

A Batch Feeder for Inhomogeneous Bulk Materials

I S Vislov¹, S N Kladiev², S M Slobodyan², A M Bogdan²

¹ JCS 'SverdNIIhimmash', 32, Griboiedova st., Yekaterinburg, 620010, Russia

² National Research Tomsk Polytechnic University, 30, Lenina ave., Tomsk, 634050, Russia

E-mail: kladiev@tpu.ru

Abstract. The work includes the mechanical analysis of mechanical feeders and batchers that find application in various technological processes and industrial fields. Feeders are usually classified according to their design features into two groups: conveyor-type feeders and non-conveyor feeders. Batchers are used to batch solid bulk materials. Less frequently, they are used for liquids. In terms of a batching method, they are divided into volumetric and weighting batchers. Weighting batchers do not provide for sufficient batching accuracy. Automatic weighting batchers include a mass controlling sensor and systems for automatic material feed and automatic mass discharge control. In terms of operating principle, batchers are divided into gravitational batchers and batchers with forced feed of material using conveyors and pumps. Improved consumption of raw materials, decreased loss of materials, ease of use in automatic control systems of industrial facilities allows increasing the quality of technological processes and improve labor conditions. The batch feeder suggested by the authors is a volumetric batcher that has no comparable counterparts among conveyor-type feeders and allows solving the problem of targeted feeding of bulk material batches increasing reliability and hermeticity of the device.

1. Introduction

1.1. Classification of feeders and batchers

Currently, in industry numerous types of feeders and batchers are used in various manufacturing fields. There are many definitions of feeders and batchers; however, we will use the following definitions.

Feeder is a device for regular and controlled feeding of bulk and packaged cargo from bunkers, trays, gutters, infeed magazines and other loading systems to transporting and processing machines (machining units, mills, screeners, etc.) [1].

Batcher is a device for automatic dosing of required mass and volume of liquid and bulk materials. Batchers are used in production of building materials, metallurgy, chemical, foodstuff, pharmaceutical and other industries. They are also used at rail facilities, marine and river transport, in laboratories and trade [2].

These two terms fully describe the principle and intention of feeders and batchers.

Feeders are usually classified according to their design features into two groups [1]:

a) devices similar to certain types of conveyors, having—in contrast to them—small length and enhanced drive motor power. This group includes the following types of feeders:



– belt feeders [3, 4] that are intended for regular feeding of dry materials with the bulk density of less than 2.8 t/m^3 into machines and transporting devices. Such feeders are implemented at mining and metallurgy enterprises, on dry mortar production lines, etc. Belt feeders feed dry materials using a belt that is driven by an electric motor via chain gear or reducing gear. The moving belt that feeds material to transporting of processing machines is located directly under the bunker that pours out the material. The amount of material fed by the feeder is controlled by a special batch gate and by the belt speed;

– plate feeders [5] are intended for transporting and regularly feeding bulk materials at mining and concentration enterprises from one reservoir (bunker, hopper) to other reservoirs, processing machines or storage facilities. The belt of a feeder usually comprises a steel hinge structure forming an integral part of the transporter feeding bulk material at open pits and con-centration plants.

– screw feeders [6, 7] are represented by a tube or a gutter with a working element in it, a screw. A revolving rod placed into a horizontal or inclined chute moves bulk or small-size material along the chute. Throughput is regulated by increasing the rotation rate of the screw. Screw feeders are basically intended for regular and continuous feeding of bulk materials. Such feeders are usually implemented at industrial facilities and processing lines with specified material dosage rate;

– reciprocating feeders [8] are the machines for continuous transportation with a working body represented by an reciprocating chute. They are intended for regular feeding of non-sticky bulk materials from bunkers, hoppers and other reservoirs to processing machines and transporting devices.

– vibrational feeders [9, 10] are intended for regular feeding of non-sticky bulk materials. They are usually installed under bunkers on horizontal sections of material-transporting raceways as loading devices of batchers. The material is transported due to the oscillations of a working element represented by a tube with round cross-section;

b) devices that have no prototype among conveyors. This group of feeders includes:

– drum feeders that suit well for transporting either bulk, granular and small-size materials or large-size materials. Bulk, granular and small-size materials are fed due to smooth internal surface of the drum. Large-size materials are transported owing to ribbed drum surface.

– disk feeders are used for transporting bulk materials. Disk feeders have a loading unit from which the material gets to a pivoting disk. The material is discarded from the disk by a fixed blade. The disk revolution rate is chosen so that the material is not discarded under centrifugal force;

– Ross Chain Feeders [11] are used for large-size materials and have so-called "chain curtain" that spans the outlet of a bunker. The revolution of a drive drum makes the chains to press the layer of material against the chute, which adjusts the material passage rate;

– pneumatic screw feeders [12] are used for feeding bulk dust-forming materials. They differ from conventional screw feeders in the principle of material transportation: at the exit, the material is entrapped and transported by a stream of oxygen.

See Table 1 for a condensed classification of feeders.

Table 1. Classification of feeders.

Feeders	
Conveyor-type	With no prototypes among conveyors
- belt feeders;	- drum feeders;
- plate feeders;	- disk feeders;
- screw feeders;	- Ross Chain feeders;
- reciprocating feeders;	- pneumatic screw feeders.
- vibrational feeders;	

The performance of all the feeders is adjusted by the speed of their working element and the size of outlet slot of a bunker. For vibrational feeders, the performance can also be adjusted by changing the frequency and amplitude of oscillations.

Batchers are usually classified according to batching procedure into two groups [13]:

a) Volumetric batchers [14, 15].

They are used to batch gases, liquids or pastes. Less frequently, they are used to batch solid bulk materials. The dose size varies from fractions of cubic centimeters to hundreds (or thousands, for gases) of cubic meters; the throughput varies from less than cubic centimeters per hour to thousands of cubic meters (dozens of thousands, for gases) per hour. These batchers have simple construction and good reliability.

b) Weigh batchers [16, 17].

Such batchers are used to batch solid bulk materials; less frequently, they are used for liquids. Dose size varies from several grams to several kilograms; the throughput varies from hundreds of kg/h to thousands of t/h.

Moreover, depending on the requirement of technological process batchers are classified as single-component batchers for continuous batching of a single material, and multicomponent batchers for continuous batching of several bulk material or liquids. Multicomponent batchers can automatically control the ratio of materials or make corrections according to the specified program. Discrete batchers usually have bunker-like structure, while continuous batchers have a bunker and a belt.

The simplest volumetric batchers do not provide for required accuracy; complex and precise technological process are usually carried out with the use of weigh batchers. Weigh automatic batchers are represented by a complex consisting of weight control sensor, automatic unit for material feeding and system for automatic dosage or mass flow control. In terms of working principle, batchers can be gravitational (hoppers) with or without forced feeding of materials by belt, screw, pan or other conveyors, or plunger, gear or other pumps.

Batchers allow decreasing consumption of initial materials, cutting material losses, expanding flow-line production, eliminating many labor-intensive processes and improving working conditions.

Generally, all feeders work as batchers and vice versa, hence, the design of such equipment shall assume the incorporation of the two functions.

2. Bucket-type batch feeder

Research goes on, and novel processes are discovered that eventually find industrial application. The development of science imposes new conditions for implementing its results in industry. Correspondingly, the development of science is paralleled with the development of technology.

For instance, working with granular materials having inhomogeneous composition has the problem in the simultaneous presence of particles with the size of several millimeters and particles with the size of several micrometer.

OAO SverdNIIhimnash have developed a bucket-type batch feeder, which found application in industry [18]. Considering the specificity of radiochemical plants, the use of weigh sensors is problematic, which excludes the application of weigh batchers. The said device belongs to weigh batchers having no counterparts among conveyor-type feeders. The scheme of the device is depicted in Figure 1.

The batch feeders includes body 1, working element 2 that contains inlet 3 and bucket 4, bunker 5 for bulk material, loading mouth 6 for material feed from a bunker into the bucket's in-let. The body includes outlet mouth 7 for unloading material from the bucket of working element outside the batch feeder. The working element at the side of bucket is connected with shaft 8 which free end goes into bearing 9 mounted on stand 10.

Figure 1 shows angle α , between shaft axis and vertical axis.

The system also includes reverse turn limiters 11 of working element that are mounted on immovable parts of the batch feeder and limiter 12 mounted on the working element of the batch

feeder. These limiters constrain the clockwise and counter-clockwise turn angle of the working element around its middle position.

Figure 2 shows the cross-section of bucket 4 of working element 2 with slot H. The cross-section obviously shows the purpose of elements of the batch feeder bucket that determine its performance considering the angle of repose α_{repose} of batched bulk material, size of its particles and the length of flat wall section 13.

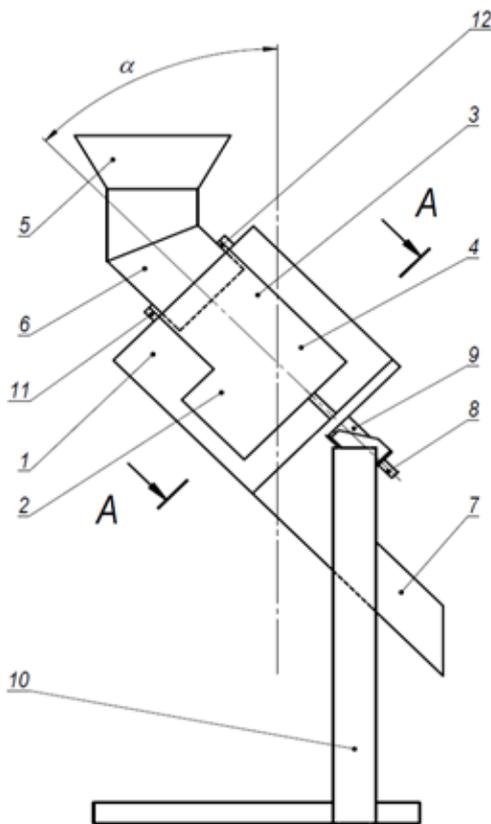


Figure 1. Bucket-type batch feeder.

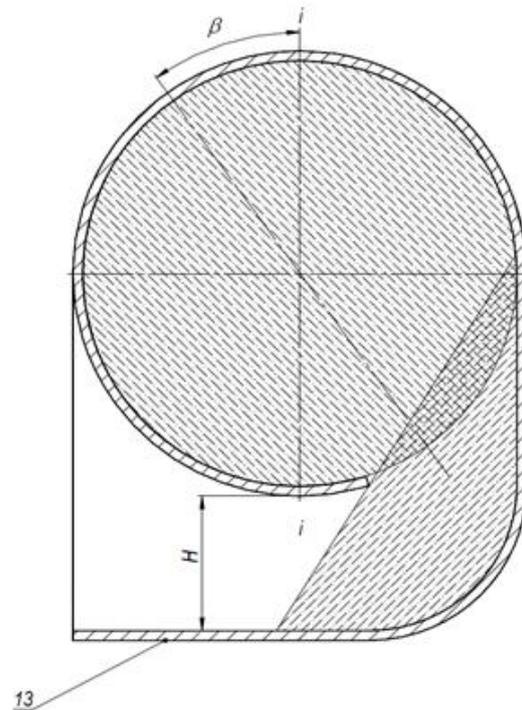


Figure 2. Cross-section of bucket.

Operation of the bucket-type batch feeder includes the following stages:

During the feeding of bulk product into bunker 5, the product fills loading mouth 6, inlet 3 and bucket 4. Nevertheless, it does not pour out from the bucket through a product-discharging slot H, since the product forms an angle of repose α_{repose} , which generatrix line does not go beyond the threads of the second section of flat wall 13 of the bucket.

Let us consider the cross-section of the batch feeder in Figure 2.

The counter-clockwise turn of the bucket for angle β around axis i-i of section A-A with preservation of angle of repose makes the lower edge of slope to shift to the edge of wall 13. This induces the pouring of product into unloading mouth 7.

The amount of material poured out from the bucket depends on turn angle β and length of wall 13.

The maximum dimensions of material's particles are determined by the size of slot H.

After pouring out a batch of the product, the bucket makes a clockwise turn around shaft axis for angle β and gets into initial position.

Further material batching is carried out in a similar way.

The throughput of such device depends on bucket rotation frequency. During testing, the accuracy of batching amounted to + 5 % for the throughput of 5 kilograms and the confidence factor of 0.95.

The application of the suggested device will allow increasing the accuracy of volumetric dosing of bulk material mix containing small and large particles.

The device also enables the targeted feed of specified single batches of bulk material without preliminary unloading of other batches of material to the same destination.

In addition, the design eliminates the jamming of working element inside the body of batch feeder and contamination of the batched material by particles produced by rubbing of body and working element during rotation. This is unachievable in conveyor-type feeders without considerable complication of their design and increase of dimensions. Besides, the body of bucket-type batch feeder is hermetic having simple design, which is not provided in similar feeders that have no prototypes among conveyors.

Thus, the presented device can find application in developing industrial fields, such as radiochemical shops. The suggested device may have the most promising deliverables in processing spent nuclear fuel by high-temperature methods [19], for instance, at the stage of loading milled fragments of fuel units or fuel pellets into chemical reactors for further processing.

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