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(54) ALUMINUM ALLOY SHEET FOR CONNECTING COMPONENTS AND MANUFACTURING PROCESS THEREFOR

ALUMINIUMLEGIERUNGSBLECH ZUM VERBINDEN VON BAUTEILEN SOWIE HERSTELLUNGSVERFAHREN DAFÜR

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(73) Proprietor: **Kabushiki Kaisha Kobe Seiko Sho (Kobe Steel, Ltd.)**
Kobe-shi, Hyogo 651-8585 (JP)

(72) Inventors:
- **MASUDA, Tetsuya**
  Tochigi 321-4367 (JP)
- **TAKAKI, Yasuo**
  Tochigi 321-4367 (JP)
- **NAKAMURA, Takahiko**
  Tochigi 321-4367 (JP)
- **HINO, Mitsuo**
  Nagoya-shi, Aichi 451-0045 (JP)

(74) Representative: **Müller-Boré & Partner Patentanwälte PartG mbB**
Friedenheimer Brücke 21
80639 München (DE)

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EP 2 813 592 B1

Description

Field of the invention

[0001] The present invention is related to an aluminum alloy sheet for connecting components which are used for electrically connecting electrical devices such as battery groups, invertors, motors, and components in the electrical devices, which are equipped on various transportation machines such as an electric automobile that use electricity as their power source, and a method for manufacturing the same.

Background of the invention

[0002] Various electric transportation machines that use electricity as their power source such as an electric automobile, a hybrid-engine vehicle, a fuel-cell vehicle, and an electric-power train, or the like are equipped with various kinds of electric device including battery groups, invertors, motors, and so on. A connecting component called bus-bar is used to electrically interconnect the electric devices as well as components therein.

[0003] It is necessary for such a connecting component to be excellent in terms of electrical conductivity to carry an electric current. When the component is connected by using a coupling device such as a bolt, heat generation by carrying the electric current may induce deformation (creep deformation) in the connecting part 1a of the coupling component 1 (see FIG. 1). Lowering of a tightening torque due to the deformation may result in loosening and releasing of the connecting device. The connecting component is thus also required to have excellent creep resistance. Moreover, a connecting component is often designed to have a curved part with a small bending radius (R) for the purpose of fulfilling demand of space saving (downsizing) in an electric device. It is also required for the connecting component to be superior in bending workability, accordingly.

[0004] Copper-based materials have been mainly researched so far aiming to develop a connecting component satisfying the above-described requirements. On the other hand, weight reduction of an automobile and an electrical device to be equipped to the automobile are required these days in order to reduce fuel consumption of an automobile. Considering such circumstances, proposed were connecting components consisting of aluminum alloy which is lighter than copper in weight.

[0005] Patent Document 1, for example, discloses an aluminum alloy for connecting components, with specifications in terms of chemical composition as well as electrical conductivity and conditions of the tempering treatment. It is described in the Patent Document 1 that the aluminum alloy is excellent in terms of electrical conductivity and creep resistance.

[0006] Patent Document 2 discloses a manufacturing method of an aluminum alloy sheet, in which an ingot of a specified chemical composition is subjected to a homogenizing heat treatment, a hot rolling, a cold rolling, and a finishing heat treatment under a prescribed condition. It is stated in the Patent Document 2 that the aluminum alloy sheet exhibits bending workability required for a printed-circuit board.

[0007] Furthermore, Patent Document 3 discloses a technology to regulate the Cube orientation distribution density to a predetermined range by controlling texture of an aluminum alloy sheet for the purpose of improvement of bending workability of Al-Mg-Si based Alloy (JIS 6000 series Al alloy) although the aluminum alloy sheet is not to be used for a connecting component but for a panel for automobile. Patent Document 4 discloses a technology to specify length of grain boundaries between crystals having crystal orientation difference of 20° or less, in a total length of grain boundaries between all of the crystals in an aluminum alloy sheet although the aluminum alloy sheet is not to be used for a connecting component but for a panel for automobile.

Prior Art References

Patent Documents

[0008]

Patent Document 1: Japanese Patent No. 3557116
Patent Document 2: Japanese Patent Application Publication No. 2009 - 242813
Patent Document 3: Japanese Patent Application Publication No. 2005 - 298922
Patent Document 4: Japanese Patent No. 3749687

Summary of the Invention

Problems to be solved by the Invention

[0009] The invention disclosed in the Patent Document 1, however, does not consider about bending workability at all and thus does not satisfy the workability required for connecting components, even though it is an invention from a viewpoint of improving creep resistance (see paragraph [0010] of the Patent Document 1). When the art disclosed in the Patent Document 1 is applied to a connecting component, bending cracking is liable to be induced in the course of forming process.

[0010] Although disclosed in the Patent Document 2 is a technology from a point of view to improvement of bending workability, no consideration was made in terms of creep resistance as described in paragraph [0001] of the Patent Document 2. The aluminum alloy sheet does not satisfy creep resistance required for a connecting component. If the manufacturing method disclosed in the Patent Document 2 is applied to a connecting component, heat generation by carrying electric current may induce deformation in the connecting part 1a of the connecting component 1 (see FIG. 1), resulting in loosening and releasing of the coupling device such as a bolt.

[0011] Although disclosed in the Patent Documents 3 and 4 are technologies from a point of view to improvement of bending workability, no consideration was made in terms of creep resistance as for the Patent Document 2. Further, the technologies are not for a connecting component but for a panel of an automobile. The aluminum alloy sheets disclosed in the Patent Documents 3 and 4 do not satisfy creep resistance required for a connecting component, accordingly. Furthermore, although the aluminum alloy sheets exhibit the bending workability required for a panel of an automobile which is about 1 mm in thickness, it is supposed to be difficult for the aluminum alloy sheets to show superior bending workability required for a connecting component which is generally about 2 mm in thickness.

[0012] As demonstrated by descriptions of the Patent Documents 1 - 4, it does not seem that there has not been a technology realizing both creep resistance and bending workability required for a connecting component while securing electrical conductivity which is an essential characteristic for a connecting component. This is in accord with a technological common sense. It is necessary to increase mechanical strength in order to enhance creep resistance of a metal sheet. However, bending workability of a metal sheet is decreased when the mechanical strength is increased. In other words, creep resistance and bending workability are in the relationship of trade-off, which has been taken for granted.

[0013] The present invention addresses the problem of providing an aluminum alloy sheet for a connecting component which exhibits excellent creep resistance and bending workability while keeping electrical conductivity and a manufacturing method therefor.

Means to solve the problem

[0014] In order to solve the problem, inventors of the present invention developed the present invention by finding that chemical compositions and Cube orientation distribution density on the surface of an aluminum alloy sheet for connecting components significantly affect to creep resistance and bending workability.

[0015] The aluminum alloy sheet for connecting components according to the present invention is constituted by an aluminum alloy which contains Si in an amount of 0.3 - 1.5 mass % and Mg in an amount of 0.3 - 1.0 mass % with the balance being Al and inevitable impurities, and optionally Fe in an amount of less than 0.5 mass % and Zn in an amount of less than 0.5 mass % among the inevitable impurities, the aluminum alloy optionally further comprising one kind or more selected from: Cu of less than 1.0 mass %, Mn of less than 1.0 mass %, Cr of less than 0.5 mass %, Zr of less than 0.3 mass %, and Ti of less than 0.1 mass %, exhibiting an electrical conductivity of 45.0 % IACS or more, and exhibiting a Cube orientation distribution density of 15 or more on the surface of the sheet as determined by crystal orientation distribution function analysis.

[0016] As the aluminum alloy sheet for connecting components specifies Cube orientation distribution density on the surface of a predetermined value or more, the creep resistance as well as the bending workability are improved. In other words, both creep resistance and bending workability required for connecting components can be secured at the same time by the aluminum alloy sheet. Further, as the aluminum alloy sheet for connecting components specifies a predetermined range of contained amount of Si and Mg, the effect of improving creep resistance can be secured. Furthermore, as the aluminum alloy sheet for connecting components specifies the electrical conductivity of 45.0 % IACS or more, electrical conductivity required for connecting components can be secured.

[0017] Regarding the inevitable impurities, it is preferred that Fe is less than 0.5 mass % and Zn is less than 0.5 mass % in the aluminum alloy sheet.

[0018] According to the aluminum alloy sheet for connecting components, the effect of improvement of bending workability can be secured because, among the inevitable impurities, the contents of Fe and Zn are controlled to less than a specified amount.

[0019] In the aluminum alloy sheet for connecting components according to the present invention, the aluminum alloy

preferably contains one kind or more selected from; Cu of less than 1.0 mass %, Mn of less than 1.0 mass %, Cr of less than 0.5 mass %, Zr of less than 0.3 mass %, and Ti of less than 0.1 mass %.

[0020] As the alloy contains less than the specified amount of one kind or more selected from Cu, Mn, Cr, Zr, Ti; according to the aluminum alloy sheet for connecting components, the effect of improving the creep resistance can be further secured without sacrificing the effect of improving the bending workability.

[0021] The manufacturing method of the aluminum alloy sheet for connecting components according to the present invention is comprising: a homogenizing heat treatment step in which an ingot consisting of the aluminum alloy is subjected to a homogenizing heat treatment at 500 - 570°C for 1 - 24 hours; a hot rolling step in which the ingot subjected to the homogenizing heat treatment is subjected to a hot rolling to produce a hot rolled sheet; a solution heat treatment step in which the hot rolled sheet is subjected, without being cold rolled, to a solution heat treatment at 500 - 570°C for 60 seconds or less; and an artificial aging treatment step in which the hot rolled sheet is subjected to an artificial aging treatment.

[0022] According to the above-described manufacturing method of the aluminum alloy sheet for connecting components, electrical conductivity, Cube orientation distribution density at the surface of the sheet, and proof stress of the aluminum alloy sheet for connecting components can be controlled to a predetermined value or more by specifying the chemical composition of the aluminum alloy, by specifying process conditions of the homogenizing heat treatment and the solution heat treatment, and by not performing a cold rolling.

[0023] The Cube orientation distribution density on the surface of the sheet as determined by orientation distribution function analysis is preferably 20 or more. The average grain size on the surface of the sheet is preferably 150 μm or less in the rolling direction. The surface bending property can be improved by refining crystal grains.

[0024] The manufacturing method of the aluminum alloy sheet for connecting components according to the present invention is comprising: a homogenizing heat treatment step in which an ingot consisting of the aluminum alloy is subjected to a homogenizing heat treatment at 500 - 570°C for 1 - 24 hours; a hot rolling step in which the ingot subjected to the homogenizing heat treatment is subjected to plural paths of hot rolling with rolling start temperatures ranging from 350 to 450°C to produce a hot rolled sheet; a solution heat treatment step in which the hot rolled sheet is subjected, without being cold rolled, to a solution heat treatment at 500 - 570°C for 100 seconds or less; and an artificial aging treatment step in which the hot rolled sheet is subjected to an artificial aging treatment.

[0025] According to the above-described manufacturing method of the aluminum alloy sheet for connecting components, electrical conductivity, Cube orientation distribution density at the surface of the sheet, and proof stress of the aluminum alloy sheet for connecting components can be controlled to a predetermined value or more, and grain size can be controlled to a predetermined value or less, by specifying the chemical composition of the aluminum alloy, by specifying process conditions of the homogenizing heat treatment, the hot rolling, and the solution heat treatment, and by not performing a cold rolling.

Effect of the invention

[0026] The aluminum alloy sheet of the present invention may be suitably used for connecting components because it excels in creep resistance and bending workability while electrical conductivity is secured by specifying predetermined values of electrical conductivity and Cube orientation distribution density on the surface or more as well as it specifies a predetermined range of contained amount of Si and Mg.

[0027] According to the manufacturing method of an aluminum alloy sheet of the present invention, an aluminum alloy sheet for connecting components of excellent creep resistance and bending workability along with good electrical conductivity can be produced as the chemical composition of the aluminum alloy is specified, conditions of the homogenizing heat treatment and the solution heat treatment are specified, and a cold rolling is not performed.

Brief description of the drawings

[0028]

Figure 1 is a perspective view indicating a connecting component (bus-bar) in relation with an embodiment according to the present invention.

Figure 2 is a flow chart indicating processes for a production method for the aluminum alloy sheet for connecting components in relation with an embodiment according to the present invention.

Figure 3 is an illustration to explain a bending test method in an example of the present invention.

Description of the preferred embodiments

The first embodiment

[0029] An embodiment for the aluminum alloy sheet for connecting components and the manufacturing method according to the present invention are explained in detail hereinbelow.

(Aluminum alloy sheet for connecting components)

[0030] The aluminum alloy sheet for connecting components (hereinafter referred to as aluminum alloy sheet) according to the present invention consists of predetermined amounts of Si and Mg, and the balance being Al and inevitable impurities. The aluminum alloy sheet is characterized in that the electrical conductivity and the Cube orientation distribution density on the surface are predetermined value or more. Among the inevitable impurities, Fe and Zn are preferably less than the predetermined values. The aluminum alloy sheet preferably contains one or more kinds of inevitable impurities selected from Cu, Mn, Cr, Zr, and Ti, in less than the respectively predetermined amount.

[0031] In the following, explanations are given in terms of the preferable content range and significance of each of the elements or the tolerable amount thereof, electrical conductivity, and Cube orientation distribution density on the surface of the aluminum alloy sheet according to the present invention.

(Si: 0.3 - 1.5 mass %)

[0032] Along with Mg, Si forms precipitates in the course of an artificial aging treatment after a solution heat treatment. Because Si has an effect of improving creep resistance by preventing grain boundary migration at high temperatures, Si is an indispensable element for the aluminum alloy sheet according to the present invention. Desirable creep resistance cannot be secured if the content of Si is less than 0.3 mass %. If the contained amount of Si is more than 1.50 mass %, on the other hand, coarse crystallized and precipitated compounds are liable to be formed to cause the deterioration of the bending workability in particular. Therefore, a contained amount of Si is to be controlled to 0.3 to 1.5 mass %. In order to further secure the effect of improving bending workability and creep resistance, the contained amount of Si is preferably 0.4 to 1.5 mass %, and more preferably 0.5 to 1.3 mass %.

(Mg: 0.3 - 1.0 mass %)

[0033] Along with Si, Mg forms precipitates in the course of an artificial aging treatment after a solution heat treatment. Because Mg has an effect of improving creep resistance by preventing grain boundary migration at high temperatures, Mg is an indispensable element for the aluminum alloy sheet according to the present invention. Desirable creep resistance cannot be secured if the content of Mg is less than 0.3 mass %. If the contained amount of Mg is more than 1.0 mass %, on the other hand, coarse crystallized and precipitated compounds are liable to be formed to cause the deterioration of the bending workability in particular. Therefore, a contained amount of mg is to be controlled to 0.3 to 1.0 mass %. A preferred contained amount of Mg is 0.5 to 0.8 mass % in order to further secure the effect of improving bending workability and creep resistance.

(Inevitable impurities)

[0034] Fe and Zn and the like may be contained within a range in which these inevitable elements do not impair the effects of the present invention. Specifically, contained amount of Fe and Zn are preferably regulated to less than 0.50 mass %, respectively. If the contained amount of Fe or Zn becomes 0.50 mass % or more, the bending workability or the corrosion resistance is deteriorated. Fe and Zn are contained in a certain quantity in scraps and recycled molten metals, for example an aluminum alloy for a clad material such as a brazing sheet. These scraps and recycled molten metals may be mixed in the manufacturing process so that the contained amounts of the elements are less than the prescribed range in the aluminum alloy sheet to reduce the cost of raw material. Further, inevitable impurities other than Fe and Zn are also tolerated in a content range in which the elements do not impair the effects of the present invention.

(Cu: less than 1.00 mass %)

[0035] Cu enhances formation of aging precipitates in an artificial aging treatment after a solution heat treatment. Creep resistance is thus enhanced by preventing dislocations from moving in a high temperature environment. It is preferred to contain Cu in an amount of 0.05 mass % or more in order to obtain the effect. On the other hand, if a contained amount of Cu is 1.00 mass % or more, stress corrosion cracking resistance, weldability, and bending workability

are markedly deteriorated. Therefore, a contained amount of Cu is to be controlled to less than 1.00 mass % when Cu is added to the aluminum alloy sheet.

(Mn: less than 1.00 mass %)

[0036] Mn develops dispersed particles (dispersed phase) in the course of a homogenizing heat treatment, and these dispersed particles have the effect of preventing grain boundary migration after recrystallization so that Mn has the effect of allowing fine grains to be obtained. The bending workability of the aluminum alloy sheet for connecting components according to the present invention improves as the grains of the structure of the aluminum alloy are finer. To effectively provide the effect, Mn is preferably contained in an amount of 0.01 mass % or more. On the other hand, if the Mn content is 1.00 mass % or more, a coarse Al-Fe-Si-Mn crystallized compound is likely to be produced to cause the degradation of the bending workability of the aluminum alloy sheet. Therefore, a contained amount of Mn is to be controlled to less than 1.00 mass % when Mn is added to the aluminum alloy sheet.

(Cr: less than 0.50 mass %)

[0037] As for Mn, Cr forms dispersed particles (dispersed phase) in the course of a homogenizing heat treatment, and these dispersed particles have the effect of preventing grain boundary migration after recrystallization so that Cr has the effect of allowing fine grains to be obtained. To effectively provide the effect, Cr is preferably contained in an amount of 0.01 mass % or more. If the contained amount of Cr is 0.50 mass % or more, on the other hand, coarse intermetallic compounds are liable to be formed during melting and casting steps to cause the deterioration of the bending workability. Therefore, a contained amount of Cr is to be controlled to less than 0.50 mass % when Cr is added to the aluminum alloy sheet.

(Zr: less than 0.30 mass %)

[0038] As for Mn, Zr forms dispersed grains (dispersed phase) in the course of a homogenizing heat treatment, and these dispersed particles have the effect of preventing grain boundary migration after recrystallization so that Zr has the effect of allowing fine grains to be obtained. To effectively provide the effect, Zr is preferably contained in an amount of 0.01 mass % or more. If the contained amount of Zr is 0.30 mass % or more, on the other hand, coarse intermetallic compounds are liable to be formed during melting and casting steps to cause the deterioration of the bending workability. Therefore, a contained amount of Zr is to be controlled to less than 0.30 mass % when Zr is added to the aluminum alloy sheet.

(Ti: less than 0.10 mass %)

[0039] Being contained in a small amount in the aluminum alloy sheet, Ti is an element effective to refine crystal grains and to improve the bending workability. To effectively provide the effect, Ti is preferably contained in an amount of 0.01 mass % or more. If contained amount of Cr is 0.10 mass % or more, on the other hand, coarse compounds are liable to be formed to cause the deterioration of the bending workability. Therefore, a contained amount of Ti is to be controlled to less than 0.10 mass % when Ti is added to the aluminum alloy sheet.

(Electrical conductivity: 45.0 % IACS or more)

[0040] Electrical conductivity of the aluminum alloy sheet for connecting components according to the present invention is set to be 45.0 % IACS or more. If the electrical conductivity is 45.0 % IACS or more, conductivity required for connecting components can be secured. However, if the electrical resistivity is high, i.e., the electrical conductivity is less than 45.0 % IACS, then it becomes necessary to increase a cross-sectional area of the connecting component in order to pass a desired density of current, which causes increasing weight of the component. The higher the electrical conductivity, the better the connecting component is. The electrical conductivity is preferably 47.0 % IACS or more, and more preferably 50.0 % IACS or more.

[0041] The electrical conductivity of an aluminum alloy sheet can be controlled by contained amounts of Si and Mg, conditions of a homogenizing heat treatment, a solution heat treatment, and an artificial aging treatment in the manufacturing process. It should be noted, however, that excessively high electrical conductivity is liable to induce excessive decrease in the amount of solid solution and formation of coarse precipitated products. The electrical conductivity is preferably 60.0 % IACS or less, accordingly.

(Cube orientation distribution density: 15 or more)

[0042] Cube orientation distribution density on the surface of the aluminum alloy sheet for connecting components according to the present invention is set to be 15 or more. Both creep resistance and bending workability required for a connecting component can be attained by the Cube orientation distribution density on the surface of the aluminum alloy sheet of 15 or more. If the Cube orientation distribution density on the surface of the aluminum alloy sheet is less than 15, the bending workability is degraded. The Cube orientation distribution density is preferably 20 or more, and more preferably 30 or more in order to secure the effect of improving creep resistance and bending workability.

[0043] According to a general manufacturing method, the Cube orientation distribution density becomes less than 15, indicating that crystal orientation on the surface of the aluminum alloy sheet is relatively random.

[0044] On the other hand, if the Cube orientation distribution density is controlled to 15 or more as specified by the present invention, in another words, if the Cube orientation reaches a predetermined level or more, then density of low-angle grain boundaries between adjacent grains having small difference in terms of crystal orientation increases, decreasing or eliminating a level difference of grain boundaries when the alloy material is deformed. Moreover, formation of a shear band is suppressed because uniform slip deformation becomes possible in the Cube orientation as compared to other crystal orientations. As a result, bending workability is improved by controlling the Cube orientation distribution function to 15 or more because the level difference of grain boundaries which are crack starting points or propagation paths for cracks during bending work as well as formation of a shear band at grain inside of crystals grains are suppressed.

[0045] It is noted here that excessive enhancement of the Cube orientation distribution density is liable to cause strict processing conditions and decreasing productivity. The Cube orientation distribution density is preferably 100 or smaller, accordingly.

[0046] In the present invention, the Cube orientation density is determined by orientation distribution function analysis (occasionally referred to ODF analysis hereinafter) which is superior in terms of accuracy to measure crystal texture.

[0047] Cube orientation density determined by the ODF analysis is capable to expressing a wide range of preferential orientation in a quantitative manner as it expresses the orientation as a dimensionless ratio to that of a randomly-oriented Al powder standard sample having no preferential orientation. This is in contrast to measurement of intensity integral which is not capable of expressing the pure Cube orientation as it is not possible to distinguish the rotational orientations within the {100} planes.

[0048] Measurement of Cube orientation distribution density on the surface of the aluminum alloy sheet by the ODF analysis is conducted by using for example an X-ray diffraction apparatus (Rigaku RAD-rX (Ru-200B) produced by Rigaku Corporation). ODF analysis by incomplete pole figures can be performed by the X-ray diffraction apparatus. By the Schluz reflection method, incomplete pole figures of {100} and {111} planes are acquired, for which Burge iterative series expansion method (positivity method) is applied to perform the ODF analysis to determine the Cube orientation distribution density.

[0049] A relationship between a bending direction and the Cube orientation (the direction of orientation) in a bending work of an aluminum alloy sheet should be noted here. If an aluminum alloy sheet is bent in a direction parallel to the Cube orientation, in other words, the bending work direction is parallel or right-angled to the rolling direction of the plate material, then the Cube orientation is stabilized during the deformation and excellent bending workability can be secured. Since the Cube orientation is aligned when it is rotated by 90°, angles of 0° and 90° are not distinguished with each other in the sheet. As such, regardless of the bending work direction is set parallel or right-angled to the rolling direction of the plate material, the Cube orientation is the same and excellent bending workability can be secured.

[0050] However, if the angle between the bending work direction and the rolling direction of the plate material is other than the two angles, for example at 45°, then the Cube orientation rotates during the deformation and the crystal orientations are randomized, resulting in poor bending workability. Accordingly, the bending work direction is preferably in either of the two angles.

[0051] The Cube orientation distribution density on the surface of the sheet can be controlled by contained amounts of Si and Mg, condition of hot rolling, and not performing a cold rolling in the manufacturing process.

(Proof stress: 180 MPa or more)

[0052] Proof stress (0.2 % proof stress) of the aluminum alloy sheet for connecting components according to the present invention is preferably 180 MPa or more. Creep resistance required for connecting components can be secured when the proof stress is 180 MPa or more. On the other hand, the creep resistance is decreased when the proof stress is less than 180 MPa. The proof stress is preferably 190 MPa or more, and more preferably 195 MPa or more in order to ensure the effect of securing the creep resistance.

[0053] The proof stress can be controlled by amounts of Si and Mg contained in the aluminum alloy sheet, conditions of a homogenizing heat treatment, a solution heat treatment, and an artificial aging treatment in the manufacturing process.

(Connecting component)

[0054] A connecting component is a component to electrically interconnect plural members. Specifically, a bus-bar is installed on various electric transportation machines using electricity as their power source such as various kinds of electric device including battery groups, invertors, motors, and so on. A connecting component called bus-bar is used to electrically interconnect the electric devices as well as components therein. Bus-bar is a component in plate or square bar shape having a certain thickness although its shape is not particularly limited. A bus-bar is in a shape, for example, as shown in FIG. 1.

[0055] It is noted here that a bus-bar made of an aluminum alloy is required to have a larger cross-sectional area as compared to that made of copper in order to secure electrical conductance as aluminum is inferior to copper in terms of electrical conductivity. Considering an area occupied by a component, the thickness of the bus-bar has to be increased as it is difficult to increase the width in many cases. In general, deformation volume on the bending surface increases with the thickness of a sheet. Accordingly, a bus-bar constituted by an aluminum alloy is accompanied by an issue of bending crack in the course of bending work. The issue to improve bending workability becomes thus tangible for such a bus-bar.

[0056] In other words, the aluminum alloy sheet according to the present invention is preferably applied to bus-bars having a thickness of 1.5 mm or more, particularly those having a thickness of 1.8 - 5.0 mm even amongst connecting components, exhibiting the remarkable effect of simultaneously satisfy the creep resistance and bending workability.

[0057] Next, a manufacturing method of the aluminum alloy sheet for connecting components according to the first embodiment is described with reference to FIG. 2.

(Manufacturing method of aluminum alloy sheet for connecting components)

[0058] The manufacturing method of the aluminum alloy sheet for connecting components according to the present invention is characterized in that it comprises of a homogenizing heat treatment step S2, a hot rolling step S3, a solution heat treatment step S4, and an artificial aging treatment step S5. Hereinbelow, each of the steps is mainly explained.

(Casting step)

[0059] In casting step S1, an aluminum alloy of the chemical composition is melted and casted by a generally known casting method such as DC casting process. An ingot of approximately 400 - 600 mm in thickness is obtained by cooling down the aluminum alloy to a temperature lower than its solidus line. The ingot is scalped if necessary.

(Homogenizing heat treatment step)

[0060] In homogenizing heat treatment step S2, a homogenizing heat treatment (a soaking treatment) is performed to the ingot casted in the casting step S1 at a predetermined temperature, prior to hot rolling. By performing a homogenizing heat treatment onto the ingot, its internal stress is eliminated, solute elements segregated during the casting step are homogenized, and intermetallic compounds precipitated in the middle of or after the cooling the casted ingot also grow in size. The homogenizing heat treatment also serves as preheating for a successive hot rolling step S3.

[0061] Heat treatment temperature (temperature of an ingot) in the homogenizing heat treatment step S2 is in a range from 500 to 570°C If the temperature is lower than 500°C, Si and Mg crystallized and precipitated during the casting step remain in the aluminum alloy without entering into solid solution, which hinders appropriate distribution of precipitated products after the solution heat treatment and the artificial aging treatment, and deteriorates proof stress and creep resistance. If the temperature is higher than 570°C, on the other hand, local melting (burning) occurs on the surface of an ingot. The temperature of the homogenizing heat treatment is more preferably 560°C or lower. Heat treatment time is preferably 1 hour or longer by taking an account of completion of even temperature distribution, and 24 hours or shorter from the point of view of the productivity.

(Hot rolling step)

[0062] In hot rolling step S3, the homogenized ingot is hot rolled successively after the homogenizing heat treatment step S2. Firstly, maintaining the finishing temperature of the homogenizing heat treatment step S2, the ingot is rough rolled, and then turned to a hot rolled sheet (hot coil) of a desired thickness by finishing rolling. Thickness of the hot rolled sheet may be set by calculating back from the final thickness of the aluminum alloy sheet. The finishing temperature of the hot rolling step also controls the Cube orientation distribution density. In order to secure excellent bending workability by particularly improving the Cube orientation distribution density, it is preferred to suppress the recrystallization at the completion of the hot rolling and to control the worked structure remain by setting the finishing temperature of the hot

rolling to 360°C or lower. More preferred finishing temperature of the hot rolling is 330°C or lower.

(Solution heat treatment step)

[0063] In the solution heat treatment step S4, the sheet rolled in the hot rolling step S3 is subjected to a solution heat treatment. In the solution heat treatment step S4, the heat treatment temperature (temperature of ingot) is in the range from 500 to 570°C. If the heat treatment temperature is lower than from 500°C, crystallized and precipitated remain in the aluminum alloy without entering into solid solution, which hinder desirable distribution of precipitated products after the solution heat treatment and the artificial aging treatment, and desirable proof stress and creep resistance cannot be secured. If the temperature is higher than 570°C, on the other hand, local melting (burning) occurs on the surface of an ingot. The temperature of the solution heat treatment is more preferably 520 - 550°C. Heat treatment time at the temperature in the step S4 is to be 60 seconds or shorter including 0 second, as the treatment longer than 60 seconds is not effective and leads to decrease in the productivity.

[0064] By controlling the heat treatment temperature to the range in the solution heat treatment S4 as well as not performing a cold rolling after the hot rolling step S3, the Cube orientation develops appropriately and the Cube orientation distribution density on the surface of the sheet reaches a predetermined value or more.

[0065] In the solution heat treatment step S4, the temperature rising rate from 200°C to the heat treatment temperature is preferably set to be 5°C/sec or more, and the temperature falling rate from the heat treatment temperature to 200°C is preferably set to be 10°C/sec or more. By setting the temperature rising and falling rates to be the respectively specified rates or more, the appropriate development of Cube orientation can be secured.

(Artificial aging treatment step)

[0066] In the artificial aging treatment step S5, the hot rolled sheet which has been subjected to a solution heat treatment during the solution heat treatment step S4 is subjected to an artificial aging treatment at a predetermined temperature and for a predetermined duration.

[0067] Heat treatment temperature in the artificial aging treatment step S5 is not particularly limited, but preferably in a range of 150 to 250°C. If the temperature is lower than 150°C, desirable proof stress and creep resistance are not obtained. If the temperature is higher than 250°C, proof stress and creep resistance decrease because the precipitate products become coarse. Heat treatment time in the step S5 is not particularly limited, but preferably in a range of 1 to 30 hours. If the duration is shorter than 1 hour, uneven temperature distribution in a coil or sheet is liable to cause the material properties become unstable, particularly by taking an account of mass production. The upper limit of the duration is set to 30 hours considering the productivity.

[0068] The manufacturing method of the aluminum alloy sheet for connecting components according to the present invention has been described above. Another processing step may be included in between or before and after each of the steps as long as it does not negatively affect to the prescribed steps of the present invention. For example, a cutting process to cut an aluminum alloy sheet into a predetermined size and/or a working step to perform working such as bending and punching into a predetermined shape may be included. Moreover, regarding processing conditions which are not clearly explained in the description, any of the conventional known conditions can be applied to each of the steps. The processing conditions may be modified in an appropriate manner as long as the modification is effective in each of the steps.

The second embodiment

[0069] An embodiment for the aluminum alloy sheet for connecting components and the manufacturing method according to the present invention are explained in detail hereinbelow.

(Aluminum alloy sheet for connecting components)

[0070] The aluminum alloy sheet for connecting components (sometimes simply referred to as aluminum alloy sheet) according to the present invention consists of predetermined amounts of Si and Mg, balance being Al and inevitable impurities. The aluminum alloy sheet is characterized in that the electrical conductivity and the Cube orientation distribution density on the surface are the predetermined values or more, and the average grain size is the predetermined value or less. Among the inevitable impurities, Fe and Zn are preferably contained in an amount of less than the predetermined values. The aluminum alloy sheet preferably contains one or more kinds of inevitable impurities selected from Cu, Mn, Cr, Zr, and Ti, in less than the respectively predetermined amount.

[0071] Explained hereinbelow are significance of numerical limitations regarding Cube orientation distribution density and grain size on the surface of the aluminum alloy sheet for connecting components according to the presentation.

Chemical composition and electrical conductivity of the aluminum alloy sheet for connecting components are not explained as they are similar to those of the first embodiment.

(Cube orientation distribution density: 20 or more)

[0072] Cube orientation distribution density on the surface of the aluminum alloy sheet for connecting components according to the present invention is set to be 20 or more. Both creep resistance and bending workability required for a connecting component can be attained by the Cube orientation distribution density on the surface of the aluminum alloy sheet of 20 or more. If the Cube orientation distribution density on the surface of the aluminum alloy sheet is less than 20, the bending workability is degraded. The Cube orientation distribution density is preferably 30 or more, and more preferably 50 or more in order to secure the effect of improving creep resistance and bending workability.

[0073] According to a general manufacturing method, the Cube orientation distribution density becomes less than 20, demonstrating that crystal orientation on the surface of the aluminum alloy sheet is relatively random. However, if the Cube orientation distribution density is controlled to 20 or more as specified by the present invention, in other words, if the Cube orientation reaches a predetermined level or more, then density of low-angle grain boundaries between adjacent grains having small difference in terms of crystal orientation increases, decreasing or eliminating a level difference of grain boundaries when the alloy material is deformed. Moreover, formation of a shear band is suppressed because uniform slip deformation becomes possible in the Cube orientation as compared to other crystal orientations. As a result, bending workability is improved by controlling the Cube orientation distribution function to 20 or more because the level difference of grain boundaries which are crack starting points or propagation paths for cracks during bending work as well as formation of a shear band at the grain level differences and inside the crystals grains are suppressed.

[0074] It is noted here that excessive enhancement of the Cube orientation distribution density is liable to cause strict processing conditions and decreasing productivity. The Cube orientation distribution density is preferably 100 or smaller, accordingly.

[0075] By controlling the Cube orientation distribution density to 20 or more, the creep resistance required for a connecting component is enhanced while the proof stress is maintained. Although the mechanism has not been clarified, it is supposed that annihilation during high temperature treatments is suppressed. The hypothesis is based on the fact that in an aluminum alloy having small Cube orientation, the Taylor factor is small and density of dislocations is not liable to increase as reported by Sai Ki et al., Keikinzoku (Journal of Japan Institute of Light Metals), vol. 49 (1999) p. 583.

(Average crystal grain size in the rolling direction: 150 μm or less)

[0076] Average crystal grain size in the rolling direction of the aluminum alloy sheet according to the present invention is set to be 150 μm or less. By controlling the average crystal grain size in the rolling direction of the aluminum alloy sheet to be 150 μm or less, quality of the aluminum alloy sheet during a bending work may be improved. If, on the other hand, the average crystal grain size in the rolling direction exceeds 150 μm, surface roughening or cracking are likely to be induced in the bending work.

[0077] The average crystal grain size in the rolling direction is preferably 100 μm or less, and more preferably 50 μm or less, in order to more certainly secure the effect of improving the surface properties for the bending work. On the other hand, it is preferably 10 μm or more because attempts excessively small average crystal grain size in the rolling direction is liable to invite stricter manufacturing conditions which deteriorate the productivity.

[0078] The average crystal grain size in the rolling direction may be measured by cutting a specimen out of the aluminum alloy sheet, polishing the surface of the specimen followed by etching an electrolytic etching solution, and observing the surface by using an optical microscope with a magnification of about x100.

[0079] The average crystal grain size in the rolling direction of the aluminum alloy sheet is controlled by the hot rolling starting temperature and the hot rolling finishing temperature in the manufacturing process.

[0080] Next, a manufacturing method of the aluminum alloy sheet for connecting components according to the second embodiment is described with reference to FIG. 2.

(Manufacturing method of aluminum alloy sheet for connecting components)

[0081] The manufacturing method of the aluminum alloy sheet for connecting components according to the present invention is characterized in that it includes a homogenizing heat treatment step S2, a hot rolling step S3, a solution heat treatment step S4, and an artificial aging treatment step S5. Hereinbelow, each of the steps that is different from the first embodiment is explained. Explanations are omitted for processing steps which are similar to those of the first embodiment.

(Hot rolling step)

[0082] The homogenized ingot is hot rolled in the hot rolling step S3. Starting temperature of the hot rolling is controlled to 350 - 450°C. Hot rolled sheet (hot coil) of desired thickness is formed by performing hot rolling comprising plural paths.

(Cooling modes after homogenizing heat treatment)

[0083] There may be two cooling modes to the hot rolling starting temperature range of 350 - 450°C after the homogenizing heat treatment. One is referred to as two-stage soaking hereinafter in which the ingot is directly cooled down to the temperature range to start the hot rolling. The other mode is referred to as double soaking hereinafter in which the ingot is cooled down to 350°C or lower followed by reheating to the hot rolling starting temperature range of 350 - 450°C to start the hot rolling.

[0084] If starting temperature of the hot rolling exceeds 450°C, then surface roughening is caused in a bending process. However, if starting temperature of the hot rolling is lower than 350°C, it becomes difficult to conduct the hot rolling process.

[0085] As mentioned below, the present invention is characterized in that a cold rolling is not performed after a hot rolling. It is thus extremely essential to control the texture of an aluminum alloy sheet. The present inventors found that recrystallized grains formed during the hot rolling cause the surface roughening in the bending process because the grains are particularly liable to become coarse, and because the structure is maintained after the solution heat treatment. By setting the hot rolling starting temperature to 450°C or lower, recrystallization during the hot rolling can be suppressed and grain size after the successive solution heat treatment can be controlled to a predetermined value or smaller. Further, Mg_2Si intermetallic compounds are formed in the ingot in the course of cooling down to the hot rolling starting temperature after the homogenizing heat treatment. As the Mg_2Si intermetallic compounds act as nucleation sites of the recrystallized grains, the grains can be refined.

[0086] Cooling rate to the hot rolling starting temperature after the homogenizing heat treatment is not particularly limited, but preferably in a range of 20 - 200°C/hr. If the cooling rate is less than 20°C/hr, the Mg_2Si intermetallic compounds become coarse. Dissolving the compounds again into the alloy for the purpose of securing desirable mechanical strength of the sheet requires a solution heat treatment for an extended period of time which deteriorates the productivity. If the cooling rate is more than 200°C /hr, the excessively high cooling rate causes non-uniform temperature distribution in the ingot, which may possibly arise another problem such as deformation and warpage by thermal contraction.

[0087] Further, the excessively high cooling rate induces excessively small average grain size of Mg_2Si intermetallic compounds which are formed during the cooling from the homogenizing heat treatment temperature down to the hot rolling starting temperature. Then it is likely to fail to distribute an appropriate number of relative coarse Mg_2Si intermetallic compounds having a diameter of 2 μm or more which are necessary as nucleation sites for the recrystallized grains.

(Means for cooling after homogenizing heat treatment)

[0088] Cooling methods of the ingot include for example forced air cooling by with an air-cooling fan in and out of a soaking furnace, contacting cooling, cooling by mist or spraying.

[0089] Finishing temperature of hot rolling step is not particularly specified. It is noted, however, that accumulated strain can be increased, by controlling the finishing temperature of hot rolling step to 300°C or lower, to enhance driving force of recrystallization during the following solution heat treatment. As such, the Cube orientation distribution density can be increased and size of the recrystallized grains can be further refined.

(Solution heat treatment step)

[0090] Holding time at the heat treatment temperature in the solution heat treatment step S4 is 100 seconds or less, including 0 second. If the heating time is more than 100 seconds, the effect is saturated and the productivity is degraded. Other conditions are not explained here as they are similar to those of the first embodiment.

[0091] In the solution heat treatment step S4, the temperature rising rate from 200°C to the heat treatment temperature is preferably set to be 5°C/sec or more, and the temperature falling rate from the heat treatment temperature to 200°C is preferably set to be 10°C/sec or more. By setting the temperature rising rate to be the specified rate or more, the appropriate development of Cube orientation can be secured. Further, by setting the temperature rate to be the specified rate or more, desirable mechanical strength can be secured.

Examples

The first example (example of the first embodiment)

[0092] Next, the aluminum alloy sheet for connecting components and the method for manufacturing the same according to the present invention are specifically explained by comparing examples which satisfy the specifications of the present invention with comparative examples which do not satisfy the specifications of the present invention.

(Preparation of test specimen)

[0093] Aluminum alloys having the composition shown in Table 1 (alloy Nos. 1 - 17) were melted and casted by a semi-continuous casting method to form ingots. After scalping, the ingots were subjected to a homogenizing heat treatment according to respective conditions shown in Table 2, followed by, without performing a cold rolling, a hot rolling of rolling reduction of 99 % to form hot rolled sheets (see Table 2 for hot rolling finishing temperatures). Then, without performing a cold rolling, except for the test specimen Nos. 21 and 22 for which a cold rolling was conducted, a solution heat treatment was conducted under respective conditions shown in Table 2. After that, an artificial aging treatment was conducted except for test specimen No. 20 at 200°C for 2 hours to prepare the test specimen of 2 mm in thickness.

[Evaluation]

(Tensile test)

[0094] Test pieces were prepared conforming to JIS Z 2241 5 so that the direction of each test piece is parallel to the direction of rolling. The tensile test was performed in accordance with JIS Z 2241 to measure the tensile strength, 0.2% proof stress, and elongation. The crosshead speed was 5 mm/min, and the test was performed at a constant speed until the specimen was fractured.

(Cube orientation distribution density)

[0095] Cube orientation distribution density on the surface of the test specimens was determined by using an X-ray diffraction apparatus (Rigaku RAD-rX (Ru-200B) produced by Rigaku Corporation). ODF analysis by incomplete pole figure can be performed by the X-ray diffraction apparatus. Specifically, by the Schluz reflection method, incomplete pole figures of {100} and {111} planes were acquired, for which Burge iterative series expansion method (positivity method) was applied to perform the ODF analysis to determine the Cube orientation distribution density.

(Electrical conductivity)

[0096] The electrical conductivity at the surface was measured by using an Eddy current type electrical conductivity meter (Sigma Test D2.068, manufactured by FOERSTER JAPAN Limited). The measurement was conducted on the surface of the test specimen at arbitral 5 points with a distance of 100 mm or more from one another. The electrical conductivity of the aluminum alloy sheet according to the present invention is a mean value of the acquired data.

(Bending workability)

[0097] Test pieces were prepared conforming to JIS Z 2204 so that longitudinal direction of each test piece matched the direction of rolling. The bending test was performed in accordance with the V block method stipulated by JIS Z 2248 by a bending angle (θ) of 60° with an inner radius (r) of 0 mm and a thickness of test piece (t) of 2 mm. The occurrence of cracks was then observed in the bent part (curved portion of 30 mm in width) after the bending test, a rating of "excellent" was given if there was no cracking of 2 mm or longer in length at the bent part in any of the 5 test pieces, "good" if cracking was observed in any of the 5 test pieces, and "bad" if cracking occurred in all of the 5 test pieces.

(Residual stress ratio)

[0098] A residual stress ratio was measured by using a cantilever beam method according to the provision EMAS-3003 standard of Japan Electronics and Information Technology Industries Association. Specifically, firstly a strip-shaped test piece of 10 mm in width, 250 mm in length, and 2 mm in thickness was cut out from an aluminum alloy plate specimen so that the longitudinal direction was perpendicular to the rolling direction of the plate material. Successively, an end of the strip-shaped test piece was fixed to a rigid test bed, and thereafter an initial deflection ($\delta 0$) in the magnitude of 10

mm was applied at the portion of the span length of 150 mm. After being retained in the state for 100 hours at 120°C, a permanent strain ε of the test piece was measured when the deflection was removed. A residual stress ratio (RSR) was obtained from the computation expression: RSR = $((\delta 0 - \varepsilon) / \delta 0) \times 100$. When the residual stress ratio was 75 % or more, the test piece was considered to have sufficient resistance to creep phenomenon in which a material deforms by sustaining strain at high temperature. In other words, the aluminum alloy of the test piece was evaluated to possess sufficient creep resistance required for a connecting component.

[0099] The compositions of the aluminum alloys, preparation conditions for each of the specimens, and the material properties (results of the measurements and evaluations) are shown in detail in Tables 1 and 2. Note that underlined values in Tables 1 and 2 indicate that they are out of the specified ranges of the present invention.

[Table 1]

Alloy		Chemical composition of aluminum alloy (*1) (mass %)								
Category	No.	Si	Mg	Fe	Mn	Cu	Cr	Zn	Zr	Ti
Examples	1	1.4	0.9	0.40	0.40	-	-	-	-	0.05
	2	1.2	0.8	0.15	0.10	0.90	0.40	0.30	0.13	0.08
	3	1.0	0.6	0.15	-	-	-	-	0.15	-
	4	1.0	0.6	0.15	-	-	-	0.30	-	-
	5	0.8	0.5	0.15	-	-	0.10	-	-	-
	6	0.4	0.4	0.07	-	0.15	-	-	-	-
	7	1.3	0.4	0.12	0.02	0.70	0.02	0.01	-	0.02
	8	0.5	0.5	0.30	-	0.25	-	-	-	-
Comparative examples	9	0.2	1.2	0.15	-	-	-	-	-	-
	10	1.7	0.2	0.15	-	-	-	-	-	-
	11	1.0	0.6	0.65	-	-	-	-	-	-
	12	1.0	0.6	0.15	1.1	-	-	-	-	-
	13	1.0	0.6	0.15	-	1.2	-	-	-	-
	14	1.0	0.6	0.15	-	-	0.7	-	-	-
	15	1.0	0.6	0.15	-	-	-	0.6	-	-
	16	1.0	0.6	0.15	-	-	-	-	0.5	-
	17	1.0	0.6	0.15	-	-	-	-	-	0.2

(*1) The balance being Al and inevitable impurities.

[Table 2]

Specimen		Alloy	Manufacturing condition						Properties						
Category	No.	No.	Homogenizing heat treatment		Hot rolling	Cold rolling	Solution heat treatment		Tensile stress (MPa)	0.2 % Proof stress (MPa)	Elongation (%)	Cube orientation distribution density	Electrical conductivity (% IACS)	Bending workability	Residual stress ratio (%)
			Temperature (°C)	Duration (hour)	Finish temperature (°C)		Temperature (°C)	Duration (sec)							
Examples	1	1	510	2	340	Unexecuted	520	0	240	205	13	40	48	good	88
	2	2	510	5	300	Unexecuted	530	10	245	210	14	38	47	good	89
	3	3	520	5	280	Unexecuted	540	20	238	197	14	48	51	excellent	87
	4	4	520	5	280	Unexecuted	540	20	240	200	14	50	51	excellent	87
	5	5	530	10	290	Unexecuted	540	30	235	200	15	50	57	excellent	82
	6	6	560	20	320	Unexecuted	550	0	230	195	15	55	59	excellent	79
	7	7	550	10	320	Unexecuted	550	10	231	200	14	35	50	good	87
	8	8	540	5	330	Unexecuted	540	5	230	195	14	52	57	excellent	78
	9	3	520	5	360	Unexecuted	550	10	239	198	15	21	51	good	86
Comparative examples	10	9	510	2	300	Unexecuted	550	20	210	175	14	35	57	bad	73
	11	10	510	2	310	Unexecuted	550	10	200	170	13	57	57	bad	71
	12	11	520	5	290	Unexecuted	540	20	239	199	14	49	51	bad	87
	13	12	520	5	300	Unexecuted	540	20	240	200	13	50	51	bad	87
	14	13	520	5	320	Unexecuted	540	20	241	201	15	30	46	bad	87
	15	14	520	5	300	Unexecuted	540	20	241	200	14	51	51	bad	87
	16	15	520	5	290	Unexecuted	540	20	238	199	14	51	50	bad	87
	17	16	520	5	290	Unexecuted	540	20	240	199	13	50	50	bad	87
	18	17	520	5	290	Unexecuted	540	20	240	199	14	50	50	bad	87
	19	1	580	10	Burning occurred, and subsequent processing and testing could not be carried out.										
	20	7	530	8	270	Executed (*2)	Heat treatment in a batch furnace (*3)		200	182	9	2	57	bad	65
	21	8	540	5	290	Executed (*2)	540	10	230	195	15	10	59	bad	76
	22	1	550	5	310	Unexecuted	580	30	Burning occurred, and subsequent processing and testing could not be carried out.						

(*2) rolling reduction of 60 %

(*3) at 240°C for 5 hours (temperature rising rate: 50°C/hour, temperature falling rate: 50°C/hour.

(Analysis of results)

[0100] The test specimen Nos. 1 - 9 which satisfy all the requirements specified in the present invention were rated excellent or good in terms of bending workability even when they are subjected to the very severe bending work condition of an inner radius (r) of 0 mm. The specimen also simultaneously exhibited creep resistance required for a connecting component.

[0101] The test specimen No. 10 (alloy No. 9) did not reach the predetermined value or more in terms of proof stress, and also found to be inferior in terms of bending workability and creep resistance because the contained amount of Si was less than the lower limit of the specified range and also because the contained amount of Mg was more than the upper limit of the specified range according to the present invention.

[0102] The test specimen No. 11 (alloy No. 10) did not reach the predetermined value or more in terms of proof stress, and also found to be inferior in terms of bending workability and creep resistance because the contained amount of Si was more than the upper limit of the specified range and also because the contained amount of Mg was less than the lower limit of the specified range according to the present invention.

[0103] The test specimens Nos. 12 - 18 (alloy Nos. 11 - 17) were evaluated to be bad in terms of bending workability because at least one of Fe, Zn, Cu, Mn, Cr, Zr, and Ti was contained in an amount more than the specified value according to the present invention.

[0104] For the test specimen No. 19, burning occurred because homogenizing heat treatment temperature exceeded the upper limit of the specified range according to the present invention. Manufacturing steps and evaluations thereinafter could not be conducted.

[0105] The test specimen Nos. 20 and 21, for which a cold rolling step was conducted, exhibited Cube orientation distribution density of less than the predetermined value, and found bad in terms of bending workability. Further, the test specimen No.20, for which annealing in a batch furnace was conducted as a solution heat treatment at 240°C for 5 hours (temperature rising rate: 50°C/hour, temperature falling rate: 50°C/hour), was evaluated to be poor in terms of creep resistance.

[0106] For the test specimen No. 22, burning occurred because solution heat treatment temperature exceeded the upper limit of the specified range according to the present invention. Manufacturing steps and evaluations thereinafter could not be conducted.

[0107] It is noted here that test specimen No. 20 stimulates an aluminum alloy sheet disclosed in the Patent Document 2, and that test specimen No. 21 stimulates an aluminum alloy sheet disclosed in the Patent Document 1.

The second example (example of the second embodiment)

[0108] Next, the aluminum alloy sheet for connecting components and the method for manufacturing the same according to the present invention are specifically explained by comparing examples which satisfy the specifications of the present invention with comparative examples which do not satisfy the specifications of the present invention. Explained hereinbelow are limited to those different from the first embodiment. Explanations are omitted for the others as they are the same as for the first embodiment.

(Preparation of test specimen)

[0109] Aluminum alloys having the composition shown in Table 1 (alloy Nos. 1 - 17) were melted and casted by a semi-continuous casting method to form ingots. After scalping, the ingots were subjected to a homogenizing heat treatment according to respective conditions shown in Table 3, followed by, without performing a cold rolling, a hot rolling of rolling reduction of 99 % to form hot rolled sheets (see Table 3 for hot rolling finishing temperatures). Then, without performing a cold rolling, except for the test specimen Nos. 24 and 25 for which a cold rolling was conducted, a solution heat treatment was conducted under respective conditions shown in Table 3. After that, an artificial aging treatment was conducted except for test specimen No. 24 at 200°C for 2 hours to form the test specimen of 2 mm in thickness. It is also noted here that a two-stage hot rolling was conducted with the two-stage soaking for test specimen Nos. 1 - 4, and that hot rolling was conducted with the double soaking for test specimen Nos. 5 - 18, 20, and 23.

(Measurement of average crystal grain size)

[0110] Surface of the specimens were ground and etched with an electrolyte. Photographs of the ground faces were taken by a microscope at a magnification of 100 times. Based on the photographs, the crystal grain size in the rolling direction was measured according to the section method. An average of measured data at 5 points was defied as the crystal grain size. The average values are shown in Tables 3.

(Bending workability)

[0111] The occurrence of cracks was then observed in the bent part (curved portion of 30 mm in width) after the bending test, a rating of "excellent" was given if no cracking or surface roughening was observed in any of the 5 test pieces, "good" if subtle surface roughening of an acceptable level was observed in any of the 5 test pieces, "bad" if significant surface roughening was observed in any of the 5 test pieces, and "poor" if a cracking of 2 mm or longer in length was observed in any of the 5 test pieces. Explanations are omitted for the rest of evaluation of bending workability as they are the same as for the first embodiment.

[0112] The compositions of the aluminum alloys, preparation conditions for each of the specimens, and the material properties (results of the measurements and evaluations) are shown in detail in Tables 1 and 3. Note that underlined values in Tables 1 and 3 indicate that they are out of the specified ranges of the present invention.

[Table 3]

Specimen			Manufacturing condition							Properties							
Category	No.	Alloy No.	Homogenizing heat treatment		Hot rolling		Cold rolling	Solution heat treatment		Tensile stress (MPa)	0.2 % Proof stress (MPa)	Elongation (%)	Cube orientation distribution density	Electrical conductivity (% IACS)	Average grain size (μm)	Bending workability	Residual stress ratio (%)
			Temperature (°C)	Duration (hour)	Start temperature (°C)	Finish temperature (°C)		Temperature (°C)	Duration (sec)								
Examples	1	1	510	2	370	270	Unexecuted	530	10	241	204	14	89	48	30	Excellent	90
	2	2	510	5	390	270	Unexecuted	540	30	245	209	13	85	48	30	Excellent	91
	3	3	520	5	400	270	Unexecuted	550	60	238	197	13	90	52	35	Excellent	88
	4	4	520	5	400	280	Unexecuted	550	60	240	201	14	66	51	40	Excellent	89
	5	5	530	10	400	280	Unexecuted	560	60	234	200	14	70	58	40	Excellent	89
	6	6	560	20	420	280	Unexecuted	570	90	225	191	15	75	59	40	Excellent	87
	7	7	540	5	420	290	Unexecuted	570	90	230	195	15	50	49	40	Excellent	78
	8	8	540	5	440	290	Unexecuted	570	90	231	196	15	58	58	40	Excellent	78
	9	6	560	20	420	310	Unexecuted	570	90	234	192	14	45	53	70	good	85
Comparative examples	10	9	510	2	420	280	Unexecuted	550	60	208	172	13	60	59	40	poor	71
	11	10	510	2	420	280	Unexecuted	550	60	199	169	13	72	58	40	poor	72
	12	11	520	5	420	280	Unexecuted	550	60	240	200	14	65	51	40	poor	89
	13	12	520	5	420	280	Unexecuted	550	60	240	199	14	65	51	30	poor	88
	14	13	520	5	420	280	Unexecuted	550	60	240	201	15	45	47	40	poor	87
	15	14	520	5	420	280	Unexecuted	550	60	240	199	15	68	50	30	poor	88
	16	15	520	5	420	280	Unexecuted	550	60	239	200	14	69	51	40	poor	89
	17	16	520	5	420	280	Unexecuted	550	60	239	198	14	70	50	40	poor	88
	18	17	520	5	420	280	Unexecuted	550	60	240	199	13	69	51	40	poor	88
	19	3	580	10	Burning occurred, and subsequent processing and testing could not be carried out.												
	20	3	550	5	400	270	Unexecuted	580	30	Burning occurred, and subsequent processing and testing could not be carried out.							
	21	3	520	5	500	360	Unexecuted	550	10	239	198	15	21	51	200	bad	86
	22	3	520	5	470	250	Unexecuted	550	60	238	196	15	35	52	170	bad	86
	23	3	520	5	320	It was hard to conduct the hot rolling, and subsequent processing and testing could not be carried out.											
	24	7	530	8	520	270	Executed (*2)	Heat treatment in a batch furnace (*3)		200	182	9	2	57	500	poor	65
	25	8	540	5	510	290	Executed (*2)	540	10	230	195	15	10	59	50	poor	76

(*2) rolling reduction of 60 %

(*3) at 240°C for 5 hours (temperature rising rate: 50°C/hour, temperature falling rate: 50°C/hour.

(Analysis of result)

[0113] Explanations are omitted for the test specimen Nos. 1 - 19 as they are the same as for the first embodiment. The test specimens Nos. 12 - 18 (alloy Nos. 11 - 17) were evaluated to be poor in terms of bending workability because at least one of Fe, Zn, Cu, Mn, Cr, Zr, and Ti was contained in an amount more than the specified value according to the present invention.

[0114] For the test specimen No. 20, burning occurred because the solution heat treatment temperature exceeded the upper limit of the specified range according to the present invention. Manufacturing steps and evaluations thereinafter could not be conducted.

[0115] The test specimen Nos. 21 and 22 were found to be bad in terms of bending workability because the starting temperature of the hot rolling was higher than the upper limit of the specified range according to the present invention, which caused the average crystal grain size in the rolling direction to exceed the predetermined value. For the test specimen No. 23, on the other hand, the staring temperature of the hot rolling was lower than the lower limit of the specified range according to the present invention, which made the hot rolling difficult to be conducted. Processing steps and evaluation thereinafter could not be conducted.

[0116] The test specimen Nos. 24 and 25, for which a cold rolling step was conducted, exhibited Cube orientation distribution density of less than the predetermined value, and found bad in terms of bending workability. Further, the test specimen No. 24, for which annealing in a batch furnace was conducted as a solution heat treatment at 240°C for 5 hours (temperature rising rate: 50°C/hour, temperature falling rate: 50°C/hour), was evaluated to be poor in terms of creep resistance.

[0117] It is noted here that test specimen No. 24 stimulates an aluminum alloy sheet disclosed in the Patent Document 2, and that test specimen No. 25 stimulates an aluminum alloy sheet disclosed in the Patent Document 1.

Numerical references

[0118]

1 connecting component (bus-bar)
1a connecting part

Claims

1. An aluminum alloy sheet for connecting components, comprising an aluminum alloy consisting of 0.3 to 1.5 mass % of Si and 0.3 to 1.0 mass % of Mg with the balance being Al and inevitable impurities, and optionally Fe in an amount of less than 0.5 mass % and Zn in an amount of less than 0.5 mass % among the inevitable impurities, the aluminum alloy optionally further comprising one kind or more selected from; Cu of less than 1.0 mass %, Mn of less than 1.0 mass %, Cr of less than 0.5 mass %, Zr of less than 0.3 mass %, and Ti of less than 0.1 mass %, **characterized in that**
the aluminum alloy sheet has an electrical conductivity of 45.0 % IACS or more, and a Cube orientation density of 15 or more on the surface of the sheet as determined by orientation distribution function analysis.

2. An aluminum alloy sheet for connecting components according to claim 1, **characterized in that**
the aluminum alloy sheet has a Cube orientation density of 20 or more on the surface of the sheet as determined by orientation distribution function analysis, and an average grain size in the rolling direction on the surface of the sheet of 150 μm or less.

3. A manufacturing method of the aluminum alloy sheet for connecting components according to claim 1 or 2, comprising:

a homogenizing heat treatment step wherein an ingot consisting of the aluminum alloy is subjected to a homogenizing heat treatment at 500 - 570°C for 1 - 24 hours;
a hot rolling step wherein the ingot subjected to the homogenizing heat treatment is subjected to a hot rolling to produce a hot rolled sheet, optionally subjecting the ingot subjected to the homogenizing heat treatment to plural paths of hot rolling with rolling start temperatures ranging from 350 to 450°C to produce a hot rolled sheet,
a solution heat treatment step wherein the hot rolled sheet is subjected, without being cold rolled, to a solution heat treatment at 500 - 570°C for 100 seconds or less, optionally 60 seconds or less; and
an artificial aging treatment step wherein the hot rolled sheet subjected to the solution heat treatment is subjected to an artificial aging treatment.

Patentansprüche

1. Aluminiumlegierungsblech für Verbindungskomponenten, umfassend eine Aluminiumlegierung, bestehend aus 0,3 bis 1,5 Masse-% Si und 0,3 bis 1,0 Masse-% Mg, wobei der Rest Al und unvermeidbare Verunreinigungen sind, und gegebenenfalls Fe in einer Menge von weniger als 0,5 Masse-% und Zn in einer Menge von weniger als 0,5 Masse-% unter den unvermeidbaren Verunreinigungen, wobei die Aluminiumlegierung gegebenenfalls weiter eine Art oder mehrere, ausgewählt aus: Cu von weniger als 1,0 Masse-%, Mn von weniger als 1,0 Masse-%, Cr von weniger als 0,5 Masse-%, Zr von weniger als 0,3 Masse-% und Ti von weniger als 0,1 Masse-% umfaßt, **dadurch gekennzeichnet, daß**
das Aluminiumlegierungsblech eine elektrische Leitfähigkeit von 45,0% IACS oder mehr und eine Cube-Orientierungsdichte von 15 oder mehr auf der Oberfläche des Blechs aufweist, bestimmt durch Orientierungsverteilungsfunktionsanalyse.

2. Aluminiumlegierungsblech für Verbindungskomponente gemäß Anspruch 1, **dadurch gekennzeichnet, daß** das Aluminiumlegierungsblech eine Cube-Orientierungsdichte von 20 oder mehr auf der Oberfläche des Blechs, bestimmt durch Orientierungsverteilungsfunktionsanalyse, und eine durchschnittliche Korngröße in der Walzrichtung auf der Oberfläche des Blechs von 150 μm oder weniger aufweist.

3. Herstellungsverfahren bezüglich des Aluminiumlegierungsblechs für Verbindungskomponenten gemäß Anspruch 1 oder 2, umfassend:

   einen homogenisierenden Wärmebehandlungsschritt, wobei ein Gußblock, bestehend aus der Aluminiumlegierung, einer homogenisierenden Wärmebehandlung bei 500 bis 570°C für 1 - 24 Stunden unterworfen wird,
   einen Heißwalzschritt, wobei der Gußblock, welcher der homogenisierenden Wärmebehandlung unterworfen worden ist, einem Heißwalzen unterworfen wird, um ein heißgewalztes Blech zu erzeugen, gegebenenfalls Unterwerfen des Gußblocks, welcher der homogenisierenden Wärmebehandlung unterworfen worden ist, mehrfachen Pfaden eines Heißwalzens mit Walzstarttemperaturen im Bereich von 350 bis 450°C, um ein heißgewalztes Blech zu erzeugen,
   einen Lösungs-Wärmebehandlungsschritt, wobei das heißgewalzte Blech, ohne kaltgewalzt zu werden, einer Lösungs-Wärmebehandlung bei 500 - 570°C für 100 Sekunden oder weniger, gegebenenfalls 60 Sekunden oder weniger, unterworfen wird, und,
   einen künstlichen Alterungsbehandlungsschritt, wobei das heißgewalzte Blech, welches der Lösungs-Wärmebehandlung unterworfen worden ist, einer künstlichen Alterungsbehandlung unterworfen wird.

Revendications

1. Feuille d'alliage d'aluminium pour composants de connexion, comprenant un alliage d'aluminium constitué de 0,3 à 1,5 % en masse de Si et de 0,3 à 1,0 % en masse de Mg, le reste étant de l'Al et d'inévitables impuretés, et éventuellement de Fe dans une quantité inférieure à 0,5 % en masse et de Zn dans une quantité inférieure à 0,5 % en masse parmi les inévitables impuretés, l'alliage d'aluminium comprenant en outre éventuellement une ou plusieurs sortes parmi : du cuivre inférieur à 1,0 % en masse, du Mn inférieur à 1,0 % en masse, du Cr inférieur à 0,5 % en masse, du Zr inférieur à 0,3 % en masse et du Ti inférieur à 0,1 % en masse, **caractérisée en ce que**
la feuille d'alliage d'aluminium présente une conductivité électrique de 45,0 % IACS ou plus, et une densité d'orientation cubique supérieure ou égale à 15 sur la surface de la feuille telle que déterminée par l'analyse de la fonction de distribution d'orientation.

2. Feuille d'alliage d'aluminium pour composants de connexion selon la revendication 1, **caractérisée en ce que**
la feuille d'alliage d'aluminium a une densité d'orientation cubique supérieure ou égale à 20 sur la surface de la feuille telle que déterminée par l'analyse de la fonction de distribution d'orientation, et une taille moyenne du grain dans la direction de laminage sur la surface de la feuille inférieure ou égale à 150 μm.

3. Procédé de fabrication de la feuille d'alliage d'aluminium pour composants de connexion selon la revendication 1 ou 2, comprenant :

   une étape de traitement thermique d'homogénéisation dans laquelle un lingot constitué de l'alliage d'aluminium est soumis à un traitement thermique d'homogénéisation à 500 - 570 °C pendant 1 à 24 heures ;
   une étape de laminage à chaud dans laquelle le lingot soumis au traitement thermique d'homogénéisation est

soumis à un laminage à chaud pour produire une feuille laminée à chaud, en soumettant éventuellement le lingot soumis au traitement thermique d'homogénéisation à plusieurs passes de laminage à chaud avec des températures de début de laminage allant de 350 à 450 °C pour produire une feuille laminée à chaud,
une étape de traitement thermique de mise en solution dans laquelle la feuille laminée à chaud est soumise, sans être laminée à froid, à un traitement thermique de mise en solution à 500 - 570 °C pendant une durée inférieure ou égale à 100 secondes, éventuellement inférieure ou égale à 60 secondes ; et
une étape de traitement de vieillissement artificiel dans laquelle la feuille laminée à chaud soumise au traitement thermique de mise en solution est soumise à un traitement de vieillissement artificiel.

FIG. 1

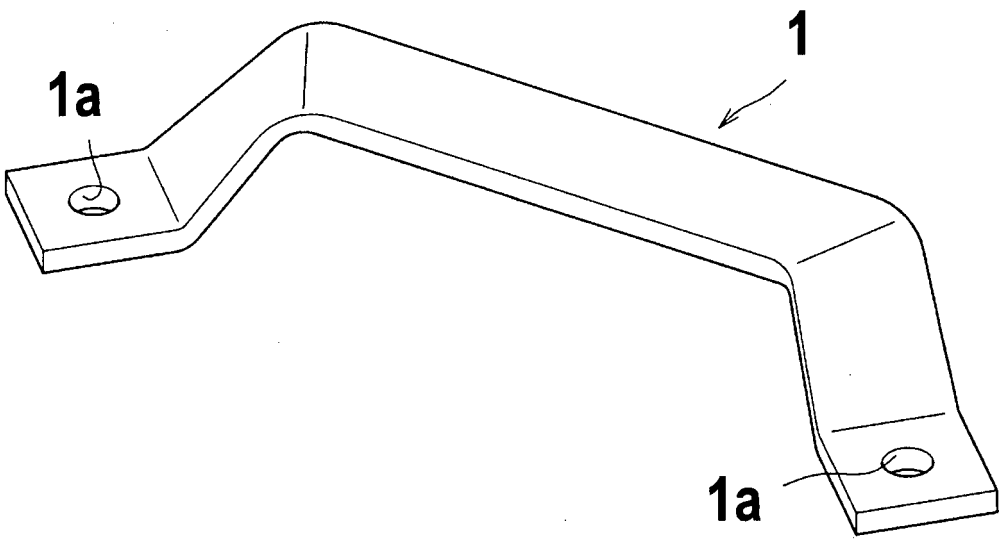


FIG. 2

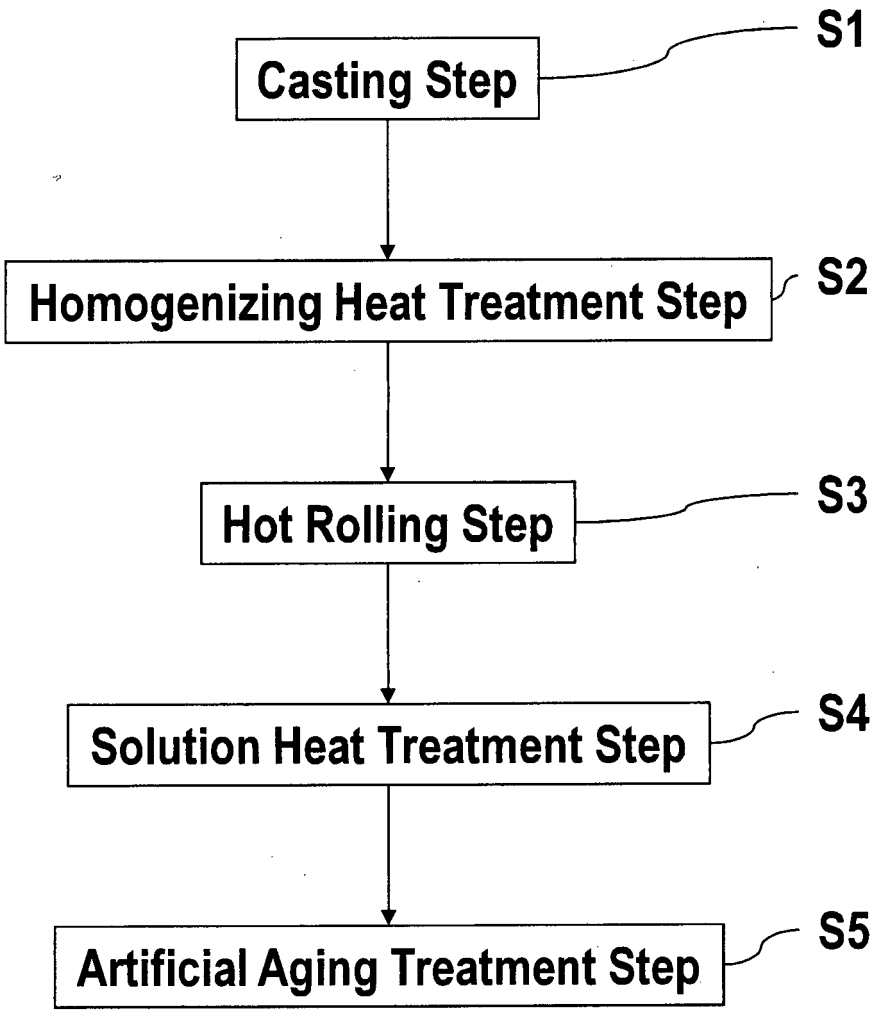
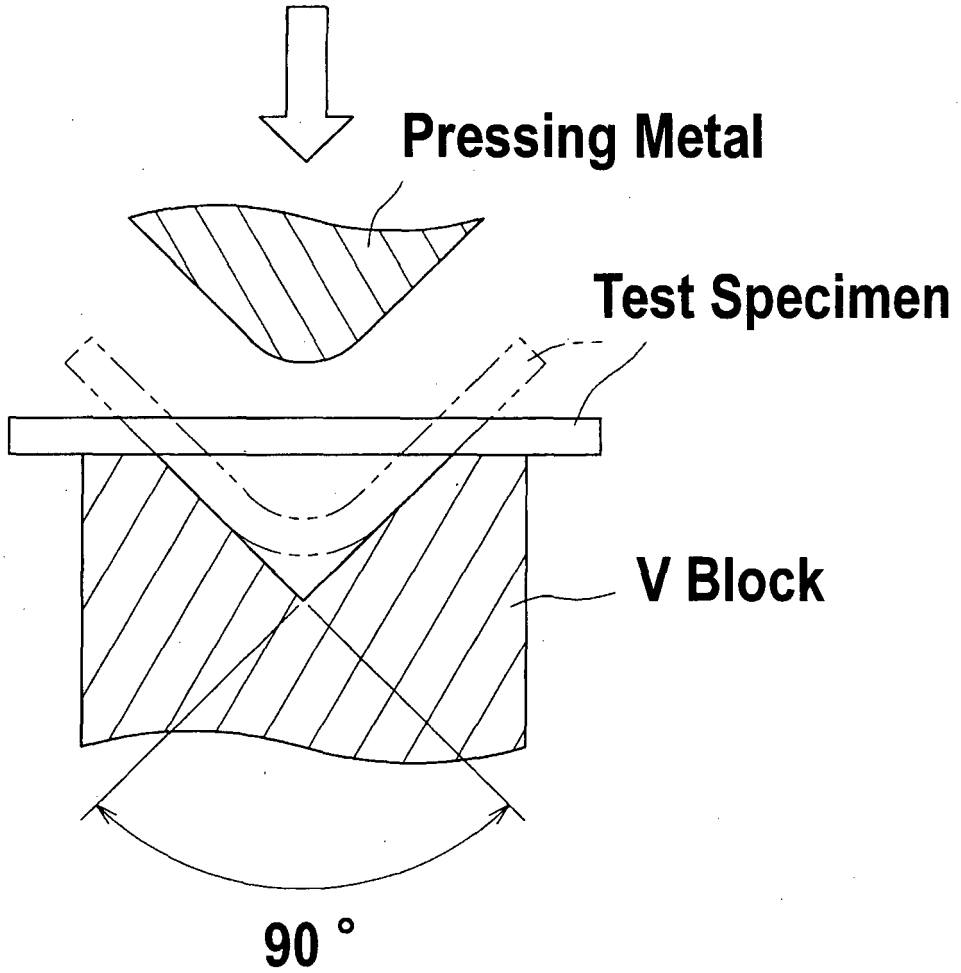

Casting Step
S1
Homogenizing Heat Treatment Step
S2
Hot Rolling Step
S3
Solution Heat Treatment Step
S4
Artificial Aging Treatment Step
S5

FIG. 3



REFERENCES CITED IN THE DESCRIPTION

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