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(54) METHOD FOR PRODUCING A HIGH STRENGTH, HIGH TOUGHNESS A1-Zn ALLOY PRODUCT

HERSTELLUNGSVERFAHREN FÜR EIN HOCHFESTES, HOCHZÄHES A1-ZINNLEGIERUNGSPRODUKT

PROCÉDÉ DE FABRICATION D'UN ALLIAGE DE AL-ZN À HAUTE RÉSISTANCE ET DE GRANDE DURETE

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Description

FIELD OF THE INVENTION

5 **[0001]** The present invention relates to a high-strength high-toughness Al-Zn alloy wrought product with elevated amounts of Zn for maintaining good corrosion resistance, and to a method for producing such a high-strength high-toughness Al-Zn alloy product and to a plate product of such alloy. More specifically, the present invention relates to a high strength, high toughness Al-Zn alloy designated by the AA7000-series of the international nomenclature of the Aluminum Association for structural aeronautical applications. Even more specifically, the present invention relates to
10 a new chemistry window for an Al-Zn alloy having improved combinations of strength and toughness by maintaining good corrosion resistance, which does not need specific ageing or temper treatments.

BACKGROUND OF THE INVENTION

15 **[0002]** It is known in the art to use heat treatable aluminium alloys in a number of applications involving relatively high strength, high toughness and corrosion resistance such as aircraft fuselages, vehicular members and other applications. Aluminium alloys AA7050 and AA7150 exhibit high strength in T6-type tempers. Also precipitation-hardened AA7x75, AA7x55 alloy products exhibit high strength values in the T6 temper. The T6 temper is known to enhance the strength of the alloy, wherein the aforementioned AA7x50, AA7x75 and AA7x55 alloy products which contain high amounts of
20 zinc, copper and magnesium are known for their high strength-to-weight ratios and, therefore, find application in particular in the aerospace industry. However, these applications result in exposure to a wide variety of climatic conditions necessitating careful control of working and ageing conditions to provide adequate strength and resistance to corrosion, including both stress corrosion and exfoliation.

[0003] In order to enhance resistance against stress corrosion and exfoliation as well as fracture toughness it is known to artificially over-age these AA7000-series alloys. When artificially aged to a T79, T76, T74 or T73-type temper their resistance to stress corrosion, exfoliation corrosion and fracture toughness improve in the order stated (T73 being best and T79 being close to T6) but at the cost of strength compared to the T6 temper condition. A more acceptable temper condition is the T74-type temper which is a limited over-aged condition, between T73 and T76, in order to obtain an acceptable level of tensile strength, stress corrosion resistance, exfoliation corrosion resistance and fracture toughness.
25 Such T74 temper is performed by over-ageing the aluminium alloy product at temperatures of 121°C for 6 to 24 hours and followed by 171°C for about 14 hours.

[0004] Depending on the design criteria for a particular aircraft component even small improvements in strength, toughness or corrosion resistance result in weight savings, which translate amongst others to fuel economy over the life time of the aircraft. To meet these demands several other 7000-series alloys have been developed.

35 **[0005]** For example each of EP-0377779, EP 0 368 005, US-5,221,377 and US-5,496,426 disclose alloy products and an improved process for producing an 7055 alloy for sheet or thin plate applications in the field of aerospace such as upper-wing members with high toughness and good corrosion properties which comprises the steps of working a body having a composition consisting of, about in wt. %: Zn 7.6 to 8.4, Cu 2.2 to 2.6, Mg 1.8 to 2.1 or 2.2, and one or more elements selected from Zr, Mn V and Hf, the total of the elements not exceeding 0.6 wt. %, the balance aluminium plus incidental impurities, solution heat treating and quenching the product and artificially ageing the product by either
40 heating the product three times in a row to one or more temperatures from 79°C to 163°C or heating such product first to one or more temperatures from 79°C to 141°C for two hours or more and heating the product to one or more temperatures from 148°C to 174°C. These products are reported to have an improved exfoliation corrosion resistance of "EB" or better with about 15% greater yield strength than similar sized 7x50 counter- parts in the T76-temper condition. They still have at least about 5% higher strength than their similarsized 7x50-T77 counterpart (7150-T77 will be used herein below as a reference alloy). Document US 6, 562, 154 discloses a rolled aluminium alloy sheet product and the production of such sheet products, which exhibit improved strength and fatigue crack growth resistance. The production method includes casting, scalping, preheating, initial hot rolling, reheating, finish hot rolling and optional cold rolling. Some suitable alloy compositions include AA2xxx, AA5xxx, AA6xxx and AA7xxx alloys.
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SUMMARY OF THE INVENTION

[0006] It is an object of the present invention to provide an improved Al-Zn alloy preferably for plate products with high (compressive) strength and high toughness. Corrosion resistance should not deteriorate.

55 **[0007]** More specifically, it is an object of the present invention to provide an alloy product which can be used for upper wing applications in aerospace with an improved compression yield strength and a high unit propagation energy with properties which are better than the properties of a conventional AA7055-alloy in the T77 temper.

[0008] It is another object of the invention to obtain an AA7000-series aluminium alloy which exhibits strength in the

range of T6-type tempers and toughness and corrosion resistance properties in the range of T73-type tempers.

[0009] It is another object of the invention to provide a method of manufacturing the aluminium alloy product according to this invention.

[0010] The present invention meets one or more of these objects by the characterizing features of the independent claims. Further preferred embodiments are described and specified within the dependent claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] As will be appreciated hereinbelow, except otherwise indicated, alloy designations and temper designations refer to the Aluminum Association designations in Aluminum Standards and Data and the Registration Records, all published by the US Aluminum Association.

[0012] One or more of the above mentioned objects of the invention are achieved by using an Al-Zn alloy product with an improved combination of high toughness and high strength by maintaining good corrosion resistance, said alloy comprising, and preferably consisting of, (in weight percent):

Zn	6.0 to 11.0
Cu	1.4 to 2.2
Mg	1.4 to 2.4
Zr	0.05 to 0.15
Ti	< 0.05,
Hf and/or V	< 0.25,

optionally Sc and/or Ce 0.05 to 0.25, and

optionally Mn 0.05 to 0.12,

and inevitable impurities and balance aluminium, preferably other elements each less than 0.05 and less than 0.50 in total, and wherein the alloy product has a substantially fully unrecrystallized microstructure at the position T/10 of the finished product.

[0013] Such chemistry window for an AA7000-series alloy exhibits excellent properties when produced to relatively thin plate products, and which is preferably useable in aerospace upper-wing applications having gauges in the range of 20 mm to 60 mm.

[0014] The above defined chemistry has properties which are comparable or better than existing alloys of the AA7x50 or AA7x55 series in the T77-temper, without using the above described cumbersome and complicated T77 three-step ageing cycles. The chemistry leads to an aluminium product which is more cost effective and is also simpler to produce since less processing steps are necessary. Additionally, the chemistry allows new manufacturing techniques like age forming or age creep forming which is not feasible when a T77-temper alloy is applied. Even better, the chemistry as defined above can also be aged to the T77-temper whereby the corrosion resistance further improves.

[0015] According to the invention it has been found that a selected range of elements, using a higher amount of Zn and a specific combination of a particular range of Mg and Cu, exhibit substantially better combinations of strength and toughness and maintaining a good corrosion performance such as exfoliation corrosion resistance and stress corrosion cracking resistance.

[0016] The present invention uses the chemistry in combination with a method to produce a rolled product from such chemistry, as explained herein below, to obtain a substantially fully unrecrystallized microstructure at least at the position T/10 of the finished product. More preferably the product is unrecrystallized across the whole thickness. With unrecrystallized we mean that more than 80%, preferably more than 90% of the gauge of the finished rolled product is substantially unrecrystallized. Hence, the present invention is disclosing an alloy product which is in particular suitable for upper wing skin applications for aircrafts and having a thickness in the range of 20 to 60 mm, preferably 30 to 50 mm.

[0017] It has been found that is not necessary to slowly quench the rolled product or to increase the gauge of the rolled product to obtain superior compression yield strength and toughness properties.

[0018] Copper and magnesium are important elements for adding strength to the alloy. Too low amounts of magnesium and copper result in a decrease of strength while too high amounts of magnesium and copper result in a lower corrosion performance and problems with the weldability of the alloy product. Prior art techniques used special ageing procedures to ameliorate the strength while low amounts of magnesium and copper are used in order to achieve a good corrosion performance. In order to achieve a compromise in strength, toughness and corrosion performance copper and magnesium amounts (in wt.%) of between 1.7 and 2.2%, preferably between 1.7 and 2.1% for Mg and 1.8 and 2.1% for Cu have been found to give a good balance for thin plate products. Throughout the claimed chemistry of the present invention it is now possible to achieve strength levels in the region of a T6-temper alloy while maintaining corrosion performance characteristics similar to those of T74-temper alloys.

[0019] Apart from the amounts of magnesium and copper the invention discloses a balance of magnesium and copper amounts to zinc, especially the balance of magnesium to zinc, which gives the alloy these performance characteristics. The improved corrosion resistance of the alloy according to the invention has exfoliation properties ("EXCO") of EB or better, preferably EA or better.

[0020] The amount (in weight%) of zinc is preferably in a range of 7.4 to 9.6%, more preferably in a range of 8.0 to 9.6%, most preferably in a range of 8.4 to 8.9%. Testing has found an optimum zinc level of about 8.6%. Further details are given in the examples as described in more details hereinbelow.

[0021] It has furthermore been shown that, according to a preferred embodiment of the present invention, a Sc-containing alloy is an excellent candidate for obtaining high strength versus high notch toughness levels. By adding Sc to an alloy comprising copper, magnesium, zinc, zirconium and titanium it has been found that the microstructure remains unrecrystallized, thereby showing superior properties with regard to strength and toughness. Hence, preferred amounts of Sc (in weight%) are in a range of $[Zr] + 1.5 [Sc] < 0.15\%$. Preferred amounts (in weight%) of Sc or Ce are in a range of 0.03 to 0.06% when the amount of Zn is about 8.70% and Mg and Cu are about 2.10%. The levels of the unit propagation energy are considerably good for an alloy with additional Sc, Ce or Mn alloying elements.

[0022] A method for producing a high strength, high toughness Al-Zn alloy product with good corrosion resistance according to the present invention comprises the steps of claim 1.

[0023] It has been found that the microstructure of the alloy product remains substantially fully unrecrystallized underneath its surface when the inventive method step of pre-working the product and hot rolling and cold rolling the pre-worked product are applied.

[0024] In accordance with an embodiment of the present invention the method includes a first hot rolling of the ingot which has been homogenised into a pre-worked product, hot rolling the re-heated product to about 150 to 250 (in final-gauge%) and then cold rolling the hot rolled product to the final gauge or hot rolling the re-heated product to about 105 to 140 (in final-gauge%) and then cold rolling the hot rolled product to the final gauge. "Final-gauge%" means a percentage in thickness compared to the thickness of the final product. 200 final-gauge% means a thickness which is twice as much as the thickness of the finally worked product. That means that it has been found that it is advantageous to first hot roll the pre-heated product to a thickness which is about twice as high as the thickness of the final product and then cold rolling the hot rolled product to the final thickness or to hot roll the pre-heated product to a thickness which is about 20% higher than the thickness of the final product and then cold rolling the product, thereby obtaining another about 20% reduction of the gauge of the hot rolled product.

[0025] According to another embodiment of the present invention it is advantageous to hot roll the re-heated product at low temperatures in the range of 300°C to 420°C so that the alloy does not recrystallise. Optionally, it is possible to artificially ageing the worked and heat-treated product with a two-step T79 or T76 temper or to use a T77-three step temper if SCC performance shall be improved.

[0026] The present invention is useful for hot-working the ingot after casting and cold-working into a worked product with a gauge in the range of 20 to 60 mm.

[0027] The present invention also concerns a plate product of high strength, high toughness Al-Zn alloy of the aforementioned composition which plate product is preferably a thin aircraft member, even more preferably an elongate structural shape member such as an upper-wing member, a thin skin member of an upper-wing or of a stringer of an aircraft.

[0028] The properties of the claimed alloy may further be enhanced by an artificial ageing step comprising a first heat treatment at a temperature in a range of 105°C to 135°C, preferably around 120°C for 2 to 20 hours, preferably around 8 hours and a second heat treatment at a higher temperature than 135°C but below 210°C, preferably around 155°C for 4 to 12 hours, preferably 8 to 10 hours.

[0029] The foregoing and other features and advantages of the alloys according to the present invention will become readily apparent from the following detailed description of

preferred embodiments.

Example 1

[0030] On a laboratory scale 14 different aluminium alloys have been cast into ingots, homogenised, pre-heated for more than 6 hours at about 410°C and hot rolled to 4 mm plates. Solution heat treatment was done at 475°C and thereafter water quenched. Thereafter, the quenched product was aged by a two-step T76 ageing procedure. The chemical compositions are set out in Table 1.

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Table 1. Chemical compositions of alloys in thin plate form, in weight%, balance aluminium and inevitable impurities, Fe 0.06, Si 0.05, Ti 0.04 and Zr 0.12.

Alloy	Cu	Mg	Zn	Others
1	2.0	2.1	8.0	0.08 Mn
2	2.1	2.1	8.1	-
3	1.7	1.75	8.7	-
4	2.1	1.7	8.6	-
5*	2.4	1.7	8.6	-
6	1.7	2.2	8.7	-
7	2.1	2.1	8.6	-
8*	2.4	2.1	8.7	-
9*	1.7	2.5	8.7	-
10	2.1	2.4	8.6	-
11	2.5	2.5	8.7	-
12	2.1	2.1	9.2	-
13*	2.1	2.1	8.7	0.03 Ce
14	2.1	2.1	8.7	0.06 Sc

*Alloy composition outside claim 1.

[0031] The alloys of Table 1 were processed using three processing variants (see step 5 variant 1 being comparative examples and variants 2 and 3 being examples of the invention) :

1. Homogenisation was performed by heating at a temperature rate of 40°C/h to a temperature of 460°C, then soaking for 12 hours at 460°C and another increase with 25°C/h to a temperature of 475°C with another soaking for 24 hours at 475°C, and air cooling to room temperature.
2. Pre-heating was done at 420°C for 6 hours with a heating rate of 40°C/h.
3. The lab scale ingots were hot rolled from 80 to 25 mm, thereby reducing the gauge by about 6 to 8 mm per pass.
4. The 25 mm thick products were reheated to 420°C for about 30 min.
- 5.

Variant 1: The reheated product was hot rolled to 4.0 mm (comparative).

Variant 2: The reheated product was hot rolled to 8.0 mm and thereafter cold rolled to 4.0 mm (comparative).

Variant 3: The reheated product was hot rolled to 5.0 mm and then cold rolled to 4.0 mm, in accordance with the invention.

6. Solution heat treatment was done for 1 hour at 475°C, thereafter water quenched.

7. Stretching was done by 1.5 to 2.0% within about 1 hour after quenching.

8. Thereafter, the stretched products were aged in accordance with a T76 ageing procedure, thereby raising the temperature to 120°C at a rate of 30°C/h and maintaining the temperature at 120°C for 5 hours, raising the temperature at a rate of 15°C/h to a temperature of 160°C and soaking for 6 hours, and air cooling the aged product to room temperature.

[0032] Strength was measured using small Euronorm and toughness were measured in accordance with ASTM B-871(1996). The results of the three above-mentioned variants are shown in Table 2a to 2c.

Table 2a. Strength and toughness properties of the alloys as shown in Table 1 in MPa and notch toughness (TYR) in accordance with Variant 1.

Alloy	Rp	UPE	TYR
1	582	211	1.31
2	564	215	1.48
3	534	243	1.49
4	550	214	1.48

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(continued)

	Alloy	Rp	UPE	TYR
5	5	579	208	1.44
	6	592	84	1.34
	7	595	120	1.32
	8	605	98	1.32
	9	612	30	1.31
10	10	613	54	1.12
	11	603	33	1.11
	12	-	-	-
	13	597	163	1.27
15	14	587	121	1.35

Table 2b. Strength and toughness properties of the alloys as shown in Table 1 in MPa and notch toughness (TYR) in accordance with Variant 2:

	Alloy	Rp	UPE	TYR
20	1	599	125	1.30
	2	567	268	1.45
	3	533	143	1.53
25	4	587	205	1.38
	5	563	178	1.45
	6	569	134	1.35
	7	-	-	-
	8	616	72	1.10
30	9	-	-	-
	10	601	22	1.00
	11	612	5	1.05
	12	-	-	-
35	13	595	88	1.16
	14	626	71	1.26

Table 2c. Strength and toughness properties of the alloys as shown in Table 1 in MPa and notch toughness (TYR) in accordance with Variant 3.

	Alloy	Rp	UPE	TYR
40	1	600	170	1.35
	2	575	211	1.47
45	3	535	232	1.59
	4	573	260	1.46
	5	604	252	1.39
	6	587	185	1.43
50	7	613	199	1.26
	8	627	185	1.18
	9	-	-	-
	10	607	31	1.09
	11	614	26	0.92
55	12	606	58	1.11
	13	601	148	1.26
	14	616	122	1.35

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[0033] From the results presented in Tables 2a to 2c it is clear that a minor degree (10 to 20%) of cold rolling is beneficial for an optimum toughness versus strength balance. The purely hot rolled material in accordance with Variant 1 (Table 2a) is close to the optimum but in general the Variant 3-alloys are better.

[0034] Furthermore, it can be seen that Sc-containing alloy 14 is advantageous if high strength versus high notch toughness is needed. Small amounts of manganese do increase the strength but at the cost of some toughness.

Example 2

[0035] Additional chemistries have been processed in accordance with the above-mentioned processing steps 1 to 8, thereby using the variant 3 of step 5 of example 1 above and a T76 ageing.

Table 3. Chemical compositions of thin plate alloys, in weight%, for all alloys balance aluminium and inevitable impurities, Fe 0.06, Si 0.05.

Alloy	Cu	Mg	Zn	Zr	Ti	Others
1	2.0	2.1	8.0	0.11	0.03	0.08 Mn
2	2.1	2.1	8.1	0.12	0.03	-
3	1.7	2.2	8.7	0.12	0.03	-
4	2.1	2.1	8.6	0.12	0.03	-
5*	2.4	2.1	8.7	0.12	0.03	-
6	2.1	2.1	9.2	0.12	0.03	-
7*	2.1	2.1	8.7	0.12	0.04	0.04 Ce
8	2.1	2.1	8.7	0.10	0.04	0.06 Sc
9	1.7	2.1	9.3	0.12	0.03	-
10*	1.6	2.5	9.2	0.12	0.04	-
11	2.1	2.4	9.2	0.12	0.04	-

*alloy composition outside claim 1

[0036] The properties of the alloys mentioned in Table 3 have been tested in the L-direction for the strength and in the L-T-direction for the toughness.

Table 4. Strength and toughness properties of the alloys as shown in Table 3 in MPa and notch toughness (TS/Rp) in accordance with Variant 3.

Alloy	Rp (MPa)	Rm (MPa)	UPE (kJ/m ²)	TS/Rp
1	601	637	177	1.35
2	575	603	221	1.48
3	591	610	194	1.45
4	613	647	199	1.34
5	624	645	178	1.18
6	608	638	63	1.13
7	601	639	163	1.27
8	618	652	132	1.35
9	613	632	75	1.25
10	618	650	5	1.29
11	619	654	26	1.18

[0037] The toughness versus tensile yield strength (Rp) shown in Table 4 clearly shows that the best toughness versus tensile yield strength value is obtained for alloys having around 8.6 to 8.7 weight% zinc. Alloys with lower levels of zinc will show similar toughness values but the tensile strength is -generally speaking- lower whereas high levels of zinc result in higher strength levels but lower toughness levels. Small amounts of manganese do increase the strength at the cost of toughness.

Example 3

[0038] Further tests were done with zinc levels of 8.6 and 8.7 thereby varying copper and magnesium levels. It can be shown that toughness levels can be elevated at the same strength levels. Some additional alloys were processed similar as to the ones in Example 2, thereby using the processing steps 1 to 8 as described above and Variant 3 of step 5 of Example 1.

Table 5. Chemical compositions of thin plate alloys, in weight%, for all alloys balance aluminium and inevitable impurities, Fe 0.06, Si 0.05.

Alloy	Cu	Mg	Zn	Zr	Ti	Others
3	1.7	2.2	8.7	0.12	0.03	-
4	2.1	2.1	8.6	0.12	0.03	-
5*	2.4	2.1	8.7	0.12	0.03	-
12*	2.5	2.5	8.7	0.11	0.03	0.08 Mn
13	2.1	2.4	8.6	0.12	0.03	-
14*	1.7	2.5	8.7	0.12	0.03	-
15	1.7	1.7	8.7	0.12	0.03	-
16*	2.4	1.7	8.6	0.12	0.03	-
17	2.1	1.7	8.6	0.12	0.04	-

*alloy composition outside claim 1

Table 6. Strength and toughness properties of the alloys as shown in Table 5 in MPa and notch toughness (TS/Rp) in accordance with Variant 3.

Alloy	Rp (MPa)	UPE (kJ/m ²)	TS/Rp
3	591	194	1.45
4	613	199	1.34
5	624	178	1.18
12	614	26	0.92
13	607	31	1.09
14	621	55	1.01
15	535	232	1.59
16	604	252	1.39
17	573	260	1.46

[0039] As shown in Table 6 it is advantageous to have magnesium levels of less than 2.4% with an optimum of about 1.7%. When magnesium levels are at about 1.7%, excellent toughness properties are obtained but the strength levels decrease. With magnesium levels of about 2.1% the best strength levels are obtained. Hence, magnesium is best in between 1.7 and 2.1%.

[0040] All above mentioned alloys have been tested on exfoliation corrosion according to ASTM G-34. They all showed a performance of EB or better.

[0041] Furthermore, it has been shown that the addition of Ce or Sc enhances the microstructure of the alloy thereby reducing recovery processes. Since the recovery within the alloy material is low, nearly no recrystallization takes place even though a solution heat treatment is used in accordance with the standard route. Sc represses recrystallization so that usually more than 90% of the thickness of the thin plate products remains unrecrystallized.

Claims

1. Method for producing a high strength, high toughness Al-Zn alloy product with good corrosion resistance, comprising the steps of:

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a.) casting an ingot with the following composition, in weight percent:

Zn	6.0 to 11.0%
Cu	1.4 to 2.2%
Mg	1.4 to 2.4%
Zr	0.05 to 0.15%
Ti	< 0.05%
Hf and/or V	< 0.25%,

optionally Sc and/or Ce 0.05 to 0.25%,
optionally Mn 0.05 to 0.12%, and
inevitable impurities and balance aluminium,

b.) homogenising and/or pre-heating the ingot after casting,

c.) hot working the ingot into a pre-worked product,

d.) reheating the pre-worked product and hot rolling the reheated product,

cold rolling the hot-rolled, product by a degree of 10 to 20% to the final gauge,

e.) solution heat treating and quenching the solution heat treated product,

f.) optionally stretching or compressing of the quenched alloy product, and

g.) optionally ageing the quenched and optionally stretched or compressed product to achieve a desired temper,

and wherein the product in its final temper has a substantially fully unrecrystallized microstructure at least at the position T/10 of the finished product.

2. Method according to claim 1, wherein hot rolling the reheated product to about 150 to 250 (in final-gauge%) and then cold rolling the hot rolled product to the final gauge.
3. Method according to claim 1 or 2, wherein hot rolling the reheated product to about 105 to 140 (in final-gauge%) and then cold rolling the hot rolled product to the final gauge.
4. Method according to any one of claims 1 to 3, comprising hot rolling the reheated product at low temperatures in the range of 300°C to 420°C to prevent the alloy product from recrystallising.
5. Method according to any one of claims 1 to 4, wherein the artificial ageing during step g.) is to temper selected from the group consisting of T79, and T76, and preferably by means of a two step ageing treatment.
6. Method according to any one of claims 1 to 5, wherein the artificial ageing during step g.) consists of a first ageing step at a temperature in a range of 105 to 135°C for 2 to 20 hours and a second ageing step at a temperature higher than 135°C but less than 210°C for 4 to 12 hours to a temper selected from T79 and T76 temper.
7. Method according to claim 6, wherein the artificial ageing during step g.) consists of a first ageing step at a temperature around 120°C for 2 to 20 hours and a second ageing step at a temperature higher than 135°C but less than 210°C for 4 to 12 hours to a temper selected from T79 and T76 temper.
8. Method according to claim 6 or 7, wherein the artificial ageing during step g.) consists of a first ageing step at a temperature around 120°C for 2 to 20 hours and a second ageing step at a temperature around 155°C for 4 to 12 hours to a temper selected from T79 and T76 temper.
9. Method according to any one of claims 1 to 8, wherein the amount of Zn is in a range of 7.4 to 9.6 wt.%.
10. Method according to claim 9, wherein the amount of Zn is in a range of 8.0 to 9.6 wt.%, and preferably in a range of 8.4 to 8.9 wt.%.
11. Method according to any one of claims 1 to 10, wherein the amount of Cu is in a range of 1.7 to 2.2 wt.%, and preferably in a range of 1.8 to 2.1 wt.%.
12. Method according to claim 11, wherein the amount of Mg is in a range of 1.7 to 2.2 wt.%, and preferably in a range of 1.7 to 2.1 wt.%.

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13. Method according to any one of claims 1 to 12, wherein the amount of Sc is in a range of $[Zr]+1.5 [Sc]<0.15$ wt.%.
14. Method according to any one of claims 1 to 13, wherein the amount of Sc is in a range of 0.03 to 0.06%, and wherein the amount of Ce is in a range of 0.03 to 0.06%.
5
15. Method according to any one of claims 1 to 14, wherein the amount of inevitable impurities are < 0.05 wt.% each, and total < 0.5 wt.%.
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16. Method according to any one of claims 1 to 15, wherein of the finished rolled product more than 80%, and preferably more than 90%, of the gauge has a substantially unrecrystallized microstructure.
17. Method according to any one of claims 1 to 16, wherein the Al-Zn product is a thin plate having a gauge in the range of 20 to 60 mm, and preferably 30 to 50 mm.
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18. Method according to any one of claims 1 to 17, wherein the Al-Zn product is a product selected from the group consisting of thin aircraft member, an upper-wing member, a thin skin member of an upper-wing, or a stringer of an aircraft.

20 Patentansprüche

1. Verfahren zur Herstellung eines hochfesten, hochzähen Al-Zn-Legierungsprodukts mit guter Korrosionsbeständigkeit, umfassend die Schritte:

25 a.) (Guss)Formen eines Barrens mit der folgenden Zusammensetzung, in Gewichtsprozent:

Zn 6,0 bis 11,0%
Cu 1,4 bis 2,2%
Mg 1,4 bis 2,4%
30 Zr 0,05 bis 0,15%
Ti < 0,05%
Hf und/oder V < 0,25%,

wahlweise Sc und/oder Ce 0,05 bis 0,25%,

35 wahlweise Mn 0,05 bis 0,12%, und
unvermeidbare Verunreinigungen und Rest Aluminium,

b.) Homogenisieren und/oder Vorwärmen des Barrens nach dem Formen,

c.) Warmbearbeiten des Barrens zu einem vorbearbeiteten Produkt,

40 d.) Wiedererwärmen des vorbearbeiteten Produkts und Warmwalzen des nacherwärmten Produkts, Kaltwalzen des warmgewalzten Produkts um ein Maß von 10 bis 20% auf Enddicke,

e.) Lösungsglühen und Abschrecken des lösungsgeglühten Produkts,

f.) optional Recken oder Komprimieren des abgeschreckten Legierungsprodukts, und

45 g.) optional Altern des abgeschreckten und ggf. gereckten oder komprimierten Produkts, um einen gewünschten Zustand bzw. Temper zu erzielen,

und wobei das Produkt in seinem Endzustand eine im Wesentlichen vollständig nicht rekristallisierte Mikrostruktur zumindest an der Position T/10 des fertigen Produkts aufweist.

2. Verfahren nach Anspruch 1, wobei das Warmwalzen des nacherwärmten Produkts auf etwa 150 bis 250 (in Prozent der Enddicke) und dann das Kaltwalzen des warmgewalzten Produkts auf die Enddicke erfolgen.
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3. Verfahren nach Anspruch 1 oder 2, wobei das Warmwalzen des nacherwärmten Produkts auf etwa 105 bis 140 (in Prozent des Endmaßes) und dann das Kaltwalzen des warmgewalzten Produkts auf die Enddicke erfolgen.

4. Verfahren nach einem der Ansprüche 1 bis 3, umfassend das Warmwalzen des nacherwärmten Produkts bei niedrigen Temperaturen im Bereich von 300°C bis 420°C, um das Legierungsprodukt am Rekristallisieren zu hindern.
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5. Verfahren nach einem der Ansprüche 1 bis 4, wobei das künstliche Altern während Schritt g.) im Tempern besteht, ausgewählt aus der Gruppe bestehend aus T79 und T76, und bevorzugt mithilfe einer zweistufigen Alterungsbe-

handlung.

- 5 6. Verfahren nach einem der Ansprüche 1 bis 5, wobei das künstliche Altern während Schritt g.) aus einem ersten Alterungsschritt besteht bei einer Temperatur in einem Bereich von 105 bis 135°C während 2 bis 20 Stunden und einem zweiten Alterungsschritt bei einer Temperatur über 135°C, aber unter 210°C während 4 bis 12 Stunden bis zu einem Zustand bzw. Temper ausgewählt aus T79- und T76-Temper.
- 10 7. Verfahren nach Anspruch 6, wobei das künstliche Altern während Schritt g.) aus einem ersten Alterungsschritt besteht bei einer Temperatur um 120°C während 2 bis 20 Stunden und aus einem zweiten Alterungsschritt bei einer Temperatur über 135°C, aber unter 210°C während 4 bis 12 Stunden bis zu einem Temper ausgewählt aus T79- und T76-Temper.
- 15 8. Verfahren nach Anspruch 6 oder 7, wobei das künstliche Altern während Schritt g.) aus einem ersten Alterungsschritt besteht bei einer Temperatur um 120°C während 2 bis 20 Stunden und aus einem zweiten Alterungsschritt bei einer Temperatur um 155°C während 4 bis 12 Stunden bis zu einem Temper ausgewählt aus T79- und T76-Temper.
- 20 9. Verfahren nach einem der Ansprüche 1 bis 8, wobei die Menge an Zn in einem Bereich von 7,4 bis 9,6 Gew.-% liegt.
10. Verfahren nach Anspruch 9, wobei die Menge an Zn in einem Bereich von 8,0 bis 9,6 Gew.-% liegt, und bevorzugt in einem Bereich von 8,4 bis 8,9 Gew.-%.
- 25 11. Verfahren nach einem der Ansprüche 1 bis 10, wobei die Menge an Cu in einem Bereich von 1,7 bis 2,2 Gew.-% liegt, und bevorzugt in einem Bereich von 1,8 bis 2,1 Gew.-%.
12. Verfahren nach Anspruch 11, wobei die Menge an Mg in einem Bereich von 1,7 bis 2,2 Gew.-% liegt, und bevorzugt in einem Bereich von 1,7 bis 2,1 Gew.-%.
- 30 13. Verfahren nach einem der Ansprüche 1 bis 12, wobei die Menge an Sc in einem Bereich von $[Zr]+1,5[Sc]<0,15$ Gew.-% liegt.
14. Verfahren nach einem der Ansprüche 1 bis 13, wobei die Menge an Sc in einem Bereich von 0,03 bis 0,06% liegt, und wobei die Menge an Ce in einem Bereich von 0,03 bis 0,06% liegt.
- 35 15. Verfahren nach einem der Ansprüche 1 bis 14, wobei die Menge an unvermeidbaren Verunreinigungen jeweils $<0,05$ Gew.-% und insgesamt $<0,5$ Gew.-% beträgt.
16. Verfahren nach einem der Ansprüche 1 bis 15, wobei über 80%, und bevorzugt über 90%, der Dicke bzw. des Maßes des fertigen gewalzten Produkts eine im Wesentlichen nicht rekristallisierte Mikrostruktur aufweisen.
- 40 17. Verfahren nach einem der Ansprüche 1 bis 16, wobei das Al-Zn-Produkt eine dünne Platte mit einer Dicke im Bereich von 20 bis 60 mm, und bevorzugt 30 bis 50 mm, ist.
- 45 18. Verfahren nach einem der Ansprüche 1 bis 17, wobei das Al-Zn-Produkt ein Produkt ist ausgewählt aus der Gruppe bestehend aus einem dünnen Flugzeugteil, einem Teil der oberen Tragfläche, einem dünnen Hautteil der oberen Tragfläche oder einem Längs(versteifungs)träger eines Flugzeugs.

Revendications

- 50 1. Procédé pour produire un produit en alliage Al-Zn à haute résistance, à ténacité élevée, offrant une bonne résistance à la corrosion, comprenant les étapes consistant à :
- a.) couler un lingot comportant la composition suivante, en pourcentage par poids :
- 55 Zn de 6,0 à 11,0 %
Cu de 1,4 à 2,2 %
Mg de 1,4 à 2,4 %
Zr de 0,05 à 0,15%

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Ti < 0,05%

Hf et/ou V < 0,25%

- 5 facultativement Sc et/ou Ce - de 0,05 à 0,25 %
facultativement Mn - de 0,05 à 0,12 %, et
des impuretés inévitables et le reste étant de
l'aluminium,
- b.) homogénéiser et/ou à préchauffer le lingot après coulage,
c.) travailler à chaud le lingot pour en faire un produit pré-ouvré,
10 d.) réchauffer le produit pré-ouvré et effectuer un laminage à chaud du produit réchauffé, effectuer un laminage à froid du produit ayant été laminé à chaud d'un degré de 10 à 20% jusqu'à l'épaisseur finale,
e.) effectuer un traitement thermique par mise en solution et tremper le produit ayant été traité thermiquement par mise en solution,
f.) étirer ou comprimer facultativement le produit trempé en alliage, et
15 g.) soumettre facultativement à un vieillissement le produit trempé et facultativement étiré ou comprimé afin d'obtenir le revenu désiré,
et dans le cadre duquel le produit lors de son étape de revenu final a une microstructure à non-recristallisation sensiblement totale au moins à la position T/10 du produit fini.
- 20 2. Procédé selon la revendication 1, le laminage à chaud du produit réchauffé étant effectué jusqu'à environ 150-250 (en pourcentage de l'épaisseur finale), et puis le laminage à froid du produit ayant été laminé à chaud est effectué jusqu'à l'épaisseur finale.
- 25 3. Procédé selon la revendication 1 ou 2, le laminage à chaud du produit réchauffé étant effectué jusqu'à environ 105-140 (en pourcentage de l'épaisseur finale), et puis le laminage à froid du produit ayant été laminé à chaud est effectué jusqu'à l'épaisseur finale.
- 30 4. Procédé selon l'une quelconque des revendications 1 à 3, comprenant le laminage à chaud du produit réchauffé à des températures faibles dans la gamme de 300°C à 420°C afin d'empêcher le produit en alliage de se recristalliser.
- 35 5. Procédé selon l'une quelconque des revendications 1 à 4, le vieillissement artificiel réalisé au cours de l'étape g.) consistant en un revenu sélectionné à partir du groupe constitué de T79 et de T76, et de préférence au moyen d'un traitement de vieillissement en deux phases.
- 40 6. Procédé selon l'une quelconque des revendications 1 à 5, le vieillissement artificiel réalisé au cours de l'étape g.) consistant en une première phase de vieillissement à une température dans la gamme de 105°C à 135°C pendant 2 à 20 heures, et en une deuxième phase de vieillissement à une température supérieure à 135°C mais inférieure à 210°C pendant 4 à 12 heures jusqu'à un revenu sélectionné parmi les trempes T79 et T76.
- 45 7. Procédé selon la revendication 6, le vieillissement artificiel réalisé au cours de l'étape g.) consistant en une première phase de vieillissement à une température aux alentours de 120°C pendant 2 à 20 heures, et en une deuxième phase de vieillissement à une température supérieure à 135°C mais inférieure à 210°C pendant 4 à 12 heures jusqu'à un revenu sélectionné parmi les trempes T79 et T76.
- 50 8. Procédé selon la revendication 6 ou 7, le vieillissement artificiel réalisé au cours de l'étape g.) consistant en une première phase de vieillissement à une température aux alentours de 120°C pendant 2 à 20 heures, et en une deuxième phase de vieillissement à une température aux alentours de 155°C pendant 4 à 12 heures jusqu'à un revenu sélectionné parmi les trempes T79 et T76.
- 55 9. Procédé selon l'une quelconque des revendications 1 à 8, la teneur en Zn se situant dans une gamme de 7,4 à 9,6 % par poids.
10. Procédé selon la revendication 9, la teneur en Zn se situant dans une gamme de 8,0 à 9,6 % par poids, et de préférence dans une gamme de 8,4 à 8,9 % par poids.
11. Procédé selon l'une quelconque des revendications 1 à 10, la teneur en Cu se situant dans une gamme de 1,7 à 2,2 % par poids, et de préférence dans une gamme de 1,8 à 2,1 % par poids.

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12. Procédé selon la revendication 11, la teneur en Mg se situant dans une gamme de 1,7 à 2,2 % par poids, et de préférence dans une gamme de 1,7 à 2,1 % par poids.
- 5 13. Procédé selon l'une quelconque des revendications 1 à 12, la teneur en Sc se situant dans une gamme de [Zr]+1,5 [Sc]<0,15 % par poids.
14. Procédé selon l'une quelconque des revendications 1 à 13, la teneur en Sc se situant dans une gamme de 0,03 à 0,06 %, et la teneur en Ce se situant dans une gamme de 0,03 à 0,06 %.
- 10 15. Procédé selon l'une quelconque des revendications 1 à 14, la teneur en impuretés inévitables étant < 0,05 % par poids chacune, et le total étant < 0,5 % par poids.
16. Procédé selon l'une quelconque des revendications 1 à 15, plus de 80 %, et de préférence plus de 90 %, de l'épaisseur du produit laminé fini ayant une microstructure sensiblement non-recristallisée.
- 15 17. Procédé selon l'une quelconque des revendications 1 à 16, le produit en Al-Zn étant une fine plaque dont l'épaisseur se situe dans la gamme de 20 à 60 mm, et de préférence de 30 à 50 mm.
- 20 18. Procédé selon l'une quelconque des revendications 1 à 17, le produit en Al-Zn étant un produit sélectionné à partir du groupe constitué des postes suivants : un élément mince pour avions, un élément d'aile haute, un élément à revêtement mince d'une aile haute ou un longeron d'un avion.

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REFERENCES CITED IN THE DESCRIPTION

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