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(54) **Title:** CONTINUOUS DOSING DEVICE FOR SOLID OR LIQUID MATERIALS AND RELEVANT OPERATING METHOD

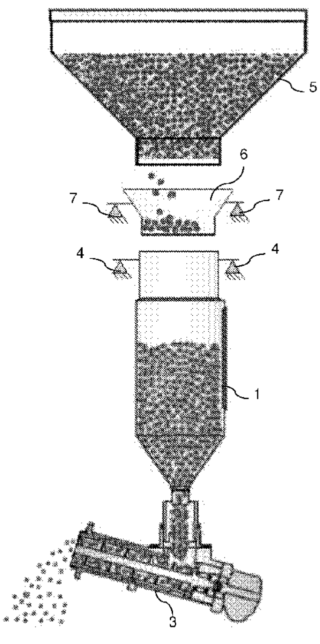

Fig.1

(57) **Abstract:** A continuous dosing device includes a hopper (1) equipped with a first weighing system (4) and configured to feed a material through a continuous feeder (3) and to receive said material from a loader (5), an intermediate hopper (6) being arranged between the hopper (1) and the loader (5) in order to receive the material from the loader (5) and load it into the material hopper (1), the intermediate hopper (6) being equipped with a second weighing system (7) independent from the first weighing system (4).

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CONTINUOUS DOSING DEVICE FOR SOLID OR LIQUID MATERIALS AND RELEVANT OPERATING METHOD

The present invention concerns a continuous dosing device for solid or liquid materials, and in particular a dosing device that allows to control in a substantially continuous way the feeding of the material by a so-called "loss-in-weight" process.

In the following, specific reference will be made to the application of this dosing device to the field of extruded plastic materials to dose plastic material in granules, but it is clear that what is said can also be applied in other fields (e.g. agro-food, pharmaceutical, etc.) to dose bulk materials of any kind, both solid and liquid. Moreover, although this dosing device is particularly advantageous in the simultaneous dosing of multiple materials, its structure and method of operation can also be applied to the dosing of a single material to achieve greater dosing accuracy. Therefore, the use of the term “component” is also intended to cover the case where the dosed component is the only material contained in the single hopper of the dosing device.

It is known that in plastics continuous extrusion processes the extruded material is typically obtained as a combination of several components (so-called recipe), which must be dosed and mixed thoroughly before being fed to the extruder. For this purpose a dosing and mixing equipment is used, which can be basically of two types, i.e. with batch feeding (so-called " gain-in-weight " or batch feeding) or with continuous feeding (so-called "loss-in-weight").

In the first type of equipment, each component is loaded into a hopper without a weighing device and the material is discharged from the hopper by gravity through the timed opening of a bottom gate, so that the material is loaded onto an underlying scale having a capacity defined in volume which determines the batch of dosing. The sequential opening of the different hoppers allows to obtain the dosing batch with the recipe obtained as the sum of partial weighings of the different components, hence "gain-in-weight", until the batch is ready to be discharged into a mixer where the materials are mixed to feed homogeneously and continuously, for example, the screw of the extruder.

The main advantage of the batch feeder is the simplicity of the components used and therefore the reduced cost, while its main limitation is the slowness in achieving the accuracy of the dosing and its hourly flow rate. In fact, the extruder flow rate is measured and adjusted in terms of the number of batches discharged over time, therefore the batch feeder opposes a great "inertia" to any error correction.

Moreover, the quantity of each component is dosed by estimating the opening time of the gate, i.e. the fall time necessary for the component to escape from the hopper and reach the scale where it is weighed, therefore the measurement is approximate and strongly dependent on the granulometry and density of the material, which are parameters that influence the fall speed. This type of dosing device therefore has the disadvantage of not allowing the formation of precise mixtures and of requiring long times for the preparation of each batch, due to the need to carry out a series of sequential weighings with the relative settlement transients of the scale between two successive weighings to allow the damping of the vibrations caused by the fall of the previous component.

In the second type of equipment, each component is loaded into a hopper equipped with an independent weighing device (e.g. load cells), and by adjusting the transport system associated with the hopper outlet (e.g. motorized auger) it is possible to keep the feeding flow of each component making up the recipe constant over time in the due ratio with the other components. In the following we will refer to continuous dosing devices with motorized auger but the principle applies to all continuous conveying systems whether they are spirals, vibrating channels or other.

All components are thus individually weighed in hoppers mounted on load cells detecting the weight reduction of the hopper, hence "loss-in-weight", and dosed simultaneously in a continuous way in a collection hopper, which in turn can be equipped with a weighing device. Mixing takes place naturally thanks to the simultaneous feeding into a cascade mixer, i.e. a funnel connecting the augers to the collection hopper.

The weight of the material in the collection hopper can be measured constantly in order to detect level changes due, for example, to changes in extruder performance, or a discrepancy between the component feeder and the extruder performance. The feeders are individually controlled to maintain the pre-set dosing ratios of the various components of the recipe, and globally to maintain a constant level in the collection hopper and consequently the correct extruder flow rate.

The presence of various augers, motors and load cells obviously makes a continuous dosing device more complex and expensive than a batch dosing device, but it has the great advantage of being extremely reactive and therefore ensuring the instantaneous achievement of dosing accuracy and hourly flow rate. In addition, dosing can take place much faster as the quantities of the recipe components are measured and fed simultaneously, and discharging them directly into the cascade mixer also improves the mixing of the different components.

A critical aspect of the continuous dosing device, however, is represented by the charging phase of the weighed hopper of the component because in this phase the degrees of freedom of the system increase, since to the outgoing flow through the auger calculated up to now is added the incoming flow from the loader, and the variables of the problem increase to two while the data acquisition signal coming from the hopper load cells continues to remain one. The problem therefore remains undetermined and the dosing device works temporarily without an effective weight loss control but simply assuming a constant auger feeding value, since there is no way to predict and compensate what happens during the loading phase.

In fact, the fall of the material from the feeder into the hopper causes variations in the density of the material and in the head present at the outlet of the hopper, with the consequence of irregularities in the filling of the auger and/or variations in the flow rate during the hopper refilling time. All this inevitably has a negative effect on the dosing accuracy both in terms of the ratio between components, in a multi-component dosing device, and in terms of hourly flow rate, even in a single-component dosing device.

The risk of dosing errors in the hopper refilling phase increases the longer the refilling time, the larger the refilled quantity and the more inconsistent the material behaviour, so the problem becomes very evident in the case of re-ground materials and/or materials with irregular grain size. Note that, due to the above-mentioned problem of scale settlement transients at each refill, it is not convenient to reduce the refill time by making smaller but more frequent refills as this implies an overall increase in the period of uncertainty.

A simple solution to overcome this problem of the recharging phase is to provide two continuous feed hoppers for each component, arranged in series or in parallel, so as to almost totally eliminate the time in which the system cannot perform weight loss control.

In the case of hoppers in series, the first hopper continuously feeds the second hopper and the control unit can control the weight loss of the latter as it receives information both of the incoming and outgoing flow into it. By suspending the feeding from the first to the second hopper during the refilling of the first hopper, the system operates during the refilling phase as a normal continuous dosing device with a single hopper per component by detecting the weight of the second hopper feeding the collection hopper.

FR 2572520 describes a continuous dosing device of this type in which the second hopper is hanging from the first hopper, so that a first weighing system connected to the first hopper detects the total weight loss of the two connected hoppers while a second weighing system connected to the second hopper detects only the weight loss of the latter. When the first hopper is empty, the connection between the two hoppers is interrupted and the auger control only proceeds with the second hopper according to its weighing system signal while the first hopper is refilled. After that, when the connection between the two hoppers is restored, the auger control is again based on the first weighing system.

In this way, however, the two weighing systems are not independent and the quantity of material loaded into the first hopper cannot be measured separately but only by difference between the total weight and the weight detected by the second weighing system, so that any errors or malfunctions of one of the weighing systems are not easily detected and affect the continuous operation of the entire dosing device. Furthermore, since the two hoppers are continuously connected until the first hopper empties and the latter is as large as the second hopper, there is a considerable difference in the weight of the material in the two hoppers as a whole between when the first hopper is full and when it is almost empty. This results in unstable feeding and flow conditions of the conveyor screw, as the density of the material and the head at the outlet of the second hopper undergo corresponding considerable variations This is also the case when the first full hopper is reconnected to the second hopper, as the head at the outlet of the second hopper practically doubles instantly.

DE 3742229 describes a continuous dosing device with a similar structure in which, however, it is the second hopper that supports the first hopper, so that a first weighing system connected to the first hopper only detects the weight loss of the first hopper while a second weighing system connected to the second hopper detects the total weight loss of the two hoppers. In this case the two hoppers are not constantly connected, since the first hopper is opened only when it is necessary to recharge the second hopper, and the auger control is always performed according to the signal of the second "total" weighing system.

In particular, while the first hopper is refilled, this "total" signal is compensated by subtracting from it the signal of the first weighing system, which is then reset to zero when said refilling of the first hopper is completed. In this way, the signal of the second weighing system again corresponds to the weight of the material contained in both hoppers, even before the second hopper is refilled from the first hopper and regardless of when the refilling takes place.

Also this dosing device, therefore, has the same drawbacks due to the fact that the two weighing systems are not independent, and both of the above mentioned dosing devices do not solve the problem of the settlement transients of the weighing system at each refilling of the first or second hopper, creating anyway an uncertainty in the system. In fact, the signal of the first weighing system that detects the weight of both hoppers, as in FR 2572520, is disturbed by the transient due to the fall of the material when the two hoppers are reconnected to refill the second hopper, while the signal of the first weighing system that detects only the weight of the first hopper, as in DE 3742229, being subtracted from the signal of the second weighing system disturbs it by transmitting thereto its transient during the refilling of the first hopper.

In the case of hoppers in parallel, the operating modes increase because the two hoppers can work incrementally, for example by feeding 50% of the material each under steady conditions and then feeding 100% of the material alternatively to allow stopping for the refilling phase of one of the two hoppers, or by limiting the flow rate of one or the other hopper to the desired percentage during the refilling phase.

WO 99/63310 describes a continuous dosing device of this type in which the auger feed hopper alternately receives material from a first of two filling hoppers which is continuously connected to it until it is almost empty. At this point, the first near-empty hopper is closed and at the same time the second filling hopper is opened, which is full and remains connected to the feed hopper, while the first closed hopper is filled via a loading tube (the reverse happens when the second hopper is near-empty). Since each of the two filling hoppers has its own weighing system, as does the feed hopper, the continuous dosing method proposed in this document is based on the sum of the weight loss signals of the feed hopper and the filling hopper connected thereto so that the feed hopper is always full and there is continuity of material flow between the two connected hoppers.

This solution is obviously very expensive, as it implies a doubling of the hoppers and related devices (load cells, gates, etc.), and makes the dispenser very cumbersome, thus being practically inapplicable in the case of dispensers that have to feed many different components to make complex recipes.

The object of the present invention is therefore to provide a continuous dosing device that is free from the above-described drawbacks. This object is achieved by means of a continuous dosing device in which each weighed hopper of a component is not reloaded directly by the relative loader but indirectly through an intermediate weighed hopper, which is arranged between the component hopper and the loader so as to receive from the latter the material to be reloaded and discharge it into the component hopper through its own bottom gate only after weighing it with its own weighing system independent of the weighing system of the component hopper. Further advantageous features of this continuous dosing device are specified in the dependent claims.

The main advantage of this dosing device is therefore that, thanks to the presence of the intermediate weighing hopper equipped with an independent weighing system, the period of absence of weight control is practically eliminated or at least considerably reduced during the refilling phase because the amount of material that is discharged into the component hopper is known having already been weighed in the intermediate hopper, so that the above-mentioned problem of the non-determination of the two-variable equations is solved. In fact, the weighed quantity contained in the intermediate hopper, when discharged, will be added to the quantity of material in the component hopper allowing to keep active the evaluation of weight loss even during the settlement transient.

In reality also the recharge coming from the intermediate hopper has a fall time and a fall law and this can generate a transient with remaining error, which is however measured and compensated and can also be limited with a good dimensional design of the intermediate hopper and the modelling of the fall cycle.

A second advantage of this dosing device is that it allows more frequent component hopper refilling cycles, since the problem of the settlement transient is overcome by the upstream weighing in the intermediate hopper, with reduced quantities of material and very short times resulting in very short uncertainty periods and a considerable increase in the accuracy of the control of the whole system. In particular, the variation in the level of material in the component hopper is reduced, making the feeding and flow conditions of the conveyor screw more stable, since the material density and the head at the hopper outlet undergo less variations.

A third advantage of the above mentioned dosing device is that since the amount of material discharged from the intermediate hopper has been weighed beforehand and is therefore known, any small transient variations can be compensated for immediately.

Another advantage of the dosing device in question is the verification of consistency between the hourly flow rates measured independently by the two weighing systems of the intermediate hopper and the component hopper, which introduces an innovative self-diagnosis function since the two systems measure the same flow over time and must indicate the same hourly flow rate. In case of data misalignment it is possible to report the anomaly, identify the load cell or the element subject to deviation and in some cases proceed, with the consent of authorized personnel, to compensate the error.

Another advantage of this dosing device is that it can be easily realized with the addition of small, simple and cheap devices. In this way, its cost and overall dimensions compared to a prior art continuous dosing device are only slightly higher, while they are considerably lower than the above-mentioned solution with the doubling of the continuous feeding hoppers.

Further advantages and characteristics of the dosing device according to the present invention will be evident to those skilled in the art from the following detailed and not limiting description of an embodiment thereof with reference to the annexed drawings in which:

Fig.1 is a frontal schematic view of a dosing device according to the present invention when loading the material into the intermediate hopper;

Fig.2 is a frontal schematic view of a pair of dosing devices like the one in Fig.1 applied to a continuous extrusion plant of a two-component material; and

Figs.3 and 4 are diagrams showing the trend over time of the quantity of material present in the component hopper and of the specific flow rate of the relevant feeding screw, respectively for a traditional dosing device and for a dosing device according to the invention.

Referring to Figs.1-2, it can be seen that a continuous dosing device according to the present invention traditionally includes a hopper 1 that feeds a component of the material to be extruded to an underlying collection hopper 2 through a feeding screw 3 that flows into a cascade mixer 8. In the example of a plant in Fig.2 there are two component hoppers 1 which, like collection hopper 2, are weighed hoppers whose weight is constantly detected by relative weighing systems, for example load cells 4, operationally connected to a control unit (not shown) which also controls screws 3 to ensure the accuracy of the mixture to be extruded. However, as mentioned above, hoppers 1 could be more and collection hopper 2 could be without weighing systems.

A loader 5 is located above hopper 1 to load therein a given quantity of material when the quantity contained in hopper 1 falls below a set threshold, according to the commands received from the control unit. Note that although loader 5 shown in Fig.1 is a simple hopper equipped with a bottom gate that dispenses the material by gravity, other types of loaders could be used in the same way (e.g. pneumatic, auger, vibrating channel, etc.).

Hopper 1 does not receive the material directly from loader 5 because an intermediate hopper 6 is located between hopper 1 and the overlying loader 5, in order to receive the material from loader 5 and discharge it by gravity into hopper 1 by opening its own bottom gate according to the commands received from the control unit.

The innovative aspect of the dosing device according to the present invention lies in the fact, as mentioned above, that the intermediate hopper 6 is an independently weighed hopper whose weight is constantly detected by a relative weighing system, for example load cells 7, operationally connected to the control unit. In this way, the weight of the quantity of material contained in the intermediate hopper 6 can be added to the weight of the material contained in hopper 1 below when reloading the latter.

It should be noted that although in the example of plant in Fig.2 the two dosing devices according to the invention feed the collection hopper 2 through the cascade mixer 8, they could also be used to directly feed an extruder or other type of machine or to fill containers for the preparation of batches of multi-component material to be used on other machines.

The advantages of this innovative configuration of the dosing device are evident from the comparison between the diagrams in Figures 3 and 4, which respectively illustrate the different performances in feeding a non-homogeneous ground material for a traditional dosing device and a dosing device according to the invention operating with very similar values of hourly flow rate and speed of rotation of the feeding screw.

More specifically, the diagram in Fig.3 shows the weight of the material in hopper 1 of a traditional continuous dosing device with a capacity of 425 kg/h and a replenishment quantity of 30 kg (from a minimum of 8 kg to a maximum of 38 kg), which results in a replenishment interval of about 254 seconds and a replenishment time of about 5 seconds. Similarly, the diagram in Fig.4 shows the weight of the material in hopper 1 of a continuous dosing device according to the invention with a capacity of 405 kg/h and a replenishment quantity of 5 kg (from a minimum of 5.9 kg to a maximum of 10.9 kg), which results into a replenishment interval of about 44 seconds and a replenishment time of less than 1.5 seconds.

In the first case, the feeding screw operates at a speed of 77.8 rotations per minute (rpm) and the line indicating the value of the specific screw capacity displays considerable undulations, with an average value of 5.463 kg/h per rpm and a maximum semi-dispersion of 1.116 kg/h per rpm, which corresponds to 20.43%. In the second case, on the contrary, said line is very little wavy, with an average value of 5.344 kg/h per rpm and a maximum semi-dispersion of 0.168 kg/h per rpm, which corresponds to

3.14%.

It is therefore evident that with the dosing device according to the present invention it is possible to replenish each component in such a way as to disturb as little as possible the regular operation of the dosing unit and of the system it feeds, minimizing the periods of absence of control and the variations in the dosing of the components and in the flow rate. In this regard, it is preferable that the capacity of the intermediate hopper 6 is not more than 50% of the capacity of the material hopper 1, more preferably not more than 30%, so as to maintain a high frequency of refilling with small quantities of material that minimize the variations in the feeding conditions of auger 3.

It is clear that the embodiment of the dosing device according to the invention described and illustrated above is just an example susceptible to numerous variations. In particular, the exact shape and arrangement of the elements can vary somewhat depending on specific construction requirements as long as the general structure described above is maintained. For example, load cells 4, 7 could be located in other positions or replaced by other weighing devices.

CLAIMS

1. Continuous dosing device comprising a material hopper (1) provided with a first weighing system (4) and configured to feed a material through a continuous feeder (3) and to receive said material from a single intermediate hopper (6) arranged between said material hopper (1) and a loader (5) so as to receive the material from said loader (5) and to subsequently load it into the material hopper (1), said intermediate hopper (6) being provided with a second weighing system (7), as well as a control unit that is operatively connected to said continuous feeder (3), to said weighing systems (4, 7), to the intermediate hopper (6) and to said loader (5), **characterized in that** the two weighing systems (4, 7) are independent of each other such that each of them detects only the weight of the respective hopper (1, 6), **and in that** said control unit is configured to use only the signal of the first weighing system (4) to control the continuous feeder (3), said signal being integrated with the signal of the second weighing system (7) only at the time when the material is discharged from the intermediate hopper (6) to the material hopper (1).

2. Dosing device according to claim 1, **characterized in that** the weighing systems (4, 7) of the material hopper (1) and/or the intermediate hopper (6) consist of load cells.

3. Dosing device according to claim 1 or 2, **characterized in that** the intermediate hopper (6) is provided with a bottom gate to discharge the material by gravity in the material hopper (1) by opening said bottom gate.

4. Dosing device according to any of the preceding claims, **characterized in that** the loader (5) is provided with a bottom gate to discharge the material by gravity in the intermediate hopper (6) by opening said bottom gate.

5. Dosing device according to any of the preceding claims, **characterized in that** the capacity of the intermediate hopper (6) is not greater than 50% of the capacity of the material hopper (1), preferably not greater than 30%.

6. Operating method of a continuous dosing device according to any of the preceding claims, comprising the steps of:

a) continuously detecting the weight of the material contained in the material hopper

(1) by means of the first weighing system (4);

b) commanding the loader (5) to dispense a pre-set amount of material to the material hopper (1) when the weight of the material contained therein falls below a set threshold;

c) loading the amount of material of the preceding step into the intermediate hopper (6) arranged between the loader (5) and the material hopper (1);

characterized in that it further includes the steps of

d) detecting the exact weight of said amount of material by means of the second weighing system (7) upon termination of the settlement transient;

e) loading said amount of material into the material hopper (1) from the intermediate hopper (6) and simultaneously communicating to the control unit the weight value detected in the preceding step to add it to the continuously detected weight of the material contained in the material hopper (1).

7. Method according to the preceding claim, **characterized in that** it further includes the steps of:

f) checking the consistency of the hourly flow rates detected independently by the two weighing system (4, 7) and, in case of misalignment of the data collected by said weighing systems (4, 7),

g) reporting the anomaly and possibly identifying the element subject to deviation and proceeding to error compensation.

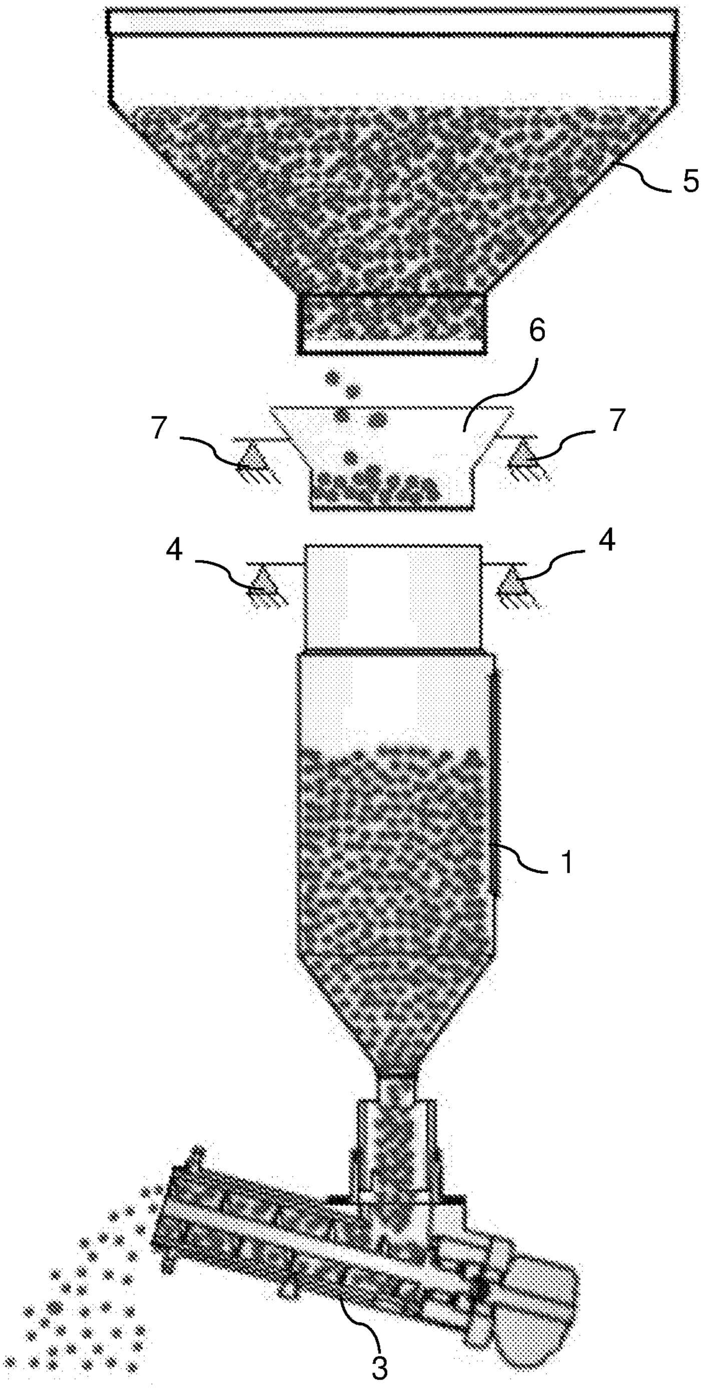

Fig.1

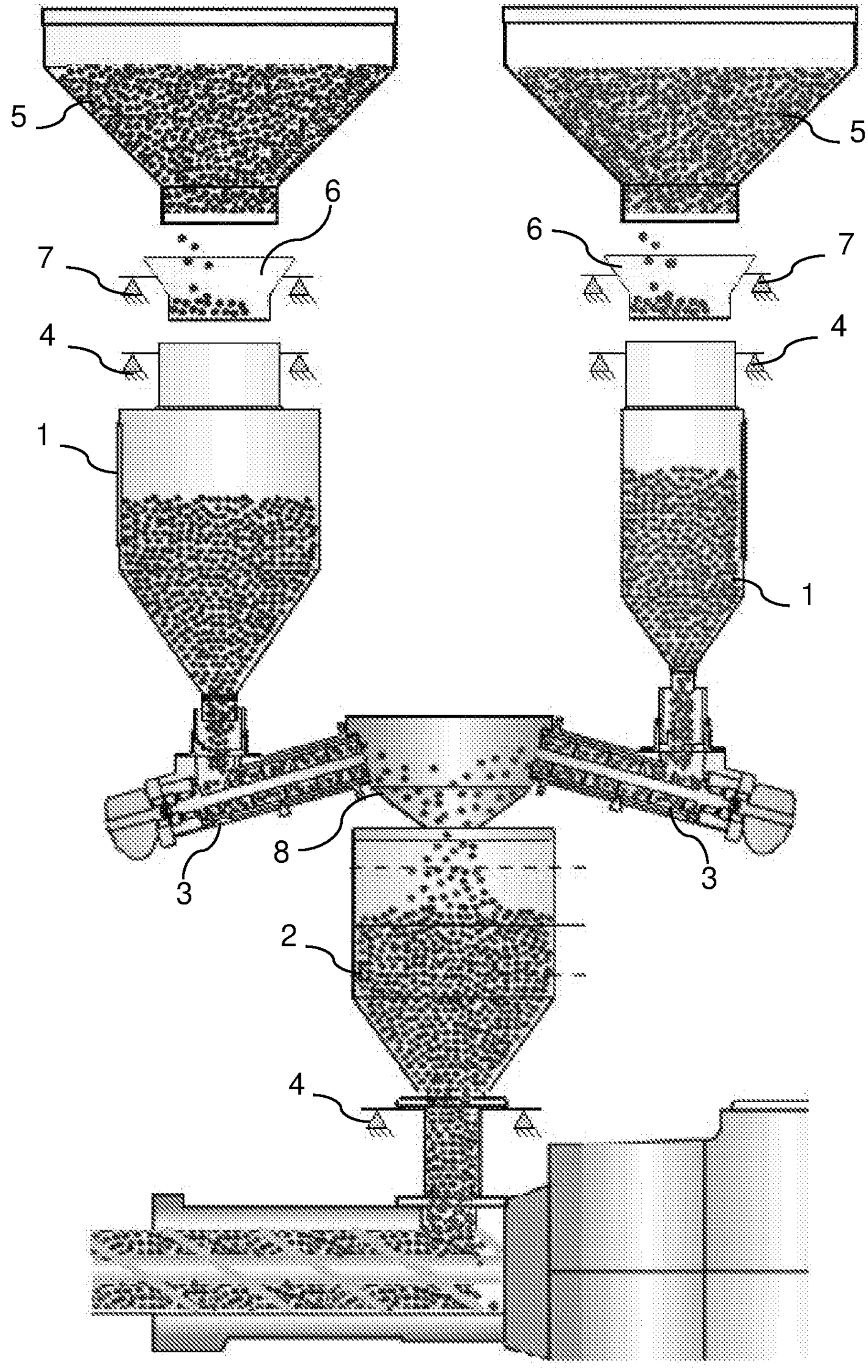

Fig.2

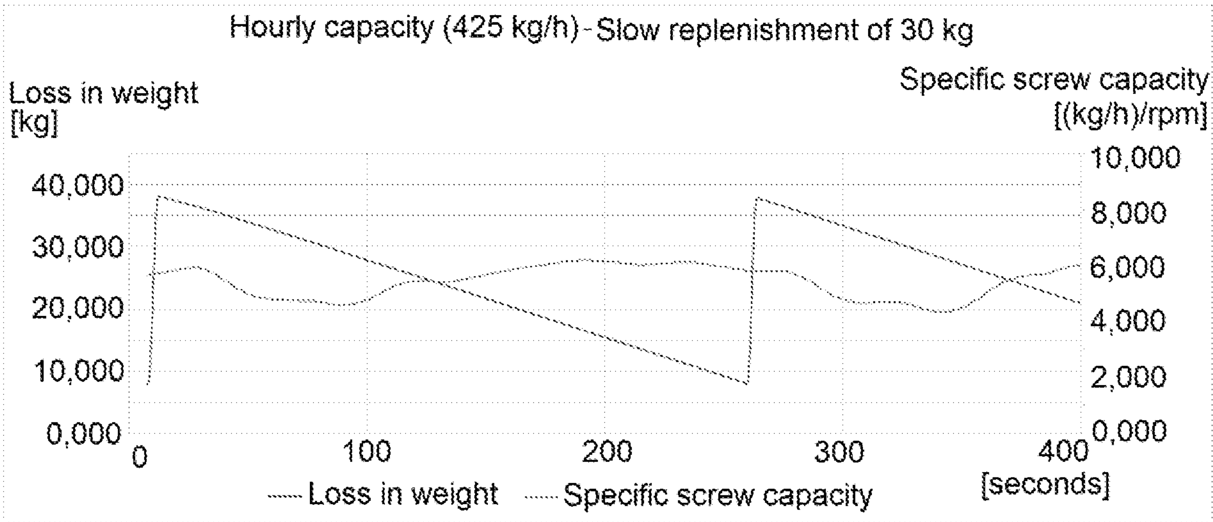
Hourly capacity (425 kg/h) - Slow replenishment of 30 kg
Loss in weight [kg]
Specific screw capacity [(kg/h)/rpm]
40,000
30,000
20,000
10,000
0,000
10,000
8,000
6,000
4,000
2,000
0,000
0
100
200
300
400
[seconds]
Loss in weight
Specific screw capacity

Fig.3

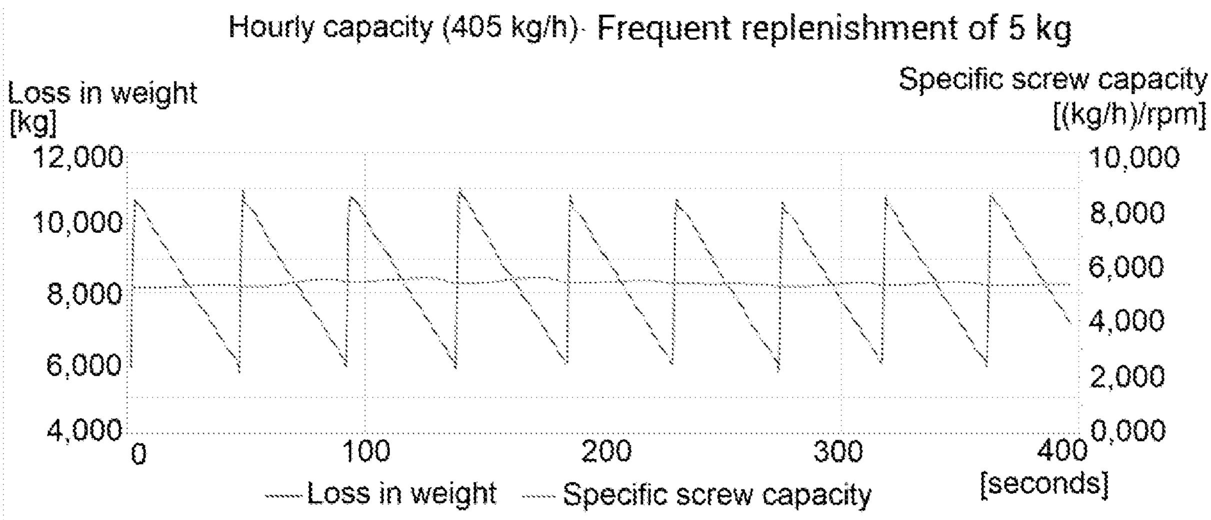
Hourly capacity (405 kg/h)- Frequent replenishment of 5 kg
Loss in weight [kg]
Specific screw capacity [(kg/h)/rpm]
12,000
10,000
8,000
6,000
4,000
10,000
8,000
6,000
4,000
2,000
0,000
0
100
200
300
400
[seconds]
Loss in weight
Specific screw capacity

Fig.4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/053554

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01G11/08 G01G13/02
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)
G01G

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	WO 99/63310 A1 (RAUTE PRECISION OY [FI]; OUTOKUMPU OY [FI] ET AL.) 9 December 1999 (1999-12-09) figures claims page 3, line 1 - page 4, line 9 -----	1-7
A	FR 2 572 520 A1 (CELLIER SA [FR]) 2 May 1986 (1986-05-02) figures claims page 5, line 5 - page 8, line 17 -----	1-7
X	DE 37 42 229 A1 (PFISTER GMBH [DE]) 22 June 1989 (1989-06-22) figures claims column 1, line 50 - column 3, line 63 -----	1-7

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

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 July 2020	06/08/2020

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2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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