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Remarks:

Amended claims in accordance with Rule 137(2)
EPC.

(54) **Aluminium alloy, in particular for heat exchangers manufacturing**

(57) The invention refers to the aluminum alloy, designated in particular for heat exchangers manufacturing, in particular for automotive industry. Aluminum alloy contains: silicon Si from 0.05 % to 1.2 % by weight, iron Fe from 0.1 % to 0.5 % by weight, manganese Mn from 0.7 % to 2.0 % by weight, titanium Ti up to 0.25 % by weight, beryllium Be up to 0.1 % by weight, wherein the ratio of

beryllium and titanium [Be/Ti] by weight is from 0.5 to 2.5. The alloy contains at least one potential regulator in the form of zinc Zn from 0.1 % to 2.0 % by weight and/or copper Cu from 0.2 % to 2.0 % by weight and at least one strengthening additive in the form of nickel Ni from 0.05 % to 0.40 % by weight and/or chromium Cr from 0.05 % to 0.40 % by weight and/or magnesium Mg up to 1.1 % by weight.

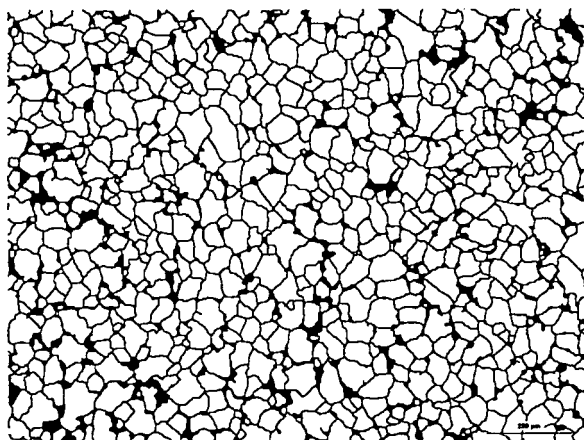


Fig. 1a

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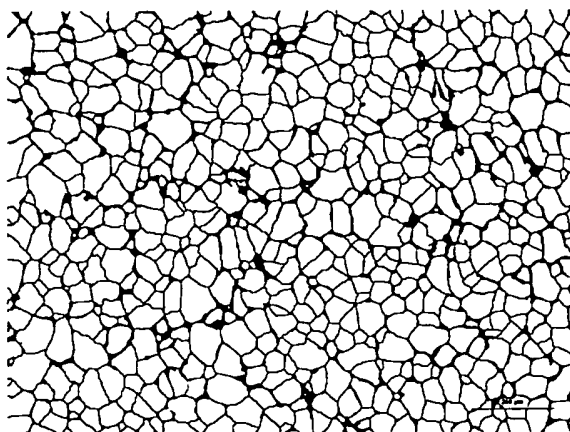


Fig. 1b

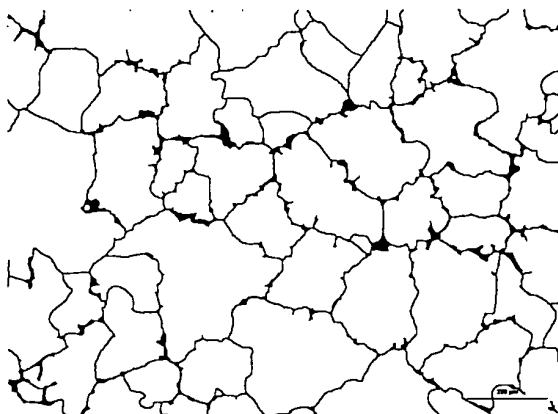


Fig. 1c

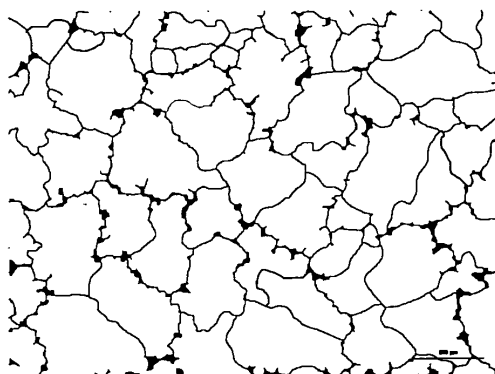


Fig. 1d

Description

[0001] The invention refers to the aluminum alloy, designated in particular for heat exchangers manufacturing, in particular for automotive industry.

[0002] Known aluminum alloys for heat exchangers manufacturing, in particular for radiators, apart from the main ingredient, that is aluminum, contain the additions, which can be divided into three groups:

- Group I - basic additions, which constitute the so-called base alloy with the main element, that is aluminum ,
- Group II - additions being basic potential regulators, and
- Group III - alloy strengthening additions.

In known alloys, Group I additions include silicon, iron, manganese, Group II additions include zinc or copper used separately or together, and Group III additions include nickel, chromium, magnesium and zirconium, used separately or together.

[0003] The known standard composition of aluminum alloy type 3003, specified in standard PN-EN573, in addition to aluminum includes also silicon Si - 0.6 %, iron Fe - 0.7 % and manganese Mn - from 1.0% to 1.5 %. The alloy may also contain potential regulators in the form of zinc Zn - up to 0.10% and copper Cu - from 0.05% to 0.20%.

[0004] The known alloys are used, among others, for manufacturing of heat exchangers for automotive industry, such as radiators and condensers. Known alloys are based on standard alloys type 3003 and 3003+ 1.5 % Zn, enriched with additions of different chemical elements, which are to regulate the corrosion potential, corrosion resistance, strength properties, thermal resistance, plasticity and formability.

[0005] In the processes for heat exchangers manufacturing, aluminum alloys are used, which according to their eventual purpose differ in mechanical properties and corrosion potential level. The alloys vary in scope of zinc content, wherein the alloys used for the manufacturing of pipes do not contain zinc, whereas the alloys used for the manufacturing of the flanges with a developed surface area, which surround the pipes and are known as fins, contain zinc, which is a known corrosion potential regulator for the alloy. In the combined working system of the heat exchanger, the fins are used as pipes protectors.

[0006] The properties of the known alloys are influenced by their chemical composition, manufacturing method and type of thermal treatment.

[0007] The properties of any aluminum alloys depend on the composition of solution α , and also crystallographic composition and structure, in particular the size and distribution of inter-metallic precipitations at grain boundaries. The direct-chill casting processes for the known aluminum alloys are characterized by a dendrite structure, which is decisive for non-homogeneity of the material, variable size of precipitations and their distribution. This material structure is then reflected in the final properties of the product, that is the properties of the rolled strip. Following local variations in microcrystalline structure, there are considerable corrosion potential gradients between precipitations and solution in the known alloys, which leads to local corrosion centers. In the process of heat exchangers manufacturing, the known process for structure homogenization is not used, as in the final product, the expected length of grains at the cross-section of the strip should be relatively low, which is connected with a large grain size. Small grains are an obstacle in the process of heat exchangers brazing.

[0008] Patent Description No. 185567 specifies the composition of aluminum alloy for fins manufacturing, with the following basic additions /group I/: silicon Si from 0.05% to 0.50% by weight, iron Fe 0.5% by weight, manganese Mn from 0.1% to 1.5 % by weight, and titanium from 0.03 % to 0.35 % by weight and additions with the purpose of potential regulators /group II/, that is zinc Zn from 0.06% to 1.0 % by weight, copper Cu 0.03 % by weight, and alloy strengthening additions /group III/including nickel Ni below 0.01 % by weight, chromium Cr 0.5 % by weight, and magnesium Mg 1.0 % by weight, and zirconium Zr 0.,3 % by weight. The alloy is designed for fins production.

[0009] European Patent Document EP 1435397B1 refers to the aluminum alloy containing silicon Si from 0.5% to 1.0 % by weight, iron Fe 0.3 % by weight, manganese Mn from 0.3 % to 0.7% by weight and zinc Zn 4 % by weight, and magnesium Mg from 0.25% to 0.6 % by weight, and zirconium Zr from 0.05% to 0.25 % by weight. This alloy is also designed for fins manufacturing.

[0010] Furthermore, European Patent Document EP 1580286 A2 refers to the alloy for the manufacturing of heat exchanger pipes, which contains silicon Si 0.1 % by weight, manganese Mn from 1.55 % to 1.9 % by weight, and copper from 0.6 % to 1.0% by weight and magnesium Mg 0.4 % by weight, and zirconium Zr from 0.05 % to 1.5 % by weight.

[0011] It is commonly known that with increasing content of additions, alloys strength and thermal resistance increase, whereas their resistance to corrosion and plasticity deteriorate. In the currently used technologies for the production of alloys to be used in the manufacturing of heat exchangers, this fact considerably limits the natural tendency to reduce the thickness of a material, in particular in the case of the strip designed for fins production. The desired properties of the material for the pipes include plasticity of material related to its formability and appropriate corrosion potential correlated with the fins potential so that the protecting effect is provided.

[0012] Material for fins manufacturing should also be characterized by good formability. Therefore, a difference in the composition of the alloy for pipes manufacturing and fins manufacturing is in corrosion potential regulators, which in the known alloys have the form of Zn and/or Cu additions and alloy strengthening additions, which in the known alloys have the form of Ni, C, Mg, Zr, which are added together or separately.

[0013] International patent application WO 2005/011889 refers to aluminum alloy designed for the production of pipes and fins for heat exchangers, containing silicon Si 0.3 % by weight, iron Fe up to 0.5 % by weight, manganese Mn from 0.5 % to 0.7 % by weight, titanium Ti below 0.2 % by weight, and zinc Zn up to 2.0 % by weight, and copper Cu from 0.06 % to 1.5 % by weight.

[0014] In order to meet the ambitious requirements for aluminum alloys designed for the manufacturing of heat exchangers, especially radiators for automotive industry, said radiators composed of pipes surrounded by fins, the base alloy was developed, which together with the complementing and modifying additions is the object of this invention. Aluminum alloy according to the present invention contains:

silicon Si from 0.05 % to 1.2 % by weight
iron Fe from 0.1 % to 0.5 % by weight,
manganese Mn from 0.7 % to 2.0 % by weight,
titanium Ti 0.25 % by weight,
beryllium Be up to 0.1 % by weight,

wherein beryllium Be to titanium Ti ratio by weight [Be/Ti] is from 0.5 to 2.5; and at least one potential regulator, in the form of zinc Zn from 0.1 % to 2.0% by weight, copper Cu 0,2 to 2,0 % by weight; and at least one strengthening addition in the form of nickel Ni from 0.05% to 0.40 % by weight, chromium Cr from 0.05% to 0.40 % by weight, and magnesium Mg up to 1.1 % by weight.

[0015] The alloy according to the invention shows the properties of the globular primary structure, which is a result of its new chemical composition. The result of crystallizing the alloy in the globular form in the presence of the elements which act as alloy strengthening additions, such as Ni, Cr, Mg and Si guarantees even distribution of undissolved elements in the form of fine inter-metallic phases at the boundary, which are formed as a result of grain crystallization process, wherein the grain size is not reflected in the final product, which is made from the alloy according to the present invention. The globular structure which is formed, makes it possible in the conventional treatment process to have the final product, i.e. rolled strip, with solution and precipitation strengthening and at the same time with high plasticity of the alloy and its good thermal and corrosion resistance.

The alloy according to the invention is designed for the manufacturing of the elements of heat exchangers, in particular radiators for automotive industry, wherein the alloy may be used for the manufacturing of both pipes and fins.

Analysis of microcrystalline structure of the alloy

[0016] The microcrystalline structure of the alloy according to the present invention was analyzed by comparing the structure of the alloy according to the present invention, of the composition as follows:

Fe - 0.274%; Si - 0.392%; Cu - 0.011%; Zn - 1.413%; Ti 0.157%; Mg - 0.022%; Mn - 1.510%; Ni - 0.136%; Be - 0.045%; Zr - 0.019; remaining Al- alloy HF 311 (Fig. 1a)
and

Fe - 0.366%; Si - 0.362%; Cu - 0.370%; Zn - 0.050%; Ti - 0.142%; Mg - 0.006%; Mn - 0.850%; Ni - 0.139%; Be - 0.025%; Zr - 0.003%; remaining Al - alloy LT325 (Fig. 1b)

with the structure of standard alloy 3003+1.5 % of zinc Zn according to PN-EN 573, of the composition as follows:

Fe - 0.290%; Si - 0.382%; Cu - 0.076%; Zn - 1.469%; Ti - 0.033%; Mg - 0.009%; Mn - 1.265%; Ni - 0.04%; Be - 0.000%; Zr - 0.033%; remaining Al - alloy LT325 (Fig. 1c).

and with the structure of reference alloy FA6815 of the following chemical composition:

Fe - 0.267%; Si - 0.974%; Cu - 0.011%; Zn - 1.473%; Ti - 0.035%; Mg - 0.030%; Mn - 1.565%; Ni - 0.009%; Be - 0.001%; Zr - 0.115%; Al - remaining %. (Fig. 1d).

The specimens of the above mentioned alloys were made, which then were used as crystalline microsections. Fig. 1a - 1d show the pictures of the primary microstructure of the tested specimens.

Strength properties tests

[0017] Strength tests were made according to the method compliant with PN-EN 10002-1. Using the strip specimens, made of the alloy according to the present invention. For the measurements, the testing device Type 1120.25 by Zwick GmbH Germany was used, and the following alloys were tested:

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- alloy HF 311 for fins manufacturing, of the following chemical composition:

Fe - 0.274%; Si - 0.392%; Cu - 0.011%; Zn - 1.413%; Ti 0.157%;
Mg - 0.022%; Mn - 1.510%; Ni - 0.136%; Be - 0.045%; Zr - 0.019; remaining Al,

and

- alloy LT 325 for pipes manufacturing, of the following chemical composition:

Fe - 0.366%; Si - 0.362%; Cu - 0.370%; Zn - 0.050%; Ti - 0.142%; Mg - 0.006%;
Mn - 0.850%; Ni - 0.139%; Be - 0.025%; Zr - 0.003%; remaining Al.

[0018] The results of strength tests for both alloys according to the invention are shown in table no. 1.

Table No. 1.

Mechanical properties of the alloys			
Alloy type	R _m [Mpa]	R ₀₂ [Mpa]	A ₅₀ [%]
HF311	205	195	2
after brazing	145	55	--
LT325	165	155	4
LT325 after brazing	156	58	--
Where: R _m - tensile strength, R ₀₂ - notional yield point, A ₅₀ - elongation.			

Thermal resistance tests

[0019] Thermal resistance tests for the alloy according to the invention were made based on the sagging distance (SD) method using the strip specimens. The tests were made on the equipment comprised of the laboratory oven and the rack, fig. 2. In order to increase the sensitivity of the measurement, test conditions were changed and instead of the circular support the edge support was used. Moreover, the length of the protruding strip was changed for the tests, given different thicknesses and widths of the strips used, on the basis of the following criterion:

strip length l measured from the support, which should be equal to the ratio between the mass of strip 1 in the length 1 to the cross-section of strip F . For the tested alloys, the ratio was specified as follows:

$$\text{HF 311} = 1.30 - 1.40 \text{ g/mm}^2$$

$$\text{LT 325} = 1.40 - 1.50 \text{ g/mm}^2.$$

[0020] During the measurement, the adjustments of heating and holding in a temperature were made using a thermocouple located under the tested material near the support in the axis of the measurement device.

[0021] Diagram of the SD test equipment is shown in Fig. 2

Table 2.

Thermal properties of the alloys	
Alloy type	SD [mm]
HF311	max 25
LT325	max 30

Testing of alloys corrosion resistance

[0022] Tests in scope of corrosion resistance of the alloys according to the invention were made in line with the method as per ASTM G 69-97. The tests were made using the apparatus Potencjostat - Galwanostat ATLAS 0531 EU and the following properties were determined:

density of passivation current I_P ,
 passivation potential E_P ,
 re-passivation potential E_R .

[0023] The lower passivation current and the higher pitting potential, the better resistance to corrosion.

[0024] The results of tests are shown in Table No. 3.

Table 3.

Corrosion properties of the alloys			
Alloy type	I_P [$\mu\text{A}/\text{cm}^2$]	E_P [mV]	E_R [mV]
HF311	82	-882	-800
LT325	72	-736	-626

Claims

1. Aluminum alloy, in particular for heat exchangers manufacturing, containing:

silicon Si from 0.05 % to 1.2 % by weight,
 iron Fe from 0.1 % to 0.5 % by weight,
 manganese Mn from 0.7 % to 2.0 % by weight.
 titanium Ti up to 0.25 % by weight,
 beryllium Be up to 0.1 % by weight,

wherein the ratio of beryllium and titanium [Be/Ti] by weight is from 0.5 to 2,5.

2. Alloy according to claim 1, containing at least one potential regulator in the form of zinc Zn from 0.1 % to 2.0 % by weight and/or copper Cu from 0.2 % to 2.0 % by weight.

3. Alloy according to claim 1 or 2, containing at least one strengthening addition in the form of nickel Ni from 0.05 % to 0.40 % by weight and/or chromium Cr from 0.05 % to 0.40 % by weight and/or magnesium Mg up to 1.1 % by weight.

Amended claims in accordance with Rule 137(2) EPC.

1. Aluminum alloy, in particular for heat exchangers manufacturing, consisting of:

silicon Si from 0.05 % to 1.2 % by weight,
 iron Fe from 0.1 % to 0.5 % by weight,
 manganese Mn from 0.7 % to 2.0 % by weight.
 titanium Ti up to 0.25 % by weight,
 beryllium Be up to 0.1 % by weight,

wherein the ratio of beryllium and titanium [Be/Ti] by weight is from 0.15 to 2.5 and containing:

at least one potential regulator in the form of zinc Zn from 0.1 % to 2.0 % by weight and/or copper Cu from 0.2 % to 2.0 % by weight and
 at least one strengthening addition in the form of nickel Ni from 0.05 % to 0.40 % by weight and/or chromium Cr from 0.05 % to 0.40 % by weight and/or magnesium Mg up to 1.1 % by weight

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and the reminder being aluminum Al with unavoidable impurities.

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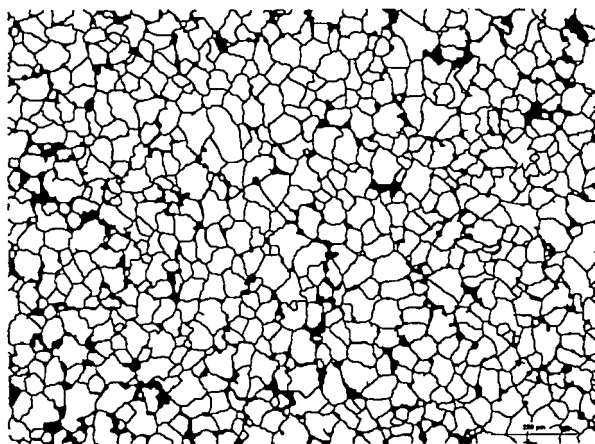


Fig. 1a

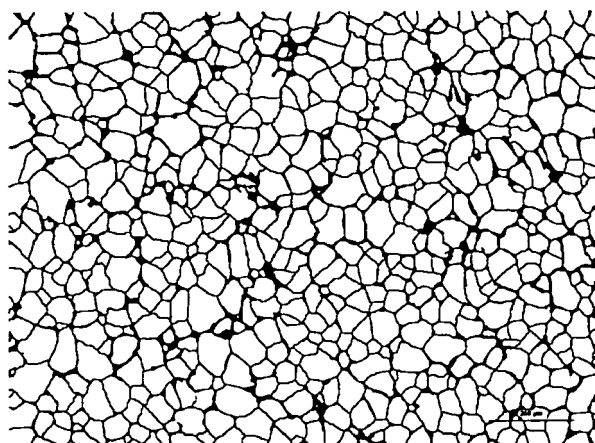


Fig. 1b

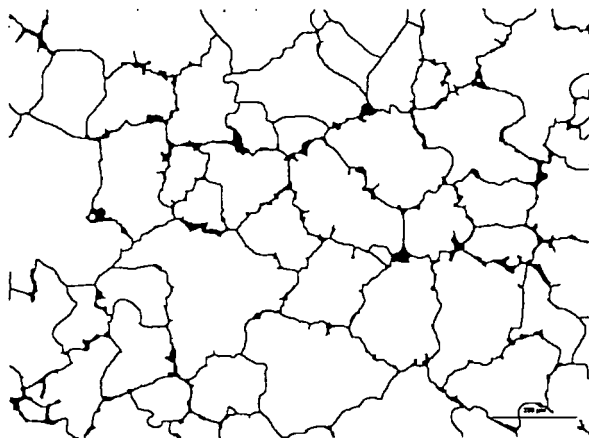


Fig. 1c

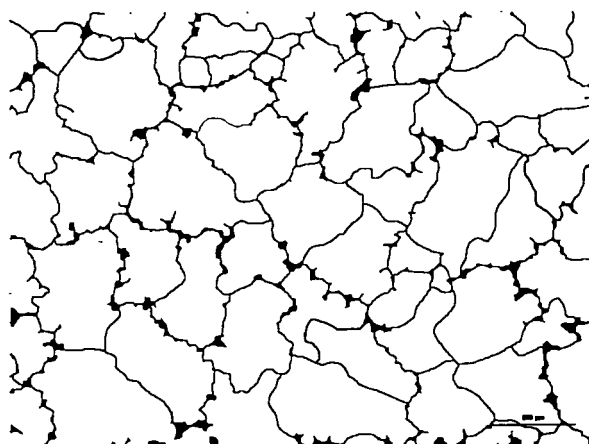


Fig. 1d

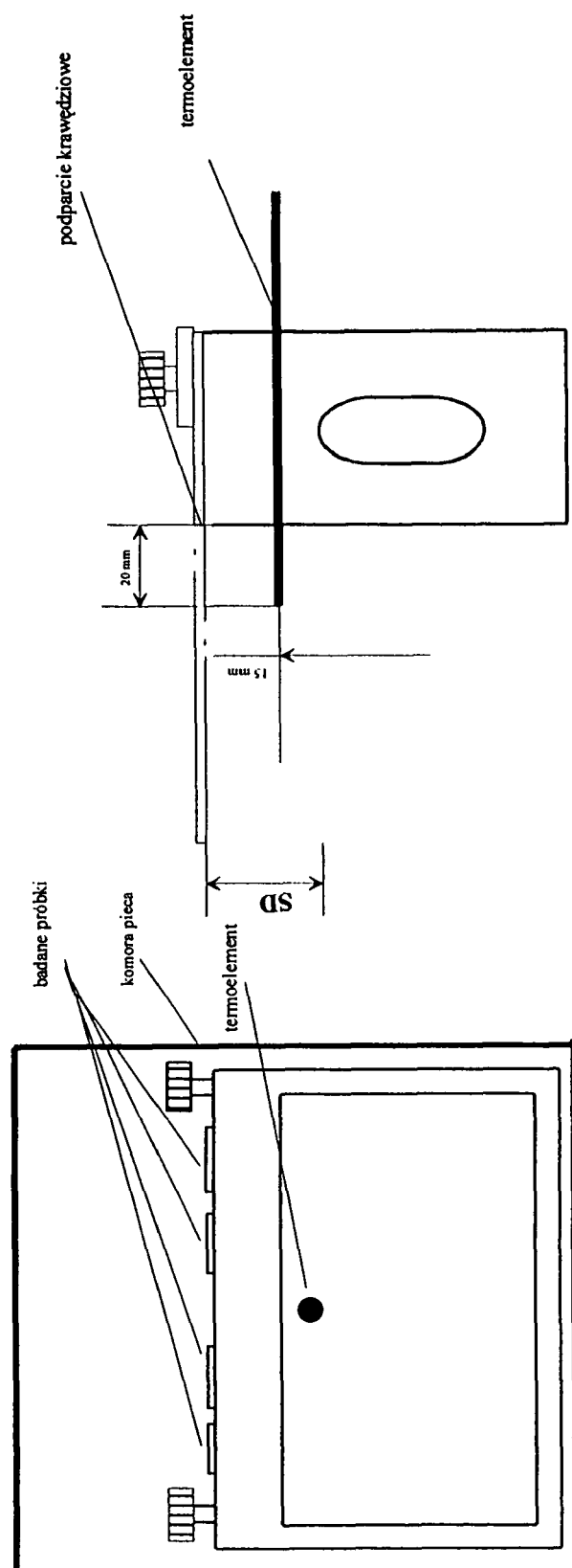


Fig. 2



EUROPEAN SEARCH REPORT

Application Number
EP 08 01 8013

DOCUMENTS CONSIDERED TO BE RELEVANT			
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X	JP 04 048045 A (NIPPON LIGHT METAL CO; NIKKEI TECHNO RES CO LTD) 18 February 1992 (1992-02-18) * abstract * * page 3; example 10; table 1 *	1-3	INV. C22C21/00
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 2 March 2009	Examiner Patton, Guy
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 T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03 82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 08 01 8013

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- EP 1580286 A2 [0010]
- WO 2005011889 A [0013]