provide molten body of Al-Zn-Cu-Mg-Ag alloy

Cast alloy at controlled rate to provide solidified body having controlled grain sizes

Homogenize body

Extrude, roll, or forge homogenized body

Solution heat treat

Stretch

Artificially age
Provide molten body of Al-Zn-Cu-Mg-Ag alloy

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Artificially age

FIG. 1
FIG. 3
FIG. 4
ALUMINUM-ZINC-COPPER-MAGNESIUM-SILVER ALLOY WROUGHT PRODUCT

CROSS REFERENCE TO RELATED APPLICATION


BACKGROUND OF THE INVENTION

[0002] This invention relates to Al—Zn—Cu—Mg—Ag alloys and more particularly it relates to Al—Zn—Cu—Mg—Ag wrought products and the method of making the same for use in aircraft applications. Further, the invention relates to Al—Zn—Cu—Mg—Ag alloy products having improved strength, fracture toughness, high electrical conductivity to strength ratio, and an exfoliation corrosion rating of EA or better in peak strength temper. Furthermore, the invention relates to Al—Zn—Cu—Mg—Ag alloy products having good galvanic corrosion behavior when attached to a carbon fiber composite member.

[0003] Existing Al—Zn—Cu—Mg alloys can have relatively high strengths at moderate corrosion resistance and moderate damage tolerance or fracture toughness. Such alloys and methods of obtaining properties are set forth in the patents. For example, U.S. Pat. No. 4,863,528 discloses a method for producing an aluminum alloy product and the resulting product having improved combinations of strength and corrosion resistance. The method includes providing an alloy consisting essentially of about 6-16% zinc, about 1.5-4.5% magnesium, about 1-3% copper, one or more elements selected from zirconium, chromium, manganese, titanium, vanadium and hafnium, the total of said elements not exceeding about 1%, the balance aluminum and incidental impurities. The alloy is then solution heat treated; precipitation hardened to increase its strength to a level exceeding the as-solution heat treated strength level by at least about 30% of the difference between as-solution heat treated strength and peak strength; subjected to treatment at a sufficient temperature or temperatures for improving its corrosion resistance properties; and again precipitation hardened to raise its yield strength and produce a high strength, highly corrosion resistant alloy product.

[0004] U.S. Pat. No. 5,221,377 discloses an alloy product having improved combinations of strength, density, toughness and corrosion resistance, said alloy product consisting essentially of about 7.6 to 8.4% zinc, about 1.8 to 2.2% magnesium, about 2 to 2.6% copper and at least one element selected from zirconium, vanadium and hafnium present in a total amount not exceeding about 0.5%, preferably about 0.05 to 0.25% zirconium, the balance aluminum and incidental elements and impurities. The alloy product, suitable for aerospace applications, exhibits high yield strength, at least about 10% greater yield strength than its 7×50-7×6 counterpart, with good toughness and corrosion resistance properties typically comparable to or better than those of its 7×50-7×6 counterpart. Upper wing members made from this alloy typically have a yield strength over 84 ksi, good fracture toughness and an EXCO exfoliation resistance level of “EC” or better, typically “ElB”.

[0005] U.S. Pat. No. 4,477,292 discloses a three-step thermal aging method for improving the strength and corrosion resistance of an article comprising a solution heat treated aluminum alloy containing zinc, magnesium, copper and at least one element selected from the group consisting of chromium, manganese and zirconium. The article is precipitation hardened at about 175° to 325° F., heat treated for from several minutes to a few hours at a temperature of about 360° to 390° F. and again precipitation hardened at about 175° to 325° F. In a preferred embodiment the article treated comprises aluminum alloy 7075 in the 16 condition. The method of the invention is easier to control and is suitable for treating articles of greater thickness than other comparable methods.

[0006] U.S. Pat. No. 5,108,520 discloses an aging process for solution-heat-treated, precipitation hardening metal alloy which includes first undergoing the alloy, such that a yield strength below peak yield strength is obtained, followed by higher aging for improving the corrosion resistance of the alloy. Followed by lower temperature aging to strength increased over that achieved initially.

[0007] U.S. Pat. No. 5,560,789 discloses AA 7000 series alloys having high mechanical strength and a process for obtaining them. The alloys contain, by weight, 7 to 13.5% Zn, 1 to 3.8% Mg, 0.6 to 2.7% Cu, 0 to 0.5% Mn, 0 to 0.4% Cr, 0 to 0.2% Zr, others up to 0.05% each and 0.15% total, and remainder Al. Either wrought or cast alloys can be obtained, and the specific energy associated with the DEA melting signal of the product is lower than 3 J/g.

[0008] U.S. Pat. No. 5,312,498 discloses a method of producing an aluminum-based alloy product having improved exfoliation resistance and fracture toughness which comprises providing an aluminum-based alloy composition consisting essentially of about 5.5-10.0% by weight of zinc, about 1.75-2.6% by weight of magnesium, about 1.8-7.25% by weight of copper with the balance aluminum and other elements. The aluminum-based alloy is worked, heat treated, quenched and aged to produce a product having improved corrosion resistance and mechanical properties. The amounts of zinc, magnesium and copper are stoichiometrically balanced such that after processing is essentially complete as a result of the aging process, no excess elements are present. The method of producing the aluminum-based alloy product utilizes either a one- or two-step aging process in conjunction with the stoichiometrically balancing of copper, magnesium and zinc.

[0009] U.S. Pat. No. 4,711,762 discloses an improved aluminum base alloy product comprising 0 to 3.0 wt. % Cu, 0 to 1.5 wt. % Mn, 0.1 to 4.0 wt. % Mg, 0.8 to 8.5 wt. % Zn, at least 0.005 wt. % Sr, max. 1.0 wt. % Si, max. 0.8 wt. % Fe and max. 0.45 wt. % Cr, 0 to 0.2 wt. % Zr, the remainder aluminum and incidental elements and impurities.

[0010] U.S. Pat. No. 1,418,303 discloses an improved aluminum alloy consisting of copper about 0.1% to any amount below 3%, titanium about 0.1% to about 2%, zinc about 6% to about 16%, iron (present as an impurity of commercial aluminum) preferably not exceeding 0.6%, silicon (present as an impurity of commercial aluminum) preferably not exceeding 0.4%, other elements (impurities) preferably not exceeding 0.4%, remainder aluminum.

and magnesium present in an amount ranging from about 2% to 20%, the preferred range being between about 3% and 15%. At room temperature the ternary compound goes into solid solution in aluminum alloys in an amount of about 2%. The percentage in solid solution increases at high temperatures and decreases upon cooling, the excess precipitating out.

[0012] U.S. Pat. No. 3,637,441 discloses an aluminum base powder metallurgy alloy article having an improved combination of high-transverse yield strength and high-stress corrosion cracking resistance. The alloy contains the basic precipitation hardening elements zinc, magnesium and copper plus dispersion strengthening elements iron and nickel. It may additionally contain chromium and/or manganese. The alloy is prepared by atomization of a melt of the elements, hot-working, solution heat treating, quenching and artificial aging. Components of the alloy in percent by weight are, in addition to the aluminum, from at least 6.5 to 13 zinc, 1.75 to 6 magnesium, 0.25 to 2.5 copper, 0.75 to 4.25 iron and 0.75 to 6 nickel, up to 3 manganese and up to 0.75 chromium. The iron to nickel ratio is from 0.2:1 to 2.0:1.

[0013] U.S. Pat. No. 5,028,393 discloses an Al-based alloy for use as a sliding material, superior in fatigue resistance and anti-seize property consisting, by weight, of 1-10% Zn, 1-15% Si, 0.1-5% Cu, 0.1-5% Pb, 0.005-0.5% Sr, and the balance Al and incidental impurities.

[0014] U.S. Pat. No. 6,315,842 discloses a mold for plastics made of a rolled, extruded or forged AlZnMgCu aluminum alloy product >60 mm thick, and having a composition including, in weight %: 5.7<Zn<8.7, 1.7<Mg<2.5, 1.2<Cu<2.2, Fe<0.14, Si<0.11, 0.05<Zr<0.15, Mn<0.02, Cr<0.02, with Cu+Mg<4.1 and Mg>Cu, other elements<0.05 each and <0.10 in total, the product being treated by solution heat treating, quenching and aging to a T6 temper.

[0015] In spite of these disclosures, there is still a great need for an improved alloy and extrusions and flat rolled products fabricated therewith for aerospace applications having high levels of strength, corrosion resistance, fracture toughness, and an exfoliation corrosion rating of EA or better. The subject invention provides such products.

SUMMARY OF THE INVENTION

[0016] It is an object of the invention to provide an improved Al—Zn—Cu—Mg—Ag wrought alloy product for use in aircraft.

[0017] It is another object of the invention to provide an Al—Zn—Cu—Mg—Ag wrought alloy product having improved fracture toughness as well as having high strength levels.

[0018] It is yet another object of the invention to provide a method for producing an Al—Zn—Cu—Mg—Ag wrought alloy product having improved strength properties, fracture toughness and resistance to fatigue crack growth.

[0019] It is still another object of the invention to provide a method for producing an Al—Zn—Cu—Mg—Ag alloy product having improved strength properties, fracture toughness, and an exfoliation corrosion resistance rating of EA or better.

[0020] It is still another object of the invention to provide a method for producing an Al—Zn—Cu—Mg—Ag wrought alloy product having improved galvanic corrosion properties when attached to a carbon fiber composite structure.

[0021] It is yet another object of the invention to provide a method for producing an Al—Zn—Cu—Mg—Ag wrought alloy product having a high electrical conductivity to strength ratio when aged to peak strength condition.

[0022] It is yet another object of the invention to provide a method for producing an Al—Zn—Cu—Mg—Ag wrought alloy product having a high electrical conductivity ratio to density ratio when aged to peak strength condition.

[0023] It is another object of this invention to provide aerospace structural members such as extrusions from the alloy of the invention.

[0024] In accordance with these objects, there is provided a method of producing wrought aluminum alloy products having improved strength, fracture toughness, and exfoliation corrosion resistance, the method comprising the steps of providing a molten body of an aluminum base alloy comprised of 0.01 to 1.0 wt. % Ag, 0.01 to 0.9 wt. % Cu, 1.6 to 2.5 wt. % Mg, 6.5 to 9.5 wt. % Zn, 0.05 to 0.25 wt. % Zr, 0.01 to 0.8 wt. % Mn, max. 0.15 wt. % Si, max. 0.15 wt. % Fe, the remainder aluminum and incidental elements and impurities; and casting the molten body of the aluminum base alloy to provide a solidified body, the molten aluminum base alloy being solidified at a rate between liquidus and solidus temperatures in the range of 600° to 800° K per second to provide a solidified body or ingot having a grain size in the range of 50 to 200 μm. Thereafter, the body or ingot is homogenized by heating in a first temperature range of 840° to 860° F. Followed by heating in a second temperature range of 680° to 890° wherein the second temperature is higher than the first to provide a homogenized body having a uniform distribution of Mg, Cu, Zn, and Ag, as well as dispersed particles in the aluminum matrix. The homogenized body is then worked, e.g., extruded, rolled or forged to provide wrought products. For the extrusion, the extruding is carried out in a temperature range of 550° to 600° to 800° F. and at a rate sufficient to maintain at least 80% of said extrusion in a non-recrystallized condition. The product is solution heat treated and artificial aged to improve strength properties and to provide a product having improved fracture toughness, exfoliation corrosion, and electrical conductivity to density ratio, for example, a minimum electrical conductivity at peak strength of 34% IACS.

[0025] The improved aluminum base alloy extrusion product can have a yield strength to fracture toughness ratio of 8% or greater than a similarly sized 7xxx product.

[0026] The improved aluminum base alloy extrusion product can have an electrical conductivity to density ration at least 8% higher than a similarly sized 7xxx product.

[0027] The invention also includes an improved aluminum base alloy and aluminum base alloy wrought product such as an extrusion, sheet, plate or forging product, the alloy consisting essentially of 0.01 to 1.0 wt. % Ag, 0.01 to 0.9 wt. % Cu, 1.6 to 2.5 wt. % Mg, 6.5 to 9.5 wt. % Zn, 0.05 to 0.25 wt. % Zr, 0.05 to 0.2 wt. % Sc, 0.01 to 0.8 wt. % Mn, max. 0.15 wt. % Si, max. 0.15 wt. % Fe, the remainder aluminum and incidental elements and impurities.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] FIG. 1 is a flow chart showing steps of the invention.

[0029] FIG. 2a illustrates the results of the exfoliation corrosion test on 7075 T651.

[0030] FIG. 2b illustrates the invention alloy in the same temper as FIG. 2a when tested in accordance to ASTM G34-99 showing an EA or better exfoliation corrosion rating.

[0031] FIG. 3 is a plot of fracture toughness in L-T orientation as a function of tensile yield strength in longitudinal
 orientation for the invention alloy in peak strength temper (T6511) in comparison to similarly sized and tempered 7xxx alloys.

[0032] FIG. 4 illustrates the electrical conductivity vs. yield strength for the invention alloy aged to peak strength condition also known as T6511 in comparison to similarly tempered 7xxx alloys.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0033] Referring to FIG. 1, there is shown a flow chart of steps in the invention. Generally, in the steps a molten body of Al—Zn—Cu—Mg—Ag alloy is cast at a controlled solidification rate to obtain a specific grain size range in the cast body. Thereafter, the cast body is homogenized under controlled conditions to obtain a uniform distribution of Mg, Cu, Zn, and Ag in the aluminum matrix. The body may be forged or rolled or sheet or plate product or it may be extruded in a specific rate range and temperature to obtain an extrusion product having a large portion thereof, e.g., at least 80%, in a non-recrystallized condition. The product is then solution heat treated and aged to very high levels of strength, fracture toughness and corrosion resistance.

[0034] The alloy of the invention contains about 6.5 to 9.5 wt. % Zn, 0.01 to 0.9 wt. % Cu, 1.6 to 2.5 wt. % Mg, 0.01 to 1.0 wt. % Ag, 0.05 to 0.25 wt. % Zr, 0.01 to 0.8 wt. % Mn, max. 0.15 wt. % Si, max. 0.15 wt. % Fe, the remainder aluminum, incidental elements and impurities.

[0035] Preferably, the alloy contains 1.95 to 2.3 wt. % Mg, 0.05 to 0.6 or 0.9 wt. % Cu, 7.5 to 8.6 wt. % Zn, 0.1 to 0.5 wt. % Ag, e.g., 0.2 to 0.4 Ag, 0.1 to 0.8 wt. % Mn, e.g., 0.2 to 0.4 Mm, and 0.05 to 0.15 wt. % Zr. For purposes of retarding recrystallization, the alloys can contain 0.01 to 0.2 wt. % Se, preferably 0.01 to 0.1 wt. %, the Ag, when added in the specified ranges, can provide strengthening precipitates such as Ag2Al and these precipitate form during artificial or natural aging. The alloys must be heat treated in accordance with specific procedures. Such alloys when processed in accordance with the invention possess marked improvements in yield strength and fracture toughness at excellent levels of exfoliation corrosion and stress corrosion cracking resistance compared to conventional 7xxx alloys such as AA7075-T6, for example. The composition of the AA 7xxx alloys are set forth in The Aluminum Association publication entitled “Registration Record of Aluminum Alloys and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys”, dated December 1993. The term “7xxx” means aluminum alloys containing zinc as a main alloying ingredient. AA 7075-T6 refers to AA compositional limits as registered with The Aluminum Association. A typical T6 aging practice for 7075 is heating at about 250° F. for 24 hours and a typical temperature range is about 175° to 330° F. for 3 to 30 hours.

[0036] The alloy of the invention contains about 6.5 to 9.5 wt. % Zn, 1.6 to 2.5 wt. % Mg, 0.01 to 1.0 wt. % Ag, 0.05 to 0.25 wt. % Zr, 0.01 to 0.8 wt. % Mn, max. 0.15 wt. % Si, max. 0.15 wt. % Fe, the remainder aluminum, incidental elements and impurities.

[0037] Further, the alloy can contain 0.05 to 0.2 wt. % Cr and/or 0.01 to 0.2 wt. % Ti.

[0038] For purposes of the present invention, a molten aluminum alloy of the invention is cast into a solidified body at a rate which provides a controlled microstructure or grain size. Such molten aluminum alloy typically is cast in the form of billet when it is desired to produce extrusion products. Further, typically such solidified body is cast at a rate of about 1 to 6 inches per minute, preferably 2 to 4 inches per minute, and typically the billet has a diameter in the range of about 5 to 29 inches. For purposes of the invention, it is preferred that the solidified body has an average grain size in the range of 50 to 200 μm, preferably 35 to 75 μm. If the alloy of the invention is cast at controlled rates and thermally mechanically processed in accordance with the invention, the molten aluminum is cast at a controlled solidification rate. It has been discovered that controlled solidification rate of the disclosed aluminum alloy in combination with subsequent controlled thermal mechanical processing results in products having superior properties, i.e., very high tensile strength, high fracture toughness, and excellent exfoliation corrosion and stress corrosion cracking resistance.

[0039] It should be noted that the strength of the subject aluminum alloys can be improved by precipitation hardening or by strain hardening. Strain hardening is the result of plastic deformation and is dependent on the degree of deformation. Precipitation hardening is produced through formation of clusters of atoms (referred to as Guiner-Preston or GP zones). In addition, precipitation hardening can result from the formation of new phases or precipitates in the alloy which form barriers against dislocation movement. This can significantly increase the strength of the alloy. In the Al—Zn—Cu—Mg—Ag alloys, new strengthening phases include MnZn, also known as M or η-phase; Mg2ZnAl2 also as the T-phase; and Ag2Al phase. Strengthening resulting from precipitation of new phases is more effective than strengthening by formation of GP zones. However, strengthening by precipitation of new phases can have an adverse effect on damage tolerance or fracture toughness. Using these higher the volume fraction of in the precipitation phases, the lower is the damage tolerance. By comparison, strengthening resulting from GP zone formation does not take place at the expense of damage tolerance. Thus, to provide for improved strength and damage tolerance, the present invention balances the volume fraction of precipitates and the volume fraction of GP zones or zinc-rich clusters in the final product while maintaining excess zinc in solution. For the purpose of the invention the GP zones size should be in the range of 2 to 35 nm and the GP zones density should be in the range of 4×1010 to 5×1011 zones per cm3.

[0040] For purposes of producing billet in accordance with the invention, casting may be accomplished using a mold cooled by an air and liquid coolant to solidify billet at a controlled rate which provides the desired grain size or structure. The grain can have a size in the range of 75 to 150 μm. The air and coolant mixture used with the molds are particularly suited for extracting heat from the body of molten aluminum alloy to obtain a solidification rate of 5° to 50° C. per second for billet having a diameter of 1 to 6 inches. Molds using the air and coolant mixture which are suitable for controlling the cooling rate for casting molten aluminum alloy of the invention are described in U.S. Pat. No. 4,598,763. The coolant for use with these molds for the invention is comprised of a gas and a liquid where gas is infused into the liquid as tiny, discrete undissolved bubbles and the combination is directed on the surface of the emerging ingot. The bubble-entrained coolant operates to cool the metal at an increased
rate of heat extraction; and if desired, the increased rate of 
extraction, together with the discharge rate of the coolant, can 
be used to control the rate of cooling at any stage in the casting 
operation, including during the steady state casting stage.

For casting metal, e.g., aluminum alloy to provide a 
microstructure suitable for purposes of the present invention, 
molten metal is introduced to the cavity of an annular mold, 
through one end opening thereof, and while the metal under-
goes partial solidification in the mold to form a body of the 
same on a support adjacent the other end opening of the 
cavity, the mold and support are reciprocated in relation to 
one another endwise of the cavity to elongate the body of 
metal through the latter opening of the cavity. Liquid coolant 
is introduced to an annular flow passage which is circum-
posed about the cavity in the body of the mold and opens into 
the ambient atmosphere of the mold adjacent the aforesaid 
opposite end opening thereof to discharge the coolant as a 
curtain of the same that impinges on the emerging body of 
metal for direct cooling. Meanwhile, a gas which is substau-
tially insoluble in the coolant liquid is charged under pressure 
into an annular distribution chamber which is disposed about 
the passage in the body of the mold and opens into the passage 
through an annular slot disposed upstream from the discharge 
opening of the passage at the periphery of the coolant flow 
therein. The body of gas in the chamber is released into the 
passage through the slot and is subdivided into a multiplicity of 
gas jets as the gas discharges through the slot. The jets are 
released into the coolant flow at a temperature and pressure at 
which the gas is entrained in the flow as a mass of bubbles that 
tend to remain discrete and undissolved in the coolant as 
the curtain of the same discharges through the opening of 
the passage and impinges on the emerging body of metal. With 
the mass of bubbles entrained therein, the curtain has an 
increased velocity, and this increase can be used to regulate 
the cooling rate of the coolant liquid, since it more than offsets 
any reduction in the thermal conductivity of the coolant. In 
fact, the high velocity bubble-entrained curtain of coolant 
seems to have a scrubbing effect on the metal, which breaks 
up any film and reduces the tendency for film boiling to occur 
at the surface of the metal, thus allowing the process to oper-
ate at the more desirable level of nucleate boiling, if desired. 
The addition of the bubbles also produces more coolant vapor 
in the curtain of coolant, and the added vapor tends to rise up 
into the gap normally formed between the body of metal and 
the wall of the mold immediately above the curtain to cool the 
metal at that level. As a result, the metal tends to solidify 
further up the wall than otherwise expected, not only as a 
result of the higher cooling rate achieved in the manner 
described above, but also as a result of the build-up of coolant 
vapor in the gap. The higher level assures that the metal will 
solidify on the wall of the mold at a level where lubricating oil 
is present; and together, all of these effects produce a superior, 
more satin-like, drag-free surface on the body of the metal 
over the entire length of the ingot and is particularly suited to 
thermal transformation.

When the coolant is employed in conjunction with 
the apparatus and technique described in U.S. Pat. No. 4,598, 
763, this casting method has the further advantage that any 
gas and/or vapor released into the gap from the curtain inter-
mixes with the annulus of fluid discharged from the cavity of 
the mold and produces a more steady flow of the latter dis-
charge, rather than the discharge occurring as intermittent 
pulses of fluid.

As indicated, the gas should have a low solubility in 
the liquid; and where the liquid is water, the gas may be air for 
cheapness and ready availability.

During the casting operation, the body of gas in the 
distribution chamber may be released into the coolant flow 
passage through the slot during both the butt forming stage 
and the steady state casting stage. Or, the body of gas may be 
released into the passage through the slot only during the 
steady state casting stage. For example, during the butt-form-
ing stage, the coolant discharge rate may be adjusted to under-
cool the ingot by generating a film boiling effect; and the body 
of gas may be released into the passage through the slot when 
the temperature of the metal reaches a level at which the 
cooling rate requires increasing to maintain a desired surface 
temperature on the metal. Then, when the surface temperature 
falls below the foregoing level, the body of gas may no longer 
be released through the slot into the passage, so as to under-
cool the metal once again. Ultimately, when steady state 
casting is begun, the body of gas may be released into the 
passage once again, through the slot and on an indefinite basis 
until the casting operation is completed. In this case, the 
coolant discharge rate may be adjusted during the butt-form-
ing stage to maintain the temperature of the metal within a 
prescribed range, and the body of gas may not be released into 
the passage through the slot until the coolant discharge rate is 
increased and the steady state casting stage is begun.

The coolant, molds and casting method are further set 
forth in U.S. Pat. Nos. 4,598,763 and 4,693,298, incorpo-
rated herein by reference.

While the casting procedure for the present invention 
has been described in detail for producing billet having 
the necessary structure for thermal transformation in ac-
cordance with the present invention, it should be understood 
that the other casting methods can be used to provide the solidi-
fication rates that result in the grain structure necessary to 
the invention. As noted earlier, such solidification can be 
obtained by belt, block or roll casting, DC and electromagnetic 
casting.

A seven inch billet of an alloy containing 7.5 wt. % 
Zn, 0.4 to 0.9 wt. % Cu, 1.6 wt. % Mg, 0.4 wt. % Ag, 0.11 wt. 
% Zr, 0.4 wt. % Mn, the remainder comprising aluminum, 
cast employing a mold using air and water coolant, at a 
cooling rate of 35° to 50° F. per second provides a satisfactory 
grain structure for extruding and thermally mechanically 
processing in accordance with the invention.

While casting has been described with respect to 
billet, it will be appreciated that the principles described 
herein may be applied to ingot or electromagnetic casting of 
the aluminum alloys.

Thus, after the ingot or billet is cast, it is subjected to a 
homogenization treatment. Preferably, the ingot or billet is 
subjected to two homogenization treatments. In the first 
2 homogenization treatment, the ingot or billet preferably is 
treated in a temperature range of 840° to 860° F. for a period 
of 6 to 18 hours. Thereafter, the ingot or billet is then prefer-
entially subjected to a temperature range of 860° to 890° F. for 
a period of 4 to 36 hours. In the second step, the temperature is 
higher than the temperature used in the first step. Subjecting 
the ingot or billet to a double homogenization treatment as 
described provides a more uniform distribution of Mg, Cu, 
Zn, and Ag as well as Fe and Mn, containing dispersoids.

After homogenization, the billet is extruded to pro-
vide an extrusion member. For purposes of extruding, the 
billet is heated to a temperature range of 525° to 750° F. and
maintained in this temperature range during extruding. Preferably, the billet is extruded at a rate in the range of 0.8 to 8 ft/min and preferably at an extrusion ratio in the range of 10 to 60. These conditions are important to obtain an extrusion wherein at least 80% and preferably 90% of the extrusion is maintained in the unrecrystallized condition. The extrusion can have an aspect ratio between the thinnest and thickest section of 1:4 to 1:18.

[0051] For purposes of producing flat rolled products, the ingot is hot rolled to a thickness, e.g., a thickness in the range of 0.35 to 12 inches. Hot rolling is usually performed in a temperature range of 625°F to 775°F for the entrance temperature and an exit temperature in the range of 625°F to 800°F.

[0052] After extruding or hot rolling, the product is solution heat treated by heating in a temperature range of about 870°F to about 890°F, with a preferred temperature range being 875°F to 885°F. Typical times at these temperatures can range from 5 to 120 minutes. The solution heat treating should be carried out for a time sufficient to dissolve a substantial portion of the alloying elements. That is, substantially all of the zinc, magnesium, copper, and silver is dissolved to provide a solid solution.

[0053] After solution heat treating, the product is rapidly cooled or quenched by immersion or spraying with room temperature water, for example. After quenching, the extrusion, for example, may be straightened and/or stretched. That is, the product is straightened or leveled prior to aging to improve strength properties.

[0054] After solution heat treating, the extrusion or flat rolled product is treated to improve properties such as strength, corrosion and fracture toughness.

[0055] Thus, the extrusion or flat rolled product may be subjected to different thermal treatments depending on the properties desired. For example, the extrusion or plate may be subjected to a single step thermal treatment to achieve high or peak strength, referred to as T6 type tempers. However, when stressed at higher stress levels, such tempers can be susceptible to stress corrosion cracking. T6 tempers are obtained by aging at a temperature range of 175°F to 325°F for 3 to 30 hours. A two step aging process may be employed wherein a first aging step is carried out at 175°F to 300°F for a period of time of 3 to 30 hours, followed by a second aging step carried out at 300°F to 360°F. For a period of time of 3 to 24 hours. This aging process produces an overaged temper referred to as T7X temper. This condition improves stress corrosion cracking but can decrease strength. Or, aging may be carried out in a temperature range of 210°F to 280°F for 4 to 24 hours followed by aging at 320°F to 400°F for 30 minutes to 14 hours.

[0056] To improve strength and corrosion resistance, the extrusion, forging or flat rolled product may be subjected to a three-step aging process. The aging steps or phases include a low-high-low aging sequence. In the first or low aging step, the product is subjected to a temperature for a period of time which precipitation hardens the extrusion to a point at or near peak strength. This can be effected by subjecting the product to precipitation hardening in a temperature range of about 150°F to 325°F, typically for a time between 2 to 30 hours. Then, the extrusion or plate is subjected to a second treatment to improve corrosion resistance. The second treatment includes subjecting the extrusion or plate to a temperature range of 300°F to 500°F, for 5 minutes to about 3 hours, for example. In the third step, the product is subject to another strengthening step. The third thermal treatment includes subjecting the product to a temperature of 175°F to 325°F for about 2 to 30 hours.

[0057] Exfoliation corrosion (EXCO) behavior of the inventive alloy was compared to 7075 T6511 and 7075 T76511 alloys. The American Society for Testing and Materials developed a method (ASTM G34-99) that provides an accelerated exfoliation corrosion test for 2xxx and 7xxx series aluminum alloys. The susceptibility to exfoliation is determined by visual examination, with performance ratings established by reference to standard photographs. When tested in accordance with this test method, the alloy of the invention exhibits a typical EA exfoliation corrosion rating when aged to a T6511 temper that is much superior to 7075 T6511 as depicted in FIG. 2. It is to be further noted that when aged to T6511 temper the invention alloy product exhibits an integralgranular corrosion resistance that is much superior to 7075 T6511. Furthermore, when aged to a T76 temper the invention alloy exhibits a typical EA exfoliation corrosion rating with improved stress corrosion cracking resistance.

[0058] The product has a significantly improved exfoliation corrosion and stress corrosion cracking resistance than a similar product fabricated from 7075 alloy.

[0059] The invention alloy when aged to peak strength condition also known as T6 temper exhibits very high fracture toughness when compared to similarly tempered conventional alloys. This relationship is depicted in FIG. 3.

[0060] The invention alloy when aged to peak strength condition also known as T6 temper exhibits very high electrical conductivity when compared to similarly tempered conventional alloys. This relationship is depicted in FIG. 4. When overaged to T76 type tempers the invention alloy exhibits electrical conductivity in the range of 43-45% IACS. Because of the alloy's ability to develop high electrical conductivity at good strength levels the invention alloy is an ideal candidate for lightning strike dissipation structure in aircraft.

[0061] The invention alloy exhibits very good galvanic corrosion when in contact with a carbon fiber reinforced polymer composite. This enhanced corrosion behavior can not be reproduced by similarly tempered traditional 7xxx alloys.

[0062] While the alloy has been described with respect to extrusion and plate products, it can find use as sheet and forged product and such is contemplated herein.

[0063] While the invention can provide extrusion with high strength and fracture toughness, it can also be used to produce sheet and plate and even forgings having similar properties. Plate has relatively thick gauges which can range from 2 to 12 inches, typically 3 to 8, and parts made or machined from such plate exhibit the high levels of strength and fracture toughness and exfoliation corrosion resistance. Machined parts from plate find use in the aircraft or aerospace industry and include spar, rib and web members which are used in wing boxes of the aircraft. As sheet, the invention finds use as sheet on aircrafts where high damage tolerance is required, particularly in fuselage skin and lower wing skin applications. It will be understood that the high strength and fracture toughness of the alloy parts permit thinner or less thick and therefore lighter parts, thereby saving weight on the aircraft. Further, aircraft parts machined from plate in accordance with the invention can have properties 5 to 10% higher than alloys such as AA7050, 7010, for example, of similar parts and still maintain good resistance to stress corrosion cracking.
Aluminum alloy 7050-T74 is often used for plate which can be machined to produce wing spars, wing ribs, etc., for large aircraft. Aerospace and Materials Specification AMS 4050F lists a minimum yield strength of 60 KSI in the longitudinal direction for AA7050-T7451 six inch plate. It also specifies a fracture toughness of 24 KCI.

Ingot for producing plate may be DC cast or electromagnetic cast. The DC cast ingots are typically sculpted to remove a thin surface layer which can contain unwanted inclusions. Therefore, the ingot is subject to a homogenization treatment, as noted.

All ranges set forth herein include all the numbers within the range as if specifically set forth.

The products or members described herein in accordance with the invention are particularly suitable for aerospace applications and finds many uses in large aircraft such as commercial and military aircrafts. As noted, the products can be used in wing components, tail assemblies, fuselage sections or in subassemblies or other components comprising the aircraft. That is, the aircraft assemblies can comprise a wing assembly or wing subassembly, a center wing box assembly or subassembly, floor assembly or subassembly including seat tracks, floor beams, standchins, cargo deck assemblies and subassemblies, floor panels, cargo floor panels, fuselage assemblies or subassemblies, fuselage frames, wing ribs, fuselage stringers and the like. Further, the products may be produced as seamless or non-seamless tubes and used in sporting goods such as baseball bats. Further the product may be used for armor applications where resistance to armor piercing projectiles or blast impact is required.

### TABLE 1a

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Temper</th>
<th>UTS, ksi</th>
<th>YS, ksi</th>
<th>EXCO* rating</th>
<th>KCI, ksi · sq in</th>
</tr>
</thead>
<tbody>
<tr>
<td>7075</td>
<td>T651</td>
<td>88</td>
<td>82</td>
<td>ED</td>
<td>24</td>
</tr>
<tr>
<td>7249</td>
<td>T651</td>
<td>93</td>
<td>86</td>
<td>EC</td>
<td>26</td>
</tr>
<tr>
<td>7136</td>
<td>T651</td>
<td>101</td>
<td>95</td>
<td>ED</td>
<td>24</td>
</tr>
<tr>
<td>7050</td>
<td>T651</td>
<td>86</td>
<td>80</td>
<td>ED</td>
<td>28</td>
</tr>
<tr>
<td>Invention Alloy **</td>
<td>T651</td>
<td>92</td>
<td>88</td>
<td>EA</td>
<td>42.2</td>
</tr>
<tr>
<td>Invention Alloy ***</td>
<td>T651</td>
<td>87</td>
<td>84</td>
<td>EA</td>
<td>47.6</td>
</tr>
<tr>
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<td>T651</td>
<td>87.5</td>
<td>85</td>
<td>EA</td>
<td>45.5</td>
</tr>
<tr>
<td>Invention Alloy</td>
<td>T651</td>
<td>88.6</td>
<td>86</td>
<td>EB</td>
<td>43.5</td>
</tr>
</tbody>
</table>

*EXCO* rating represents the exfoliation corrosion rating per ASTM G34-99 with EA being the best and ED being the worst exfoliation corrosion resistance.

**Nominal chemical composition of Alloy 2, 3, and 4 are presented in Table 1b.

### TABLE 1b

<table>
<thead>
<tr>
<th>Zn, wt. %</th>
<th>Cu, wt. %</th>
<th>Mg, wt. %</th>
<th>Ag, wt. %</th>
<th>Mn, wt. %</th>
<th>Zr, wt. %</th>
<th>Ti, wt. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy 1</td>
<td>8.81</td>
<td>0.1</td>
<td>2.16</td>
<td>0.33</td>
<td>0.006</td>
<td>0.13</td>
</tr>
<tr>
<td>Alloy 2</td>
<td>7.63</td>
<td>0.2</td>
<td>1.58</td>
<td>0.46</td>
<td>0.012</td>
<td>0.122</td>
</tr>
<tr>
<td>Alloy 3</td>
<td>7.58</td>
<td>0.4</td>
<td>1.56</td>
<td>0.74</td>
<td>0.014</td>
<td>0.117</td>
</tr>
<tr>
<td>Alloy 4</td>
<td>7.43</td>
<td>0.6</td>
<td>1.64</td>
<td>0.98</td>
<td>0.006</td>
<td>0.085</td>
</tr>
</tbody>
</table>

The table illustrates the mechanical properties of the inventive alloy when aged to a peak strength 76 temper.

The following examples are still further illustrative of the invention.

**Example 1**

A billet of an alloy containing 8.8 wt. % Zn, 0.1 wt. % Cu, 2.2 wt. % Mg, 0.33 wt. % Ag, 0.13 wt. % Zr, 0.02 wt. % Ti incidental elements and impurities, the balance aluminum, was cast into a seven inch diameter billet. The billet was cast using casting molds utilizing DC casting technique. The as-cast structure had an average grain size of 125 μm. The billet was homogenized for 8 hours at 860° F and then for 24 hours at 880° F followed by air cooling. Thereafter, the billet was brought to a temperature of 725° F and extruded into an extrusion with a width of 3 inches and a thickness of 1.25 inches.

The extrusion had a non-recrystallized grain structure. The extrusion was solution heat treated for 45 minutes at 880° F and quenched in a water-15% glycol solution. Thereafter, the quenched extrusion was stretched 1.5% permanent stretch and precipitation hardened for 24 hours at 250° F. The extrusion was then tested for tensile strength and yield strength and compared to AA 7075 T6. The results are reproduced in Table 1.

**Example 2**

The extrusion was then tested for damage tolerance by measuring the fracture toughness resistance in accordance to ASTM E399. It is seen for Table 1 that the fracture toughness resistance of the invention alloy is greatly superior to 7075. Furthermore, the invention alloy shows significant exfoliation corrosion and stress corrosion cracking resistance when compared to 7075 and 7150 alloys.

**Example 3**

Billet of alloys containing 7.6 wt. % Zn, 0.4 wt. % Cu, 1.6 wt. % Mg, 0.12 wt. % Zr, 0.02 wt. % Mn, and different amounts of Ag were cast into a seven inch diameter billet. Table 2 details the chemical composition and corresponding mechanical properties. The billet was cast using casting molds utilizing DC casting technique. The as-cast structure had an average grain size of 100 μm. The billet was homogenized for 8 hours at 8700 and then for 24 hours at 880° F followed by air cooling. Thereafter, the billet was brought to a temperature of 725° F and extruded into an aircraft stringer having a “T” shaped cross section and dominant wall thickness of 1.5 inches.

**Example 4**

The extrusion had a non-recrystallized grain structure. The extrusion was solution heat treated for 55 minutes at 880° F and quenched in a water-15% glycol solution. Thereafter, the quenched extrusion was precipitation hardened for 24 hours at 250° F. The extrusion was then tested for tensile strength and yield strength and fracture toughness, exfoliation, etc.
tion corrosion and stress corrosion cracking resistance. The results are reproduced in Table 2. It will be seen that the inventive alloy has superior strength and fracture toughness combination when compared to AA 7075 T6511 and AA 7150 T77511. Also, the extrusion has a unique combination of tensile strength and corrosion resistance.

[0075] The electrical conductivity of the invention alloy in its peak strength condition was found to be substantially higher than the electrical conductivity of comparable 7xxx alloys in their peak strength condition. This relationship is depicted in FIG. 4.

[0076] 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. A method of producing a wrought aluminum alloy product having: improved strength, fracture toughness, excellent exfoliation corrosion resistance, and a minimum electrical conductivity in peak strength of 34% IACS, the method comprising the steps of:

(a) providing a molten body of an aluminum base alloy comprised of 0.01 to 0.9 wt. % Cu, 1.6 to 2.5 wt. % Mg, 6.5 to 9.5 wt. % Zn, 0.01 to 1 wt. % Ag, 0.05 to 0.25 wt. % Sn, 0.01 to 0.8 wt. % Mn, max. 0.15 wt. % Si, max. 0.15 wt. % Fe, the remainder aluminum and incidental elements and impurities;

(b) casting said molten body of said aluminum base alloy to provide a solid body, said molten aluminum base alloy being cast at a rate of the range of 1 to 6 inches per minute;

(c) homogenizing said solid body by heating in a first temperature range of 840 to 860°F followed by heating in a second temperature range of 800°F to 910°F, the second homogenization temperature being greater than the first temperature to provide a homogenized body having a uniform distribution of Zn, Cu, Mg, Ag, and dispersoids;

(d) working said homogenized body to provide a wrought product, said working being carried out in a temperature range of 550°F to 850°F;

(e) solution heat treating said wrought product; and

(f) artificial aging said product to provide a product having improved strength, fracture toughness, and an exfoliation corrosion rating of EA or better.

2. The method in accordance with claim 1 wherein the wrought product is an extrusion or flat rolled product stretched between 0.5 and 5% permanent stretch.

3. The method in accordance with claim 1 wherein the wrought product is a forging.

4. The method in accordance with claim 1 wherein the alloy contains 0.1 to 0.5 wt. % Ag.

5. The method in accordance with claim 1 wherein the alloy contains 0.05 to 0.6 wt. % Cu.

6. The method in accordance with claim 1 wherein the alloy contains 1.6 to 2.5 wt. % Mg.

7. The method in accordance with claim 1 wherein the alloy contains 0.2 to 0.4 wt. % Ag.

8. The method in accordance with claim 1 wherein the alloy contains 7.5 to 8.6 wt. % Zn.

9. The method in accordance with claim 1 wherein the alloy contains 0.01 to 0.25 wt. % Sc.

10. The method in accordance with claim 1 wherein the alloy contains 0.05 to 0.2 wt. % Cr.

11. The method in accordance with claim 1 wherein the alloy contains 0.2 to 0.4 wt. % Mn.

12. The method in accordance with claim 1 wherein the alloy contains 0.01 to 0.2 wt. % Ti.

13. The method in accordance with claim 1 wherein the second homogenization step is carried out for a period of 4 to 56 hours.

14. The method in accordance with claim 1 including rapidly quenching said wrought product from its solution heat treatment temperature.

15. The method in accordance with claim 1 wherein said solution heat treatment is carried out in a temperature range of 875°F to 885°F for 5 to 120 minutes.

16. The method in accordance with claim 1 wherein said artificial aging is carried out by aging in a temperature range of 175°F to 300°F for 3 to 30 hours.

17. The method in accordance with claim 1 wherein said artificial aging is carried out by aging in a temperature range of 175°F to 300°F for 3 to 30 hours followed by aging at 280°F to 360°F for 3 to 24 hours.

18. The method in accordance with claim 1 wherein said artificial aging is carried out by aging in a temperature range of 210°F to 280°F for 4 to 24 hours followed by aging at 340°F to 400°F for 30 minutes to 120 minutes.

19. The method in accordance with claim 1 wherein said artificial aging is carried out by aging in a temperature range of 150°F to 325°F for 2 to 30 hours followed by aging at 300°F to 500°F for 5 minutes to 3 hours followed by aging at 175°F to 325°F for 2 to 30 hours.

20. The method in accordance with claim 1 wherein said artificial aging is a three-step process wherein the first and third steps improve strength and the second step improves stress corrosion resistance.

21. The method in accordance with claim 1 wherein said artificial aging includes aging:

(i) at a low temperature above room temperature to precipitation harden said extrusion;

(ii) at temperatures to improve corrosion resistance properties of said extrusion; and

(iii) at lower temperatures above room temperature to precipitation harden said extrusion.

22. The method in accordance with claim 1 wherein the product has a fracture toughness at least 10% greater than a similarly tempered product fabricated from 7075 alloy.

23. The method in accordance with claim 1 wherein the product has a significantly improved exfoliation corrosion and stress corrosion cracking resistance than a similarly tempered product fabricated from 7075 alloy.

24. The method in accordance with claim 1 wherein the product has a significantly higher electrical conductivity than a similarly tempered product fabricated from 7075 alloy.

25. The method in accordance with claim 1 wherein the product has a fracture toughness at least 25% greater than a similar product fabricated from 7075 alloy.

26. The method in accordance with claim 1 wherein the extruded product is an extrusion having a thickness in the range of 0.04 to 10 inches.

27. The method in accordance with claim 1 wherein the flat rolled product is a sheet product having a thickness in the range of 0.035 to 0.25 inches.

28. The method in accordance with claim 1 wherein the flat rolled product is a plate product having a thickness in the range of 0.25 to 12 inches.
29. A method of producing a wrought aluminum alloy product having improved strength, fracture toughness and an EA or better exfoliation corrosion resistance rating, the method comprising the steps of:
   (a) providing a molten body of an aluminum base alloy comprised of 1.6 to 2.3 wt. % Mg, 0.01 to 0.9 wt. % Cu, 7.5 to 9.5 wt. % Zn, 0.1 to 0.5 wt. % Ag, 0.05 to 0.4 wt. % Mn, 0.05 to 0.15 wt. % Zr, max. 0.15 wt. % Si, max. 0.15 wt. % Fe, the remainder aluminum and incidental elements and impurities;
   (b) casting said molten body of said aluminum base alloy to provide an ingot, said molten aluminum base alloy being cast at a rate in the range of 1 to 6 inches per minute;
   (c) said ingot being heat treated in a temperature range of 840° to 910° F. for 6 to 36 hours to provide a homogenized body having a uniform distribution of Zn, Cu, Mg, Ag and zirconium and chromium containing dispersoids;
   (d) extruding said homogenized ingot to provide an extrusion product, said extruding being carried out in a temperature range of 550° to 850° F.;
   (e) solution heat treating said extrusion product;
   (f) stretching said extruded product 0.5 to 5% permanent stretch of said product to reduce internal residual stresses;
   (g) artificial aging said product to provide a product having improved strength, fracture toughness, and an exfoliation corrosion resistance rating of EA or better;

30. The method in accordance with claim 29 wherein the alloy contains 0.01 to 0.1 wt. % Sc.

31. The method in accordance with claim 29 wherein the alloy contains 0.01 to 0.2 wt. % Ti.

32. The method in accordance with claim 29 wherein the alloy contains 0.05 to 0.2 wt. % Cr.

33. The method in accordance with claim 29 wherein said solution heat treating is carried out in a temperature range of 875° to 890° F. for 5 to 120 minutes.

34. The method in accordance with claim 29 wherein said artificial aging is carried out by aging in a temperature range of 175° to 300° F. for 3 to 30 hours followed by aging at 280° to 360° F. for 3 to 24 hours.

35. The method in accordance with claim 29 wherein said artificial aging is carried out by aging in a temperature range of 175° to 300° F. for 3 to 30 hours.

36. The method in accordance with claim 29 wherein said artificial aging is carried out by aging in a temperature range of 245° to 255° F. for 6 to 24 hours followed by aging at 310° to 340° F. for 5 to 120 minutes.

37. The method in accordance with claim 29 wherein said artificial aging is carried out by aging in a temperature range of 245° to 255° F. for 6 to 24 hours followed by aging at 340° to 400° F. for 5 to 120 minutes.

38. The method in accordance with claim 29 wherein said artificial aging is a three-step process wherein said first and third steps improve strength and the second step improves corrosion resistance.

39. The method in accordance with claim 29 wherein said artificial aging includes aging:
   (i) at a low temperature above room temperature to precipitation harden said extrusion;
   (ii) at temperatures to improve corrosion resistance properties of said extrusion; and
   (iii) at lower temperatures above room temperature to precipitation harden said extrusion.

40. The method in accordance with claim 29 wherein the product has a fracture toughness at least 10% greater than a similar plate product fabricated from 7075 alloy.

41. The method in accordance with claim 29 wherein the product has an electrical conductivity of 34% IACS or greater when aged to peak strength.

42. The method in accordance with claim 29 wherein said artificial aging is carried out by aging in a temperature range of 150° to 325° F. for 2 to 30 hours followed by aging at 300° to 500° F. for 5 minutes to 3 hours followed by aging at 175° to 325° F. for 2 to 30 hours.

43. The method in accordance with claim 29 wherein the wrought product is an extrusion having thickness in the range of 0.04 to 10 inches.

44. A method of producing a wrought aluminum alloy flat rolled product having improved strength, fracture toughness, and an exfoliation corrosion resistance rating of EA or better, the method comprising the steps of:
   (a) providing a molten body of an aluminum base alloy comprised of 1.8 to 2.2 wt. % Mg, 0.01 to 0.9 wt. % Cu, 7.5 to 9.5 wt. % Zn, 0.1 to 0.4 wt. % Ag, 0.07 to 0.15 wt. % Zr, 0.05 to 0.8 wt. % Mn, max. 0.10 wt. % Si, max. 0.10 wt. % Fe, the remainder aluminum and incidental elements and impurities;
   (b) casting said molten body of said aluminum base alloy to provide an ingot, said molten aluminum base alloy being cast at a rate in the range of 1 to 4 inches per minute;
   (c) homogenizing said ingot by heating in a 840° to 910° F. to provide a homogenized ingot having a uniform distribution of Zn, Cu, Mg, Ag;
   (d) rolling said homogenized ingot to provide a flat rolled product, said rolling being carried out in a temperature range of 600° to 850° F. to provide said flat rolled product in a substantially non-recrystallized condition;
   (e) solution heat treating said flat rolled product; and
   (f) stretching said flat rolled product 0.5 to 5% permanent stretch or compressing said product in order to relieve the internal stresses imposed during the quenching of the product.

45. The method in accordance with claim 44 wherein the alloy contains 0.05 to 0.2 wt. % Cr.

46. The method in accordance with claim 44 wherein the alloy contains 0.01 to 0.2 wt. % Ti.

47. The method in accordance with claim 44 wherein the alloy contains 0.01 to 0.2 wt. % Sc.

48. The method in accordance with claim 44 wherein said solution heat treating is carried out in a temperature range of 875° to 885° F. for 5 to 120 minutes.

49. The method in accordance with claim 44 wherein said artificial aging is carried out by aging in a temperature range of 175° to 300° F. for 3 to 30 hours followed by aging at 280° to 360° F. for 3 to 24 hours.

50. The method in accordance with claim 44 wherein said artificial aging is carried out by aging in a temperature range of 175° to 300° F. for 3 to 30 hours.

51. The method in accordance with claim 44 wherein said artificial aging is carried out by aging in a temperature range of 210° to 280° F. for 4 to 24 hours followed by aging at 300° to 400° F. for 1 to 14 hours.

52. The method in accordance with claim 44 wherein said artificial aging includes aging:
(i) at a low temperature above room temperature to precipitation harden said extrusion;
(ii) at temperatures to improve corrosion resistance properties of said extrusion; and
(iii) at lower temperatures above room temperature to precipitation harden said extrusion.

53. The method in accordance with claim 44 wherein said artificial aging is carried out by aging in a temperature range of 150° to 325° F. for 2 to 30 hours followed by aging at 300° to 500° F. for 5 minutes to 3 hours followed by aging at 175° to 325° F. for 2 to 30 hours.

54. The method in accordance with claim 44 wherein the flat rolled product is a sheet product having thickness in the range of 0.35 to 0.25 inches.

55. The method in accordance with claim 44 wherein the flat rolled product is a plate product having thickness in the range of 0.5 to 12 inches.

56. An improved aluminum base alloy extrusion product consisting essentially of 1.6 to 2.5 wt. % Mg, 0.01 to 0.9 wt. % Cu, 7.5 to 9.5 wt. % Zn, 0.1 to 0.8 wt. % Mn, 0.05 to 0.15 wt. % Zr, 0.05 to 0.5 wt. % Ag, max. 0.15 wt. % Si, max. 0.15 wt. % Fe, max. 0.1 wt. % Mn, the remainder aluminum and incidental elements and impurities, said extrusion product having a fracture toughness of 10% or more and an exfoliation corrosion resistance significantly greater than a similarly sized 7075 product.

57. The extrusion product in accordance with claim 56 wherein the alloy contains 0.2 to 0.45 wt. % Ag.

58. The extrusion product in accordance with claim 56 wherein the alloy contains 1.8 to 2.2 wt. % Mg.

59. The extrusion product in accordance with claim 56 wherein the alloy contains 0.05 to 0.6 wt. % Cu.

60. The extrusion product in accordance with claim 56 wherein the alloy contains 0.05 to 0.5 wt. % Mn.

61. The extrusion product in accordance with claim 56 wherein the alloy contains 7.5 to 8.8 wt. % Zn.

62. The extrusion product in accordance with claim 56 wherein the alloy contains 0.01 to 0.2 wt. % Sc.

63. The extrusion product in accordance with claim 56 wherein the alloy contains 0.01 to 0.2 wt. % Ti.

64. The extrusion product in accordance with claim 56 wherein said product is a wing spar.

65. The extrusion product in accordance with claim 56 wherein said product is a wing rib.

66. The extrusion product in accordance with claim 56 wherein said product is an aircraft stringer.

67. The extrusion product in accordance with claim 56 wherein said product is an aircraft floor beam.

68. The extrusion product in accordance with claim 56 wherein said product is an aircraft fuselage beam.

69. An aluminum base alloy comprised of 1.6 to 2.5 wt. % Mg, 0.01 to 0.8 wt. % Cu, 7.5 to 9.5 wt. % Zn, 0.1 to 1 wt. % Ag, and at least one of the elements selected from the group Mn, Si, Fe, the remainder aluminum and incidental elements and impurities.

70. An aluminum base alloy comprised of 1.2 to 2.5 wt. % Mg, 0.01 to 1.0 wt. % Cu, 6.5 to 10.5 wt. % Zn, 0.01 to 1 wt. % Ag, 0.01 to 0.25 wt. % Zr, 0.01 to 0.8 wt. % Mn, 0.01 to 0.2 wt. % Ti, 0.01 to 0.4 wt. % Sc, max. 0.1 wt. % Si, max. 0.1 wt. % Fe, the remainder aluminum and incidental elements and impurities.

* * * * *