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(54) ALUMINUM ALLOY FOR CASTING, HAVING HIGH RIGIDITY AND LOW LINER EXPANSION COEFFICIANT

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(57) **ABSTRACT**

An aluminum alloy for casting with excellent rigidity and having a low coefficient of linear expansion containing 13-25% by mass of silicon, 2-8% by mass of copper, 0.5-3% by mass of iron, 0.3-3% by mass of manganese, 0.001-0.02% by mass of phosphorus, and the remainder comprising aluminum and inevitable impurities, wherein the total amount of iron and manganese is 3.0% by mass or greater. Said alloy may further contain 0.5-6% by mass of nickel, and the total amount of iron, manganese, and nickel may be 3.0% by mass or greater. Further, said alloy may further contain one or more of 0.1-1.0% by mass of chromium, 0.05-1.5% by mass of magnesium, 0.01-1.0% by mass of titanium, 0.0001-1.0% by mass of boron, 0.1-1.0% by mass of zirconium, 0.1-1.0% by mass of vanadium, or 0.01-1.0% by mass of molybdenum.

ALUMINUM ALLOY FOR CASTING, HAVING HIGH RIGIDITY AND LOW LINER EXPANSION COEFFICIANT

TECHNICAL FIELD

[0001] The present invention concerns an aluminum alloy for casting, and particularly concerns an aluminum alloy for casting that may be used optimally for the casting of members for which high rigidity and a low linear thermal expansion coefficient are particularly required, such as ladder frames, perimeter frames, and cases for various types of vehicles such as automobiles.

BACKGROUND ART

[0002] Conventionally, cast iron was used for members such as automobile frames that require particularly high rigidity, but in recent years, from the standpoint of energy conservation, the need for weight reduction of automobiles has increased, and attention has been paid to aluminum alloy as a material that can meet these needs.

DISCLOSURE OF THE INVENTION

Problem to be Solved by the Invention

[0003] As aluminum alloys having high rigidity, aluminum alloy composites compounding Al_2O_3, SiC, and the like as reinforcing materials are known, but these composites have the problem that the manufacturing processes thereof are complex and the cost becomes high. Additionally, there are problems such as the fact that since Al_2O_3, SiC, and the like are contained, there are many restrictions at the time of recycling.

[0004] Japanese Unexamined Patent Publication No. H01-180938 discloses an aluminum alloy with improved wear resistance, but the aluminum alloy disclosed therein has the problem that when substituted for cast iron products being used for automobile frames and the like, its rigidity is low, and its linear expansion coefficient is too high. Additionally, Japanese Unexamined Patent Publication No. H03-199336 also similarly discloses an aluminum alloy with improved wear resistance, but the aluminum alloy disclosed therein also has the problem that when substituted for cast iron products being used for automobile frames and the like, its rigidity is low, and its linear expansion coefficient is too high, and further, sticking to the die occurs easily.

[0005] [Patent Document 1] Japanese Unexamined Patent Publication No. H01-180938

[0006] [Patent Document 2] Japanese Unexamined Patent Publication No. H03-199336

Means for Solving the Problem

[0007] In order to solve the abovementioned problems of conventional aluminum alloys, the present invention offers an aluminum alloy for casting having excellent rigidity and a low linear expansion coefficient, containing 13-25% by mass of silicon, 2-8% by mass of copper, 0.5-3% by mass of iron, 0.3-3% by mass of manganese, 0.001-0.02% by mass of phosphorus, and the remainder comprising aluminum and inevitable impurities, wherein the total amount of iron and manganese is 3.0% by mass or greater.

[0008] Further, 0.5-6% by mass of nickel may be added to make the total amount of iron, manganese, and nickel 3.0% by mass or greater.

[0009] Further, in place of the abovementioned nickel, or in addition to the nickel, one or more of 0.1-1.0% by mass of chromium, 0.05-1.5% by mass of magnesium, 0.01-1.0% by mass of titanium, 0.0001-1.0% by mass of boron, 0.1-1.0% by mass of zirconium, 0.1-1.0% by mass of vanadium, or 0.01-1.0% by mass of molybdenum may be contained.

[0010] It is desirable for the alloy of the present invention to be cast at a cooling rate of 30 degrees C. per second or greater, and in order to cast at a high cooling rate, it is desirable to do the casting by the die casting method.

[0011] The inventors of the present invention, as a result of keen research regarding aluminum alloy, discovered that there is a correlation between the area ratio of crystallized products and the rigidity and linear expansion coefficient of aluminum alloys, and as a result of further research, discovered that by the alloy composition described above, it was possible to disperse minute crystallized particles of Al—Ni, Nl-Ni—Cu, Al—Cu, Al—Fe—Si, Al—Fe—Mn, or Al—Si—Mn compounds, and the necessary high rigidity and low linear expansion coefficient was realizable. Herebelow, the effects of each component in said aluminum alloy shall be described.

EFFECTS OF THE INVENTION

[0012] Silicon: 13-25% by Mass

[0013] Silicon crystallizes as eutectic silicon, primary silicon, and as Al—Fe—Si compounds, and has the effect of improving rigidity. This effect becomes marked at greater than 13% by mass, but at greater than 25% by mass, primary silicon becomes coarse, and the rigidity improving effect is reduced. Additionally, it is necessary to improve the casting temperature. Further, machinability becomes markedly worse due to coarse silicon. Silicon also has the effects of decreasing the linear expansion coefficient, and improving wear resistance. A more desirable range for silicon is 13-17% by mass.

[0014] Copper: 2-8% by Mass

[0015] Copper crystallizes as Al—Cu and Al—Ni—Cu compounds, and contributes to the improvement of rigidity. This effect becomes marked at 4% by mass or greater, but at greater than 8% by mass, the compounds become coarse and elongation is reduced, and further, corrosion resistance is also reduced. A more desirable range for Cu is 3-6 wt %.

[0016] Iron+Manganese (+Nickel): 3.0% by Mass or Greater

[0017] Iron, manganese, and nickel crystallize as Al—Fe—Mn, Al—Fe—Si, Al—Ni, Al—Ni—Cu, Al—Ni—Fe—Mn, and Al—Si—Fe—Mn compounds, contribute to the improvement of rigidity, and have the effect of reducing the linear expansion coefficient. Additionally, they have the effect of improving heat resistance. This effect becomes marked when iron+manganese (+nickel) is 3% by mass or greater, but since at greater than 12% by mass, the crystallized products become coarse, and the rigidity improving effect is lessened, it is desirable to keep the total amount of iron+manganese (+nickel) at 12% by mass or less.

[0018] Phosophorus: 0.001-0.02% by Mass

[0019] Phosphorus has the effect of miniaturizing and dispersing uniformly the primary silicon. This effect is marked at 0.001% by mass or greater, but at greater than 0.02% by mass, the viscosity of the molten metal increases, and castability becomes worse.

[0020] Magnesium: 0.05-1.5% by Mass

[0021] Mg dissolves in solid solution in the matrix and contributes to the improvement of rigidity. This effect is marked at 0.05% by mass or greater, but at greater than 1.5% by mass, elongation is reduced, and castability markedly worsens. More desirably, magnesium should be 0.4% by mass or less.

[0022] Chromium: 0.1-1.0% by Mass

[0023] Chromium crystallizes as Al—Si—Fe—Mn—Cr compounds, and contributes to the improvement of rigidity. Additionally, it has the effect of dispersing primary silicon minutely and uniformly. Said effect is marked for 0.1% by mass or greater of chromium, but at greater than 1.0% by mass, coarse compounds are formed, and elongation is reduced.

[0024] Titanium: 0.01-1.0% by Mass

[0025] Titanium miniaturizes the alpha phase, and contributes to the improvement of castability, and also has the effect of preventing the coarsening of Al—Ni compounds. Such effects become marked at 0.01% by mass or greater of titanium, but at greater than 1.0% by mass, coarse compounds are formed, and elongation is reduced.

[0026] Boron: 0.0001-1.0% by Mass, Vanadium: 0.1-1.0% by Mass, Zirconium: 0.1-1.0% by Mass, Molybdenum: 0.01-1.0% by Mass

[0027] Boron, vanadium, zirconium, and molybdenum form highly rigid crystallized products, and contribute to the improvement of rigidity. For any of these elements, if greater than the upper limit is added, coarse crystallized products are formed, and elongation is reduced.

BEST MODES FOR EMBODYING THE INVENTION

[0028] The inventors of the invention of the present application manufactured the aluminum alloys according to the present invention, and confirmed experimentally the relationship between composition and crystalline structure, rigidity and linear expansion coefficient, and the results shall be described herebelow.

[0029] The composition of the aluminum alloys used in the experiment is shown in table 1. The aluminum alloy used in the experiment, after being cast in a 200×200×10 mm planar form at a casting temperature of 720 degrees C., was aged by maintaining at 200 degrees C. for 4 hours, and then the rigidity (Young's modulus) and the linear expansion coefficient (thermal expansion coefficient) were measured. Alloys No. 1-17 are aluminum alloys according to the present invention, and alloys No. 18-24 are comparative examples that do not satisfy at least one of the conditions for the range of the compositions described above. Compositions that do not satisfy the conditions are shown underlined.

TABLE 1

		Composition (wt %)													Characteristics	
No.		Si	Cu	Ni	Fe	Mn	Mg	Cr	Ti	B	V	Zr	Mo	P	E (GPa)	α ($\times 10^{-6}$/° C.)
1	Compositions According to the Present Invention	13	5	3	2	1	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.01	96	17.8
2		24	5	3	2	1	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.01	103	14.6
3		16	3	3	2	1	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.01	96	17.2
4		16	7	3	2	1	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.01	100	16.7
5		16	5	1	1	1	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.01	93	17.5
6		16	5	3	2	2	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.01	98	17.0
7		16	5	6	2	3.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.01	106	16.4
8		16	5	1	1	1	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.01	98	16.9
9		16	5	—	2	2	—	0.4	—	—	—	—	—	0.01	92	17.8
10		16	5	—	2	2	0.5	0.4	—	—	—	—	—	0.01	92	17.8
11		16	5	—	2	2	—	0.4	—	0.4	—	—	—	0.01	94	17.7
12		16	5	—	2	2	—	0.4	0.4	—	—	—	—	0.01	93	17.7
13		16	5	—	2	2	—	0.4	—	—	0.4	—	—	0.01	93	17.7
14		16	5	—	2	2	—	0.4	—	—	—	0.4	—	0.01	94	17.7
15		16	5	—	2	2	—	0.4	—	—	—	—	0.4	0.01	94	17.7
16		14	4	2	2.5	1.2	—	0.5	0.5	—	0.5	—	—	0.01	94	17.6
17		16	5	—	2	2	0.5	—	—	—	—	—	—	0.01	90	17.9
18	Comparative Examples	12	1	1	1	0.5	1	—	—	—	—	—	—	—	80	20.0
19		11	2.5	—	0.8	0.2	0.2	—	—	—	—	—	—	—	78	21.0
20		16	5	0.5	1	0.5	0.5	0.4	—	—	—	—	—	0.01	87	17.9
21		16	5	2	—	2	—	0.4	—	—	—	—	—	0.01	91	17.8
22		16	5	2	2	—	—	0.4	—	—	—	—	—	0.01	—	17.4
23		16	1	—	2	2	—	0.4	—	—	—	—	—	0.01	86	18.5
24		12	5	—	2	2	—	0.4	—	—	—	—	—	0.01	88	18.9

[0030] The abovementioned measurement results are shown in Table 1 along with compositions.

[0031] Here, regarding Young's modulus, the criterial value is taken to be 90 GPa, and any composition with a value above this is judged to satisfy the criterion, and regarding the coefficient of linear thermal expansion, the criterial value is taken to be $18\times10^{-6}/°$ C., and any composition with a value lower than this is judged to satisfy the criterion.

[0032] As shown in table 1, Alloy No. 18 has a Young's modulus of 80 GPa so has a lower value than the criterial value (90 GPa), and at the same time, its coefficient of linear thermal expansion is $20.0\times10^{-6}/°$ C., higher than the criterial value ($18\times10^{-6}/°$ C.), and neither value satisfies the criteria. The cause is thought to be the fact that the contained amount of any of silicon, copper, and nickel+iron+manganese is insufficient, and therefore is below the range described above.

[0033] Alloy No. 19, similarly with Alloy No. 18, satisfies the criteria neither for the Young's modulus nor the coefficient of linear thermal expansion. The cause is thought to be the fact that, although the content of copper is within the range described above, the contained amount of both silicon and nickel+iron+manganese is insufficient (below the range described above).

[0034] Alloy No. 20 has a Young's modulus lower than the criterial value, and the cause is thought to be the fact that the total contained amount of nickel+iron+manganese is 2.0% by mass, and this is below the condition described above of a total nickel+iron+manganese content of 3.0% by mass.

[0035] Alloy No. 21 satisfies the criteria for Young's modulus and coefficient of linear thermal expansion, but caused sticking to the die. The cause is thought to be the fact that iron was not substantially added, and this did not satisfy the conditions described above.

[0036] Alloy No. 22 had insufficient elongation, and since the test piece broke within the elastic deformation region, the Young's modulus was not measurable. This is thought to be because manganese was not substantially added, and the conditions described above regarding the composition were not satisfied.

[0037] Alloy No. 23 does not satisfy the criteria for either Young's modulus or coefficient of linear thermal expansion. The cause is thought to be the fact that the copper content is insufficient at 1% by mass (is below the range described above).

[0038] Alloy No. 24 also does not satisfy the criteria for either Young's modulus or coefficient of linear thermal expansion. The cause is thought to be the fact that the silicon content is insufficient at 12% by mass (is below the range described above).

[0039] In contrast, aluminum alloys No. 1-17 of the present invention, satisfying the range of composition described above, as shown in table 1, have Young's moduli and coefficients of linear thermal expansion that satisfy the criteria.

INDUSTRIAL APPLICABILITY

[0040] The aluminum alloy for casting of the present invention may be used optimally for the casting of members particularly requiring a high rigidity and low linear expansion coefficient.

1-3. (canceled)

4. An aluminum alloy for casting having excellent rigidity and a low linear expansion coefficient, containing 13-25% by mass of silicon, 2-8% by mass of copper, 0.5-3% by mass of iron, 0.3-3% by mass of manganese, 0.001-0.02% by mass of phosphorus, and the remainder comprising aluminum and inevitable impurities, wherein the total amount of iron and manganese is 3.0% by mass or greater.

5. An aluminum alloy for casting having excellent rigidity and a low linear expansion coefficient, containing 13-25% by mass of silicon, 2-8% by mass of copper, 0.5-3% by mass of iron, 0.3-3% by mass of manganese, 0.5-6% by mass of nickel, 0.001-0.02% by mass of phosphorus, and the remainder comprising aluminum and inevitable impurities, wherein the total amount of iron manganese, and nickel is 3.0% by mass or greater.

6. An aluminum alloy for casting having excellent rigidity and a low linear expansion coefficient recited in either claim **1**, further containing one or more of 0. 1-1.0% by mass of chromium, 0.05-1.5% by mass of magnesium, 0.01-1.0% by mass of titanium, 0.0001-1.0% by mass of boron, 0.1-1.0% by mass of zirconium, 0.1-1.0% by mass of vanadium, or 0.01-1.0% by mass of molybdenum.

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