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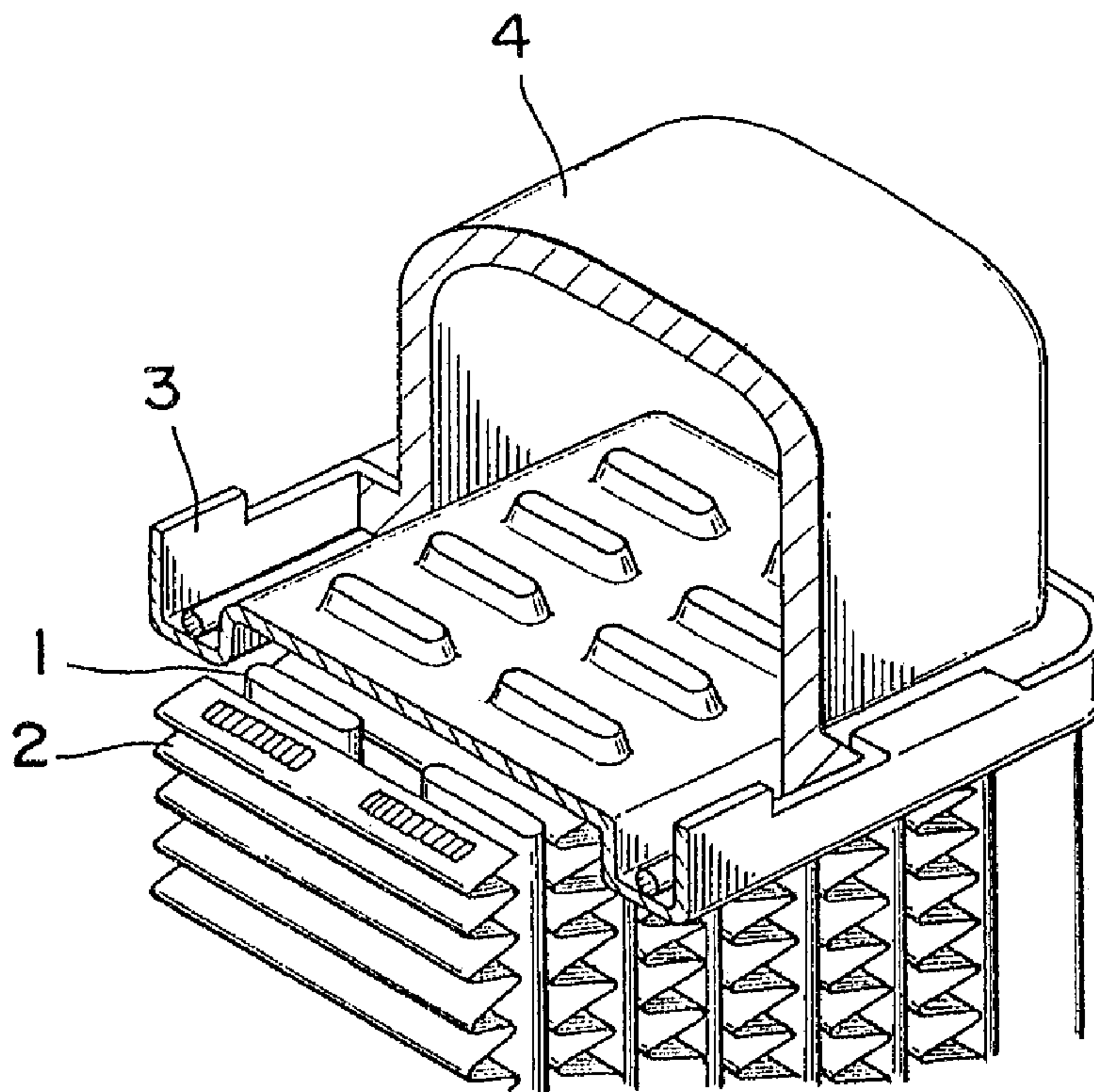
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(54) Title: ALUMINUM ALLOY FIN MATERIAL FOR HEAT-EXCHANGER



(57) Abrégé/Abstract:

An aluminum alloy fin material for heat-exchangers, with excellent thermal conductance and strength after brazing, comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to 2.0 wt. % of Ni, and the balance of Al and inevitable impurities is disclosed. It may additionally contain 0.01 to 0.2 wt. % of Zr and/or at least one of: 1) not more than 2.0 wt. % of Zn; 2) not more than 0.3 wt. % of In; and 3) not more than 0.3 wt. % of Sn.

ABSTRACT

An aluminum alloy fin material for heat-exchangers, with excellent thermal conductance and strength after brazing, comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to 2.0 wt. % of Ni, and the balance of Al and inevitable impurities is disclosed. It may additionally contain 0.01 to 0.2 wt. % of Zr and/or at least one of: 1) not more than 2.0 wt. % of Zn; 2) not more than 0.3 wt. % of In; and 3) not more than 0.3 wt. % of Sn.

ALUMINUM ALLOY FIN MATERIAL FOR A HEAT-EXCHANGER

BACKGROUND OF THE INVENTION

The present invention relates to an aluminum alloy fin
5 material with high thermal conductance for heat-exchangers.
It relates, in particular, to an aluminum alloy fin material
useful for fins of radiators used as heat-exchangers for
cars, heaters, condensers and the like, especially when
assembled using a brazing method.

10 The majority of heat-exchangers for cars are made with Al
or an Al alloy and are assembled by brazing. Usually, for
brazing, an Al-Si type filler alloy is used, hence the
brazing is performed at high temperatures of around 600°C.
In the heat-exchangers of radiators etc., a thin-wall fin
15 machined in a corrugated shape is interconnected between a
plurality of flat tubes. Each end of the flat tubes opens
respectively in spaces provided by a header and a tank.
High-temperature refrigerant is fed from one tank to the
other tank through the flat tubes. Heat is exchanged through
20 the walls of flat tube and the thin-walled fins, and the
cooled refrigerant is recirculated.

A recent trend requires that heat-exchangers be light in
weight and miniaturized. To accomplish this, improved
thermal efficiency of heat-exchangers is required and
25 improved thermal conductance of heat-exchanger material is
desired. In particular, an improved thermal conductance of
fin material has been proposed. An alloy fin material with a

composition close to pure aluminum has been proposed for use as a high thermal conductance fin. After drawing the fin material to a thin condition, however, there are problems in that if the strength of the finished fin is insufficient the
5 fin collapses when the heat-exchanger is assembled, or the fins break when the heat-exchanger is used. In particular, a fin of pure aluminum type alloy has a drawback of insufficient strength. A fin with high strength and improved thermal conductance has not yet been developed. This is
10 because the addition of alloy elements such as Mn is effective for high strength but since the production process includes brazing at temperatures near 600°C, the elements added to the alloy form a solid solution during brazing that interferes with thermal conductance.

15 In view of the foregoing, the inventors strove to develop a fin material that maintained high strength and thermal conductance after soldering. To accomplish this they wished to improve the strength of the fin material by adding appropriate quantities of Si and Fe to the alloy. They also
20 wished, if possible, to find alloy elements which would significantly improve strength without decreasing the thermal conductance of a fin material.

SUMMARY OF THE INVENTION

25 In accordance with the invention, aluminum alloy fin materials for heat-exchangers with excellent thermal conductance and strength after brazing have been developed.

A first embodiment of the invention provides a heat exchanger having high strength and improved thermal conductance, said heat exchanger having one or more fins formed essentially of an aluminum alloy comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to 2.0 wt. % of Ni, and the balance of Al and inevitable impurities.

A second embodiment of the invention provides a heat exchanger having high strength and improved thermal conductance, said heat exchanger having one or more fins formed essentially of an aluminum alloy comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to 2.0 wt. % of Ni, 0.01 to 0.2 wt. % of Zr, and the balance of Al and inevitable impurities. Moreover, a third embodiment of the invention provides a heat exchanger having high strength and improved thermal conductance, said heat exchanger having one or more fins formed essentially of an aluminum alloy comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to 2.0 wt. % of Ni, and at least one of the following:

- 1) not more than 2.0 wt. % of Zn;
- 2) not more than 0.3 wt. % of In;
- 3) not more than 0.3 wt. % of Sn; and

the balance of Al and inevitable impurities. Furthermore, a fourth embodiment of the invention provides a heat exchanger having high strength and improved thermal conductance, said heat exchanger having one or more fins

formed essentially of an aluminum alloy comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to 2.0 wt. % of Ni, 0.01 to 0.2 wt. % of Zr, and at least one of the following:

- 5 1) not more than 2.0 wt. % of Zn;
 2) not more than 0.3 wt. % of In;
 3) not more than 0.3 wt. % of Sn; and
the balance of Al and inevitable impurities.

10 BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is an oblique view of a partial section showing one end of a radiator.

DETAILED DESCRIPTION OF THE INVENTION

The role of addition elements in the inventive fin materials and the reasons for limitations in the concentrations of the elements in the alloy compositions is described in detail below.

The addition of Si improves the strength of metal alloys. Since Si promotes the precipitation of Fe and Ni, particularly when alloyed with Fe and Ni, besides improving the strength of an alloy through solid-solution hardening, it increases the intermetallic compounds that contribute to dispersion, which also improves the strength of the alloy. Furthermore, since Si decreases the quantity of solid solution Fe and Ni in the fin material by promoting the precipitation of Fe and Ni, it improves the thermal conductance of the material. It has been established that if Si is less than 0.005 wt. % of an alloy, its effect on strength improvement is insufficient and a high-purity metal is required to produce the fin, which is undesirable for reasons of cost. If, however, Si is more than 0.8 wt. % of the alloy, the diffusion of filler becomes significant during brazing, resulting in a decrease in the thermal conductance and interfering with the solderability of the alloy.

Hence, the range of Si is preferably from 0.005 to 0.8 wt. %, but the appropriate quantity of Si varies somewhat depending on the physical properties required for the fin. First, if the quantity of Si is low, a fin material with excellent thermal conductance is obtained, and, since the

natural electrical potential of the fin material is lowered, a fin material advantageous from the viewpoint of a sacrificial anode effect can be obtained. For such characteristics, a range from 0.05 to 0.2 wt. % shows stable characteristics and is preferred. Moreover, if the quantity of Si is high, the thermal conductance of the fin is not as good, but the fin has excellent strength even after soldering. For such characteristics, a range from 0.4 to 0.6 wt. % shows stable characteristics and is preferred.

10 A certain amount of Fe in the alloy promotes solid-solution hardening. The remainder of the Fe in the alloy exists as intermetallic compounds. The former improves the strength, but significantly decreases thermal conductance. The latter slightly improves the strength because the compounds reinforce dispersion, but has an inverse effect on the strength contributed by Si addition by forming intermetallic compounds with Si. If the addition level of Fe is under 0.5 wt. %, the improvement effect on strength will be insufficient and, if over 1.5 wt. %, the malleability will deteriorate, resulting in a fin material that is difficult to corrugate.

It has become clear as a result of diligent investigations by the inventors that Ni has an effect of improving the strength without decreasing the thermal conductance of the alloy. This is an important feature of the invention. Specifically, Ni improves the strength of the alloy through solid-solution hardening, but, at the same time, it decreases the concentration of solid solution Fe to an

equivalent of the concentration of solid solution of Ni.

While Fe and Ni have almost the same effect on the improvement in strength in the solid solution, Ni decreases the thermal conductance far less. Hence, when adding Ni to an alloy containing the quantities of Fe described above, the strength of the alloy is improved without decreasing thermal conductance. If the concentration of Ni is under 0.1 wt. %, the effect will be insufficient, but if more than 2.0 wt. % is added, the malleability will deteriorate, resulting in a fin material that is difficult to corrugate.

An alloy for a heat-exchanger in which Ni is added to pure aluminum is shown in Japanese Unexamined Patent Publication No. Sho 57-60046. Although that application describes to an alloy for a heat-exchanger material, it does not contemplate the use of the alloy as a fin material. This is obvious because the application describes improvements in corrosion resistance and sag property. It does not describe the thermal conductance required for a fin material, and the plate thickness shown in the examples is much thicker than that suitable for fin material.

The Japanese Unexamined Patent Publication No. Sho 57-60046 does not describe a fin material with excellent thermal conductance or the relationship between the quantity of Fe and the quantity of Ni as a consideration in compounding an alloy for heat-exchangers. That is to say, the invention of the published application and the present invention are quite different in their respective industrial applications.

Besides, with respect to the alloy composition, the invention of Japanese Unexamined Patent Publication No. Sho 57-60046 considers Si and Fe to be impurity elements, while in accordance with the present invention these elements are
5 considered positive addition elements.

In accordance with certain embodiments of the invention, 0.01 to 0.2 wt. % of Zr are added. Zr coarsens the recrystallized grains produced on soldering and prevents the sagging of a soldered fin and the diffusion of solder into
10 the fin. Since the inventive alloy contains relatively large quantities of Fe, the recrystallized grains tend to become fine, and the addition of Zr is beneficial to counteract this tendency. If less than 0.01 wt. % of Zr is added, its effect will not be sufficient. According to investigations by the
15 inventors, Zr has little effect on the strength of the alloy and it tends to decrease the thermal conductance, hence the upper limit of concentration was determined to be 0.2 wt. %.

To the inventive alloy, at least one of the following may be added, 1) not more than 2.0 wt. % of Zn; 2) not more than
20 0.3 wt. % of In; and 3) not more than 0.3 wt. % of Sn are added in some cases. These are added to produce a sacrificial anode effect in the fin material but, if more than the quantities respectively listed above are added, the thermal conductance is decreased.

25 Now, the inevitable impurities and the elements added for reasons other than the above include Ti, B, etc. which are added to make the texture of an ingot fine, and these

elements may be safely added, if their concentration is under 0.03 wt. %, respectively. Moreover, when adding elements such as Cu, Mn, Mg, Na, Cd, Pb, Bi, Ca, Li, Cr, K and V to improve strength, prevention of ingot cracking, improvement
5 in malleability and the like, the addition of not more than 0.03 wt. % is required, respectively. This is because adding more than 0.03 wt. %, of any of these elements will decrease the thermal conductance of the fin material.

The alloy composition of the invention is as described
10 above. The inventive fin material can be used as a bare material and it can also be used as a brazed core material of sheet fin. For the soldering material in the latter case, the traditional soldering alloy may be used as is.

For a heat-exchanger using the inventive fin material,
15 radiator for cars, condensers, evaporators, oil coolers, etc. are potential applications, but the heat-exchangers are not confined to these.

Moreover, the inventive fin material, may be soldered using noncorrosive brazing, flux brazing, vacuum brazing,
20 etc. Any traditional soldering method may be used.

The inventive fin can be produced by ingot production, by semi-continuous casting, hot rolling, cold rolling and annealing, or it can be produced by a process of continuous casting and rolling, cold rolling and annealing.

25 In following, the invention will be illustrated concretely based on examples.

Example

Aluminum alloy fin materials (sheet thickness: 60 μm , H14 refining) with alloy compositions shown in Table 1 and Table 2 were fabricated according to a usual method. The strength, electroconductivity and natural electrical potential of these fin materials was determined using a saturated calomel electrode in 5 % aqueous solution of NaCl after soldering under heat. The soldering under heat involved heating the material for 5 minutes at 600°C in nitrogen gas atmosphere. The results are shown in Table 3 and Table 4.

Here, the electroconductivity is an index of thermal conductance and, if the electroconductivity of a fin improves by 5 % IACS, then the thermal efficiency of a heat-exchanger made with the fin improves by 1 % or so.

Table 1

	No	Alloy composition (wt. %)										
		S i	F e	N i	Z r	Z n	I n	S n	M n	C u	T i	A l
Inventive example	1	0.10	1.1	0.4	—	—	—	—	—	—	—	Bal- ance
	2	0.10	1.1	0.4	—	0.8	—	—	—	—	—	"
	3	0.10	1.1	0.4	—	—	0.1	0.1	—	—	—	"
	4	0.10	1.1	0.4	0.10	—	—	—	—	—	0.01	"
	5	0.05	0.7	0.8	0.10	1.1	—	—	—	—	—	"
	6	0.05	1.0	1.0	—	—	—	—	—	—	—	"
	7	0.10	0.65	0.8	—	—	—	0.1	—	—	—	"
	8	0.20	1.0	0.5	—	—	0.001	—	—	—	—	"
	9	0.20	1.0	1.0	—	0.8	—	—	—	—	0.01	"
	10	0.25	0.75	0.4	—	—	0.002	—	—	—	—	"
	11	0.25	1.1	0.3	—	0.8	—	—	—	—	0.01	"
	12	0.01	0.8	0.4	—	—	—	—	—	—	—	"
	13	0.03	0.8	0.4	—	0.4	—	—	—	—	—	"
	14	0.03	0.8	0.4	—	—	0.01	0.01	—	—	—	"
	15	0.01	1.1	0.4	0.10	—	—	—	—	—	0.01	"
	16	0.02	0.6	0.8	—	—	—	0.1	—	—	—	"
	17	0.01	0.8	0.8	—	—	—	—	—	—	—	"
	18	0.02	1.1	0.3	—	0.4	—	—	—	—	—	"
	19	0.03	1.4	0.3	—	—	0.001	—	—	—	—	"
	20	0.25	1.4	0.3	—	0.1	0.002	0.001	—	—	—	"
	21	0.50	1.0	0.4	—	—	—	—	—	—	—	"
	22	0.50	1.0	0.4	—	0.8	—	—	—	—	0.01	"

Table 2

	No.	Alloy composition (wt%)										
		S i	F e	N i	Z r	Z n	I n	S n	M n	C u	T i	A l
Inventive example	23	0.50	1.0	0.4	—	—	0.1	0.1	—	—	0.01	Balance
	24	0.50	1.0	0.3	0.10	—	—	—	—	—	0.01	"
	25	0.75	1.15	0.4	—	—	—	0.1	—	—	—	"
	26	0.6	0.6	0.6	—	—	0.1	—	—	—	0.01	"
	27	0.6	0.9	0.4	—	—	—	—	—	—	—	"
	28	0.6	1.0	0.6	—	1.1	—	—	—	—	—	"
	29	0.6	1.1	0.4	—	—	0.002	—	—	—	0.01	"
	30	0.55	0.7	0.3	—	—	—	—	—	—	0.01	"
	31	0.45	0.7	1.0	—	—	—	—	—	—	0.01	"
	32	0.4	0.6	0.6	—	1.1	—	—	—	—	—	"
	33	0.4	0.9	0.4	0.1	—	—	—	—	—	—	"
	34	0.4	1.0	0.8	—	1.0	—	—	—	—	0.01	"
	35	0.4	1.1	0.3	—	—	0.1	—	—	—	—	"
	36	0.7	0.6	0.5	—	—	0.005	—	—	—	—	"
	37	0.65	1.3	0.2	0.15	0.1	—	—	—	—	—	"
	38	0.35	1.2	0.9	0.05	—	—	0.002	—	—	—	"
Conventional example	39	0.5	0.5	—	0.15	1.0	—	—	—	—	0.01	"
	40	0.4	0.6	—	—	1.0	—	—	1.1	0.1	0.01	"
Comparative example	41	0.002	0.8	0.03	—	1.0	—	—	—	—	—	"
	42	0.2	0.45	0.4	—	—	—	—	—	—	—	"
	43	0.1	0.1	0.6	—	1.0	—	—	—	—	—	"
	44	0.5	0.1	0.6	—	—	—	—	—	—	—	"
	45	1.0	0.4	0.6	—	—	—	—	—	—	—	"
	46	1.0	1.1	0.3	—	1.0	—	—	—	—	—	"
	47	0.7	1.8	0.6	—	1.0	—	—	—	—	—	"
	48	0.03	0.8	0.03	—	1.0	—	—	—	—	—	"
	49	0.03	0.8	2.5	—	1.0	—	—	—	—	—	"
	50	0.1	0.45	0.4	—	—	—	—	—	—	—	"
	51	0.5	1.0	2.5	—	—	—	—	—	—	—	"

Table 3

	No	Tensile strength (MPa)	Electro-conductivity (%IACS)	Natural potential (mV)
Inventive example	1	125	59	-790
	2	125	58	-850
	3	125	58	-860
	4	125	56	-790
	5	120	57	-870
	6	115	60	-800
	7	120	59	-790
	8	130	58	-830
	9	130	57	-850
	10	130	57	-840
	11	125	56	-860
	12	110	62	-800
	13	115	59	-860
	14	115	60	-850
	15	115	61	-800
	16	110	61	-850
	17	120	61	-810
	18	120	59	-860
	19	110	59	-850
	20	130	56	-860
	21	140	57	—
	22	140	57	—

Table 4

	No.	Tensile strength (MPa)	Electro-conductivity (%IACS)	Natural potential (mV)
Inventive example	23	140	57	—
	24	145	56	—
	25	145	56	—
	26	140	56	—
	27	140	56	—
	28	137	57	—
	29	137	58	—
	30	135	57	—
	31	140	57	—
	32	130	58	—
	33	140	56	—
	34	145	57	—
	35	135	58	—
	36	135	56	—
	37	140	55	—
	38	143	55	—
Conventional example	39	90	52	-840
	40	115	40	-810
Comparative example	41	70	60	-760
	42	80	58	-790
	43	75	59	—
	44	85	60	—
	45	130	49	—
	46	130	45	—
	47	135	52	—
	48	75	60	—
	49	120	58	—
	50	85	61	—
	51	140	55	—

As evident from Table 3 and Table 4, none of the conventional fin materials are excellent in both tensile strength and electroconductivity, whereas the fin materials of the inventive examples show excellent values in both
5 tensile strength and electroconductivity.

Example No. 39 relates to a fin material of a conventional pure aluminum alloy with excellent thermal conductance and example No. 40 relates to a fin material of conventional Al-Mn alloy. Example Nos. 1 through 20 are
10 alloys with a relatively low quantity of Si in accordance with the invention. They have excellent thermal conductance and strength properties when compared to conventional pure aluminum alloys, while maintaining the same degree of sacrificial anode effect as the conventional material. The
15 strength of the inventive alloys is equal to that of conventional Al-Mn type alloy and the thermal conductance is very excellent. Moreover, examples No. 21 through 38 relate to fin materials in accordance with the invention with relatively high concentration of Si. They have a thermal
20 conductance equal or superior to that of a conventional pure aluminum type alloy and are very excellent in the strength. These alloys also have strength characteristics equal or superior to that of a conventional Al-Mn type alloy and the thermal conductance is excellent. In examples No. 21 through
25 38, those alloys with added Zn, In and Sn have the same sacrificial anode effect as that of conventional materials, though the electrical potentials are not listed. Those

alloys without any Zn, In and Sn are poor in the sacrificial effect, hence they should be used for the heat-exchangers not requiring fins with sacrificial anode properties, limiting their industrial application.

5 Comparative example No. 41 relates to any alloy made with a high-purity metal, which is undesirable because of cost. Moreover, the malleability of all fin materials was tested by corrugating a sample, and it was found that the fin materials of examples No. 47, 49 and 51 cracked when corrugated and
10 could not be readily bent.

As descried above, the fin materials in accordance with the invention have high strength and excellent thermal conductance and can be used suitably for heat-exchangers for cars, in particular. For these and other reasons, the
15 invention has remarkable industrial potential.

20

25

CLAIMS:

1. A heat exchanger having high strength and improved thermal conductance, said heat exchanger having one or more fins formed essentially of an aluminum alloy comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to 2.0 wt. % of Ni, and the balance of Al and inevitable impurities.
2. A heat exchanger having high strength and improved thermal conductance, said heat exchanger having one or more fins formed essentially of an aluminum alloy comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to 2.0 wt. % of Ni, 0.01 to 0.2 wt. % of Zr, and the balance of Al and inevitable impurities.
3. A heat exchanger having high strength and improved thermal conductance, said heat exchanger having one or more fins formed essentially of an aluminum alloy comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to 2.0 wt. % of Ni, at least one of: 1) not more than 2.0 wt. % of Zn; 2) not more than 0.3 wt. % of In; 3) not more than 0.3 wt. % of Sn; and the balance of Al and inevitable impurities.
4. A heat exchanger having high strength and improved thermal conductance, said heat exchanger having one or more fins formed essentially of an aluminum alloy comprising 0.005 to 0.8 wt. % of Si, 0.5 to 1.5 wt. % of Fe, 0.1 to

2.0 wt. % of Ni, 0.01 to 0.2 wt. % of Zr, at least one of:
1) not more than 2.0 wt. % of Zn; 2) not more than 0.3 wt.
% of In; 3) not more than 0.3 wt. % of Sn; and the balance
of Al and inevitable impurities.

Fig. 1

