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(54) AL-SI ALLOY FOR CASTING, AL-SI ALLOY CASTING AND AL-SI ALLOY CASTING JOINT

(57) Provided is an Al-Si alloy for casting which is capable of imparting high yield strength to an Al-Si alloy casting in addition to being capable of effectively suppressing the occurrence of cracking when press-fitting a self-piercing rivet into an aluminum alloy casting. In addition, provided are: an Al-Si alloy casting which has high yield strength and effectively suppresses the occurrence of cracking when press-fitting a self-piercing rivet therein; and an Al-Si alloy casting joint in which said Al-Si alloy casting is the material to be joined. The Al-Si alloy for casting in the present invention is characterized by comprising Si in the amount of 5.0-12.0 mass%, Mn in the amount of 0.4-1.5 mass%, Mg in the amount of 0.05-0.6 mass%, Cr in the amount of 0.1-0.5 mass%, and Fe in an amount greater than 0 and no greater than 0.6 mass%, with the remainder constituting Al and inevitable impurities.

Description

THECHNICAL FIELD

[0001] The present invention relates to an Al-Si alloy that can be suitably used for casting, particularly for die casting, and an Al-Si alloy casting cast from the Al-Si alloy is suitable for mechanical joining by using rivets (particularly self-piercing rivets) and the like.

PRIOR ARTS

[0002] Brazing, adhesion, welding, friction stir welding, friction welding and the like are used to join aluminum materials. Here, in recent years, mechanical joining by using a self-piercing rivet or the like has been attracting attention as a simpler joining method.

[0003] Self-piercing rivet joining is a joining method where two materials to be joined are overlapped, a receiving die is placed on the underside of the lower material, and a self-piercing rivet is driven into the upper material from above, and the shank of the self-piercing rivet expands when driven into the materials to achieve the joining.

[0004] For example, Patent Literature 1 (JP 2020-66751 A) discloses a plastically worked material to be used for self-piercing rivet joining, the Al-Mg-Si-based aluminum alloy plastically worked material being containing 0.95% by mass to 1.25% by mass of Si, 0.80% by mass to 1.05% by0 mass of Mg, 0.30% by mass to 0.50% by mass of Cu, 0.40% by mass to 0.60% by mass of Mn, 0.15% by mass to 0.30% by mass of Fe, 0.09% by mass to 0.21% by mass of Cr, and 0.0001% by mass to 0.03% by mass of B, and a content of Zn is 0.25% by mass or less, a content of Zr is 0.05% by mass or less, a content of Ti is 0.10% by mass or less, with the balance being Al and inevitable impurities, and is characterized in that a self-piercing riveted joint between the aluminum alloy plastically worked materials has a shearing tensile maximum load measured according to JIS Z3136-1999 is 8.5 kN or more.

[0005] In the plastically worked Al-Mg-Si-based aluminum alloy material described in Patent Literature 1, it is said that by optimizing the composition, it is possible to provide an Al-Mg-Si-based aluminum alloy plastically worked material having excellent joining strength in self-piercing rivet joining.

[0006] Further, Patent Literature 2 (JP 2002-121635 A) discloses an aluminum alloy extrusion material for automobile frames having excellent self-piercing rivet joinability, which is made of an Al-Mg-Si-based aluminum alloy extrusion material containing 0.30 to 0.70% (mass%, hereinafter the same)of Mg, 0.40 to 0.80% of Si, 0.05 to 0.40% of Cu, 0.05 to 0.30% of Mn, 0.05 to 0.20% of Zr, with the balance being Al and inevitable impurities, and which is subjected to press quenching by air cooling followed by aging treatment to have a yield strength of 200 N/mm^2 or more and a local elongation of 3.5% or more.

[0007] In the aluminum alloy extrusion material for automobile frames described in Patent Literature 2, it is said that an aluminum alloy extrusion material having the strength (yield strength) required for automobile frames and excellent self-piercing rivet joinability can be obtained by performing the aging treatment on the Al-Mg-Si-based aluminum alloy extrusion material after press quenching by air cooling, which is advantageous in terms of dimensional accuracy and cost.

CITATION LIST

Patent Literature

[0008]

Patent Literature 1: JP 2020-66751 A
Patent Literature 2: JP 2002-121635 A

SUMMARY OF INVENTION

Technical Problem

[0009] However, the subject of Patent Literature 1 is a plastically worked Al-Mg-Si-based aluminum alloy material, and the subject of Patent Literature 2 is an extruded aluminum alloy material, and in both cases, the subjects are the aluminum alloy materials whose microstructure and mechanical properties are controlled by plastic working.

[0010] In contrast, there are many cases where aluminum alloy castings such as die-cast materials are necessarily joined to other structural members by using mechanical joining such as self-piercing rivets, and when the mechanical joining is applied to aluminum alloy castings, suppressing of cracks that occur during joining becomes more serious.

[0011] In view of the problems in the prior arts as described above, an object of the present invention is to provide an Al-Si alloy for casting which is capable of imparting high yield strength to an Al-Si alloy casting in addition to being capable of effectively suppressing the occurrence of cracking when piercing a self-piercing rivet into an aluminum alloy casting. Further, the other objects of the present invention are also to provide an Al-Si alloy casting which has high yield strength and effectively suppresses the occurrence of cracking when piercing a self-piercing rivet therein, and an Al-Si alloy casting joint in which said Al-Si alloy casting is the material to be joined.

Solution to Problem

[0012] In order to accomplish the above objects, the present inventors have conducted intensive research as to the relationship among the composition, microstructure and mechanical properties of the Al-Si alloy castings and the cracks during piercing the self-piercing rivet, and as a result, have found that the occurrence of cracks can be suppressed by controlling the added amounts of Mg and Mn, in particular, and that the occurrence of cracks is strongly correlated with the limit bending angle in the VDA bending test, and have reached the present invention.
[0013] Namely, the present invention provides an Al-Si alloy for casting, characterized by containing:

5.0 to 12.0% by mass of Si,
0.4 to 1.5% by mass of Mn,
0.05 to 0.6% by mass of Mg,
0.1 to 0.5% by mass of Cr, and
more than 0 and not more than 0.6% by mass of Fe,
with the balance being Al and inevitable impurities.

[0014] In the Al-Si alloy for casting of the present invention, by adding 0.4% by mass or more of Mn, it is possible to prevent seizure onto a mold, suppress the formation of needle-like Al-Si-Fe-based crystallized products, and suppress the decrease in elongation of the Al-Si alloy casting. Further, by setting the added amount of Mn to 1.5% by mass or less, it is possible to suppress the decrease in elongation of the Al-Si alloy casting, which would be caused by coarsening of the Al-Si-(Fe, Mn)-based crystallized products.
[0015] In addition, by adding 0.05% by mass or more of Mg, due to solid solution strengthening of Mg and precipitation strengthening of Mg-Si-based compounds, it is possible to improve the mechanical properties of the Al-Si alloy casting. Further, by setting the added amount of Mg to 0.6% by mass or less, since excessive increase in deformation resistance is suppressed, it is possible to extremely effectively suppress the occurrence of cracks during the piercing of the self-piercing rivet.
[0016] Further, it is preferable that the Al-Si alloy for casting of the present invention contains one or more of:

0.05 to 0.5% by mass of Cu,
0.005 to 0.03% by mass of Ca,
0.001 to 0.02% by mass of B,
0.005 to 0.03% by mass of Sr,
0.01 to 0.2% by mass of Sb, and
0.002 to 0.02% by mass of Na.

[0017] By further adding these elements, since the microstructure and mechanical properties of the Al-Si alloy casting can be adjusted, it is possible to further enhance the effect of suppressing cracks during the piercing of the self-piercing rivet. Further, it is possible to impart a desired yield strength to the Al-Si alloy casting.
[0018] By adding Cu, it is possible to increase the strength and yield strength of the Al-Si alloy casting, and by adding B, it is possible to improve the local elongation of the Al-Si alloy casting. Further, since Ca, Sr, Sb and Na have the effect of refining and granulating the eutectic Si, it is possible to improve the elongation of the Al-Si alloy casting.
[0019] Further, the present invention also provides an Al-Si alloy casting comprising the Al-Si alloy for casting of the present invention. The Al-Si alloy casting of the present invention is capable of effectively suppressing the occurrence of cracks when piercing the self-piercing rivet, and in addition, has high yield strength.
[0020] In the Al-Si alloy casting of the present invention, it is preferable that the limit bending angle in the VDA bending test specified in VDA238-100 is 28° or more. The limit bending angle is more preferably 30° or more, and most preferably 33° or more.
[0021] Here, the VDA is the German Association of the Automotive Industry Standard (Verband der Automobilindustrie), and VDA238-100 is specified as a plate bending test aimed at evaluating the cracking behavior when a component is crushed.
[0022] In addition, in the Al-Si alloy casting of the present invention, it is preferable that the 0.2% yield strength is 100 MPa or more. The 0.2% yield strength is more preferably 105 MPa or more, and most preferably 110 MPa or more.

[0023] Furthermore, the present invention also provides a self-piercing rivet joint which is a joint joined by using the self-piercing rivet, wherein at least one of the joined members is the Al-Si alloy casting of the present invention.

[0024] The self-piercing rivet joint of the present invention is the Al-Si alloy casting having excellent mechanical properties and imparted with various shapes, which is firmly mechanically fastened to another metal member, and the occurrence of cracks at the joined portion is suppressed, and therefore the joint can be suitably applied to a wide variety of applications.

EFFECT OF THE INVENTION

[0025] According to the present invention, it is possible to provide the Al-Si alloy for casting which is capable of imparting high yield strength to an Al-Si alloy casting in addition to being capable of effectively suppressing the occurrence of cracking when piercing a self-piercing rivet into an aluminum alloy casting. Further, the present invention can also provide the Al-Si alloy casting which has high yield strength and effectively suppresses the occurrence of cracking when piercing a self-piercing rivet therein, and the Al-Si alloy casting joint in which said Al-Si alloy casting is the material to be joined.

BRIEF DESCRIPTION OF DRAWINGS

[0026]

FIG. 1 is a photograph showing the appearance of the self-piercing rivet joined portion (Example 2).
FIG. 2 is a photograph showing the appearance of the Al-Si alloy sheet material after the VDA bending test (Example 2).
FIG. 3 is a photograph showing the appearance of the self-piercing rivet joined portion (Comparative Example 1).

Embodiments for achieving the invention

[0027] In the followings, the Al-Si alloy for casting, the Al-Si alloy casting, and the Al-Si alloy casting joint of the present invention will be described in detail, but the present invention is not limited thereto.

1. Al-Si alloy for casting

[0028] The Al-Si alloy for casting of the present invention is characterized by the combined addition of Mn, Mg, Cr and Fe to a hypoeutectic Al-Si alloy. Each component will be described in detail below.

(1) Essential Additive Elements

Si: 5.0 to 12.0% by mass

[0029] Si has the effect of improving the castability of the aluminum alloy, as well as having the effect of improving the mechanical properties such as tensile strength. This effect becomes significant when the content is 5.0% by mass or more, but when added in excess of 12.0% by mass, since the eutectic Si and primary Si crystals tend to coarsen to reduce elongation, the cracks are easy to occur when the self-piercing rivet is piercd. The added amount of Si is preferably set to 6.0 to 9.0% by mass.

Mn: 0.4 to 1.5% by mass

[0030] Mn has the effect of preventing seizure onto the mold, and has the effect of suppressing the formation of needle-like Al-Si-Fe-based crystallized products, and suppressing the decrease in elongation. These effects become significant at 0.4% by mass or more, whereas when more than 1.5% by mass, the Al-Si-(Fe, Mn)-based crystallized products tend to become coarse, which causes the decrease in elongation. The Mn content is preferably set to 0.5 to 0.7% by mass.

Mg: 0.05 to 0.6% by mass

[0031] Mg has the effect of improving the mechanical properties by solid-dissolving in Al, and has the effect of improving the mechanical properties by aging treatment which is performed to precipitate together with Si as an Mg-Si-based compound. These effects become significant at 0.05% by mass or more, whereas when more than 0.6% by mass, the deformation resistance increases and cracks become more likely to occur when the self-piercing rivet is driven. The added amount of Mg is preferably set to 0.05 to 0.3% by mass, more preferably set to 0.05 to 0.14% by mass.

Cr: 0.1 to 0.5% by mass

[0032] Cr has the effect of preventing seizure onto the mold and improving corrosion resistance. This effect becomes significant at 0.1% by mass or more. On the other hand, when more than 0.5% by mass, the coarse compounds tend to be formed, and elongation tends to decrease.

Fe: More than 0 and not more than 0.6% by mass

[0033] Fe has the effect of improving the mechanical properties such as tensile strength and the effect of preventing mold seizure, but when more than 0.6% by mass, elongation decreases and cracks are more likely to occur when the self-piercing rivet is driven.

(2) Optional Added Elements

Cu: 0.05 to 0.5% by mass

[0034] Cu has the effect of improving the mechanical properties, and this effect becomes significant at 0.05% by mass or more. On the other hand, when more than 0.5% by mass, the corrosion resistance decreases. The content of Cu is preferably set to 0.2 to 0.4% by mass.

B: 0.001 to 0.02% by mass

[0035] B has the effect of improving the local elongation and enhancing the self-piercing rivet joinability. This effect becomes significant at 0.001% by mass or more. On the other hand, when more than 0.02% by mass, there is a factor of the increase in production costs.

Ca: 0.005 to 0.03% by mass

[0036] By adding 0.005 to 0.03% by mass of Ca, it is possible to make the eutectic Si fine and granular. When the eutectic Si is fine and granulated, the elongation is improved, and the occurrence of cracks during the piercing of the self-piercing rivet can be suppressed.

Sr: 0.005 to 0.03% by mass

[0037] By adding 0.005 to 0.03% by mass of Sr, it is possible to make the eutectic Si fine and granular. When the eutectic Si is fine and granulated, the elongation is improved, and the occurrence of cracks during the piercing of the self-piercing rivet can be suppressed.

Sb: 0.01 to 0.2% by mass

[0038] By adding 0.01 to 0.2% by mass of Sb, it is possible to make the eutectic Si fine and granular. When the eutectic Si is fine and granulated, the elongation is improved, and the occurrence of cracks during the piercing of the self-piercing rivet can be suppressed.

Na: 0.002 to 0.02% by mass

[0039] By adding 0.002 to 0.02% by mass of Na, it is possible to make the eutectic Si fine and granular. When the eutectic Si is fine and granulated, the elongation is improved, and the occurrence of cracks during the piercing of the self-piercing rivet can be suppressed.

Ti: 0.005 to 0.2% by mass

[0040] Ti has the effect of refining the casting structure and improving castability and elongation. This effect becomes significant at 0.005% by mass or more.
On the other hand, when more than 0.2% by mass, the coarse crystallized products tend to form and the elongation tends to decrease.

2. Al-Si alloy casting

[0041] The Al-Si alloy casting of the present invention is made of the Al-Si alloy for casting of the present invention, and is characterized by having high yield strength and, at the same time, suppressing the occurrence of cracks when piercing the self-piercing rivet. In the following, the microstructure and mechanical properties will be described in detail.

(1) Metal structure

[0042] The reason why the Al-Si alloy casting of the present invention has excellent self-piercing rivet joinability from the metal structural point of view has not been fully clear, but it is considered that this is due to the fact that the needle-like formation and coarsening of various crystallized products are suppressed, as well as the suppression of the formation of eutectic Si aggregates.

[0043] When brittle aggregates of the eutectic Si are formed, since the cracks tend to propagate along the aggregates, the cracks tend to be occurred during the piercing of the self-piercing rivet. In the Al-Si alloy casting of the present invention, it has been observed that the formation of eutectic Si aggregates tends to be suppressed, and the generation of cracks during the piercing of the self-piercing rivet is effectively suppressed.

[0044] Note, the method for confirming the presence or absence of the eutectic Si aggregates is not particularly limited, and any of various conventionally known microstructure observation methods may be used. For example, when a mirror-polished cross section of the Al-Si alloy casting is observed with an optical microscope or a scanning electron microscope (SEM), if the eutectic Si is formed continuously to a size of 50 μm or more, it can be determined that the aggregate of eutectic Si that promotes the occurrence and propagation of the cracks has been formed.

(2) Mechanical Properties

[0045] The Al-Si alloy casting of the present invention has excellent tensile properties including high strength, yield strength and ductility. In addition, the occurrence of cracks when the self-piercing rivet is pierced is effectively suppressed.

[0046] The mechanism by which the cracks occur when the self-piercing rivet is pierced is complex, and it is difficult to evaluate solely from measured values related to the mechanical properties of the Al-Si alloy casting, such as tensile properties and hardness. With respect to this, the present inventors have conducted intensive research and found that there is a strong correlation between the limit bending angle in the VDA bending test specified in VDA238-100 and the presence or absence of cracks when the self-piercing rivet is pierced.

[0047] More specifically, in order to suppress the cracking when the self-piercing rivet is pierced, it is preferable that the limit bending angle in the VDA bending test specified in VDA238-100 is set to 28° or more. The limit bending angle is more preferably 30° or more, and most preferably 33° or more. For example, in the case of the Al-Si alloy casting having tensile properties of a 0.2% yield strength of 100 to 120 MPa and an elongation at break of about 10 to 14%, by setting the limit bending angle in the VDA bending test to 28° or more, it is possible to almost completely suppress the occurrence of cracks under general joining conditions.

[0048] In the Al-Si alloy casting of the present invention, it is preferable that the 0.2% yield strength is 100 MPa or more. The 0.2% proof stress is more preferably 105 MPa or more, and most preferably 110 MPa or more. The elongation at break is preferably 10%, more preferably 12% or more, and most preferably 14% or more.

[0049] The Al-Si alloy casting of the present invention can be produced by preparing raw materials so that they have the composition of the Al-Si alloy for casting of the present invention, and casting according to various conventionally known casting methods (sand casting, metal mold casting, gravity casting, low-pressure casting, die casting, and the like). That is, the aluminum alloy casting of the present invention is not limited to those produced by a specific casting method.

[0050] Further, the casting conditions are not particularly limited as long as the effects of the present invention are not impaired and various conventionally known casting conditions can be used.

3. Al-Si alloy casting joint (self-piercing rivet joint)

[0051] The self-piercing rivet joint of the present invention is characterized in that at least one of the members joined by using the self-piercing rivet is the Al-Si alloy casting of the present invention.

[0052] The self-piercing rivet joint is the Al-Si alloy casting having excellent mechanical properties and imparted with various shapes, which is firmly mechanically fastened to another metal member, and the occurrence of cracks at the joined portion is suppressed, and therefore the joint can be suitably applied to a wide variety of applications.

[0053] The material, shape and size of the self-piercing rivet are not particularly limited as long as the effects of the present invention are not impaired, and various conventionally known self-piercing rivets can be used. Further, the piercing region of the self-piercing rivet is not particularly limited as long as the effects of the present invention are not impaired, and may be appropriately determined depending on the desired joint.

[0054] Further, the other material to be joined to the Al-Si alloy casting of the present invention is not particularly limited as long as the effects of the present invention are not impaired, and various conventionally known materials to which self-piercing rivets can be applied can be used.

[0055] Furthermore, the conditions for piercing in the self-piercing rivet are not particularly limited as long as the effects of the present invention are not impaired, and may be adjusted as appropriate depending on the material, shape, size, and the like of the self-piercing rivet and the materials to be joined.

[0056] Although representative embodiments of the present invention have been described above, the present invention is not limited to these, and various design changes are possible, and all such design changes are included in the technical scope of the present invention.

EXAMPLE

«Examples»

[0057] Raw materials which were mixed to obtain the compositions (% by mass) shown in Table 1 as Examples 1 to 8 were melted at 750°C, and, after subjected to the slag removal treatment by using a molten metal cleaning flux and the degassing treatment by blowing Ar gas therein, pore free die casting was performed under the conditions of a high speed injection speed: 2.0 mm/s, a casting pressure: 80 ± 5 MPa, a casting temperature: 730 ± 10°C (Examples 1 to 8, Comparative Example 3), 700 ± 10°C (Comparative Examples 1 and 2), and a mold temperature: 100 to 150°C to obtain an Al-Si alloy sheets which are the Al-Si alloy castings according to the present invention. The size of the Al-Si alloy sheet is 110 × 110 × 3 mm.

[Table 1]

	Analytical data (% by mass)									Tensile strength (MPa)	0.2% Yield strength (MPa)	Elongation at break (%)	Limit bending angle (°)	Crack rate (%)
	Si	M n	Mg	Cu	Cr	Fe	Ti	Ca	Al					
Ex. 1	6. 7	0. 55	0.1 9	-	0. 20	0. 10	0.1 3	0.0 09	Bal.	261	115	12.7	32.3	27
Ex. 2	6. 6	0. 54	0.1 8	-	0. 30	0. 10	0.1 6	0.0 07	Bal.	258	116	12.7	31.9	0
Ex. 3	6. 8	0. 57	0.1 1	<0. 01	0. 19	0. 10	<0. 01	0.0 10	Bal.	244	101	15.2	33.9	0
Ex. 4	6. 7	0. 59	0.1 0	0.1 9	0. 22	0. 10	<0. 01	0.0 06	Bal.	253	103	13.6	32.1	0
Ex. 5	6. 8	0. 59	0.1 0	0.3 8	0. 22	0. 10	<0. 01	0.0 20	Bal.	260	106	13.3	31.2	0
Ex. 6	6. 5	0. 48	0.2 6	<0. 01	0. 46	0. 08	-	0.0 10	Bal.	261	127	15.5	28.8	20
Ex. 7	5. 2	0. 44	0.0 6	<0. 01	0. 11	0. 14	-	0.0 10	Bal.	218	90	16.4	35.0	0
Ex. 8	5. 1	1. 20	0.0 6	<0. 01	0. 11	0. 14	-	0.0 08	Bal.	219	93	14.9	34.2	0
Com. Ex. 1	9. 5	0. 55	-	-	0. 19	0. 10	0.1 0	0.0 09	Bal.	272	122	12.5	25.5	73
Com. Ex. 2	9. 4	0. 60	<0. 01	-	0. 19	0. 11	<0. 01	0.0 06	Bal.	260	110	13.7	27.9	87
Com. Ex. 3	4. 8	1. 90	0.8 0	<0. 01	0. 13	0. 13		0.0 08	Bal.	277	168	8.8	16.3	100

[0058] An Al-Si alloy sheet was cut to a size of 100 × 30 × 3 mm, and a steel sheet (SPCC) of 100 × 30 × 1 mm was placed thereon, and then, self-piercing rivet joining was performed by driving rivets with a body outer diameter of 5.2 mm and a length of 4.4 mm into three places from the steel sheet side. The joining test was carried out five times for each composition, and the presence or absence of cracks was checked for a total of 15 self-piercing rivet jointed portions to evaluate the crack occurrence rate. More specifically, the crack occurrence rate is calculated as "crack occurrence rate = (number of joints where cracks were found / 15) × 100". The crack occurrence rates obtained are shown in Table 1. Further, FIG. 1 shows a photograph of the appearance of the self-piercing rivet joined portion in the Al-Si alloy sheet having the composition of Example 2. In the self-piercing rivet joined portion shown in FIG. 1, no crack was observed.

[0059] Further, the Al-Si alloy sheet was subjected to the VDA bending test specified in VDA238-100 to evaluate the limit bending angle. The obtained limit bending angles are shown in Table 1. FIG. 2 shows a photograph of the appearance of the Al-Si alloy sheet having the composition of Example 2 after the VDA bending test.

[0060] Furthermore, the tensile properties of the Al-Si alloy sheet were evaluated. JIS Z 2241 14B tensile test pieces were cut out from the Al-Si alloy sheet and the tensile tests were conducted at a tensile speed of 5 mm/min. The obtained tensile strength, 0.2% yield strength and elongation at break are shown in Table 1.

<<Comparative Examples>>

[0061] The Al-Si alloy sheets, which are comparative Al-Si alloy castings in the present invention, were obtained in the same manner as in the Examples, except that raw materials which were mixed to obtain the compositions (% by mass) shown in Table 1 as Comparative Examples 1 to 3 were used.

[0062] Further, in the same manner as in the Examples, the crack occurrence rate of the self-piercing rivet joined portion and the limit bending angle in the VDA bending test were evaluated. The crack occurrence rates and limit bending angles obtained are shown in Table 1. Further, with respect to the Al-Si alloy sheet having the composition of Comparative Example 1, FIG. 3 shows a photograph of the appearance of the self-piercing rivet joined portion. Remarkable occurrence of the cracking is observed in the self-piercing rivet joined portion.

[0063] From the results shown in Table 1, it can be confirmed that the Al-Si alloy sheet which is the present Al-Si alloy casting of the present invention has excellent self-piercing rivet joinability. Further, the strong correlation is observed between the crack occurrence rate and the limit bending angle in the VDA bending test, and it has been found that the occurrence of cracks can be effectively suppressed by setting the limit bending angle to 28° or more.

[0064] Further, from the results of the tensile test, it is clear that the Al-Si alloy sheet, which is the present Al-Si alloy casting of the present invention, has a low crack occurrence rate and excellent tensile properties.

[0065] In contrast, in the cases of Comparative Examples 1 and 2, which have a low Mg content, and in the case of Comparative Example 3, which has a high Mn and Mg content, the limit bending angle in the VDA bending test is small, and the crack occurrence rate of the self-piercing rivet joined portion has a high point.

Claims

1. An Al-Si alloy for casting, **characterized by** comprising:

   5.0 to 12.0% by mass of Si,
   0.4 to 1.5% by mass of Mn,
   0.05 to 0.6% by mass of Mg,
   0.1 to 0.5% by mass of Cr, and
   more than 0 and not more than 0.6% by mass of Fe,
   with the balance being Al and inevitable impurities.

2. The Al-Si alloy for casting according to claim 1, which comprises one or more of:

   0.05 to 0.5% by mass of Cu,
   0.005 to 0.03% by mass of Ca,
   0.001 to 0.02% by mass of B,
   0.005 to 0.03% by mass of Sr,
   0.01 to 0.2% by mass of Sb, and
   0.002 to 0.02% by mass of Na.

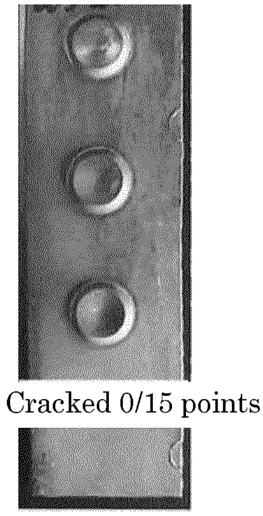
3. An Al-Si alloy casting, comprising the Al-Si alloy for casting according to claim 1 or 2.

4. The Al-Si alloy casting according to claim 3, wherein a limit bending angle in the VDA bending test specified in VDA238-100 is 28° or more.

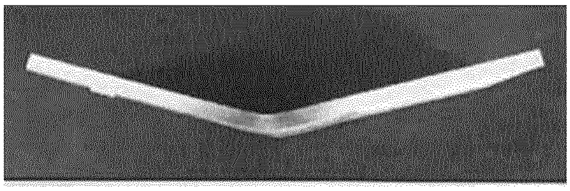
5. The Al-Si alloy casting according to claim 3, wherein a 0.2% yield strength is 100 MPa or more.

6. A self-piercing rivet joint, which is a joint joined by using a self-piercing rivet, and **characterized in that** at least one of the joined members is the Al-Si alloy casting according to claim 3.

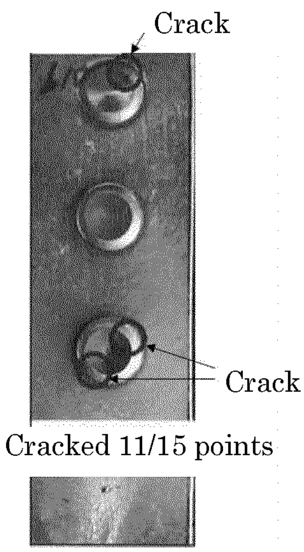
[FIG.1]



[FIG.2]



[FIG.3]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/008001

A. CLASSIFICATION OF SUBJECT MATTER

C22C 21/02(2006.01)i; ***F16B 19/08***(2006.01)i
FI: C22C21/02; F16B19/08 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; F16B19/08

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016/166779 A1 (DAIKI ALUMINIUM INDUSTRY CO., LTD.) 20 October 2016 (2016-10-20) claims, tables 1-3	1-6
X	WO 2016/120905 A1 (DAIKI ALUMINIUM INDUSTRY CO., LTD.) 04 August 2016 (2016-08-04) claims, table 1	1-6
X	JP 2006-336044 A (HITACHI METALS LTD) 14 December 2006 (2006-12-14) claims, tables 1-2	1-6
X	WO 2018/189869 A1 (DAIKI ALUMINIUM INDUSTRY CO., LTD.) 18 October 2018 (2018-10-18) claims, tables 1-2	1-6
X	JP 2021-21138 A (AISIN KEIKINZOKU CO LTD) 18 February 2021 (2021-02-18) claims, fig. 1-2	2-6

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 March 2023	**11 April 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/008001

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2016/166779 A1	20 October 2016	US 2017/0121793 A1 claims, tables 1-3 EP 3121302 A1 CN 106255770 A KR 10-2017-0138916 A MX 2016010352 A	
WO 2016/120905 A1	04 August 2016	US 2018/0002787 A1 claims, table 1 EP 3216884 A1 CN 107208196 A MX 2017007836 A	
JP 2006-336044 A	14 December 2006	(Family: none)	
WO 2018/189869 A1	18 October 2018	(Family: none)	
JP 2021-21138 A	18 February 2021	US 2021/0025034 A1 claims, fig. 1-2	

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- JP 2020066751 A **[0004] [0008]**
- JP 2002121635 A **[0006] [0008]**