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(54) **ALUMINUM ALLOY MATERIAL**

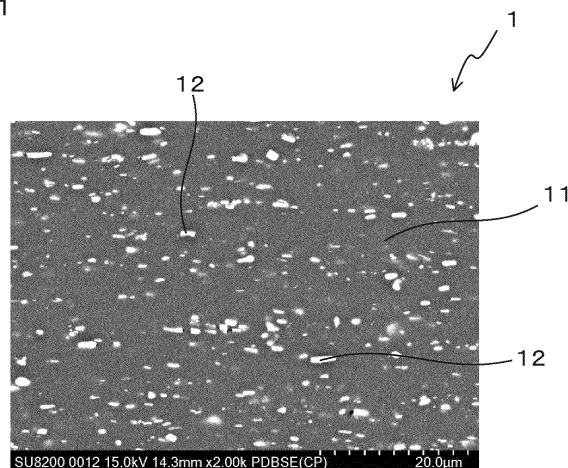
(57) An aluminum-alloy material (1) has an Al matrix and second-phase particles dispersed in the Al matrix, wherein the value of a metallographic-structure factor F indicated in Equation (1) below is 0.005 or more.

$$F = A \cdot \rho \cdot L \cdot \exp(B \cdot E) \quad (1) \quad (1)$$

Therein, in the above-mentioned Equation (1), L is

the total [$\mu\text{m}/\mu\text{m}^2$] of the perimeters of the second-phase particles, from among the second-phase particles present in an arbitrary cross section, whose circle-equivalent diameters are 0.2 μm or more, ρ is the dislocation density [μm^{-2}], E is the electrical conductivity [% IACS] at 25°C, A and B are correction coefficients determined in accordance with the chemical composition of the aluminum-alloy material, $0.2 \times 10^{-15} \leq A \leq 20 \times 10^{-15}$, and $0.1 \leq B \leq 1.0$.

FIG. 1



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to an aluminum-alloy material.

BACKGROUND ART

10 **[0002]** In various fields, such as industrial products, buildings, and structures, vibration that is generated during use of equipment, vibration that is imparted from outside the equipment, and the like sometimes gives rise to a variety of problems. For example, in transportation equipment, such as automobiles and rail transport, there is a risk that the comfort of the crew will decrease owing to vibration itself, noise generated by vibration, and the like. In consumer electronics, acoustic equipment, and the like, there is a risk that the noise generated by the vibration will cause discomfort to the user. In addition, for example, in precision equipment, there is a risk that vibration will cause a hindrance in the operation of the equipment.

15 **[0003]** To curtail the occurrence of these problems, various techniques that attenuate vibration have been proposed. For example, in the fields of buildings, structures, and the like, methods that incorporate a damping member, such as a damper, methods that use, as a member that constitutes the building or the like, a member having a shape that readily attenuates vibration, and the like are widely used. Nevertheless, in methods that incorporate a damping member, there is a risk that it will lead to an increase in the number of members in industrial products and the like. In addition, methods that attenuate vibration owing to the shape of a member are difficult to apply to transportation equipment, consumer electronics, precision equipment, and the like, in which the dimensions, masses, and shapes of members are greatly constrained.

20 **[0004]** To overcome such problems, methods are being studied in which, taking advantage of the characteristics of aluminum alloys, which are comparatively lightweight and excel in workability, industrial products and the like are constructed using members composed of aluminum alloys having a high damping ability. For example, Patent Document 1 describes a method of manufacturing an aluminum-alloy damping material in which an aluminum-alloy ingot containing Fe: 0.5-20 wt%, the remainder being Al and unavoidable impurities, is subjected to plastic working with a surface-reduction percentage of 30% or more.

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PRIOR ART LITERATURE

Patent Documents

35 **[0005]** Patent Document 1
Japanese Laid-open Patent Publication H3-223446

SUMMARY OF THE INVENTION

40 PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] There has been demand in recent years for an aluminum-alloy material having a damping ability higher than that of the aluminum-alloy damping material described in Patent Document 1.

45 **[0007]** The present invention was conceived considering such a background, and an object of the present invention is to provide an aluminum-alloy material having a high damping ability.

MEANS FOR SOLVING THE PROBLEMS

50 **[0008]** One aspect of the present invention is an aluminum-alloy material having an Al matrix and second-phase particles dispersed in the Al matrix,
wherein the value of a metallographic-structure factor F indicated in Equation (1) below is 0.005 or more.

$$F = A \cdot \rho \cdot L \cdot \exp(B \cdot E) \quad (1)$$

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[0009] Therein, in the above-mentioned Equation (1), L is the total [$\mu\text{m}/\mu\text{m}^2$] of the perimeters of the second-phase particles, from among the second-phase particles present in an arbitrary cross section, whose circle-equivalent diameters are 0.2 μm or more, ρ is the dislocation density [μm^{-2}], E is the electrical conductivity [% IACS] at 25°C, and A and B

are correction coefficients determined in accordance with the chemical composition of the aluminum-alloy material. A and B can be values within the ranges of $0.2 \times 10^{-15} \leq A \leq 20 \times 10^{-15}$ and $0.1 \leq B \leq 1.0$, respectively.

EFFECTS OF THE INVENTION

[0010] In the above-mentioned aluminum-alloy material, the value of the metallographic-structure factor F expressed by the total L of the perimeters of the second-phase particles having a circle-equivalent diameter of 0.2 μm or more, the dislocation density ρ , and the electrical conductivity E, is within the above-mentioned specific range. Thereby, owing to interactions between the above-mentioned second-phase particles and dislocations in the Al matrix, vibration imparted from outside of the above-mentioned aluminum-alloy material can be attenuated with good efficiency. As a result, damping ability can be increased beyond that of preexisting aluminum-alloy materials.

[0011] Therefore, according to the above-mentioned aspect, an aluminum-alloy material having excellent damping ability can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is an example of a reflection-electron image of an L-LT cross section of an aluminum-alloy material according to a working example.

FIG. 2 is an example of a binarized image produced by subjecting the reflection-electron image in FIG. 1 to a binarization process.

FIG. 3 is a side view that shows the principal parts of a loss-factor measuring apparatus according to the working example.

FIG. 4 is an explanatory diagram that shows one example of an amplitude-frequency curve according to the working example.

MODES FOR CARRYING OUT THE INVENTION

(Chemical Composition)

[0013] The above-mentioned aluminum-alloy material contains Al (aluminum) and one or two or more of additional elements for forming second-phase particles in the Al matrix. For example, Fe (iron), Mn (manganese), Si (silicon), Cu (copper), Mg (magnesium), Zn (zinc), Ni (nickel), Cr (chrome), Ti (titanium), V (vanadium), Zr (zirconium), or the like can be used as the additional elements. By adding these additional elements to the aluminum alloy, second-phase particles that contain the above-mentioned additional elements can be formed in the Al matrix.

• Fe (iron): 0.30-3.0 mass%

[0014] The above-mentioned aluminum-alloy material may contain 0.30-3.0 mass% of Fe. By setting the Fe content to 0.30 mass% or more, the amount of second-phase particles in the Al matrix can be made greater, and thereby the damping ability of the aluminum-alloy material can be improved. From the viewpoint of further improving the damping ability of the aluminum-alloy material, the Fe content is preferably set to 0.50 mass% or more.

[0015] On the other hand, in the situation in which the Fe content is excessively high, there is a risk that coarse second-phase particles will tend to be formed in the aluminum-alloy material, leading to a decrease in rollability. By setting the Fe content to 3.0 mass% or less and preferably to 2.0 mass% or less, the damping ability of the aluminum-alloy material can be improved while easily avoiding such problems.

• Mn: 0.10-1.50 mass%

[0016] The above-mentioned aluminum-alloy material may contain 0.10-1.50 mass% of Mn. By setting the Mn content to 0.10 mass% or more, the amount of second-phase particles in the Al matrix can be made greater, and thereby the damping ability of the aluminum-alloy material can be further improved. From the viewpoint of further improving the damping ability of the aluminum-alloy material, the Mn content is more preferably set to 0.20 mass% or more.

[0017] On the other hand, in the situation in which the Mn content is excessively high, there is a risk that coarse second-phase particles will tend to form in the aluminum-alloy material, leading to a decrease in reliability. From the viewpoint of obtaining a damping-improvement effect while easily avoiding such problems, the Mn content is preferably set to 1.50 mass% or less and more preferably set to 1.0 mass% or less.

• Si: 0.0050-3.0 mass%

[0018] The above-mentioned aluminum-alloy material may contain 0.0050-3.0 mass% of Si. By setting the Si content to 0.0050 mass% or more, the amount of second-phase particles in the Al matrix can be made greater, and thereby the damping ability of the aluminum-alloy material can be further improved. From the viewpoint of further improving the damping ability of the aluminum-alloy material, the Si content is more preferably set to 0.050 mass% or more.

[0019] On the other hand, in the situation in which the Si content is excessively high, there is a risk that coarse second-phase particles will tend to form in the aluminum-alloy material, leading to a decrease in reliability. In addition, by virtue of the amount of the additional elements that have formed a solid solution in the Al matrix becoming large in this situation, there is a risk that it will lead to a decrease in damping ability. From the viewpoint of avoiding such problems and obtaining the damping-improvement effect, the Si content is preferably set to 3.0 mass% or less and more preferably set to 2.0 mass% or less.

• Cu: 0.0030-0.10 mass%

[0020] The above-mentioned aluminum-alloy material may contain 0.0030-0.10 mass% of Cu. By setting the Cu content to 0.0030 mass% or more, the amount of second-phase particles in the Al matrix can be made greater, and thereby the damping ability of the aluminum-alloy material can be further improved. From the viewpoint of further improving the damping ability of the aluminum-alloy material, the Cu content is more preferably set to 0.010 mass% or more.

[0021] On the other hand, in the situation in which the Cu content is excessively high, there is a risk that coarse second-phase particles will tend to form in the aluminum-alloy material, leading to a decrease in reliability. In addition, by virtue of the amount of the additional elements that have formed a solid solution in the Al matrix becoming large in this situation, there is a risk that it will lead to a decrease in damping ability. From the viewpoint of easily avoiding such problems and obtaining the damping-improvement effect, the Cu content is preferably set to 0.10 mass% or less and more preferably set to 0.050 mass% or less.

• Mg: 0.0050-3.0 mass%

[0022] The above-mentioned aluminum-alloy material may contain 0.0050-3.0 mass% of Mg. By setting the Mg content to 0.0050 mass% or more, the amount of second-phase particles in the Al matrix can be made greater, thereby further improving the damping ability of the aluminum-alloy material. From the viewpoint of further improving the damping ability of the aluminum-alloy material, the Mg content is more preferably set to 0.050 mass% or more.

[0023] On the other hand, in the situation in which the Mg content is excessively high, by virtue of the amount of additional elements that have formed a solid solution in the Al matrix becoming large, there is a risk that it will lead to a decrease in damping ability. From the viewpoint of avoiding such problems and obtaining the damping-improvement effect, the Mg content is preferably set to 3.0 mass% or less and more preferably set to 1.50 mass% or less.

• Zn: 0.10-0.50 mass%

[0024] The above-mentioned aluminum-alloy material may contain 0.10-0.50 mass% of Zn. By setting the Zn content to 0.10 mass% or more, the amount of second-phase particles in the Al matrix can be made greater, thereby further improving the damping ability of the aluminum-alloy material. From the viewpoint of further improving the damping ability of the aluminum-alloy material, the Zn content is more preferably set to 0.20 mass% or more.

[0025] On the other hand, in the situation in which the Zn content is excessively high, by virtue of the amount of additional elements that have formed a solid solution in the Al matrix becoming large, there is a risk that it will lead to a decrease in damping ability. From the viewpoint of easily avoiding such problems and obtaining the damping-improvement effect, the Zn content is preferably set to 0.50 mass% or less and more preferably set to 0.40 mass% or less.

• Ni: 0.050-0.30 mass%, Cr: 0.050-0.30 mass%, Ti: 0.050-0.30 mass%, and V: 0.050-0.30 mass%

[0026] The above-mentioned aluminum-alloy material may contain one or two or more of elements from among elements selected from the group consisting of Ni: 0.050-0.30 mass%, Cr: 0.050-0.30 mass%, Ti: 0.050-0.30 mass%, and V: 0.050-0.30 mass%. By setting the content of these additional elements to 0.050 mass% or more, the damping ability of the aluminum-alloy material can be further improved. From the viewpoint of further improving the damping ability of the aluminum-alloy material, the content of these additional elements is more preferably set to 0.10 mass% or more.

[0027] On the other hand, in the situation in which the content of these additional elements is excessively high, there is a risk that coarse second-phase particles will tend to form in the aluminum-alloy material, leading to a decrease in rollability. From the viewpoint of obtaining the damping-improvement effect while avoiding such problems, the content

of these additional elements is preferably set to 0.30 mass% or less and more preferably set to 0.20 mass% or less.

• Zr: 0.0010-0.30 mass%

[0028] The above-mentioned aluminum-alloy material may contain 0.0010-0.30 mass% of Zr. By setting the Zr content to 0.0010 mass% or more, the damping ability of the aluminum-alloy material can be further improved. From the viewpoint of further improving the damping ability of the aluminum-alloy material, the Zr content is more preferably set to 0.010 mass% or more.

[0029] On the other hand, in the situation in which the Zr content is excessively high, there is a risk that coarse second-phase particles will tend to form in the aluminum-alloy material, leading to a decrease in reliability. From the viewpoint of obtaining the damping-improvement effect while avoiding such problems, the Zr content is preferably set to 0.30 mass% or less and more preferably set to 0.20 mass% or less.

[Metallographic Structure]

[0030] The above-mentioned aluminum-alloy material has second-phase particles that are dispersed in the Al matrix. The second-phase particles are composed of, for example, an Al-Fe-based compound, Si, an Al-Fe-Mn-based compound, an Al-Fe-Si-based compound, an Al-Mn-based compound, an Al-Mn-Si-based compound, an Al-Fe-Mn-Si-based compound, an Al-Cu-based compound, an Al-Mg-based compound, an Mg-Si-based compound, an Al-Mg-Zn-based compound, an Al-Cu-Zn-based compound, an Al-Ni-based compound, an Al-Cr-based compound, an Al-Ti-based compound, an Al-V-based compound, an Al-Zr-based compound, or the like. The second-phase particles may be precipitates or may be crystallized products.

[0031] The second-phase particles dispersed in the Al matrix have various particle sizes. In addition to second-phase particles having a circle-equivalent diameter of 0.2 μm or more, the aluminum-alloy material may contain second-phase particles having a circle-equivalent diameter of less than 0.2 μm , but does not have to contain second-phase particles having a circle-equivalent diameter of less than 0.2 μm . The above-mentioned aluminum-alloy material can exhibit the functions and effects of improving damping ability as long as the Al matrix has second-phase particles having a circle-equivalent diameter of 0.2 μm or more.

[0032] In addition, as described above, in the situation in which coarse second-phase particles are formed in the Al matrix, there is a risk that it will lead to a decrease in rollability. From the viewpoint of easily avoiding such a problem, the circle-equivalent diameter of the second-phase particles dispersed in the Al matrix is preferably 20 μm or less.

[Metallographic-Structure Factor F]

[0033] With regard to the above-mentioned aluminum-alloy material, as described above, vibration can be attenuated by interactions between the second-phase particles dispersed in the Al matrix and dislocations. For this reason, to increase the damping ability of the above-mentioned aluminum-alloy material, it is necessary to control not only the mode of the second-phase particles in the metallographic structure but also the mode of the dislocations. A characteristic of the metallographic structure relating to the damping ability of the above-mentioned aluminum-alloy material can be expressed by the value of the metallographic-structure factor F that appears in Equation (1) below.

$$F = A \cdot \rho \cdot L \cdot \exp(B \cdot E) \quad (1)$$

[0034] Therein, symbol L in the above-mentioned Equation (1) is the total [$\mu\text{m}/\mu\text{m}^2$] of the perimeters of the second-phase particles, from among the above-mentioned second-phase particles present in an arbitrary cross section, having a circle-equivalent diameter of 0.2 μm or more; symbol ρ is the dislocation density [μm^{-2}]; symbol E is the electrical conductivity [% IACS] at 25°C; and symbol A and symbol B are correction coefficients that are determined in accordance with the chemical composition of the above-mentioned aluminum-alloy material.

[0035] In a metallographic structure in which the value of the metallographic-structure factor F is 0.005 or more, the mode of existence of the additional elements contained in the aluminum-alloy material and the mode of existence of the dislocations in the matrix tend to be suitable modes for attenuating vibration. For this reason, with regard to an aluminum-alloy material whose metallographic-structure factor F value is 0.005 or more, damping ability can be improved. From the viewpoint of further increasing damping ability, the above-mentioned metallographic-structure factor F value is preferably 0.01 or more and more preferably 0.05 or more. It is noted that, from the viewpoint of improving damping ability, although there is no upper limit to the metallographic-structure factor F value, it is difficult in typical manufacturing methods to obtain an aluminum-alloy material for which the metallographic-structure factor F value is greater than 400.

[0036] In the situation in which the above-mentioned metallographic-structure factor F value is less than 0.005, because

the damping-reduction effect owing to the solid-solution elements tends to surpass the damping-improvement effect owing to interactions between the second-phase particles and the dislocations, there is a risk that it will lead to a decrease in damping ability.

[0037] The individual parameters used in the calculation of the metallographic-structure factor F value can be determined as below.

• Perimeter L of Second-Phase Particles

[0038] The total L of the perimeters of the second-phase particles having a circle-equivalent diameter of 0.2 μm or more can be calculated by the following method. First, a cross section of the above-mentioned aluminum-alloy material is observed using a scanning electron microscope, and a reflection electron image is acquired. The magnification during the observation can be set as appropriate from the range of, for example, 1,000-5,000 times.

[0039] The cross section of the observation target is not particularly limited. For example, in the situation in which the above-mentioned aluminum-alloy material is a rolled plate, the cross section of the observation target may be a cross section that is perpendicular to the rolling direction (i.e., an LT-ST plane) or may be a cross section that is parallel to the rolling direction, such as an L-LT plane (i.e., a cross section parallel to the plate surface), an L-ST plane, or the like. In addition, in the situation in which the above-mentioned aluminum-alloy material is an extruded material, the cross section of the observation target may be a cross section that is parallel to the extrusion direction or may be a cross section that is perpendicular to the extrusion direction. Furthermore, the cross section of the observation target may be some other cross section.

[0040] Next, the reflection electron image is subjected to a binarization process using an image-processing apparatus or the like to obtain a binarized image, in which the Al matrix and the second-phase particles are indicated by differing brightnesses. Second-phase particles having a circle-equivalent diameter of 0.2 μm or more are sampled from this binarized image; furthermore, the perimeters of these second-phase particles are calculated. Then, the total of the perimeters of the second-phase particles having a circle-equivalent diameter of 0.2 μm or more present in the binarized image is converted to a value per 1 μm² of surface area. The value obtained by the above is taken as the value L [μm/μm²] of the total of the perimeters of the second-phase particles having a circle-equivalent diameter of 0.2 μm or more.

[0041] The total L of the perimeters of the second-phase particles described above is preferably 0.1 μm/μm² or more and is more preferably 0.2 μm/μm² or more. By setting the total L of the perimeters of the second-phase particles to be large, interactions between the second-phase particles and the dislocations can be made stronger. As a result, the damping ability of the above-mentioned aluminum-alloy material can be further improved. It is noted that, from the viewpoint of improving damping ability, there is no upper limit to the above-mentioned total of the perimeters; however, in common manufacturing methods, it is difficult to obtain an aluminum-alloy material in which the above-mentioned total L of the perimeters is greater than 3.0 μm/μm².

• Dislocation Density ρ

[0042] The dislocation density ρ in the aluminum-alloy material can be measured by the following method. First, diffraction profiles for a plurality of aluminum-alloy materials are obtained by X-ray diffractometry. Next, the peak location 2θ of the peaks present in each of the diffraction profiles and the integration width β of each peak (i.e., the full width of each peak) are read.

[0043] Next, based on the Williamson-Hall equation (Equation (2) below), the nonuniform strain h value of the aluminum-alloy material is calculated from the peak location 2θ value and the integration width β value. It is noted that λ in Equation (2) below is a symbol that represents the wavelength of the incident X-rays, and D is a symbol that represents the size of the crystallites.

[0044] No. 1

$$\frac{\beta \cos \theta}{\lambda} = \frac{1}{D} + 2h \frac{\sin \theta}{\lambda} \quad \dots (2)$$

[0045] As shown in the above-mentioned Equation (2), the value of the nonuniform strain h is equal to one half the value of the slope of a straight line in which the βcosθ/λ values serve as the ordinate of a graph and the sinθ/λ values serve as the abscissa. Accordingly, first, for all peaks present in each of the diffraction profiles, a Williamson-Hall plot is prepared by plotting all data points in a graph such that the ordinate values are βcosθ/λ and the abscissa values are sinθ/λ. Subsequently, a straight-line approximation of these data points is determined using the least squares method. The nonuniform strain h value can be calculated by halving the slope of this straight-line approximation.

[0046] It is noted that, in situation in which, for example, the crystal grains of the aluminum-alloy material are coarse,

sometimes the intensity of a peak relating to a specific crystal orientation in a diffraction profile becomes extremely low. In that situation, the integration width of that peak is strongly affected by the background, and there are situations in which a data point that constitutes an abnormal value appears in the Williamson-Hall plot. In this situation, upon eliminating the relevant data point from the Williamson-Hall plot, the measurement location should be modified, a diffraction profile should once again be obtained for the aluminum-alloy material in which the relevant data point was obtained, and data points should be added to the Williamson-Hall plot using a procedure the same as that mentioned above.

[0047] The dislocation density ρ value can be calculated by substituting the nonuniform strain h value in Equation (3) below. It is noted that b in Equation (3) below is a symbol that represents the Burgers vector of the aluminum. The b value is, specifically, 0.2863 nm.

No. 2

$$\rho = 16.1 \times \left(\frac{h}{b}\right)^2 \dots (3)$$

[0048] The dislocation density ρ of the above-mentioned aluminum-alloy material is preferably $10 \mu\text{m}^{-2}$ or more, more preferably $20 \mu\text{m}^{-2}$ or more, and yet more preferably $50 \mu\text{m}^{-2}$ or more. By setting the dislocation density ρ to be large, interactions between the second-phase particles and the dislocations can be made stronger. As a result, the damping ability of the above-mentioned aluminum-alloy material can be further improved. It is noted that, from the viewpoint of improving damping ability, there is no upper limit to the dislocation density ρ of the aluminum-alloy material; however, in typical manufacturing methods, it is difficult to obtain an aluminum-alloy material in which the dislocation density is greater than $2,000 \mu\text{m}^{-2}$.

• Electrical Conductivity E

[0049] The electrical conductivity E of the above-mentioned aluminum-alloy material at 25°C is 50% IACS or more. The electrical conductivity E of the aluminum-alloy material increases as the additional elements precipitate or crystallize as second-phase particles and the smaller the amount of the additional elements, which have formed a solid solution in the Al matrix becomes. By setting the electrical conductivity E of the above-mentioned aluminum-alloy material to 50% IACS or more, the amount of the additional elements that has formed a solid solution, which becomes a hindrance to dislocation movements, can be reduced. As a result, the damping ability improvement effect owing to interactions between the dislocations and the second-phase particles can be further increased. From the viewpoint of further improving damping ability, the electrical conductivity of the above-mentioned aluminum-alloy material at 25°C is more preferably 55% IACS or higher.

[0050] In the situation in which the above-mentioned electrical conductivity E is less than 50% IACS, dislocation movements tend to become impeded due to the additional elements that have formed a solid solution in the Al matrix. As a result, there is a risk that interactions between the dislocations and the second-phase particles will tend not to occur, leading to a decrease in damping ability.

[0051] It is noted that, from the viewpoint of increasing damping ability, although there is no limit to the electrical conductivity E value, the electrical conductivity value is 64% IACS or less due to the physical properties of the aluminum alloy.

• Correction Coefficients A, B

[0052] Correction coefficient A and correction coefficient B of the above-mentioned metallographic-structure factors can be various values in accordance with the type and amount of the additional elements contained in the aluminum-alloy material. As the reason for this, it is conceivable that, for example, when the types and the amounts of the additional elements change, the phase that constitutes the second-phase particles changes, and thereby the contribution of the interactions between the second-phase particles and the dislocations changes, or that, when the types and the amounts of the additional elements change, the extent to which dislocation movements are impeded due to the additional elements that have formed a solid solution in the Al matrix changes.

[0053] Specifically, the range of the correction coefficient A value is $0.2 \times 10^{-15} \leq A \leq 20 \times 10^{-15}$, and the range of the correction coefficient B value is $0.1 \leq B \leq 1.0$. The same correction coefficient A value and the same correction coefficient B value can be used for aluminum-alloy materials, among the multiple aluminum-alloy materials in which the types or amounts of additional elements differ, in which the additional element type of the highest content is the same. For example, in the situation in which the above-mentioned aluminum-alloy material contains 0.3-3.0 mass% of Fe as the highest content additional element, 2.0×10^{-15} can be used as the A value, and 0.4851 can be used as the B value.

[0054] The correction coefficient A value and the correction coefficient B value can be determined by the following

method. First, multiple types of aluminum-alloy materials are prepared, in which the highest content additional element is in common, and the content of that additional element, the content of other additional elements, the manufacturing conditions, and the like differ. Furthermore, the values of the previously described total L of the perimeters, the dislocation density ρ , and the electrical conductivity E for these aluminum-alloy materials are calculated. Furthermore, the correction coefficient A value and the correction coefficient B value can be determined by approximating, using the above-mentioned Equation (1), a plot prepared using these values.

[Damping Ability]

[0055] The damping ability of the above-mentioned aluminum-alloy material can be evaluated based on a correction-loss coefficient η_c (refer to Equation (4) below) obtained by correcting a loss factor η , which is determined by a free-resonance method, for the sample shape of the above-mentioned aluminum-alloy material.

$$\eta_c = \eta - 0.556 \times t^{-2.434} + 1.5 \quad (4)$$

[0056] It is noted that symbol t in the above-mentioned Equation (4) is the thickness [mm] of the test piece used in the measurement of the loss factor η . The length of the test piece used in the measurement of the loss factor η is 60 mm, and the width is 8 mm.

[0057] The correction-loss coefficient η_c is preferably 1.6×10^{-3} or more, more preferably 1.8×10^{-3} or more, and yet more preferably 2.0×10^{-3} or more. In this situation, the damping ability of the above-mentioned aluminum-alloy material can be further improved. From the viewpoint of improving damping ability, there is no upper limit to the correction-loss coefficient η_c ; however, in an aluminum-alloy material having a metallographic-structure factor F in the above-mentioned specific range, the correction-loss coefficient η_c is normally 300×10^{-3} or less.

[0058] It is noted that techniques for measuring the loss factor include, in addition to the free-resonance method, methods such as, for example, cantilever-vibration methods. However, as a result of diligent investigation conducted by the present inventors, it became clear that, in the situation in which the loss factor value in the cantilever-vibration method varies with the shape of the test piece and the length of the test piece is long, particularly as described in Patent Document 1, there is a tendency for the loss factor value to become larger than in the situation in which the length of the test piece is short-regardless of whether the chemical compositions were the same or the metallographic structures were the same. Accordingly, the value of the loss factor in the cantilever-vibration method and the value of the loss factor obtained using the free-resonance method could not be simply compared.

[0059] In addition, as a result of diligent investigation conducted by the present inventors, it became clear that, in the free-resonance method as well, the value of the loss factor varied in accordance with the thickness, the surface area, and the like of the test pieces. It is conceivable that this was caused by friction or the like between the test piece and the air during the measurement. Accordingly, the value of the loss factor in the free-resonance method could not be simply compared with the values of the correction-loss coefficients.

• Crystal Grains

[0060] The above-mentioned aluminum-alloy material preferably includes a fibrous structure and more preferably is composed of a fibrous structure. In this situation, the damping ability of the above-mentioned aluminum-alloy material can be further improved.

[0061] It is noted that a fibrous structure refers to a structure that comprises numerous crystal grains that have been stretched in a processing direction by wrought working such as rolling, extrusion, forging, and the like. For example, in the situation in which a cross section of the fibrous structure parallel to the processing direction was observed using a metallurgical microscope at a magnification of 25-100 times, the fibrous structure was observed as a stripe-shaped pattern extending in the processing direction. In addition, an equiaxial structure refers to a structure that comprises numerous equiaxial crystal grains. For example, in the situation in which a cross section of the equiaxial structure parallel to the processing direction was observed using a metallurgical microscope at a magnification of 25-100 times, the equiaxial structure was observed as a granular pattern, in which the difference between the major axis and the minor axis was relatively small.

[0062] The above-mentioned aluminum-alloy material can be manufactured by, for example, casting an ingot having the above-mentioned specific chemical composition, and then performing, in accordance with the casting method, an appropriate combination of wrought working, such as rolling, extrusion, and forging, and heat treatment on the above-mentioned ingot.

[0063] For example, as one aspect of the manufacturing method, a method can be used in which, after casting a slab, which serves as an ingot, using a DC-casting method, hot rolling and cold rolling are sequentially performed, as the

wrought working, on the slab.

[0064] The casting speed in the DC casting is preferably within the range of 20-100 mm/min. By setting the casting speed to within the above-mentioned specific range, the formation of coarse second-phase particles can be curtailed.

[0065] In the present aspect, after the DC casting has been performed, a homogenization treatment may be performed by heating the slab prior to performing the hot rolling, or the hot rolling may be performed without performing the homogenization treatment. In the situation in which the homogenization treatment is to be performed, the heating temperature can be set as appropriate from the range of, for example, 200°C-550°C. The heating temperature of the homogenization treatment is preferably 500°C or lower and more preferably 340°C or lower. In this situation, the second-phase particles in the Al matrix can be made finer, and thereby the perimeters of the second-phase particles can be made even larger. As a result, the damping ability due to interactions between the dislocations and the second-phase particles can be further improved.

[0066] In addition, in the homogenization treatment, the heating may be ended immediately after the temperature of the slab has reached the above-mentioned heating temperature, or the above-mentioned heating temperature may be held for a fixed time. The hold time in the latter situation can be set to 50 h or less.

[0067] In the situation in which the heating temperature of the homogenization treatment is lower than 200°C, there is a risk that the homogenization of the slab will become insufficient. In addition, in the situation in which the heating temperature of the homogenization treatment is above 550°C or in the situation in which the hold time is more than 50 h, there is a risk that coarse second-phase particles will tend to form in the slab, leading to a decrease in damping ability.

[0068] Next, a hot-rolled plate is manufactured by hot rolling the slab. The temperature of the slab at rolling start of the hot rolling is preferably 200°C-550°C. In the situation in which the temperature of the slab at rolling start is lower than 200°C, it is difficult to perform hot rolling because the slab tends not to deform. In the situation in which the temperature of the slab at rolling start is above 550°C, there is a risk that coarse second-phase particles will tend to form in the slab, leading to a decrease in damping ability.

[0069] The above-mentioned hot rolling may be performed while the temperature of the slab after casting is within the above-mentioned specific range. In the situation in which the temperature of the slab after casting is lower than the above-mentioned specific temperature, the temperature of the slab can still be set to the above-mentioned specific range by heating the slab prior to performing the hot rolling.

[0070] In the situation in which the slab is to be heated prior to the hot rolling, the heating may be ended immediately after the temperature of the slab has reached a desired temperature, or the desired temperature may be held for a fixed time. The hold time in the situation of the latter can be set to 30 h or less. In the situation in which the hold time is more than 30 h, there is a risk that coarse second-phase particles will tend to form in the slab, leading to a decrease in damping ability.

[0071] In the present aspect, after the hot rolling has been performed and before the cold rolling is performed, annealing may be performed by heating the hot-rolled plate. The heating temperature of this annealing can be set as appropriate in the range of 200°C-400°C. In the situation in which the heating temperature of the annealing is lower than 200°C, there is a risk that the annealing effect will become insufficient. In the situation in which the heating temperature of the annealing is higher than 400°C, there is a risk that coarse second-phase particles will tend to form in the hot-rolled plate, leading to a decrease in damping ability.

[0072] With regard to the above-mentioned annealing, heating may be ended immediately after the above-mentioned heating temperature has been reached, or the above-mentioned heating temperature may be held for a fixed time. The hold time in the situation of the latter can be set to 10 h or less. In the situation in which the hold time is more than 10 h, there is a risk that coarse second-phase particles will tend to form in the hot-rolled plate, leading to a decrease in damping ability.

[0073] Subsequently, by performing one or more passes of cold rolling on the hot-rolled plate, the above-mentioned aluminum-alloy material can be obtained. With regard to the cold rolling, the rolling is preferably performed such that the total rolling reduction becomes 50% or more. That is, the difference between the thickness of the hot-rolled plate after hot rolling has been performed and before the cold rolling and the thickness of the desired aluminum-alloy material is preferably 50% or more of the thickness of the above-mentioned hot-rolled plate. Thereby, the dislocation density of the above-mentioned aluminum-alloy material can be further increased, and thereby the damping ability of the above-mentioned aluminum-alloy material can be further improved.

[0074] In the situation in which the number of passes of the cold rolling is two or more passes, an intermediate annealing can also be performed by heating the hot-rolled plate between passes of the cold rolling. The heating temperature of the intermediate annealing can be set as appropriate in the range of 200°C-400°C. In the situation in which the heating temperature of the intermediate annealing is lower than 200°C, there is a risk that the intermediate-annealing effect will become insufficient. In the situation in which the heating temperature of the intermediate annealing is higher than 400°C, there is a risk that coarse second-phase particles will tend to form in the aluminum-alloy material, leading to a decrease in damping ability.

[0075] In addition, with regard to the intermediate annealing, the heating may be ended immediately after the above-

mentioned heating temperature has been reached, or the above-mentioned heating temperature may be held for a fixed time. The hold time in the situation of the latter can be set to 10 h or less. In the situation in which the hold time is more than 10 h, there is a risk that coarse second-phase particles will tend to form in the aluminum-alloy material, leading to a decrease in damping ability.

[0076] In the situation in which the above-mentioned intermediate annealing is to be performed, it is preferable to perform the rolling such that the rolling reduction after the intermediate annealing becomes 50% or more. That is, the difference between the thickness of the hot-rolled plate after the intermediate annealing has been performed and before resuming the cold rolling and the thickness of the desired aluminum-alloy material is preferably 50% or more of the thickness of the hot-rolled plate before the cold rolling resumes. Thereby, the dislocation density of the above-mentioned aluminum-alloy material can be increased, and thereby the damping ability of the above-mentioned aluminum-alloy material can be improved.

[0077] In the present aspect, a final annealing may be performed by heating the aluminum-alloy material after the cold rolling. The heating temperature of the final annealing can be set as appropriate in the range of 100°C-200°C. In the situation in which the heating temperature of the final annealing is less than 100°C, there is a risk that the final annealing effect will become insufficient. In the situation in which the heating temperature of the final annealing is higher than 200°C, there is a risk that the dislocation density will greatly decrease due to the rearrangement, the disappearance, or the like of the dislocations, leading to a decrease in damping ability.

[0078] In addition, in the final annealing, the heating may be ended immediately after the above-mentioned heating temperature has been reached, or the above-mentioned heating temperature may be held for a fixed time. The hold time in the situation of the latter can be set to 10 h or less. In the situation in which the hold time is more than 10 h, there is a risk that the dislocation density will decrease due to the rearrangement, the disappearance, or the like of the dislocations, leading to a decrease in damping ability.

[0079] As another aspect of the method of manufacturing the above-mentioned aluminum-alloy material, it is also possible to use a method in which a strip is cast as the ingot by a continuous-casting method, such as a twin-roll continuous casting and hot rolling method, a twin-belt casting method, or the like, after which the strip is cold rolled as the wrought working.

[0080] The casting speed of the continuous casting is preferably within the range of 500-3,000 mm/min. By setting the casting speed to within the above-mentioned specific range, the formation of coarse second-phase particles can be curtailed.

[0081] After the continuous casting has been performed, the above-mentioned aluminum-alloy material can be obtained by performing one or more passes of the cold rolling on the strip. With regard to the cold rolling, it is preferable to perform the rolling such that the total rolling reduction becomes 50% or more, the same as the process condition for the situation in which the DC casting described above is performed. That is, the difference between the thickness of the strip after the continuous casting has been performed and before the cold rolling is performed and the thickness of the desired aluminum-alloy material is preferably 50% or more of the thickness of the above-mentioned strip. Thereby, the dislocation density of the above-mentioned aluminum-alloy material can be further increased, thereby further improving the damping ability of the above-mentioned aluminum-alloy material.

[0082] In addition, in the present aspect as well, the same as the situation in which the DC casting described above is performed, the intermediate annealing may be performed between passes of the cold rolling, or the final annealing may be performed after the cold rolling has been completed. The process conditions of the intermediate annealing, the process conditions of the final annealing, and the functions and effects thereof according to the present aspect are the same as the process conditions of the situation in which the DC casting described above is performed.

Working Examples

[0083] Working examples of the above-mentioned aluminum-alloy material will now be explained, with reference to FIG. 1 to FIG. 4. It is noted that the specific aspects of the aluminum-alloy material according to the present invention are not limited to the aspects of the working examples described below, and the configuration of the working examples can be modified as appropriate within a range that does not depart from the gist of the present invention.

[0084] Aluminum-alloy materials according to the present example were manufactured by the following method. First, ingots having the chemical compositions listed in Table 1 were cast using a DC casting method. After heating these ingots at the heating temperatures listed in the "Pre-Rolling Temperature" column in Table 1, they were hot rolled to manufacture hot-rolled plates having the thicknesses listed in Table 1. The obtained hot-rolled plates were cold rolled such that their total rolling reductions became the values listed in Table 1. In addition, with regard to Test Materials 10-12 and Test Material 14, after the cold rolling was completed, a final annealing was performed at the heating temperatures listed in the "Final Annealing" column in Table 1. Based on the above, Test Materials 1-12 having a thickness of 0.75 mm and Test Materials 13-14 having a thickness of 2.0 mm, as listed in Table 1, were obtained. It is noted that, with regard to Test Materials 15, 16 listed in Table 1, because the Fe content and Mn content in the ingots were excessively

high, coarse second-phase particles readily formed. Consequently, it was difficult to roll these test materials.

[0085] In these test materials, the method of calculating the metallographic-structure factor F value, the method of calculating the correction-loss coefficient η_c , and the method of evaluating the mode of the crystal grains were as below.

[Method of Calculating the Metallographic-Structure Factor F]

[0086] The metallographic-structure factor F value was calculated by substituting, in Equation (1) below, the value of the total L [$\mu\text{m}/\mu\text{m}^2$] of the perimeters of the second-phase particles having a circle-equivalent diameter of $0.2 \mu\text{m}$ or more obtained by the method below, the value of the dislocation density ρ [μm^{-2}], and the value of the electrical conductivity E [% IACS]. It is noted that, in the present example, the correction coefficient A value was 2.0×10^{-15} , and the correction coefficient B value was 0.4851 . The metallographic-structure factor F values of the test materials were as listed in Table 2.

$$F = A \cdot \rho \cdot L \cdot \exp(B \cdot E) \quad (1)$$

[0087] The methods of measuring the L , ρ , and E values will be explained below.

• Total L of Perimeters of Second-Phase Particles Having a Circle-Equivalent Diameter of $0.2 \mu\text{m}$ or More

[0088] First, the plate surface of the test material was polished to expose an L-LT plane (a plane parallel to the plate surface). Five observation locations randomly selected from the L-LT plane were observed using a scanning electron microscope, and reflection electron images at a magnification of 2,000 times were acquired. In the reflection electron images, the Al matrix and the second-phase particles dispersed in the Al matrix were indicated by brightnesses that differ from one another. For example, in FIG. 1, second-phase particles 12 in an aluminum-alloy material 1 are indicated with a brightness that is brighter than that of an Al matrix 11.

[0089] Next, a binarized image shown in FIG. 2 was prepared by subjecting the reflection electron image to a binarization process using an image-processing apparatus or the like. It is noted that, in FIG. 2, for the sake of convenience, after the binarization process was performed, an inversion process was performed in which white and black were switched. The threshold of the binarization process should be set as appropriate such that the contours of the second-phase particles 12 in the reflection electron image are maintained even after the binarization process.

[0090] After having sampled, from the binarized image, the second-phase particles 12 having a circle-equivalent diameter of $0.2 \mu\text{m}$ or more, the perimeter of each of the second-phase particles 12 (i.e., the length of the contour of the second-phase particle 12) was measured. By dividing the total of these perimeters by the total of the surface area of the visual field, the total L [$\mu\text{m}/\mu\text{m}^2$] of the perimeters of the second-phase particles 12 having a circle-equivalent diameter of $0.2 \mu\text{m}$ or more listed in Table 2 was calculated.

• Dislocation Density ρ

[0091] First, an X-ray diffraction profile of each test material was acquired using an X-ray diffraction apparatus. The conditions of the X-ray diffractions were as below.

Measuring apparatus: "SmartLab (registered trademark)" manufactured by Rigaku Corporation

Incident X-ray: Cu-K α line ($\lambda = 0.15405 \text{ nm}$)

Tube voltage: 40 kV

Tube current: 20 mA

Sampling width: 0.004°

Scanning speed: $0.2^\circ/\text{min}$

2θ scan range: 40° - 80°

[0092] A Williamson-Hall plot was prepared using the acquired X-ray diffraction profiles and the method described above. Furthermore, after calculating the nonuniform strain h from the slope of the straight-line approximation in the Williamson-Hall plot, the dislocation density ρ value was calculated by substituting the obtained h value in the above-mentioned Equation (3). The dislocation density ρ values of the test materials are listed in Table 2. In addition, the values calculated by multiplying the total L values of the perimeters of the second-phase particles calculated using the above-described method by the dislocation density ρ values are listed in the " $L \times \rho$ " column in Table 2.

• Electrical Conductivity E

[0093] For example, an electrical-conductivity meter ("Sigma Tester Model 2.069" manufactured by Foerster Japan Limited) was used in the measurement of the electrical conductivity E. The electrical conductivity E of each of the test materials at 25°C is listed in Table 2. It is noted that, to set the temperature of each of the test materials to 25°C, for example, the test materials should be left stationary for approximately 1 h in a temperature-controlled chamber at 25°C. In addition, in the situation in which the above-mentioned electrical-conductivity meter is used, the measurement frequency can be set to, for example, 480 kHz.

[Mode of Crystal Grains]

[0094] Each test material was cut parallel to the rolling direction to expose an L-ST plane. After having polished the L-ST plane, an oxide film having a polarization dependent on the crystal orientation was formed on the surface of the sample by performing anodization. Subsequently, three observation locations randomly selected from the L-ST plane were observed at a magnification of 100 times using a polarizing microscope, and micrographs were acquired. In addition, the aspect ratio, that is, the ratio of the crystal grain length to the crystal grain thickness, was calculated for each individual crystal grain in the micrograph using an image-processing apparatus or the like.

[0095] Furthermore, in the situation in which equiaxial crystal grains (i.e., recrystallized grains) were not present in the micrograph and the average value of the aspect ratios was 10 or more, it was determined that the test material was composed of a fibrous structure; in the situation in which equiaxial crystal grains were present in the micrograph and the average value of the aspect ratios was less than 10, it was determined that the test material included an equiaxial structure. It is noted that, in the situation in which the aspect ratios of the crystal grains were extremely high, the number of crystal grains for which both ends in the rolling direction were present within the visual field became few, and therefore the average of the aspect ratios could not be calculated accurately. In this situation, it was determined whether the average of the aspect ratios was or was not 10 or more by comparing it with a sample for which the average of the aspect ratios was 10.

[Correction-Loss Coefficient η c]

[0096] First, the loss factor η was measured by a free-resonance method using strip-shaped test pieces, which were collected from the test materials, having a length of 60 mm and a width of 8 mm.

[0097] A free-resonance-type internal-friction measuring apparatus ("JE-RT" manufactured by Nihon Techno-Plus Co. Ltd.) was used in the measurement of the loss factor η . As shown in FIG. 3, the measuring apparatus 2 comprises a drive electrode 21 and an amplitude sensor 22, which faces the drive electrode 21. A strip-shaped test piece S is disposed horizontally between the drive electrode 21 and the amplitude sensor 22, and the strip-shaped test piece S is fixed by fine wires 23 at locations where vibration nodes form. In this state, the strip-shaped test piece S can be caused to vibrate by supplying an alternating current to the drive electrode 21 to cause a Coulomb force to act upon the strip-shaped test piece S. Furthermore, by using the amplitude sensor 22 to measure the amplitude of the strip-shaped test piece S, the waveform of the vibration can be obtained.

[0098] In the present example, an electrostatic force was generated from the drive electrode 21 to forcibly cause the strip-shaped test piece S to vibrate, and the amplitude of the strip-shaped test piece S was measured. At this time, the amplitude-frequency curve was obtained, as shown in FIG. 4, by causing the strip-shaped test piece S to vibrate while sweeping the frequencies of the vibration. It is noted that the ordinate in FIG. 4 represents the common logarithm of the magnitude of the amplitude, and the abscissa represents the frequency [Hz].

[0099] The loss factor η of each test material was calculated, using a full width at half maximum method, based on the amplitude-frequency curve shown in FIG. 4. First, the frequency at which the amplitude on the amplitude-frequency curve becomes maximal was derived, and this frequency was taken as resonance frequency f_0 . Next, a full width at half maximum Δf of the resonance peak was derived. The full width at half maximum Δf was calculated specifically as follows. First, within the range at which the frequency was lower than the resonance frequency f_0 , a frequency f_1 , at which the amplitude value was half of the amplitude value A_0 at the resonance frequency f_0 , was derived. Next, in the range in which the frequency was higher than the resonance frequency f_0 , a frequency f_2 , at which the amplitude value became half the amplitude value A_0 at the resonance frequency f_0 , was derived. The value of the difference $f_2 - f_1$ between the frequency f_2 and the frequency f_1 thus derived is the full width at half maximum Δf .

[0100] By substituting the resonance frequency f_0 and the full width at half maximum Δf , which were obtained above, in Equation (5) below, the loss factor η was calculated.

[0101] No. 3

$$\eta = \frac{\Delta f}{\sqrt{3}f_0} \dots (5)$$

[0102] Furthermore, by substituting the loss factor η thus obtained in Equation (4) below, the correction-loss coefficient η_c was calculated. The correction-loss coefficient η_c value of each test material is listed in Table 2.

$$\eta_c = \eta - 0.556 \times t^{-2.434} + 1.5 \quad (4)$$

Table 1

Test Material Symbol	Chemical Composition (mass%)			Hot Rolling		Cold Rolling	Final Annealing	Thickness (mm)
	Fe	Other Elements	A1	Pre-Rolling Temp. (°C)	Hot-Rolled Plate Thickness (mm)	Rolling Reduction (%)	Heating Temp. (°C)	
1	1.0	-	Bal.	500	3.0	75	-	0.75
2	1.5	-	Bal.	500	3.0	75	-	0.75
3	2.0	-	Bal.	500	3.0	75	-	0.75
4	1.0	Mn: 0.30	Bal.	500	3.0	75	-	0.75
5	1.0	Mn: 0.60	Bal.	500	3.0	75	-	0.75
6	1.0	Mn: 0.90	Bal.	500	3.0	75	-	0.75
7	1.5	Zr: 0.15	Bal.	500	3.0	75	-	0.75
8	1.5	Mn: 0.30	Bal.	500	3.0	75	-	0.75
9	1.0	-	Bal.	300	3.0	75	-	0.75
10	1.5	-	Bal.	500	3.0	75	100	0.75
11	1.5	-	Bal.	500	3.0	75	200	0.75
12	1.0	Mn: 0.90	Bal.	500	3.0	75	600	0.75
13	1.5	-	Bal.	300	5.0	60	-	2.0
14	0.2	Si: 0.70, Mg: 0.70	Bal.	580	5.0	60	520	2.0
15	5.0	-	Bal.	Rolling Difficulty				
16	2.0	Mn: 2.0	Bal.	Rolling Difficulty				

Table 2

Test Material Symbol	Total L of Perimeters ($\mu\text{m}/\mu\text{m}^2$)	Dislocation Density ρ (μm^{-2})	Electrical Conductivity E (% IACS)	Metallographic-Structure Factor F	Crystal Grains	Loss Factor η	Correction-Loss Coefficient η_c
1	0.36	436	60.0	1.37	Fibrous	3.01×10^{-3}	3.39×10^{-3}
2	0.58	420	60.9	3.30	Fibrous	3.70×10^{-3}	4.08×10^{-1}
3	0.68	449	59.0	1.64	Fibrous	3.04×10^{-3}	3.42×10^{-3}
4	0.46	551	57.9	0.80	Fibrous	2.22×10^{-3}	2.60×10^{-3}

(continued)

Test Material Symbol	Total L of Perimeters ($\mu\text{m}/\mu\text{m}^2$)	Dislocation Density ρ (μm^{-2})	Electrical Conductivity E (% IACS)	Metallographic-Structure Factor F	Crystal Grains	Loss Factor η	Correction-Loss Coefficient η_c
5	0.37	590	56.9	0.42	Fibrous	1.96×10^{-3}	2.34×10^{-3}
6	0.52	610	54.4	0.18	Fibrous	1.70×10^{-3}	2.08×10^{-3}
7	0.38	438	53.1	0.05	Fibrous	2.77×10^{-3}	3.15×10^{-3}
8	0.58	535	57.2	0.70	Fibrous	2.54×10^{-3}	2.92×10^{-3}
9	0.45	547	59.6	1.77	Fibrous	3.17×10^{-3}	3.55×10^{-3}
10	0.38	358	60.8	1.75	Fibrous	3.18×10^{-3}	3.56×10^{-3}
11	0.38	71	61.4	0.47	Fibrous	2.08×10^{-3}	2.46×10^{-3}
12	0.58	12	51.5	0.00	Equiaxial	1.19×10^{-3}	1.57×10^{-3}
13	0.32	499	55.5	0.16	Fibrous	1.19×10^{-3}	2.59×10^{-3}
14	0.02	67	54.5	0.00	Fibrous	0.16×10^{-3}	1.56×10^{-3}
15	Rolling Difficulty						
16	Rolling Difficulty						

[0103] As shown in Table 1 and Table 2, the metallographic-structure factor F values of Test Materials 1-11 and Test Material 13 were within the above-mentioned specific ranges. Consequently, the correction-loss coefficient η_c values of these test materials were 1.6×10^{-3} or more. For this reason, these test materials had excellent damping ability.

[0104] The metallographic-structure factor F values of Test Material 12 and Test Material 14 were smaller than the above-mentioned specific ranges. Consequently, the damping ability of these test materials was inferior to Test Materials 1-11 and Test Material 13.

Claims

1. An aluminum-alloy material having an Al matrix and second-phase particles dispersed in the Al matrix, wherein: the value of a metallographic-structure factor F indicated in Equation (1) below is 0.005 or more:

$$F = A \cdot \rho \cdot L \cdot \exp(B \cdot E) \quad (1)$$

(wherein, in the above-mentioned Equation (1), L is the total [$\mu\text{m}/\mu\text{m}^2$] of the perimeters of the second-phase particles, from among the second-phase particles present in an arbitrary cross section, whose circle-equivalent diameters are $0.2 \mu\text{m}$ or more, ρ is the dislocation density [μm^{-2}], E is the electrical conductivity [% IACS] at 25°C , A and B are correction coefficients determined in accordance with the chemical composition of the aluminum-alloy material, $0.2 \times 10^{-15} \leq A \leq 20 \times 10^{-15}$, and $0.1 \leq B \leq 1.0$.)

2. The aluminum-alloy material according to claim 1, wherein the aluminum-alloy material has a chemical composition that contains Fe: 0.30-3.0 mass%, the remainder being Al and unavoidable impurities.
3. The aluminum-alloy material according to claim 1 or 2, wherein the aluminum-alloy material further contains Mn: 0.10-1.50 mass%.
4. The aluminum-alloy material according to any one of claims 1-3, wherein the aluminum-alloy material contains one or two or more of additional elements from among additional elements selected from the group consisting of Si: 0.0050-3.0 mass%, Cu: 0.0030-0.10 mass%, Mg: 0.0050-3.0 mass%, Zn: 0.10-0.50 mass%, Ni: 0.050-0.30 mass%, Cr: 0.050-0.30 mass%, Ti: 0.050-0.30 mass%, V: 0.050-0.30 mass%, and Zr: 0.0010-0.30 mass%.

5. The aluminum-alloy material according to any one of claims 1-4, wherein the aluminum-alloy material includes a fibrous structure.

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FIG. 1

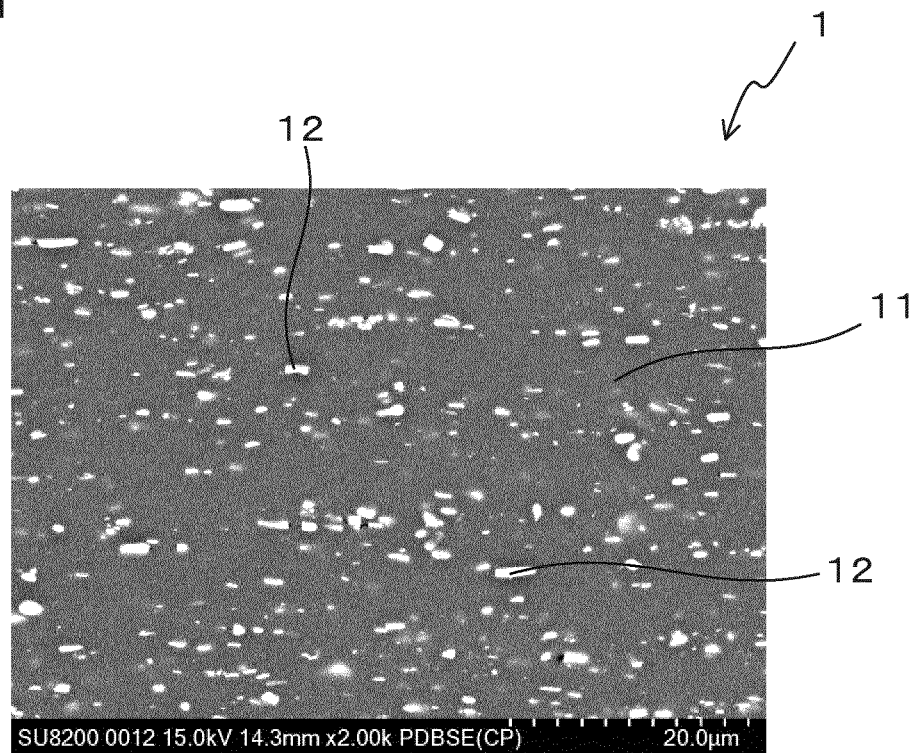


FIG. 2

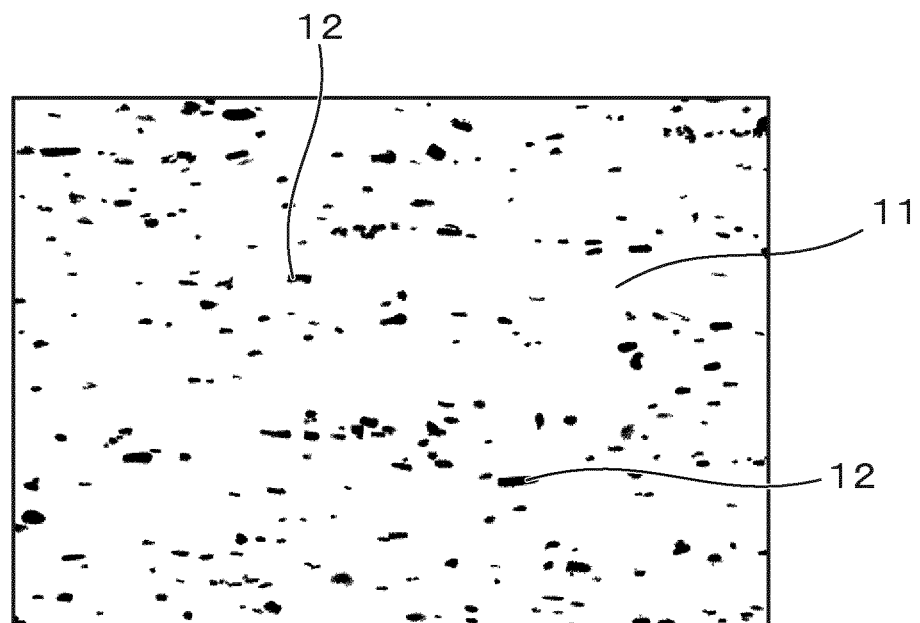


FIG. 3

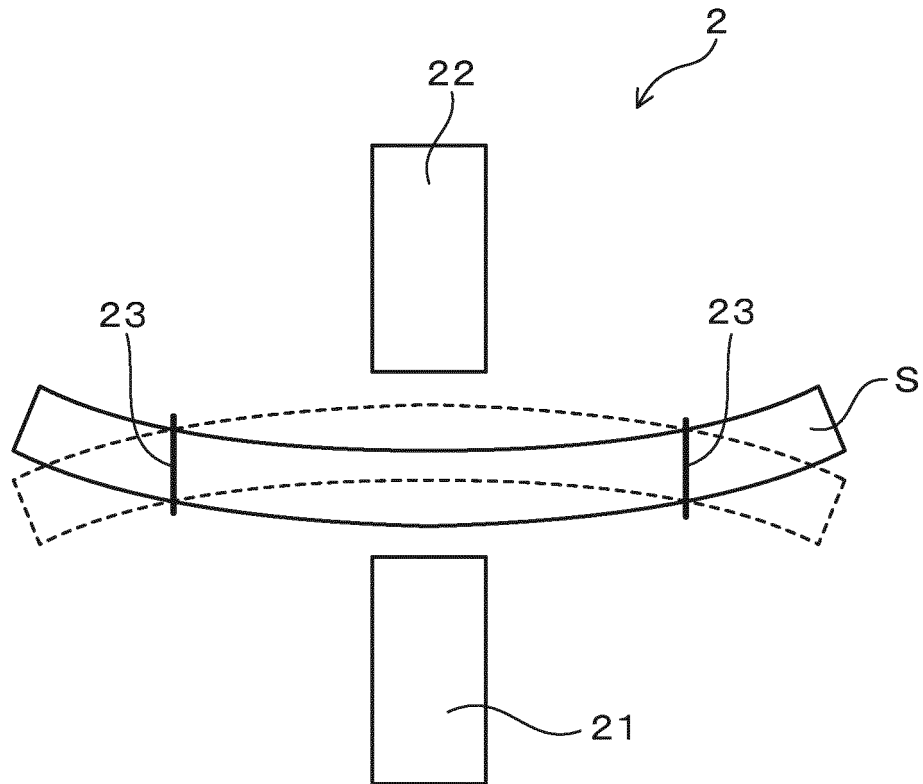
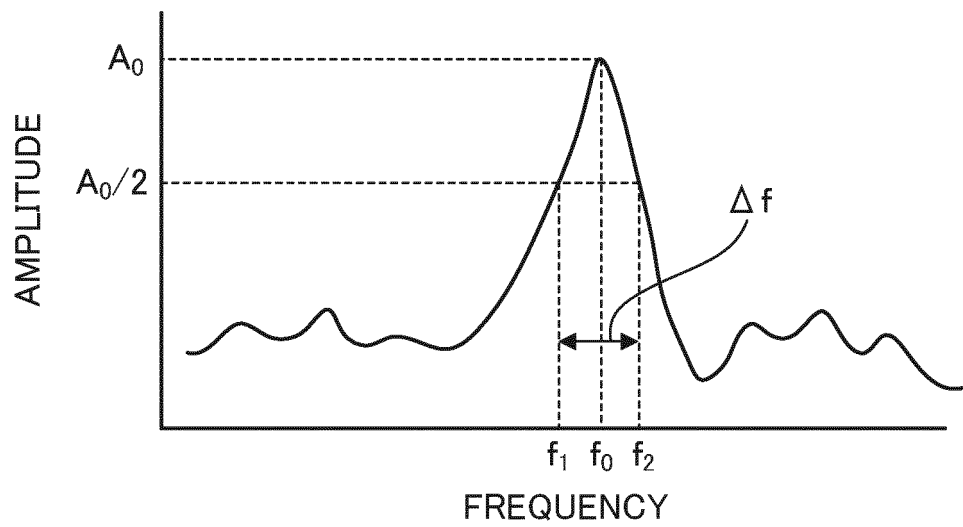


FIG. 4



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/020118

A. CLASSIFICATION OF SUBJECT MATTER

C22C 21/00 (2006.01) i; C22F 1/00 (2006.01) n; C22F 1/04 (2006.01) n
 FI: C22C21/00 M; C22F1/00 601; C22F1/00 623; C22F1/00 630H; C22F1/00
 661A; C22F1/00 681; C22F1/00 682; C22F1/00 683; C22F1/00 685Z;
 C22F1/00 686A; C22F1/00 691B; C22F1/00 691C; C22F1/00 694A;
 C22F1/00 694B; C22F1/04 A

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)

C22C21/00-21/18; C22F1/00; C22F1/04-1/057

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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.
A	JP 2019-65312 A (UACJ CORP.) 25.04.2019 (2019-04-25)	1-5
A	JP 6506896 B1 (UACJ CORP.) 24.04.2019 (2019-04-24)	1-5
A	JP 3-223446 A (FURUKAWA ALUM CO., LTD.) 02.10.1991 (1991-10-02)	1-5
A	JP 62-188763 A (RES INST ELECTRIC MAGNETIC ALLOYS) 18.08.1987 (1987-08-18)	1-5



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search
07 August 2020 (07.08.2020)Date of mailing of the international search report
18 August 2020 (18.08.2020)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2020/020118

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REFERENCES CITED IN THE DESCRIPTION

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