Disclosed is a method for producing aluminum vehicular structural parts or members such as from molten aluminum alloy using a continuous caster to cast the alloy into a slab. The method comprises providing a molten aluminum alloy consisting essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.05 to 0.30 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities and providing a continuous caster such as a belt caster, block caster or roll caster for continuously casting the molten aluminum alloy. The molten aluminum alloy is cast into a slab which is rolled into a sheet product and then annealed. The sheet has an improved distribution of intermetallic particles (Al—Fe, Al—Fe—Mn or Mg, Si) and improved formability. Thereafter, the sheet product is formed into the vehicular structural part or member with sufficient strength and formability required by automotive industry.
PROVIDING MOLTEN ALUMINUM ALLOY

PROVIDING A CONTINUOUS BELT CASTER

CASTING A CONTINUOUS SLAB OF ALUMINUM ALLOY 0.2 TO 2.0 INCH THICK

HOT ROLLING SLAB

ANNEALING HOT ROLLED SHEET

ANNEALING COLD ROLLED SHEET

FORMING ALUMINUM ALLOY SHEET INTO AUTOMOTIVE STRUCTURAL PARTS OR MEMBERS

FIG. 2
FIG. 3

Grain structure of DC 5754 aluminum alloy, 1.5 mm, O-temper

FIG. 4

Grain structure of CC 5754 aluminum alloy, 1.5 mm, O-temper
BACKGROUND OF THE INVENTION

This invention relates to aluminum alloy vehicular structural parts or members and more particularly, it relates to a method of casting aluminum alloy into sheet having good forming characteristics and to forming the sheet into vehicular structural parts or members such as dash panel, floor panel, door panel, window trim, radio bracket, reinforcements for panels, etc.

In many instances, continuous casting of molten aluminum into slab utilizing twin belt, twin roll or block casters is favored over DC casting because continuous casting can result in substantial energy savings and total conversion cost savings compared to the DC cast method. In the continuous casting process, molten metal is continuously introduced to an advancing mold and a slab is produced which may be continuously formed into a sheet product which is collected or wound into a coil. However, the continuous casting is not without problems. For example, it has been discovered that the alloy composition and the processing steps must be carefully controlled in order to have the formability level to avoid cracking during forming and yet have the requisite strength properties in the final product. That is, the alloy and the processing thereof must be carefully controlled to provide sheet having the formability suited to the fabricating steps necessary to form the final product or vehicular structural parts. If the alloy and processing steps are not controlled, then in the forming steps, fracture can occur and the formed parts have to be scrapped. Thus, there is a great need for selection of an aluminum alloy, continuous casting thereof, and thermal mechanical processing methods which provide a sheet product having forming characteristics and strength properties which permit forming operations such as bending, stamping, deep drawing, stretching or crimping to hold fasteners during production of vehicular structural parts or members while avoiding problems of fracturing or cracking, for example.

The continuous casting of molten aluminum and rolling slab produced therefrom into a sheet product is disclosed in various patents. For example, U.S. Pat. No. 5,976,279 discloses a process for continuously casting aluminum alloys and improved aluminum alloy compositions. The process includes the steps of continuously annealing the cold rolled strip in an intermediate anneal using an induction heater and/or continuously annealing the hot rolled strip in an induction heater. The alloy composition has mechanical properties that can be varied selectively by varying the time and temperature of a stabilizing anneal.

U.S. Pat. No. 6,264,765 discloses a method and apparatus for casting, hot rolling and annealing non-heat treatment aluminum alloys. The method and apparatus comprises continuous casting, hot rolling and in-line inductively heating the aluminum sheet to obtain the mechanical properties within the specification tolerance of the hot rolled product.

U.S. Pat. No. 5,985,058 discloses a process for continuously casting aluminum alloys and improved aluminum alloy compositions. The process includes the step of heating the cast strip before, during or after hot rolling to a temperature in excess of the output temperature of the cast strip from the chill blocks. The alloy composition has a relatively low magnesium content yet possesses superior strength properties.

U.S. Pat. No. 5,993,573 discloses a process for continuously casting aluminum alloys and improved aluminum alloy compositions. The process includes the steps of (a) heating the cast strip before, during or after hot rolling to a temperature in excess of the output temperature of the cast strip from the chill blocks and (b) stabilization or back annealing in an induction heater of cold rolled strip produced from the cast strip.

U.S. Pat. No. 5,833,775 discloses an aluminum alloy sheet and a method for producing an aluminum alloy sheet. The aluminum alloy sheet is useful for forming into drawn and ironed container bodies. The sheet preferably has an after-bake yield strength of at least about 37 ksi and an elongation of at least about 2 percent. Preferably the sheet also has aching of less than about 2 percent.

U.S. Pat. No. 6,086,690 discloses a process of producing an aluminum alloy sheet article of high yield strength and ductility suitable, in particular, for use in manufacturing automotive panels. The process comprises casting a non-heat-treatable aluminum alloy to form a cast slab, and subjecting said cast slab to a series of rolling steps to produce a sheet article of final gauge, preferably followed by annealing to cause recrystallization. The rolling steps involve hot and warm rolling the slab to form an intermediate sheet article of intermediate gauge, cooling the intermediate sheet article, and then warm and cold rolling the cooled intermediate sheet to final gauge at a temperature in the range of ambient temperature to 340°C. to form said sheet article. The series of rolling steps is carried out continuously without intermediate cooling or full annealing of the intermediate sheet article. The invention also relates to the alloy sheet article produced by the process.

U.S. Pat. No. 5,244,516 discloses an aluminum alloy plate for discs superior in Ni—P platability and adhesion of plated layer and having a high surface smoothness with a minimum of nodules and micropits, said aluminum alloy plate comprising an aluminum alloy containing as essential elements Mg in an amount more than 3% and equal to or less than 6%, Cu in an amount equal to or more than 0.03% and less than 0.3%, and Zn in an amount equal to or more than 0.03% and equal to or less than 0.4%, and as impurities Fe in an amount equal to or less than 0.07% and Si in an amount equal to or less than 0.06% in the case of semi-continuous casting, or Fe in an amount equal to or less than 0.1% and Si in an amount equal to or less than 0.1% in the case of strip casting, and also containing Al—Fe phase intermetallic compounds, with the maximum size being smaller than 10 μm and the number of particles larger than 5 μm being less than 5 per 0.2 mm², and Mg—Si phase intermetallic compounds, with the maximum size being smaller than 8 μm and the number of particles larger than 5 μm being less than 5 per 0.2 mm².

U.S. Pat. No. 5,514,228 discloses a method for manufacturing aluminum sheet stock which includes hot rolling an aluminum alloy sheet stock, annealing and solution heat treating it without substantial intermediate cooling and rapid quenching.

In spite of these disclosures, there is a great need for selection of aluminum alloy and method for producing
vehicular parts or members utilizing a continuous caster, optimized thermal mechanical processing, to provide good strength and levels of formability which permit ease of forming into intricate parts without cracking.

[0012] The term “formability” when used herein is used to describe the ease with which a sheet of metal can be shaped through plastic deformation. Formability of a metal can be evaluated by measuring strength, ductility, and the amount of deformation to cause failure.

[0013] The term “aluminum” when used herein is meant to include aluminum and its alloys.

[0014] The term “automotive” as used herein is meant to include automobile and other vehicular parts or members as described herein and other transport parts or members having similar construction.

SUMMARY OF THE INVENTION

[0015] It is an object of the invention to provide an improved, low cost process including continuous casting and rolling to continuously produce aluminum sheet product having consistent levels of formability.

[0016] It is another object of the invention to provide a process including continuously casting a slab and rolling the slab into a sheet product suitable for use in producing vehicular parts.

[0017] It is still another object of the invention to provide a process employing continuous casting of molten aluminum into slab and rolling the slab into sheet product for meeting the forming requirements, such as bending, stamping, stretching or deep drawing of vehicle structural parts or members.

[0018] And yet it is another object of the invention to provide an improved process for producing aluminum sheet product employing a continuous caster to produce slab, continuously rolling the slab to produce a sheet product and annealing the sheet product for forming into vehicular structural parts or panel members having fasteners such as threaded fasteners attached thereto by crimping the sheet product around the fastener.

[0019] It is yet another object of the invention to provide a process for producing vehicular members such as shallow or deep formed panel members which includes continuously casting an aluminum alloy into a slab, rolling the slab to a sheet product and annealing the sheet product having good levels of formability, forming the sheet product into a panel having threaded fasteners attached thereto by crimping to provide a formed vehicular member for mechanically fastening to support members, for example.

[0020] And yet it is another object of the invention to provide a process for casting a molten alloy comprising 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.05 to 0.30 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities, casting the alloy into a slab which is hot rolled and annealed to provide a sheet product suitable for forming into a vehicular structural part or frame member where good formability is necessary.

[0021] In accordance with these objects, there is provided a process for producing aluminum vehicular structural parts or members from molten aluminum alloy using a continuous caster to cast the alloy into a slab. The method comprises providing a molten aluminum alloy consisting essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.05 to 0.25 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities and providing a continuous caster such as a belt caster for continuously casting the molten aluminum alloy. The molten aluminum alloy is cast into a slab having Al—Fe, Al—Fe—Mn or Mg—Si containing intermetallic particles. The slab is rolled into a sheet product which is then annealed to provide a sheet product having a substantially uniform distribution or less striations of intermetallic particles for improved formability. Thereafter, the sheet product is formed into a vehicular structural part or member such as a panel member for a door or hood, for example, having fasteners cramped thereto.

[0022] Alternatively, the hot rolled sheet may be cold rolled after hot rolling, and then annealed prior to the forming steps. In yet another embodiment, the hot rolled sheet may be annealed or even homogenized and then cold rolled to a cold rolled sheet product. The cold rolled product can be annealed to provide a product suited to the various forming steps.

[0023] These and other objects will become apparent from a reading of the specification and claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] FIG. 1 is a schematic of a continuous caster, hot rolling mill and rolls of sheet material.

[0025] FIG. 2 is a flow chart showing steps in the invention.

[0026] FIG. 3 is a micrograph showing microstructure of D.C. cast material.

[0027] FIG. 4 is a micrograph showing microstructure of sheet material formed by continuous casting (CC) and rolling in accordance with the invention.

[0028] FIG. 5 is a schematic of a vehicular rear hatch door or lift gate.

[0029] FIG. 6 is a side view of a vehicle showing rear door open.

[0030] FIG. 7 is a perspective view showing structural members of a rear hatch door separated.

[0031] FIG. 8 is a cross-sectional view showing structural members hemmed together.

[0032] FIG. 9 is a cross-section of a threaded fastener crimped into the metal.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0033] The vehicular structural parts or members, for example, of the invention are comprised of an aluminum base alloy containing controlled amounts of magnesium, iron, silicon and manganese for the required strength and formability in the sheet product produced by the casting and thermomechanical process. The total amounts of the alloying elements are required to be controlled to meet the
strength requirement without causing casting difficulty in the process. Further, the amount of alloying elements also is required to be controlled to meet the formability requirements, especially the amount of iron, manganese and silicon. Al—Fe, Al—Fe—Mn or Mg—Si intermetallic particles form during solidification. That is, the distribution, size and amount of such intermetallic particles after rolling of continuous cast slab can drastically influence the formability of the sheet material.

The Al—Fe, Al—Fe—Mn or Mg—Si containing intermetallic particles form during solidification. The distribution of such intermetallic particles after rolling of continuous belt cast aluminum slab can be severely striated or lined causing forming problems. By comparison, direct chill (D.C.) ingot cast material has a more uniform distribution of intermetallic particles providing good formability. Striations of intermetallic particle structure causes stress concentration during plastic deformation which deteriorate formability of the sheet product. Thus, it is desired that the rolled sheet of the invention has a substantially uniform distribution or less striations of intermetallic particles to provide for improved formability.

Accordingly, the aluminum base alloy consists essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.20 to 0.2 wt. % Si, 0.05 to 0.3 wt. % Fe, 0.05 to 0.3 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities. Preferably, magnesium is maintained in the range of 2.8 to 3.5 wt. % and manganese is preferably maintained in the range of 0.1 to 0.25 or 0.35 wt. %. Furthermore, iron is maintained in the range of 0.05 or 0.10 to 0.25 wt. %, typically 0.05 to 0.2 wt. % and silicon is maintained in the range of 0.05 to 0.15 wt. %. Impurities are preferably limited to not more than 0.05 wt. % each and the combination of impurities should not be greater than 0.15 wt. % total.

It will be understood that to use an alloy of the above composition in the process of the invention to form automotive members having the requisite properties requires careful control of the alloying elements in the alloy and the casting thereof to avoid forming intermetallic particle structures adverse to the forming operation. That is, it will be appreciated that in the present process, there is great difficulty in balancing all the constituents in the alloy for strength and procedural steps necessary to forming a sheet product having desirable properties for forming into the final product while avoiding undesirable properties which leads to fracture or cracking, for example, during the forming process.

Not only is it important to have alloying elements and impurities in the controlled amounts as herein described, but the slab produced by continuous casting, the sheet formed from the slab and automotive member fabricated from the sheet must be prepared in accordance with specific method steps in order to produce sheet and automotive structural parts or members therefrom having the desirable characteristics. That is, the process must be controlled in order to produce product having near formability properties of DC ingot fabricated material without the cost penalties of the DC ingot process.

Thus, referring now to FIG. 1, there is shown a schematic illustration of a belt caster 2 and rolling mill 30 for producing sheet suitable for forming into vehicular structural parts or members in accordance with the invention.

In FIG. 1, molten aluminum 10 is provided in a furnace or reservoir 12. Molten aluminum from reservoir 12 is directed along line 14 to a turbish 16 from where it is metered through a nozzle 18 into an advancing mold created by revolving belts 20 and 22 and side dam blocks (not shown). Belts 20 and 22 are turned by means of rolls 24. Molten metal, e.g., molten aluminum, is solidified to form a continuous slab 15 between belts 20 and 22 which are chilled using coolant spray 26. Belt caster 2 is described in U.S. Pat. Nos. 3,864,973; 3,921,697; 4,638,438; 4,940,076 and 4,972,500, incorporated herein by reference as if specifically set forth. Improved nozzles for a belt caster are set forth in U.S. Pat. No. 5,452,827, incorporated herein by reference.

Another casting apparatus that may be used in the present invention is a block caster wherein the blocks are connected to form belts and is included herein as a belt caster. As described with respect to belt caster 2, a turbish and nozzle are provided to transfer molten metal to the block belts of the block caster wherein solidification occurs to provide a solidified slab 15 and the blocks are chilled to aid in solidification of the molten metal.

Yet another apparatus that may be utilized to cast a continuous strip or slab 15 is a roll caster which includes two rolls which rotate to provide the continuously advancing mold. As in the belt caster, a turbish and nozzle are used to transfer molten aluminum to the mold defined by the two rolls. Again, the rolls are normally chilled to aid in solidification of the molten metal into a strip or slab. The different casters are described in U.S. Pat. No. 5,452,827. By the use of the term “continuous caster” is meant to include all these casters.

Molten aluminum alloy of the invention is introduced to the caster in a temperature range of about 1220° to 1320° F., typically 1250° to 1285° F., and exits the caster at a temperature in the range of 750° to 1150° F., typically 860° to 950° F. In addition, typically the continuous slab exiting the belt caster has a thickness in the range of 0.2 to 2 inches, for example, 0.2 to 1 inch. A typical slab thickness for the belt caster is about 0.6 to 0.875 inch. Belt casting speed can range from 10 to 40 ft./min, depending on the thickness of the slab. It is important to adhere to these casting conditions in order to obtain microstructures with less striations or lines of intermetallics such as Al—Fe, Al—Fe—Mn or Mg—Si for purposes of formability and corrosion resistance. It should be noted that DC cast material normally has good or substantially uniform distribution of intermetallic particles. But, as noted earlier, DC cast material has the penalty of higher conversion costs than the subject continuous cast slab. Thus, the present invention provides continuous cast slab for forming into sheet material with near DC cast properties to obtain the cost savings and yet retain the desirable properties such as formability.

After exiting the caster, the slab 15 is directed to rolling mill 30 where it is rolled to form a rolled strip or flat product 34 using preferably a hot mill. Hot mill 30 is comprised of one or more pairs of oppositely opposed rolls 32 which reduces the thickness of the slab a controlled amount as it passes between each stand of rolls. Three sets of hot stands or rolls are illustrated in FIG. 1. For example, slab 15 having a thickness of about 0.2 to 1 inch would be reduced to a sheet product having a thickness of about 0.01
to 0.25 inch. Typically, for vehicular structural parts or plural panel members the sheet product would have a thickness in the range of 0.02 to 0.1 or 0.2 inch, for example, depending on the application. The temperature of the slab entering hot mill 30 would typically be in the range of about 700°F to 1100°F, if no heat is added. Typically, temperature of sheet product exiting mill 30 would be in the range of 350°F to 700°F. In another aspect of the invention, the slab from caster 3 may be heated prior to hot rolling (not shown in FIG. 1) to a temperature of 800°F to 1100°F, to increase the rolling temperature prior to hot rolling. Thus, slab entering the hot mill can have temperatures of about 800°F to 1100°F.

[0044] Hot mill 30 can reduce the thickness of the slab about 60 to 95% of its original thickness, with typical reduction being 75 to 95%. Depending on the end use of the sheet product, heat may be applied to the strip or slab between hot stands in addition to or instead of heating prior to the hot mill.

[0045] The temperature of the aluminum alloy sheet exiting the hot mill can be in the range of about 400°F to 825°F, depending on whether there was heat input before or during hot rolling.

[0046] After hot rolling, hot rolled strip 34 can have a deformation texture and deformed grain structure. The hot rolled strip can have a partially or fully recrystallized grain structure with an optimum texture depending on previous heat input and rolling reduction. If the structure remains deformed and a recrystallized grain structure is necessary for the end product, then annealing of the hot rolled strip 34 can be applied to promote recrystallization of the deformed structures. For example, it is important for automotive application using the aluminum alloy of the invention to have a fine, fully recrystallized grain structure with random texture for the purpose of forming automotive parts in accordance with the invention. Thus, in the present invention, it is preferred that the hot rolled sheet be fully annealed to O-temper in annealer 40. Hot rolled sheet in the fully annealed condition can have a tensile strength in the range of 28 to 35 ksi, a yield strength in the range of 12 or 13 to 17.5 ksi and an elongation greater than 19%.

[0047] Referring to FIG. 1, it will be seen in the embodiment illustrated that the hot rolled sheet product is directed to a continuous annealer 40, using a heater such as an infrared, solenoidal or transverse flux induction heater. While any continuous heater may be used, an induction heater is preferred. Continuous anneal may also be required if cold rolling (not shown in FIG. 1) of the hot rolled strip is necessary. Thus, the hot or cold rolled strip may be continuously annealed in annealer 40 in a temperature range of 600°F to 1100°F, in time periods from 0.5 to 60 seconds in order to effect fully recrystallized sheet having fine grains and highly desired formability properties. However, care is required that the sheet product is not over annealed to the point where secondary recrystallization occurs. Secondary recrystallization is the growth of fine grains into undesirable coarse grains which are detrimental to formability.

[0048] Instead of continuous annealing, the hot rolled sheet may be batch annealed. That is, hot rolled sheet 42 is wound into coils 48 or 49. These coils are then placed in a furnace and soaked in a temperature range of 600°F to 1000°F for 2 to 10 hours to provide the rolled sheet in a fully annealed or O-temper condition. If the slab has been hot rolled to a gauge suitable for forming, then no further thermal mechanical processing is necessary and the sheet is in condition for the forming steps. If the slab has been hot rolled to an intermediate gauge, then after annealing, the annealed material is subjected to cold rolling followed by further annealing to provide sheet in the O-temper for forming operations.

[0049] After hot rolling, the hot rolled sheet or flat product may be allowed to cool prior to other operations. For example, after hot rolling, with or without annealing and cooling, the resulting strip 42 may be cold rolled (not shown in FIG. 1) to a sheet product having a final gauge. The cold rolling may be performed by passing strip 42 through several pairs or stands comprising a cold mill to provide the cold rolling required to produce the final gauge. Cold rolling can reduce the thickness of strip 42 by 20% to 90% or 90%. Final gauge can range from 0.02 to 0.09 or even 0.2 inch, typically 0.03 to 0.12 inch, for automotive applications. It will be appreciated that the cold rolling, which is rolling at lower than 300°F, can be performed in a cold rolling line separate from the subject continuous casting and rolling line.

[0050] After cold rolling to final gauge, the sheet product is subject to further anneal to ensure the required crystallographic texture and grain structure necessary for forming into the final automotive product.

[0051] After hot rolling or annealing sheet 42 may be subject to a continuous rapid quenching such as cold water quench 50 prior to further operations. Quench 50, if used and shown after anneal, can be located at different locations in the process.

[0052] Referring to FIG. 2, it will be seen that in an alternate process annealed hot rolled sheet may subject cold rolling followed by further annealing prior to forming. In a further embodiment or alternate process, after hot rolling, the sheet may be directly cold rolled followed by annealing of the cold rolled sheet prior to being formed into a vehicular structural part or member. The cold rolled and annealed sheet, along the rolling direction, can have a tensile strength in the range of 28 to 35 ksi, a yield strength in the range of 12 to 17.5 ksi and an elongation greater than 19%. Further, the finish gage coils may go through one or combination of steps before the forming process, such as tension leveling, slitting, surface pretreatment, lubrication or cut-to-length.

[0053] As an example of the desirable microstructures which have good forming characteristics of continuously cast (CC) aluminum sheet, reference is made to FIGS. 3 and 4. FIG. 4 shows the microstructure of CC 5754 alloy with controlled chemistry while FIG. 3 shows that of the commercially used DC 5754 alloy sheet. Both sheets are 0.060 inch in thickness and are in the O-temper condition. SEM inspection of the particles which were formed during solidification shows that they are comprised of Al—Fe, Al—Fe—Mn and Mg,Si. The particle structure of CC sheet is substantially uniformly distributed with only minimal strations or lines while the intermetallic particles of DC sheet are uniformly distributed. The intermetallic particle size of CC material ranges from about 0.1 to 7 μm while that of DC material ranges from about 0.5 to 10 μm. The area fraction of intermetallic particles is 0.43% for CC material while the area fraction is 0.56% for DC material. Also, with the optimum-processing route, CC sheet has a finer grain structure than DC sheet. The measurement of the grain size shows
that CC material has an average grain size of 16.6 μm while DC material has an average grain size of 17.8 μm. Thus, it will be seen that with control of chemistry and optimization of processing, the continuous cast technology can produce microstructures which are similar to those produced by the DC cast technology and thus provides formability properties required by automotive industry, for example.

[0054] Referring now to FIG. 5 there is illustrated an automotive lift gate 100 provided as part of a sports utility vehicle (SUV). The lift gate is comprised of a bottom metal portion 102 and a window frame portion 104 covered with glass. Lift gate 100 is mounted to roof 108 of the SUV using hinges 106 and is closed or secured to the vehicle using handle 110. Generally, sides 112, bumper 114 and roof 108 define the opening closed by the lift gate. In FIG. 6, lift gate 100 is shown partially open and supported by strut 116. Compared to steel, a lift gate fabricated from an aluminum alloy of the invention can result in substantial weight savings which can be as much as 20 pounds, depending on the vehicle. Further, lighter and less costly struts can be used to open and support the lift gate, adding to the weight savings. It will be noted that strut 116 is fastened to lift gate 100 at 118 which requires the aluminum alloy to have good forming characteristics to hold a threaded fastener.

[0055] FIG. 7 shows an exploded view of an automotive lift gate structure comprised of an outer panel 120 and an inner panel 122 which are peripherally provided to provide a dual panel lift gate structure. It will be appreciated that doors, hoods, fenders and the like can employ the same type of construction, i.e., inner and outer panels. Further, it will be seen from FIGS. 7 and 8 that outer panel 120 employs a generally curved, smooth shape. Also from FIG. 7 it will be seen that outer panel 120 configuration shows window frame 104 as an integral part of bottom portion 102. Referring further to FIG. 7, it will be noted that inner panel 122 uses a more complicated design which includes dished portions 124 and can have raised channels and open portions (not shown), particularly when used for doors or hoods. The inner panel with its dished portions and raised portions serves to increase the flexural strength of the lift gate. Further, the inner panel or outer panel can be shaped from a single sheet using stamping between mating dies to provide the structural features necessary to the lift gate assembly. While the outer panel is relatively smooth and curved, as noted, the inner panel will usually be shaped to form a channel 126 (FIG. 8) to provide increased strength to the window frame portion. It should be noted that outer panel 120 can be formed of steel or, for example, aluminum alloys AA6111 or AA5083, the composition of which is provided in the Aluminum Association publication entitled “International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys”, dated January 2001, all of which is incorporated herein by reference as if specifically set forth.

[0056] FIG. 8 shows a cross section of a lift gate employing outer panel 120 hemmed or scarred to inner panel 122. Thus, outer panel 120 is relatively smooth and inner panel 122 has recessed areas and employs a channel around the window frame 104 for increased strength. The lift gate derives its strength from the dual or plural structure of the two formed panels.

[0057] Formed panels can include doors, hoods, trunk lids, fenders, floors, wheels and bumper backup bars and can be formed from flat sheets of aluminum alloy formed between mating dies to provide a three-dimensional structure. The dual or plural structure as depicted employs peripheral seaming or hemming to provide the vehicular structural member; however, other means of joining can include welding, riveting, adhesive bonding and thus the inner and outer panels can be joined by any of these methods and such is contemplated. The seaming or hemming referred to is shown in FIG. 8 where outer panel 120 is hemmed around inner panel 122. Thus, outer panel 120 should be capable of forming or bending 180° without cracking where the radius of the bend is about half the thickness of the metal.

[0058] In some instances, the structural member may include a combination of steel and aluminum alloy, but such structure would not provide the same weight savings.

[0059] The alloy of the invention is required to have good formability for yet another reason. That is, hinges 106 and struts 116, for example, are preferred to be joined to steel threaded fasteners. Thus, at 118 where strut 116 is connected to lift gate 100, it is preferred to use a metal fastener such as a steel fastener. Accordingly, a threaded fastener 130 is crimped into the sheet metal of the inner panel as shown in FIG. 9. The crimping must be of a severity to pull the sheet metal around shoulder 132 of the threaded fastener without forming cracks in the sheet metal. The locking of the threaded fastener in the sheet metal must be sufficiently tight to permit screwing a bolt through an eye in the strut into the fastener. Crimping in this manner obviates welding and readily permits joining of aluminum to a steel threaded fastener for ease of fabrication. Crimping is alloy sensitive and if the iron is too high, the metal can crack during the crimping operation. Thus, for purposes of crimping, it is preferred to keep iron less than 0.25 wt. % and preferably in the range of 0.05 or 0.1 to 0.2 wt. %.

[0060] Thus, aluminum alloy vehicular parts or members produced in accordance with the foregoing practices provide material having the strength and formability for use as vehicular or automotive sheet which can be formed into many different automotive structural members.

[0061] All ranges provided herein are meant to include all the numbers within the range as if specifically set forth, e.g., 1 to 5 would include 1.1, 1.2, 1.3, etc., or e.g., 2, 3, 4.

[0062] The following example is further illustrative of the invention.

EXAMPLE

[0063] An aluminum base alloy containing 3.267 wt. % Mg, 0.201 wt. % of Mn, 0.080 wt. % Si, 0.164 wt. % Fe, 0.020 wt. % Cu, 0.004 wt. % Cr and 0.024 wt. % Zn, was fed to a twin belt caster at a temperature of 1260°F. and solidified to produce a 0.875 inch thick slab existing the caster at a temperature of 900°F. The slab was directly fed into a three stand hot rolling mill and rolled to final gauge of 0.100 inch. The temperature of introducing the slab to the hot rolling mill was at about 820°F. and the temperature of exiting the mill was at about 520°F. The hot rolled sheet was wound into a coil. The coil was annealed in an anneal furnace at a temperature of 730°F. for 4 hours. The annealed coil was tension leveled and slit into the required width and then the coil was given a surface pretreatment and lubricated. The material had properties in the rolling direction
before forming into automotive parts of: ultimate tensile strength of 32.8 ksi, yield strength of 15.5 ksi, elongation of 21.4%. All these properties met the requirement identified by Aluminum for Automotive Body Sheet Panels, published by The Aluminum Association. The material was formed into inner structural panels, and threaded fasteners were crimped into the sheet with satisfied quality inspection. Thus, the alloy can be cast in a twin belt caster, rolled into a sheet product, stamped or shaped into an automotive structural part or member with sufficient strength and formability.

[0064] It will be seen that the continuous caster can be used to produce a slab which can be thermomechanically treated to form a sheet product having the properties for forming into vehicular parts or members.

[0065] Having described the presently preferred embodiments, it is to be understood that the invention may be otherwise embodied within the scope of the appended claims.

What is claimed is:

1. In the production of an aluminum automotive structural part or member from a molten aluminum alloy using a continuous caster to cast the alloy into a slab, the method comprising:
   (a) providing a molten aluminum alloy consisting essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.05 to 0.30 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities;
   (b) providing a continuous caster for continuously casting said molten aluminum alloy;
   (c) casting said molten aluminum alloy into a slab having Al—Fe, Al—Fe—Mn or Mg2Si intermetallic particles;
   (d) rolling said slab into a sheet product;
   (e) annealing said sheet product to an O-temper condition, said sheet having substantially uniform distribution or minimized striations of said intermetallic particles; and
   (f) forming said sheet in said O-temper into said structural part or member.

2. In the production of the aluminum structural member in accordance with claim 1 wherein manganese is maintained in the range of 0.1 to 0.35 wt. %.

3. In the production of the aluminum structural part or member in accordance with claim 1 wherein magnesium is maintained in the range of 2.8 to 3.5 wt. %.

4. In the production of the aluminum structural part or member in accordance with claim 1 wherein iron is maintained in the range of 0.5 to 0.25 wt. %.

5. In the production of the aluminum structural part or member in accordance with claim 1 wherein said continuous caster is a belt caster, a block caster or a roll caster.

6. In the production of the aluminum structural part or member in accordance with claim 1 including annealing said sheet product in a temperature range of 650°F to 950°F.

7. In the production of the aluminum structural part or member in accordance with claim 1 including annealing said sheet product in a temperature range of 700°F to 900°F.

8. In the production of the aluminum structural part or member in accordance with claim 1 including annealing for about 2 to 10 hours.

9. In the production of the aluminum structural part or member in accordance with claim 1 including continuously annealing said sheet product.

10. In the production of the aluminum structural part or member in accordance with claim 1 including hot rolling said slab to a hot rolled sheet product.

11. In the production of the aluminum structural part or member in accordance with claim 1 including hot rolling said slab to a hot rolled sheet product followed by cold rolling.

12. In the production of the aluminum structural part or member in accordance with claim 11 wherein said cold rolling provides a 25 to 80% gauge reduction.

13. In the production of the aluminum structural part or member in accordance with claim 11 including annealing said cold rolled sheet product.

14. In the production of the aluminum structural part or member in accordance with claim 13 wherein said cold rolled sheet product is annealed in a temperature range of 600°F to 950°F.

15. In a method for the production of an aluminum automotive structural part or member from molten aluminum alloy using a continuous caster to cast the alloy into a slab, the method comprising:
   (a) providing a molten aluminum alloy consisting essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.05 to 0.30 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities;
   (b) providing a continuous caster for continuously casting said molten aluminum alloy;
   (c) casting said molten aluminum alloy into a slab having a thickness in the range of 0.2 inch to 2 inch and having Al—Fe, Al—Fe—Mn or Mg2Si intermetallic particles;
   (d) rolling said slab into a hot rolled sheet product, said hot rolling starting in a temperature range of 750°F to 1000°F and ending in a temperature of 400°F to 825°F;
   (e) annealing said hot rolled sheet product to an O-temper condition, said hot rolled sheet product in said condition having a tensile strength in the range of 20 to 35 ksi, a yield strength in the range of 12 to 17.5 ksi, and an elongation greater than 19% and having substantially uniform distribution or minimized striations of said intermetallic particles; and
   (f) forming said sheet product in said O-temper condition into said structural part or member.

16. The method in accordance with claim 15 wherein magnesium is maintained in the range of 2.8 to 3.5 wt. %.

17. The method in accordance with claim 15 wherein iron is maintained in the range of 0.05 to 0.25 wt. %.

18. The method in accordance with claim 15 including annealing said hot rolled sheet in a temperature range of 650°F to 950°F.

19. The method in accordance with claim 15 including annealing said hot rolled sheet in a temperature range of 700°F to 900°F.
20. The method in accordance with claim 18 including annealing for about 2 to 10 hours.

21. The method in accordance with claim 15 including continuously annealing said sheet product.

22. A method for producing an aluminum automotive structural part or member from molten aluminum alloy using a continuous caster to cast the alloy into a slab, the method comprising:

(a) providing a molten aluminum alloy consisting essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.05 to 0.3 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities;

(b) providing a continuous caster for continuously casting said molten aluminum alloy;

(c) casting said molten aluminum alloy into a slab having a thickness in the range of 0.2 to 2 inches, said slab containing Al—Fe, Al—Fe—Mn or Mg, Si intermetallic particles;

(d) hot rolling said slab into a hot rolled sheet product, said hot rolling starting in a temperature range of 750°F to 1000°F and ending in a temperature range of 400°F to 825°F;

(e) annealing said hot rolled sheet product to provide an annealed sheet product;

(f) cold rolling said annealed sheet product to a thickness in the range of 0.01 inch to 0.2 inch to provide a cold rolled sheet product;

(g) annealing said cold rolled sheet product to provide a sheet product having a tensile strength in the range of 28 to 35 ksi, a yield strength in the range of 12 to 17.5 ksi and an elongation greater than 19%, said cold rolled and annealed sheet product having a substantially uniform distribution or minimized striations of said intermetallic particles; and

(h) forming said annealed sheet product into said automotive structural part or member.

23. The method in accordance with claim 22 including annealing said cold rolled product to an O-temper.

24. The method in accordance with claim 22 including annealing in a temperature range of 650°F to 950°F.

25. The method in accordance with claim 22 including annealing in a temperature range of 700°F to 900°F.

26. The method in accordance with claim 22 including annealing for about 2 to 9 hours.

27. The method in accordance with claim 22 including continuously annealing said sheet product.

28. The method in accordance with claim 22 wherein said cold rolling provides a 25 to 80% gauge reduction.

29. A method for producing aluminum automotive structural part or member from molten aluminum alloy using a continuous caster to cast the alloy into a slab, the method comprising:

(a) providing a molten aluminum alloy consisting essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.05 to 0.3 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities;

(b) providing a continuous caster for continuously casting said molten aluminum alloy;

(c) casting said molten aluminum alloy into a slab having a thickness in the range of 0.2 to 2 inches, said slab containing Al—Fe, Al—Fe—Mn or Mg, Si intermetallic particles;

(d) hot rolling said slab into a hot rolled sheet product, said hot rolling starting in a temperature range of 750°F to 1000°F and ending in a temperature range of 400°F to 825°F;

(e) annealing said hot rolled sheet product to provide an annealed sheet product;

(f) cold rolling said annealed sheet product to a thickness in the range of 0.01 inch to 0.2 inch to provide a cold rolled sheet product;

(g) annealing said cold rolled sheet product to provide a sheet product having a tensile strength in the range of 28 to 35 ksi, a yield strength in the range of 12 to 17.5 ksi and an elongation greater than 19%, said cold rolled and annealed sheet product having a substantially uniform distribution or minimized striations of said intermetallic particles; and

(h) forming said annealed sheet product into said automotive structural part or member.
stantially uniform distribution or minimized striations of said intermetallic particles; and

(e) forming said rolled and annealed sheet into a vehicular structural part or member.

40. The method in accordance with claim 39 wherein said rolled sheet product has Al—Fe, Al—Fe—Mn or Mg, Si intermetallic particles formed during solidification in a size range of 0.05 to 10 μm.

41. A process for producing plural panel automotive members having inner and outer panels connected to form said members, said inner panels having threaded fasteners securely crimped into said inner panels to provide means for bolting accessories to said automotive member, said inner panel formed by the process comprising:

(a) providing a molten aluminum alloy consisting essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.1 to 0.25 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities;

(b) providing a continuous caster for continuously casting said molten aluminum alloy;

(c) casting said molten aluminum alloy into a slab having Al—Fe, Al—Fe—Mn or Mg, Si intermetallic particles;

(d) rolling said slab into a sheet product;

(e) annealing said sheet product to an O-temper condition, said sheet having substantially uniform distribution or minimized striations of said intermetallic particles;

(f) forming a portion of said sheet product in said O-temper into said inner panels by stamping to provide inner panels having raised portions and recessed portions to provide stiffeners to said inner panels;

(g) crimping at least one threaded fastener to said inner panel;

(h) providing an outer panel for joining to said inner panel; and

(i) connecting said outer panel to said inner panels to provide said plural panel automotive member having threaded fasteners joined thereto.

43. A process for producing plural panel automotive members having inner and outer panels connected to form said members, said inner panels having threaded fasteners securely crimped into said inner panels to provide means for bolting accessories to said automotive member, said inner panel formed by the process comprising:

(a) providing a molten aluminum alloy consisting essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.05 to 0.25 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities;

(b) providing a continuous caster for continuously casting said molten aluminum alloy;

(c) casting said molten aluminum alloy into a slab having a thickness in the range of 0.2 to 2 inches thick, said slab containing Al—Fe, Al—Fe—Mn or Mg, Si intermetallic particles;

(d) hot rolling said slab into a hot rolled sheet product, said hot rolling starting in a temperature range of 750°F to 1000°F and ending in a temperature of 400°F to 825°F;

(e) annealing said hot rolled sheet product to an O-temper condition, said hot rolled sheet product in said condition having a tensile strength in the range of 28 to 35 ksi, a yield strength in the range of 12 to 17.5 ksi, and an elongation greater than 19% and having substantially uniform distribution or minimized striations of said intermetallic particles;

(f) forming a portion of said sheet product in said O-temper into said inner panels by stamping to provide inner panels having raised portions and recessed portions to provide stiffeners to said inner panels;

(g) crimping at least one threaded fastener to said inner panel;

(h) providing an outer panel for joining to said inner panel; and

(i) connecting said outer panel to said inner panels to provide said plural panel automotive member having threaded fasteners joined thereto.
44. A process for producing plural panel automotive members having inner and outer panels connected to form said members, said inner panels having threaded fasteners securely crimped into said inner panels to provide means for bolting accessories to said automotive member, said inner panel formed by the process comprising:

(a) providing a molten aluminum alloy consisting essentially of 2.7 to 3.6 wt. % Mg, 0.1 to 0.4 wt. % Mn, 0.02 to 0.2 wt. % Si, 0.05 to 0.25 wt. % Fe, 0.1 wt. % max. Cu, 0.25 wt. % max. Cr, 0.2 wt. % max. Zn, 0.15 wt. % max. Ti, the remainder aluminum, incidental elements and impurities;

(b) providing a continuous caster for continuously casting said molten aluminum alloy;

(c) casting said molten aluminum alloy into a slab having a thickness in the range of 0.2 to 2 inches, said slab containing Al—Fe, Al—Fe—Mn or Mg—Si intermetallic particles;

(d) hot rolling said slab into a hot rolled sheet product, said hot rolling starting in a temperature range of 750°F to 1000°F, and ending in a temperature range of 450°F to 800°F;

(e) annealing said hot rolled sheet product to provide an annealed sheet product;

(f) cold rolling said annealed sheet product to a thickness in the range of 0.01 inch to 0.2 inch;

(g) annealing said cold rolled sheet product to provide a cold rolled and annealed sheet product having a tensile strength in the range of 28 to 35 ksi, a yield strength in the range of 12 to 17.5 ksi and an elongation greater than 19%, said cold rolled and annealed sheet product having a substantially uniform distribution or minimized striations of said intermetallic particles;

(h) forming the said annealed sheet into said inner panel;

(i) crimping at least one threaded fastener to said inner panel;

(j) providing an outer panel for joining to said inner panel; and

(k) connecting said outer panel to said inner panels to provide said plural panel automotive member having threaded fasteners joined thereto.