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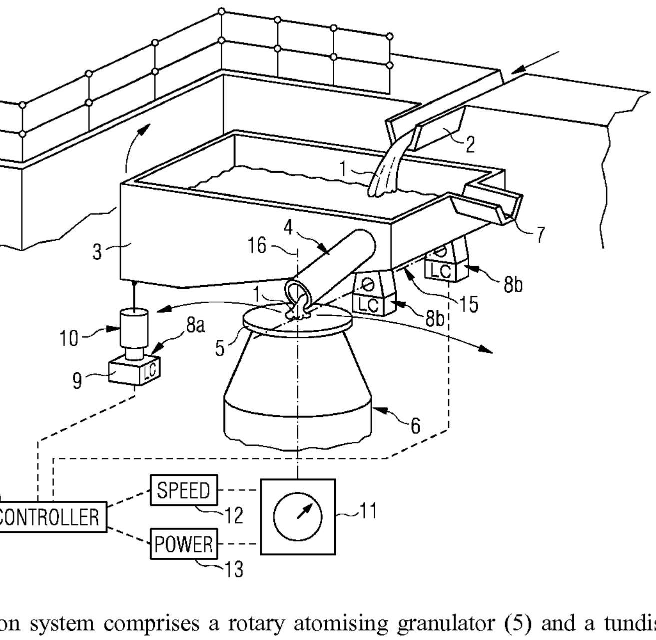
(54) Title: DRY SLAG GRANULATION SYSTEM AND METHOD

FIG 1



(57) Abstract: A dry slag granulation system comprises a rotary atomising granulator (5) and a tundish (3); wherein the tundish comprises a delivery outlet (4), an overflow outlet (7) and a set of moveable mounts (8a, 8b). The device further comprises at least one of a tundish weight sensor (9), a granulator drive motor power sensor (13), a granulator drive motor current sensor and a granulator drive motor speed sensor (12). A controller (14) receives measurements from at least one of the sensors and controls angle of inclination of the tundish on the moveable mounts; or speed of rotation of the granulator in accordance with the received measurements. The moveable mounts allow movement of the tundish to any orientation between a first, substantially vertical, orientation and a second, substantially horizontal, orientation.

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DRY SLAG GRANULATION SYSTEM AND METHOD

This invention relates to a dry slag granulation system, for creating granulated glassy slag, in particular using a rotary atomising granulator.

The slag material may be of any type, for example, metal based, such as iron; a metal oxide, such as titanium oxide; a non-metal, such as slag generated as a by-product of a metals production process; or a mixture thereof. In the example of slag derived from a metals production process, when blast furnace slag is tapped from a furnace, the slag flow is variable and can result in short term peaks in a flow rate which overall has a generally increasing trend. In a typical blast furnace, high slag flow rates may be as much as 6 to 12 tonnes per minute, which can overwhelm the granulator with the potential for damage to the granulator and downtime in operation. There is a particular problem in systems which are coupled to a heat recovery mechanism as the heat recovery mechanism cannot easily cope with peaks and troughs in slag (and hence heat) supply.

The problem is not relevant to wet slag granulation, which is not so sensitive to irregular flow because wet slag granulation involves use of an oversupply of water and there is no facility for heat recovery. Dry slag granulation is not a well developed technology and the problems associated with the need for a steady flow have not been addressed to date.

In accordance with a first aspect of the present invention, a dry slag granulation system comprising a rotary atomising granulator and a tundish; wherein the granulator comprises a cup or disk; wherein the tundish comprises a delivery outlet, an overflow outlet and a set of moveable mounts; and wherein the device further comprises at least one of a tundish weight sensor, a granulator drive motor power sensor, a granulator drive motor current sensor and a granulator drive motor speed sensor; the device further comprising a controller to receive measurements from at least one of the sensors and to control angle of inclination of the tundish on moveable mounts; or speed of rotation of the granulator in accordance with the received measurements; wherein the moveable mounts allow movement of the tundish to any orientation between a first, substantially vertical, orientation and a second, substantially horizontal, orientation.

The invention stabilises the slag flow thereby allowing a better optimised design of the granulator and heat recovery system to be used.

At the first orientation, effectively the maximum tilt of the tundish, the slag flows in and out of the tundish, with little or no storage effect. At the second orientation, effectively the minimum tilt, the available storage volume is at its maximum. Once this storage has been used up, any additional slag flows out of the overflow outlet.

Preferably, the moveable mounts further comprise load cells.

Preferably, the system further comprises a heat recovery system coupled to the granulator.

In accordance with a second aspect of the present invention, a method of operating a dry slag granulation system comprising a rotary atomising granulator and a tundish, the tundish having a delivery outlet and an overflow outlet and a set of moveable mounts comprises supplying slag to the tundish; measuring at least one of tundish weight, granulator drive motor power, granulator drive motor current; and granulator drive motor speed; and controlling angle of inclination of the tundish by means of the moveable mounts in accordance with the measurements; wherein, the angle of inclination of the tundish is varied by moving the tundish to any orientation between a first, substantially vertical, orientation and a second, substantially horizontal, orientation.

Preferably, when measured power exceeds a threshold for power, moving the tundish towards the second orientation

Typically, moving the tundish towards the second orientation increases the size of a storage buffer and moving the tundish towards the first orientation reduces the size of the storage buffer.

Preferably, when the slag has filled the storage buffer at the second orientation, additional slag is discharged through the overflow outlet.

Preferably, when measured speed exceeds a threshold for speed, moving the tundish towards the second orientation.

Preferably, when measured speed of the granulator drive motor falls outside a predetermined range for speed, modifying the speed of the drive motor to bring it back within the range..

Preferably, when measured power or current of the drive motor falls outside a predetermined range for power or current, modifying the power or current of the drive motor to bring it back within the range.

Preferably, when measured weight falls outside predetermined thresholds for weight, modifying the speed of rotation of the granulator.

Preferably, when measured speed exceeds a threshold for speed, reducing power to the granulator.

Preferably, when measured weight exceeds a safety threshold for weight, tilting the tundish to discharge slag through the slag overflow outlet to a slag pit.

An example of a dry slag granulation system and a method of operation will now be described with reference to the accompanying drawings in which:

Figure 1 illustrates an example of a dry slag granulation system according to the present invention;

Figure 2 is a graph illustrating one aspect of operation of the system of Fig.1;

Figure 3 is a graph illustrating another aspect of operation of the system of Fig.1; and,

Figure 4 is flow diagram illustrating a control process for operation of the system of Fig.1.

During blast furnace operation the flow rate and direction of flow of molten materials can be controlled using sand dams of various heights. In this case, any slag flow rate above that required is diverted to an open slag pit. However, for efficient heat recovery in dry slag granulation it is advantageous to store peak flows for granulation later when either the flow from the furnace reduces, or at the end of the slag tapping period.

An intermediate storage vessel having an outlet orifice near its base to control the downstream flow may be used. In this case the intermediate vessel, which may be a slag pot fitted with a discharge orifice, needs to be of sufficient height to provide the necessary volume for storage. As the vessel fills, the flow rate through the orifice increases, but, because the flow rate is a function of the square root of the slag depth, the variation in slag flow to the downstream device is much reduced. Since the storage volume is limited, an overflow to a slag pit is provided.

The disadvantage of the intermediate vessel is the height requirement. In many blast furnace plants there may not be sufficient height available to allow slag to pour into the top of the vessel and discharge at its base into the top of the granulator.

Fig.1 shows one embodiment of a slag granulation system according to the present invention. Slag 1 flows along a slag runner 2 from a taphole in a blast furnace (not shown) and the molten slag collects in a tundish 3. The tundish has a delivery outlet 4, which discharges slag onto a rotating disk 5 of a rotary atomising granulator 6, rotating about an axis of rotation 16 and the tundish also has an overflow outlet 7 to direct excess slag to a slag pit. The disk may be flat, or concave, i.e. a cup or dish shaped rotating disk. The tundish 3 is mounted on moveable mounts 8a, 8b, which in this example are illustrated as comprising load cells 9. At least one of the moveable mounts 8a is provided with a drive mechanism 10 to enable the tundish to be tilted about a pivot axis 15 running through one or more other ones of the moveable mounts 8b in order to tilt the tundish 3, so that slag flows towards the overflow outlet 7 during excessive slag flow rate operation when the tundish is full, During normal operation, the tundish is pivotable, so that the angle of inclination of the tundish may be varied. At one extreme, the tundish has a substantially horizontal orientation as shown in Fig.1 where the tundish has a storage function and no inclination is applied. At the other extreme, the angle of inclination has moved through 90 degrees to a substantially vertical orientation (not shown), where slag flows directly through the delivery outlet onto the rotating disc, without any substantial amount collecting and being stored in the tundish. The angle of inclination may take any value between these two extremes of horizontal and vertical orientation.

The granulator 6 further comprises a drive motor 11 to rotate the disk 5 and the system is provided with a drive motor power sensor 13 or current sensor, which is coupled to a controller 14. The controller also receives signals from the load cells 9. A drive motor speed sensor 12 may also be provided.

An additional feature of the tundish system (not shown) is a hood and blast furnace gas burner to maintain the temperature at the surface of the slag and eliminate the formation of a slag skull in the tundish.

Fig.2 shows how as tundish weight varies with slag casting time, the speed at which the disk, or cup, is rotated may be automatically selected in response to data received by the controller 14. When the tundish is at or near to its minimum weight, the speed of rotation of the disk 5 is set to a first value, typically around 800 rpm. As the slag flows into the tundish, the weight increases until the weight sensed by the load cells 9 reaches a predetermined maximum permitted safe value 20. Reaching the maximum causes the controller to increase the disk speed by a predetermined amount, in this example 100 rpm, to increase the slag flow rate that the granulator processes at.

If the speed of the disk has already reached its maximum permitted value, then, the controller causes the tundish to pivot such that excess slag is poured out of the overflow outlet to a slag pit. The effect of the increase in speed of rotation is to gradually reduce the weight of the tundish, assuming that the inward flow of slag has not changed, until the weight reaches its minimum permitted level 21 for that speed again, triggering the controller to reduce the disk speed by a predetermined amount.

Fig.3 illustrates change in speed with drive power for the rotating cup 5 for the purpose of selecting power. Maximum speed and power settings for the drive motor in operation mean that the relative values need to be optimised. Speed to power relationships are preferably in a target operating region 22, but if they stray into region 23, where the measured speed is high relative to the power, then the controller causes a reduction in speed, whereas if the relationship moves into the region 24, where the measured power is high relative to speed, then the controller causes the speed to increase to bring it back into the target range 22. The controller may combine this with data on changes in weight of the tundish to optimise each parameter, or to make use of the overflow if any other modification is not within permitted ranges.

Operation of the system of the present invention is illustrated in the flow diagram of Fig. 4. This example assumes that all the parameters, tundish weight, motor power or current and motor speed are measurable and variable, but the system may still be operated even if there is only one measureable or variable parameter available. Initially, the tundish is set to maximum tilt 30, i.e. a vertical orientation and the required cup speed is set 31 (if variable) or the motor is started (if the speed is fixed) The control system 14 operates in the following manner. The tundish weight is read 32. If the weight is within safe operating limits 33, 34, the cup motor’s power consumption or current is read 35. If the measured motor power/current 34 is within the normal operating range and not too high 36, 37 or too low 40, 47, there is no change to the tundish tilt 48. If the motor power/current is high 38, this indicates that the slag flow rate has increased above the design flow for the granulator. The tundish is untilted 39, i.e. moved to an orientation which is more horizontal to allow excess slag to run into the tundish. If the motor power/current is too low 41, the system checks that the tundish is not fully tilted 42 and, if not 43, the tundish is tilted 45 to increase the slag flow rate and the power/current. If the tundish is already at maximum tilt 44, then this orientation is maintained 46. In the event that the tundish becomes full 49 and the slag flow from the furnace remains above the design flow rate, then a check 50 is made for a further speed band 51 and if there is one, then the disc speed is increased to . If there is no further speed band 50, 52 to move up to the depth of slag in the tundish increases until the slag flows over a weir into the overflow outlet, a slag runner and on to the slag pit, The slag flow to the granulator remains virtually constant since the difference between the normal slag depth and the overflow slag depth is relatively small. The arrangement illustrated in the example of Fig.1 is such that the slag flow to the granulator is not interrupted whilst the overflow is active, but slag is discharged through both outlets 4, 7 at the same time. Optionally, the controller may tilt 54 the tundish towards the overflow outlet 7 to speed up the weight reduction.

The specifics of the heat recovery system are not described, but when molten slag is delivered to the rotating cup within the granulator chamber, the cup is rotated at such a speed that the slag is converted into droplets with minimal slag wool generation. The slag droplets cool in flight before impacting with a cooled wall and entering an air flow that cools the slag further, finally resting in an an air cooled fixed bed of granulated slag from which it is discharged at a controlled rate. The air flow rate is controlled in such a manner that the air leaving the granulator chamber is at about 600°C. This heated air may be used in different ways depending upon requirements. Hot air may be used to preheat or dry raw materials prior to use in the process. It may be passed through a boiler/heat exchanger in which steam is generated. The steam may then be used to generate electricity. A further benefit of the system described is that the granulated blast furnace slag produced is glassy and can be used as a substitute for Portland cement.

The invention is able to regulate the flow of slag to the granulating device by use of a tipping tundish, which acts as a storage buffer, with an overflow facility, and enables the granulator to operate either at a fixed maximum slag flow rate, or with speed control. When the slag flow from the blast furnace is below the design flow of the granulator, the tundish operates at its maximum tilt and the slag runs in and out of the tundish along a narrow slag runner within the tundish. When the slag flow exceeds the design flow of the granulator, as specified by the power/current consumption of the cup drive motor, the tundish untilts to gradually open a storage volume for the excess slag. In the event of the tundish becoming full in its most horizontal position, any more slag will increase the depth in the tundish so that this slag flows to the slag pit. The process control allows for the handling and storage despite any irregularities in the flow. Optimization of slag flow to the granulating device, which would otherwise be overwhelmed, as described above, makes the system of the present invention suitable for use together with heat recovery system because it gives a more stable heat throughput to the heat recover system. It also means that a smaller granulator and heat recovery system are possible as they do not need to deal with peak flow.

CLAIMS

1. A dry slag granulation system comprising a rotary atomising granulator and a tundish; wherein the granulator comprises a cup or disk; wherein the tundish comprises a delivery outlet, an overflow outlet and a set of moveable mounts; and wherein the device further comprises at least one of a tundish weight sensor, a granulator drive motor power sensor, a granulator drive motor current sensor and a granulator drive motor speed sensor; the device further comprising a controller to receive measurements from at least one of the sensors and to control angle of inclination of the tundish on moveable mounts; or speed of rotation of the granulator in accordance with the received measurements; wherein the moveable mounts allow movement of the tundish to any orientation between a first, substantially vertical, orientation and a second, substantially horizontal, orientation.

2. A system according to claim 1, wherein the moveable mounts further comprise load cells.

3. A system according to any preceding claim, wherein the system further comprises a heat recovery system coupled to the granulator.

4. A method of operating a dry slag granulation system comprising a rotary atomising granulator and a tundish, the tundish having a delivery outlet and an overflow outlet and a set of moveable mounts; the method comprising supplying slag to the tundish; measuring at least one of tundish weight, granulator drive motor power, granulator drive motor current; and granulator drive motor speed; and controlling angle of inclination of the tundish by means of the moveable mounts in accordance with the measurements; wherein the angle of inclination of the tundish is varied by moving the tundish to any orientation between a first, substantially vertical, orientation and a second, substantially horizontal, orientation.

5. A method according to claim 4, wherein, when measured power exceeds a threshold for power, moving the tundish towards the second orientation

6. A method according to claim 4 or claim 5, wherein moving the tundish towards the second orientation increases the size of a storage buffer and moving the tundish towards the first orientation reduces the size of the storage buffer.

7. A method according to claim 4 or claim 5 , wherein, when the slag has filled the storage buffer at the second orientation, additional slag is discharged through the overflow outlet.

8. A method according to claim 4, wherein, when measured speed exceeds a threshold for speed, moving the tundish towards the second orientation.

9. A method according to claim 4, wherein, when measured speed of the granulator drive motor falls outside a predetermined range for speed, modifying the speed of the drive motor to bring it back within the range..

10. A method according to claim 4, wherein, when measured power or current of the drive motor falls outside a predetermined range for power or current, modifying the power or current of the drive motor to bring it back within the range.

11. A method according to claim 4, wherein, when measured weight falls outside predetermined thresholds for weight, modifying the speed of rotation of the granulator.

12. A method according to claim 4, wherein, when measured speed exceeds a threshold for speed, reducing power to the granulator.

13. A method according to claim 4, comprising when measured weight exceeds a safety threshold for weight, tilting the tundish to discharge slag through the slag overflow outlet to a slag pit.

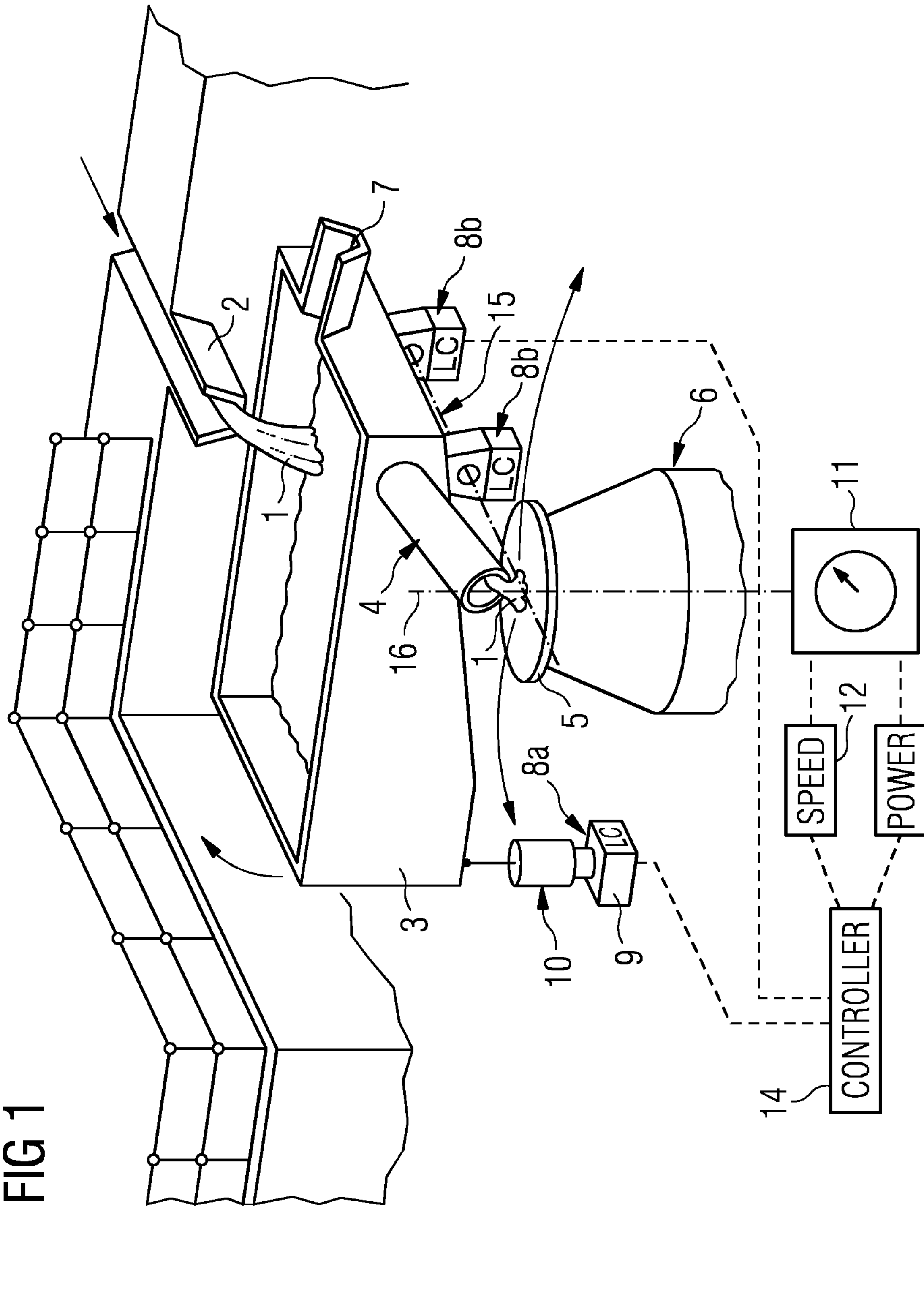

7
2
8b
LC
15
8b
LC
1
6
4
16
1
11
5
SPEED
12
POWER
13
8a
LC
3
10
9
CONTROLLER
14

FIG 1

FIG 2

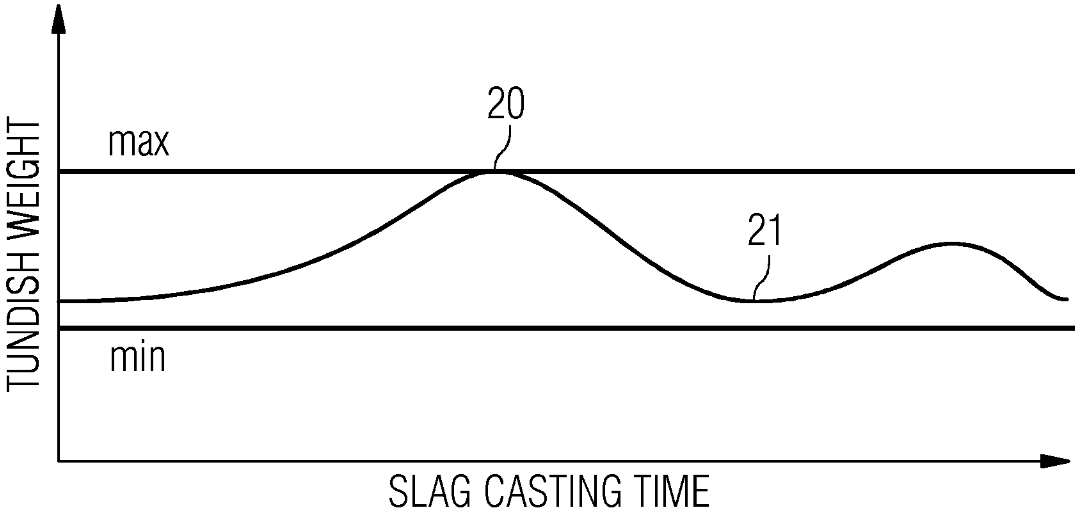

TUNDISH WEIGHT
max
20
21
min
SLAG CASTING TIME

FIG 3

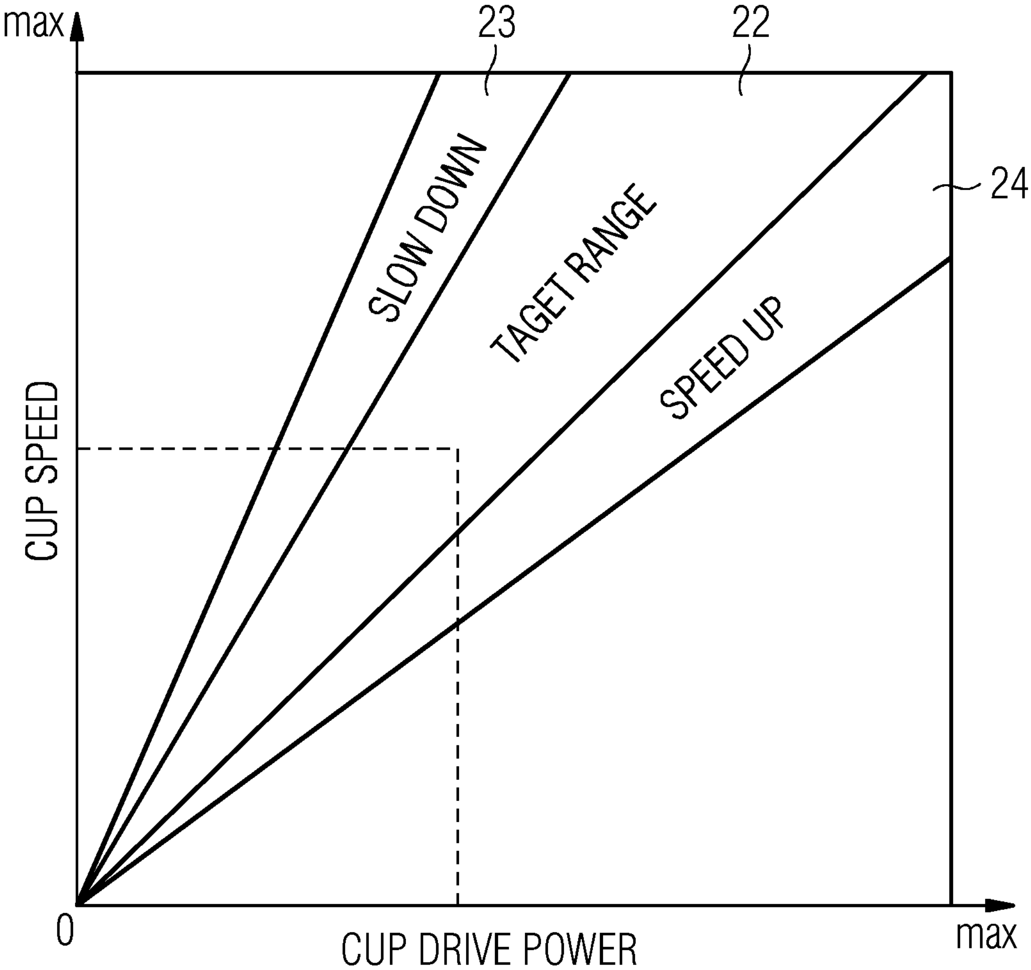
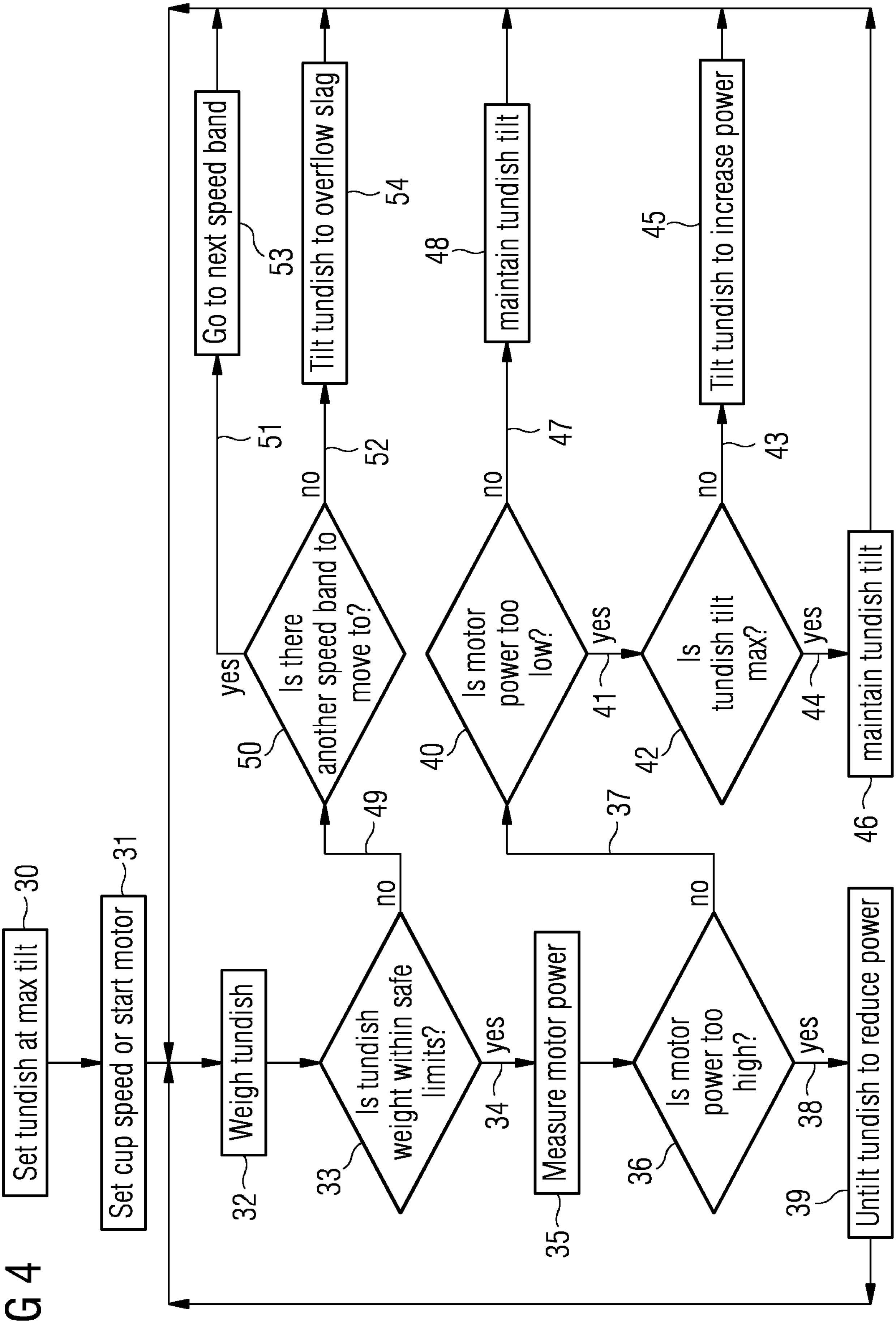

max
23
22
24
SLOW DOWN
TAGET RANGE
SPEED UP
CUP SPEED
0
CUP DRIVE POWER
max

FIG 4


Set tundish at max tilt
30
Set cup speed or start motor
31
Weigh tundish
32
Is tundish weight within safe limits?
33
yes
34
no
49
Measure motor power
35
Is motor power too high?
36
yes
38
no
37
Untilt tundish to reduce power
39
Is there another speed band to move to?
50
yes
51
no
52
Go to next speed band
53
Tilt tundish to overflow slag
54
Is motor power too low?
40
yes
41
no
47
maintain tundish tilt
48
Is tundish tilt max?
42
yes
44
no
43
Tilt tundish to increase power
45
maintain tundish tilt
46

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/074029

A. CLASSIFICATION OF SUBJECT MATTER
INV. C21B3/08
ADD.

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)
C21B

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SU 893 240 A1 (KH POLT I IM V I LENINA [SU]) 30 December 1981 (1981-12-30) abstract figure 1 -----	1-13
A	US 5 259 861 A (YEH JIEN-WEI [TW] ET AL) 9 November 1993 (1993-11-09) figure 2 column 4, line 13 - line 22 -----	1-13
A	DE 10 2010 021661 A1 (SIEMENS AG [DE]) 1 December 2011 (2011-12-01) abstract; figures 2-4 -----	1-13
A	WO 95/05485 A1 (DAVY MCKEE STOCKTON [GB]; FEATHERSTONE WILLIAM BARRY [GB]) 23 February 1995 (1995-02-23) figures 5,6 -----	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
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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 December 2013	07/01/2014

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, Fax: (+31-70) 340-3016	Gimeno-Fabra, Lluis

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/074029

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