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Description

The present invention relates to a process of manufacturing products from an aluminium alloy having lithium together with 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 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 under-aging 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 7XXX-series.

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

- preparing an alloy of the following composition:

Element	Amount (wt%)
Li	2.0 to 2.4
Mg	0 to 0.9
Cu	2.3 to 2.7
Zr	0.12 max
Fe plus Si	0.30 max
Other Trace elements	0.25 max
Al	Balance

- casting the alloy into an ingot,
- homogenising the ingot,
- forming articles from said alloy,
- subjecting the articles to a solution heat treatment and a quenching step,
- and aging the alloy in such articles.

Preferably, the alloy has a nominal composition of 2.2 percent Li, 0.5 percent Mg, 2.5 percent Cu and 0.12 percent Zr, with the balance being Al and trace elements.

It is noted that an earlier proposal to manufacture Al-Li-Mg-Cu alloy products for use in aircraft has been disclosed in R.J.Kar, J.W. Bohlen and G.R. Chanani, p.257 and p.266, which does not disclose a content of Zn limited as in the present invention. Noble and Thompson, Metal Science Journal (1972) p.167-74 discloses a process of treating Al-Li-Cu alloys, but said alloys do not contain Zn.

An aluminium-lithium alloy formulated in accordance with the present invention will contain 2.0 to 2.4 percent lithium, 0 to 0.9 percent magnesium, 2.3 to 2.7 percent copper and a maximum of 0.12 percent zirconium as a grain refiner. Preferably, from 0.10 to 0.12 percent zirconium is incorporated. All percentages herein are by weight based on the total weight of the alloy unless otherwise indicated. While no magnesium need be employed in the alloy, it is preferred that magnesium be included to increase strength without increasing density. Magnesium also provides solid solution strengthening. Preferred amounts of magnesium range from 0.5 to 0.9 percent, with 0.7 percent being more preferred. The copper adds strength to the alloy.

Iron and silicon can be present only in trace amounts, limiting the iron to a maximum of 0.15 percent and the silicon to a maximum of 0.12 percent, and preferably limiting them to maximums of 0.10 and 0.10 percent respectively. Certain trace elements such as zinc, may be present in amounts up to but not exceeding 0.25 percent of the total. Other elements such as chromium and manganese must be held to levels of 0.05 percent or below. If these maximums 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 15-30 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 said forth in the forgoing 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 as 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 66 °C. If the alloy has been rolled or extruded, it is generally stretched on the order of 1 to 3 percent 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 66 °C.

Thereafter, in accordance with the present invention, the article is subjected to an aging treatment at relatively low temperatures on the order of from 93 °C to 149 °C. Since this alloy is intended to replace conventional 7XXX-series type alloys, it is preferred that the alloy be aged for a period of time that will allow it to achieve at least about 95% of its peak strength. It is preferred that the alloy be aged for a period of time allowing it to achieve 95-97% of its peak strength. Preferred aging temperatures range from 121 °C to 135 °C. Within these temperature ranges, 95-97% peak strength can be achieved by aging from about 4 to 120 hours.

Example

An aluminium alloy containing 2.2 percent lithium, 0.5 percent magnesium, 2.5 percent copper, 0.1 percent zirconium with the balance being aluminium was formulated. The trace elements present in the formulation constituted less than 0.25 percent of the total. The iron and silicon present in the formulation constituted less than 0.07 percent 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 percent of its initial length. The material was 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, which measure fracture toughness. The specimens prepared for the tensile strength tests were 2.54 cm by 10.2 cm by 0.5 cm. A plurality of specimens were then aged for 120 hours at 135 °C. Each of the specimens aged at each of the temperatures and times were then subjected to the tensile strength and precrack Charpy impact tests in accordance with standard ASTM testing procedures.

The specimens underaged at 135 °C exhibit an ultimate strength ranging from about 586 MPa to about 655 MPa with a toughness on the order of 0.039 J/mm^2 to 0.049 J/mm^2.

Claims

1. A process of manufacturing products from an aluminum alloy having lithium together with copper and the grain refiner zirconium as obligatory alloying elements, said process comprising the steps of:

a) preparing an alloy of the following composition:

Element	Amount (wt.%)
Li	2.0 to 2.4
Mg	0 to 0.9
Cu	2.3 to 2.7
Zr present up to a maximum of	0.12
Fe plus Si maximum	0.30
Other trace elements maximum	0.25
Al	balance;

b) casting the alloy into an ingot;
c) homogenising the ingot;
d) forming an article
e) subjecting the article to a solution heat treatment;
f) quenching the article in a quenching medium; and
g) ageing the article.

2. The process as claimed in claim 1, wherein magnesium is present in an amount ranging from 0.5 to 0.9 wt.%.

3. The process as claimed in claims 1 or 2, wherein magnesium is present in the amount of 0.7 wt.%.

4. The process as claimed in claims 1-3, wherein iron is present in amounts up to 0.15 wt%.

5. The process as claimed in claims 1-4, wherein iron is present in amounts up to 0.10 wt%.

6. The process as claimed in claims 1-5, wherein silicon is present in amounts up to 0.12 wt.%.

7. The process as claimed in claims 1-6, wherein silicon is present in amounts up to 0.10 wt.%.

8. The process as claimed in claims 1-7, wherein the alloy has a nominal composition of 2.2 wt.% Li, 0.5 wt.% Mg, 2.5 Wt.% Cu and 0.12 wt.% Zr, with the balance being Al and trace elements.

9. The process as claimed in claims 1-8, wherein the alloy is aged for a period of time sufficient to reach at least 95% of its peak strength.

10. The process as claimed in claims 1-9, wherein the alloy is aged for a period of time sufficient to reach 95 to 97% of its peak strength.

11. The process as claimed in claims 1-10, wherein the article is aged at temperature in the range of 93 °C (200 °F) to 149 °C (300 °F).

12. The process as claimed in claim 11, wherein the alloy is aged at a temperature in the range of 121 °C (250 °F) to 135 °C (275 °F).

13. The process as claimed in claims 1-12, wherein the alloy is aged for a period of time ranging from 4-120 hours.

14. The process as claimed in claim 1, wherein zirconium is present in an amount of 0.10 to 0.12 wt.%.

Patentansprüche

1. Verfahren zur Herstellung von Erzeugnissen aus einer Aluminiumlegierung, die gemeinsam mit Lithium, Kupfer und das Kornverfeinerungsmittel Zirconium als obligatorische Legierungselemente aufweist, wobei das Verfahren die Schritte umfaßt:
a) Herstellen einer Legierung der folgenden Zusammensetzung:

Element	Menge (Gew.%)
Li	2,0 bis 2,4
Mg	0 bis 0,9
Cu	2,3 bis 2,7
Zr vorliegend bis zu einem Maximum von	0,12
Fe plus Si maximal	0,30
weitere Spurenelemente maximal	0,25
Al	Rest;

b) Gießen der Legierung zu einem Block;

c) Homogenisieren des Blocks;
d) Umformen zu einem Gegenstand;
e) den Gegenstand einem Lösungsglühen unterziehen;
f) Abschreckhärten des Gegenstands in einem Abschreckmittel;
g) Altern des Gegenstands.

2. Verfahren nach Anspruch 1, bei welchem Magnesium in einer Menge im Bereich von 0,5 % bis 0,9 Gew.% vorliegt.

3. Verfahren nach Anspruch 1 oder 2, bei welchem Magnesium in einer Menge von 0,7 Gew.% vorliegt.

4. Verfahren nach Anspruch 1 bis 3, bei welchem Eisen in Mengen bis zu 0,15 Gew.% vorliegt.

5. Verfahren nach Anspruch 1 bis 4, bei welchem Eisen in Mengen bis zu 0,10 Gew.% vorliegt.

6. Verfahren nach Anspruch 1 bis 5, bei welchem Silicium in Mengen bis zu 0,12 Gew.% vorliegt.

7. Verfahren nach Anspruch 1 bis 6, bei welchem Silicium in Mengen bis zu 0,10 Gew.% vorliegt.

8. Verfahren nach Anspruch 1 bis 7, bei welchem die Legierung eine Nennzusammensetzung 2,2 Gew.% Li, 0,5 Gew.% Mg, 2,5 Gew.% Cu und 0,12 Gew.% Zr, Rest Al und Spurenelemente aufweist.

9. Verfahren nach Anspruch 1 bis 8, bei welchem die Legierung für eine zum Erreichen von mindestens 95 % ihrer Höchstfestigkeit ausreichenden Zeitdauer gealtert wird.

10. Verfahren nach Anspruch 1 bis 9, bei welchem die Legierung für eine zum Erreichen von 95 % bis 97 % ihrer Höchstfestigkeit ausreichenden Zeitdauer gealtert wird.

11. Verfahren nach Anspruch 1 bis 10, bei welchem der Gegenstand bei einer Temperatur im Bereich von 93 °C (200 °F) bis 149 °C (300 °F) gealtert wird.

12. Verfahren nach Anspruch 11, bei welchem die Legierung bei einer Temperatur im Bereich von 121 °C (250 °F) bis 135 °C (275 °F) gealtert wird.

13. Verfahren nach Anspruch 1 bis 12, bei welchem die Legierung für eine Zeitdauer im Bereich von 4 bis 120 Stunden gealtert wird.

14. Verfahren nach Anspruch 1, bei welchem Zirconium in einer Menge von 0,10 bis 0,12 Gew.%. vorliegt.

Revendications

1. Procédé de fabrication de produits à partir d'un alliage d'aluminium comprenant du lithium et du cuivre et le zirconium affineur de grains, en tant qu'éléments d'alliage obligatoires, ledit procédé comprenant les étapes consistant à:
a) préparer un alliage ayant la composition suivante :

Eléments	Quantité (% en poids)
Li	2,0 à 2,4
Mg	0 à 0,9
Cu	2,3 à 2,7
Zr jusqu'à un maximum de	0,12
Fe plus Si, au maximum	0,30
Autres éléments trace, au maximum	0,25
Al	le reste

b) mouler l'alliage en un lingot;
c) homogénéiser le lingot;

d) former un objet;
e) soumettre l'objet à un traitement à la chaleur en solution;
f) tremper l'article dans un milieu de trempe ; et
g) faire vieillir l'objet.

2. Procédé selon la revendication 1, dans lequel le magnésium est présent en une quantité comprise dans l'intervalle de 0,5 à 0,9 % en poids.

3. Procédé selon la revendication 1 ou 2, dans lequel le magnésium est présent à raison de 0,7 % en poids.

4. Procédé selon les revendications 1 à 3, dans lequel le fer est présent en des quantités allant jusqu'à 0,15 % en poids.

5. Procédé selon les revendications 1 à 4, dans lequel le fer est présent en des quantités allant jusqu'à 0,10 % en poids.

6. Procédé selon les revendications 1 à 5, dans lequel le silicium est présent en des quantités allant jusqu'à 0,12 % en poids.

7. Procédé selon les revendications 1 à 6, dans lequel le silicium est présent en des quantités allant jusqu'à 0,10 % en poids.

8. Procédé selon les revendications 1 à 7, dans lequel l'alliage a une composition nominale de 2,2 % en poids de Li, 0,5 % en poids de Mg, 2,5 % en poids de Cu et 0,12 % en poids de Zr, le reste étant constitué de Al et d'éléments trace.

9. Procédé selon les revendications 1 à 8, dans lequel on fait vieillir l'alliage pendant une durée suffisante pour atteindre au moins 95 % de sa résistance maximale.

10. Procédé selon les revendications 1 à 9, dans lequel on fait vieillir l'alliage pendant une durée suffisante pour atteindre de 95 à 97 % de sa résistance maximale.

11. Procédé selon les revendications 1 à 10, dans lequel on fait vieillir l'objet à une température comprise dans l'intervalle de 93 °C (200 °F) à 149 °C (300 °F).

12. Procédé selon la revendication 11, dans lequel on fait vieillir l'alliage à une température comprise dans l'intervalle de 121 °C (250 °F) à 135 °C (275 °F).

13. Procédé selon les revendications 1 à 12, dans lequel on fait vieillir l'alliage pendant une durée comprise dans l'intervalle de 4 à 120 h.

14. Procédé selon la revendication 1, dans lequel le zirconium est présent à raison de 0,10 à 0,12 % en poids.