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(54) Aluminium alloy for making fin stock material

(57) An aluminium alloy for making fin stock material, having the composition in weight percent:

Si ≤ 1.2
Mn ≤ 0.10
Mg ≤ 0.15
Fe ≤ 2.0
0.05 ≤ Ni ≤ 2.0
0.05 ≤ Cu ≤ 1.0
0.5 ≤ Zn ≤ 4.0 and/or 0.1 ≤ Sn ≤ 2.0 and/or 0.01 ≤ In ≤ 0.5
{ Ti and/or V and/or Cr and/or Zr } ≤ 0.40
other elements up to 0.05 each, up to 0.15 in total
Al balance.

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Description

FIELD OF THE INVENTION

[0001] The invention relates to an aluminium alloy for making fin stock material. Fin stock material is used in heat exchanger devices. The fin stock material is used for making for instance corrugated fins, by which the heat from the heat exchanger must be removed. Furthermore, the invention relates to fin stock material made from the aluminium alloy according to the invention, and to a brazed heat exchanger having fins made of this alloy.

DISCRIPTION OF THE RELATED ART

[0002] In the prior art, aluminium alloys are used for fins in heat exchanger applications because of their desirable combination of strength, low weight, good thermal conductivity, brazeability, corrosion resistance and formability.

[0003] Heat exchangers from aluminium can be fabricated by stacking aluminium alloy sheets, which have been formed to a desired configuration, so as to form fluid passageways or tubes, and by securing aluminium alloy fins between the fluid passageways by brazing. The aluminium alloy sheets used to make the fluid passageways and/or the aluminium alloy used for the fins are provided with a low melting clad layer. The bonding between the alloy clad sheets and the fins is achieved by melting the cladding or filler material of the sheets and/or fin material. As a brazing method, typically vacuum brazing or controlled atmosphere brazing is used. To improve the corrosion resistance of the fluid passageways, fin materials are used which are electrochemically anodic (less noble) relative to the fluid passageways material, so that this fin material has a sacrificial anode effect.

[0004] An example of an aluminium alloy for making fin material is given in International patent application no. WO 01/36697. This alloy has the following composition, in weight percent:

Si	0.7 - 1.2
Mn	0.7 - 1.2
Mg	up to 0.35
Fe	up to 0.8
Zn	up to 3.0
Ni	up to 1.5
Cu	up to 0.5
Ti	up to 0.20
In	up to 0.20
Zr	up to 0.25
V	up to 0.25
Cr	up to 0.25
others up to 0.05 each, and up to 0.15 in total.	
Al	balance.

This disclosed alloy is said to have an improved post-braze 0.2% yield strength over conventional alloys for the same application.

SUMMARY OF THE INVENTION

[0005] It is an object of the present invention to provide an aluminium alloy for making fin stock material which can be used for heat exchangers, and which has an improved thermal conductivity.

[0006] It is another object of the invention to provide such an aluminium alloy, which has a strength which is at least as good as the strength of conventional aluminium alloys for making fin stock material.

[0007] It is still another object of the invention to provide such an aluminium alloy, which has a corrosion potential which is at least as negative as the corrosion potential of conventional aluminium alloys for making fin stock material.

[0008] In one aspect of the invention one or more of these objects are reached with an aluminium alloy for making fin stock material, having the composition in weight percent:

$$Si \leq 1.2$$

Mn ≤ .010

Mg ≤ 0.15

Fe ≤ 2.0

0.05 ≤ Ni ≤ 2.0

0.05 ≤ Cu ≤ 1.0

0.5 ≤ Zn ≤ 4.0 and/or 0.1 ≤ Sn ≤ 2.0 and/or 0.01 ≤ In ≤ 0.5

{ Ti and/or V and/or Cr and/or Zr } ≤ 0.40

other elements up to 0.05 each, up to 0.15 in total
Al balance.

[0009] This aluminium alloy has a very good thermal conductivity, thereby improving the heat exchange properties of the fins made from this aluminium alloy . Moreover, this aluminium alloy has a satisfactory mechanical properties in the post-brazed condition, such as tensile strength and corrosion potential.

[0010] Although this aluminium alloy is primarily intended as fin stock material for heat exchangers, it may be used for other parts of heat exchange units, such as tube plate, or other uses.

[0011] The heat exchanger market, particularly in the automotive industry, requires a balance of properties for fin stock alloys, which includes strength, conductivity, formability, brazeability and corrosion potential. If one of these properties should be improved where the other properties must remain as good as they are, often many of the alloying elements in the composition must be changed in relation to each other.

[0012] In the present case it is the merit of the invention that has been seen that the conductivity of the alloy could be improved by decreasing the solid solution in the alloy through carefully selecting the content of certain alloying elements. This has resulted in the following limitations of the alloying elements in the aluminium alloy according to the present invention. All percentages are by weight.

[0013] Si is an important alloying element in the alloy according to the invention; it is expected that Si improves the strength of the alloy by solid solution hardening and precipitation hardening. Because the solid solution in the alloy should be as low as possible for the required conductivity, the amount of Si should not be higher than 1.2 %. When the amount of Si is higher, too much Si will remain in solid solution, resulting in a lower conductivity. A more preferred range for Si is 0.4 to 0.8 %. Within this range the required combination of strength and conductivity is reached best.

[0014] Mn is an important alloying element in conventional alloys for making fin stock material. Mn is normally added for strength. In the alloy according to this invention, the Mn content is kept very low so as to reduce the amount of solid solution in the alloy. Preferably Mn ≤ 0.05 %, and more preferably Mn ≤ 0.01 %, thereby improving the conductivity as much as possible.

[0015] Mg increases the strength of the alloy significantly, but has a detrimental effect on controlled atmosphere brazeability because it tends to interact with the flux material. For this reason the Mg content has a maximum of 0.15 %, and preferably Mg ≤ 0.05 %, and more preferably Mg ≤ 0.01%, to keep the Mg content as low as possible.

[0016] Fe is an alloying element that is present in all known aluminium alloys. Fe is added for post-braze strength and sag resistance. It is supposed to form precipitates with Al, Ni and Si. The solid solubility of Fe in Al is extremely low, therefore Fe can be used to improve the strength without compromising the conductivity. Preferably Fe is in the range of 0.3 % to 1.6 %, and more preferably in the range of 0.7 % to 1.3 %, so as to reach a preferred strength without compromising the formability.

[0017] Ni is also present to improve the post-braze strength of the alloy. Like Fe, the solid solubility of Ni in Al is extremely low, therefore Ni can be used to improve the strength without compromising the conductivity. However, when the Ni content is > 2 %, the formability becomes too low. Ni is preferably present in the range of 0.5 to 1.5 %, and more preferably in the range of 0.8 to 1.2 % because in these ranges the best combination of strength and formability is found.

[0018] Cu is present in the alloy according to the invention to improve the post-braze strength of the alloy. The amount of Cu is preferably restricted to the range of 0.1 % to 0.8 %, and more preferably to the range of 0.1 % to 0.6 %, so as to reach the required strength. However, Cu is believed to increase the corrosion potential of the alloy, whereas the corrosion potential should be low to allow the fin material to act as a sacrificial anode. For this reason, at least one of the elements Zn, Sn or In should be present.

[0019] Zn, Sn or In, or a combination of these three elements, are present to counteract the effect of Cu on the corrosion potential of the alloy. The amount of these elements must therefore be higher than zero, taking into account the stronger effect of Sn and especially In as compared to Zn. The amounts of Zn, Sn and In should not be higher than necessary and therefor preferably Zn is in the range of 1.0 % to 3.0 % and/or Sn is in the range of 0.1 % to 1.0 % and/or In is in the range of 0.01 % to 0.05 %. Preferably, only Zn is present, but Zn can be (partly) replaced by Sn and/or In.

[0020] Ti, V, Cr and Zr are to be avoided as much as possible, because they have a negative effect on the conductivity of the alloy. Preferably, these elements are below 0.01 % each.

[0021] It is expected that all elements present in the aluminium are detrimental to the conductivity of the alloy. Both impurities and intentionally added elements should therefore be as low as possible, the intentionally added elements being added in so far as they are needed to reach the desired properties.

[0022] In a second aspect of the invention there is provided fin stock material made from the aluminium alloy as specified above, wherein the fin stock material has a post-braze conductivity of at least 26 MS/m (45 % IACS), and preferably at least 29 MS/m (50 % IACS). A conductivity of more than 45 % IACS is good and a conductivity of more than 50 % IACS is very good in comparison to conventional fin stock material for heat exchangers.

[0023] Preferably the fin stock material has a corrosion potential between -750 mV and -950 mV versus SCE (ASTM G69), more preferably between -750 mV and -850 mV according to SCE (ASTM G69). The indication SCE means that the voltage in mV has been measured in relation to a saturated calomel electrode. These values for the corrosion potential give a good sacrificial anode effect when this fin stock material is used in heat exchangers.

[0024] According to a preferred embodiment the fin stock material has a post braze UTS (Ultimate Tensile Strength) between 135 and 155 MPa, and/or a 0.2%PS > 50 MPa. This strength is sufficiently high for normal use of fin stock material.

[0025] According to a third aspect of the invention, there is provided a brazed heat exchanger having fins made of an aluminium alloy according the first aspect of the invention, or having fins made of fin stock material according to the second aspect of the invention.

EXAMPLES

[0026] The aluminium alloy and fin stock material in accordance with the invention will now be illustrated by non-limitative and comparative examples.

[0027] On a laboratory scale nine alloys have been cast with solidification rates in the same range as obtained with industrial scale DC casting. These alloys are manufactured on a laboratory scale , but the aluminium alloy in accordance with this invention can be manufactured on an industrial scale using various standard industrial scale DC casting and continuous aluminium casting methods, followed by hot and/or cold rolling.

[0028] The chemical compositions of the nine alloy examples are given in table 1, some relevant properties after brazing simulation are given in table 2.

Table 1.

Chemical composition, in wt%, of the aluminium alloys tested, the balance is aluminium and impurities.										
alloy	**Si**	**Mn**	**Mg**	**Fe**	**Ni**	**Cu**	**Zn**	**Ti**	**Zr**	**V**
1	0.70	<0.01	0.01	1.05	0.94	0.15	1.52	<0.01	<0.01	<0.01
2	0.70	<0.01	<0.01	0.87	0.99	0.30	1.99	<0.01	<0.01	<0.01
3	0.48	<0.01	<0.01	0.92	1.05	0.50	2.50	<0.01	<0.01	<0.01
4	0.49	0.16	0.01	0.90	1.02	0.31	1.99	<0.01	<0.01	<0.01
5	0.78	0.26	<0.01	0.76	0.66	0.51	0.51	0.03	<0.01	<0.01
6	0.78	0.96	<0.01	0.76	0.73	0.25	1.01	0.03	0.106	<0.01
7	0.76	0.97	0.11	0.29	0.71	0.25	0.20	0.13	<0.01	<0.01
8	0.79	0.99	<0.01	0.31	0.71	0.25	1.49	0.03	<0.01	0.15
9	1.07	0.92	0.21	0.31	0.49	0.25	0.20	0.02	<0.01	<0.01

Table 2.

Properties after simulated brazing cycle.				
alloy	**conductivity [%IACS]**	**corrosion potential [mV SCE]**	**UTS [MPa]**	**proof stress 0.2% [MPa]**
1	49.3	-783	137	53
2	51.4	-779	143	59
3	46.0	-786	149	57
4	43.2	-778	134	54
5	42.8	-732	142	56
6	42.3	-770	156	70
7	40.5	-748	166	76
8	36.6	-805	154	67
9	43.3	-747	161	69

[0029] The nine different chemistries as specified in table 1 were cast and sawed to pieces with a thickness of 80 mm, and thereafter preheated to a temperature below 540°C, the alloys were not homogenised. Subsequently hot rolled at a temperature below 540°C and cold rolled to a thickness of 0.15 mm. After inter annealing, the pieces were cold rolled to a thickness of 0.1 mm.

[0030] In the alloys 1 to 4 of table 1, no Ti, V, Cr or Zr are present. The Zn present in the alloys can be (partly) replaced by Sn and/or In, as is known in the art.

[0031] As can be seen, the alloys 4 to 9 are comparative examples that do not fit in the alloy ranges according to the invention. The amount of Mn is too high. In alloys 6.7 and 8 additions of Zr, Ti and V, respectively, are also present. Despite the fact that the Mn level of alloys 4 and 5 is increased as compared to alloys 1, 2 and 3, the strength is not significantly increased. This is attributed to the decrease in Ni. Alloys 6, 7 and 8 show that with the Ni level of alloys 4 and 5 high strength can be reached when Zr, Ti or V additions are present. However, due to the additions of Mn, Zr, Ti or V in the alloys 4 to 9, the conductivity of these alloys is comparatively low.

[0032] The three alloys 1, 2 and 3 having a composition according to the invention clearly have a high conductivity, a sufficiently high strength and a corrosion potential within the required range to get the sacrificial anode effect.

Claims

1. An aluminium alloy for making fin stock material, having the composition in weight percent:

$$Si \leq 1.2$$

$$Mn \leq 0.10$$

$$Mg \leq 0.15$$

$$Fe \leq 2.0$$

$$0.05 \leq Ni \leq 2.0$$

$$0.05 \leq Cu \leq 1.0$$

$$0.5 \leq Zn \leq 4.0 \text{ and/or } 0.1 \leq Sn \leq 2.0 \text{ and/or } 0.01 \leq In \leq 0.5$$

$$\{ Ti \text{ and/or } V \text{ and/or } Cr \text{ and/or } Zr \} \leq 0.40$$

other elements up to 0.05 each, up to 0.15 in total
Al balance.

2. An aluminium alloy according to claim 1, wherein Si is in the range of 0.4 % to 0.8 %.

3. An aluminium alloy according to claim 1 or 2, wherein Mn ≤ 0.05 %, and preferably Mn ≤ 0.01 %.

4. An aluminium alloy according to claim 1, 2 or 3, wherein Mg ≤ 0.05 %, and preferably Mg ≤ 0.01 %.

5. An aluminium alloy according to any of the preceding claims, wherein Fe is in the range of 0.3 % to 1.6 %, and preferably in the range of 0.7 % to 1.3 %.

6. An aluminium alloy according to any of the preceding claims, wherein Ni is in the range of 0.5 % to 1.5 %, and preferably in the range of 0.8 % to 1.2 %.

7. An aluminium alloy according to any of the preceding claims, wherein Cu is in the range of 0.1 % to 0.8 %, and preferably in the range of 0.1 % to 0.6 %.

8. An aluminium alloy according to any of the preceding claims, wherein Zn is in the range of 1.0 % to 3.0 % and/or Sn is in the range of 0.1 % to 1.0 % and/or In is in the range of 0.01 % to 0.05 %.

9. An aluminium alloy according to any of the preceding claims, wherein no In and no Sn is present.

10. An aluminium alloy according to any of the preceding claims, wherein Ti and/or V and/or Cr and/or Zr are <0.01 % each.

11. Fin stock material made from the aluminium alloy according to any of the preceding claims, wherein the fin stock material has a post-braze conductivity of at least 26 MS/m (45 % IACS), and preferably at least 29 MS/m (50 % IACS).

12. Fin stock material according to claim 11, wherein the fin stock material has a corrosion potential between -750 mV and -950 mV versus SCE (ASTM G69), preferably between -750 mV and -850 mV versus SCE (ASTM G69).

13. Fin stock material according to claim 11 or 12, wherein the fin stock material has a post braze Ultimate Tensile Strength between 135 and 155 MPa.

14. Fin stock material according to claim 11, 12 or 13, wherein the fin stock material has a proof stress at 0.2% elongation > 50 MPa.

15. Fin stock material according to one of claims 11 - 14, wherein the fin stock material has been clad on at least one side with a clad layer having a lower melting point than the fin stock material.

16. A brazed heat exchanger having fins made of an aluminium alloy according to any one of claims 1- 10.

17. A brazed heat exchanger having fins made of fin stock material according to any one of claims 11 - 15.

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EUROPEAN SEARCH REPORT

Application Number
EP 01 20 3759

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	10 December 2001	Patton, G

CATEGORY OF CITED DOCUMENTS

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EUROPEAN SEARCH REPORT

Application Number
EP 01 20 3759

DOCUMENTS CONSIDERED TO BE RELEVANT

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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