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Description

The present invention relates to a process of manufacturing products from an aluminium alloy having lithium together with magnesium and copper as main alloying elements. Its object is particularly to provide products of high fracture toughness and high strength that may be used in the aircraft industry.

Heretofore, aluminium-lithium alloys have been used only sparsely in aircraft structure. Their relatively low use has been caused by casting difficulties associated with aluminium-lithium alloys and by their relatively low fracture toughness compared to other more conventional aluminium alloys. Aluminium-lithium alloys, however, provide a substantial lowering of the density of aluminium alloys (as well as a relatively high strength to weight ratio), which has been found to be very important in decreasing the overall weight of structural materials used in an aircraft. While substantial strides have been made in improving the aluminium-lithium processing technology, a major challenge is still to obtain a good blend of fracture toughness and high strength in an aluminium-lithium alloy.

In accordance with the invention, it has been found that an excellent blend of fracture toughness and strength can be achieved if an aluminium-lithium-magnesium-copper alloy of certain compositional limitations is used and if such alloy after forming into articles is subjected to underaging at a low temperature in the range of 93°C to 149°C. In fact, products of high strength, good fracture toughness and relatively low density can be made which have potential use of replacing conventional aluminium alloy products of the 2000-series.

The invention thus provides a process of manufacturing products from an aluminium alloy having lithium together with magnesium and copper as main alloying elements, which process comprises the steps of:

—preparing an alloy of the following composition:

Element	Amount (wt%)
Li	2.2 to 2.8
Mg	0.2 to 0.8
Cu	1.5 to 2.1
Zr	0.15 max
Fe	0.15 max
Si	0.12 max
Other trace elements	0.25 max
Al	Balance

—forming articles from the alloy,

—subjecting the articles to a solution heat treatment and a quenching step,

—and aging the alloy in such articles at a temperature in the range from 93°C to 149°C.

Preferably, the alloy has a nominal composition of 2.45 weight-% lithium, 0.6 weight-% magnesium, 1.8 weight-% copper and 0.12 weight-% zirconium, the balance being aluminium and trace elements.

It is noted that an earlier proposal to manufacture Al-Li-Mg-Cu alloy products for use in aircrafts has been disclosed in EP—A—0 124 286 (GB—A—2 137 227). Some alloy compositions exemplified therein are falling within the compositional ranges of the alloy of the present invention but, on the other hand, all articles formed from the exemplified alloys in EP—A—0 124 286 are subjected to an aging step at a conventional temperature of about 170°C or 190°C.

Other proposals of the same type have been disclosed in EP—A—0 090 583 and GB—A—2 115 836. The alloy compositions exemplified therein have a lower copper content than in the alloy of the present invention, however, and the final aging step of the products is always effected at a temperature of 170°C or 190°C.

An aluminium-lithium alloy formulated in accordance with the present invention will contain 2.2 to 2.8% lithium, 0.2 to 0.8% magnesium, 1.5 to 2.1% copper and max 0.15% zirconium. All percentages herein are by weight based on the total weight of the alloy unless otherwise indicated. The magnesium in the alloy functions to increase strength and slightly decreases density. It also provides solid solution strengthening. The copper adds strength to the alloy. Zirconium functions as a grain refiner.

Iron and silicon can be present only in trace amounts, limiting the iron to a maximum of 0.15% and the silicon to a maximum of 0.12%, and preferably limiting them to less than 0.10% and 0.10%, respectively. Certain trace elements such as zinc, may be present in amounts up to, but not exceeding 0.25% of the total. Other elements such as chrominium and manganese must be held to levels of 0.05% or below. If the maximums of these trace elements are exceeded, the desired properties of the aluminium-lithium alloy will tend to deteriorate. The trace elements sodium and hydrogen are also thought to be harmful to the properties (fracture toughness in particular) of aluminium-lithium alloys and should be held to the lowest levels practically attainable, for example on the order of 15 to 30 ppm (0.0015—0.0030 wt.%) for the sodium and less than 15 ppm (0.0015 wt.%) and preferably less than 1.0 ppm (0.0001 wt.%) for the hydrogen. The balance of the alloy, of course, comprises aluminium.

An aluminium-lithium alloy formulated in the proportions set forth in the foregoing paragraph is processed into an article utilizing known techniques. The alloy is formulated in molten form and cast into an ingot. The ingot is then homogenized at temperatures ranging from 496°C to 538°C. Thereafter, the alloy is converted into a usable article by conventional mechanical formation techniques such a rolling, extrusion or the like. Once an article is formed, the alloy is

normally subjected to a solution treatment at temperatures ranging from 510°C to 538°C, quenched in a quenching medium such as water that is maintained at a temperature on the order of 21°C to 67°C. If the alloy has been rolled or extruded, it is generally stretched on the order of 1 to 3% of its original length to relieve internal stresses.

The aluminium alloy can then be further worked and formed into the various shapes for its final application. Additional heat treatments, such as solution heat treatment can be employed if desired. For example, an extruded product after being cut to desired length is generally solution heat-treated at temperatures on the order of 524°C for 1 to 4 hours. The product is then quenched in a quenching medium held at temperatures ranging from about 21°C to 67°C.

Thereafter, in accordance with the present invention, the article is subjected to an aging treatment that will increase the strength of the material, while maintaining its fracture toughness and other engineering properties at relatively high levels. In accordance with the present invention, the articles are subjected to a low temperature underage heat treatment at temperatures ranging from about 93°C to about 149°C. It is preferred that the alloy be heat treated in the range of from about 121°C to 135°C. At the higher temperatures, less time is needed to bring about the proper balance between strength and fracture toughness than at lower aging temperatures, but the overall properties mix will be slightly less desireable. For example, when the aging is conducted at temperatures on the order of 135°C to 149°C, it is preferred that the product be subjected to the aging temperature for periods of from 1 to 40 hours. On the other hand, when aging is conducted at temperatures on the order of 121°C or below, aging times from 2 to 80 hours or more are preferred to bring about the proper balance between fracture toughness and strength. After the aging treatment, the aluminium-lithium articles are cooled to room temperature.

When the low temperature underaging treatment is conducted in accordance with the parameters set forth above, the treatment will result in an aluminium-lithium alloy having an ultimate strength on the order of 448 to 483 MPa. The fracture toughness of the material, however, will be on the order of 1.5 to 2 times greater than that of similar aluminium-lithium alloys subjected to conventional aging treatments, which are normally conducted at temperatures greater than 149°C. The superior strength and toughness combination achieved by the low temperature underaging techniques in accordance with the present invention also surprisingly causes some aluminium-lithium alloys to exhibit an improvement in stress corrosion resistance when contrasted with the same alloy aged with standard aging practices. Examples of these improved characteristics will be set forth in more detail in conjunction with the ensuing example.

Example

An aluminium alloy containing 2.4% lithium, 0.6% magnesium, 1.8% copper, 0.15% zirconium with the balance being aluminium was formulated. The trace elements present in the formulation constituted less than 0.25% of the total. The iron and silicon present in the formulation each constituted less than 0.07% of the formulation. The alloy was cast and homogenized at about 524°C. Thereafter, the alloy was hot rolled to a thickness of 0.5 cm. The resulting sheet was then solution treated at about 524°C for about 1 hour. It was then quenched in water maintained at about 21°C. Thereafter, the sheet was subjected to a stretch of 1.5% of its initial length and then cut into specimens. The specimens were cut to a size of 1.27 cm by 6.35 cm by 0.5 cm for the precrack Charpy impact tests, one method of measuring fracture toughness. The specimens prepared for the tensile strength tests were 2.5 cm by 10.2 cm by 0.5 cm. A plurality of specimens were then aged for 16 and 40 hours at 135°C and 121°C for 40 and 72 hours. Each of the specimens aged at each of the temperatures and times were then subjected to the tensile strength and precrack Sharpy impact tests in accordance with standard testing procedures.

The specimens underaged at 135°C had ultimate strengths ranging from about 448 MPa to about 483 MPa with a toughness on the order of 0.114 to 0.131 J/mm^2. The specimens at 121°C exhibit an ultimate strength ranging from 427 to 448 MPa ksi, while their toughness was in the range of 0.131 to 0.149 J/mm^2. These values compare with toughness values less than about 0.079 J/mm^2 for similar materials aged at temperatures over 149°C, yet having similar ultimate strengths.

Claims

1. A process of manufacturing products from an aluminium alloy having lithium together with magnesium and copper as main alloying elements, said process comprising the steps of:

a) preparing an ingot of an alloy of the following composition:

Element	Amount (wt.%)
Li	2.2 to 2.8
Mg	0.2 to 0.8
Cu	1.5 to 2.1
Zr	0.15 max
Fe	0.15 max.
Si	0.12 max.
Other trace elements	0.25 max.
Al	balance;

b) homogenising the ingot;

c) forming an article;

d) subjecting the article to a solution heat treatment;

e) quenching the article in a quenching medium;

f) ageing the article at a temperature in the range of about 93°C (200°F) to about 149°C (300°F).

2. The process as claimed in claim 1, wherein zirconium is present in an amount ranging from 0.1 to 0.15 wt.%.

3. The process as claimed in claim 1 or 2, wherein the alloy has a nominal composition of 2.45 wt.% lithium, 0.6 wt.% magnesium, 1.8 wt.% copper and 0.12 wt.% zirconium, the balance being aluminium and trace elements.

4. The process as claimed in claim 1—3, wherein the alloy is aged at a temperature in the range of about 121°C (250°F) to about 135°C (275°F).

5. The process as claimed in claims 1—4, wherein the alloy is aged for a period of 1—80 hours.

6. Aluminium alloy article comprising an alloy of the following composition:

Element	Amount (wt.%)
Li	2.2 to 2.8
Mg	0.2 to 0.8
Cu	1.5 to 2.1
Zr	0.15 max.
Fe	0.15 max.
Si	0.12 max.
Other trace elements	0.25 max.
Al	balance;

and having an ultimate tensile strength from about 427 to about 483 MPa (62—70 ksi) in combination with a fracture toughness from about 114 to about 149×10^3 J/m^2 (650—850 in-lbs/in^2).

7. Aluminium alloy article as claimed in claim 6, wherein zirconium is present in an amount ranging from 0.1 to 0.15 wt.%.

8. Aluminium alloy article as claimed in claim 6 or 7, wherein the alloy has a nominal composition of 2.45 wt.% lithium, 0.6 wt.% magnesium, 1.8 wt.% copper and 0.12 wt.% zirconium, the balance being aluminium and trace elements.

9. Aluminium alloy article as claimed in claim 6—8, having an ultimate tensile strength from about 448 to about 483 MPa (65—70 ksi) in combination with a fracture toughness from about 114 to about 131×10^3 J/m^2 (650—750 in-lbs/in^2).

10. Aluminium alloy article as claimed in claims 6—8, having an ultimate tensile strength from about 427 to about 448 MPa (62—65 ksi) in combination with a fracture toughness from about 131 to about 149×10^3 J/m^2 (750—850 in-lbs/in^2).

Patentansprüche

1. Verfahren zur Herstellung von Produkten aus einer Aluminiumlegierung, die zusammen mit Magnesium und Kupfer Lithium als Hauptlegierungselemente aufweist, gekennzeichnet durch die Stufen

a) Herstellung eines Barrens einer Legierung mit folgender Zusammensetzung:

Element	Menge (Gew.-%)
Li	2,2 bis 2,8
Mg	0,2 bis 0,8
Cu	1,5 bis 2,1
Zr	0,15 max.
Fe	0,15 max.
Si	0,12 max.
weitere Spuren elemente	0,25 max.
Al	Rest

b) Homogenisierung des Barrens;

c) Formung eines Gegenstands;

d) Unterwerfung des Gegenstands einer Lösungsglühungsbehandlung;

e) Abschrecken des Gegenstands in einem Abschreckungsmedium;

f) Alterung des Gegenstands bei einer Temperatur im Bereich von etwa 93°C (200°F) bis etwa 149°C (300°F).

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß Zirkonium in einer Menge von 0,1 bis 0,15 Gew.-% vorhanden ist.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Legierung eine nominale Zusammensetzung von 2,45 Gew.-% Lithium, 0,6 Gew.-% Magnesium, 1,8 Gew.-% Kupfer und 0,12 Gew.-% Zirconium, Rest Aluminium und Spurenelemente aufweist.

4. Verfahren nach den Ansprüchen 1 bis 3, dadurch gekennzeichnet, daß die Legierung bei einer Temperatur im Bereich von etwa 121°C (250°F) bis etwa 135°C (275°F) gealtert wird.

5. Verfahren nach den Ansprüchen 1 bis 4, dadurch gekennzeichnet, daß die Legierung über einen Zeitraum von 1 bis 80 Stunden gealtert wird.

6. Gegenstand aus einer Aluminiumlegierung, gekennzeichnet durch eine Legierung der folgenden Zusammensetzung:

Element	Menge (Gew.-%)
Li	2,2 bis 2,8
Mg	0,2 bis 0,8
Cu	1,5 bis 2,1
Zr	0,15 max.
Fe	0,15 max.
Si	0,12 max.
weitere Spuren elemente	0,25 max.
Al	Rest

hat und eine Zerreißfestigkeit von etwa 427 bis etwa 483 MPa (62 bis 70 ksi) in Kombination mit einer Bruchzähigkeit von etwa 114 bis etwa 149×10^3 J/m^2 (650 bis 850 in-lbs/in^2) hat.

7. Gegenstand aus einer Aluminiumlegierung nach Anspruch 6, dadurch gekennzeichnet, daß Zirkonium in einer Menge von 0,1 bis 0,15 Gew.-% vorhanden ist.

8. Gegenstand aus einer Aluminiumlegierung nach Anspruch 6 oder 7, dadurch gekennzeichnet, daß die Legierung eine Nominalzusammenset-

zung von 2,45 Gew.-% Lithium, 0,6 Gew.-% Magnesium, 1,8 Gew.-% Kupfer und 0,12 Gew.-% Zirconium, Rest Aluminium und Spurenelemente hat.

9. Gegenstand aus einer Aluminiumlegierung nach den Ansprüchen 6 bis 8, dadurch gekennzeichnet, daß er eine Zerreißfestigkeit von etwa 448 bis etwa 483 MPa (65 bis 70 ksi) in Kombination mit einer Bruchzähigkeit von etwa 114 bis etwa 131×10^3 J/m^2 (650 bis 750 in-lbs/in^2) hat.

10. Gegenstand aus einer Aluminiumlegierung nach den Ansprüchen 6 bis 8, dadurch gekennzeichnet, daß er eine Zerreißfestigkeit von etwa 472 bis etwa 448 MPa (62 bis 65 ksi) in Kombination mit einer Bruchzähigkeit von etwa 131 bis etwa 149×10^3 J/m^2 (750 bis 850 in-lbs/in^2) hat.

Revendications

1. Un procédé de fabrication des produits à partir d'un alliage d'aluminium contenant du lithium ensemble avec du magnésium et du cuivre comme éléments d'alliage principaux, ledit procédé comprenant les étapes suivantes:

a) préparation d'un lingot d'un alliage ayant la composition suivante:

Elément	Quantité (% en poids)
Li	2,2 à 2,8
Mg	0,2 à 0,8
Cu	1,5 à 2,1
Zr	0,15 max
Fe	0,15 max
Si	0,12 max
Autres éléments à l'état de trace	0,25 max
Al	le restant

b) homogénéisation du lingot;

c) formation d'un article;

d) soumition de l'article à un traitement thermique en solution;

e) trempe de l'article dans un milieu de trempe;

f) vieillissement de l'article à une température dans l'intervalle d'environ 93°C à environ 149°C.

2. Le procédé selon la revendication 1, selon lequel le zirconium est présent en quantité dans l'intervalle de 0,1 à 0,15% en poids.

3. Le procédé selon la revendication 1 ou 2, selon lequel l'alliage a une composition nominale de 2,45% en poids de lithium, 0,6% en poids de magnésium, 1,8% en poids de cuivre et 0,12% en poids de zirconium, le restant étant de l'aluminium et des éléments à l'état de trace.

4. Le procédé selon l'une des revendications 1 à 3, selon lequel l'alliage est vieilli à une température comprise dans l'intervalle d'environ 121°C à environ 135°C.

5. Le procédé selon l'une des revendications 1 à 4, selon lequel l'alliage est vieilli pendant une période de 1—80 h.

6. Article en alliage d'aluminium comprenant un alliage ayant la composition suivante:

Elément	Quantité (% en poids)
Li	2,2 à 2,8
Mg	0,2 à 0,8
Cu	1,5 à 2,1
Zr	0,15 max
Fe	0,15 max
Si	0,12 max
Autres éléments à l'état de trace	0,25 max
Al	le restant

et ayant une résistance limite à la traction d'environ 427 à environ 483 MPa en combinaison avec une ténacité à la rupture d'environ 114 à environ 149×10^3 J/m^2.

7. Article en alliage d'aluminium selon la revendication 6, selon lequel le zirconium est présent en quantité dans l'intervalle de 0,1 à 0,15% en poids.

8. Article en alliage d'alumunium selon la revendication 6 ou 7, selon lequel l'alliage a une composition nominale de 2,45% en poids de lithium, 0,6% en poids de magnésium, 1,8% en poids de cuivre et 0,12% en poids de zirconium, le restant étant de l'alumimium et des éléments à l'état de trace.

9. Article en alliage d'aluminium selon l'une des revendications 6 à 8, ayant une résistance limite à la traction d'environ 448 à environ 483 MPa en combinaison avec une ténacité à la rupture d'environ 114 à environ 131×10^3 J/m^2.

10. Article en alliage d'aluminium selon l'une des revendications 6 à 8, ayant une résistance limite à la traction d'environ 427 à environ 448 MPa en combinaison avec une ténacité à la rupture d'environ 131 à environ 149×10^3 J/m^2.