(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 126 550**
A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **84302679.0**

(22) Date of filing: **19.04.84**

(51) Int. Cl.³: **B 22 D 27/00**, B 22 D 27/04

(30) Priority: **21.04.83 GB 8310852**

(43) Date of publication of application: **28.11.84 Bulletin 84/48**

(84) Designated Contracting States: **DE FR GB IT SE**

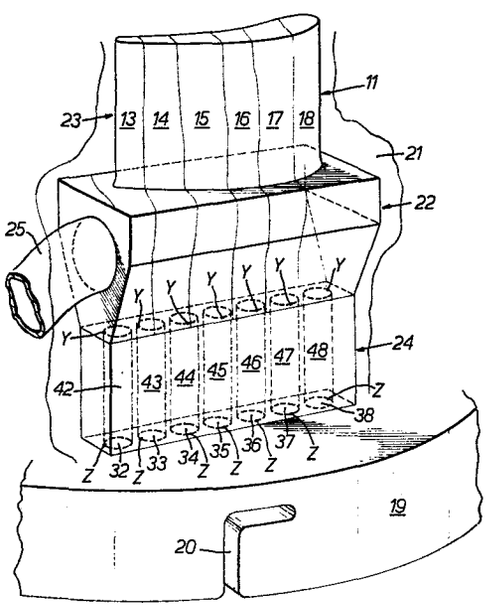
(71) Applicant: **AEPLC, Cawston House Cawston Rugby, Warwickshire, CV22 7SA (GB)**

(72) Inventor: **Paine, Brian, 47 Leafield Avenue, Bradford Yorkshire (GB)**

(74) Representative: **Rees, David Christopher et al, Kilburn & Strode 30 John Street, London WC1N 2DD (GB)**

(54) Casting articles by directional solidification.

(57) A method for moulding an article, for example a turbine blade, which is made up of one or more directionally solidified crystals of metal. A mould (21) is produced having a series of bores (32 to 38) in which seed crystals (42 to 48) are located, the seed crystals having previsously been calibrated to determine the angle and direction of inclination of their 100 planes. The seed crystals are arranged so that the orientation of the 100 planes coincide with that desired in the article relative to the geometry of the article and the mould is located on the chill plate (19). Molten alloy is then admitted to the mould cavity and directional solidification takes place with the result that crystals (13 to 18) solidify from the seed crystals having the same crystallographic orientation.



0126550

CASTING ARTICLES BY DIRECTIONAL SOLIDIFICATION

The present invention relates to casting articles by directional solidification, a process which is favoured when the article to be produced benefits from having a particular crystallographic structure/ orientation, e.g. turbine blades.

In a simple directional solidification casting process, the melt is cooled at a water cooled copper chill plate where nucleation occurs randomly at first, but which, after an initial growth zone, develops into a reasonably uniform grain growth pattern. Thus, a structure is produced composed of a number of crystals having a primary vertical grain growth direction and a lateral grain growth abutting adjacent crystals to form finite continuous grain boundaries.

It has also been proposed to cast articles by directional solidification, as a single crystal. This has been carried out by initially employing the copper chill plate to produce directionally solidified crystals but after the growth zone, the solidification is forced to take place via a constriction which allows only one crystal to develop thereby producing a single crystal casting.

As an alternative method of single crystal casting, it has been proposed to use "seed" crystals to act as a "starter" for crystal growth in each case. The crystal which grows from the seed crystal has a crystallographic orientation identical to that of

the seed crystal. Thus, results which are more predictable can be obtained once one has managed to obtain seed crystals with a known and acceptable crystallographic orientation.

In each of these proposals, the general objective is to achieve a direction of crystal growth wherein the primary 001 growth direction of the crystal follows essentially the major stress axis of the component and for this direction of growth to be generally axial with respect to the geometry of the article. However, it is suggested by the applicants that it might be advantageous to employ a crystallographic oreintation in which the 100 plane of the crystal is inclined to the axis of the article at a predetermined angle and in a specific direction relative to the component geometry. It is therefore an object of the present invention to provide a method of producing a cast article in which the crystallographic orientation of an individual crystal or crystals within the article relative to its geometry can be accurately predetermined.

According to the invention there is provided a method for producing a cast article having a specific crystallographic orientation relative to the goemetry of the article which comprises: forming a mould, locating relative to the mould cavity a seed crystal which has been calibrated to determine the angle and direction of inclination of its 100 plane relative to a reference direction, arranging the seed crystal so that the orientation of its 100 plane coincides with that desired in the article relative to the geometry of the article, admitting to the mould in the molten state the material from which the article is to be cast, and cooling the mould so that solidification of the cast article takes place in a direction away from the seed crystal.

The seed crystals may be produced by any convenient method, for example by way of a growth restrictor which may be in a helical form or alternatively by "cloning" from existing seed crystals. They are preferably calibrated by an X-ray diffraction technique to determine the angle of inclination of the 100 plane from a reference direction and the direction of inclination is preferably marked on the seed crystal relative to a reference line marked along the length of the seed crystal.

The seed crystal may be located within the mould cavity after the mould has been completely formed. If the mould is made by a lost-wax process, then the seed crystal may be located at the wax assembly stage.

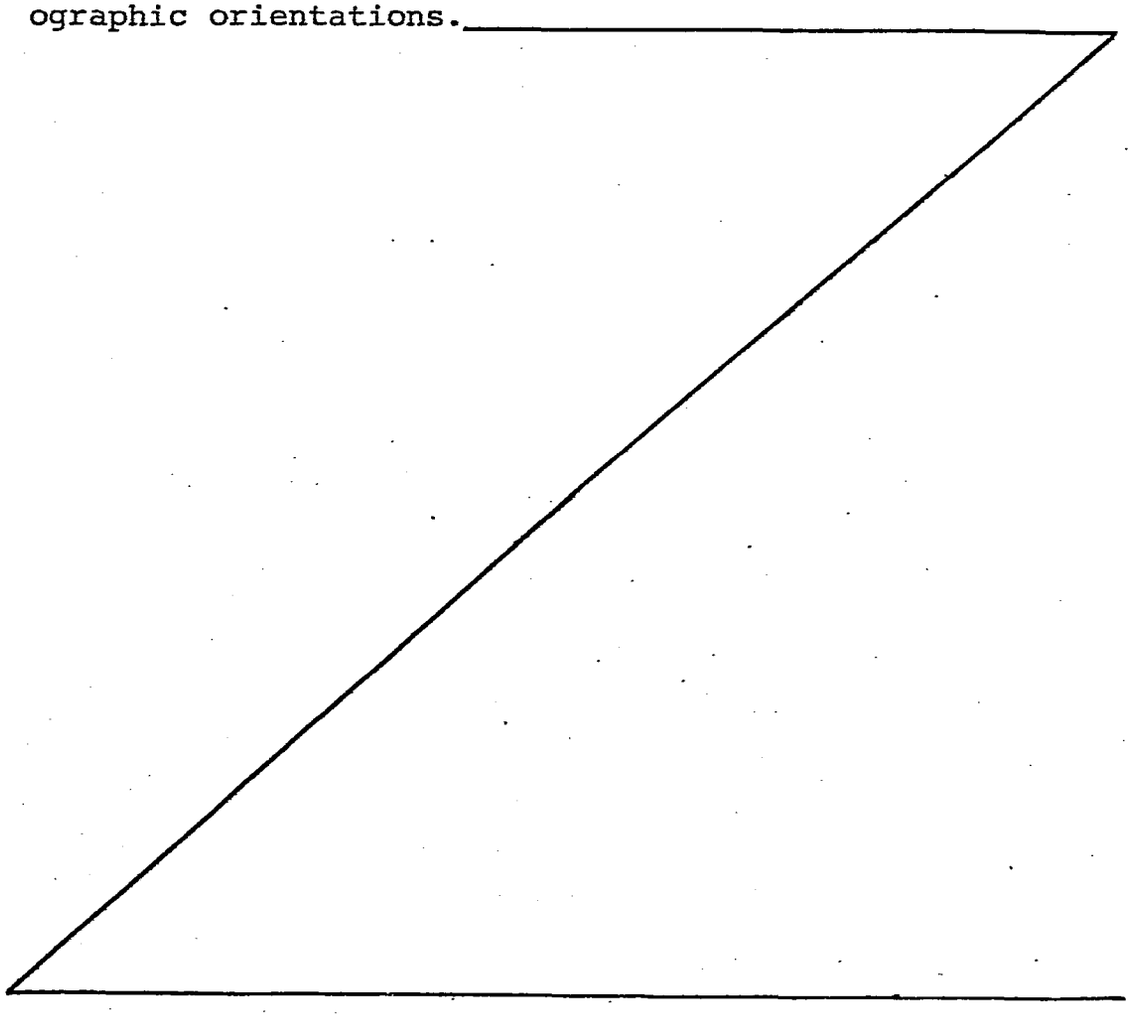
It will be appreciated that, using the method of the invention, it is possible to incline the 100 plane direction relative to the stress axis in the article to any desired extent and in any desired direction.

It is sometimes a requirement in the production of, for example turbine blades, that the articles produced have a minimum number of grains. While this can generally be achieved by the simple chill plate directional solidification method, their number and orientation cannot be accurately predetermined. It is therefore a further object of the present invention to provide a method of casting an article by directional solidification in which the number of grains and their crystallographic orientations can be predetermined with accuracy.

In a preferred method therefore a plurality of

seed crystals are located relative to the mould cavity and arranged so that the orientation of their 100 planes coincides with that desired in corresponding crystals making up the article. In this way, it may be possible to produce an article made up from a specific number of directionally solidified grains, each having its own optimum crystallographic orientation.

In all cases, it should be possible to enhance the properties of the article and in addition, to reduce the percentage of wastage due to unsuitable crystallographic orientations.



The invention may be carried into practice in various ways and some embodiments will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a plan view of a seed crystal which has been calibrated;

Figure 2 is an isometric sketch of the seed crystal of Figure 1;

Figure 3 is a diagrammatic representation of the crystallographic orientation of the seed crystal of Figures 1 and 2;

Figure 4 is an isometric sketch showing the grain growth in a turbine blade produced from a number of seed crystals; and

Figure 5 is a horizontal section through the turbine blade of Figure 4.

Figures 1 and 2 show a calibrated seed crystal. The seed crystal is elongate and cylindrical in shape It has a central axis X-X and a reference line O-O parallel to X-X inscribed upon its outer surface. The inclination θ of the 100 plane relative to the axis X-X and the reference line O-O is determined by an X-ray diffraction technique. This inclination is indicated by the arrow A. The direction of the inclination of the 100 plane is indicated by a point Y on the circumference of the seed crystal. Thus, the 100 plane of the seed crystal is inclined by an angle θ relative to the X-X reference axis in a direction towards the point Y from the X-X reference axis. This is shown schematically in Figure 3 in which

the 100 plane of a notional cube is cross-hatched.

Figure 4 shows the casting of a turbine blade 11. The turbine blade is composed of six individual metal crystals 12 to 18 each having its 100 plane in a particular desired orientation. The apparatus used to cast the turbine blade comprises a chill plate 19 having a bayonet fitting 20 and upon which a ceramic mould 21 is located. The mould may have conveniently been produced by a conventional lost-wax process.

The mould cavity comprises a starter block 22, above that a blade section 23, and below the starter block, a seed block 24. A molten alloy inlet 25 leads into the mould cavity. Alternatively, molten alloy may be introduced through the major mould aeorfoil cavity or any other suitable direction above the seed crystal or crystals.

The blade section 23 has a contour which corresponds to the desired contour of the finished product. The starter block 22 is merely a zone in which crystal growth is allowed to develop as a result of directional solidification. The seed block 24 comprises a series of cylindrical bores 32 to 38.

The bores 32 to 38 are intended to receive seed crystals 42 to 48 which are of the same alloy as that of the component to be cast and which act as starters for the metal crystals 13 to 18 making up the final turbine blade. Each bore 32 to 38 is therefore marked with a point Z with which the corresponding point Y on the appropriate seed crystal is aligned prior to moulding so that the eventual crystals 13 to 18 have

the desired crystallographic orientation. Each seed crystal 42 to 48 is fixed in position with the aid of a ceramic air-drying cement. In an alternative method, the seed crystals 42 to 48 can be located in position at the wax assembly stage.

After the seed crystals 42 to 48 have been correctly positioned, the molten casting alloy is admitted to the mould cavity via the alloy inlet 25. The seed crystals are then partially melted back and then directionally solidified grains with the same crystallographic orientation as the seeds develop growing upwards to the blade section 23 via the starter block 22. The crystallographic orientation of the seed crystals is reproduced in the crystals making up the solidified casting alloy.

As can be seen from Figure 5, in this embodiment, the 100 planes of the crystals making up the blade section 23 are generally inclined towards the convex surface of the aerofoil section with the exception of the end crystals which lean towards the component trailing edge and the component leading edge. These directions are indicated by the arrows A. Naturally, this particular crystallographic orientation is merely an example and it will be appreciated that any alternative crystallographic orientation may be achieved if desired, using the same general method, including control of the relative orientation of crystal to crystal for property optimisation and grain boundary defect minimisation.

CLAIMS

1. A method for producing a cast article (11) having a specific crystallographic orientation relative to the geometry of the article which comprises; forming a mould (21), locating relative to the mould cavity a seed crystal (43), admitting to the mould (21) in the molten state the material from which the article is to be cast, and cooling the mould (21) so that solidification of the cast article (11) takes place in a direction away from the seed crystal (13), characterised in that the seed crystal (43) has been calibrated to determine the angle and direction of inclination of its 100 plane relative to a reference direction and by arranging the seed crystal (43) so that the orientation of its 100 plane coincides with that desired in the article (11) relative to the geometry of the article (11).

2. A method as claimed in Claim 1 characterised in that the seed crystal (43) is located within the mould cavity after the mould has been completely formed.

3. A method as claimed in Claim 1 characterised in that the mould is made by a lost-wax process and the seed crystal (43) is located at the wax assembly stage.

4. A method as claimed in any preceding claim characterised in that a plurality of seed crystals (43 to 48) are located relative to the mould cavity and arranged so that the orientation of each of their 100 planes coincides with that desired in corresponding

crystals (13 to 18) making up the article (11).

5. A method as claimed in Claim 4 characterised in that the mould includes a seed section (24) comprising a series of bores (32 to 38) for the location of the seed crystals (42 to 48) and the molten material is brought into contact with the seed crystals (42 to 48) in the bores (32 to 58).

6. A method as claimed in Claim 5 characterised in that the mould includes a starter section (22) between the seed section (24) and the section (23) in which the final article (11) is to be cast, in which starter section (22) solidification takes place prior to casting of the final article (11).

7. A method as claimed in Claim 6 characterised in that the calibration of the seed crystals (42 to 48) includes marking a point (Y) on each crystal (42 to 48) corresponding to the direction of inclination of its 100 plane, marking a point (Z) on each bore (32 to 38) corresponding to the desired direction of crystallographic inclination and aligning the points (Y) on seed crystals (42 to 48) with the points (Z) on the bores.

1/2

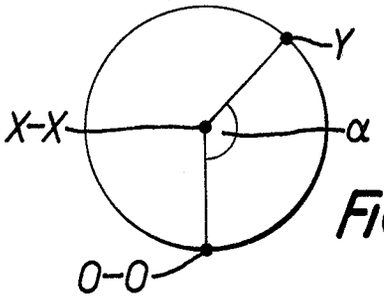


FIG.1.

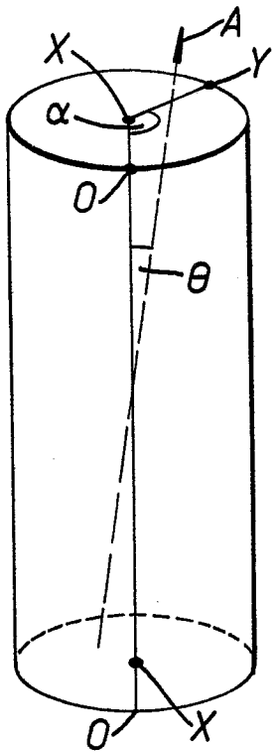


FIG.2.

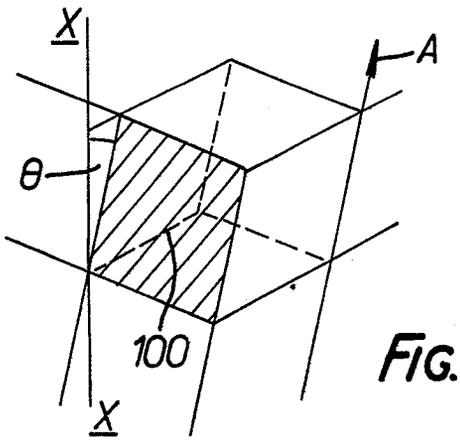


FIG.3.

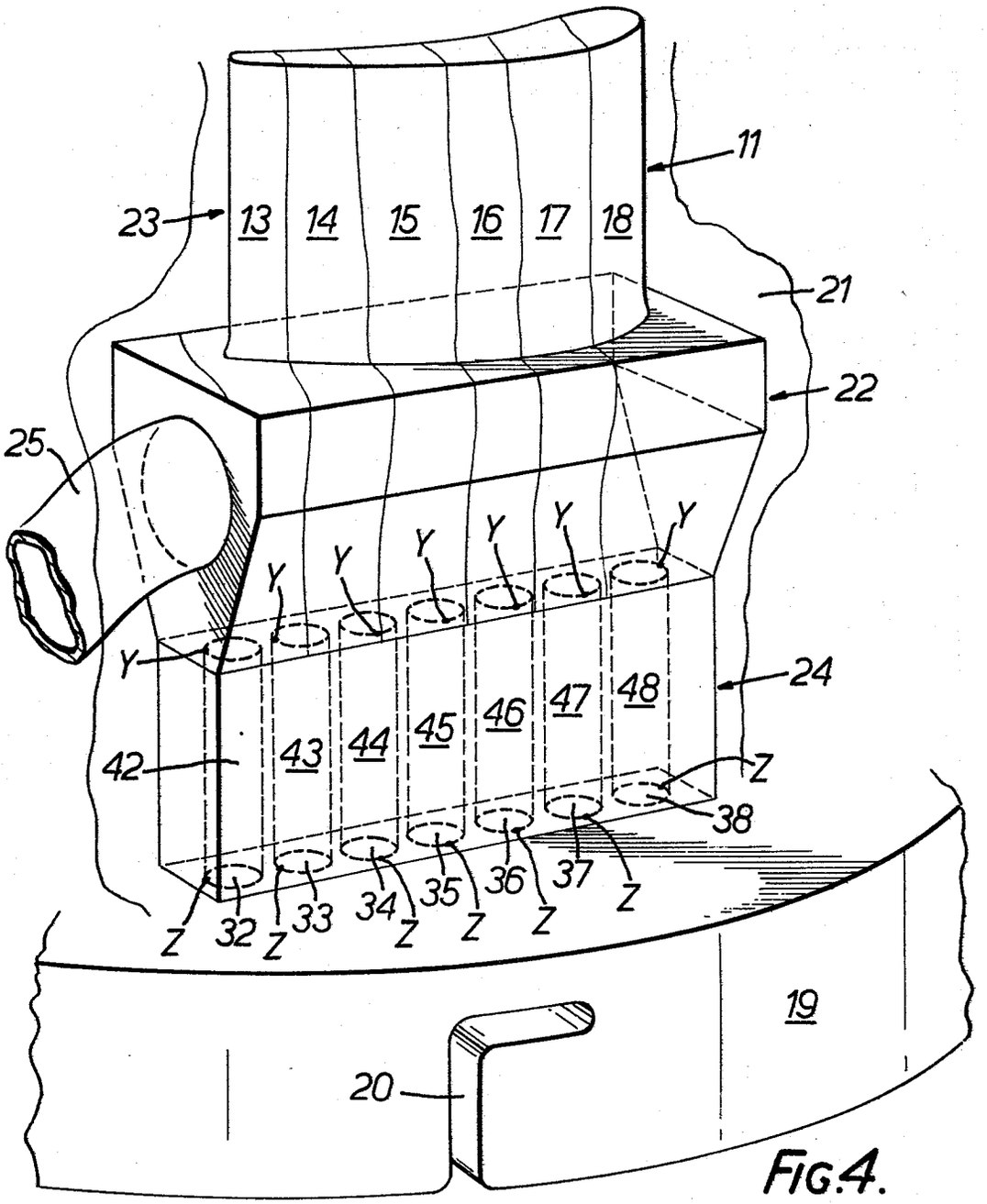

11
23
13
14
15
16
17
18
21
22
25
Y
24
42
43
44
45
46
47
48
Z
38
32
33
34
35
36
37
19
20

FIG.4.

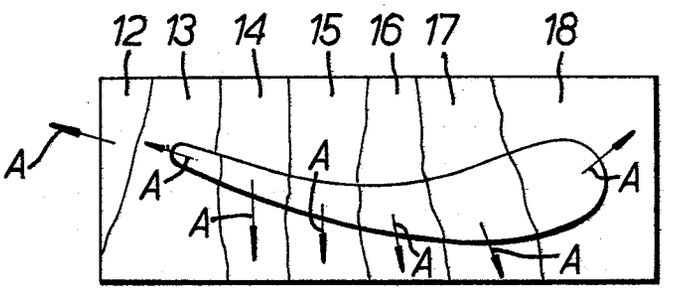

12
13
14
15
16
17
18
A

FIG.5.

0126550

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 84 30 2679

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. ³)
A	GB-A-2 030 233 (ROLLS-ROYCE LTD.) * Claims 13, 14 *	1	B 22 D 27/00 B 22 D 27/04
A	DE-A-2 909 844 (REMET CORP.) * Claims 1, 9; page 6, lines 14-30 *	1,3	
A	EP-A-0 034 021 (TRW INC.) * Abstract *	1	
A	EP-A-0 059 549 (TRW INC.) * Figures 4, 5 *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

B 22 D 27/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	12-07-1984	GOLDSCHMIDT G

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