ABSTRACT

Methods of and apparatus for treating particulate material for the purpose of improving the flow characteristics of the material so that it can be readily conveyed, dispensed, shaped or formed by moulding wherein the material is fluidized with gas under pressure to reduce its bulk density whilst being simultaneously vibrated.

19 Claims, 8 Drawing Figures
TREATMENT OF PARTICULATE MATERIAL

THIS INVENTION relates to the treatment of particulate material particularly granular or powdery materials for the purpose of improving the flow characteristics of the material so that the material may be readily mixed with other substances which may also be of a particulate nature or which may for example be fibrous or so that the material can be readily conveyed, dispensed or shaped or formed as by the moulding.

The invention provides a method of treating a particulate material for the purpose indicated wherein a flow of gas is caused to permeate through the material in a container to fluidize the material i.e., decrease its bulk density whilst vibrations are simultaneously applied to the material.

The invention also provides apparatus for treating particulate material for the purpose indicated comprising a container having at least one perforated wall whereby a flow of gas can be introduced to the container for fluidizing particulate material contained therein, and means for simultaneously applying vibrations to the material in the container.

The invention finds application in the mixing of particulate material with other substances, and for the conveying of particulate material particularly at a controlled rate of flow where, for example, it is required in continuous feeding and metering processes or continuous forming processes such as for example a process for the continuous production of building panels as described in our co-pending application number 63582/69 entitled "Improvements relating to Building or Constructional Material."

A combined vibrating and fluidizing technique according to the invention will from time to time hereinafter be referred to as "vibro-fluidization."

The invention will be further described with reference to the accompanying drawings in which:

FIG. 1 is a cross sectional view of a typical vibro-fluidization apparatus which could for example be used for mixing and/or conveying.

FIG. 2 is a section through a further form of vibro-fluidization apparatus.

FIG. 3 is a sectional view of a vibro-fluidization feeding and metering arrangement.

FIG. 4 is a perspective view of a further type of vibro-fluidization feeder.

FIG. 5 is a sectional view of the lower part of the apparatus shown in FIG. 4.

FIGS. 6 and 7 are partly diagrammatic views of vibro-fluidization forming arrangements and

FIG. 8 is a sectional view through a continuous extrusion device employing the vibro-fluidization principle.

Vibro-fluidization is essentially the simultaneous application of vibration and fluidization to a powdered granular fibrous or powder fiber mixed materials with the effect that the flow characteristics of the materials are improved so that the materials act in many respects like a fluid. The technique has application in the handling of cohesive or damp powders and powder fiber mixtures, neither of which can readily be handled either by pure vibration or pure fluidization on their own.

In all cases, the object of the vibro-fluidization process is continually to break the bonds between particles which prevent flow of the material, through for example frictional resistance or mechanical interlocking. There is a tendency for sticky or fibrous powder mixes to break into "fissures" under fluidization alone and the fluidizing gas to escape through those fissures without permeating throughout the particular main. Also there is a tendency for such materials to compact solid or "arch" under vibration alone. The effect of vibro-fluidization is that

a. fissures are continuously broken up by vibration

b. compacted zones or "arches" are continuously broken up by the fluidizing gas.

Hence a state of "mobile equilibrium" is established which is more extensive in scope compared to either technique used on their own.

It should also be noted that effective fluidization is only achieved when each particle is separated from the next by the (generally upward) flow of gas. In effect each particle is suspended in a stream of air and the downward forces of gravity are balanced by the upward forces for the air resistance of the particles. By being separated in this manner, the particles can flow past each other. Hence detrimental effects of local agglomerations separated by comparatively wide fissures--as happens when fibrous materials are fluidized without vibration--are minimized.

FIG. 1 illustrates a typical vibro-fluidization apparatus for mixing and/or conveying, comprising a container 1 having a supporting grid 2 over an air permeable diaphragm 3, the grid and diaphragm being spaced from the base of the container to define an air chamber 4 having an air inlet 5. The container is covered by an air permeable cover membrane 6 and is mounted on a vibrating table 7. In use, air of a generally low pressure for example 0.5 to 10 pounds per square inch is introduced to the inlet 5 and the table is set in (vertical or other) vibrations of about (for example) one hundredth to one tenth of an inch amplitude at about three thousand to six thousand cycles per second.

FIG. 2 shows the vibro-fluidization technique applied to a hopper, for the controlled discharge of particulate material therefrom the vibrating means in this Figure not being shown. A bottom wall of the hopper is perforated and forms the inner wall of a plenum chamber which is provided with an inlet (not shown) for gas under pressure derived for example from an air pump, for fluidizing material in the hopper. The hopper can be vibrated by any known vibrating means.

Fluidization may be achieved either by the use of gas under pressure, or by the application of suction and the gas may be recirculated by a pump. Any suitable gas may be used. The dispensing membrane or container wall through which the gas is introduced should be of a fine porous material with a suitably high resistance to flow in order to disperse the gas evenly throughout the particulate mass. The material under treatment may be at any suitable temperature.

The imposed vibrations may be horizontal vertical or any combination of these which effect mechanical break-up of the particulate material. Any suitable wave forms amplitude or frequency may be used and in this regard with coarse mixtures for example long fibers clinging powders, relatively coarse vibrations are often the most effective although for certain applications vibrations of ultra-sonic frequency can be used. The application of the vibrations may be by numerous means for example by vibrating the entire container in which the material is situated or by inserting a vibratory member into the material.
The process is suitable for any dry particulate material but is particularly useful for those which cannot effectively be handled by normal vibratory or fluidizing methods. The materials may also be hydroscopic and/or damp and examples include powders such as cement, plaster, silica, flour, plastics metal powders, chemicals, pigments or the like, granular materials such as sand, salt crystals, sugar, plastic beads, encapsulated liquids, ice crystals, fibers such as asbestos, glass, carbon, polypropylene, jute or sisal and mixtures of any of the above materials. The temperature of the fluidizing medium can be adjusted to maintain the proportion of the materials being treated for example, cold air can be circulated in the case of mixtures including ice crystals to maintain those in their solid state.

Powdered or crystallized ice in a water-setting powder/fibre mixture is believed to be original and attractive from the commercial point of view where somewhat porous/cellular products are required (due to voids left by ice when it melts and is drawn into the powder by capillary action).

Ice may be in the form of ice crystals or may simply be powdered ice made by crushing or grinding solid ice.

**MIXERS, MIXER HEATERS AND CONTINUOUS MIXER FEEDERS**

Vibro-fluidization mixers are essentially vibro-fluidizing containers in which powders or fibrous materials are given a superimposed circulatory or mixing movement, usually by varying the intensity and direction of fluidizing medium in different parts of the container, while often in combination with suitable orientation of the applied vibration. The mixers can be designed without moving internal parts and their operation can be readily extended to incorporate heating, cooling and/or gaseous reactions by suitable pretreatment of the fluidizing gas.

Vibro-fluidization techniques are useful in the manufacture of fiber reinforced products when, for strength reasons, relatively long fibers are required and in order to achieve a satisfactory bond between these and the particulate matrix material, intimate contact between the fibers and the matrix powder is needed. By vibro-fluidization mixing, the powder can be made to permeate throughout the interstices between “bundles” of fibers with substantially no damage to the fibers themselves. By pre-processing the fluidizing gas, the range of such mixtures that can be effectively processed is increased. For example, the water needed for cement or plaster mixtures can be included at the dry mixing stage by adding powdered ice or “freeze-drying” the water first into a fine crystalline powder and keeping the ice in the powder state by blowing sufficiently cool air through as the fluidizing gas when mixing with the powder constituent. Similar effects can be obtained by using granulated pitch as silic fibers and cold air for pitch fiber pipes or hot air and cement and thermal plastic fiber.

Circulation of the material within a vibro-fluidization mixture can also be achieved by local air jets, suitably directed within the vibro-fluidized mass, or alternatively by suitable orientation of the vibration with non-directional fluidization or suitable orientation of the fluidization with non-directional vibration.

**FEEDING AND METERING**

Vibro-fluidization feeding and metering devices are essentially bottom opening vibro-fluidized hoppers in which a flow of material from a vibro-fluidized zone is decelerated sufficiently to ensure compaction within an exit zone beneath the vibro-fluidization zone, the exit zone being under the action of pure vibration this tends to compact and solidify a moving column of material to form a continuously moving “plug” which can be controlled with the minimum of deformation by simple mechanical constant feed devices controlling the rate of flow of material as it becomes progressively more compacted. The method is particularly suited to cohesive fibrous materials, the upper vibro-fluidization feed hopper ensuring even flow of the material into the vibrating compacting zone and the nature of the vibro-compacted plug below the vibrating zone facilitating control of the rate of throughput of material (this material being at a constant density having been compacted to this density by the vibration).

A basic form of feeding and metering device is shown in FIG. 3 and comprises an upper vibro-fluidizing hopper 17 (of the type shown in FIG. 2) discharging into a vibrating tube 18 where, due to the lack of fluidization, the material is compacted, the tube in turn discharging into a flow control zone 19 in the form of a non-vibratory or reduced vibration structure. This structure may for example comprise a rigid outer rotating member having internal threads acting on a flexible sleeve, the rotation of the threads controlling the rate of flow of the material.

Full vibro-fluidization in the uppermost zone, with sufficiently smooth sides to the apparatus allowed unusually small apertures to be used in relation to the type of material being handled and the tendency for the material to arch or clog which is normally a severe handicap with very fibrous or damp materials is actually made use of in the lowermost control zone and the more cohesive the material, the less “bite” is necessary in the control zone. The control zone requires much less vibrational energy than the upper zones as the requirement of this last phase is that the material acts as a continuous coherent plug and vibration could disturb this condition. Some vibration of the side walls may however be necessary in the control zone to relieve the frictional resistance at the sides. Any suitable materials for the construction of the feeder can be used including steel, aluminum, plastics for the rigid parts, polyethylene, plasticized P.V.C. P.T.F.E. or the like for the flexible sheath in the control zone. Any suitable form of vibration can be used from relatively coarse shaking up to ultrasonic vibration and numerous materials are suitable for the porous wall or membrane in the fluidization zone for example sintered metal powder, porous clay, sintered glass, cloth, chamois leather and the like. With suitably cooled or heated air, material such as ice powder, bitumen powder or the like can be metered, the same considerations applying as in the case of vibro-fluidization mixers described above.

One of the main points about vibro-fluidization metering devices is that the pure vibrating zone immediately below the vibro-fluidization zone can be made sufficiently long to ensure full (and therefore
3,684,253

constant) compaction prior to the material reaching the control/exit zone. Hence with a constant rate of ejection and a consistent density, the weight of material metered out will be reasonably consistent—and not only a consistent volume.

Alternative forms of mechanical feed rate control equipment useful in the control zone a pair of endless bands, the inner laps of which travel to control the outflow of material, or a central rotating screw.

FIGS. 4 and 5 show a practical arrangement of a device employing a control screw where the hopper and vibrating zones are mounted on a vibrating pedestal 22 and the material is discharged into a vibrating chute 23 associated with the pedestal the central screw 12 is rotated by means of a motor 24 and the structure 25 constituting the control zone is non-vibratory. The discharge rate of material can be adjusted by changing the diameter of the central screw.

The control arrangement may also comprise a central screw and an outer screw sleeve rotating in the reverse direction to the central screw.

The control arrangement may also comprise a central screw, and an outer screw sleeve rotating in the reverse direction to the central screw.

FORMING AND EXTRUSION

Vibro-fluidization forming and extrusion is essentially an extension of the metering and mixing technique as described above, the main departure being that the shape of the compaction and control zones correspond to the required shape of an extruded object being manufactured, and suitable devices are incorporated which receive the compacted material and process if further into permanently stable forms.

In its simplest form a vibro-fluidization extrusion unit would consist of a vibro-fluidizing hopper as shown in FIG. 3 with the lower control device replaced by a mould having flow control means associated therewith in the form of a piston plunger, screw or the like. Depending on the materials being extruded, the relatively dry compacted materials within the mould can be stabilized for example by heating e.g., sintered thermoplastics, ambient thawing, e.g., cement powder and ice powder, steaming or the like for dry cement powders followed by ejection of the stabilized product on return action of the piston.

The same basic principles can be applied to a wide variety of forms and with suitable central control mechanisms in the mould can produce hollow shapes and even sandwich composite products comprising layers of different materials and various configurations as described for example in our co-pending application mentioned above. As for other vibro-fluidization applications, the extrusion technique has particular use in the manufacture of fiber reinforced products.

Of particular practical significance is the facility whereby widely dissimilar materials can be extruded simultaneously and remain in their fully compacted state precisely in their required position until stabilized as described for example in the above mentioned co-pending patent application in which dissimilar layers of polystyrene bead and cement/fiber powder is stabilized by steam in the lower part of the extruder. This means for example that continuous fiber reinforcement can be fed into an extruder say containing short chopped glass fiber and two part frozen thermosetting resin powder to produce continuous longitudinal reinforced pipe (or the equivalent of continuously spiral wound pipes) or of continuous strand reinforced sheets, in both cases with great precision and economy. Alternatively film-like materials e.g., P.V.C. film can be fed down the sides of the extruder to produce film coated products or granular non-fluidized materials e.g., polystyrene semi-expanded beads can be fed down a central chute fixed within a vibro-fluidization extruder containing powder fiber e.g., cement asbestos to produce polystyrene cooled sandwich panels when suitably processed by for example steam injection within the mould.

In basic designs of vibro-fluidization extrusion or forming equipment an extruder dispenses material onto a horizontal moving band where it is stabilized, the band serving itself as feed rate control means dependent on its speed or as shown in FIG. 6 a vibro-fluidization extruder discharges into moulds each having associated therewith a vertically movable feed rate plunger. Conversion of the material into a coherent mass is then performed in the mould.

FIG. 7 shows a vibro-fluidization extruder moving over a fixed battery of moulds, each having an associated plunger or like control device associated therewith. Alternatively, the moulds could move in turn under the hopper.

FIG. 8 shows a continuous extrusion arrangement in which a vibro-fluidization hopper 30 discharges into a vibratory compaction duct 31 and hence into a mould 32. Feed rate control is obtained by a central screw 33 extending down into the mould and means for performing a conversion process on the material can be effected within the mould. For example where the granular material requires heat and/or moisture to convert same into a coherent mass (for example in the case of a polystyrene bead/cement mixture) this can be introduced to the mould in the form of steam say through the interior of screw 33. Setting of the material commences within the mould and threads bite into the setting material within the mould to provide feed rate control. The setting product issues continuously from the mould and can be cut to length by a knife 34.

A more satisfactory form of apparatus working on the same principle as FIG. 8 is described in the above mentioned co-pending application.

It should be emphasized that the basic principles governing all vibro-fluidization metering and extrusion technique according to the invention reside in the provision of a vibro-fluidization hopper which discharges into a pure vibratory compaction zone, in turn discharging into a zone having means acting on the compacted material for regulating the throughput of such material through the apparatus by retarding its flow. In the case of metering the material is discharged from the last mentioned zone, and in the case of forming or continuous extrusion the material is stabilized into a coherent mass by performing a conversion process on the material either within the last mentioned zone, which acts as a mould, or on discharge from the last mentioned zone. It is also within the scope of the invention to vibrate mould and the extruder together. Feed rate control can be obtained by friction from endless belt or belts acting on the compacted material
issuing from the vibration zone and suction may be applied to the belt or belts. In this case stabilization of the product is then effected on a horizontal run portion of the belt or a further belt.

1. A method of metering particulate material comprising causing a flow of gas to permeate through the material in a fluidizing zone to fluidize the material, i.e., decrease its bulk density while simultaneously applying vibrations to the material, allowing fluidized material to flow from the fluidizing zone into a non-fluidized compacting zone, and discharging the compacted material from the compacting zone at a controlled rate by mechanically controlling the flow of compacted material.

2. A method as claimed in claim 1 wherein the material is a mixture of at least two constituents.

3. A method as claimed in claim 2 wherein one of the constituents is a fibrous constituent.

4. A method as claimed in claim 1 wherein material is compacted in the compacting zone by subjecting the material to pure vibration.

5. A method of forming a particulate material into a coherent mass comprising causing a flow of gas to permeate through the material in a fluidizing zone to fluidize the material, i.e., decrease its bulk density whilst simultaneously applying vibrations to the material, allowing the fluidized material to flow into a non-fluidized compacting zone, discharging the material from the compacting zone at a controlled rate by mechanically controlling the flow of compacted material, and performing a conversion process on the compacted material to convert the same into a coherent mass.

6. A method as claimed in claim 5 wherein the material is a mixture of at least two constituents.

7. A method as claimed in claim 6 wherein one of the constituents is a fibrous constituent.

8. A method as claimed in claim 5 wherein material is compacted in the compacting zone by subjecting the material to pure vibration.

9. A method as claimed in claim 5 wherein said conversion process is performed in a zone in which the flow of material is mechanically controlled.

10. A method as claimed in claim 5 wherein said conversion process is performed on discharge of the material from a zone in which the flow of material is mechanically controlled.

11. Apparatus for treating particulate material comprising a hopper, at least one wall of said hopper being perforated and forming an inner wall of a plenum chamber, means for supplying gas under pressure to said plenum chamber to fluidize material in said hopper, means for vibrating said hopper, a material compacting duct in communication with an outlet of said hopper, said duct having an imperforate wall, and mechanical means for controlling flow of material through said duct.

12. Apparatus as claimed in claim 11 having vibrating means for vibrating said hopper and said duct in unison.

13. Apparatus as claimed in claim 11 wherein said flow control means is situated beyond an outlet of said duct.

14. Apparatus as claimed in claim 13 wherein said flow control means comprises screw means.

15. Apparatus as claimed in claim 14 wherein said screw means includes a screw formed on an interior wall of a sleeve adapted to receive material from said duct.

16. Apparatus as claimed in claim 11 wherein said flow control means is a screw arranged in a tube adapted to receive material from said duct.

17. Apparatus as claimed in claim 11 wherein said flow control means is a movable plunger contained in a mould adapted to receive material from said duct.

18. Apparatus as claimed in claim 11 including means for performing a conversion process on material received from said duct to convert the material into a coherent mass.

19. Apparatus as claimed in claim 18 wherein said means for performing a conversion process is operative in a zone containing said flow rate control means.