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(73)

Proprietor: **MPD Technology Corporation**
681 Lawlins Road
Wyckoff New Jersey 07481 (US)

(72)

Inventor: **Weber, John Herbert**
49-B Johnstown Road
Sloatsburg New York 10974 (US)
Inventor: **Pickens, Joseph Robert**
11603-35 Avenue
Beltsville Maryland 20705 (US)

(74)

Representative: **Greenstreet, Cyril Henry et al**
Thames House (Fifth floor) Millbank
London SW1P 4QF (GB)

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Description

This invention relates to dispersion-strengthened mechanically alloyed aluminium alloys, and methods of producing and age-hardening them.

5 There is a demand in the aircraft industry for aluminium alloys having high strength, elastic modulus, and corrosion resistance coupled with low density. The addition of lithium to aluminium offers the possibility of producing improvements in the density and elastic modulus. Several Al-Li alloy systems are presently being studied. For example, T. H. Sanders and E. S. Balmuth have reported on three experimental alloy systems in "Metal Progress", pp. 32—37 (March 1978). These alloys which
10 apparently are formed by conventional melting and casting techniques, are Al-Li containing 2.83 and 2.84 wt. % Li, Al-Cu-Li containing 1.5 wt. % Li, and Al-Mg-Li containing 1.37 to 3.14 wt. % Li. They derive their strength from precipitates of the δ' phase, Al_3Li . This δ' phase may coarsen at elevated temperatures and transform to the incoherent δ phase, which does not confer so much strength on the alloy. It has been reported that the δ' phase coarsens rapidly at temperatures of about 200°C.
15 Furthermore, conventionally produced Al-Li alloys suffer from severe oxidation during melting, and it may be difficult to break down the cast ingot during subsequent working.

It has already been proposed to make *inter alia* dispersion strengthened Al-Li alloys by a powder metallurgy technique known as mechanical alloying.

Mechanical alloying techniques are disclosed in, for example, U.S. Patents Nos. 3 591 362;
20 3 740 210 and 3 816 080. Mechanical alloying is a method of producing composite metal powders with a controlled, uniform, fine microstructure by means of the fracturing and rewelding of a mixture of powder particles during high energy impact milling, e.g., in an attritor grinding mill. The process takes place entirely in the solid state. The repetitive cold welding and fracturing of the powder particles during mechanical alloying of aluminium incorporates dispersoid materials, such as the naturally
25 occurring oxides on the surface of the powder particles, into the interior of the composite powder particles. As the process continues, the incorporated dispersoid particles become homogeneously dispersed throughout the powder particles. In a similar fashion metallic alloy ingredients also are finely distributed within the powder particles. Powder produced by mechanical alloying may be subsequently consolidated by known methods such as hot compaction followed by extrusion, rolling or forging.

30 Of the patents mentioned above, the latter two are specifically directed to mechanically alloyed aluminium and alloys containing one or more other elements, for example up to 1.5 wt. % lithium. Various solubility limits for Li in Al at room temperature have been reported, including 0.6, 0.7 and 1.5%.

It has now surprisingly been found that certain mechanically produced alloys containing more
35 than 1.5 wt. % lithium, i.e. with lithium available over the solubility limit, have improved strength, specific modulus, corrosion resistance and thermal stability, particularly when in the age-hardened condition.

Accordingly, the present invention provides a dispersion-strengthened mechanically alloyed aluminium-lithium alloy which consists of more than 1.5 but less than 3.5 wt. % lithium, from 0.4 to
40 1.5 wt. % oxygen, and from 0.2 to 1.2 wt. % carbon, optionally up to 0.5 wt. % iron, up to 1.0 wt. % magnesium, the balance being aluminium and incidental impurities.

The essential components of dispersion strengthened aluminium base alloys of the present invention are aluminium, lithium, oxygen and carbon. Small percentages of these components are present in combination as insoluble dispersoids, such as oxides of lithium. Optionally up to 1.0 wt. %
45 magnesium and up to 0.5 wt. % iron may be incorporated in the alloy matrix, e.g. for solid solution strengthening, and at these levels they do not interfere with the desired properties of the alloy for a particular end use.

The lithium content of the alloy must exceed 1.5% and is preferably at least 1.7%. Amounts of lithium up to 1.5% may be present in equilibrium solution, and further amounts may be present in
50 supersaturated solution. A small fraction of the lithium e.g. from 0.03 to 0.5%, depending on the available oxygen content of the powder charge and the total lithium content of the alloy, may be present as a stable insoluble oxide dispersoid which forms *in situ* during mechanical alloying and/or consolidation and is uniformly distributed in the alloy matrix. This dispersoid is believed to be lithium peroxide, and is particularly effective in increasing the strength of the alloy.

55 The lithium content must not exceed 3.5 wt. % since above this figure excessive amounts of δ' phase may form, and the alloy may be embrittled. Preferably the lithium content does not exceed 2.8%, as additional strength gained by the use of larger amounts does not compensate for the loss in ductility.

The lithium is introduced into the alloy system as a powder (elemental or prealloyed with aluminium), thereby avoiding problems which accompany the melting of lithium.

60 The oxygen content is from 0.4 wt. % to 1.5 wt. % and preferably does not exceed 1.0 wt. %. The oxygen content should be sufficient to provide enough dispersoid for the desired level of strength without being so high as to combine with the lithium in solid solution and reduce the amount of dissolved lithium below the solubility limit, taking into account the amount of lithium which may be present in supersaturated solution. As excessive amounts of both lithium and oxygen tend to embrittle
65 the alloys, when the Li content is at the low end of the specified range, e.g. about 1.6 wt. %, the oxygen

level may be up to 1.5 wt. %, whilst when the Li content is high, e.g. 2.3 wt. %, the oxygen content is preferably less than 1 wt. %, e.g. 0.4 to 0.5 wt. %.

The carbon content is from 0.2 to 1.2 wt. % and more preferably from 0.25 to 1 wt. %. The carbon is generally provided by the process control agent used during mechanical alloying to control inter-particle welding, as described below.

Dispersion strengthening in alloys of the present invention is provided by oxide- and carbide-based dispersoids which may be formed during the mechanical alloying or subsequent consolidation or both. Alternatively, they may be added as such to the powder. Examples of dispersoid that may be present are Al_2O_3 , AlOOH , Li_2O , Li_3AlO_4 , LiAlO_2 , LiAl_5O_8 , Li_5AlO_4 , Li_2O_2 and Al_4C_3 . Other dispersoids may be used provided that they are stable in the Al-Li matrix at the temperature of service. Oxides of lithium are particularly suitable for use as dispersoid in alloys of the present invention, and, of these, Li_2O_2 is preferred.

Preferably, the dispersoid content is as low as possible consistent with the desired strength. The dispersoid content may thus be up to 8% by volume and more preferably lies in the range from 3 to 5 vol. %. The dispersoid should be very fine, preferably having a particle size of about 0.02 microns, and should be uniformly dispersed throughout the alloy. It is believed that the fine grain size of alloys of this invention (about 0.1 microns) is, at least in part, responsible for their high room temperature strength.

The mechanical alloying process used to prepare the alloys of the present invention comprises the dry, high energy milling of aluminium and lithium powders in the presence of a grinding medium, e.g. balls, and a carbon-containing process control agent, so as to comminute the powder particles and, by a combination of repeated comminution and welding, to create new, dense composite particles containing fragments of the initial powder materials intimately associated and uniformly interdispersed. The process control agent, which serves to control interparticle welding, may for example be graphite or a volatilisable organic compound which may also contain oxygen. We prefer to use methanol, stearic acid, or graphite, but other organic acids, alcohols, aldehydes, ethers, or heptanes may be used. The process control agent is added intermittently during milling, the amount used being calculated based in known manner on such factors as the ball-to-powder ratio, starting powder size, and mill temperature. The milling is carried out under a blanket of argon or nitrogen to facilitate control of the oxygen content of the powder, as virtually the only sources of oxygen are the starting powders and the process control agent (if this contains oxygen). The powder may be prepared in an attritor using a ball-to-powder weight ratio of from 15:1 to 60:1.

The dispersion strengthened mechanically alloyed powder is then degassed and consolidated at a temperature below its liquation temperature. Degassing may be carried out at a temperature in the range from 220° to 600°C. Subsequent consolidation may also be carried out at a temperature in the range from 220 to 600°C, preferably at about 500°C. If desired a separate compaction step may be employed. For example, the powder may be canned, degassed at 510°C, hot compacted and extruded at a temperature in the range from 315° to 510°C. It is believed that these preferred conditions produce alloys in which fine grain size, high dislocation density, fine uniform dispersion of oxides and carbides, and lithium in solid solution all contribute to strength. The lithium present in solid solution (equilibrium and supersaturated) and that present as oxide dispersoid contribute to the high specific modulus. In addition to high strength, low density and high elastic modulus, alloys of the invention have good resistance to corrosion including stress corrosion cracking, and good thermal stability.

The strength of alloys according to the invention may be further increased by an age-hardening heat treatment.

This heat treatment consists of two steps; a solution treatment at a temperature not exceeding that used in the degassing or consolidation and an ageing treatment, between which the alloy is cooled. The cooling may be in air, or by quenching, for example in water or oil.

Preferably the solution treatment is effected at the same temperature as the consolidation. A suitable temperature range for both operations is from 400 to 540°C. The solution treatment may be carried out for a length of time ranging from that sufficient to bring the alloy up to temperature (generally at least 0.5 hours) up to 4 hours.

The age-hardening may be effected at a temperature in the range from 95 to 260°C for a period of from 1 to 48 hours. More preferably, the age-hardening temperature range is from 120 to 230°C and the duration of the ageing is from 1 to 24 hours. It will be appreciated by those skilled in the art that for both solution treatment and age-hardening the time element bears an inverse relationship to the temperature.

Alloys of the present invention, particularly those containing less than 3% lithium and at least 0.25% carbon, may also, of course, be used without age-hardening. In this event, the strength of the alloys may be maximised by controlling their composition very carefully to avoid excessive uncontrolled precipitation of the δ' phase (Al_3Li) as this tends to render the alloys somewhat brittle and may impair their corrosion resistance. Thus if the alloys are not to be further strengthened by age-hardening the lithium content preferably does not exceed 2.3% so as to minimise the risk of δ' phase formation. The Li in the system then comprises about 1.5 wt. % in equilibrium solid solution and up to about 0.8 wt. % in supersaturated solid solution. Some Li, of course, will be tied up with available oxygen as dispersoid.

Thus a preferred composition range for alloys which are not to be age-hardened is from 1.7 to 2.3 wt. % lithium, from 0.4 to 1.0 wt. % oxygen and from 0.25 to 0.7 wt. % carbon.

The invention will now be further described with reference to some examples.

5 Example I

Specimens of two Al-Li alloys according to the invention (Alloys A and B) were prepared from dispersion-strengthened, mechanically alloyed powders which had been ground in a high energy impact mill for 4 hours using a ball:powder ratio by weight of 40:1 under a blanket of argon in the presence of a process control agent. The powders were canned, vacuum degassed for 3 hours and
10 compacted at 510°C, then extruded to rod of diameter 1.6 cm at a temperature of 343°C.

The compositions of alloys A and B are shown in Table I below.

Alloy	Li	O	C	Fe
A	2.6*	1.13*	0.49	0.06
B	1.93	0.45	0.26	0.08

20 * Analysis of chips from extruded rod—other analyses are of the powder.

Samples of alloys A and B were subjected to different heat treatments after extrusion and the effect of the heat treatments on the hardness of the alloys was determined. The heat treatments began
25 with a solution treatment of duration 0.5 hours at 510°C. The specimens were quenched in water and then age-hardened at 177°C for various periods between 0 and 16 hours. The age hardened alloys were air cooled and their hardnesses on the Rockwell B (R_B) scale were determined at room temperature.

The results of the tests are shown in Table II.

Alloy	Ageing time (hours)	Hardness, R_B
A	0 (Solution treated only)	79.5
	1	85.5
	4	83.5
	16	78.0
	0 (Solution treated only)	70.5
B	1	69.0
	4	71.5
	16	65.0

50 From Table II it can be seen that with a lithium content of 2.6 wt. % (alloy A), there is a significant ageing response, whereas the effect of heat treatment on the 1.9 wt. % lithium alloy (alloy B) is minimal, apparently because the lithium content is only slightly above the solubility limit and there is little lithium available for precipitation. It therefore appears that the heat treatment produces an ageing response which is dependent on the lithium contents of the alloys. One familiar with ageing in alloys
55 would expect the extent of the response to be dependent also on the ageing temperature, with lower temperatures producing a greater response albeit at longer treatment times.

Example II

60 Samples of the two alloys A and B used in Example I were subjected to different heat treatments after extrusion and the effect of these heat treatments on their strength was determined. As in Example I, a solution treatment of duration 0.5 hours at the temperature previously used for degassing and consolidation, (in this case 510°C) was carried out. This was followed by a water quench and then an age hardening treatment at 177°C. Specimens of alloy A were age hardened for 1 hour whilst specimens of alloy B were age hardened for 4 hours. The alloys were air cooled and their tensile
65 strengths were measured at room temperature.

The results of these measurements are shown in Table III below together with data for the as-extruded alloys. The parameters measured were ultimate tensile strength (UTS), yield strength (YS), % elongation to fracture (% El), % reduction in area to fracture (% RA) and elastic modulus (E).

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TABLE III

Sample	Condition	YS (N/mm ²)	UTS (N/mm ²)	El (%)	RA (%)	E (KN/mm ²)
A	As extruded	465	527	2.0	6.0	80.0
	Aged	568	612	2.5	7.5	75.8
B	As extruded	380	403	13.0	38.5	80.6
	Aged	381	411	10.0	29.0	77.9

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From Table III, it can be seen that for Alloy A (2.6 wt. % Li) the heat treatment improves the strength and this is indicative of age hardening of the alloy. Again the effect of heat treatment on Alloy B (1.9 wt. % Li) is minimal.

20 From the above tests it appears that heat treatment is beneficial for alloys containing more than about 2.0 wt. % lithium in that the tensile properties can be improved. The thermal stability of the alloys may also be improved by age-hardening. Ageing treatments at lower temperatures are expected to produce benefits in Al-Li alloys with lower lithium contents.

25 Example III

The effect of alloying element content on the tensile properties of dispersion-strengthened mechanically alloyed Al-Li alloys was investigated. Samples of 16 different alloys were prepared by high energy impact milling mixtures of powders in a 15 litre attritor for from 6 to 18 hours at various ball-to-powder weight ratios (B/P) under a blanket of nitrogen or argon and in the presence of either 30 methanol (M) or stearic acid (S) as the process control agent (PCA). The PCA was introduced either by discrete additions or by absorption through the attritor atmosphere when this was bubbled through a flask containing the PCA ("the bubbler"). The mechanically alloyed powders were canned, vacuum degassed and compacted at 510°C and extruded to rod of diameter 1.6 cm at a temperature of 343°C or 427°C. The composition of each sample was analysed either as powder or as rod or both.

35 The compositions of, and process details used for, the different alloys are shown in Table IV as is the Brinell hardness of the consolidated billets (Can BHN) at 500 and 3000 kg load. Alloys 9 and 10 were degassed for 4 hours and the other alloys were all degassed for 3 hours. Alloys 1 to 12 are in accordance with the invention and alloys W, X, Y, Z are by way of comparison.

40 The following tensile properties were determined at room temperature for rod extruded from each alloy: UTS, YS, % El, % RA, E, density (δ), and specific modulus (E/δ). The results are shown in Table V.

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TABLE IV.

Alloy	PCA	Powder preparation			Hrs. in attritor	Li	Composition (wt. %)			Fe	Other	Can BHN	
		Atm.	Hrs. in bubbler	B/P			O	C	500			3000	
1	1.4M	N	0	20	16	1.52*	.95*	.67*	.06	.20 Mg	184	209	
2	1.0M	Ar	0	40	8	2.35*	1.16*	.54	.18	—	154	174	
3	1.1M	Ar	3.25	40	8	1.67	1.48	.58	.20	—	158	183	
4	.7M	Ar	4	40	8	1.62*	1.10*	.70	.11	—	180	212	
5	.3M	Ar	2.5	40		3.47*	1.32	.73	.17	—	180	214	
6	.3M	Ar	6.75	40	6.75	1.83	.60*	.32	.17	—	136	148	
7	.5S	Ar	0	40	6.2	1.74*	.44*	.40	.24	—	143	156	
8	1.2S	Ar	0	20	8	1.53*	.45	.72	.11	—	172	187	
9	1.0M	N	0.5	20	18	1.74	1.40	.54	—	—	206	—	
10	1.0M	N	9.5	30	12	1.87	1.49	.78	.073	—	195	—	
11	.5S	Ar	0	40	4	2.6*	1.13*	.49	.06	—	156	156	
12	.6M	Ar	0	40	4	1.93	.45	.26	.26	—	124	124	
W	.6M	N	0	20	16	1.53*	1.04	.29	.28	3.59 Mg	247	277	
X	1.0M	Ar	0	50	8	1.12*	1.53*	.84*	—	.72 Mg	204	237	
Y	1.0M	Ar	1.5	40	8	1.46*	2.12	1.12*	.15	—	169	205	
Z	.3M	Ar	4	40	9	3.44*	1.58	1.35	.12	—	180	205	

* Analysis of chips from extruded rod. Other analysis is of powder. The units in which PCA content is given are % by weight based on the powder charge.

TABLE V

	Alloy	Extrusion temp (°C)	YS N/mm ²	UTS N/mm ²	EI (%)	RA (%)	E KN/mm ²	δ g/cm ³	E/ δ mx 10 ⁶
5	1	343	646	772	2.5	2	78.5	2.63	3.05
	2	343	NDO	473	Nil	Nil	84.1	2.53	3.38
10	3	343	474	582	5	17	73.7	2.65	2.89
	4	427	518	632	2.5	7.5	77.2	2.597	3.00
	5	427	NDO	148	Nil	Nil	81.3	2.458	3.38
15	6	343	385	435	9.5	37.25	ND	2.567	2.89
	7	343	425	451	7.5	29.5	69.6	2.477	2.95
20	8	343	480	576	3	11	75.8	2.61	2.97
	9	427	NDO	260	Nil	Nil	ND	ND	ND
	10	427	NDO	203	Nil	Nil	ND	ND	ND
25	11	343	465	527	2	6	79.9	2.53 ^e	3.22 ^e
	12	343	380	405	13	38.5	80.6	2.57 ^e	3.20 ^e
30	W	343	NDO	294	Nil	Nil	82.7	2.619	3.20
	X	343	624	681	<1	1.5	77.2	2.638	3.00
	Y	427	547	635	1	3.5	82.7	2.61	3.23
35	Z	343	NDO	263	Nil	Nil	77.2	2.48	3.18

ND=No data

NDO=0.2% offset not attained before fracture

e=estimate.

Alloys 1 to 12 are according to the present invention. Of these alloys, particularly good properties are shown by alloys 1, 3, 4, 6, 7, 8, 11 and 12. All these alloys have a yield strength of at least 380 N/mm² (tensile elongation between 2 and 13%) and a specific modulus of at least 2.89×10^6 m. It can be seen from Table IV that none of these alloys has a lithium content greater than 2.6 wt. %. The deleterious effect of too much oxygen is shown by the results for alloy Y.

The presence of small amounts of Mg may increase the strength. However, it appears that alloys of the invention which have a high specific modulus, (3, 4, 6, 7 and 8) have sufficiently high strength without magnesium. The allowable magnesium content seems to be governed at least in part by the oxygen content. Alloy X, for example, has a magnesium content of 0.72 wt. % and an oxygen content of 1.53 wt. % and the ductility is poor. With higher amounts of Mg, (see Alloy W) the effect is even more marked. The Mg content is therefore restricted to a maximum of 1.0 wt. %.

Example IV

The effect of alloying element content on the resistance to corrosion of Al-Li alloys was investigated. Samples of extruded rod were intermittently immersed in an aqueous solution of 35 wt. % NaCl at 35°C. Table VI shows corrosion rates in mg/dm²/day (mdd) of alloys 4, 5 and 6 of Example III, a commercially available corrosion resistant alloy 5083, alloy 7075, and a sample of electrically conductive aluminium (EC Al).

From Table VI it can be seen that the corrosion resistance of alloys 4 and 6 of the present invention is at least as good as that of the known alloys.

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TABLE VI

	Alloy	Condition	Exposure (days)	Corrosion rate (mdd)
5	4	As extruded	30	0.434
		"	90	0.271
10		343°C/1 hr./FC	30	0.252
		"	90	0.276
	6	As extruded	30	0.257
15		"	90	0.165
		343°C/1 hr./FC	30	0.184
		"	90	0.442*
20	5	As extruded	30	0.508*
		"	90	0.448*
25		343°C/1 hr./FC	30	0.450*
		"	90	0.250*
30	Alloy 5083	H-112	30	0.833
			90	0.583
			90	0.446
35	Alloy 7075 (Alclad)	T-651	30	12.45 ⁽¹⁾
			90	7.06 ⁽¹⁾
			30	5.05 ⁽²⁾
40			90	3.75 ⁽²⁾
	EC Al	(Unknown)	30	0.657
45			90	0.406

* Cracking noted

⁽¹⁾ Edges were coated with sealant.

⁽²⁾ Edges were not coated with sealant.

50 FC: furnace cooled.

Samples of extruded rod were also subjected to intermittent immersion (10 minutes immersion, 15 minutes out), stress corrosion cracking tests in 3.5 wt. % NaCl at 35°C for 45 days, whilst loaded at or near the yield stress. Table VII shows the results of these tests on samples of alloys 4, 6 and 7 of Example 3, and on a sample of alloy 7075.

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TABLE VII

	Alloy	YS N/mm ²	Loading (% of YS)	Time to failure (hrs.)
5	4	520	100	Broke on loading
		520	90	"
	6	290	100	>1138.8*
10	7	425	100	>1108.8*
	7075-1		80	36.1
15	7075-2		90	30.4
	7075-3		100	17.5
20	7075-4		100	17.9

* Removed from test-no failure occurred.

From Table VII it can be seen that alloys 6 and 7 of this invention showed excellent resistance to stress corrosion cracking even when loaded at the yield stress.

Further tests

In an attempt to determine the nature of the dispersoid, the electron diffraction pattern of a foil of alloy 1 and the X-ray diffraction pattern of extruded rod of alloy W were studied. Electron diffraction patterns using transmission electron microscopy and the X-ray diffraction data suggest that the dispersoid is Li_2O_2 .

The thermal stability of samples of alloys 4 and 7 was investigated and it was found that there was no loss in room temperature strength after 100 hrs. at 135°C. The results were as follows:

	Alloy	UTS (As extruded) N/mm ²	UTS (After exposure) N/mm ²
35	4	632	637
40	7	451	444

The electrical resistivity of various Al-Li alloys was measured and the accompanying Figure shows these results plotted as a function of Li content. From the Figure it can be seen that there is a steady increase in resistivity as the Li content is increased even above 1.5 wt. %. This increase, which does not end until an Li content of 2.3 wt. % has been reached suggests that above 1.5 wt. % Li a number of different processes compete for the extra Li, these being supersaturation, formation of incoherent dispersoid and formation of coherent δ' . Although δ' formation is facilitated by its low energy of formation, the results suggest that there is a high degree of supersaturation.

Transmission electron microscopy of a sample of alloy 1 showed a grain size of about 0.1 microns.

Tensile strength tests at elevated temperatures showed a sharp drop in strength with increasing temperature. It appears that alloys of the present invention which are not hardened are suitable for use at temperatures in the range from room temperature up to about 93°C. Further increases in temperature up to about 195°C do not change the room temperature strength.

Claims

1. A dispersion-strengthened mechanically alloyed aluminium lithium alloy which consists of more than 1.5 but less than 3.5 wt. % lithium, from 0.4 to 1.5 wt. % oxygen, and from 0.2 to 1.2 wt. % carbon, optionally up to 0.5 wt. % iron, up to 1.0 wt. % magnesium, the balance being aluminium and incidental impurities.

2. An alloy as claimed in claim 1, which contains less than 3 wt. % lithium and at least 0.25 wt. % carbon.

3. An alloy as claimed in claim 1 or 2, which contains from 1.7 to 2.8 wt. % lithium.

4. An alloy as claimed in any preceding claim, which contains up to 8 vol. % of dispersoid.

5. An alloy as claimed in claim 4, which contains from 3 to 5 vol. % of dispersoid.

6. An alloy as claimed in any preceding claim, in which lithium is present in solid solution and as an oxide dispersoid.
7. An alloy as claimed in claim 6, in which the dispersoid is Li_2O_2 .
8. An alloy as claimed in any preceding claim which contains from 0.4 to 1.0 wt. % oxygen.
- 5 9. An alloy as claimed in any preceding claim, which contains 0.25 to 1.0 wt. % carbon.
10. An age-hardened dispersion-strengthened mechanically-alloyed aluminium-lithium alloy as claimed in any one of the preceding claims.
11. A method of producing an alloy as claimed in claim 10, which comprises degassing and compacting the mechanically-alloyed powder at an elevated temperature but below its liquation
- 10 temperature, solution treating the compacted powder at a temperature not exceeding that used in the degassing and compaction, cooling the solution treated alloy and aging the alloy at an elevated temperature.
12. A method as claimed in claim 11, wherein the solution treatment is carried out at the same temperature as the compaction.
- 15 13. A method as claimed in claim 11 or 12, wherein both the compaction and solution treatment are carried out at a temperature in the range from 400 to 540°C, the maximum solution treatment time being 4 hours.
14. A method as claimed in any one of claims 11 to 13, wherein the solution treated alloy is cooled by water quenching.
- 20 15. A method as claimed in any one of claims 11 to 14, wherein the alloy is aged at a temperature in the range from 95 to 260°C for from 1 to 48 hours.
16. A method as claimed in claim 15, wherein the alloy is aged at a temperature in the range from 120 to 230°C for from 1 to 24 hours.
17. A method as claimed in any one of claims 1 to 16, wherein the alloy is compacted at 510°C,
- 25 solution treated for 0.5 hours at 510°C, and aged at 177°C for from 1 to 4 hours.
18. A method of producing an alloy as claimed in any one of claims 2 to 9, comprising degassing and compacting the mechanically alloyed powder at a temperature in the range from 220°C to 600°C.
19. A compacted alloy produced by the method of claim 18 which comprises from 1.7 to 2.3 wt. % lithium, from 0.4 to 1.0 wt. % oxygen and from 0.25 to 0.7 wt. % carbon.

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Patentansprüche

1. Eine dispersionsgehärtete mechanisch legierte Aluminium-Lithium-Legierung mit mehr als 1,5,
- 35 jedoch weniger als 3,5 Gew.-% Lithium, 0,4 bis 1,5 Gew.-% Sauerstoff, 0,2 bis 1,2 Gew.-% Kohlenstoff, wahlweise bis zu 0,5 Gew.-% Eisen, max. 1,0 Gew.-% Magnesium; Rest Aluminium und zufällige Spurenelemente.
2. Eine Legierung gemäß Anspruch 1, mit weniger als 3 Gew.-% Lithium und mindestens 0,25 Gew.-% Kohlenstoff.
- 40 3. Eine Legierung gemäß Anspruch 1 bzw. 2, mit 1,7 bis 2,8 Gew.-% Lithium.
4. Eine Legierung gemäß den vorgenannten Ansprüchen, mit max. 8 Vol.-% Dispersoid.
5. Eine Legierung gemäß Anspruch 4 mit 3 bis 5 Vol.-% Dispersoid.
6. Eine Legierung gemäß den vorgenannten Ansprüchen, in der Lithium in fester Lösung und als Oxiddispersoid vorliegt.
- 45 7. Eine Legierung gemäß Anspruch 6, in der das Dispersoid Li_2O_2 ist.
8. Eine Legierung gemäß den vorgenannten Ansprüchen, die 0,4 bis 1,0 Gew.-% Sauerstoff enthält.
9. Eine Legierung gemäß den vorgennanten Ansprüchen, die 0,25 bis 1,0 Gew.-% Kohlenstoff enthält.
- 50 10. Eine ausscheidungs- und dispersionsgehärtete mechanisch legierte Aluminium-Lithium-Legierung entsprechend den vorgenannten Ansprüchen.
11. Ein Verfahren zur Herstellung einer Legierung gemäß Anspruch 10, wobei das mechanisch legierte Pulver bei erhöhter Temperatur, jedoch unterhalb seiner Schmelztemperatur, entgast und verdichtet wird. Das Lösungsglühen des verdichteten Pulvers erfolgt bei einer Temperatur, die nicht
- 55 höher liegt als beim Entgasen und Verdichten; nach dem Abkühlen der lösungsgeglühten Legierung erfolgt das Aushärten der Legierung bei erhöhter Temperatur.
12. Ein Verfahren gemäß Anspruch 11, wobei das Lösungsglühen bei der gleichen Temperatur wie beim Verdichten durchgeführt wird.
13. Ein Verfahren gemäß Anspruch 11 bzw. 12, wobei sowohl das Verdichten als auch das
- 60 Lösungsglühen im Temperaturbereich von 400 bis 540°C durchgeführt wird und die Lösungsglühzeit maximal 4 Stunden beträgt.
14. Ein Verfahren entsprechend den Ansprüchen 11 bis 13, wobei die lösungsgeglühte Legierung durch Wasserabschreckung abgekühlt wird.
15. Ein Verfahren entsprechend den Ansprüchen 11 bis 14, wobei die Aushärtung der Legierung
- 65 bei 95 bis 260°C über 1 bis 48 Stunden erfolgt.

16. Ein Verfahren gemäß Anspruch 15, wobei die Aushärtung der Legierung bei 120 bis 230°C für 1 bis 24 Stunden erfolgt.

17. Ein Verfahren gemäß den Ansprüchen 1 bis 16, wobei die Legierung bei 510°C verdichtet, für 0,5 Stunden bei 510°C lösungsgeglüht und bei 177°C für 1 bis 4 Stunden ausgehärtet wird.

18. Ein Verfahren zur Herstellung einer Legierung entsprechend den Ansprüchen 2 bis 9, wobei das mechanisch legierte Pulver bei einer Temperatur zwischen 220°C und 600°C entgast und verdichtet wird.

19. Eine nach dem Verfahren gemäß Anspruch 18 hergestellte verdichtete Legierung, die 1,7 bis 2,3 Gew.-% Lithium, 0,4 bis 1,0 Gew.-% Sauerstoff und 0,25 bis 0,7 Gew.-% Kohlenstoff enthält.

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Revendications

1. Alliage d'aluminium-lithium allié mécaniquement et renforcé par dispersion, constitué de plus de 1,5% mais moins de 3,5% en poids de lithium, de 0,4 à 1,5% en poids d'oxygène, et de 0,2 à 1,2% en poids de carbone, éventuellement jusqu'à 0,5% en poids de fer, jusqu'à 1,0% en poids de magnésium, le reste étant de l'aluminium et des impuretés fortuites.

2. Alliage selon la revendication 1, contenant moins de 3% en poids de lithium et au moins 0,25 en poids de carbone.

3. Alliage selon les revendications 1 et 2, contenant de 1,7 à 2,8% en poids de lithium.

4. Alliage selon l'une quelconque des revendications précédentes, contenant jusqu'à 8% en volume de dispersoïde.

5. Alliage selon la revendication 4, contenant de 3 à 5% en volume de dispersoïde.

6. Alliage selon l'une quelconque des revendications précédentes, où le lithium est présent en solution solide et sous forme de dispersoïde oxyde.

7. Alliage selon la revendication 6, où le dispersoïde est Li_2O_2 .

8. Alliage selon l'une quelconque des revendications précédentes contenant de 0,4 à 1,0% en poids d'oxygène.

9. Alliage selon l'une quelconque des revendications précédentes, contenant de 0,25 à 1,0% en poids de carbone.

10. Alliage aluminium-lithium allié mécaniquement et renforcé par dispersion selon l'une quelconque des revendications précédentes.

11. Procédé de production d'un alliage selon la revendication 10, dans lequel on dégaze et on compacte la poudre allié mécaniquement à une température élevée mais en-dessous de sa température de liquéfaction, on traite en solution la poudre compactée à une température ne dépassant pas celle utilisée dans le dégazage et le compactage, on refroidit l'alliage traité en solution et on fait vieillir l'alliage à une température élevée.

12. Procédé selon la revendication 11, où le traitement en solution est conduit à la même température que le compactage.

13. Procédé selon les revendications 11 et 12, où le compactage et le traitement en solution sont conduits à une température située dans un intervalle allant de 400 à 540°C, la durée maximale de traitement en solution étant de 4 heures.

14. Procédé selon l'une quelconque des revendications 11 à 13, où l'on refroidit l'alliage traité en solution par trempage à l'eau.

15. Procédé selon l'une quelconque des revendications 11 à 14, où l'on fait vieillir l'alliage à une température située dans un intervalle allant de 95 à 260°C pendant 1 à 48 h.

16. Procédé selon la revendication 15, où l'on fait vieillir l'alliage à une température située dans un intervalle allant de 120 à 230°C pendant 1 à 24 h.

17. Procédé selon l'une quelconque des revendications 1 à 16, où l'on compacte l'alliage à 510°C, on le traite en solution pendant $\frac{1}{2}$ h à 510°C, et on le fait vieillir à 177°C pendant 1 à 4 h.

18. Procédé de production d'un alliage selon l'une quelconque des revendications 2 à 9, dans lequel on dégaze et on compacte la poudre allié mécaniquement à une température située dans un intervalle allant de 220°C à 600°C.

19. Alliage compacté produit par le procédé de la revendication 18 comprenant de 1,7 à 2,3% en poids de lithium, de 0,4 à 1,0% en poids d'oxygène et de 0,25 à 0,7% en poids de carbone.

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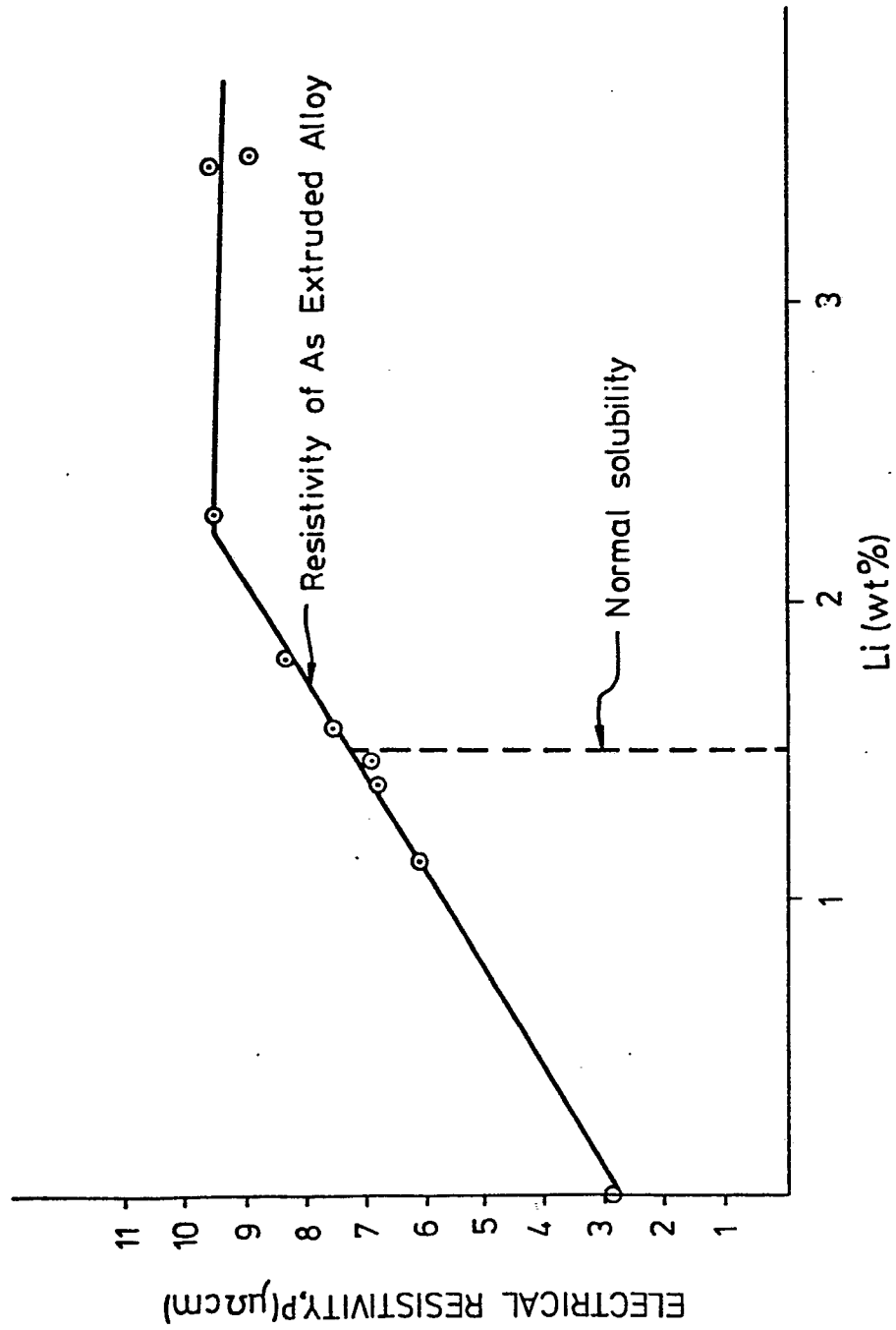


Fig.1.