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(54) **Endless capillary tubes in aluminium alloy, lamination valves comprising aluminium alloy capillary tubes and an aluminium alloy**

(57) The present invention provides new endless capillary tubes in aluminium alloy, new lamination valves comprising capillary tubes in aluminium alloy obtainable from the aforesaid endless tubes, and a new aluminium alloy, suitable for the production of endless capillary tubes.

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Description

FIELD OF THE INVENTION.

[0001] The present invention relates to new "endless" capillary tubes, used preferably in the production of lamination valves.

BACKGROUND ART.

[0002] In cooling circuits mounted on electrical household appliances, it is common practise to use capillary tubes as lamination valves, adapted to regulate the thermodynamic cycle of the circuit. In these capillary tubes, the length and the internal diameter basically determine the pressure drop of the cooling means used in the circuit. Therefore in the aforesaid valves the so-called flow rate of the capillary tubes employed, constitutes, together with the choice of fluid used, the key factor for the dimensioning and project design of the whole cooling system.

[0003] For this reason it is important that this flow rate is maintained within very strict tolerance levels. The term "flow rate" refers to the volume of fluid (generally nitrogen or dry air is used as measuring fluid or gas) that passes through the section of the capillary tube during a unit of time at a determined inlet pressure. The flow rate is conventionally measured in litres per minute. In industrial practise the flow rate of a capillary tube is measured according to UNI EN 12450 standards. In fact, specific instruments are available on the market designed for this purpose. Preferably, in order to measure the flow rate, the gas is sent into the capillary tube at a pressure between 0.5 and 20 bar, more preferably between 4 and 15 bar. Even more preferably, the measuring gas pressure ranges between 5 and 10 bar.

[0004] Given that in industrial production of these valves destined for use in household appliances mass produced in vast quantities, it would be far too laborious to individually adjust the internal volume of every single capillary tube used in valve construction, by means of (1) individual measurement, using the aforesaid fluid mechanics, of its flow rate and (2) successive adjustment of its length, the household appliance industry requests capillary tubes of its suppliers that are extremely long (practically "endless"), whose internal volume (defined, as stated previously, through the "flow rate") is strictly proportional with the length, in other words, whose interior must be completely clean of all production residue and must be characterized by a constant diameter . This is in order to avoid individual interventions of the type (1) and/or (2) on each single capillary tube employed in the valve, and to ensure that it is possible to obtain the exact flow rate as designed by simply dividing the endless capillary tube supplied, in pieces of a suitable length, destined for use as lamination valves.

[0005] At present, the capillary tubes destined for the aims specified herein, are produced as "endless" tubes wound in rolls (so-called wound coils) and obtained through continuous machining comprising a succession of cold-drawning operations with a floating chuck on roughly semi-machined blanks obtained through extrusion. To guarantee the constant level of the capillary tube flow rate, it is essential that the internal diameter be constant, and it is thus important that materials in use possess well-defined chemical, physical and mechanical characteristics. Other important characteristics that are required and that cannot be modified because these are dictated by the preferred use are the resistance of the employed material to corrosion, as well as its compatibility with the fluids and other materials used in the cooling circuit. As the reader will become aware, the complexity of the problems described herein originate above all in the enormous difference between the size of the various dimensions of the "endless" tubes described herein, given that the length can reach as much as 5 kilometres in some cases, while the internal diameter does not exceed a few millimetres. For this reason, to guarantee the constant levels necessary for the flow rate along the total length of the endless capillary tube has required considerable productive effort in the past, both as far as materials are concerned, as well as the tools used.

[0006] For these reasons, the only material that has been considered actually usable (and is actually used) in the production of wound coil "endless" capillary tubes, able to provide very high constancy levels for the flow rate, is copper and its alloys.

[0007] This results in the fact that all the lamination valves mounted in cooling circuits in household appliances in common mass-produced industrial production are in copper or copper alloy. Therefore, the machinery used in this technical field is optimised for machining this metal. At present, the exclusive use of copper in this technical field ties the actual market price for these common lamination valves for household appliance cooling circuits, very closely to the price of the raw materials. The result is that, given increasing industrialisation in emerging countries under development, and given the increased needs for raw materials, the price of copper (LME) has increased in the last ten years alone, from 2610 US$ per ton in 1996 to over 5000 US$ per ton (02/2006). Given the large number of pieces obtainable with machinery available, this price has a considerable effect on that of the lamination valves obtained from copper and its alloys. In the immediate future, and in any case, in the medium term, this situation will become far worse because of the fact that in these same emerging countries under development, and above all in those even less developed countries, at the same time, and as an indicator of a constant improvement in the lifestyle quality, there is an increase in the demand for household appliances for immediate necessity (such as refrigerators), on condition that the price is not too high.

[0008] This has led to the need for obtaining capillary tubes with a constant flow rate, in the form of endless tubes, preferably wound in rolls or coils, preferably to be used to obtain lamination valves for household appliance

cooling circuits from an alternative material, also less costly and less valuable than copper. Therefore there is a definite need for the provision of new lamination valves available for household appliance cooling circuits, in which the capillary tube, while providing the same performance level, is composed of a more economical alternative material. Moreover, it would be particularly advantageous if the said new lamination valves comprise a capillary tube composed of a material that is more resistant to corrosion and particularly suitable for use in the context of cooling circuits.

[0009] For this reason it is necessary that a material be found for the aforesaid uses, as an alternative to copper and its alloys, a material that is less valuable but just as easily machined.

SUMMARY.

[0010] This problem is solved by the Applicants of the present invention, by providing an endless capillary tube in aluminium alloy characterised in that the flow rate of two segments of the capillary tube having a length of 2500 mm cut from two positions taken at random from the endless capillary tube do not vary more than ±6%. Therefore, the endless capillary tube according to the present invention can be used for example, without any further adjustment to the single capillary tubes obtained from it to form the lamination valves for household appliances.

[0011] The present invention also provides a new aluminium alloy, particularly suitable for the aforesaid aims, since it is able to be used on existing machines without the need for any modifications.

DETAILED DESCRIPTION OF THE INVENTION.

[0012] In particular, in order to provide a solution to the aforesaid technical problem, in other words, in searching for an alternative material, preferably less costly, but just as easily used for the production of endless capillary tubes with a constant flow rate in rolls or wound coils, the inventors of the present application have surprisingly discovered that it is possible to use aluminium alloy for this purpose. Certain aluminium alloys are particularly preferable.

[0013] Within the context of the present invention, the term "capillary tube" refers to a tube whose internal diameter is very small, in particular, less than 4.5mm. Preferably, the internal diameter is such that the behaviour of a fluid in the tube interior, in particular a fluid commonly used in household appliance cooling circuits, is controlled by the so-called physical principle of capillarity. Therefore, more preferably, the capillary tubes of the present invention are characterised by an internal diameter less than 3mm, even more preferably less than 1.0mm. More preferred capillary tubes have an internal diameter less than 0.7mm. Instead, the minimum diameter of the capillary tubes according to the present invention is preferably 0.2mm, more preferably 0.3mm, even more preferably 0.4mm, and most preferably 0.5mm.

[0014] Therefore, preferably the capillary tubes of the present invention have an internal diameter less than 4,5mm, preferably less than 3mm, more preferably less than 1 mm, even more preferably less than 0.7 mm.

[0015] Preferably the capillary tubes of the present invention have an internal diameter that ranges between less than 4,5mm and 0.2 mm, preferably between less than 3mm and 0.2mm, more preferably between less than 1 mm and 0.2mm, even more preferably between less than 0.7 mm and 0.2mm.

[0016] More preferably the capillary tubes of the present invention have an internal diameter between less than 4.5mm and 0.3 mm, preferably between less than 3mm and 0.3mm, more preferably between less than 1 mm and 0.3mm, even more preferably between less than 0.7 mm and 0.3mm.

[0017] Even more preferably the capillary tubes of the present invention have an internal diameter that ranges between less than 4.5mm and 0.4 mm, preferably between less than 3mm and 0.4mm, more preferably between less than 1 mm and 0.4mm, even more preferably between less than 0.7 mm and 0.4mm.

[0018] Most preferable among the capillary tubes of the present invention have an internal diameter ranging between less than 4.5mm and 0.5 mm, preferably between less than 3mm and 0.5mm, more preferably between less than 1 mm and 0.5mm, even more preferably between less than 0.7 mm and 0.5mm.

[0019] Within the context of the present invention the term "endless" capillary tube refers to a seamless capillary tube obtained by means of continuous production. Preferably, said "endless" capillary tube is at least 100 metres long, more preferably at least 500 metres long, even more preferably at least 1000 metres long. Preferably, the endless capillary tube is wound to form rolls or wound coils.

[0020] The endless capillary tubes in aluminium alloy of the present invention are characterised by a very strict proportionality between flow rate and length. In particular, the flow rates of two segments of capillary tube having a length of 2500mm cut from two positions taken at random from the endless tube, do not vary by more than ±6%, preferably ± 3%, even more preferably ± 2% and most preferably ±1%.

[0021] Therefore, it is possible to obtain from the aforesaid endless capillary tube in aluminium alloy by means of simple division, single capillary tubes having a predetermined length, preferably ranging between 100mm and 10 000mm, more preferably between 500mm and 5000mm, even more preferably between 1000mm and 3000mm, providing a consequential flow rate, preferably destined to obtain lamination valves for household appliances. The proportionality between length and flow rate of said single capillary tubes is such that if the capillary tubes according to the present invention are in turn, also cut in half, the flow rates of the resulting two halves will

not differ by more than ± 6%, preferably ±3%, even more preferably 2%, and most preferably 1%.

[0022] The production of endless capillary tubes in aluminium alloy according to the present invention is obtained using common processes already in practise in the sector for the production of traditional endless capillary tubes in a known copper alloy.

[0023] For example the production of endless capillary tubes in aluminium alloy occurs according to a process comprising the following steps:

- Hot extrusion of a rough blank;
- Successive stages of cold drawing, the number of stages depending on the envisaged machining cycle; the external diameter and the tube thickness are reduced with each extrusion stage until the final measure is obtained;
- Winding to form wound coils;
- Washing of the internal surface to eliminate machining residue (lubricants, etc.);
- heat treatment aimed at modifying the mechanical characteristics of the capillary tube increasing the ductility.

[0024] As stated previously, a fundamental characteristic of the endless capillary tubes as well as their segments as defined previously, and above all of single capillary tubes (obtained from endless tubes) described herein -according to the present invention and unlike traditional tubes already widely used, is the fact that for the first time tubes are obtained from an aluminium alloy.

[0025] When the endless capillary tube in aluminium alloy according to the present invention, divided to form the single particular capillary tubes used for lamination valves and placed in comparison with similar copper capillary tubes, the aluminium tube is able to guarantee:

- At least equivalent performance, preferably even better, in terms of flow rate constancy;
- Mechanical characteristics that permit handling and assembling of the component in cooling circuits without any particular restrictions;
- Strong resistance to corrosion (over 500 hours in ASTM G85-98 A3).

[0026] Research performed by the inventors of the present Application has also demonstrated that it is possible to obtain on machinery commonly destined for the production of traditional endless capillary tubes in copper o copper alloy, without the need for any modification-capillary tubes in a new aluminium alloy, composed of: Si: 0.15% in weight max; Fe: 0.25% in weight max.; Cu: 0.10% in weight max.; Mn: 0.90-1,10% in weight; Mg: 0.06% in weight max.; Cr:0.06% in weight max.; Zn: 0.10% in weight max.; Ti: 0.06 % in weight max.; the remainder being aluminium and inevitable impurities.

[0027] A new aluminium alloy is preferred, composed of: Si: 0.10% in weight max.; Fe: 0.20% in weight max.; Cu: 0.10% in weight max.; Mn: 0.90 -1,10% in weight; Mg: 0.03% in weight max.; Cr: 0.03% in weight max.; Zn: 0.07% in weight max.; Ti: 0.03% in weight max.; the remainder being aluminium and inevitable impurities.

[0028] Particularly preferred is a new aluminium alloy composed of: Si: 0.10% in weight max.; Fe: 0.15% in weight max.; Cu: 0.10% in weight max.; Mn: 1.00 - 1.10% in weight; Mg: 0.03% in weight max.; Cr: 0.03% in weight max.; Zn: 0.07% in weight max.; Ti: 0.03% in weight max.; the remainder being aluminium and inevitable impurities.

[0029] From the experiments performed by the inventors of the present Application it has appeared that the combination of the elements described above, (exemplified by the three alloys described) can guarantee the workability levels necessary to obtain the "endless" tubes described herein, and that they are particularly suited to achieve the aims of the present invention - and therefore this combination is particularly preferred.

[0030] However, theoretically this does not exclude that in view of the teachings of the present Application, which describes for the first time the use of aluminium alloy to resolve the aforesaid technical problem, those skilled in the art could find further aluminium alloys suitable for this purpose, perhaps using different alloy elements, or in a different combination.

[0031] As stated previously, the new aluminium alloy identified above permits the production of endless capillary tubes of the present invention, using the same processes used to produce endless capillary tubes in copper, without the need for any modifications.

[0032] The new aluminium alloy according to the present invention is particularly preferable because it permits continuous production without the forming of faults or rupture during the working.

[0033] In particular, by using the new aluminium alloy according to the present invention, the machine tools traditionally optimised for the production of copper capillary tubes can be used to total benefit without the need for modification.

[0034] This is because the use of an aluminium alloy that belongs to the general class 3103 (in other words aluminium alloy composed of Si: 0.50% in weight max.; Fe: 0.70% in weight max.; Cu: 0.05% - 0.10% in weight; Mn: 0.90 - 1.50% in weight; Mg: 0.30% in weight max.; Cr: 0.10% in weight max.; Zn: 0.20% in weight max.; Ti: absent, the remainder being aluminium and inevitable impurities), as defined by UNI EN 9003/3 standards, is not sufficient to guarantee material workability of a level that permits continuous production of capillary tubes with homogeneous quality with the current technology available. In fact, within this class alloys exist with similar compositions, but with different performance levels in terms of mechanical characteristics, even up to a level of 25 %: this fact makes it impossible to obtain constant production (continuous and with homogeneous quality) using machinery currently available.

[0035] For example, with an alloy of the identified composition but with a magnesium content equal to 0.30%

(outside the object of the present invention but within class 3103), a material is obtained that has low workability levels and consequential frequent rupture of the capillary tubes.

[0036] In addition, the reduction of the maximum Fe content from 0.70 % (alloy 3103) to 0.25 % provides an improvement in productivity and the surface quality of the product because of a lesser quantity of precipitates with abrasive action.

[0037] For example, an alloy with the identified composition but with an Fe content equal to 0.40 % (outside the specific object of the present invention but within class 3103) produces roughness on the extruded tube equal to 2,5 μm (Ra) compared to 1 μm (Ra) of the alloy object of the invention. During the successive operations, the new alloy permits better use of the machining tools because of reduced wear, and also makes the formation of material agglomerates on the tools less probable, a problem that can cause productive line arrest in order to replace the deteriorated tools.

[0038] In relation to the elements Si, Cr, Zn, according to the present invention, these must be considered as undesirable contaminants, and therefore should be reduced as far as possible according to the possibilities of current foundry production technology. The limits fixed by the present invention can be reasonably obtained in practise, without particular modifications to current productive processes or an increase in production costs.

[0039] Therefore, the newly identified alloy can be considered as an evolution of the alloy class 3103 according to UNI 9003/3 standards, which, in itself is not suited to the production of "endless" capillary tube.

[0040] Even the use of aluminium with a level of commercial purity (for example alloy 1070 previously according to UNI 9001/3, now according to UNI EN 573-3 which has replaced it) has also been revealed as not the best choice for the production of "endless" capillary tube because the workability level of this material "1070" (which is a very pure alloy composed of 99.7% in weight of Al and comprising Si at 0.20% in weight max.; Cu at 0.03% in weight max.; Mg at 0.03% in weight max.; Fe at 0.25% in weight max.; and Mn at 0.03% in weight max.; as well as the inevitable impurities) was demonstrated as being critical and not sufficient to guarantee continuous homogeneous endless capillary tube production according to the present invention. This fact can be explained if it is considered that this material generally offers excellent plastic cold workability levels, but combined with a very low mechanical resistance which creates a decided drop in tool performance caused by accumulated material residue on the tools during machining. The interiors of the capillary tubes realised in this manner also show a high level of machining residue.

[0041] On the other hand, the alloy 3103 according to UNI 9003/3 has manganese as the main alligation element and is currently widely used in particularly strict applications such as the automotive industry. Alloy 3103 has a mechanical resistance, in the same physical state, of approximately 50 % more than alloy 1070 and maintains good plastic cold workability characteristics. The problems described for alloy 1070 were also encountered by the inventors of the present Application with the alloy 3103 although at a slightly lesser level. In any case, as demonstrated above, it is important to emphasise the fact that alloy 3103 was not generally suitable for the production of "endless" capillary tubes according to the present invention since the composition interval defined by the standards in question, identifies an alloy family with properties that are too different from one another. If it is considered that for an alloy 3103 the corresponding mechanical characteristics can vary by more than 25 % in terms of mechanical resistance (from 95 to over 120 N/mm2 for an extruded tube, and from approximately 145 to over 185 N/mm2 for a capillary tube not subjected to heat treatment), and since this is only the first step in a succession of further mechanical operations, it would seem that this variability is excessive because it does not permit a production process able to provide constant and repeatable performance with the variations in the composition of the material within acceptable limits.

Claims

1. Endless capillary tube in aluminium alloy **characterised in that** the flow rate of two segments of the capillary tube having a length of 2500 mm cut from two positions taken at random from the endless capillary tube does not vary by more than ±6%.

2. Endless capillary tube in aluminium alloy according to the first claim **characterised in that** the flow rate of the two segments does not vary by more than ±3%, preferably ±2%, more preferably ±1 %.

3. Endless capillary tube in aluminium alloy according to claim 1 or 2, **characterised in that** it is wound to form rolls or wound coils.

4. Method for the production of endless capillary tubes in aluminium alloy as described in the previous claims comprising the following stages:

   - Hot extrusion of a roughed blank;
   - Successive stages of cold drawing, the number of stages depending on the envisaged machining cycle;the external diameter and the tube thickness are reduced with each extrusion stage until the final measurement is obtained;
   - Winding to form wound coils;.
   - Washing of the internal surface to eliminate machining residue (lubricants etc.);
   - Heat treatment to modify the mechanical characteristics of the capillary tube increasing the ductility;

5. Capillary tube in aluminium alloy, whose length ranges between 100mm and 10000 mm **characterised in that** geometrical division in two of the capillary tube produces two equal sections having the same length , and whose respective flow rates do not differ from each other by more than ±6%.

6. Capillary tube according to claim 5 wherein the flow rate of the two halves does not vary by more than ±3%, preferably ±2%, more preferably ±1%.

7. Use of the capillary tube according to claim 5 or 6 to obtain a lamination valve for household appliances.

8. Aluminium alloy composed of: Si: 0.15% in weight max.; Fe: 0.25% in weight max.; Cu: 0.10% in weight max.; Mn: 0.90 -1.10% in weight; Mg: 0.06% in weight max.; Cr: 0.06% in weight max.; Zn: 0.10% in weight max.; Ti: 0.06 in weight max.; the remainder being aluminium and inevitable impurities.

9. Aluminium alloy according to claim 8, composed of: Si: 0.10% in weight max.; Fe: 0.20% in weight max.; Cu: 0.10% in weight max.; Mn: 0.90 -1.10% in weight; Mg: 0.03% in weight max.; Cr: 0.03% in weight max.; Zn: 0.07% in weight max.; Ti: 0.03 in weight max.; the remainder being aluminium and inevitable impurities.

10. Aluminium alloy according to claim 9, composed of Si: 0.10% in weight max.; Fe: 0.15% in weight max.; Cu: 0.10% in weight max.; Mn: 1.00 -1.10% in weight; Mg: 0.03% in weight max.; Cr: 0.03% in weight max.; Zn: 0.07% in weight max .; Ti: 0.03 in weight max.; the remainder being aluminium and inevitable impurities.

11. Endless capillary tube according to claim 1 or 2, wherein the aluminium alloy is that described in claim 8, 9 or 10.

12. Capillary tube according to claim 5 or 6 wherein the aluminium alloy is that described in claim 8, 9 or 10.

13. Use of the capillary tube according to claim 5, 6 or 12 to obtain a lamination valve for household appliances.

14. Lamination valve for household appliances comprising a capillary tube according to claim 5, 6 or 12.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 11 2083

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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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
The Hague	30 October 2006	Vlassi, Eleni

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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EUROPEAN SEARCH REPORT

Application Number
EP 06 11 2083

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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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
The Hague	30 October 2006	Vlassi, Eleni

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X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

European Patent Office

Application Number
EP 06 11 2083

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

European Patent Office

LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 06 11 2083

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-7

Endless capillary tube in aluminium alloy
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2. claims: 8-14

Aluminium alloy composition

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 06 11 2083

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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30-10-2006

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