(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 May 2009 (28.05.2009)

PCT

(10) International Publication Number
WO 2009/066331 A1

(51) International Patent Classification:
G01F 1/66 (2006.01) *C03B 37/05* (2006.01)

(21) International Application Number:
PCT/IT2007/000817

(22) International Filing Date:
21 November 2007 (21.11.2007)

(25) Filing Language: Italian

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **GAMMA MECCANICA S.P.A.** [IT/IT]; Via Sacco e Vanzetti, 13, I-42021 BIBBIANO (REGGIO EMILIA) (IT).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **SIROK, Brane** [SI/SI]; Ob potoku 34, 1360 Vrhnika (SI). **HOCEVAR, Marko** [SI/SI]; Ljubljanska 13 G, 1236 TRZIN (SI). **BAJCAR, Tom** [SI/SI]; Trg komandanta Staneta 5, 1000 Ljubljana (SI). **BLAGOJEVIC, Bogdan** [SI/SI]; Svetceva pot 2, 1241 Kamnik (SI). **JAMNIK, Janez** [SI/SI]; Martinceva ul.48, 1117 Ljubljana (SI). **BURINI, Giovanni** [IT/IT]; Via Alighieri, 41, I-42021 BIBBIANO (REGGIO EMILIA) (IT).

(74) Agent: **TANSINI, Elio Fabrizio**; c/o BUGNION S.P.A., Viale Lancetti, 17, I-20158 Milano (IT).

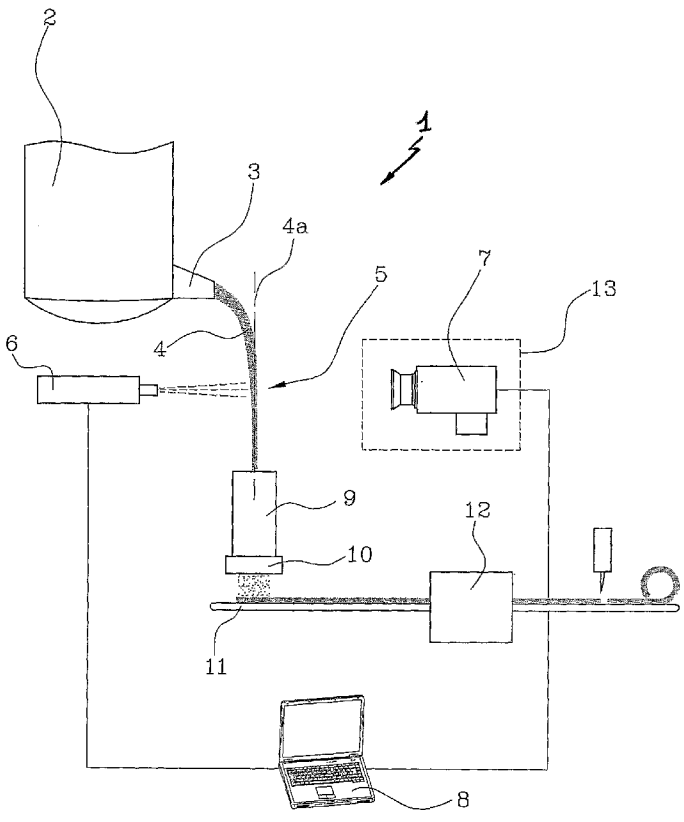
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL,

[Continued on next page]

(54) Title: METHOD AND DEVICE FOR DETERMINING THE MASS FLOW OF A CASTING OF MOLTEN MATERIAL

FIG 1



(57) Abstract: A method of determining the mass flow of a casting of molten material, in particular in the process for producing rock wool, comprising the steps of: perturbing, through perturbation means (6), the casting (4) of molten material falling in a gravitational field along an advancing axis (4a); acquiring, through video acquisition means (7), a propagation of the perturbation (P) along the casting (4) of free-falling molten material; calculating the propagation rate (vp) of the perturbation along the casting (4) of molten material through data processing means (8) co-operating with the video acquisition means (7); calculating the flow rate (m) of the casting (4) of molten material as a function of said propagation rate (v_p).

WO 2009/066331 A1

PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

METHOD AND DEVICE FOR DETERMINING THE MASS FLOW OF A CASTING OF MOLTEN MATERIAL

The present invention relates to a method of determining the mass flow of a casting of molten material, in particular in the process for producing mineral wool, such as glass wool and rock wool.

In particular, the present invention relates to evaluation of the flow rate of a flow of molten material, such as molten rock or glass, free falling in a gravitational field.

In common processes for producing rock wool or glass wool, melting of the material takes place in a cupola to a temperature of approximately 1500-1600°C. The material casting, once molten, comes out of the cupola through a siphon and falls freely downwards, being directed to a fibering device, adapted to reduce the molten material jet to fibre; this device consists of one or more centrifugal disks that, by rotation, converts the casting to thin fibres settling in the settling chamber and after, by means of pendulum belts, the fibers felt is laid on suitable conveyor belts.

The material is impregnated with water-repellent substances (resins and oils) and binders, so as to obtain a compact fibrous mat from which, after a cooling and solidification process carried out in

suitable furnaces, the final product is prefabricated, which product has the required fibre structure, specific weight and insulating thickness.

The characteristics and structure of the final product depend both on the type of mineral introduced into the cupola and on the flow rate of the molten material coming out of the furnace and directed to the fibering device. In order to keep a good quality of the final product it is therefore of the greatest importance that the quality of the mass in the fluid state be monitored, being it necessary to act on the whole working process by adjusting both the process speed and the chemical composition of the material introduced upstream; this is made possible by a control of the flow rate coming onto the centrifugation device. For evaluation of the mass flow it is necessary to know the advancing speed of the fluid.

A method proposed for evaluation of the flowing speed of the casting involves observation of the advancing motion of an air bubble within the fluid mass. The air bubble is already present in the material and creates a visual reference moving with the movement of the casting of molten material.

Unfortunately, this method is only applicable to transparent materials capable of making the air bubbles

visible. In addition, following experimental tests, this method appeared to be not very efficient from a practical point of view, since arrival of an air bubble is not a phenomenon that can be determined with time precision, and it is also not very reliable as regards the numerical results supplied.

The methods currently used are based on measurements carried out on the mass of material already cooled and reduced into fibre and therefore performed in a too advanced step of the production process. This does not allow a correct and precise regulation both of the speed of the production line, and the material density, with suitable variations in the composition of the materials introduced upstream. A non-calibration or a wrong calibration of some factors can give rise to characteristics of the material different from the desired ones.

Document US 4090241 proposes a mathematical model for calculation of the mass flow, based on evaluation of the diameter of the casting at two different positions along the advancing axis of the casting, located at a known distance from each other, and on the estimate of the average viscosity of the fluid. This method, which is a non-invasive one, however lacks precision and is not sufficiently reliable.

Accordingly, it is an aim of the present invention to propose an alternative method of determining the mass flow of a casting of molten material, that is adaptable to any type of free-falling fluid in a gravitational field.

A further aim of the present invention is to make available a method of determining the mass flow of a casting of molten material that can be put into practice with ease, can be repeated and gives reliable results.

The foregoing and further aims that will become more apparent during the following description are substantially achieved by a method of determining the mass flow of a casting of molten material, in accordance with the appended claims.

Further features and advantages will be best understood from the detailed description of a preferred but not exclusive embodiment, in accordance with the accompanying drawings, in which:

- Fig. 1 is a diagrammatic representation of an apparatus for putting into practice the method for determination of the mass flow of a casting of molten material in accordance with the present invention;
- Fig. 2 shows a first image acquired from an element

of the apparatus diagrammatically shown in Fig. 1, to which a first calculation method is applied;

- Fig. 3 shows a second image acquired from an element of the apparatus diagrammatically shown in Fig. 1, to which a first calculation method is applied;

- Fig. 4 shows the image in Fig. 2, to which a second calculation method is applied;

- Fig. 5 shows the image in Fig. 3, to which a second calculation method is applied;

- Fig. 6 shows an example of a relation function between two variables used in the calculation method described in the following specification.

A numerical evaluation of the mass flow of a fluid in producing mineral wool or in similar metallurgic processes has a great importance in carrying out and setting up the production process itself.

The method herein described aims at calculating the mass flow of a casting of molten material coming out of a cupola.

The operating limits for measuring the flow rate of the molten material are preferably included between 800°C and 1800°C as to temperature values, between 5 and 20 dPas (deci Pascal seconds) as to viscosity values and between 0.1 an 3 m/s as to speed values.

The raw materials for producing rock wool, after

weighing and measuring them to the right proportions, are automatically loaded into a cupola, in which melting of the rock takes place.

The molten rock is directed, through a siphon, to a fibering device 9 comprising one or more rotating discs that through centrifugation of the casting, convert it into fibres settling in the settling chamber 10.

The rock wool layer that is formed is subsequently distributed by means of pendulum a collection belt 11 creating a mat that is caused to pass into a polimerization oven 12, in order to enable hardening of the binder. Afterwards the material is cut to size and packaged.

With reference to the accompanying Fig. 1, an apparatus for calculation of the flow rate in a molten material is denoted at 1. In a cupola 2 the material (rocks, minerals, glass and the like) used for producing mineral wool is molten. The molten material comes out of cupola 2 through a siphon 3 in the form of a casting 4 falling in a gravitational free field along a preferably vertical direction substantially coincident with an advancing axis 4a.

Therefore the described method takes place along a vertical stretch of casting 4, in a measurement region 5 included between siphon 3 and the fibering device 9.

Apparatus 1 further comprises perturbation means 6 for perturbing casting 4, that is adapted to cause a perturbation or disturbance remaining in the casting 4 for a given time and space interval along the advancing axis 4a of casting 4. This perturbation means 6 acts at a position arbitrarily selected inside said measurement region 5.

Advantageously, the perturbation means 6 creates a disturbance in a direction transverse to the advancing axis 4a of casting 4, preferably in a perpendicular direction. The disturbance generated by the perturbation means 6 can consist either of air jets causing deviation of casting 4 from the advancing axis 4a or jets of sand or small solid particles marking a given area of casting 4 in a visible manner. These jets are operated by control valves of known type and therefore not shown. Preferably, air streams generated by pneumatic systems are used.

Opposite to the perturbation means 6 relative to axis 4a, apparatus 1 comprises video acquisition means 7 connected to and co-operating with data processing means 8. The video acquisition means 7 is such positioned as to be in the line of sight of casting 4 and of perturbation P generated by the perturbation

means 6, so as to follow the perturbation motion along the casting at the inside of the measurement region 5.

Preferably, the video acquisition means 7 comprises a videocamera for example a CMOS or a CCD camera(charge coupled device)or others which is provided with a small silicon plate that, together with the lens, is able to capture the images and convert them, due to sensors with which it is covered, into electric signals that in turn are interpreted as to position, colour, intensity, etc. and converted into bits to be sent to the processing means 8.

Advantageously, the videocamera is mounted in a transparent protective housing 13 inside which a slight overpressure is created relative to the external environment, to keep the lens clean and cool the videocamera 7. Videocamera 7 acquires a plurality of images referring to advancing of casting 4 free falling from siphon 3 to the fibering device 9, and in particular referring to the advancing motion of perturbation P introduced by the perturbation means 6.

The processing means 8 comprises a computer including an image acquisition unit directly co-operating with the video acquisition means 7 and a digital input-output unit for operation of the perturbation means 6.

In addition the computer preferably comprises an

analysis unit capable of analysing the plurality of acquired images and a calculation unit capable of carrying out the necessary calculations and measurements. In this way, the processing means is able to acquire the digitised images and process them, based on a software to calculate the mass flow of the casting of molten material.

The proposed method is based on hypotheses that the casting 4 of molten material coming out of cupola 2 is an incompressible stationary isothermal fluid, with a uniform motion and an axially symmetric geometry. In addition, shearing stresses, surface tensions and any other effect due to drag are ignored.

The proposed method contemplates creation of a disturbance seen as a perturbation P of the geometry of the flow of molten material coming out of cupola 2. In other words, the disturbance generated in this case by an air flow discharged against casting 4 temporarily alters the geometric profile of the casting edges, thus obtaining a visual reference to be followed during the casting motion.

A plurality of images of this phenomenon are acquired and stored by the acquisition means 7 and processing means 8.

Based on the above mentioned hypotheses, in order to

determine the casting flow rate, the continuity equation is adopted:

$$\dot{m} = \rho \cdot S \cdot v_p = \frac{\rho \cdot d^2 \pi \cdot v_p}{4} \qquad (1)$$

wherein:

ρ is the density of the casting of molten material,

S is the surface of the transverse advancing section of the casting,

v_p is the advancing speed of the perturbation that, taking into account the preceding hypotheses, is the same as the casting advancing speed.

In the hypotheses of cylindrical geometry of casting 4 and therefore of axial symmetry, the surface of the transverse section of the casting is equal to $d^2\pi/4$, where d is the casting diameter; in addition, in the hypotheses of uniform fluid, the propagation speed of the perturbation is equal to the advancing speed of the casting in a region not subjected to disturbance.

Therefore, following the perturbation motion and succeeding in determining the speed v_p, the advancing speed of the casting and therefore the maximum flow rate through application of the continuity equation (1) is obtained.

The software installed in the computer, by analysing

the acquired images, enables measurement:

- of the diameter d of the casting measured in a direction orthogonal to the advancing axis 4a of casting 4,
- of the advancing speed of the perturbation v_p along the casting,
- of the density ρ of the casting based on the known chemical composition of the minerals introduced in the cupola and based on temperature measurements,
- of the mass flow $\dot{m}$ of the casting.

The method herein proposed consists of two main steps: a first step during which periodic measurements of the flow rate are carried out, through evaluation of the casting diameter, of some parameters characteristic of the molten mass such as density and viscosity and the advancing speed v of the casting through measurements of the propagation speed v_p of a perturbation produced; and a second step during which the molten material flow is no longer perturbed but the speed course and therefore the flow rate is calculated as a function of the spatial co-ordinate along axis 4a of the casting utilising, as the starting condition, the speed v_p obtained by calculations done during the first step. This second step allows a continuous measurement of the flow rate of the molten material, without repeated and

frequent perturbation actions on the casting being required.

The results obtained from the first step can be used as independent variables for direct use in the control of the mineral-wool production process or as boundary conditions for performing the second step.

Both steps are performed with the aid of the acquisition means 7 and processing means 8. The results thus obtained are used by a control system for regulation and calibration of the whole mineral-wool production process.

First Step of the Measurement Method

The acquisition means 7 acquires a plurality of images for a given preestablished time interval, during which the molten material flow is perturbed by the perturbation means 6 and the thus created perturbation P moves along the advancing axis 4a of the casting.

The images are acquired downstream of the siphon, before the casting impinges on the fibering device 9.

The acquired images are sent to the processing means 8 where the acquisition unit imports them and the analysis unit compares the grey levels of a plurality of areas of these images.

Diagrammatically shown in Figs. 2 and 3 are two subsequent images of the casting in the measurement

region 5 at perturbation P. The movement of perturbation P is captured in a plurality of subsequent images, and since the videocamera is located at a fixed position, it is possible to see that perturbation P has moved downwards, following the advancing motion of the casting.

Through analysis of at least two subsequent images and mutual comparison, the processing means 8 is able to determine deviation h of perturbation P between the first and second images. Preferably, this deviation h is evaluated in terms of pixels interposed between a given line of reference identified on the first image and the corresponding line, in an offset position, on the second image.

The time Δt elapsed between said two subsequent images is known, as it is fixed by the regulation parameters of the videocamera. This time interval corresponds to the time elapsed between acquisition of each of the two images.

Finally, by dividing deviation h of the perturbation by the elapsed time interval Δt, the propagation speed of the perturbation is obtained:

$$v_p = \frac{h}{\Delta t} \qquad (2)$$

In order to determine the advancing speed of the perturbation v_p from analysis of two subsequent images, two alternate methods can be used, both based on evaluation of the grey levels of the images by the analysis unit.

The first method that can be used is known as "correlation method" and is adapted to evaluate the vertical component of the advancing speed of the casting under any condition. In the inner surface confined by contour "a" in Fig. 2, the analysis unit in co-operation with the calculation unit evaluates the intensity of the grey level A of each image *i* through the following equation:

$$A(i)=\frac{1}{N}\cdot\sum_{j}^{N}E_p(i,j) \qquad (3)$$

wherein:

E_p is the grey level in the *j*th line of the *i*th image,

N is the number of pixels in each line *j*.

Index *j* covers all lines in the region confined by contour "a" in Fig. 2.

The variable E_p *(i,j)* has 256 grey levels included between 0 (black) and 1 (white) if a 8-bit videocamera is utilised.

The preceding equation (3) applies to the subsequent

images, preferably to one of the subsequent images, using, as the calculation area, the region included in contour "b(h)" (Fig. 3) having the same size as the area included in contour "a".

As can be noticed from a comparison between Fig. 2 and Fig. 3, the contour "b(h)" is shifted by a value *h* relative to contour "a" along the advancing direction of the casting. Parameter *h* takes whole values included between 0 and H(0<h<H), where H is the maximum admitted deviation, determined by the limits of the visual area of the videocamera, for example.

Therefore, the equation (3) applied to contour "b(h)" is expressed as a function of parameter *h*, to be determined.

This analysis and calculation procedure can be repeated on a plurality of pairs of subsequent images acquired.

Through intensity of the grey levels obtained with equation (3) it is possible to obtain a cross-correlation function *r(h)* between the grey level intensity and the average intensity of the grey levels in contours "a" and "b(h)", expressed by the following equation:

$$r(h)=\frac{\sum_i\left[\left(A_a(i)-\overline{A}_a\right)\cdot\left(A_{b(h)}(i+1)-\overline{A}_{b(h)}\right)\right]}{\sqrt{\sum_i\left(A_a(i)-\overline{A}_a\right)^2}\cdot\sqrt{\sum_i\left(A_{b(h)}(i+1)-\overline{A}_{b(h)}\right)^2}} \qquad (4)$$

where A_a and $A_{b(h)}$ are the grey level intensities of the images in the areas confined by contours "a" and "b(h)", while $\overline{A}_a$ and $\overline{A}_{b(h)}$ are the average intensities of the grey levels of the images in the areas confined by contours "a" and "b(h)" of a plurality of pairs of subsequent images acquired by the videocamera.

Index i is the number of the digitised image in the series of subsequent images representing advancing of the perturbation in the casting of molten material. The cross-correlation function $r(h)$ is a statistic parameter used in searching for similitudes between images or image parts.

In other words, the processing means 8 reads and mutually compares several values referring to the information on the grey levels of the plurality of acquired images.

A given starting reference area being fixed, the corresponding areas of the acquired subsequent images are compared, by evaluating the intensity of the grey levels, until the image or image area having the maximum correlation with the reference image is found.

Therefore, with monotonic increases of parameter h and calculation of the related cross-correlation function

$r(h)$, it is possible to find which is the value $h_{r,max}$ of parameter h maximising the cross-correlation function $r(h)_{max}$.

An example of the course of the cross-correlation function $r(h)$ is shown in Fig. 6. The determined value of $h_{r,max}$ is the deviation of perturbation P between two subsequent images, evaluated in terms of pixels. Then this value is to be converted into the correct physical sizes (mm) through a suitable calibration constant k of the videocamera ($h^*_{r,\max} = k \cdot h_{r,\max}$). Value $h^*_{r,\max}$ thus obtained is the deviation h to be used in equation (2) for calculation of the propagation speed of the perturbation:

$$v_p = \frac{h^*_{r,\max}}{\Delta t}$$

where Δt is the time interval elapsed between acquisition of the two subsequent images.

The second method to be used for evaluating the advancing speed of perturbation v_p is known as to be adapted when the disturbance profile is well defined. This method contemplates identification of at least one reference region on the casting at the perturbation. In particular, should the disturbance be generated by an air stream interfering in a direction transverse to

casting, the region of maximum deflection of the casting from its advancing axis 4a can be found.

Should perturbation P be caused by a jet of sand or admission of small solid particles, a region of different colour relative to the rest of the casting is identified. In two subsequent images acquired, the height $j_{max,i}$ of a region taken as visual reference in the first image and the height $j_{max,i+1}$ of the same region in the second image is measured. Indexes i and $i+1$ identify two subsequent images acquired in a known time interval Δt. The reference region, the casting edge that mostly deviate from the advancing axis 4a for example, is identified through the maximum gradient of the grey levels or through a threshold value, for example.

Therefore, deviation of the disturbance between the two subsequent images is given by:

$$h = j_{\max,i} - j_{\max,i+1}$$

For each perturbation, measurement of a plurality of deviations h is possible and therefore an average deviation can be obtained h^* by which the advancing speed of perturbation v_p by means of the equation (2) can be calculated. In this case too, Δt is the time

interval elapsed between acquisition of each of the two images.

Using one of the two methods described above, it is possible to calculate the casting flow rate by means of the equation (1). The casting diameter d is obtained through measurement of the distance between the side edges of the casting, in a direction transverse to axis 4a. By analysing one of the acquired images, the casting diameter in the measurement region where the speed has been calculated, is evaluated. By considering a determined height h on the image as the reference x axis, the difference is made between two co-ordinates at which the side edges of the casting are located, and this value is multiplied by the calibration coefficient k:

$$d = k(x_{L,h} - x_{R,h}) \qquad (5)$$

In this case too, the processing means 8 calculates the position of the edges through evaluation of the grey levels. On the contrary, density ρ is obtained through measurement of the temperature, the chemical composition of the casting being known, at the point where the diameter is calculated, in a manner presently known to a person skilled in the art.

Each time a disturbance is generated, it is possible to obtain measurement of the flow rate.

However, for the production process a continuous control on the flow rate value is important. On the other hand, it is not possible to continuously perturb the casting, since this would interfere with the production process.

To avoid the system being frequently perturbed, the first step hitherto described is integrated with a second step contemplating calculations alone.

Second Step of the Measurement Method

The second step contemplates return of the casting to an undisturbed condition. In this case too the flow is imagined to be isothermal, stationary and free falling in a gravitational field.

The equation used for speed calculation is:

$$v = v_p \exp(\xi \cdot y) \qquad (6)$$

where:

y is the dimension along the advancing axis 4a of the casting,

ξ is the deformation gradient given by equation:

$$\xi = \frac{1}{v} \cdot \frac{dv}{dy}$$

The casting diameter corresponding to height y at which the advancing speed of the casting is calculated is given by equation:

$$d(y) = d_0 \cdot \exp(-\xi \cdot y/2) \qquad (7)$$

wherein:

d_0 is the diameter calculated with equation (5).

The function expressing the advancing speed of the casting as a function of the spatial co-ordinate calculated along the casting axis 4a is given by the equation:

$$v(y) = v_p \cdot \exp\left(- \int_{y_0}^{y} \frac{2}{y} \ln \frac{d(y)}{d_0} dy \right) \qquad (8)$$

Equation (8) enables the course of the casting speed along the advancing axis to be obtained, and therefore the flow rate based on equation (1).

By introducing this second step, the number of the disturbance actions introduced into the casting is reduced, since the first step is only used to carry out periodic calibrations of the method.

Periodic measurements of the flow rate of the casting of molten material allow a precise regulation and

careful calibration of the mineral-wool production process.

Based on the values obtained by the previously described method, it is possible to act on given parameters of the production system such as transportation speed of the material in the settling chamber, stirring speed of the pendulum, or speed of the conveyor belts.

The proposed method is ininvasive, since with a limited number of perturbation actions on the casting, carried out upstream of the interaction with the fibering device, the speed profile and therefore the flow rate of the casting can be calculated.

In addition, from the experimental tests executed, the proposed method appeared to be very precise and efficient in measuring the flow rate of a casting of molten material.

C L A I M S

1. A method of determining the mass flow of a casting of molten material in particular in a process for producing rock wool, comprising the steps of:

- perturbing, through perturbation means (6), the casting (4) of molten material falling in a gravitational field along an advancing axis (4a);
- acquiring, through video acquisition means (7), a propagation of the perturbation (P) along the casting (4) of free-falling molten material;
- calculating the propagation rate (v_p) of the perturbation along the casting (4) of molten material through data processing means (8) co-operating with the video acquisition means (7);
- calculating the flow rate ($\dot{m}$) of the casting (4) of molten material as a function of said propagation rate (v_p).

2. A method as claimed in claim 1, comprising the step of calculating a diameter (d) of the casting in a direction transverse to the advancing axis (4a); said flow rate ($\dot{m}$) being calculated also as a function of the propagation rate (v_p) of the perturbation and the diameter (d) of the casting (4).

3. A method as claimed in one of the preceding claims,

wherein perturbation (P) of the casting of molten material takes place through interaction of a disturbance element in a transverse direction, preferably orthogonal, to the advancing axis (4a) of the casting (4) of molten material.

4. A method as claimed in one of the preceding claims, comprising the step of processing, through data processing means (8), the acquired images, to draw the perturbation speed (v_p) of the casting (4).

5. A method as claimed in one of the preceding claims, wherein said data processing means (8) compares a plurality of acquired subsequent images, to determine the deviation (h) of the perturbation (P).

6. A method as claimed in one of the preceding claims, wherein said data processing means (8) analyses the grey levels of a plurality of acquired images.

7. A method as claimed in one of the preceding claims, wherein said data processing means (8) compares the grey levels of a given area of an acquired first image with the grey levels of a plurality of areas of at least one acquired subsequent image and determines the deviation (h) of the perturbation (P) between said two subsequent images, preferably in terms of pixels and based on the best correspondence between the analysed areas of two subsequent images, the time interval (Δt)

elapsed between acquisition of each of said two images being known.

8. A method as claimed in claim 7, wherein said data processing means (8) calculates the propagation rate (v_p) of the perturbation (P) by dividing the deviation (h) of the perturbation (P) between said two subsequent images by the acquisition time interval elapsed between said two images.

9. A method as claimed in one of claims 5 to 8, wherein said data processing means (8) determines the deviation (h) of the perturbation (P) by maximising a cross-correlation function (r(h)) statistically obtained through evaluation of the intensities of the grey levels of the plurality of acquired images.

10. A method as claimed in one of claims 5 to 8, wherein said data processing means (8) determines the deviation (h) of the perturbation (P) by identifying corresponding regions ($j_{max,i}$, $j_{max,i+1}$) of the casting (4) between two subsequent images.

11. A method as claimed in claim 10, wherein said regions are identified at the maximum deflection of the perturbation from the advancing axis (4a) of the casting (4).

12. A method as claimed in anyone of the preceding claims, comprising the step of determining the course

of the local speed (v) of the casting of molten material in the absence of perturbation, as a function of the spatial position (y) along the casting advancing axis (4a) and as a function of the propagation rate of the perturbation (v_p) already calculated by the data processing means (8) by analysing the plurality of acquired images.

13. An apparatus for evaluating the mass flow of a casting of molten material, comprising:

- video acquisition means (7) capable of acquiring a plurality of images of a given casting portion;
- perturbation means (6) capable of causing a perturbation (P) in the casting (4) of molten material;
- data processing means (8) having an analysis unit adapted to analyse the plurality of acquired images and a calculation unit adapted to calculate the propagation rate of the perturbation (v_p) along the casting of molten material.

14. An apparatus as claimed in claim 13, wherein said analysis unit is able to compare grey levels of a plurality of acquired subsequent image areas and determine the best correspondence between the analysed areas of two subsequent images.

15. An apparatus as claimed in claim 13 or 14, wherein said calculation unit co-operates with the analysis

unit to measure the deviation (h) of the perturbation (6) between two subsequent images having the best correspondence between analysed areas, and to determine the propagation rate of the perturbation (P), the time interval (Δt) elapsed between acquisition of each of said two images being known.

16. An apparatus as claimed in one of claims 13 to 15, wherein said perturbation means (6) comprises a pneumatic device adapted to produce an air jet interfering with the casting (4) of molten material and transversely directed, preferably at right angles, to the advancing axis (4a) of the casting (4).

FIG 1

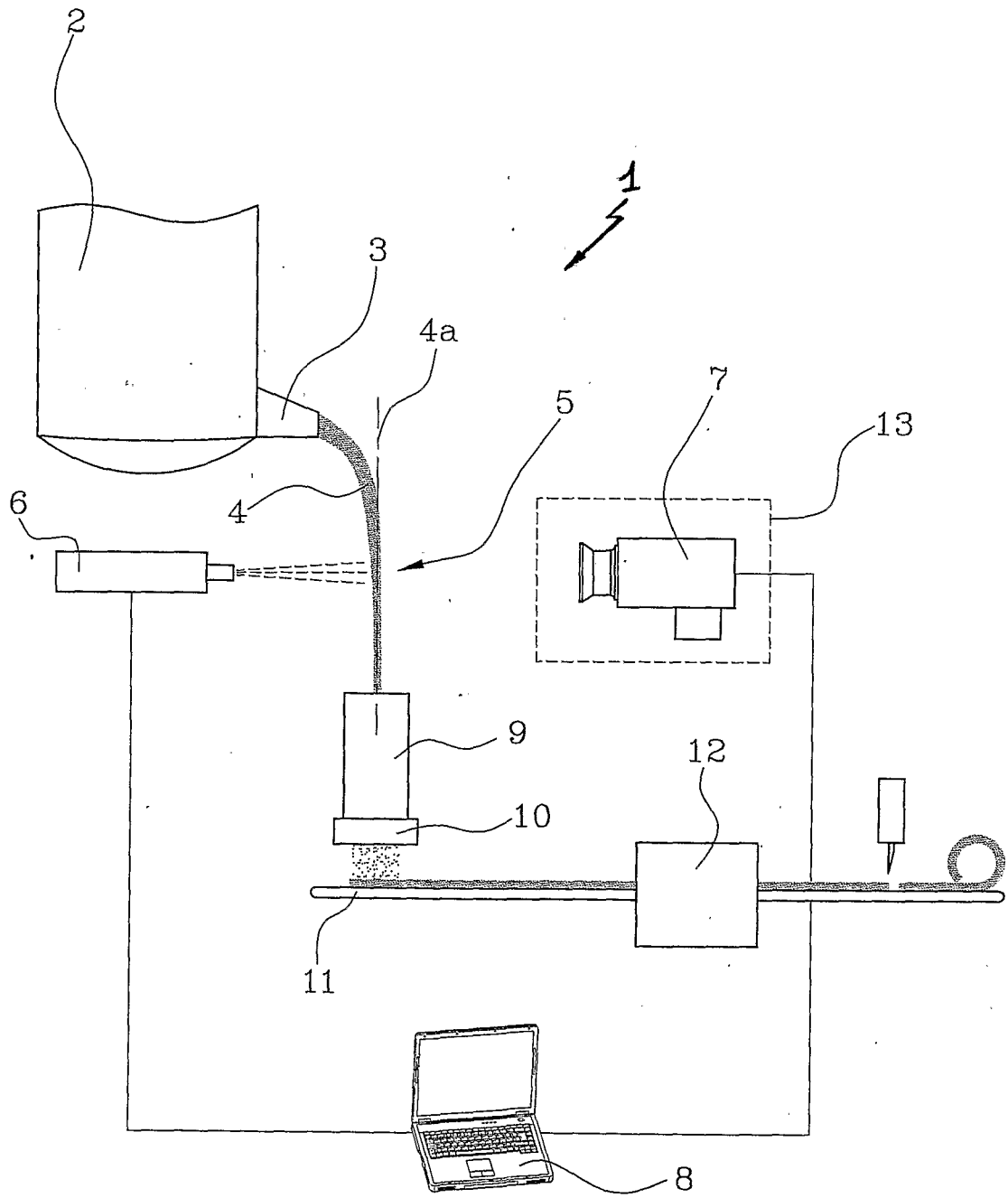


FIG 2

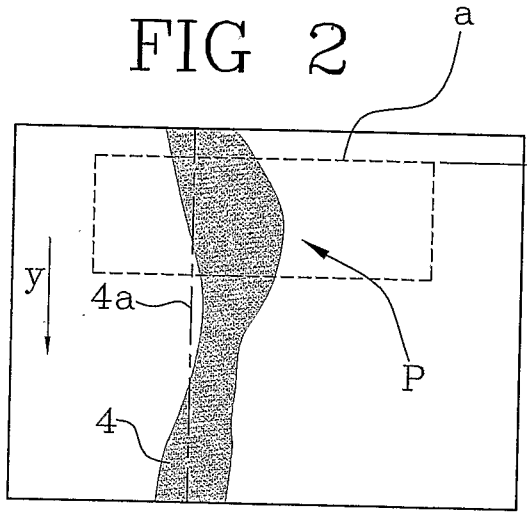


FIG 3

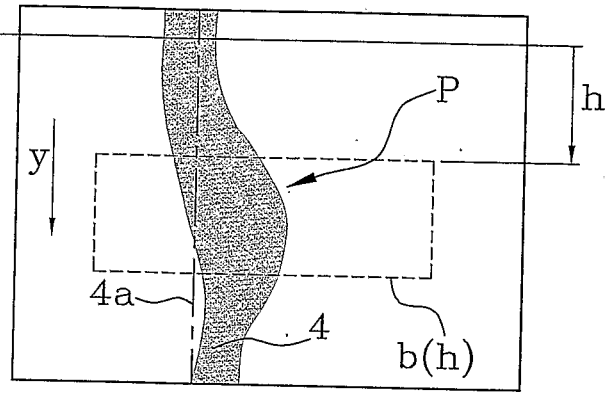


FIG 4

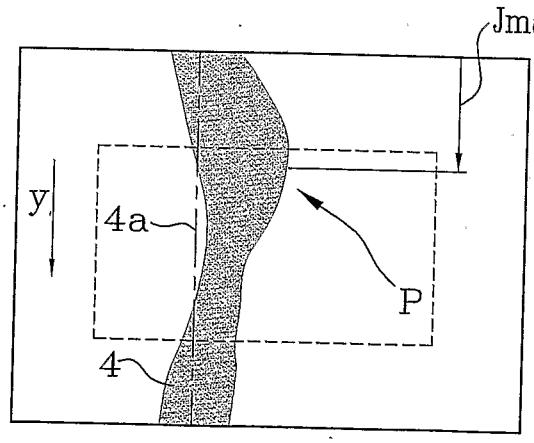


FIG 5

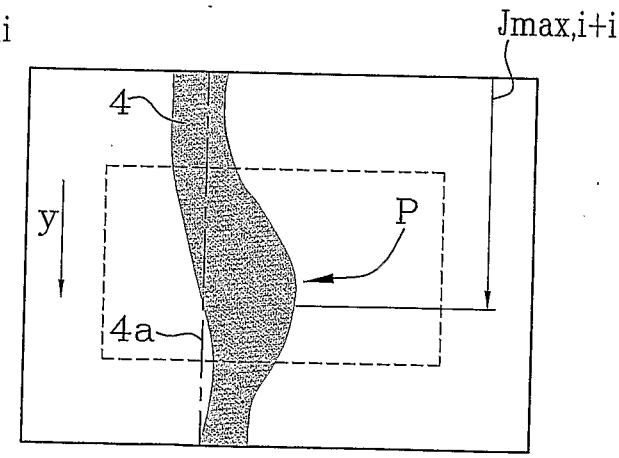
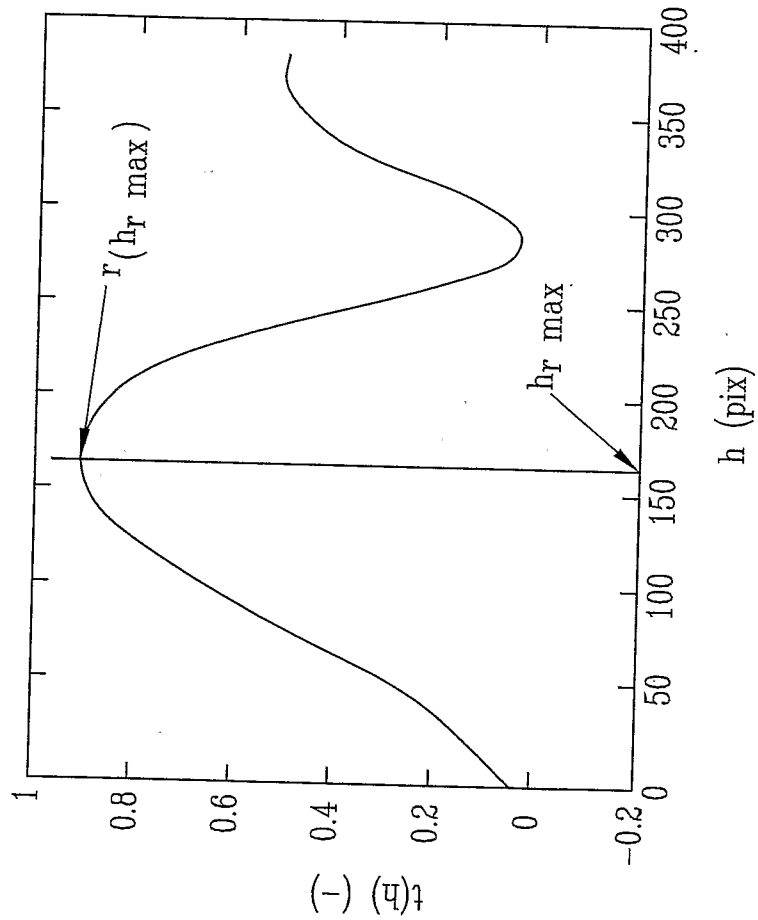


FIG 6


r(h)
1
0.8
0.6
0.4
0.2
0
-0.2
0
50
100
150
200
250
300
350
400
h (pix)
r(hr max)
hr max

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2007/000817

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01F1/66 C03B37/05

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01F C03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC, COMPENDEX, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2005 233679 A (ISHIKAWAJIMA HARIMA HEAVY IND) 2 September 2005 (2005-09-02) abstract	1,2, 4-10, 12-15
A	JP 56 147013 A (KYOTO ELECTRONICS MFG) 14 November 1981 (1981-11-14) abstract	1,13
A	US 5 170 060 A (MAILLARD ALAIN [FR] ET AL) 8 December 1992 (1992-12-08) column 3, lines 9-19; claims 1,3,5; figure 2b column 6, lines 31-42	1,13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 July 2008	29/07/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Creux, Sophie

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IT2007/000817

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2005233679 A	02-09-2005	NONE	
JP 56147013 A	14-11-1981	NONE	
US 5170060 A	08-12-1992	AR 246610 A1	31-08-1994
		AT 146587 T	15-01-1997
		AU 650283 B2	16-06-1994
		AU 8466391 A	09-04-1992
		BR 9104281 A	09-06-1992
		CA 2052530 A1	05-04-1992
		DE 69123685 D1	30-01-1997
		EP 0479676 A1	08-04-1992
		FI 914658 A	05-04-1992
		FR 2667689 A1	10-04-1992
		JP 4248415 A	03-09-1992
		NO 913865 A	06-04-1992
		TR 28899 A	05-08-1997
		ZA 9107603 A	24-06-1992