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(71) Applicant:
GUIDO BAGGIOLI S.N.C. DI BAGGIOLI GIUSEPPE & PELLEGRINI CLEMENTINA
22053 Lecco (IT)

(72) Inventor: **Baggioli, Guido**
22053 Lecco (IT)

(74) Representative:
Righetti, Giuseppe
Bugnion S.p.A.
Via Carlo Farini, 81
20159 Milano (IT)

(54) A process for manufacturing alloy castings

(57) The described process contemplates formation of an aluminium casting (1a) by high-pressure or gravity die-casting. Casting (1a) drawn out of the casting mould, is heated and submitted to compacting by being closed into a forging die geometrically similar to, but of smaller sizes than the workpiece itself. Elimination of any porosities in the material, and also crushing of dendritic crystalline aggregates and elongation of the aluminium crystals in the form of fibres parallel to the finished-casting (1) surfaces, is achieved.

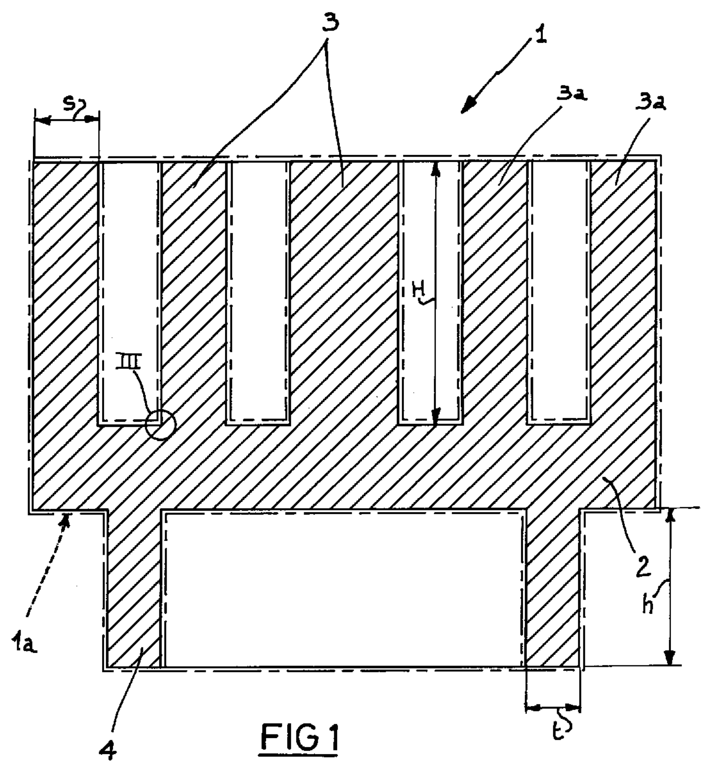

FIG 1

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Description

The present invention relates to a process for manufacturing alloy castings of the type comprising the following steps: filling a shaped cavity of a casting mould with an alloy in a fluid state; cooling and solidifying the alloy within the casting mould. drawing the obtained casting out of the casting mould.

The present invention applies to the production field of articles made of an aluminium alloy or other alloys, obtained from any casting process, by high-pressure die-casting or gravity die-casting, using either a permanent mould (or chill) or molding sand, for example.

By way of example only, in the progress of the present invention reference will be made to the production of aluminium alloy articles, and more particular impellers and/or gas compressors to be used in refrigerating circuits, obtained from an usual high-pressure die-casting process, to the accomplishment of which the invention is particularly appropriate and advantageous.

It is known that high-pressure die-casting is a process essentially consisting in filling a mould cavity with a molten alloy, generally an aluminium alloy, so as to form a semifinished or finished article usually named "casting", following solidification of the obtained alloy by heat exchange with the mould walls.

In comparison with the other gravity die-casting processes either in the sand or in a chill, high-pressure die-casting generally enables achievement of a greater productivity.

However, even when resort is made to the use of the most modern apparatuses and technologies, castings obtained by high-pressure die-casting, as well as those obtained using other casting techniques, in all cases exhibit typical defects of different kinds.

The most common defects, in addition to blowholes to be essentially ascribed to air inclusion into the molten alloy during the mould filling step, are represented by macroporosities, microporosities, and/or cracks and shrinkage crackings essentially due to unevenness in cooling and therefore shrinkage of the material during solidification and subsequent cooling.

In order to conveniently restrict formation of surface crackings, particular expedients need to be adopted during the mould planning and manufacturing steps, one of which for example consists in avoiding sudded thickness changes between the different parts of a workpiece. In many cases, it is however necessary to greatly oversize the casting to be obtained and subsequently resort to mechanical workings involving removal of material so as to bring the different casting parts to their nominal values by eliminating that material portion that is potentially subjected to cracking phenomena.

It is also to note that with the presently-employed casting processes it is very difficult, and sometimes even impossible, to achieve a perfectly homogeneous distribution of the different alloying substances and/or other alloy components within the aluminium matrix. In conclusion, in the solidified casting the more or less marked presence of crystalline aggregates can be found, such as silicon-based quaternary oxides of very high hardness. The presence of these crystalline aggregates, in addition to bringing about an undesired structural unevenness in the material, also makes the subsequent tooling of the obtained casting very difficult, giving rise to an early wear and/or breaking phenomena interesting the tools employed in the working operations. This aspect obviously involves a further rise in the mechanical working prices for the casting manufacture and, in conclusion, a rise in the finished-product prices.

It should be also pointed out, with reference to high-pressure die-casting processes, that application of high pressures in the molten alloy within the mould, aiming at minimizing defects such as crackings, shrinkage cavities and the like, has a tendency to cause phenomena of localized welding of the alloy to the inner walls of the mould, which will create serious problems when the obtained casting is to be drawn out of the mould. In order to facilitate casting drawing, therefore the mould surfaces need to be treated with great amounts of appropriate lubricants. Inevitably these lubricants mix with the molten alloy, which will result in consequent localized alterations in the crystalline structure of the obtained casting.

In addition, in spite of the fact that the most modern and sophisticated technologies are adopted which, on the other hand, cause an important increase in the production costs, it is to note that at all events no expedient exists adoption of which enables a complete elimination of the intercrystalline microporosities and/or macroporosities that are formed in the whole casting section due to the material shrinkage.

However, these porosities bring to a reduction in the imperviousness features of the material which are particularly critical above all with reference to castings intended for forming parts of devices for processing of very volatile gases, such as the components of refrigerating-circuit compressors.

As a result, when working has been completed, the obtained pieces must be in any case submitted to impregnation processes and severe controls leading to many production discards caused by an unsatisfactory imperviousness due to the unavoidable presence of inner microporosities in the material.

In accordance with the present invention, it has been found that mechanical properties, imperviousness and tool workability of a casting obtained by any casting process are greatly increased if the casting itself, once it has been drawn out of the casting mould, is submitted to dynamic shocks, carried out by forging for example.

In more detail, the process for making alloy castings in accordance with the present invention is characterized in that the casting previously drawn out of the casting form or mould, is submitted to at least one dynamic shock carried out by forcedly closing at least one portion of the casting itself into at least one shaped cavity of a forging die, geometrically similar to and of lower sizes than the sizes exhibited by said at least one portion of the casting drawn out of the casting mould.

Further features and advantages will become more apparent from the detailed description of a preferred but not exclusive embodiment of a process for manufacturing alloy castings in accordance with the present invention. This description will be taken hereinafter with reference to the accompanying drawing given by way of illustration and not of limitation, in which:

- Fig. 1 is a cross-sectional view, by way of example only, of an alloy casting obtained as a result of compacting carried out in accordance with the process in question, showing in chain line the contours exhibited by the casting itself at the end of high-pressure die-casting and before the compacting step;
- Figs. 2a and 2b are micrographic images carried out on different magnification scales and showing the crystalline structure of a casting obtained according to the process in question close to a surface area thereof;
- Figs. 3a and 3b are micrographic images showing the metallographic structure of the casting referred to in the preceding figures 2a and 2b, at a more internal area of the piece thickness;
- Figs. 4a and 4b are micrographic representations showing the crystalline structure of a casting made in accordance with the present invention, before carrying out compacting of same;
- Figs. 5a and 5b are micrographic representations showing the metallographic crystalline structure of a casting obtained according to a traditional high-pressure die-casting process.

Referring particularly to Fig. 1, an alloy casting made following a process in accordance with the present invention has been generally identified by reference numeral 1.

In the embodiment shown by way of example only, casting 1 is intended for the manufacture of an impeller for a conventional compressor to be employed in refrigerating circuits, and for the purpose it has a substantially disc-shaped base portion 2, provided with a first projecting portion 3 consisting of a winding wall extending in a plurality of coils 3a each of them being of a height "H" considerably greater than its thickness "S". By way of example, the height "H"-thickness "S" ratio is provided to be greater than 3.

On the opposite side from coils 3a, there is a second projecting portion 4 consisting of a cylindrical wall intended for offering a seat for a bearing, It too has a height "H" considerably greater than its thickness "t".

Manufacture of casting 1 takes place by a cast moulding operation, under pressure or gravity for example, essentially involving filling of a shaped cavity of a mould with an appropriate alloy in the molten state. The alloy is allowed to cool and solidify within the mould. When the alloy has reached solidification and is sufficiently cold, extraction of the casting from the casting mould is carried out.

In more detail, the alloy herein employed may be any aluminium alloy of the type currently employed in moulding by high-pressure or gravity casting into sand or a chill.

In a preferential solution, in which manufacturing of the casting takes place by an usual high-pressure die-casting machine, of the hot-chamber type for example, not shown and not further described in that known per se and conventional, an aluminium alloy with a silicon content in the range of 4% to 14%, a copper content of 0.05% to 4%, an iron content of 0.25% to 2%, a zinc content of 0.5% to 3% and optionally other components to an extent not exceeding 1% altogether can be used. By way of example only, the composition of an alloy which can be used in accordance with the present invention is given hereinafter: Al 87.13%, Si 7.376%, Cu. 2.803%, Fe 0.766%, Mn 0.252%, Mg 0.465%, Zn 0.839%, Pb 0.115%, Sn 0.021%, Ni 0.094%, Ti 0.072%, Cr 0.0663%.

In an original manner, the casting resulting from the casting process has linear sizes slightly higher, just as an indication in a range included between 0.5 and 2%, than the nominal sizes that casting 1 will have at the end of the process of the invention and before the execution of possible mechanical finishing workings. The chain line 1a in Fig. 1 shows, by way of example, the outline of a casting (identified by 1a as well) drawn out of the casting mould, before the execution of the subsequent process steps.

Casting 1a thus obtained is submitted to a dynamic shock achieved by carrying out at least one compacting step by closing said casting into the cavity of a forging die suitably sized in accordance with said nominal values. In conclusion, the forging die cavity (the die is not shown as it is known per se and conventional) is geometrically similar to casting 1a drawn out of the casting mould, and its sizes are proportionally smaller than said mould.

Advantageously, before closing it into the forging die, casting 1a is heated until the latent liquefaction temperature of aluminium or in any case of at least one of the alloy components forming the casting itself. More particularly, in a preferential solution, the casting is brought to a temperature of about 520°C, or at all events a temperature preferably included between 500 and 550°C, so as to cause a partial liquefaction of the alloy that can be quantified, just as an indication, in a percentage included between 5% and 40% of liquid fraction.

Following its closure into the forging die, casting 1a is submitted to a dynamic shock essentially embodied by a sudded compression action homogeneously distributed over the whole casting surface, causing compacting of said casting to the nominal sizes corresponding to the forging die cavity. The partial change of state of the alloy obtained by heating and also by conversion into heat of the impact energy absorbed by the casting, facilitates the mutual flowing of the crystals forming the alloy and, as a result, the geometrical and dimensional adaptation of casting 1a to the forging die cavity without causing undesired material upsettings or other anomalous deformations of the projecting portions 3, 4.

Closing of the forging die, carried out with the aid of a power hammer or a fly press for example, takes place at high speed, in such a short period of time that a great impact energy is transmitted to the casting being worked. This dynamic shock involves compacting of the material forming the casting and brings about many advantageous effects in terms of quality of the finished product.

First of all, an important reduction in the microporosity and macroporosity present in the crystalline structure of the casting can be achieved and sometimes even the complete elimitation of same. This results in a dimensional reduction in the casting, as shown in Fig. 1, and a consequent increase in the specific mass thereof which takes a value almost identical with the nominal specific mass of the employed alloy, in the absence of porosities or cracks.

In addition, the shock wave transmitted to the casting causes crushing of possible crystalline aggregates and a homogeneous dispersion of same in the aluminium matrix. This leads to advantage to a further increase in the homogeneous distribution of the crystalline structure of the material forming the casting, which enhances its mechanical features and, above all, its tool workability.

Furthermore, the compacting action causes elongation of the aluminium matrix crystals which tale the aspect of fibres extending in a direction parallel to the adjacent casting surfaces. This phenomenon is particularly apparent in parts of small thickness and, at all events, close to the outer casting surfaces.

In the innermost areas of parts having a great thickness, the compacting effect leads in any case to the elimination of cracks and shrinkage cavities and crushing of the crystalline aggregates.

By comparing the micrographic representations shown in Figs. 2a to 5b one can clearly see the morphologic modification of the crystalline structure in the alloy as a result of the compacting step, and the advantageous effects resulting therefrom.

In each of said figures, segment denoted b "X" corresponds to a section having a length of 0.1 mm on the sample surface reproduced in the micrographic images.

Shown in Figs. 4a and 4b is the crystalline structure of a casting obtained by high-pressure die-casting before execution of the compacting step in accordance with the present invention. The presence of many microporosities and macroporosities corresponding to the areas of darker background can be clearly seen, which are due to the material shrinkage during the solidification and cooling steps.

In addition, the crystalline aggregations of the different alloy components can be detected, in particular in Fig. 4b, among the different aluminium crystals, the latter corresponding to the the areas of ligher background.

Figs. 3a and 3b show the crystalline structure detected in the innermost part of the thickness of a casting identical with that shown in Figs. 4a and 4b, but submitted to a compacting step.

With reference to Figs. 3a and 3b, the surface of the examined piece was treated with a 0.05% solution of hydrofloric acid over a period of fifteen seconds, in order to better highlight the crystalline structure thereof.

From a comparison between Figs. 3a and 3b and Figs. 4a and 4b, one can immediately see that compacting has brought to a complete elimination of porosities and a more homogeneous distribution of the crystalline aggregates in the aluminium matrix.

Figs. 2a and 2b refer to the same compacted sample as shown in Figs. 3a and 3b, and reproduce the crystalline structure of same close to its outer surfaces and more particularly at the connection area, denoted by III in Fig. 1, between the base portion 2 and one of the projecting portions 3.

Appearing more clearly from said figures is crushing of the crystalline aggregates and distribution of said aggregates following lines parallel to the fibres generated by elongation of the aluminium crystals, deformed in an elongated configuration in a direction substantially parallel to the adjacent outer casting surface. Also detectable is the complete absence of cavities and/or surface crackings due to the material shrinkage.

Figs. 5a and 5b refer to a casting obtained by a high-pressure die-casting operation performed with the aid of advanced technologies, aimed at minimizing formation of porosities. The sample examined in said figures was further submitted to a mechanical working involving material removal which lead to the elimination of all surface crackings. From said figures one can notice the presence of microcavities in the crystalline structure, although in a lower amount than in Figs. 2a and 2b, and also of many crystalline aggregates making tooling of the obtained casting difficult.

Most of the shrinkage cavities present in Figs. 2a and 2b are merely due to the fact that, in the process in question, adoption of particular and expensive expedients for minimizing the formation of said cavities already in the die-casting step is not needed. It is actually possible to adapt the [high-pressure] die-casting process so as to achieve given features in the material to the detriment of porosity which is however completely eliminated in the following compacting step.

In addition, the complete elimination of crackings as a result of compacting enables castings having important thickness variations to be manufactured directly by casting, so that also the necessity to arrange important removable stocks is eliminated. which stocks were provided in the prior art for eliminating crackings by means of long mechanical material-removal processes that, on the other hand, were made still more difficult by the presence of crystalline aggregates.

Removal of microporosities gives the material the best mechanical features and, above all, a perfect imperviousness to the most volatile gases as well, thereby eliminating the impregnation processes and greatly simplifying quality controls and eliminating production discards almost completely, which discards are presently inevitable with reference to articles in which the presence of microporosities represents a particularly critical factor.

Obviously many modifications and variations can be made to the invention as conceived, all of them falling within the scope of the inventive idea. In particular, the process can be adapted for the production of castings involving the use of alloys different from those herein described, optionally by gravity die-casting instead of high-pressure die-casting. In addition, should it he convenient, the compacting step can be performed many times by closing the casting in succession into cavities of sizes becoming increasingly smaller, each of these steps being alternated with a fresh heating to give the material the desired plasticity.

Furthermore, compacting can be indifferently executed over the whole casting as previously described, or on one or more distinct portions thereof, in a single step or in several steps in succession.

Claims

1. A process for manufacturing alloy castings, comprising the steps of:
   - filling a shaped cavity of a casting mould with an alloy in a fluid state;
   - cooling and solidifying the alloy within the casting mould;
   - drawing the obtained casting (1a) out of the casting mould,
     characterized in that
     the casting (1a) drawn out of the casting mould is submitted to at least one dynamic shock carried out by forcedly closing at least one portion (2, 3, 4) of the casting itself into at least one shaped cavity of a forging die, geometrically similar to and of lower sizes than the sizes exhibited by said at least one portion (2, 3, 4) of the casting (1a) drawn out of the casting mould.

2. A process according to claim 1, characterized in that before the compacting step, a heating step is carried out in which casting (1a) is heated until the latent liquefaction temperature of at least one of the components of said alloy.

3. A process according to claim 2, characterized in that the casting (1a) heating step is carried out until melting of the alloy is achieved in a percentage included between 5% and 40%.

4. A process according to claim 2, characterized in that the casting (1a) heating step is carried out until casting (1a) is brought to a temperature included between 500°C and 550°C, said alloy being an aluminium alloy.

5. A process according to claim 1, characterized in that before the compacting step, said at least one portion (2, 3, 4) of casting (1a) exhibits linear sizes 0.5% to 2% greater than the linear sizes detectable on the compacted casting (1).

6. A process according to claim 1, characterized in that the compacting step is carried out simultaneously over the whole casting (1a) being worked.

7. A process according to claim 1, characterized in that said at least one portion (2, 3, 4) of casting (1a) is compacted by closing the same in succession into at least first and second shaped cavities of said at least one forging die, said second cavity having lower sizes than said first cavity.

8. A process according to claim 1, characterized in that the compacting step is carried out over the whole casting (1a) being worked by sequentially closing several casting portions in succession into the forging die.

9. A process according to claim 1, characterized in that the casting (1a) to be submitted to the compacting step is obtained by high-pressure die-casting involving said steps of filling the mould, solidifying the alloy and drawing the casting out.

10. A process according to claim 1, characterized in that casting (1) is formed of an aluminium alloy containing silicon in an amount included between 4% and 14% and copper in an amount included between 0.05% and 4%.

11. A process according to claim 10, characterized in that said aluminium alloy further contains iron in an amount included between 0.25% and 2% and zinc in an amount included between 0.5% and 3%.

12. A process according to claim 1, characterized in that the casting (1a) to be submitted to the compacting step is obtained by gravity die-casting including said steps of filling the mould, solidifying the alloy and drawing the casting out.

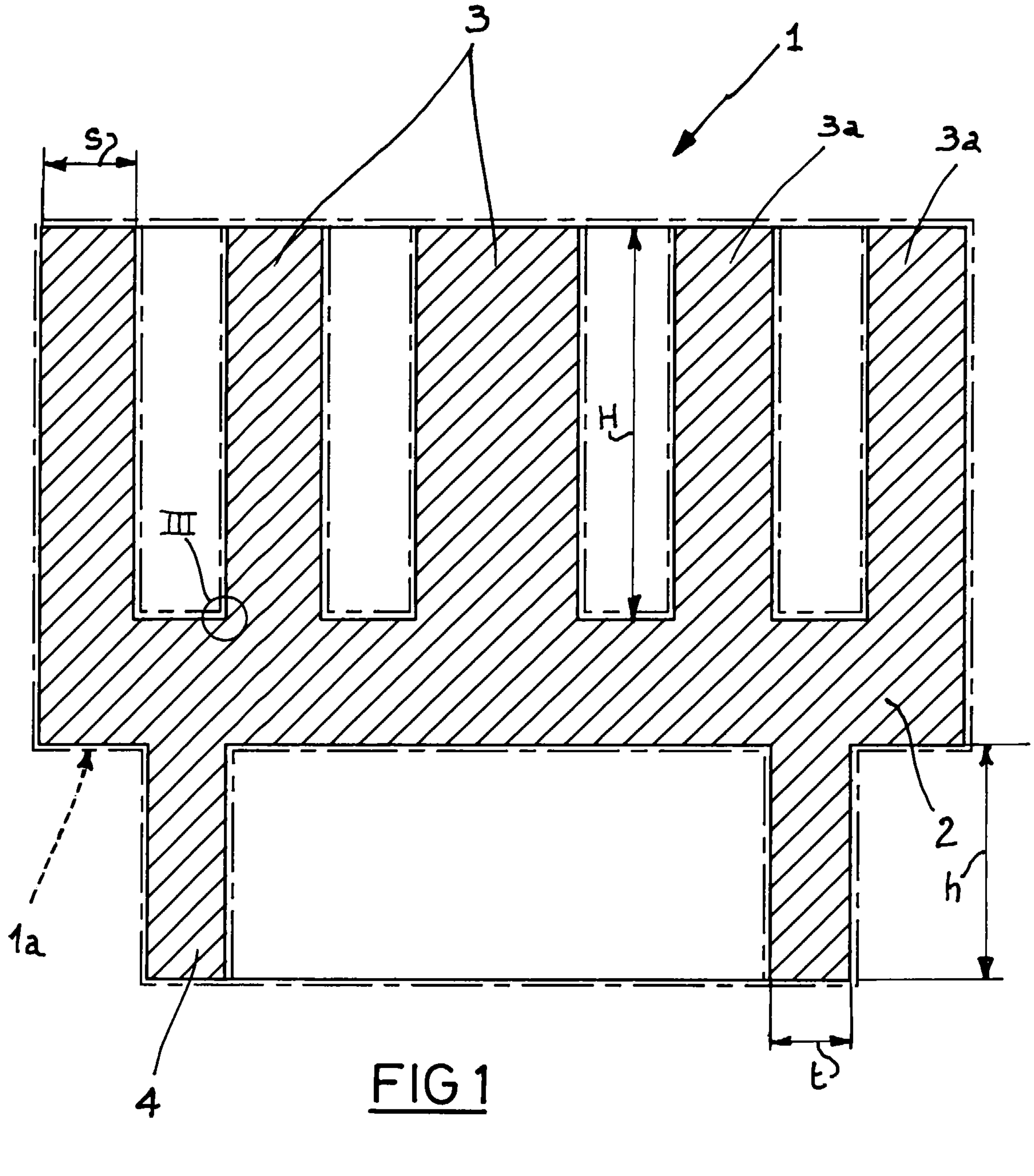

FIG 1

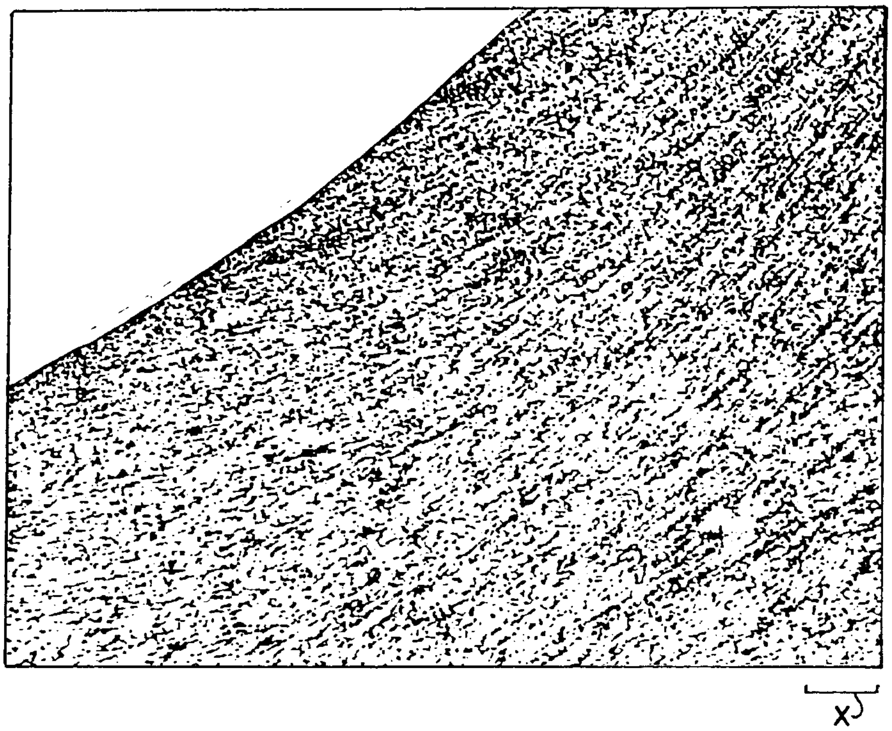

FIG2a

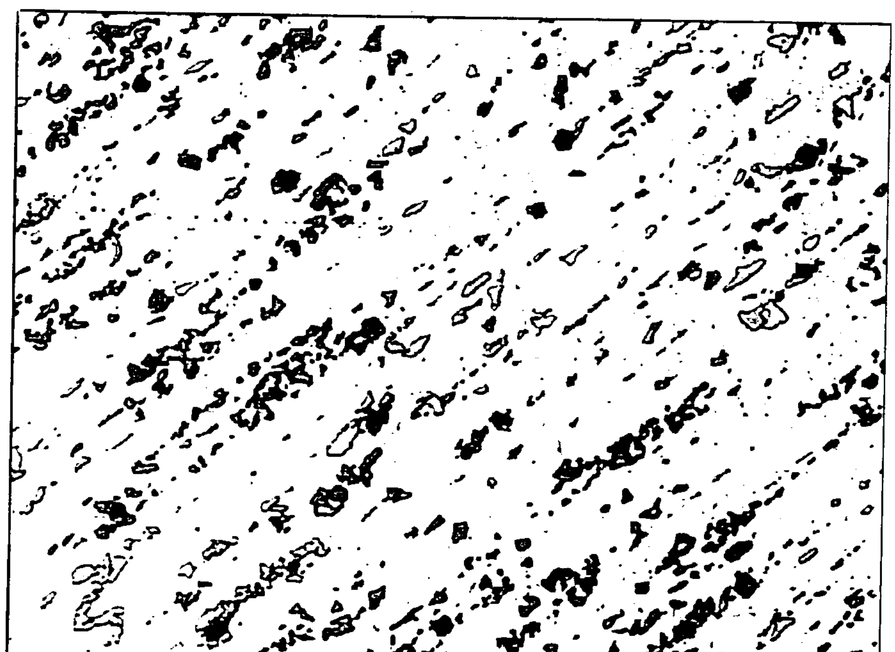

FIG2b

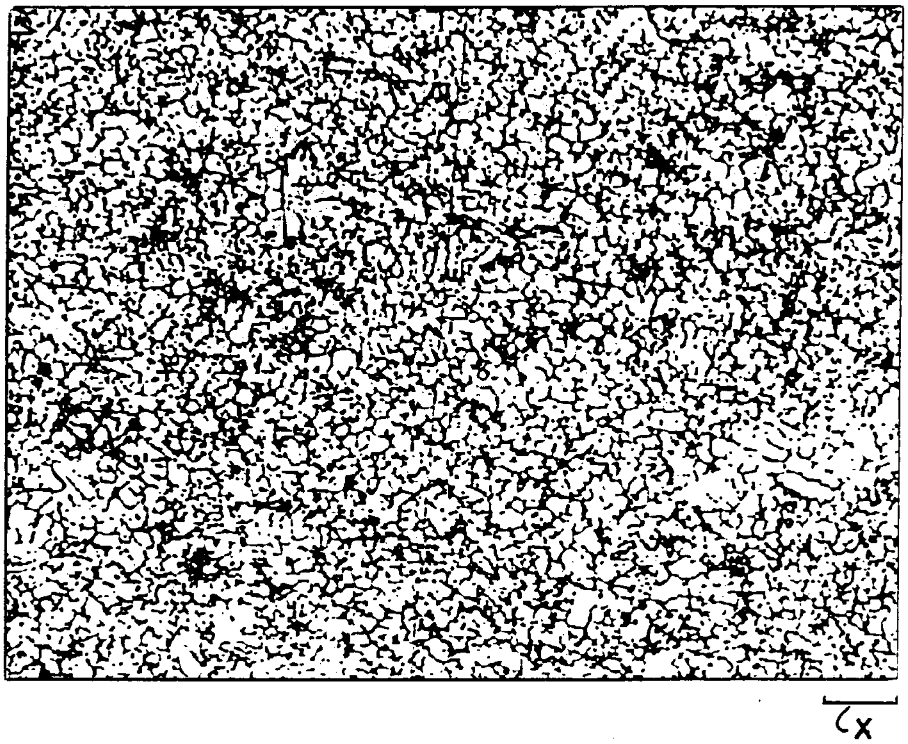

FIG3a

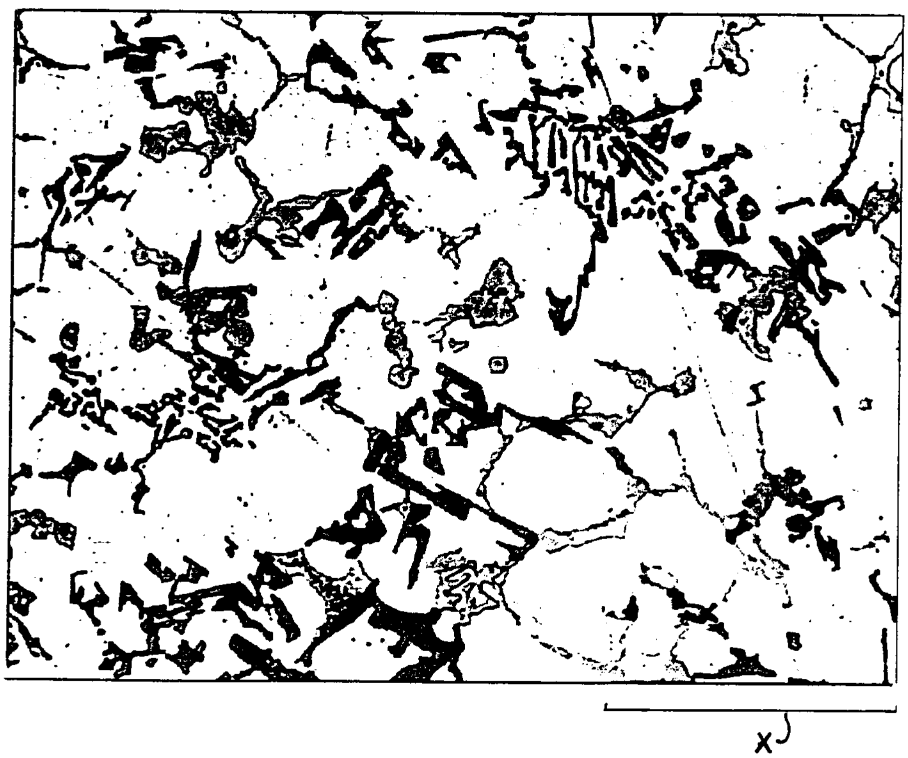

FIG3b

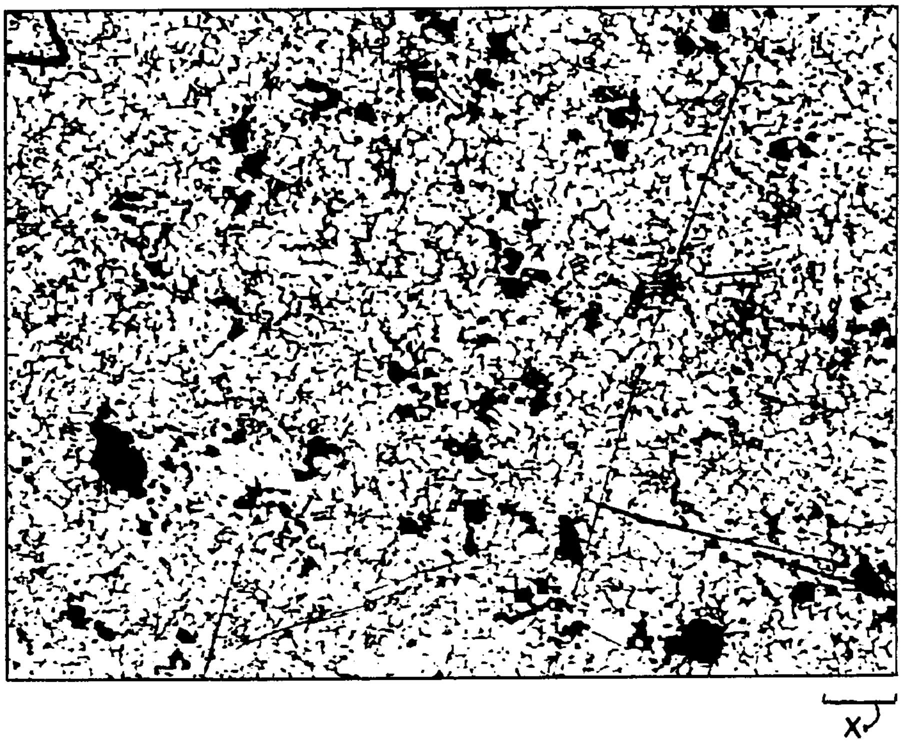

FIG4a

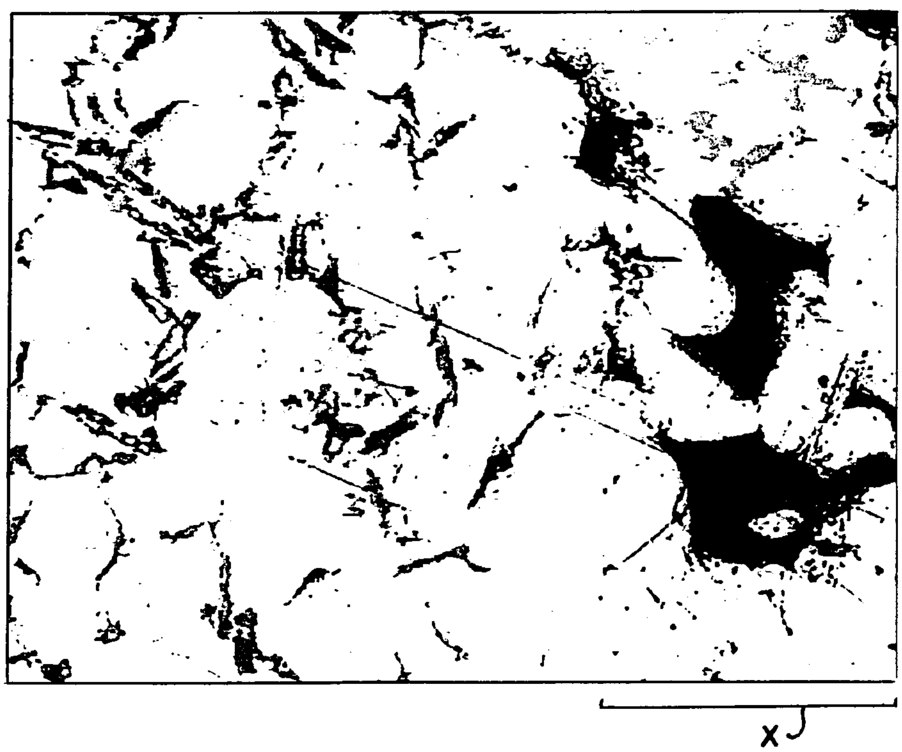

FIG4b

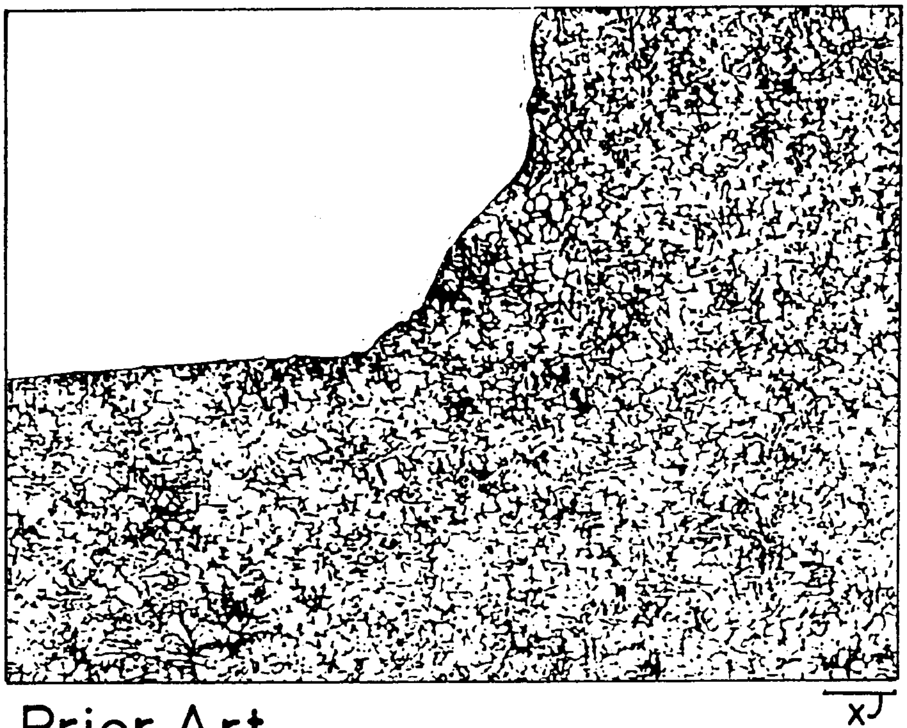

FIG 5a

Prior Art

Prior Art

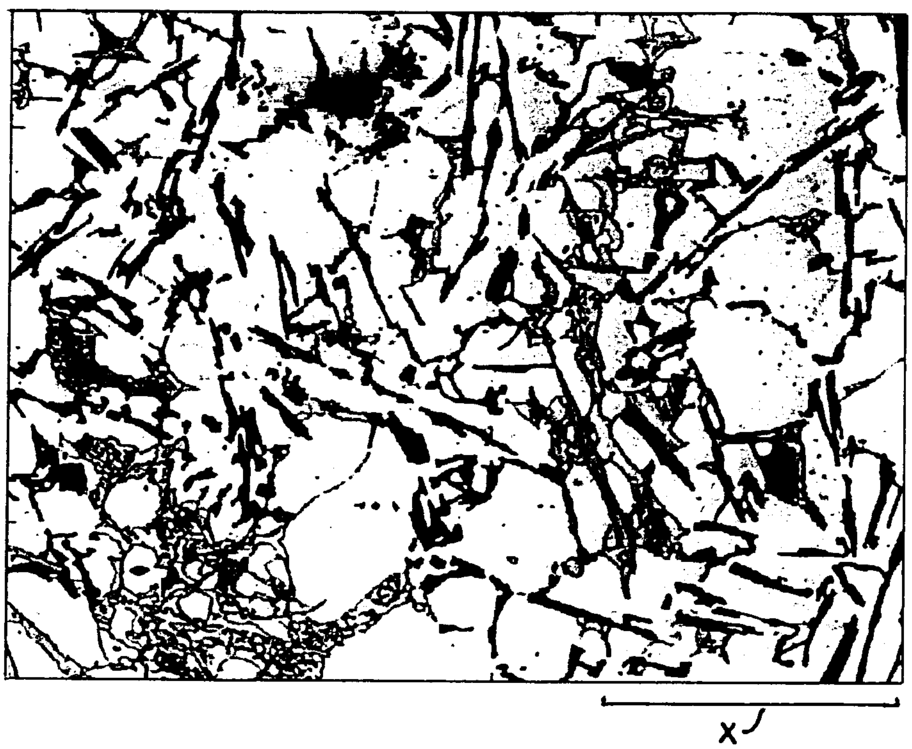

FIG 5b

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 83 0377

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	EP-A-0 119 365 (SERIO THOMAS DI) 26 September 1984 * page 1, line 25 - page 2, line 9; claims 1-5 * * page 3, line 4 - line 35 * ---	1,6,10, 12 2-4	B29C45/00 B22D31/00 B21J5/00 C21D7/02
X Y	FR-A-2 614 814 (DI SERIO) 10 November 1988 * page 4, line 1-29; claims 1-7 * ---	1,6,9-12 2-4	
X Y	US-A-1 711 000 (C.R.SHORT) * page 1, line 35 - line 99 * * page 2, line 51 - line 66 * ---	1,6,12 2-4	
X	US-A-4 775 426 (MURLEY JOHN ET AL) 4 October 1988 * column 3, line 27 - column 4, line 18 * ---	1,6	
X	PATENT ABSTRACTS OF JAPAN vol. 007, no. 237 (M-250), 21 October 1983 & JP-A-58 125328 (NISSAN JIDOSHA KK), 26 July 1983, * abstract * ---	1	**TECHNICAL FIELDS SEARCHED (Int.Cl.6)** B22D B21J C21D C21C
Y	US-A-4 177 086 (BOUVAIST JEAN-MARIE A ET AL) 4 December 1979 * column 7, line 25 - line 39; claim 1 * ---	2-4	
A	GB-A-1 078 781 (J.F.W.SCHLEGEL) * page 3, line 28 - line 51; claims 1-8 * -----	2	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26 November 1996	Mailliard, A

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
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& : member of the same patent family, corresponding document