularly preferably 1.5 mm or less, more preferably 1 mm or less. Within the foregoing range, the magnesium alloy sheet having a larger thickness has higher strength, and the magnesium alloy sheet having a smaller thickness is more suitable for a thin, lightweight housing. The thickness may be selected, depending on an intended use.

«Mechanical Properties»

[0023] The alloy sheet of the present invention is less likely to be dented when subjected to an impact, such as falling. Specifically, in the case where a dent test of a 30 mm x 30 mm specimen with a thickness of t_b cut from the alloy sheet of the present invention is performed as described below, the depth x_b of the dent of the specimen meets the expression $x_b \leq 0.47 \times t_b^{-1.25}$. Furthermore, in the formed product of the present invention, a flat portion that is not subjected to drawing deformation has a small number of coarse precipitations as described above. The properties of the alloy sheet of the present invention are substantially maintained as described above. Thus, after a specimen (thickness: t_p) the same as that of the alloy sheet of the present invention as described above is cut from the flat portion, the dent test described below is performed. The depth x_p of the dent of the specimen meets the expression $x_p \leq 0.47 \times t_p^{-1.25}$. Note that the thickness t_p of the specimen cut from the flat portion of the formed product of the present invention is substantially equal to the thickness t_b (i.e., $t_p = t_b$) of the specimen cut from the magnesium alloy sheet serving as a material for press forming, for example, the alloy sheet of the present invention.

(Dent Test)

[0024] A specimen is arranged on a support having an opening with a diameter of 20 mm so as to close the hole. In this state, a cylindrical bar having a weight of 100 g and a tip radius r of 5 mm is allowed to free fall from a position 200

mm above the specimen.

The depth x_b of the dent or the depth x_p of the dent are each defined as a distance between a straight line that connects both sides of the specimen and the most dented point after the dent test.

5 «Shape of Formed Product»

10 **[0025]** The formed product of the present invention typically has a shape including a top plate (bottom face) and side walls each extending upright from the outer edge of the top plate. More specific examples thereof include a bracket shape consisting of a rectangular plate-like top plate and a pair of opposite side walls; a box shape including two pairs of opposite side walls and having a bracket-shaped cross section; and a closed-end cylinder including a disk-like top plate and a cylindrical side wall.

15 **[0026]** The shape of each of the top plate and the side walls is typically a flat plane. The shape and size thereof are not limited. Each of the top plate and the side walls may include a boss and so forth integrally formed or joined, a through hole and a recess formed in the thickness direction, a groove formed in the thickness direction, a bump, and a portion having a locally varying thickness formed by plastic forming, surface cutting, or the like. In the formed product of the present invention, the flat portion that is not subjected to drawing is defined as follows: When a piece cut from a region excluding a portion that includes the boss and so forth is placed on a horizontal plane, a portion of the piece where the degree of warpage is low is referred to as the flat portion. More specifically, with respect to a surface of the piece placed on the horizontal plane, the surface facing the horizontal plane, a portion where a distance between the horizontal plane and a point of the surface most remote from the horizontal plane is within 1 mm in the vertical direction is defined as the flat portion. A dent is commonly likely to be made in a flat portion. So, for the alloy sheet of the present invention and the formed product of the present invention, dent resistance is evaluated in the flat portion described above.

25 «Surface of Formed Product»

30 **[0027]** The formed product of the present invention may include a covering layer for corrosion prevention, protection, an ornament, or the like on a surface of the magnesium alloy sheet. The magnesium alloy mainly contained in the formed product of the present invention has an Al content of 7% by mass or more and thus has excellent corrosion resistance compared with alloys having a low Al content, for example, the AZ31 alloy. Furthermore, the magnesium alloy sheet is subjected to anticorrosion treatment, e.g., chemical-conversion treatment or anodic-oxidation treatment, to form a corrosion prevention layer, thereby further enhancing the corrosion resistance of the formed product of the present invention. Note that a step of forming the covering layer for corrosion prevention, coating, or the like, does not substantially affect the size and deposition of precipitations. Thus, even when the formed product of the present invention includes the covering layer for corrosion prevention or the like, the number of the coarse particles is five or less. Furthermore, in the case where the dent test is performed, $x_p \leq 0.47 \times t_p^{-1.25}$ is met.

<<Production Method>>

40 [Preparation Step]

[0028] A cast sheet produced by a continuous casting process, such as a twin-roll casting process, in particular, a casting process described in WO/2006/003899 is preferably used. In the continuous casting process, rapid solidification can be performed, thereby reducing oxide and segregation and providing a cast sheet having excellent rollability. The size of the cast sheet is not particularly limited. An excessively thick cast sheet is liable to cause segregation. So, the thickness is preferably 10 mm or less and particularly preferably 5 mm or less.

[Solution Heat Treatment Step]

50 **[0029]** The cast sheet is subjected to solution heat treatment to homogenize the composition. In the solution heat treatment, the holding temperature is set to 350°C or higher. In particular, preferably, the holding temperature is in the range of 380°C to 420°C for a holding time of 60 to 2400 minutes. In the case of a higher Al content, the holding time is preferably increased. Furthermore, to produce the alloy sheet of the present invention, in the cooling substep from the holding temperature, the holding time in the temperature range of 350°C to 250°C is controlled. Specifically, to reduce the holding time in the foregoing temperature range as illustrated in part (1) of Fig. 2, the cooling rate in this temperature range is set to 0.1 °C/sec or more (holding time: about 16.6 minutes or less) and preferably 0.5 °C/sec or more (holding time: 3.3 minutes or less). Such a cooling rate can be achieved by forced cooling, e.g., water cooling or an air blast. The minimization of the holding time in the foregoing temperature range prevents the precipitation of an intermetallic compound containing Al and Mg and, in particular, effectively inhibits the formation of coarse particles even in the case of a

magnesium alloy having a high Al content.

[Rolling Step]

[0030] To increase the plastic formability (rollability) of the sheet that has been subjected to the solution heat treatment, in at least rough rolling, a sheet material heated to 200°C or higher and, in particular, 250°C or higher is preferably subjected to rolling, as described above. A higher heating temperature enhances the plastic formability of the sheet material. However, a heating temperature exceeding 350°C causes problems of the occurrence of seizure and the coarsening of crystal grains to reduce the mechanical properties of the sheet material after rolling. Thus, the heating temperature is preferably 350°C or lower and more preferably 270°C to 330°C. Rolling is performed multiple times (multipass), thereby achieving an intended thickness, reducing the average crystal grain size of the magnesium alloy, and enhancing the press formability. Rolling may be performed under known conditions. For example, rollers may be heated in addition to the sheet material. Controlled rolling disclosed in Patent Literature 1 may be combined. Furthermore, in the final pass and passes near the final pass, in order to increase dimensional accuracy and so forth, the heating temperature of the sheet material may be set to a low temperature (for example, room temperature).

[0031] In the rolling step described above, the holding time in the temperature range of 250°C to 350°C is controlled. Specifically, as illustrated in part (1) of Fig. 2, in order to reduce the holding time in the foregoing temperature range in each pass in the rolling step, for example, the heating time to heat a workpiece is reduced, the rolling speed (circumferential speed of the roll) is increased, or the cooling rate is increased. The rolling conditions are controlled in such a manner that the total holding time in the temperature range of 250°C to 350°C in the rolling step is within 60 minutes or less. A higher Al content facilitates the deposition of precipitations. So, the total holding time is preferably adjusted, depending on the Al content. Furthermore, the total holding time is preferably minimized. The total holding time is preferably 45 minutes or less and particularly preferably 30 minutes. This specific rolling results in the alloy sheet of the present invention having a small number of coarse precipitations in the surface area region and excellent impact resistance, as described above.

[0032] Intermediate heat treatment is performed between the passes of the rolling to eliminate or reduce strain, residual stress, texture, and so forth, which are introduced into the sheet material, which is a workpiece, by processing before the intermediate heat treatment, thereby preventing inadvertent cracking, strain, and deformation in the subsequent rolling and achieving smoother rolling. The intermediate heat treatment is preferably performed at a holding temperature of 250°C to 350°C. This temperature range is liable to cause the growth of precipitations to form coarse particles as described above. Thus, in the case where the intermediate heat treatment is performed, preferably, the total holding time includes the treatment time of the intermediate heat treatment and is controlled.

<<Treatment after Rolling>>

(Final Heat Treatment (Annealing))

[0033] The resulting rolled sheet may be subjected to final heat treatment at, for example, 300°C or higher, thereby eliminating processing strain and performing complete recrystallization. In this final heat treatment, precipitations are liable to grow in the temperature range of 250°C to 350°C. So, in the case where the final heat treatment is performed after rolling, preferably, the total holding time includes the treatment time of the final heat treatment and is controlled. The time of the final heat treatment is controlled as described above, so that the magnesium alloy sheet of the present invention has a small number of coarse precipitations.

(Warm Flattening Treatment)

[0034] Alternatively, the final heat treatment is not performed after rolling, and warm flattening treatment may be performed in which strain is imparted to the resulting rolled sheet using a roller leveler or the like with the rolled sheet heated to 100°C to 250°C. In the case where the resulting sheet that has been subjected to the warm flattening treatment is subjected to press forming, the sheet is recrystallized during the press forming, thereby resulting in a formed product having a fine crystal texture. Fine crystal grains are likely to be formed, and a texture in which fine precipitations are more evenly dispersed is likely to be formed, as compared with the case where the final heat treatment is performed. Thus, in the case where the warm flattening treatment is performed, the magnesium alloy sheet of the present invention has higher impact resistance because of a small number of coarse precipitations and the foregoing fine texture. Note that in the warm flattening treatment, the heating temperature of the rolled sheet is set to at most 250°C, so that precipitations may be less likely to coarsen.

[Press Forming]

[0035] The formed product of the present invention may be produced by press-forming a rolled sheet obtained by the foregoing rolling step or press-forming a treated sheet obtained by subjecting the rolled sheet to the final heat treatment or the warm flattening treatment described above. The press forming is preferably performed in the temperature range of 200°C to 300°C in order to increase the plastic formability of the rolled sheet or the treated sheet, which is a workpiece. It is believed that even if the press forming is performed at a temperature in the temperature range of 250°C to 350°C, the problems, such as the coarsening of precipitations as described above are less likely to occur because the holding time in the temperature range of 250°C to 350°C in the press forming is very short.

[0036] After the press forming, heat treatment may be performed to eliminate strain and residual stress introduced by press forming and to improve the mechanical properties. With respect to heat treatment conditions, the heating temperature is in the range of 100°C to 400°C, and the heating time is in the range of about 5 minutes to about 60 minutes. Also in this heat treatment, it is preferred that the holding time in the temperature range of 250°C to 350°C is not long. Furthermore, a formed product obtained by pressing may not be treated. However, as described above, if treatment to form the covering layer for corrosion prevention, protection, an ornament, or the like is performed, the corrosion resistance, the commodity value, and so forth are further enhanced.

Advantageous Effects of Invention

[0037] A formed product of an magnesium alloy of the present invention and a magnesium alloy sheet of the present invention have excellent impact resistance.

Brief Description of Drawings

[0038]

[Fig. 1] Figure 1 illustrates schematic views of the textures of magnesium alloy sheets, part (1) illustrating a sample in which the total holding time in a temperature range of 250°C to 350°C in a rolling step is within 60 minutes, and part (2) illustrating a sample in which the total holding time exceeds 60 minutes.

[Fig. 2] Figure 2 illustrates graphs each showing the relationship between a temperature mainly in a rolling step and a holding time at the temperature in the production process of a magnesium alloy sheet, part (1) illustrating the case where the total holding time (total time) in the temperature range of 250°C to 350°C in the rolling step is within 60 minutes, and part (2) illustrating the case where the total holding time (total time) exceeds 60 minutes.

[Fig. 3] Figure 3 is a schematic explanatory drawing illustrating a dent test.

[Fig. 4] Figure 4 illustrates graphs of the degree of the dent of a magnesium alloy sheet after the dent test, part (1) illustrating sample a, and part (2) illustrating sample d.

[Fig. 5] Figure 5 is a graph showing the relationship between the thickness of a sheet constituting a formed product of a magnesium alloy and the depth of the dent. Description of Embodiments

[0039] Embodiments of the present invention will be described below.

[Test Example 1]

[0040] A plurality of sheets composed of a magnesium alloy and press-formed bodies obtained by press-forming these magnesium alloy sheets were produced and examined for metal textures and impact resistance.

[0041] A plurality of cast sheets (thickness: 4 mm) composed of a magnesium alloy having a composition equivalent to that of the AZ91 alloy (Mg-9.0% Al-1.0% Zn (all units are percent by mass)) were prepared by a twin-roll casting process. Each of the resulting cast sheets were subjected to solution heat treatment at 400°C for 24 hours. Cooling in the solution heat treatment was performed by an air blast in such a manner that the cooling rate in the temperature range of 350°C to 250°C was 0.1 °C/sec or more. The sheet material that had been subjected to the solution heat treatment was rolled multiple times under rolling conditions described below so as to have a thickness of 0.6 mm. The resulting rolled sheets were subjected to final heat treatment at 300°C for 10 minutes, thereby resulting in magnesium alloy sheets.

(Rolling Conditions)

[0042]

Working ratio (rolling reduction): 5% per pass to 40% per pass

Heating temperature of sheet: 200°C to 400°C

Roll temperature: 100°C to 250°C

[0043] In this test, for each pass in the rolling step, the heating temperature of the sheets and the rolling speed (circumferential speed of the roll) were adjusted to change the total holding time that the sheet materials, which were workpieces subjected to rolling, were held in the temperature range of 250°C to 350°C, thereby preparing four types of samples in which the total holding times were 20 minutes (sample a), 35 minutes (sample b), 50 minutes (sample c), and 80 minutes (sample d).

[0044] The magnesium alloy sheets that had been subjected to the final heat treatment were subjected to square cup deep-drawing processing at a heating temperature of 250°C, thereby providing press-formed bodies. Each of the press-formed bodies had a box shape including a rectangular top plate having dimensions of 48 mm x 98 mm and side walls each extending upright from the top plate.

[0045] For comparison, a commercially available AZ31 alloy material (thickness: 0.6 mm) and aluminium alloy material (A5052 material, thickness: 0.6 mm) were prepared. The AZ31 alloy material was subjected to square cup deep-drawing processing under conditions the same as those of the rolled sheets composed of the AZ91 alloy described above. Similarly, the A5052 material was subjected to square cup deep-drawing processing at room temperature.

[0046] The metal texture of each of the resulting magnesium alloy sheets and the press-formed bodies was observed as described below, and precipitations were studied. Furthermore, a dent test of each of the resulting magnesium alloy sheets and the resulting press-formed bodies was performed, and impact resistance was evaluated.

<Magnesium Alloy Sheet>

<<precipitations>>

[0047] Each of the resulting magnesium alloy sheets composed of the AZ91 alloy was cut in the thickness direction. The resulting cross section was observed with an optical microscope (1000×). In the cross section, any two 100 μm × 100 μm areas in the surface area region were selected from a surface area region extending from a surface of the sheet to a position one-third of the thickness from the surface. These areas were defined as the fields of observation. In each of the fields of observation, the particle size of particles composed of an observed intermetallic compound containing Al and Mg was measured. The number of particles having a particle size of 5 μm or more was counted.

«Impact Resistance»

[0048] The resulting magnesium alloy sheets composed of the AZ91 alloy and the prepared AZ31 alloy material and A5052 material (aluminium alloy material) were cut into 30 mm x 30 mm specimens. In this test, as illustrated in Fig. 3, a support 20 having a horizontal surface with a round hole 21 having a diameter d of 20 mm was prepared. The depth of the round hole 21 was set in such a manner that a cylindrical bar 10 described below was able to be sufficiently inserted therein. A specimen 1 was placed so as to close the round hole 21. In this state, the cylindrical ceramic bar 10 having a weight of 100 g and a tip radius r of 5 mm was arranged at a position 200 mm above the specimen 1 in such a manner that the central axis of the bar was arranged coaxially with the central axis of the round hole 21. After the cylindrical bar 10 was allowed to free fall from the position toward the specimen 1, the depth of the dent of the specimen 1 was measured. With respect to the depth (mm) of the dent, a distance between a straight line that connected both opposite sides of the specimen 1 and the most dented point was measured with a point micrometer. Regarding each of samples a and d, in a 30 mm × 30 mm specimen, a straight line which was parallel to a side having a length of 30 mm and which passed through the most dented point was selected. The depth of the dent was measured at each of a plurality of points on the straight line as described above. Fig. 4 illustrates the results.

<Press-Formed Body>

<<precipitations>>

[0049] In each of the resulting box-shaped press-formed bodies composed of the AZ91 alloy, a flat portion that was not subjected to drawing deformation, specifically, the top plate, was cut in the thickness direction. The resulting cross section was observed in the same way as the magnesium alloy sheet described above, and fields of observation were set. In two fields of observation, the number of particles which was composed of an intermetallic compound containing Al and Mg and which had a particle size of 5 μm or more was counted.

<<Impact Resistance>>

[0050] In each of the resulting box-shaped press-formed bodies composed of the AZ91 alloy and a press-formed body composed of the AZ31 alloy and a press-formed body composed of A5052, which were separately produced, a 30 mm x 30 mm specimen was cut from a flat portion that was not subjected to drawing deformation, specifically, the top plate. As with the magnesium alloy sheet described above, the depth (mm) of the dent was measured with the jig illustrated in Fig. 3.

<<Thickness>>

[0051] In each of the resulting box-shaped press-formed bodies composed of the AZ91 alloy, the thickness was measured at any four points in the 30 mm x 30 mm specimen cut from the top plate. The results demonstrated that the thickness at any point was equal to the thickness of the magnesium alloy sheet described above (thickness of the specimen: 0.6 mm).

[0052] Table I shows the number of precipitations (number) and the depth (mm) of the dent. Table I also shows the value x of the expression $x = 0.47 \times t^{1.25}$ for samples a to d. With respect to the number of precipitations, Table I shows a smaller number of precipitations in the two fields of observation.

[0053]

[Table I]

Sample	Alloy sheet		Press-formed body		Value of expression $x = 0.47 \times t^{1.25}$
	Number of intermetallic compound	Depth of dent (mm)	Number of intermetallic compound	Depth of dent (mm)	
a(20min)	0	0.68	0	0.68	0.890
b(35min)	0	0.70	0	0.70	
c(50min)	0	0.73	0	0.73	
d(80min)	6	0.91	7	0.92	
AZ31	-	0.99	-	1.00	-
A5052	-	1.45	-	1.48	-

[0054] It is found that the sheets and the press-formed bodies composed of the magnesium alloy having an Al content of 7% by mass or more has excellent impact resistance compared with the sheet and the press-formed body composed of the AZ31 alloy having a low Al content and the sheet and the press-formed body composed of the aluminum alloy.

[0055] Observation of the metal texture demonstrated that in samples a to d composed of the magnesium alloy having an Al content of 7% by mass or more, a large number of precipitations of an intermetallic compound ($Mg_{17}Al_{12}$) containing Al and Mg were deposited. However, as shown in Table I, for each of samples a to c in which the total holding time in the temperature range of 250°C to 350°C was within 1 hour (60 minutes) in the rolling step, each of the magnesium alloy sheet and the press-formed body did not have a coarse intermetallic compound but had a texture in which a fine intermetallic compound was dispersed as illustrated in part (1) of Fig. 1. It is found that in each of samples a to c having a small number of coarse precipitations, the depth of the dent is small; hence, samples a to c have excellent impact resistance. It is also found that even in the case where the final heat treatment is performed after the rolling, the holding time is controlled in such a manner that the total of the holding time in the temperature range of 250°C to 350°C during the rolling step and the holding time in the temperature range of 250°C to 350°C during the final heat treatment after the rolling is within 1 hour, thereby resulting in excellent impact resistance.

[Test Example 2]

[0056] Magnesium alloy sheets having different thicknesses and press-formed bodies obtained by press-forming these magnesium alloy sheets were produced and examined for metal textures and impact resistance.

[0057] A plurality of cast sheets (each having a composition equivalent to that of the AZ91 alloy and a thickness of 4 mm) similar to those in Test Example 1 were prepared. Under the same conditions as those in Test Example 1, the solution heat treatment (400°C for 24 hours, the cooling rate from 350°C to 250°C: 0.1 °C/sec or more) and multipass rolling (rolling reduction: 5 % per pass to 40% per pass, heating temperature of the sheets: 200°C to 400°C, and roll

temperature: 100°C to 250°C) were performed to provide rolled sheets. As with Test Example 1, also in this test, the total holding time that the sheet materials were held in the temperature range of 250°C to 350°C in the rolling step, was changed. Furthermore, in this test, the rolled sheets having different thicknesses were produced by adjusting the rolling reduction. The total time was set to 35 minutes or 80 minutes by adjusting the heating time of the sheets and the rolling speed. Moreover, in this test, samples in which the total holding times, including the time of the final heat treatment after the rolling, in the foregoing temperature range were 45 minutes (sample α) and 90 minutes (sample β) were prepared.

[0058] The resulting rolled sheets were subjected to the final heat treatment at 300°C for 10 minutes and then were subjected to square cup deep-drawing processing at a heating temperature of 250°C, thereby providing box-shaped press-formed bodies similar to those in Test Example 1.

[0059] In each of the resulting magnesium alloy sheets and the press-formed bodies that had been subjected to the final heat treatment, the number of precipitations was measured by the observation of the texture of a cross section as in Test Example 1. Furthermore, similarly to Test Example 1, a specimen was formed, and a dent test was performed to measure the depth of the dent. Table II shows the results. In Table II, the results of samples each having a thickness of 0.6 mm (0.6 mm) are those of Test Example 1.

[0060]

[Table II]

Sample	Alloy sheet		Press-formed body		Value of Depth of expression $x = 0.47 \times t^{1.25}$
	Number of intermetallie compound (number)	Depth of dent (mm)	Number of intermetallic compound (number)	dent (mm)	
05 mmt- α	0	0.98	0	0.99	1.118
0.5mmt- β	7	1.22	6	1.21	
0.6mmt- α	0	0.70	0	0.70	0.890
0.6mmt- β	6	0.91	7	0.92	
0.8mmt- α	0	0.51	0	0.52	0.621
0.8mmt- β	8	0.68	7	0.71	

[0061] Table II shows that although the depth of the dent varies depending on the thickness of the magnesium alloy sheet or the press-formed body (top plate), sample α in which the total holding time in the temperature range of 250°C to 350°C is within 60 minutes in the rolling step does not have a coarse intermetallic compound having a particle size of 5 μm or more in the surface area region (the number of the coarse intermetallic compound is zero), regardless of the thickness, and has a smaller depth of the dent than that of sample β having the same thickness.

[0062] For such a press-formed body having excellent impact resistance, the relationship between the thickness t_p of the press-formed body (top plate) and the depth x of the dent was studied. Figure 5 illustrates the results. From a graph illustrated in Fig. 5, the relationship between the thickness t_p and the depth x of the dent in sample α can be most simply represented by $x = k \times t_p^{-1}$ (where k represents a coefficient). With respect to the coefficient k that distinguishes between sample α and sample β , when values from 0 to 1 in 0.01 steps are substituted for k at the thicknesses t_p ranging from 0.5 to 0.8, the expression was evaluated. In this case, it is believed that k is preferably 0.5 and the neighborhood thereof. However, the coefficient k tends to vary slightly, depending on the thickness. So, in view of the case of a thickness t_p of less than 0.5 mm or more than 0.8 mm, the relational expression to distinguish between sample α and sample β was reviewed to the extent that sample α did not deviate from the relational expression $x = 0.5 \times t^{-1}$ (i.e., $k = 0.5$) as much as possible. Specifically, with the coefficient k fixed to 0.5, values from -1 in 0.01 steps were substituted for the exponent of the thickness t_p to determine a preferred curve. Then the coefficient k was again determined in the same way as above. As a result, the expression was found to be $x = 0.47 \times t^{-1.25}$. Thus, $x \leq 0.47 \times t_p^{-1.25}$ is used as an index of the formed product of the present invention. Furthermore, a magnesium alloy sheet was similarly examined. For the magnesium alloy sheet, $x \leq 0.47 \times t_b^{-1.25}$ (where t_b : thickness) was also applicable. Thus, $x \leq 0.47 \times t_b^{-1.25}$ is used as an index of the magnesium alloy sheet of the present invention.

[Test Example 3]

[0063] Magnesium alloy sheets produced by performing another treatment after the rolling were prepared. The magnesium alloy sheets were subjected to press forming to produce press-formed bodies. They were examined for metal

textures and impact resistance.

[0064] In this test, a plurality of cast sheets (each having a composition equivalent to that of the AZ91 alloy and a thickness of 4 mm) similar to those in Test Example 1 were prepared. Under the same conditions as those in Test Example 1, the solution heat treatment (400°C for 24 hours, the cooling rate from 350°C to 250°C: 0.1 °C/sec or more) was performed. The sheet materials that had been subjected to the solution heat treatment were subjected to multipass rolling (rolling reduction: 5 % per pass to 40% per pass, heating temperature of the sheets: 200°C to 280°C, and roll temperature: 100°C to 250°C), thereby providing rolled sheets. In this test, the total time that each of the sheet materials was held in the temperature range of 250°C to 350°C in the rolling step was set to 45 minutes.

[0065] The resulting rolled sheets were subjected to warm flattening treatment. Here, the warm flattening treatment is performed with a roller leveler including a furnace capable of heating a rolled sheet and a roller section that includes a plurality of rollers configured to continuously impart a bend (strain) to a heated rolled sheet. The roller section includes the plural rollers which face each other and which are located above and below in a staggered configuration.

[0066] In the roller leveler, each of the rolled sheets is transferred to the roller section while being heated in the furnace. Each time the sheet is passed between the upper rollers and the lower rollers in the roller section, these rollers impart a series of bends to the sheet. Here, the warm flattening was performed in the temperature range of 220°C to 250°C. The transfer speed and so forth during the flattening was adjusted in such a manner that the total time that the rolled sheet was held in the temperature range of 250°C to 350°C was within 60 minutes.

[0067] The magnesium alloy sheets that had been subjected to the warm flattening treatment were subjected to square cup deep-drawing processing at a heating temperature of 250°C, thereby providing box-shaped press-formed bodies similar to those in Test Example 1.

[0068] In each of the resulting magnesium alloy sheets and the press-formed bodies, the number of precipitations was measured by the observation of the texture of a cross section as in Test Example 1. Furthermore, similarly to Test Example 1, a specimen was formed, and a dent test was performed to measure the depth of the dent. Table III shows the results.

[0069]

[Table III]

Sample	Alloy sheet		Press-formed body		Value of expression $x = 0.47 \times t^{1.25}$
	Number of intermetallic compound (number)	Depth of dent (mm)	Number of intermetallic compound (number)	Depth of dent (mm)	
3-1	0	0.68	0	0.68	0.890
2-1 (0.6mmt- α)	0	0.70	0	0.70	

[0070] Table III shows that any sample has a small depth of the dent and excellent impact resistance. In particular, it is found that sample 3-1, in which the magnesium alloy sheet that had been subjected to the warm flattening treatment after the rolling was used, has a small depth of the dent and excellent impact resistance, compared with sample 2-1 (0.6 mmt- α in Test Example 2), in which the final heat treatment was performed after the rolling.

[0071] The foregoing embodiments may be appropriately changed without departing from the scope of the present invention. The present invention is not restricted to the foregoing configurations. For example, the composition of the magnesium alloy, the thickness of the magnesium alloy sheet, the shape of the press-formed body, and so forth may be appropriately changed.

Industrial Applicability

[0072] A formed product of a magnesium alloy of the present invention can be suitably used for components of various electronic devices, in particular, housings for mobile electronic devices. A magnesium alloy sheet of the present invention can be suitably used as a material for the formed product of the magnesium alloy of the present invention. Reference Signs List

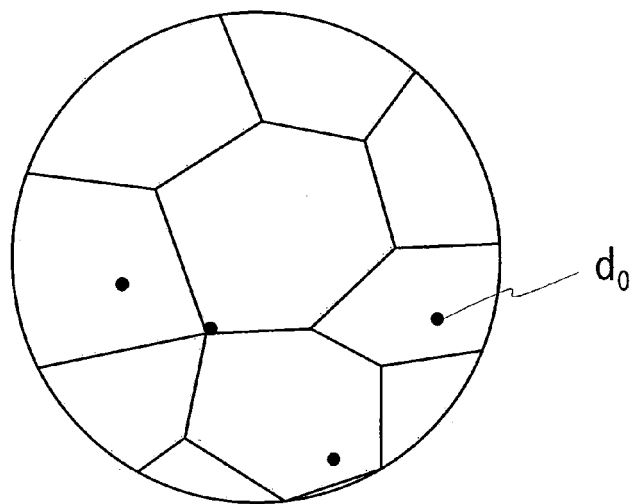
[0073] 1 specimen, 10 cylindrical bar, 20 support, 21 round hole, d_0 , d_1 intermetallic compound (precipitation)

Claims

1. A formed product of a magnesium alloy produced by press-forming a sheet composed of a magnesium alloy, wherein the magnesium alloy contains 7% by mass to 12% by mass Al, the formed product has a flat portion that is not subjected to drawing deformation, and wherein in the case where in a metal texture in a cross section of the flat portion in the thickness direction, a region extending from a surface of the flat portion to a position one-third of the thickness from the surface in the thickness direction is defined as a surface area region, two $100\ \mu\text{m} \times 100\ \mu\text{m}$ areas in the surface area region are set to fields of observation, and where particles composed of an intermetallic compound containing Al and Mg and each having a particle size of $5\ \mu\text{m}$ or more are defined as coarse particles, the number of the coarse particles present in each of the fields of observation is five or less.
2. The formed product of a magnesium alloy according to Claim 1, wherein when the following dent test of a 30 mm x 30 mm specimen with a thickness of t_p cut from the flat portion is performed, the depth x_p of the dent of the specimen meets the expression $x_p \leq 0.47 \times t_p^{-1.25}$:
(Dent Test)
The specimen is arranged on a support having an opening with a diameter of 20 mm so as to close the hole; in this state, a cylindrical bar having a weight of 100 g and a tip radius r of 5 mm is allowed to free fall from a position 200 mm above the specimen; and wherein the depth x_p of the dent is defined as a distance between a straight line that connects both sides of the specimen and the most dented point after the dent test.
3. The formed product of a magnesium alloy according to Claim 1 or 2, wherein the magnesium alloy contains at least one element selected from Zn, Mn, Si, Ca, Sr, Y, Cu, Ag, and rare-earth elements (except Y).
4. The formed product of a magnesium alloy according to Claim 3, wherein the magnesium alloy contains, on a mass percent basis, 8.3%-9.5% Al and 0.5%-1.5% Zn.
5. The formed product of a magnesium alloy according to Claim 4, wherein a corrosion prevention layer is formed by chemical-conversion treatment on a surface of the sheet of the magnesium alloy.
6. A magnesium alloy sheet used for press forming, wherein the magnesium alloy contains 7% by mass to 12% by mass Al, and wherein in the case where in a metal texture in a cross section of the sheet in the thickness direction, a region extending from a surface of the sheet to a position one-third of the thickness from the surface in the thickness direction is defined as a surface area region, two $100\ \mu\text{m} \times 100\ \mu\text{m}$ areas in the surface area region are set to fields of observation, and where particles composed of an intermetallic compound containing Al and Mg and each having a particle size of $5\ \mu\text{m}$ or more are defined as coarse particles, the number of the coarse particles present in each of the fields of observation is five or less.
7. The magnesium alloy sheet according to Claim 6, wherein when the following dent test of a 30 mm x 30 mm specimen with a thickness of t_b cut from the sheet is performed, the depth x_b of the dent of the specimen meets the expression $x_b \leq 0.47 \times t_b^{-1.25}$:
(Dent Test)
The specimen is arranged on a support having an opening with a diameter of 20 mm so as to close the hole; in this state, a cylindrical bar having a weight of 100 g and a tip radius r of 5 mm is allowed to free fall from a position 200 mm above the specimen; and wherein the depth x_b of the dent is defined as a distance between a straight line that connects both sides of the specimen and the most dented point after the dent test.
8. The magnesium alloy sheet according to Claim 6 or 7, wherein the magnesium alloy contains at least one element selected from Zn, Mn, Si, Ca, Sr, Y, Cu, Ag, and rare-earth elements (except Y).
9. The magnesium alloy sheet according to Claim 8, wherein the magnesium alloy contains, on a mass percent basis, 8.3%-9.5% Al and 0.5%-1.5% Zn.

FIG. 1

(1)



(2)

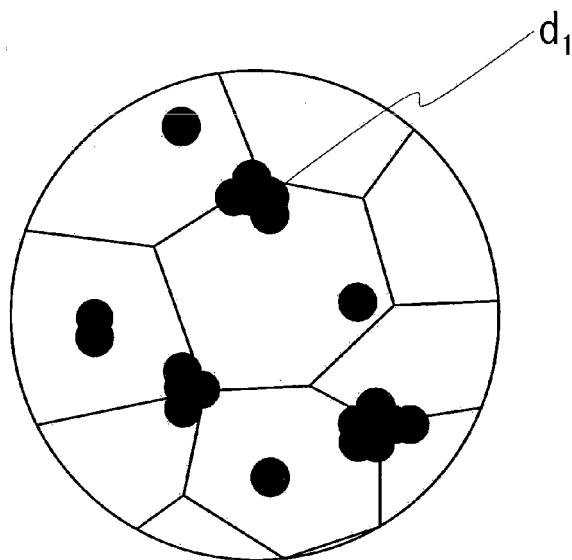


FIG. 2

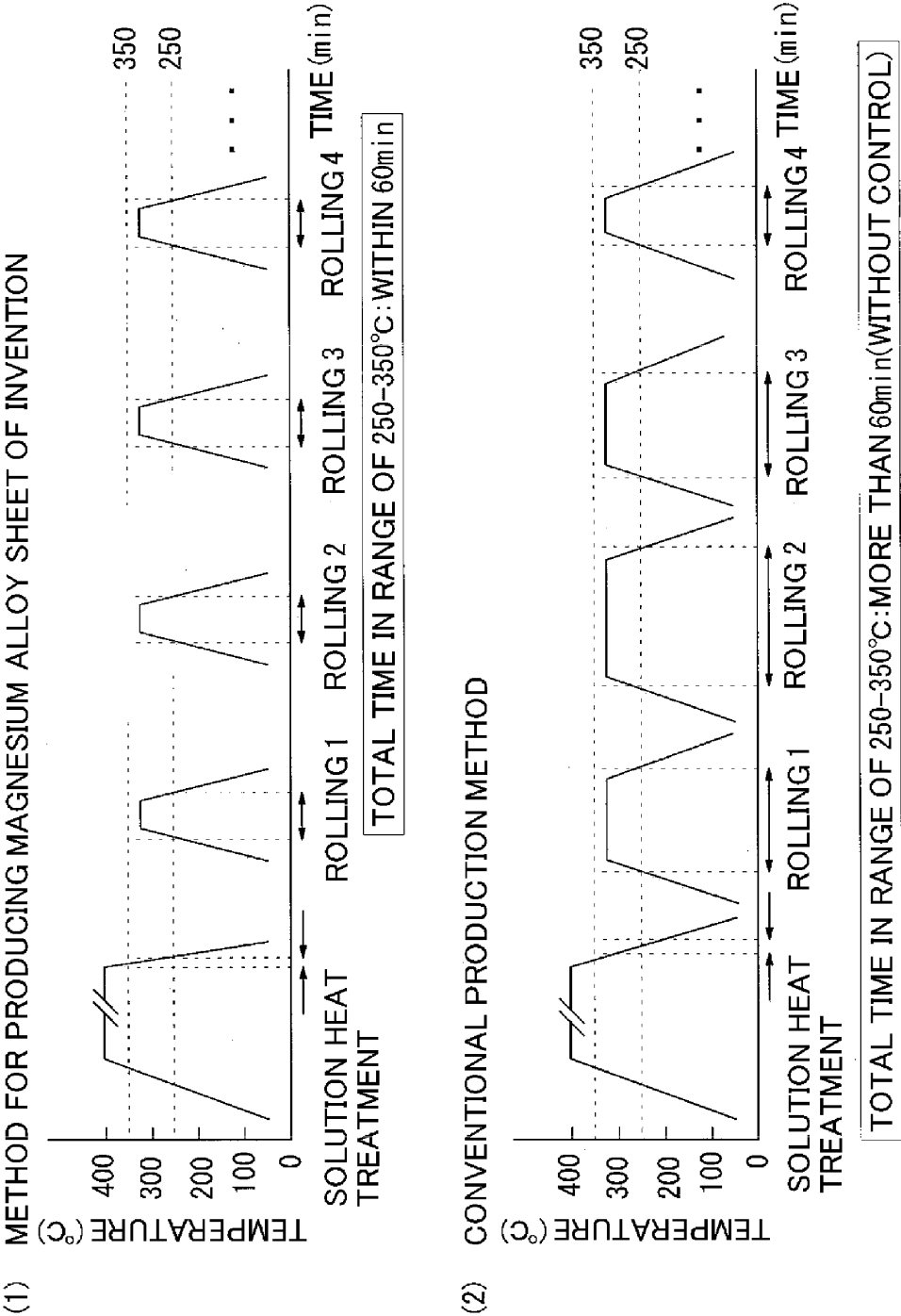


FIG. 3

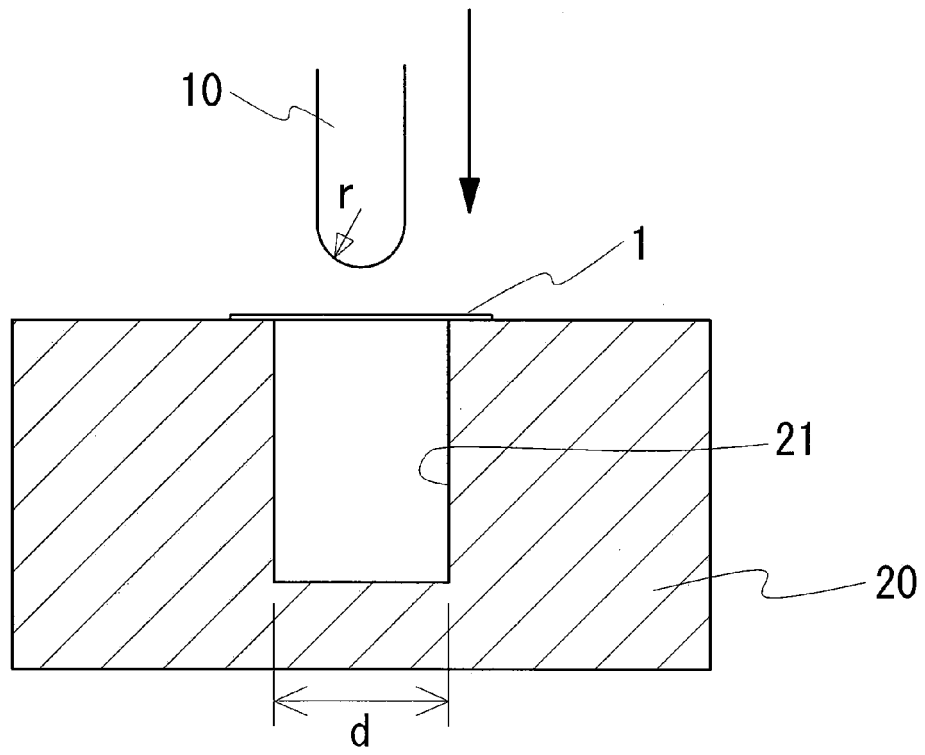
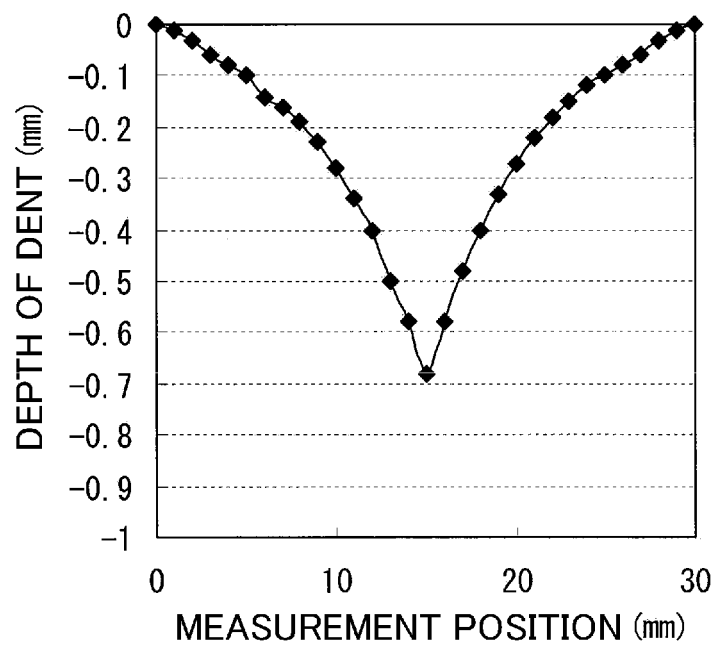


FIG. 4

(1) SAMPLE a (20min)



(2) SAMPLE d (80min)

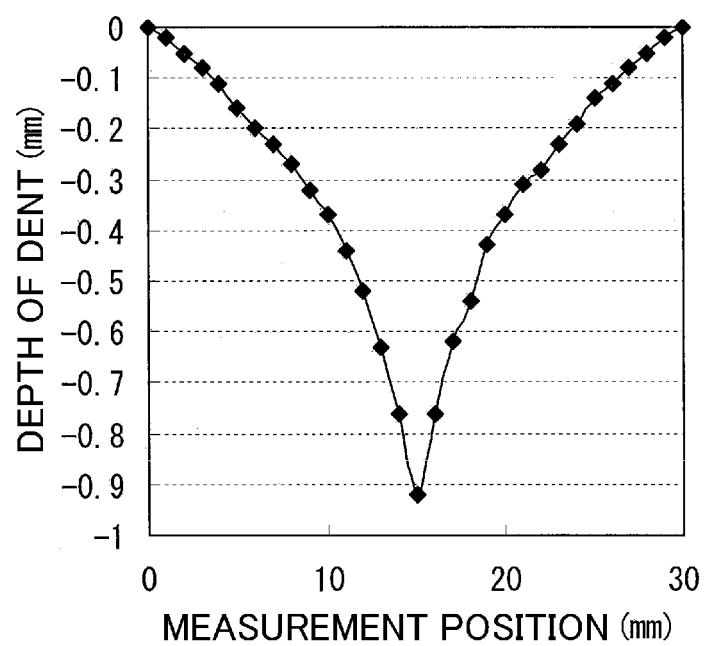
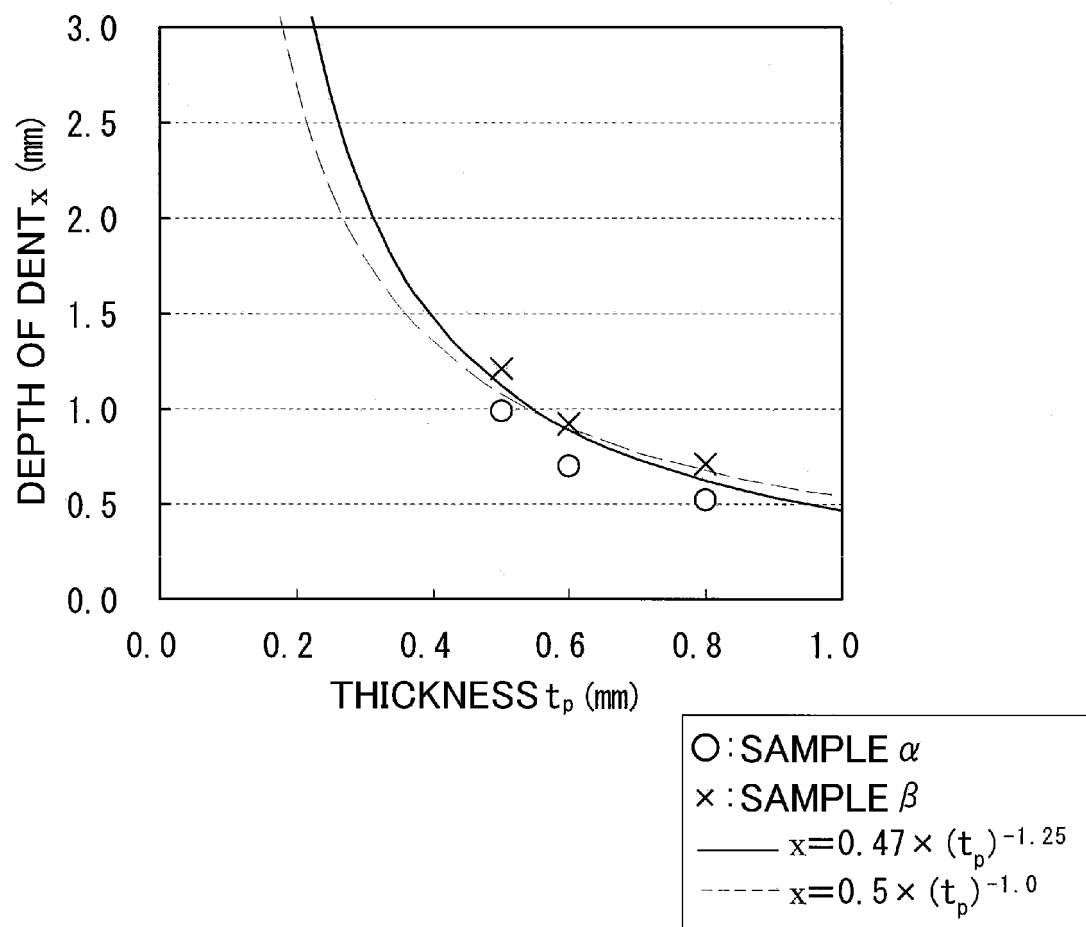


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/005004

A. CLASSIFICATION OF SUBJECT MATTER

C22C23/02(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, 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	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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 Y	WO 2006/003899 A1 (Sumitomo Electric Industries, Ltd.), 12 January 2006 (12.01.2006), claims 10, 43, 46; paragraphs [0053], [0054], [0056]; No.6 on tables 2, 7; No.15 on tables 4, 9; No.17 on tables 5, 10 & US 2008/311423 A1 & EP 1777022 A1 & CA 2572480 A & KR 10-2007-0030243 A & CN 1980759 A	1-4, 6-9 5
X Y	JP 2006-152401 A1 (Sumitomo Electric Industries, Ltd.), 15 June 2006 (15.06.2006), claims 1, 3, 5; paragraph [0013]; tables 1, 2 (Family: none)	1-4, 6-9 5

☒ 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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

"I" 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
15 December, 2009 (15.12.09)Date of mailing of the international search report
28 December, 2009 (28.12.09)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/005004

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2008-106337 A1 (Kabushiki Kaisha Shingijutsu Kenkyusho, Kenji HIGASHI), 08 May 2008 (08.05.2008), claims 1, 2, 5; paragraphs [0003], [0005] (Family: none)	1-4, 6-9 5
X Y	JP 2000-271631 A1 (Kenji HIGASHI, YKK Corp.), 03 October 2000 (03.10.2000), claim 1; paragraph [0006] (Family: none)	1-4, 6-9 5
X Y	JP 2000-313948 A1 (YKK Corp.), 14 November 2000 (14.11.2000), claim 1; paragraph [0007] (Family: none)	1-4, 6-9 5
Y	WO 2008/029497 A1 (Sumitomo Electric Industries, Ltd.), 13 March 2008 (13.03.2008), paragraph [0005] & EP 2060642 A1 & KR 10-2009-0051080 A	5

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/005004

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The inventions of claims 1-4 relate to a formed article of magnesium alloy.

The invention of claim 5 relates to a formed article of magnesium alloy which is provided with an anticorrosive layer formed by chemical conversion treatment.

The inventions of claims 6-9 relate to a magnesium alloy sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- JP 2007098470 A [0005]
- WO 2006003899 A [0028]