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(19) **United States**(12) **Patent Application Publication****Lin et al.**(10) **Pub. No.: US 2005/0167012 A1**(43) **Pub. Date: Aug. 4, 2005**(54) **AL-SI-MN-MG ALLOY FOR FORMING
AUTOMOTIVE STRUCTURAL PARTS BY
CASTING AND T5 HEAT TREATMENT****Related U.S. Application Data**

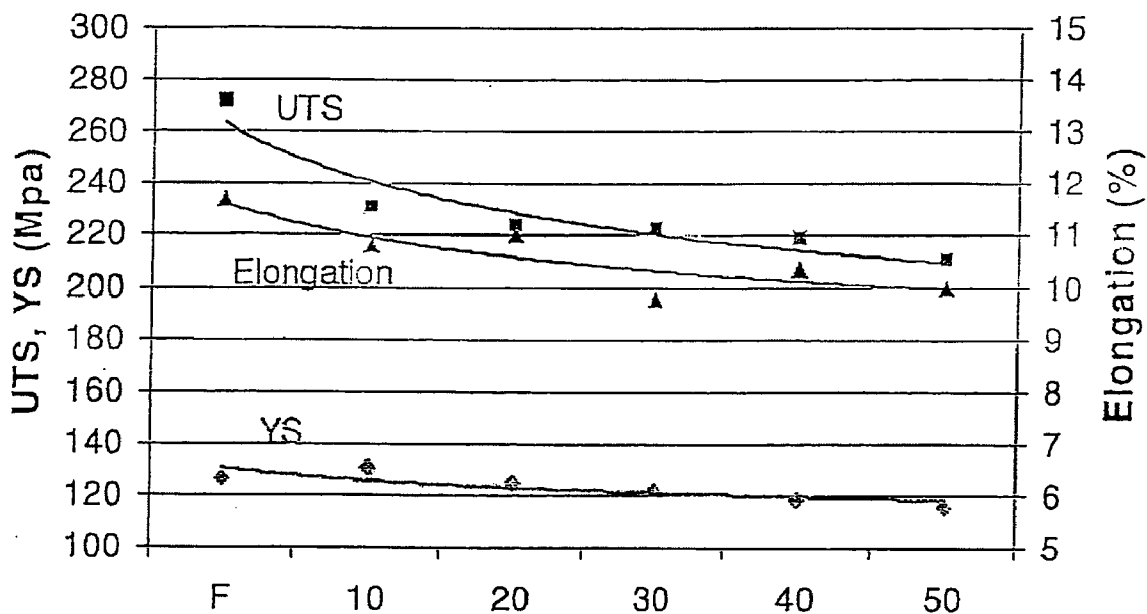
(60) Provisional application No. 60/535,713, filed on Jan. 9, 2004.

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LLC****ALCOA TECHNICAL CENTER****100 TECHNICAL DRIVE****ALCOA CENTER, PA 15069-0001 (US)**(57) **ABSTRACT**

An aluminum alloy shaped casting includes about 6.3 wt. % to 9 wt. % silicon, about 0.05 wt. % to 0.4 wt. % magnesium, no more than about 0.8 wt. % manganese, no more than 0.5 wt. % copper, no more than about 1 wt. % zinc, no more than about 0.2 wt. % iron, no more than about 0.2 wt. % titanium, and no more than about 0.04 wt. % strontium, the aluminum alloy shaped casting receiving a T5 heat treatment.

(21) Appl. No.: **11/031,095**(22) Filed: **Jan. 6, 2005****TYE results in C611-T5 with different age soak time at
330C****Age soak time at 330C**

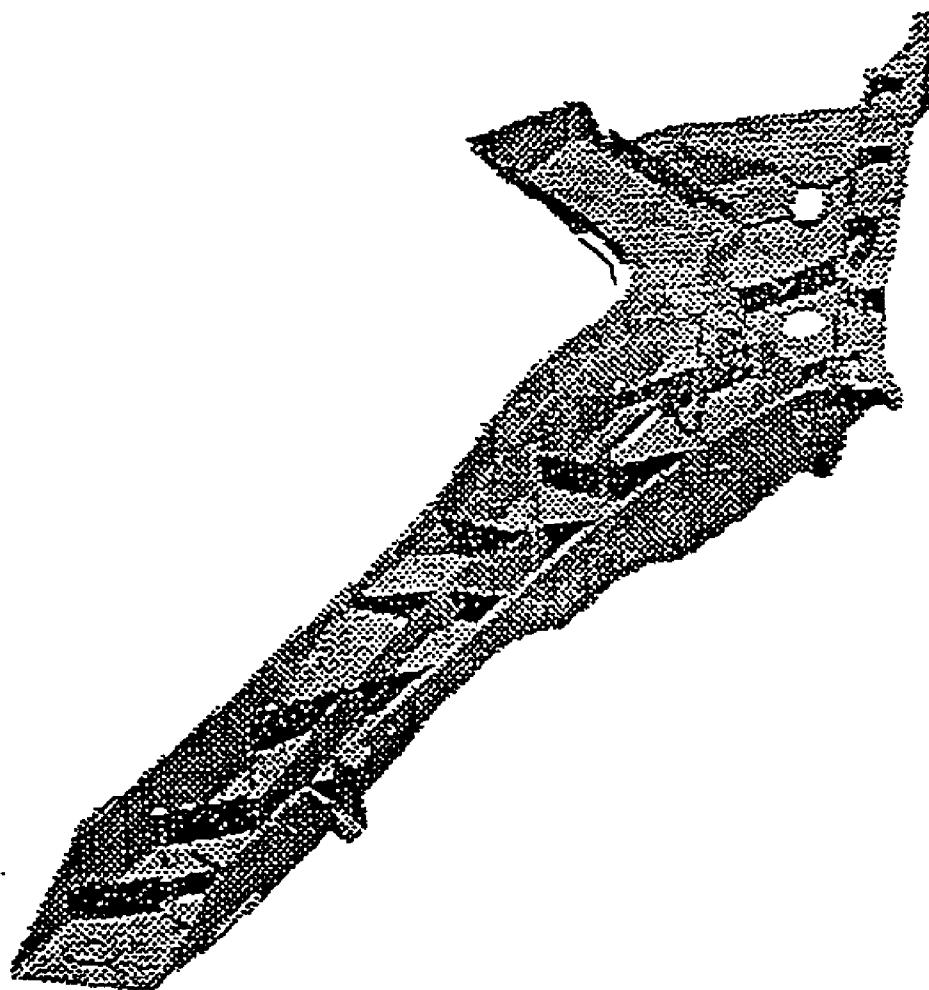


FIGURE 1

TYE results in C611-T5 with different age soak time at
330C

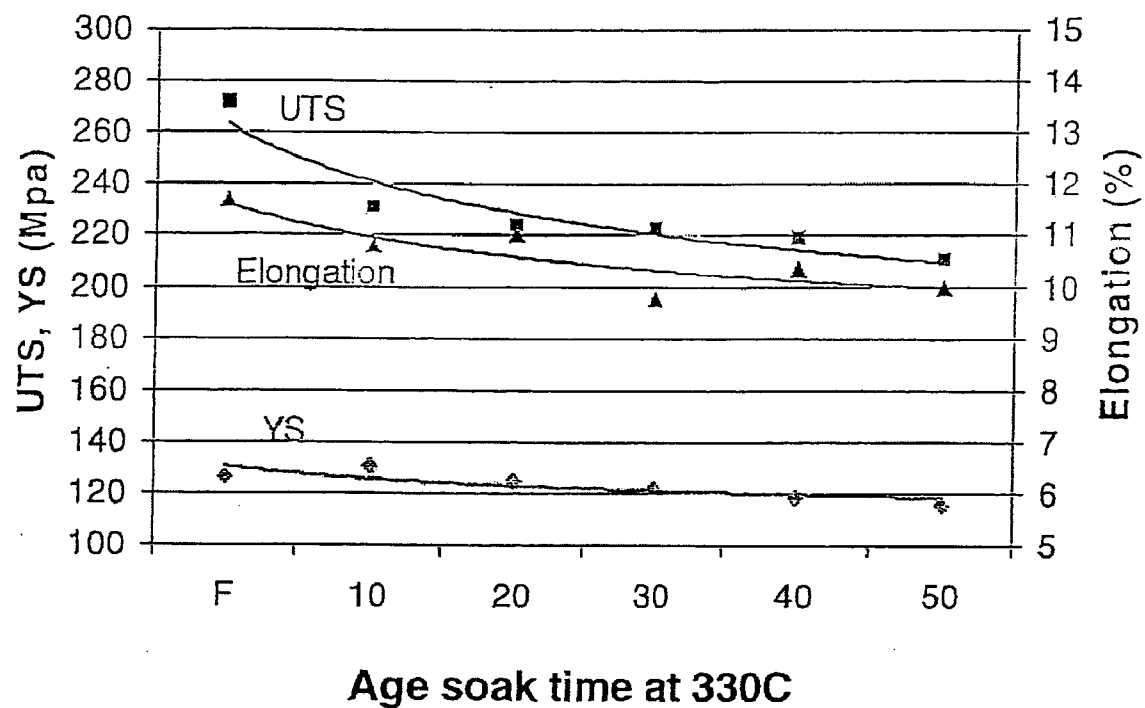


FIGURE 2

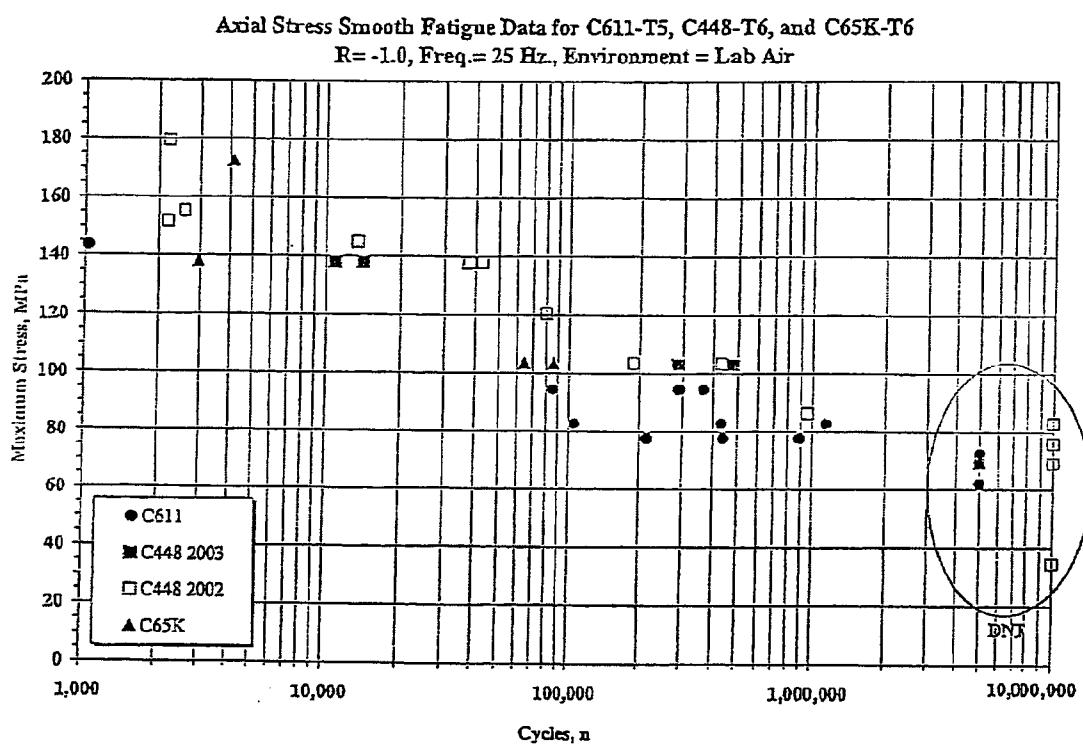


FIGURE 3

AL-SI-MN-MG ALLOY FOR FORMING AUTOMOTIVE STRUCTURAL PARTS BY CASTING AND T5 HEAT TREATMENT

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present invention is based on the provisional patent application entitled An Al—Si—Mn—Mg Alloy for Forming Automotive Structural Parts by Casting and T5 heat Treatment, Application No. 60/535,713, filed on Jan. 9, 2004.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH AND DEVELOPMENT

[0002] The early stage of this invention was developed under a contract with the U.S. Department of Energy, Contract No. DE-AC05-84OR21400.

FIELD OF THE INVENTION

[0003] This invention pertains to an aluminum-silicon alloy for shaped castings wherein the casting process is followed by a T5 heat treatment to improve or stabilize mechanical properties without introducing dimensional changes.

BACKGROUND OF THE INVENTION

[0004] Currently known aluminum die casting alloys for automotive structural applications have silicon contents between about 9-11% by weight. Examples of these alloys include C448 and Silafont 36. The high Si content of these alloys results in brittle Al—Si eutectic networks in the as-cast condition. In order to increase ductility, fracture toughness, and crushability, these alloys need a high temperature solution heat treatment that serves, principally, to break down the eutectic network and to spheroidize the Si particles. The solution heat treatment increases costs and also introduces part distortion which requires straightening or machining, which adds cost in the manufacturing process.

[0005] In recent years, the automotive industry's demand for large aluminum castings for structural components has increased tremendously. These large components include A, B and C posts, engine cradles, door frames, and the like. Due to their size and complexity, it is very difficult, if not impossible, to apply known straightening practices on these castings. As a result, the cost for producing these components using an alloy that requires solution heat treatment and straightening would be very high.

[0006] One non-heat-treatable alloy for which a patent has been obtained is U.S. Pat. No. 6,132,531. That alloy was developed for castings requiring high ductility (>15%) and crushability. Such properties are useful in the manufacture of nodes for a vehicular space frame. A major drawback of that alloy is that it contains beryllium which poses a health hazard during production, and complicates the recycling process.

[0007] There appears to be a need for a beryllium-free aluminum casting alloy having good castability, good mechanical properties, and which does not require high temperature solution heat treatment. For many applications,

including engine cradles and door frames, the alloy is required to have only intermediate ductility (9-15% elongation) and crushability.

SUMMARY OF THE INVENTION

[0008] In one aspect, the present invention is a method of making an aluminum alloy shaped casting. The method includes preparing an aluminum alloy melt with a composition substantially within the following ranges:

[0009] Si: 6.3 wt. %-9 wt. %,

[0010] Mg: 0.05 wt. %-0.4 wt. %,

[0011] Mn<0.8wt. %,

[0012] Cu<0.5 wt. %,

[0013] Zn<1.0 wt. %,

[0014] Fe<0.2wt. %,

[0015] Ti<0.2 wt. %

[0016] Sr<0.04 wt. %.

[0017] The method further includes casting the melt in a mold configured to produce the shaped casting and the method includes a heat treating step wherein the shaped casting is held at a temperature between about 170 C. and about 400 C. for a time between about 10 minutes and about 180 minutes.

[0018] In another aspect, the present invention is a method of making an aluminum alloy shaped casting. The method includes: preparing an aluminum alloy melt with a composition substantially within the following ranges:

[0019] Si: 6.3 wt. %-9 wt. %,

[0020] Mg: 0.05 wt. %-0.4 wt. %,

[0021] Mn<0.8wt. %,

[0022] Cu<0.5 wt. %,

[0023] Zn<1.0 wt. %,

[0024] Fe<0.2wt. %,

[0025] Ti<0.2 wt. %,

[0026] Sr<0.04wt. %.

[0027] The method further includes thixoforming the melt in a mold configured to produce the shaped casting, and the method further includes a heat treating step wherein the shaped casting is held at a temperature between about 170 C. and about 400 C. for a time between about 10 minutes and about 180 minutes.

[0028] In an additional aspect, the present invention is an aluminum alloy shaped casting having a composition substantially in the range

[0029] Si: 6.3 wt. %-9 wt. %,

[0030] Mg: 0.05 wt. %-0.4 wt. %,

[0031] Mn<0.8wt. %,

[0032] Cu<0.5 wt. %,

[0033] Zn<1.0 wt. %,

[0034] Fe<0.2 wt. %,

[0035] Ti<0.2 wt. %

[0036] Sr<0.04 wt. %;

[0037] the aluminum alloy shaped casting receiving a T5 heat treatment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] **FIG. 1** is a photograph of a shaped casting used for testing tensile, yield and elongation properties of alloys according to the present invention after artificial ageing;

[0039] **FIG. 2** is a plot of ultimate tensile strength, yield stress and elongation versus artificial ageing of an alloy according to the present invention; and

[0040] **FIG. 3** is a plot presenting fatigue data for an alloy according to the present invention in comparison with prior art alloys after solution heat treatment.

BRIEF DESCRIPTION OF THE INVENTION

[0041] The invention consists of an Al—Si base alloy for die castings or semi-solid metal forming with the following composition ranges (all in weight percent): Si about 6.3-9 wt. %, Mg about 0.05-0.4 wt. %, Mn<0.8 wt. %, Cu<0.5 wt. %, Zn<1.0 wt. %, Fe less than about 0.2 wt. %, Ti less than about 0.2 wt. %, Sr<0.04, the balance aluminum, incidental elements and impurities.

[0042] Plates (12 mm thick) made with selected compositions within the aforementioned composition ranges using a steel book mold have shown ultimate tensile strengths (UTS) greater than 30 ksi (207 megaPascals), yield strengths (YS) greater than 15 ksi (103 megaPascals), and elongations greater than 15% in the as-cast condition. The mechanical properties after a T5 temper, at 190° C. for 90 minutes, were 35 ksi UTS (241 megapascals), 23 ksi YS (159 megaPascals), and 10% elongation. Die casting or semi-solid metal forming with these compositions for thin-wall castings (about 2-4 mm thick) produces even better properties because thin wall castings have much higher cooling rates, resulting in finer grain size. Castings formed by semi-solid metal forming practices (thixoforming) generally have a non-dendritic microstructure.

[0043] **FIG. 1** is a photograph of a vacuum die cast part comprised of an aluminum alloy including:

[0044] 6.8 wt. % Si,

[0045] 0.097 wt. % Fe,

[0046] 0.577 wt. % Mn,

[0047] 0.251 wt. % Mg,

[0048] 0.0652 wt. % Ti,

[0049] 0.0163 wt. % Ga, and

[0050] 0.0313 wt. % Sr.

[0051] The mass of this casting was 5.2 Kilograms. Its dimensions were 117 cm, 42 cm and 37 cm. The thickness of the ribs was 1.5 mm at peak.

[0052] **FIG. 2** presents tensile, yield and elongation (TYE) data for samples cut from the casting shown in **FIG. 1**. Data are shown for various amounts of artificial ageing at 330 C. The ultimate tensile strength (UTS), Yield stress (YS) and elongation, all desirable properties, decrease during the

artificial ageing. The reason for the artificial ageing is to stabilize the properties of the casting, so they do not change during service. This is particularly a concern for parts which are made for service near a hot engine.

[0053] In another experiment, two alloy compositions, within the limits of the present invention, were tested after artificial ageing at 330 C. for 20 minutes. The alloy labeled as lot 2 was the alloy cited above. The alloy labeled as lot 5 was an aluminum alloy including:

[0054] 7.19 wt. % Si;

[0055] 0.1 wt. % Fe;

[0056] 0.619 wt. % Mn;

[0057] 0.271 wt. % Mg;

[0058] 0.1023 wt. % Ti;

[0059] 0.0174 wt. % Ga; and

[0060] 0.0294 wt. % Sr.

[0061] The following table presents yield, tensile and elongation data for the two alloys. The column labeled "Lot" defines the alloy. The column labeled "Position" gives one of three positions cut from the casting. The row labeled "Average" presents averaged data for the three positions. Each entry in the table is an average of ten or more measurements.

[0062] The data for yield stress (YS) were obtained at a strain of 0.2%. The column labeled UTS refers to ultimate tensile strength. The column labeled Elong. machine refers to elongation in percent measured by machine, and Elong. manual refers to elongation in percent measured manually.

Lot	Position	YS (mPA)	UTS (mPA)	Elong. machine	Elong. manual
2	2	134	275	9.0	11.0
2	4	119	263	11.5	11.7
2	5	127	276	10.9	11.0
2	Average	127	272	10.5	11.2
5	2	137	269	6.7	7.8
5	4	127	270	9.5	10.3
5	5	138	280	10.2	10.2
5	Average	134	273	8.8	9.4

[0063] A Fracture toughness test (Kahn Tear) was also performed on the alloy of lot 2. For an as-cast sample, the fracture toughness in kiloJoules/square meter was 54.9. For a sample artificially aged at 330 C. for 20 minutes, the fracture toughness was 53.4.

[0064] Axial stress smooth fatigue tests were also performed comparing the alloy of lot 2, which is in accordance with the present invention, with two prior art alloys, denoted C65K and C448.

[0065] The alloy denoted C65K is an aluminum alloy including about:

[0066] 10 wt. % Si,

[0067] 0.13wt % Fe,

[0068] 0.60 wt % Mn,

[0069] 0.32 wt % Mg,

[0070] 0.02 wt. % Sr.

[0071] The alloy denoted C448 is an aluminum alloy including about:

[0072] 10 wt. % Si,

[0073] 0.13 wt. % Fe,

[0074] 0.6 wt. % Mn,

[0075] 0.18 wt. % Mg

[0076] 0.02 wt. % Sr.

[0077] The alloy of lot 2 was in T5 condition, the prior art alloys were in T6 condition. Results are presented in FIG. 3. The stress levels were cycled equally between tension and compression, in accordance with the ordinate in FIG. 3. The abscissa denotes the number of cycles to failure. The samples were cycled at 25 Hz, and the environment was laboratory air.

[0078] It is noted, in FIG. 3, that the group of samples at the lower right labeled DNF are samples which did not fail after 5 million or ten million cycles. It is seen in FIG. 3, that the alloy, C611, which is in accordance with the present invention, compares favorably with the prior art alloys, C65K and C448.

[0079] For aluminum alloys of the present invention, the presently preferred composition ranges are as follows:

[0080] Si about 7-8.5 wt. %,

[0081] Mg about 0.1-0.3 wt. %,

[0082] Mn 0.3-0.7 wt. %,

[0083] Cu<0.15 wt. %,

[0084] Zn<0.5 wt. %,

[0085] Fe less than about 0.15 wt. %,

[0086] Ti less than about 0.15 wt. %,

[0087] Sr<0.025.

[0088] Plus incidental elements and impurities. Each incidental element should, preferably, have a concentration of no more than 0.05 wt. %, and the total of incidental elements should, preferably, be no more than about 0.15 wt. %.

[0089] For an alloy in the range cited above, the heat treatment should be a T5 temper in the range from 170 C. to 400 C. with a time at temperature of at least about ten minutes, and no more than about 180 minutes.

[0090] The preferred heat treatment includes heating the casting quickly to a temperature in the range from 250 C. to 350 C. and holding it at that temperature for a time of at least ten minutes, and no more than about half an hour.

[0091] Regarding the composition ranges cited above, it is believed that a lower silicon concentration provides better ductility, a higher silicon concentration provides better castability, i.e., less shrinkage and cracking.

[0092] It is believed that lower magnesium provides better ductility, higher magnesium provides better strength.

[0093] Regarding manganese, it is believed that lower manganese provides better ductility and toughness, and that

higher manganese prevents die sticking. Cobalt, Chromium, Vanadium or Molybdenum may also be used to prevent die sticking.

[0094] Regarding zinc, some indications show that Zn improves ductility and strength of the component in F temper and T5 temper.

[0095] Copper appears to improve the strength of the component after T5 temper.

[0096] Lower iron provides better ductility and toughness, and higher iron prevents die sticking.

[0097] Strontium may be used as a modifier. Alternatively, sodium, antimony or rare earths may be employed as modifiers. Modifiers may be employed to change the form of the silicon phase, either to spheroidize the silicon phase, or to reduce its grain size.

[0098] Alloys according to the present invention may be formed by die casting, vacuum die casting, high pressure die casting, thixotropic metal forming, and by other processes known in the art.

[0099] While the alloys of the present invention have been discussed in some detail above, it is noted that other compositions, falling within the limits of the appended claims, are also within the scope of this invention.

We claim:

1. A method of making an aluminum alloy shaped casting, said method comprising:

preparing an aluminum alloy melt with a composition substantially within the following ranges:

Si: 6.3 wt. %-9 wt. %,

Mg: 0.05 wt. %-0.4 wt. %,

Mn<0.8wt. %,

Cu<0.5 wt. %,

Zn<1.0 wt. %,

Fe<0.2 wt. %,

Ti<0.2 wt. %

Sr<0.04wt. %;

casting said melt in a mold configured to produce said shaped casting; and

a heat treating step wherein said shaped casting is held at a temperature between about 170 C. and about 400 C. for a time between about 10 minutes and about 180 minutes.

2. A method, according to claim 1, wherein said temperature in said heat treating step is in the range from about 250 C. to about 350 C.

3. A method, according to claim 1, wherein said time in said heat treating step is in the range from about 10 minutes to about 30 minutes.

4. A method of making an aluminum alloy shaped casting, said method comprising:

preparing an aluminum alloy melt with a composition substantially within the following ranges:

Si: 6.3 wt. %-9 wt. %,

Mg: 0.05 wt. %-0.4 wt. %,

Mn<0.8 wt. %,

Cu<0.5 wt. %,

Zn<1.0 wt. %,

Fe<0.2 wt. %,

Ti<0.2 wt. %,

Sr<0.04 wt. %;

thixoforming said melt in a mold configured to produce said shaped casting; and

a heat treating step wherein said shaped casting is held at a temperature between about 170 C. and about 400 C. for a time between about 10 minutes and about 180 minutes.

5. A method, according to claim 4, wherein said temperature in said heat treating step is in the range from about 250 C. to about 350 C.

6. A method, according to claims 4, wherein said time in said heat treating step is in the range from about 10 minutes to about 30 minutes.

7. An aluminum alloy shaped casting having a composition substantially in the range

Si: 6.3 wt. %-9 wt. %,

Mg: 0.05 wt. %-0.4 wt. %,

Mn<0.8 wt. %,

Cu<0.5 wt. %,

Zn<1.0 wt. %,

Fe<0.2wt. %,

Ti<0.2 wt. %

Sr<0.04 wt. %;

said aluminum alloy shaped casting receiving a T5 heat treatment.

8. An aluminum alloy shaped casting, according to claim 7, wherein a temperature of said T5 heat treatment is at least about 170 C.

9. An aluminum alloy shaped casting, according to claim 7 wherein a temperature of said T5 heat treatment is no more than about 400 C.

10. An aluminum alloy shaped casting, according to claim 7, wherein a temperature of said T5 heat treatment is at least about 250 C.

11. An aluminum alloy shaped casting, according to claim 7, wherein a temperature of said T5 heat treatment is no more than about 350 C.

12. An aluminum alloy shaped casting, according to claim 7, wherein a time of said T5 heat treatment is at least about 10 minutes.

13. An aluminum alloy shaped casting, according to claim 7, wherein a time of said T5 heat treatment is no more than about 180 minutes.

14. An aluminum alloy shaped casting, according to claim 7, wherein a time of said T5 heat treatment is no more than about 30 minutes.

15. An aluminum alloy shaped casting, according to claim 7, wherein said aluminum alloy shaped casting is a vehicle body structure casting.

16. An aluminum alloy shaped casting, according to claim 7, wherein said Si is in a range from about 7 wt. % to about 8.5 wt. %.

17. An aluminum alloy shaped casting, according to claim 7, wherein said Mg is in a range from about 0.1 wt. % to about 0.3 wt. %.

18. An aluminum alloy shaped casting, according to claim 7, wherein said Mn is in a range from about 0.3 wt. % to 0.7 wt. %.

19. An aluminum alloy shaped casting, according to claim 7, wherein said Cu is limited to a maximum of about 0.15 wt. %.

20. An aluminum alloy shaped casting, according to claim 7, wherein said Zn is limited to a maximum of about 0.5 wt. %.

21. An aluminum alloy shaped casting, according to claim 7, wherein said Fe is limited to a maximum of about 0.15 wt. %.

22. An aluminum alloy shaped casting, according to claim 7, wherein said Ti is limited to a maximum of about 0.15 wt. %.

23. An aluminum alloy shaped casting, according to claim 7, wherein said Sr is limited to a maximum of about 0.025 wt. %.

24. An aluminum alloy shaped casting, according to claim 7, further comprising additional elements, wherein each additional element is limited to a maximum of about 0.05 wt. %.

25. An aluminum alloy shaped casting, according to claim 7, further comprising additional elements, wherein a total of said additional elements is limited to a maximum of about 0.15 wt. %.

26. An aluminum alloy shaped casting, according to claim 7, wherein said aluminum alloy shaped casting has a non-dendritic microstructure.

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