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(54) METHOD AND APPARATIS FOR TRANSPORT OF FINE SOLIDS INCLUDING POWDERS

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(51) Int. Cl.

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B01F 23/60	(2022.01)
B22F 12/58	(2021.01)
B29C 64/336	(2017.01)
B33Y 30/00	(2015.01)
B65G 33/08	(2006.01)
B65G 47/19	(2006.01)
B65G 51/02	(2006.01)

(52) U.S. Cl.
CPC ***B65G 47/19*** (2013.01); ***B01F 23/69*** (2022.01); ***B65G 33/08*** (2013.01); ***B65G 51/02*** (2013.01); *B65G 2201/042* (2013.01); *B65G 2203/0258* (2013.01)

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CPC B65G 33/08; B65G 47/19; B65G 51/02; B01F 23/69; B65D 83/06; B22F 12/52; B22F 12/55; B22F 12/58; B29C 64/336; B33Y 30/00
See application file for complete search history.

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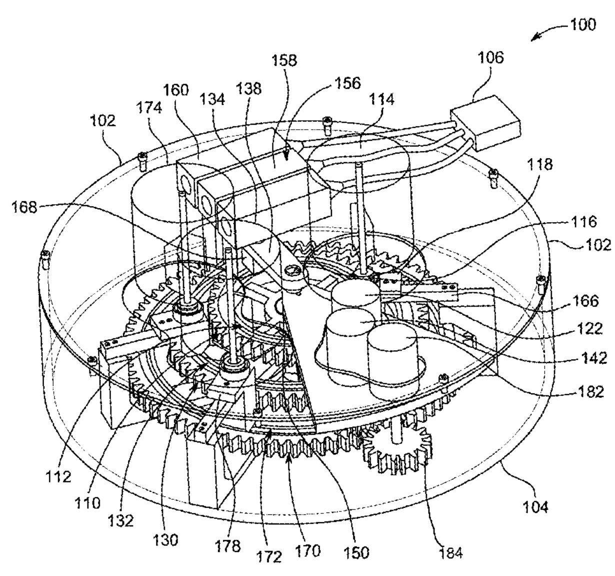
(57) ABSTRACT

A method and system for transporting and delivering fine solids in the form of powders includes a wheel-based coax control systems with individually controlled and motored wheels functioning to feed the solids. The apparatus includes a first wheel having a groove that permits powder flow. A hopper positioned above the wheel stores material to be fed to a conduit connected to the hopper thereby defining a feeding/flow path. A mixer unit is connected to the groove via a first suction head and a motor rotates the wheel, transferring powder from the hopper to the groove an into mixer unit. The method and system provide a coaxial wheel arrangement with independent material flow control.

20 Claims, 8 Drawing Sheets



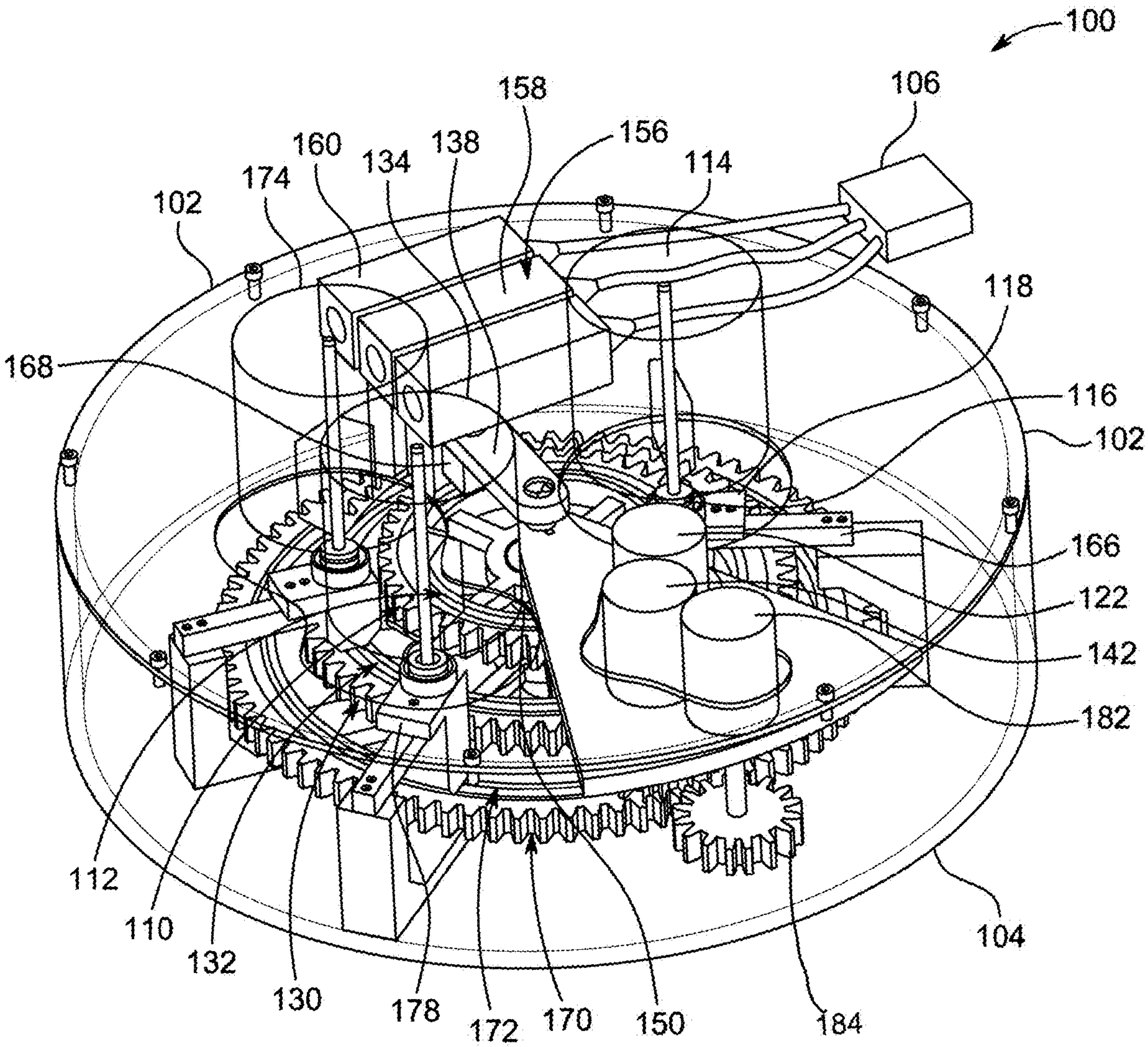

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FIG. 1A

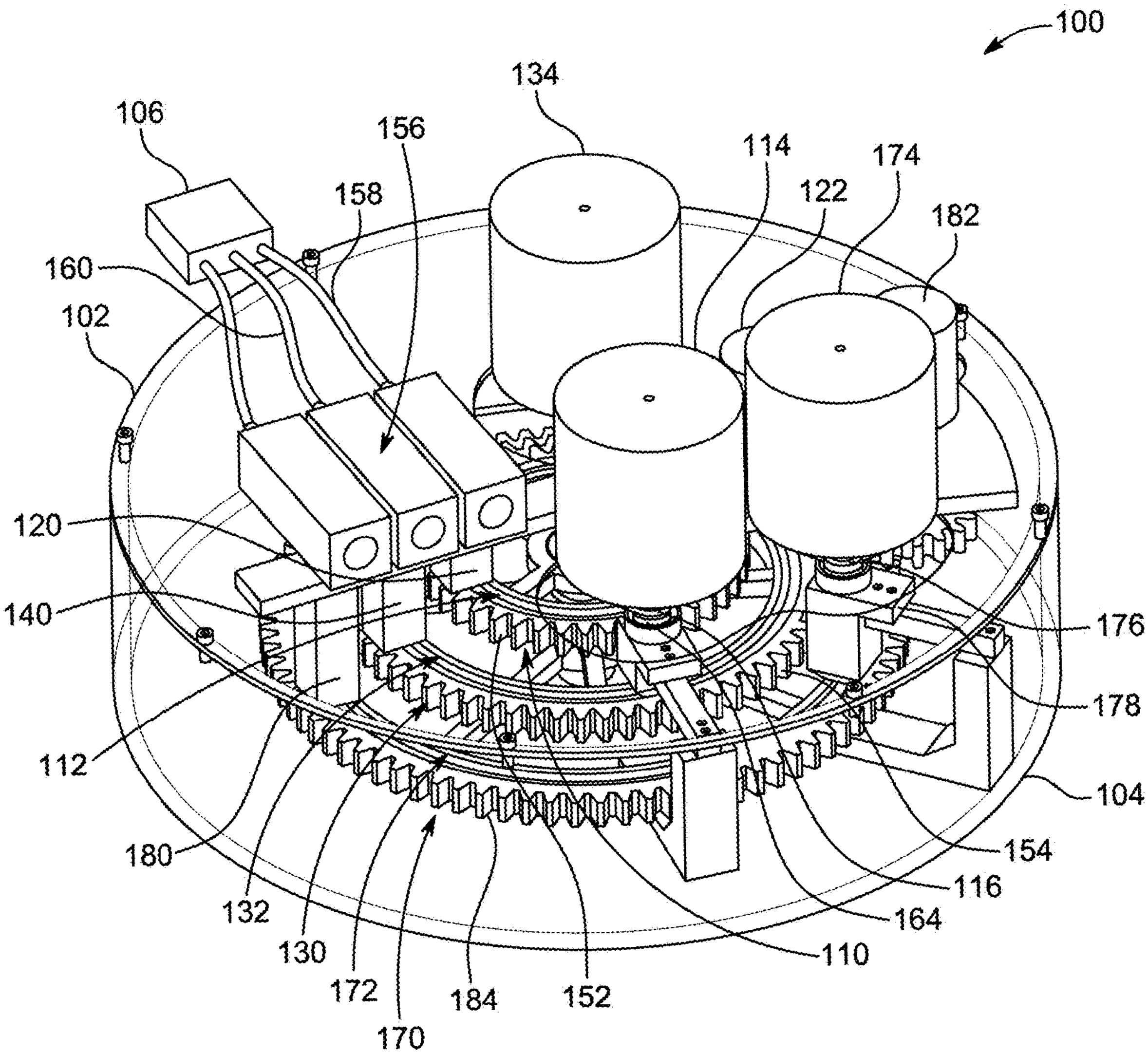
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FIG. 1B

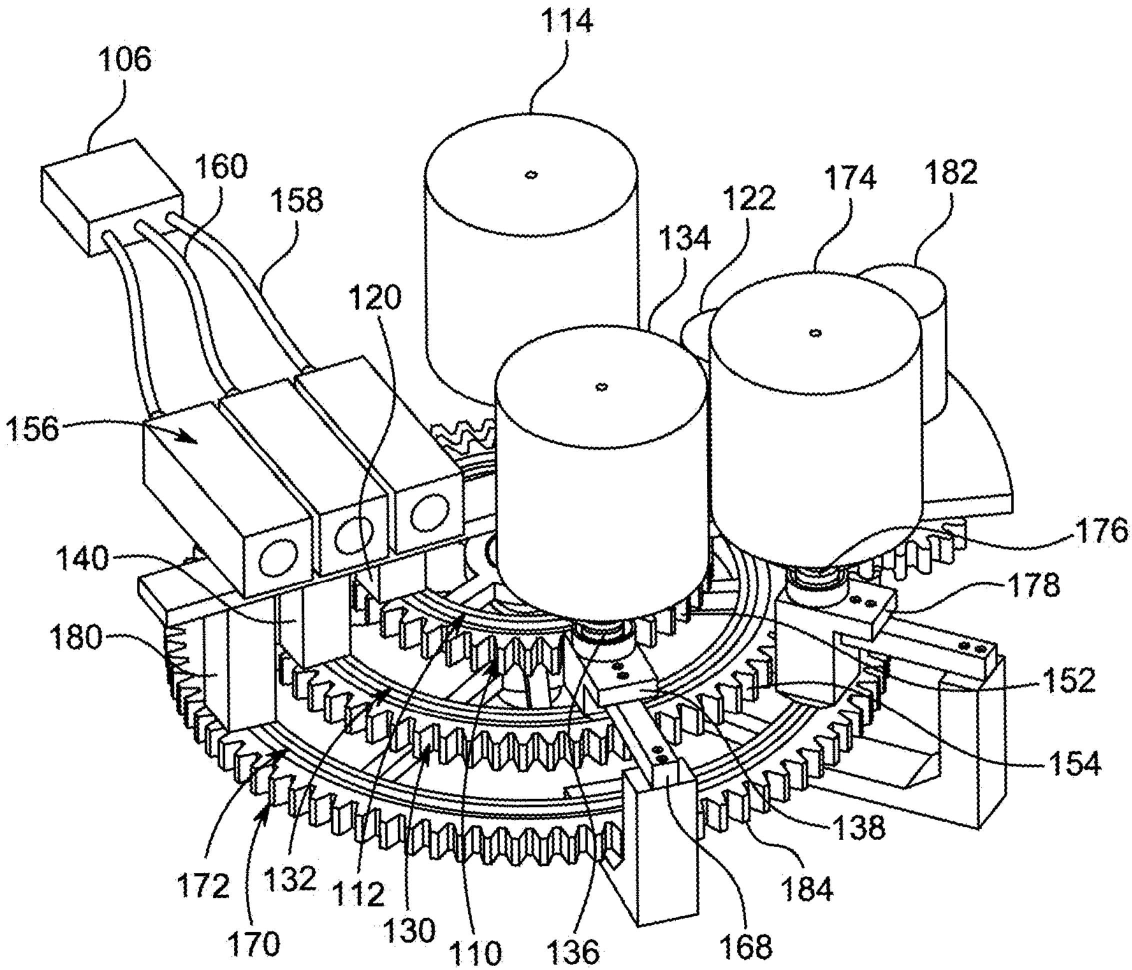

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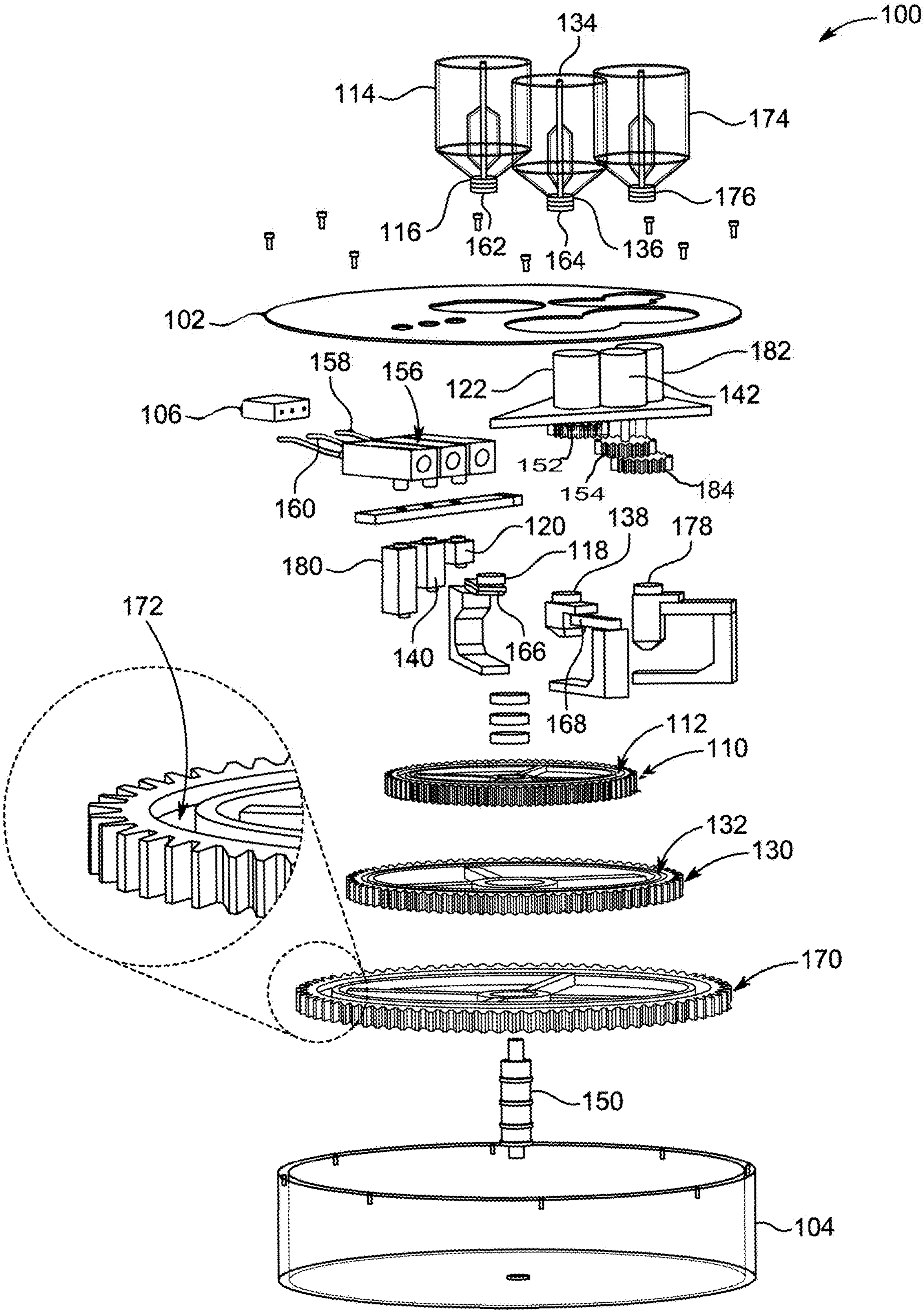
FIG. 1C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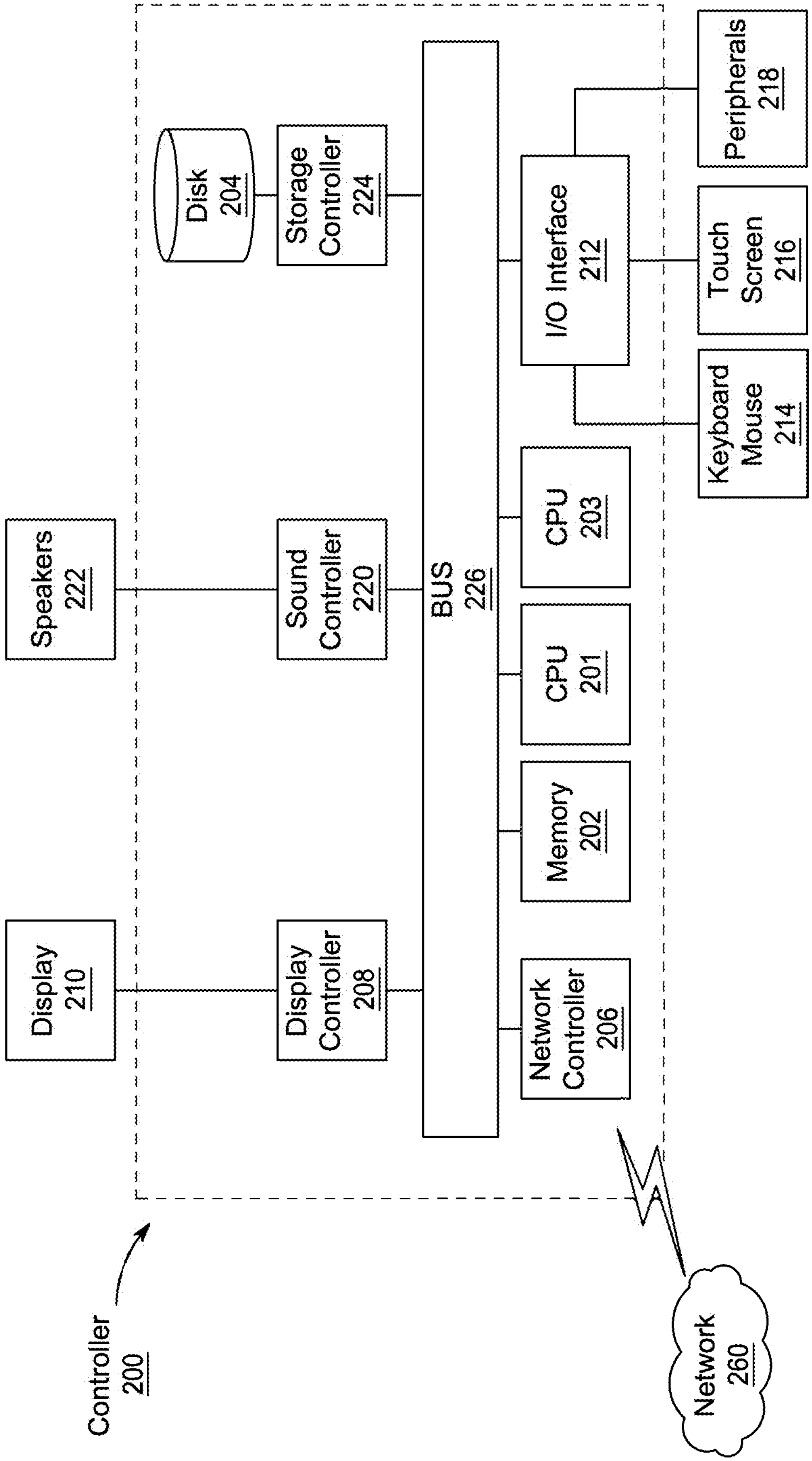
104

FIG. 1D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Display 210
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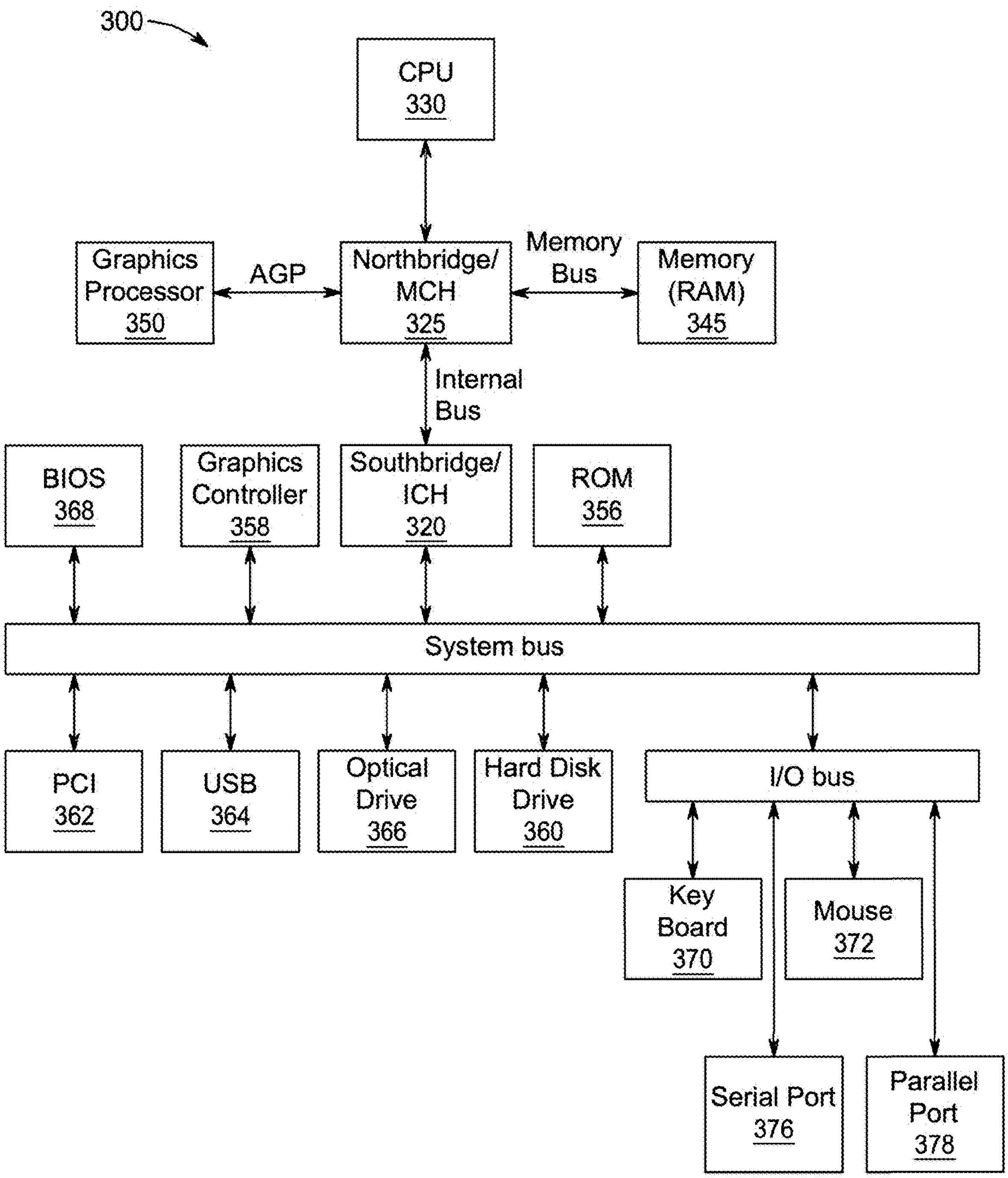
Network Controller 206
Controller 200
Network 260

FIG. 2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Parallel
Port
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FIG. 3

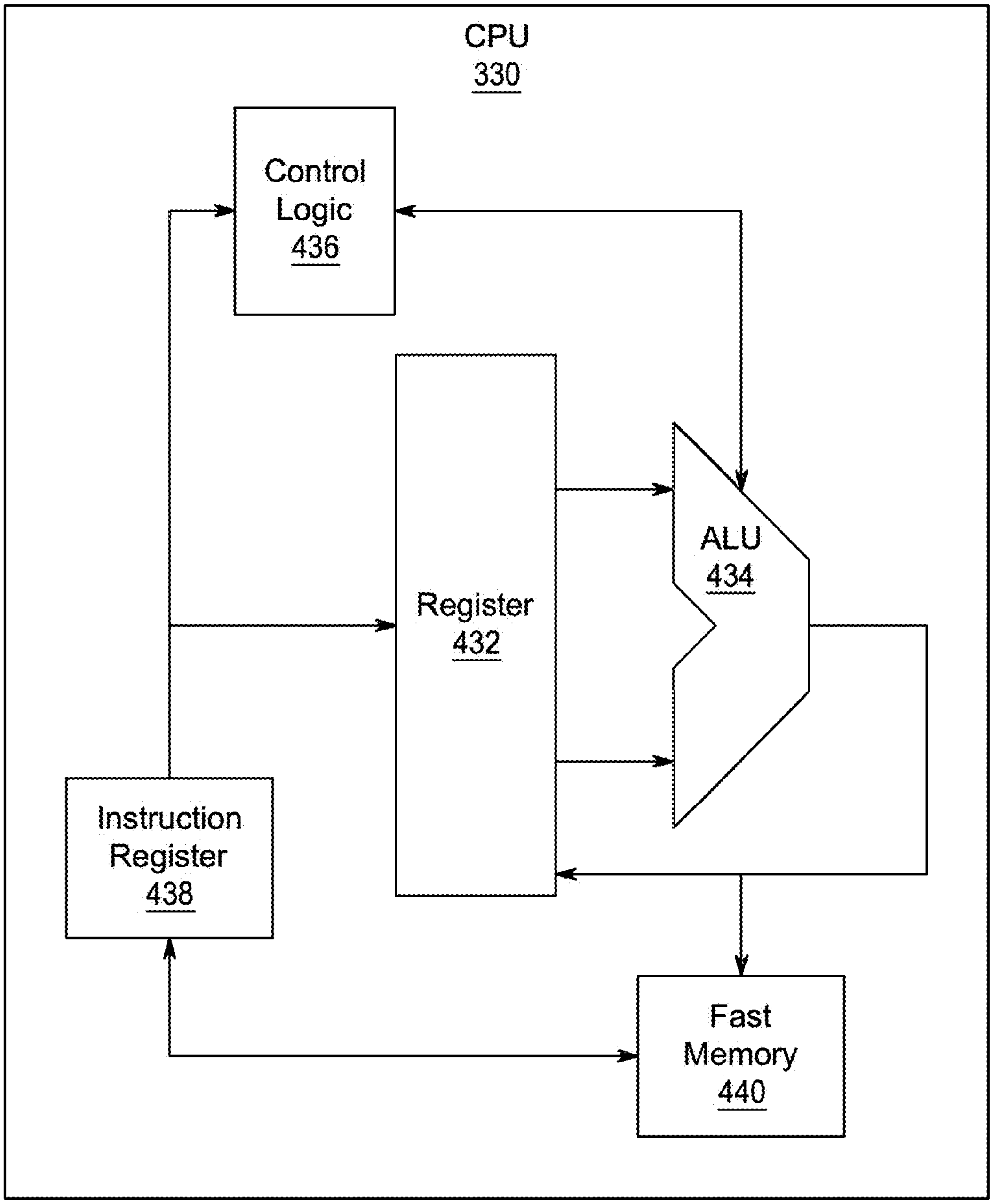
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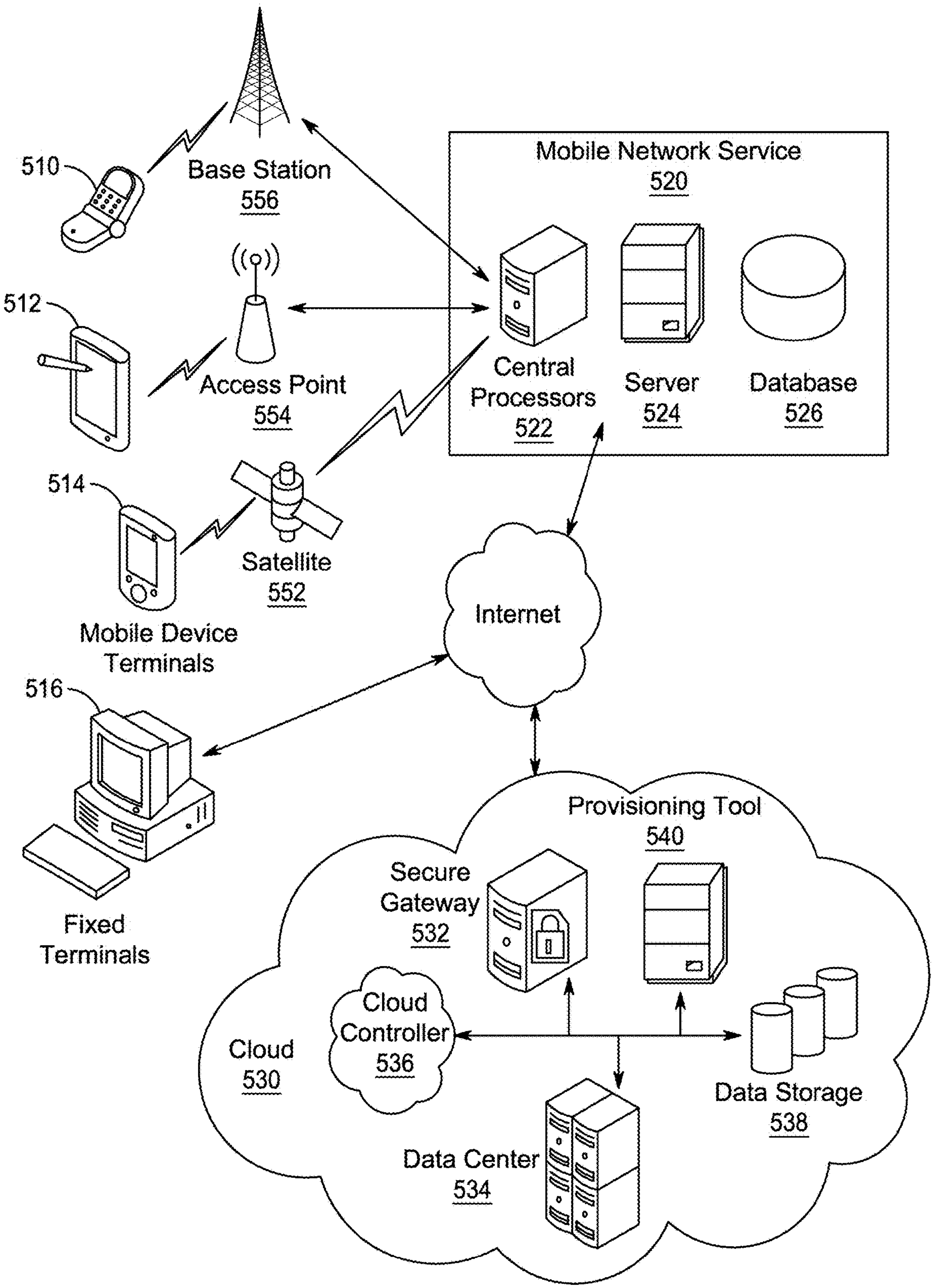
FIG. 4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Access Point
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Fixed
Terminals
Provisioning Tool
540
Secure
Gateway
532
Cloud
Controller
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Data Storage
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Data Center
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FIG. 5

METHOD AND APPARATIS FOR TRANSPORT OF FINE SOLIDS INCLUDING POWDERS

BACKGROUND

Technical Field

The present disclosure relates to a method, apparatus and system for delivery and transport of fine solids such as powders, and more particularly to a multi-disc apparatus that controls powder flow and further controls powder mixing and formulation.

Description of Related Art

The “background” description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description which may not otherwise qualify as prior art at the time of filing, are neither expressly or impliedly admitted as prior art against the present invention.

The controlled dispensing and transport (feeding) of fine solids (e.g., powder or pulverulent materials) typically employs complex constructive devices. Rotating disc mechanisms can also be used for powder flow control. These systems utilize individual disc setups where each disc controls the flow of a single powder material. The powder flow rate in such systems is primarily controlled through the rotational speed of the disc, typically measured in revolutions per minute (rpm) or rotations per minute. However, these conventional systems present several technical challenges and operational limitations.

Conventional systems require extensive experimentation and calibration to establish the relationship between disc rotational speed and powder flow rate for different materials. This calibration process involves rotating the disc at various speeds and measuring the amount of powder collected over specific time intervals to calculate the powder flow rate in units such as grams per minute. Furthermore, since powder flow rate depends on material density, this calibration process must be repeated whenever the material type or composition changes. The limitations of conventional systems become particularly apparent in applications requiring real-time composition control or the production of functionally graded materials. These systems typically lack the capability of simultaneous control of multiple powder flows and real-time composition adjustment. Additionally, their individual disc configurations result in larger spatial footprints and increased complexity in setup and operation of such systems.

CN 112157259B describes a powder feeding apparatus utilizing a hopper and rotating disk configuration. The system implements an air pump for generating pressure differential to facilitate powder transport, while incorporating a screw mechanism in the feed hopper for controlled powder delivery to the rotating disk.

CN 207222942U describes a powder feeding mechanism incorporating a powder disc with integrated groove features. The system utilizes a protective gas flow within a chamber, where powder accumulates on the powder disc and transfers through coordinated alignment between the groove and a powder suction port.

U.S. Pat. No. 10,786,870 B2 describes a powder supply apparatus incorporating screw conveyor mechanisms for powder transfer operations. The system implements powder

stirring functionality during transport between primary and intermediate hoppers to maintain material flow characteristics.

CN 217941858U describes a powder distribution mechanism incorporating weight measurement capabilities through sensor implementation. The system utilizes screw conveyor configurations for spiral mixing operations in conjunction with distribution funnel geometries.

Each of the aforementioned references suffers from one or more drawbacks hindering their adoption, such as limited material handling capabilities, complex calibration requirements, constrained flow rate ranges, inability to achieve compositional control, substantial spatial requirements, and operational inefficiencies arising from non-integrated configurations. None of the aforementioned references describe providing simultaneous control over multiple powder materials through compact mechanical configurations while maintaining independent control over material flow rates and enabling real-time composition monitoring capabilities. Accordingly, it is one object of the present disclosure to provide a feeder system that enables control over multiple powder materials while maintaining compact dimensional characteristics and real-time monitoring capabilities for advanced manufacturing applications.

SUMMARY

In one aspect the present disclosure includes a fine solids transport and metering system that includes first and second hoppers for powder reception, first and second sensors below the hoppers, first and second rig-shaped wheels each having a groove recessed below a top surface. The hoppers are positioned above the wheels and conduits connecting bottoms of the first and second hoppers to the respective grooves and define feedings paths. First and second suction heads having a first end connected to the respective grooves and a second end connected to a mixer unit and first and second motors to rotate the wheels and transfer the powders the hoppers to the grooves via conduits and then to the mixer unit via the suction heads.

In another embodiment the system includes a shaft extending through a center of the first wheel and a center of the second wheel, wherein the first wheel and the second wheel are co-axial.

In another embodiment the first wheel is positioned above the second wheel, and the first wheel has a smaller circumference than the second wheel.

In another embodiment the first groove surrounds an inner side surface of the first wheel by 360 degrees and is surrounded by an outer side surface of the first wheel by 360 degrees, and the second groove surrounds an inner side surface of the second wheel by 360 degrees and is surrounded by an outer side surface of the second wheel by 360 degrees.

In another embodiment the first conduit and the first suction head are positioned at different angular positions of the first groove, and the second conduit and the second suction head are positioned at different angular positions of the second groove.

In another embodiment the first suction head and the second suction head are positioned at a same angular position relative to the shaft.

In another embodiment the first groove is ring-shaped, and the second groove is ring-shaped.

In another embodiment, when viewed along the shaft, the outer side surface of the first wheel is surrounded by the inner side surface of the second wheel by 360 degrees.

In another embodiment the system includes, when viewed along the shaft, the outer side surface of the first wheel is spaced apart from the inner side surface of the second wheel.

In another embodiment the first groove defines a first continuous ring-shaped space to receive the first powder, and the second groove defines a second continuous ring-shaped space to receive the second powder.

In another embodiment the first suction head is shorter than the second suction head.

In another embodiment the first end of the first suction head is tapered and is positioned in the first groove, and the first end of the second suction head is tapered and is positioned in the second groove.

In another embodiment the system includes a vacuum pump having a first flow line connecting the second end of the first suction head to the mixer unit; and a second flow line connecting the second end of the second suction head to the mixer unit.

In another embodiment the first hopper comprises a first screw feeder, and the second hopper comprises a second screw feeder.

In another embodiment a first screw motor configured to rotate the first screw feeder; and a second screw motor configured to rotate the second screw feeder.

In another embodiment the first screw motor is configured to rotate the first screw feeder at a different speed from the first wheel, and the second screw motor is configured to rotate the second screw feeder at a different speed from the second wheel.

In another embodiment the sensors are configured to measure a weight of the hoppers and the powders therein.

The foregoing general description of the illustrative embodiments and the following detailed description thereof are merely exemplary aspects of the teachings of this disclosure, and are not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of this disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings.

FIG. **1**A is an exemplary perspective view of a feeder system from one side, according to certain embodiments.

FIG. **1**B is an exemplary perspective view of the feeder system from another side, according to certain embodiments.

FIG. **1**C is an exemplary perspective view illustrating arrangement of internal components of the feeder system, according to alternate embodiments.

FIG. **1**D is an exemplary exploded view of the feeder system, according to certain embodiments.

FIG. **2** is an illustration of a non-limiting example of details of computing hardware used in the computing system, according to certain embodiments.

FIG. **3** is an exemplary schematic diagram of a data processing system used within the computing system, according to certain embodiments.

FIG. **4** is an exemplary schematic diagram of a processor used with the computing system, according to certain embodiments.

FIG. **5** is an illustration of a non-limiting example of distributed components which may share processing with the controller, according to certain embodiments.

DETAILED DESCRIPTION

In the drawings, like reference numerals designate identical or corresponding parts throughout the several views. Further, as used herein, the words "a," "an" and the like generally carry a meaning of "one or more," unless stated otherwise.

Furthermore, the terms "approximately," "approximate," "about," and similar terms generally refer to ranges that include the identified value within a margin of 20%, 10%, or preferably 5%, and any values therebetween.

Aspects of this disclosure are directed to a feeder system incorporating multiple material handling mechanisms arranged in a spatially efficient configuration. The feeder system implements a coaxial multi-disc compact design with real-time weight and flow rate measurement of the powder materials by simultaneous rotation of screw feeders and rotating discs in order to achieve controlled composition of the powder materials. The feeder system integrates powder transport pathways, coordinated motion control, and real-time measurement capabilities to achieve regulation of powder material flow rates and compositions. The feeder system enables simultaneous processing of multiple powder materials while maintaining independent control over individual material parameters.

Referring to FIGS. **1**A-**1**D in combination, illustrated are different views of a feeder system (as represented by reference numeral **100**) in which, FIG. **1**A illustrates a perspective view of the feeder system **100** from one side, FIG. **1**B illustrates a perspective view of the feeder system **100** from another side, FIG. **1**C illustrates a perspective view of the feeder system **100** without its covers (as discussed later) for simplification, and FIG. **1**D illustrates an exploded view of the feeder system **100** for showing its internal components in detail. The feeder system **100** of the present disclosure is a coaxial multi-disc powder feeder system (with the two terms being interchangeably used herein) that addresses fundamental challenges in material processing applications. The feeder system **100** combines multiple powder transport mechanisms, measurement capabilities, and control functionalities within a unified framework to enable material composition control.

The feeder system **100** implements geometric arrangements that reduces spatial requirements while improving operational efficiency. The feeder system **100** also supports implementation of automated control strategies for maintaining various material compositions during extended operation periods. The feeder system **100** employs advanced control algorithms to enable real-time adjustment of processing parameters based on continuous monitoring of material flow characteristics. The feeder system **100** maintains compatibility with diverse powder materials including metals, ceramics, and polymers, enabling applications across multiple industrial sectors including additive manufacturing, pharmaceutical processing, and advanced materials development.

As illustrated in FIGS. **1**A-**1**D, the feeder system **100** includes multiple mechanical components configured for controlled delivery of powder materials. The feeder system **100** includes multiple wheels arranged in a vertical stack configuration, in which each wheel includes specific structural features for powder transport operations. The configuration of the feeder system **100** enables generation of functionally graded materials through control over constituent ratios, while maintaining scalability to accommodate varying throughput requirements. Further, the integration of multiple measurement technologies in the feeder system **100** enables process verification without requiring external calibration procedures.

In particular, the feeder system **100** includes a structural enclosure defined by a top cover **102** and a bottom cover

104, which establish the dimensional envelope for mounting and operational containment of internal components of the feeder system 100. The top cover 102 may include mounting features configured to support multiple powder material hoppers, drive motors, and associated mechanical components, while maintaining various geometric relationships between assembled elements. The bottom cover 104 may include structural support features that enable accurate positioning of bearing assemblies, sensor components, and powder transport mechanisms. The top cover 102 and the bottom cover 104 may maintain sealed interfaces through gasket elements and mechanical fasteners, establishing controlled environmental conditions for powder material handling operations in the feeder system 100.

The feeder system 100 also includes a mixer unit 106. The mixer unit 106 includes a mixing chamber having a volumetric capacity, which is not particularly limited and can for example be between 50 cubic centimeters and 2,000 cubic centimeters. Geometric parameters of the mixer unit 106 including chamber height, diameter, and internal surface characteristics are not particularly limited. The mixer unit 106 includes multiple inlet ports configured to receive powder materials. In some examples, the mixer unit 106 may also include features for prevention of material accumulation or stagnation during operation. The mixer unit 106 interfaces with other components in the feeder system 100 which generate controlled negative pressure conditions for powder material transport through the connected flow paths, as discussed later in the description in more detail.

The feeder system 100 includes a first wheel 110 that is donut-ring-shaped and has a first groove 112 recessed below a top surface of the first wheel 110. The first wheel 110 of the feeder system 100 has the donut-ring shape having a first diameter and includes the first groove 112 defined within the first wheel 110. The first groove 112 extends in the circumferential direction and is recessed below the top surface of the first wheel 110 by a certain depth. Further, an outer side surface of the first wheel 110 surrounds the first groove 112 through a complete 360-degree circumference. The first groove 112 defines a material containment volume configured for temporary retention of powder material during transport operations. The dimensional parameters of the first groove 112, including its width and depth, are not particularly limited and may vary for example based on required powder material and flow rate ranges.

The feeder system 100 further includes a first hopper 114 positioned above the first wheel 110 and configured to receive a first material. The first hopper 114 is mounted in a position above the first wheel 110. The first hopper 114 has an internal volume configured for receiving and storing a first powder material. Herein, the vertical spacing between the bottom surface of the first hopper 114 and the top surface of the first wheel 110 enables controlled powder material flow. The dimensional parameters of the first hopper 114, including its height and cross-sectional area, are not particularly limited and may vary for example based on required material processing duration and flow rate requirements. The first hopper 114 may include geometric features designed for consistent powder material flow characteristics, including sidewall angles to prevent material agglomeration.

In some embodiments, the first hopper 114 includes a first screw feeder 116. The first hopper 114 of the feeder system 100 includes the first screw feeder 116 that implements helical geometry for controlled powder material transport. The first screw feeder 116 may have various thread pitch, flight depth, shaft diameter, and other relevant parameters based on flow requirements of the powder material in the feeder system 100. The first screw feeder 116 maintains proper fit within the first hopper 114 through bearing supports and shaft seals, enabling controlled powder material transfer from the first hopper 114 to the first groove 112 within the feeder system 100.

The feeder system 100 further includes a first conduit 118 connecting a bottom of the first hopper 114 to the first groove 112 and defining a first feeding path for the first material. Herein, the first conduit 118 extends from the bottom section of the first hopper 114 to the first groove 112, such that the first conduit 118 defines a first feeding path for directing the first powder material from the first hopper 114 to the first groove 112. The first conduit 118 can maintain fixed alignment with both the first hopper 114 and the first groove 112 to ensure consistent powder material transport through the defined feeding path. In some configurations, the first conduit 118 may include a connection interface at the first hopper 114 to maintain various angular orientation relative to vertical. The first conduit 118 may terminate at an interface with the first groove 112, in which the interface position maintains an angular offset from the material extraction position. It may be understood that the dimensional parameters of the first conduit 118, including its internal diameter and length, are not particularly limited and may vary for example based on required powder material flow characteristics.

The feeder system 100 further includes a first suction head 120 having a first end connected to the first groove 112 and a second end connected to the mixer unit 106. In particular, the first end of the first suction head 120 has a tapered geometry that extends into the first groove 112. The second end of the first suction head 120 connects to a designated inlet port of the mixer unit 106 through a flow line. Herein, the first conduit 118 and the first suction head 120 connect to the first groove 112 at different angular positions. The dimensional parameters of the first suction head 120, including its length and any bend radius, and the like, are not particularly limited and may for example be configured based on the spatial arrangement between the first wheel 110 and the mixer unit 106.

The feeder system 100 further includes a first motor 122 configured to rotate the first wheel 110 so that the first material is transferred from the first hopper 114 to the first groove 112 via the first conduit 118 and then to the mixer unit 106 via the first suction head 120. The first motor 122 of the feeder system 100 generates rotational motion having angular velocity within an operational range of e.g. 0-300 rpm such as 0 rpm, 50 rpm, 100 rpm, 150 rpm, 200 rpm, 250 rpm, 300 rpm or any values therebetween. The first motor 122 connects to the first wheel 110 through a drive assembly that maintains mechanical coupling for torque transmission. The rotational motion of the first motor 122 enables controlled transport of the first material from the first conduit 118 to the first suction head 120 through the first groove 112. The first motor 122 can maintain rotational speed regulation through closed-loop control based on feedback signals from rotational position sensors (not shown). The operational parameters of the first motor 122, including torque output and speed stability, are not particularly limited and may vary for example based on requirements for consistent powder material transport rates under varying load conditions.

The feeder system 100 further includes a second wheel 130 that is donut-ring-shaped and has a second groove 132 recessed below a top surface of the second wheel 130. The second wheel 130 of the feeder system 100 has the donut-ring-shaped configuration having an outer diameter and an inner diameter, with the outer diameter of the second wheel

130 exceeding the outer diameter of the first wheel **110**. The second wheel **130** includes the second groove **132** that extends continuously around the circumference of the second wheel **130**. Herein, the second groove **132** maintains a recessed position below the top surface of the second wheel **130**. The second groove **132** defines a material containment volume configured for temporary retention of powder material during transport operations. The dimensional parameters of the second groove **132**, including its width and depth, are not particularly limited and may vary for example based on required powder material flow rate ranges.

The feeder system **100** further includes a second hopper **134** positioned above the second wheel **130** and configured to receive a second material. The second hopper **134** of the feeder system **100** maintains a fixed position above the second wheel **130**, in which vertical spacing between the bottom surface of the second hopper **134** and the top surface of the second wheel **130** enables controlled powder material flow. The second hopper **134** includes an internal volume configured for containment of the second powder material. The second hopper **134** includes geometric features for consistent powder material flow characteristics, including sidewall angles to prevent material agglomeration. The dimensional parameters of the second hopper **134**, including height and cross-sectional area, are not particularly limited and may vary for example based on required material processing duration and flow rate requirements.

In some embodiments, the second hopper **134** includes a second screw feeder **136**. The second hopper **134** of the feeder system **100** includes the second screw feeder **136** that implements helical geometry designed for controlled powder material transport. The second screw feeder **136** may have various thread pitch, flight depth, shaft diameter, and other relevant parameters based on flow requirements of the powder material in the feeder system **100**. The second screw feeder **136** maintains proper fit within the second hopper **134** through bearing supports and shaft seals, enabling controlled powder material transfer from the second hopper **134** to the associated second groove **132** within the feeder system **100**.

The feeder system **100** further includes a second conduit **138** connecting a bottom of the second hopper **134** to the second groove **132** and defining a second feeding path for the second material. The second conduit **138** of the feeder system **100** extends from the bottom section of the second hopper **134** to the second groove **132**, in which the second conduit **138** defines a second feeding path for directing the second powder material. The dimensional parameters of the second conduit **138**, including internal diameter and length, are not particularly limited and may vary for example based on required powder material flow characteristics. The second conduit **138** can maintain fixed alignment with both the second hopper **134** and the second groove **132** to ensure consistent powder material transport through the defined second feeding path.

The feeder system **100** further includes a second suction head **140** having a first end connected to the second groove **132** and a second end connected to the mixer unit **106**. The first end of the second suction head **140** includes a tapered geometry that extends into the second groove **132**. The second end of the second suction head **140** connects to a designated inlet port of the mixer unit **106** through a flow line. The second suction head **140** and the second conduit **138** are at different angular positions of the second wheel **130**. The dimensional parameters of the second suction head **140**, including length and bend radius, are configured based on the spatial arrangement between the second wheel **130** and the mixer unit **106**. Geometric features of the second suction head **140** including internal diameter, wall thickness, and taper angle are not particularly limited and may vary depending on specific design requirements.

The feeder system **100** further includes a second motor **142** configured to rotate the second wheel **130** so that the second material is transferred from the second hopper **134** to the second groove **132** via the second conduit **138** and then to the mixer unit **106** via the second suction head **140**. The second motor **142** of the feeder system **100** generates rotational motion having angular velocity within an operational range of e.g. 0-300 rpm such as 0 rpm, 50 rpm, 100 rpm, 150 rpm, 200 rpm, 250 rpm, 300 rpm or any values therebetween. The second motor **142** connects to the second wheel **130** through a drive assembly that maintains mechanical coupling for torque transmission. The rotational motion of the second motor **142** enables controlled transport of the second material from the second conduit **138** position to the second suction head **140** position through the second groove **132**. The second motor **142** maintains rotational speed regulation through closed-loop control based on feedback signals from rotational position sensors. The operational parameters of the second motor **142**, including torque output and speed stability, are not particularly limited and may for example vary based on requirements for consistent powder material transport rates under varying load conditions.

In the feeder system **100**, the mixer unit **106** is configured to mix the first material and the second material. Herein, the mixer unit **106** mixes the first material and the second material to generate powder mixtures having various compositional ratios. The mixer unit **106** implements a mixing chamber configuration that enables uniform distribution of powder materials received through the first suction head **120** and the second suction head **140**. The mixing chamber of the mixer unit **106** enables efficient powder material combination operations. The mixer unit **106** can include flow control features that regulate powder material transport rates through the first suction head **120** and the second suction head **140** connected thereto.

In some embodiments, during operation of the feeder system **100**, the powder materials are initially loaded into the first hopper **114** and the second hopper **134**. The first motor **122** and the second motor **142** generate rotational motion of the first wheel **110** and the second wheel **130** respectively and independently, maintaining respective angular velocities. As the first wheel **110** rotates, the first material transfers from the first hopper **114** through the first conduit **118** into the first groove **112**. Simultaneously or separately, rotation of the second wheel **130** enables transfer of the second material from the second hopper **134** through the second conduit **138** into the second groove **132**. The rotational motion of the wheels **110**, **130** transports the powder materials from their respective conduits **118**, **138** to the corresponding suction head positions. The first suction head **120** and the second suction head **140** extract the powder materials from the first groove **112** and the second groove **132** respectively, utilizing vacuum pressure generated by a pump system (as discussed later in detail) to transport the materials to the mixer unit **106**. Within the mixer unit **106**, the powder materials undergo mixing operations to achieve various compositional distributions for subsequent processing applications. Details of other components supporting this operation have been discussed in the proceeding paragraphs. The weight ratio of the first material to the second material can be controlled by e.g. rotational speeds of the first wheel **110**, the second wheel **130**, the first screw feeder **116** and the second screw feeder **136**.

In some embodiments, the feeder system **100** includes a main shaft **150** extending through a center of the first wheel **110** and a center of the second wheel **130**. Herein, the first wheel **110** and the second wheel **130** are co-axial, i.e., are maintained in a co-axial configuration. The main shaft **150** establishes a central rotational axis for both wheels **110**, **130** and implements mechanical support features that enable independent wheel rotation while maintaining axial alignment. For example, the main shaft **150** can interface with bearing assemblies mounted within central openings of the first wheel **110** and second wheel **130**, in which these bearing assemblies facilitate smooth rotational motion while maintaining dimensional stability. The main shaft **150** extends vertically through the complete assembly of the feeder system **100**, providing structural support and maintaining geometric alignment of rotating components including the first wheel **110** and the second wheel **130**.

In the feeder system **100**, the first wheel **110** is positioned above the second wheel **130**. The feeder system **100** maintains a vertical arrangement in which the first wheel **110** is positioned above the second wheel **130**, establishing a multi-level powder transport configuration. Herein, the first wheel **110** has a smaller circumference than the second wheel **130**. The first wheel **110** includes a circumferential dimension that is smaller than the circumferential dimension of the second wheel **130**, enabling a compact nested and staggered arrangement of the two wheels **110**, **130**. The vertical spacing between the first wheel **110** and the second wheel **130** may be maintained by spacers mounted on the main shaft **150**. This spacing enables independent rotation of the wheels **110**, **130** without mechanical interference. The smaller circumference of the first wheel **110** relative to the second wheel **130** enables implementation of different powder transport volumes while maintaining coordinated powder delivery through the vertical arrangement of components in the feeder system **100**.

In some embodiments, the first groove **112** surrounds an inner side surface (facing the main shaft **150**) of the first wheel **110** by 360 degrees and is surrounded by an outer side surface (facing away from the main shaft **150**) of the first wheel **110** by 360 degrees. The first groove **112** of the feeder system **100** maintains a continuous ring-shaped configuration that extends completely around the inner side surface of the first wheel **110** through a full 360-degree circumference, while the outer side surface of the first wheel **110** provides complete 360-degree circumferential containment of the first groove **112**. Similarly, the second groove **132** surrounds an inner side surface (facing the main shaft **150**) of the second wheel **130** by 360 degrees and is surrounded by an outer side surface (facing away from the main shaft **150**) of the second wheel **130** by 360 degrees. The second groove **132** extends continuously around the inner side surface of the second wheel **130** through a complete 360-degree circumference while being fully contained by the outer side surface of the second wheel **130** through a complete 360-degree circumference. The geometric configuration of both grooves **112**, **132** enables continuous powder material transport through complete rotational cycles of the respective wheels **110**, **130** while maintaining material containment within the defined volumes by the respective grooves **112**, **132** of the feeder system **100**.

In some embodiments, the first groove **112** is ring-shaped. The second groove **132** is ring-shaped. Both grooves **112**, **132** include geometric features designed for powder material containment and transport. Herein, the ring-shaped configuration enables continuous material flow during wheel rotation while preventing material dispersion outside the defined groove boundaries within the feeder system **100**.

In some embodiments, when viewed along (e.g. a longitudinal direction of) the main shaft **150**, the outer side surface of the first wheel **110** is surrounded by the inner side surface of the second wheel **130** by 360 degrees. Further, when viewed along (e.g. a longitudinal direction of) the main shaft **150**, the outer side surface of the first wheel **110** is spaced apart from the inner side surface of the second wheel **130**. That is, when viewing the feeder system **100** along the axial direction of the main shaft **150**, the outer side surface of the first wheel **110** is completely encompassed by the inner side surface of the second wheel **130** through a complete 360-degree circumference, establishing a nested and staggered wheel configuration. The feeder system **100** maintains a radial clearance between the outer side surface of the first wheel **110** and the inner side surface of the second wheel **130**. This spacing prevents mechanical interference during independent rotation of the wheels while maintaining compact dimensional characteristics of the overall assembly. The concentric arrangement of the first wheel **110** and second wheel **130** enables implementation of multiple powder transport paths with reduced space requirements for the feeder system **100**.

Further, in the feeder system **100**, the first groove **112** defines a first continuous ring-shaped space to receive the first material and transport the first material during operation.

Similarly, the second groove **132** defines a second continuous ring-shaped space to receive the second material and transport the second material. The continuous nature of both grooves **112**, **132** enables uninterrupted powder material flow through complete rotational cycles of the respective wheels **110**, **130**. Herein, the ring-shaped configuration maintains consistent material containment volume throughout the rotation. The dimensional specifications of both grooves **112**, **132** are not particularly limited and may for example vary based on required powder material flow rates and transport characteristics within the feeder system **100**.

Furthermore, in some embodiments, the first conduit **118** and the first suction head **120** are positioned at different angular positions of the first groove **112**. Similarly, the second conduit **138** and the second suction head **140** are positioned at different angular positions of the second groove **132**. That is, the feeder system **100** implements offset angular positioning of powder transport components in which the first conduit **118** and the first suction head **120** maintain different angular positions along the first groove **112** to enable controlled material transport sequences. Similarly, the second conduit **138** and the second suction head **140** are positioned at different angular positions along the second groove **132**. The angular separation between conduit and suction head positions can be used to establish required powder material residence time within each groove during wheel rotation. The first conduit **118** maintains a first angular position while the first suction head **120** is positioned at a second angular position, such that the difference between the two angular positions defines the powder transport arc length along the first groove **112**. Independently, the second conduit **138** and the second suction head **140** maintain similar or different angular positions along the second groove **132**.

In some embodiments, the first suction head **120** and the second suction head **140** are positioned at a same angular position relative to the shaft **150**. The feeder system **100** can therefore include a synchronized powder extraction configuration by maintaining the first suction head **120** and second suction head **140** at an identical angular position relative to the main shaft **150**. This aligned positioning of suction heads enables compact space-saving design and coordinated powder material extraction from both wheels **110**, **130** while maintaining uniform flow path geometry to the mixer unit **106**. The angular position of both suction heads **120**, **140** can be used to control powder material extraction efficiency based on rotational dynamics and vacuum transport parameters within the feeder system **100**. The common radial positioning further enables implementation of simplified support structures and vacuum flow path routing within the feeder system **100**.

In the feeder system **100**, the first suction head **120** is shorter than the second suction head **140**. The feeder system **100** implements such suction head configuration to accommodate the vertical spacing between the first wheel **110** and the second wheel **130**, while maintaining identical outlet positions at the mixer unit **106**. The length difference between the suction heads **120**, **140** based on the vertical spacing between the wheels **110**, **130** is not particularly limited.

Further, in the feeder system **100**, the first end of the first suction head **120** is tapered and is positioned in the first groove **112**, and the first end of the second suction head **140** is tapered and is positioned in the second groove **132**. The feeder system **100** includes such geometry for the suction heads **120**, **140** with tapered configuration at the powder extraction interfaces to maintain dimensional fit within the respective grooves **112**, **132**. The tapered configurations of both suction heads **120**, **140** enable efficient powder material extraction while reducing disruption to material flow within the grooves **112**, **132**. The taper angles and dimensional specifications are not particularly limited and may for example vary based on powder material characteristics and required extraction performance parameters of the feeder system **100**.

As mentioned in the preceding paragraphs, the feeder system **100** further includes at least one vacuum pump **156**, e.g. a venturi vacuum pump, a first flow line **158** connecting the second end of the first suction head **120** to the mixer unit **106**, and a second flow line **160** connecting the second end of the second suction head **140** to the mixer unit **106**. The feeder system **100** includes the vacuum pump **156** to provide vacuum-driven material transport configuration in which the first flow line **158** establishes a powder transport path between the second end of the first suction head **120** and the mixer unit **106**, and the second flow line **160** similarly connects the second end of the second suction head **140** to the mixer unit **106**. Both flow lines **158**, **160** can be tuned for consistent powder material transport under vacuum conditions. The flow lines **158**, **160** interface with dedicated inlet ports on the mixer unit **106**. In the present configuration, the mixer unit **106** interfaces with the vacuum pump **156** that generates controlled negative pressure conditions e.g. within a range of 0.2 to 0.8 bar for consistent powder material transport through the connected flow lines **158**, **160**.

Further, in some embodiments, the feeder system **100** includes a first screw motor **162** configured to rotate the first screw feeder **116**, and a second screw motor **164** configured to rotate the second screw feeder **136**. The feeder system **100** implements such independent screw feeder control through the first screw motor **162** configured to generate rotational motion of the first screw feeder **116** and the second screw motor **164** similarly providing rotational drive for the second screw feeder **136**. Both motors **162**, **164** include closed-loop control capabilities enabling regulation of rotational speeds of the respective screw feeders **116**, **136**. The motors **162**, **164** connect to their respective screw feeders **116**, **136** through mechanical drive assemblies that maintain positive engagement.

In some embodiments, the first screw motor **162** is configured to rotate the first screw feeder **116** at a different speed from the first wheel **110**, and the second screw motor **164** is configured to rotate the second screw feeder **136** at a different speed from the second wheel **130**. That is, the first screw motor **162** of the feeder system **100** operates to rotate the first screw feeder **116** at a rotational speed independently controlled relative to the rotational speed of the first wheel **110**. Similarly, the second screw motor **164** maintains independent speed control of the second screw feeder **136** relative to the second wheel **130**. This independent speed control capability enables control of powder material transfer rates through independent adjustment of screw feeder and wheel rotational parameters. The operational speed ranges are not particularly limited and can for example extend from 0 to 300 rpm such as 0 rpm, 50 rpm, 100 rpm, 150 rpm, 200 rpm, 250 rpm, 300 rpm or any values therebetween for screw feeders **116**, **136**, and from 0 to 300 rpm such as 0 rpm, 50 rpm, 100 rpm, 150 rpm, 200 rpm, 250 rpm, 300 rpm or any values therebetween for wheels **110**, **130** within the feeder system **100**.

In some embodiments, the feeder system **100** includes a first sensor **166** positioned below the first hopper **114** and configured to measure a weight of the first hopper **114** and the first material therein, and a second sensor **168** positioned below the second hopper **134** and configured to measure a weight of the second hopper **134** and the second material therein. The feeder system **100** includes such weight monitoring capabilities through the first sensor **166** positioned below the first hopper **114** to measure the combined weight of the first hopper **114** and contained first material. The second sensor **168** maintains similar measurement capability for the second hopper **134** and second material. Both sensors **166**, **168** generate continuous weight measurement signals enabling real-time monitoring of powder material consumption rates. The measurement range is not particularly limited and can for example extend from 0 to 5000 grams with resolution of 0.1 grams, enabling tracking of material transfer rates through the feeder system **100**. The sensors **166**, **168** outputs interface with control systems to enable automated regulation of powder material flow rates based on measured weight changes.

In some embodiments, the feeder system **100** further includes a first wheel disc **152** that is in direct contact with the first wheel **110**, and a second wheel disc **154** that is in direct contact with the second wheel **130**. Herein, the first wheel disc **152** has a drive interface geometry configured for positive engagement with the first wheel **110**, such that this interface enables efficient torque transmission while maintaining rotational alignment. The second wheel disc **154** implements similar or identical interface characteristics with the second wheel **130**. In the feeder system **100**, the first motor **122** is configured to rotate the first wheel **110** by rotating the first wheel disc **152** which rotates the first wheel **110**, and the second motor **142** is configured to rotate the second wheel **130** by rotating the second wheel disc **154** which rotates the second wheel **130**. The first motor **122** connects to the first wheel disc **152** through a drive assembly that converts motor rotational output to wheel rotation, in which rotation of the first wheel disc **152** directly drives rotation of the first wheel **110**. Similarly, the second motor **142** connects to the second wheel disc **154**, enabling controlled rotation of the second wheel **130** through direct mechanical coupling with the second wheel disc **154**. Both wheel discs **152**, **154** include dimensional specifications designed for stable torque transmission while maintaining concentricity with the main shaft **150** of the feeder system **100**.

During operation of the feeder system **100**, powder materials are initially loaded into the first hopper **114** and the second hopper **134**, with material weights continuously monitored by the first sensor **166** and the second sensor **168** respectively. The first screw feeder **116** and the second screw feeder **136**, driven by the first screw motor **162** and the second screw motor **164** respectively, operate at independently controlled speeds of e.g. 0-300 rpm such as 0 rpm, 50 rpm, 100 rpm, 150 rpm, 200 rpm, 250 rpm, 300 rpm or any values therebetween to transport powder materials from the hoppers **114**, **134** to their corresponding grooves **112**, **132**. Independently, the first motor **122** and the second motor **142** drive rotation of the first wheel **110** and the second wheel **130** through the first wheel disc **152** and the second wheel disc **154** respectively, maintaining speeds of e.g. 0-300 rpm such as 0 rpm, 50 rpm, 100 rpm, 150 rpm, 200 rpm, 250 rpm, 300 rpm or any values therebetween.

As the wheels **110**, **130** rotate, powder materials deposited in the first groove **112** and the second groove **132** through the first conduit **118** and the second conduit **138** are transported to positions aligned with the first suction head **120** and the second suction head **140**, respectively. The vacuum pump generates negative pressure through the first flow line **158** and the second flow line **160**, enabling extraction of powder materials through the tapered ends of the suction heads **120**, **140**. The extracted materials travel through the flow lines **158**, **160** to the mixer unit **106**, where controlled mixing operations generate powder mixtures with various compositional characteristics. This coordinated operation of multiple mechanical components enables control over the rate of transfer of the powder material and the mixing ratios thereof, within the feeder system **100**.

In some embodiments, as illustrated, the feeder system **100** includes a third wheel **170**. The embodiment of the third wheel **170** is similar to the embodiment of the first wheel **110** and the embodiment of the second wheel **130**, with differences in e.g. dimensions. For example, the third wheel **170** is donut-ring-shaped and has a third groove **172** recessed below a top surface of the third wheel **170**. The third wheel **170** has the donut-ring-shaped configuration having an outer diameter exceeding the outer diameter of the second wheel **130**. The third wheel **170** includes the third groove **172** extending continuously around the circumference and recessed below the top surface of the third wheel **170**. The feeder system **100** further includes a third hopper **174** positioned above the third wheel **170** and configured to receive a third material. The third hopper **174** can maintain fixed position above the third wheel **170** and include a third screw feeder **176** for controlled powder transport. The feeder system **100** further includes a third conduit **178** connecting a bottom of the third hopper **174** to the third groove **172** and defining a third feeding path for the third material. The feeder system **100** further includes a third suction head **180** having a first end connected to the third groove **172** and a second end connected to the mixer unit **106**. Herein, the first end includes tapered geometry for powder extraction. The feeder system **100** further includes a third motor **182** configured to rotate the third wheel **170** so that the third material is transferred from the third hopper **174** to the third groove **172** via the third conduit **178** and then to the mixer unit **106** via the third suction head **180**. Herein, the third motor **182** connects to the third wheel **170** through a third wheel disc **184**, enabling controlled wheel rotation for powder material transport from the third hopper **174** to the mixer unit **106**. In this configuration of the feeder system **100**, the mixer unit **106** is configured to mix the first material, the second material and the third material.

In some embodiments, the first wheel **110**, the second wheel **130** and the third wheel **170** are co-axial. Specifically, the main shaft **150** of the feeder system **100** extends through central axes of all three wheels, maintaining coaxial alignment of the first wheel **110**, the second wheel **130**, and the third wheel **170**. This vertical arrangement positions the first wheel **110** above the second wheel **130**, which is positioned above the third wheel **170**. Further, herein, the first wheel **110** is positioned above the second wheel **130** which is positioned above the third wheel **170**; and the first wheel **110** has a smaller circumference than the second wheel **130** which has a smaller circumference than the third wheel **170**. That is, the wheels **110**, **130**, **170** implement progressively increasing circumferential dimensions, in which the first wheel **110** maintains smaller circumference than the second wheel **130**, which maintains smaller circumference than the third wheel **170**. This nested arrangement enables compact integration of three independent powder transport paths while maintaining spacing between adjacent wheels for interference-free rotation.

During operation of the feeder system **100**, the third wheel **170**, the first wheel **110** and the second wheel **130** can operate independently to enable simultaneous transport of three distinct powder materials. The third screw feeder **176** operates at independently controlled rotational speed to regulate powder flow from the third hopper **174** into the third groove **172**. The third motor **182** drives rotation of the third wheel **170** through the third wheel disc **184**, transporting powder material to position of the third suction head **180**. The vacuum-driven powder extraction through the third suction head **180** enables material transport to the mixer unit **106**, where mixing of three powder materials generates mixtures with controlled compositional characteristics based on the regulated material flow rates from wheels and screw feeders of the feeder system **100**.

In particular, during operation of the feeder system **100**, the first hopper **114**, the second hopper **134**, and the third hopper **174** receive designated powder materials for processing. Each hopper includes an integrated screw feeder wherein the first screw feeder **116** is incorporated within the first hopper **114**, the second screw feeder **136** is incorporated within the second hopper **134**, and the third screw feeder **176** is incorporated within the third hopper **174**. The hoppers maintain fixed positions on the feeder system **100** while the first sensor **166**, the second sensor **168**, and corresponding weight measurement devices monitor material mass within each hopper. The first screw feeder **116**, the second screw feeder **136**, and the third screw feeder **176** independently operate at various rotational velocities through their respective motors, enabling measured powder material deposition into the first groove **112**, the second groove **132**, and the third groove **172** respectively.

As each wheel rotates with contained powder material, the bulk density of the powder material within each groove is calculated according to the following equation:

$$\text{Bulk density} = \text{mass of powder material}/\text{volume of groove}$$

The bulk density calculation includes mass measurements from the weight sensors and known volumetric parameters of the grooves. This calculated bulk density, combined with measured rotational speeds and groove volumes, enables determination of powder material flow rates through the first suction head **120**, the second suction head **140**, and the third suction head **180** without requiring separate calibration procedures for different materials. That is, there is no need for additional experimentation to measure the material flow rate at various rotation speed of the disc or change in material. The suction heads connect to the mixer unit **106**, wherein vacuum pressure generates controlled material transport to the mixer unit **106**.

The feeder system **100** includes computer-based control systems (as discussed later in reference to FIGS. **2-5**) that maintain real-time regulation of motor speeds including the first motor **122**, the second motor **142**, the third motor **182**, the first screw motor **162**, the second screw motor **164** and the like. This coordinated control enables adjustment of powder material composition through independent regulation of screw feeder and wheel rotational speeds. Such control capabilities of the feeder system **100** enable implementation in functionally graded material manufacturing processes including Laser Direct Energy Deposition additive manufacturing applications where controlled material composition gradients are required.

It may be appreciated that the illustrations of the present disclosure depict the feeder system **100** incorporating the first wheel **110**, the second wheel **130**, and the third wheel **170**. However, the feeder system **100** maintains operational capabilities with various wheel configurations including implementation with only the first wheel **110** and the second wheel **130**, or configurations incorporating four or more wheels arranged in the coaxial configuration. The reduced operational requirement includes the first wheel **110** and the second wheel **130** maintained in the coaxial arrangement along the main shaft **150**, enabling basic two-material processing capabilities. The scope and the spirit of the present disclosure encompasses any number of wheels arranged in the coaxial configuration while maintaining various geometric relationships, material transport mechanisms, and operational parameters described herein.

The feeder system **100** of the present disclosure maintains operational compatibility with multiple powder processing applications including powder-based Additive Manufacturing processes. The coaxial arrangement of multiple powder transport mechanisms enables flow rate control and material composition adjustment required in Laser Direct Energy Deposition (LDED) processes. The compact dimensional characteristics and real-time monitoring capabilities of the feeder system **100** further enable implementation in pharmaceutical manufacturing operations where controlled powder mixing and compositional control are required. The feeder system **100** includes vacuum-driven powder transport mechanisms and integrated measurement capabilities that maintain applicability across diverse powder processing requirements including metal powder, ceramic powder, and polymer powder applications.

The feeder system **100** of the present disclosure represents advancement in powder material processing through implementation of multiple material handling mechanisms in a compact coaxial configuration. The integration of multiple powder transport paths within a unified framework enables simultaneous processing of multiple materials while maintaining independent control over individual material parameters. The incorporation of real-time weight measurement capabilities eliminates requirements for separate calibration procedures while enabling direct calculation of material flow rates during operation. The feeder system **100** provides multiple advantages over conventional powder feeding mechanisms through implementation of the coaxial wheel arrangement. This configuration reduces spatial requirements compared to individual disc arrangements while maintaining independent control over multiple powder materials. The incorporation of both screw feeder and rotating disc mechanisms enables wide range flow rate control without requiring separate calibration procedures for different materials. The real-time weight measurement capabilities and vacuum-driven material transport enable composition control required for functionally graded material applications while maintaining operational efficiency through the compact mechanical arrangement.

Next, further details of the hardware description of a computing environment according to exemplary embodiments is described with reference to FIG. **2**. In FIG. **2**, a controller **200** is described is representative of the computer-based control systems for the feeder system **100** to control operations of various electrical components therein, in which the controller **200** is a computing device which includes a CPU **201** which performs the processes described above/below. The process data and instructions may be stored in memory **202**. These processes and instructions may also be stored on a storage medium disk **204** such as a hard drive (HDD) or portable storage medium or may be stored remotely.

Further, the claims are not limited by the form of the computer-readable media on which the instructions of the inventive process are stored. For example, the instructions may be stored on CDs, DVDs, in FLASH memory, RAM, ROM, PROM, EPROM, EEPROM, hard disk or any other information processing device with which the computing device communicates, such as a server or computer.

Further, the claims may be provided as a utility application, background daemon, or component of an operating system, or combination thereof, executing in conjunction with CPU **201**, **203** and an operating system such as Microsoft Windows 7, Microsoft Windows 8, Microsoft Windows 10, UNIX, Solaris, LINUX, Apple MAC-OS and other systems known to those skilled in the art.

The hardware elements in order to achieve the computing device may be realized by various circuitry elements, known to those skilled in the art. For example, CPU **201** or CPU **203** may be a Xenon or Core processor from Intel of America or an Opteron processor from AMD of America, or may be other processor types that would be recognized by one of ordinary skill in the art. Alternatively, the CPU **201**, **203** may be implemented on an FPGA, ASIC, PLD or using discrete logic circuits, as one of ordinary skill in the art would recognize. Further, CPU **201**, **203** may be implemented as multiple processors cooperatively working in parallel to perform the instructions of the inventive processes described above.

The computing device in FIG. **2** also includes a network controller **206**, such as an Intel Ethernet PRO network interface card from Intel Corporation of America, for interfacing with network **260**. As can be appreciated, the network **260** can be a public network, such as the Internet, or a private network such as an LAN or WAN network, or any combination thereof and can also include PSTN or ISDN sub-networks. The network **260** can also be wired, such as an Ethernet network, or can be wireless such as a cellular network including EDGE, 3G, 4G and 5G wireless cellular systems. The wireless network can also be WiFi, Bluetooth, or any other wireless form of communication that is known.

The computing device further includes a display controller **208**, such as a NVIDIA Geforce GTX or Quadro graphics adaptor from NVIDIA Corporation of America for interfacing with display **210**, such as a Hewlett Packard HPL2445w LCD monitor. A general purpose I/O interface **212** interfaces with a keyboard and/or mouse **214** as well as a touch screen panel **216** on or separate from display **210**. General purpose I/O interface also connects to a variety of peripherals **218** including printers and scanners, such as an Office et or DeskJ et from Hewlett Packard.

A sound controller **220** is also provided in the computing device such as Sound Blaster X-Fi Titanium from Creative, to interface with speakers/microphone **222** thereby providing sounds and/or music.

The general purpose storage controller **224** connects the storage medium disk **204** with communication bus **226**, which may be an ISA, EISA, VESA, PCI, or similar, for interconnecting all of the components of the computing device. A description of the general features and functionality of the display **210**, keyboard and/or mouse **214**, as well as the display controller **208**, storage controller **224**, network controller **206**, sound controller **220**, and general purpose I/O interface **212** is omitted herein for brevity as these features are known.

The exemplary circuit elements described in the context of the present disclosure may be replaced with other elements and structured differently than the examples provided herein. Moreover, circuitry configured to perform features described herein may be implemented in multiple circuit units (e.g., chips), or the features may be combined in circuitry on a single chipset, as shown on FIG. **3**.

FIG. **3** shows a schematic diagram of a data processing system, according to certain embodiments, for performing the functions of the exemplary embodiments. The data processing system is an example of a computer in which code or instructions implementing the processes of the illustrative embodiments may be located.

In FIG. **3**, data processing system **300** employs a hub architecture including a north bridge and memory controller hub (NB/M CH) **325** and a south bridge and input/output (I/O) controller hub (SB/ICH) **320**. The central processing unit (CPU) **330** is connected to NB/M CH **325**. The NB/M CH **325** also connects to the memory **345** via a memory bus, and connects to the graphics processor **350** via an accelerated graphics port (AGP). The NB/M CH **325** also connects to the SB/ICH **320** via an internal bus (e.g., a unified media interface or a direct media interface). The CPU Processing unit **330** may contain one or more processors and even may be implemented using one or more heterogeneous processor systems.

For example, FIG. **4** shows one implementation of CPU **330**. In one implementation, the instruction register **438** retrieves instructions from the fast memory **440**. At least part of these instructions are fetched from the instruction register **438** by the control logic **436** and interpreted according to the instruction set architecture of the CPU **330**. Part of the instructions can also be directed to the register **432**. In one implementation the instructions are decoded according to a hardwired method, and in another implementation the instructions are decoded according a microprogram that translates instructions into sets of CPU configuration signals that are applied sequentially over multiple clock pulses. After fetching and decoding the instructions, the instructions are executed using the arithmetic logic unit (ALU) **434** that loads values from the register **432** and performs logical and mathematical operations on the loaded values according to the instructions. The results from these operations can be feedback into the register and/or stored in the fast memory **440**. According to certain implementations, the instruction set architecture of the CPU **330** can use a reduced instruction set architecture, a complex instruction set architecture, a vector processor architecture, a very large instruction word architecture. Furthermore, the CPU **330** can be based on the Von Neuman model or the Harvard model. The CPU **330** can be a digital signal processor, an FPGA, an A SIC, a PLA, a PLD, or a CPLD. Further, the CPU **330** can be an x86 processor by Intel or by AMD; an ARM processor, a Power architecture processor by, e.g., IBM; a SPARC architecture processor by Sun Microsystems or by Oracle; or other known CPU architecture.

Referring again to FIG. **3**, the data processing system **300** can include that the SB/ICH **320** is coupled through a system bus to an I/O Bus, a read only memory (ROM) **356**, universal serial bus (USB) port **364**, a flash binary input/output system (BIOS) **368**, and a graphics controller **358**. PCI/PCIe devices can also be coupled to SB/ICH **388** through a PCI bus **362**.

The PCI devices may include, for example, Ethernet adapters, add-in cards, and PC cards for notebook computers. The Hard disk drive **360** and CD-ROM **366** can use, for example, an integrated drive electronics (IDE) or serial advanced technology attachment (SATA) interface. In one implementation the I/O bus can include a super I/O (SIO) device.

Further, the hard disk drive (HDD) **360** and optical drive **366** can also be coupled to the SB/ICH **320** through a system bus. In one implementation, a keyboard **370**, a mouse **372**, a parallel port **378**, and a serial port **376** can be connected to the system bus through the I/O bus. Other peripherals and devices that can be connected to the SB/ICH **320** using a mass storage controller such as SATA or PATA, an Ethernet port, an ISA bus, a L PC bridge, SM Bus, a DMA controller, and an Audio Codec.

Moreover, the present disclosure is not limited to the specific circuit elements described herein, nor is the present disclosure limited to the specific sizing and classification of these elements. For example, the skilled artisan will appreciate that the circuitry described herein may be adapted based on changes on battery sizing and chemistry or based on the requirements of the intended back-up load to be powered.

The functions and features described herein may also be executed by various distributed components of a system. For example, one or more processors may execute these system functions, wherein the processors are distributed across multiple components communicating in a network. The distributed components may include one or more client and server machines, such as cloud **530** including a cloud controller **536**, a secure gateway **532**, a data center **534**, data storage **538** and a provisioning tool **540**, and mobile network services **520** including central processors **522**, a server **524** and a database **526**, which may share processing, as shown by FIG. **5**, in addition to various human interface and communication devices (e.g., display monitors **516**, smart phones **510**, tablets **512**, personal digital assistants (PDAs) **514**). The network may be a private network, such as a LAN, satellite **552** or WAN **554**, or be a public network, may such as the Internet. Input to the system may be received via direct user input and received remotely either in real-time or as a batch process. Additionally, some implementations may be performed on modules or hardware not identical to those described. Accordingly, other implementations are within the scope that may be claimed.

While specific embodiments of the invention have been described, it should be understood that various modifications and alternatives may be implemented without departing from the spirit and scope of the invention. For example, different cellular automata rules or encryption algorithms could be employed, or alternative feature extraction and face recognition techniques could be integrated into the system.

The above-described hardware description is a non-limiting example of corresponding structure for performing the functionality described herein.

Numerous modifications and variations of the present disclosure are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

The invention claimed is:

1. A fine solids transport and metering system, comprising:

a first hopper configured to receive a first powder;

a second hopper configured to receive a second powder;

a first sensor positioned below the first hopper;

a second sensor positioned below the second hopper;

a first wheel that is donut-ring-shaped and has a first groove recessed below a top surface of the first wheel;

wherein the first hopper is positioned above the first wheel;

a first conduit connecting a bottom of the first hopper to the first groove and defining a first feeding path for the first powder;

a mixer unit;

a first suction head having a first end connected to the first groove and a second end connected to the mixer unit;

a first motor configured to rotate the first wheel so that the first powder is transferred from the first hopper to the first groove via the first conduit and then to the mixer unit via the first suction head;

a second wheel that is donut-ring-shaped and has a second groove recessed below a top surface of the second wheel;

wherein the second hopper is positioned above the second wheel;

a second conduit connecting a bottom of the second hopper to the second groove and defining a second feeding path for the second powder;

a second suction head having a first end connected to the second groove and a second end connected to the mixer unit; and

a second motor configured to rotate the second wheel so that the second powder is transferred from the second hopper to the second groove via the second conduit and then to the mixer unit via the second suction head, wherein

the mixer unit is configured to mix the first powder and the second powder.

2. The system of claim **1**, further comprising:

a shaft extending through a center of the first wheel and a center of the second wheel, wherein the first wheel and the second wheel are co-axial.

3. The system of claim **2**, wherein:

the first wheel is positioned above the second wheel, and

the first wheel has a smaller circumference than the second wheel.

4. The system of claim **3**, wherein:

the first groove surrounds an inner side surface of the first wheel by 360 degrees and is surrounded by an outer side surface of the first wheel by 360 degrees, and

the second groove surrounds an inner side surface of the second wheel by 360 degrees and is surrounded by an outer side surface of the second wheel by 360 degrees.

5. The system of claim **4**, wherein:

the first conduit and the first suction head are positioned at different angular positions of the first groove, and

the second conduit and the second suction head are positioned at different angular positions of the second groove.

6. The system of claim **5**, wherein:

the first suction head and the second suction head are positioned at a same angular position relative to the shaft.

7. The system of claim **6**, wherein:

the first groove is ring-shaped, and

the second groove is ring-shaped.

8. The system of claim **4**, wherein:

when viewed along the shaft, the outer side surface of the first wheel is surrounded by the inner side surface of the second wheel by 360 degrees.

9. The system of claim **8**, wherein:

when viewed along the shaft, the outer side surface of the first wheel is spaced apart from the inner side surface of the second wheel.

10. The system of claim **4**, wherein:

the first groove defines a first continuous ring-shaped space to receive the first powder, and

the second groove defines a second continuous ring-shaped space to receive the second powder.

11. The system of claim **3**, wherein:

the first suction head is shorter than the second suction head.

12. The system of claim **1**, wherein:

the first end of the first suction head is tapered and is positioned in the first groove, and

the first end of the second suction head is tapered and is positioned in the second groove.

13. The system of claim **1**, further comprising a vacuum pump including:

a first flow line connecting the second end of the first suction head to the mixer unit; and

a second flow line connecting the second end of the second suction head to the mixer unit.

14. The system of claim **1**, wherein:

the first hopper comprises a first screw feeder, and

the second hopper comprises a second screw feeder.

15. The system of claim **14**, further comprising:

a first screw motor configured to rotate the first screw feeder; and

a second screw motor configured to rotate the second screw feeder.

16. The system of claim **15**, wherein:

the first screw motor is configured to rotate the first screw feeder at a different speed from the first wheel, and

the second screw motor is configured to rotate the second screw feeder at a different speed from the second wheel.

17. The system of claim **1**, further comprising:

wherein the first sensor is configured to measure a weight of the first hopper and the first powder therein; and

wherein the second sensor is configured to measure a weight of the second hopper and the second powder therein.

18. The system of claim **1**, further comprising:

a first wheel disc that is in direct contact with the first wheel; and

a second wheel disc that is in direct contact with the second wheel, wherein

the first motor is configured to rotate the first wheel by rotating the first wheel disc which rotates the first wheel, and the second motor is configured to rotate the second wheel by rotating the second wheel disc which rotates the second wheel.

19. The system of claim **1**, further comprising:

a third wheel that is donut-ring-shaped and has a third groove recessed below a top surface of the third wheel;

a third hopper positioned above the third wheel and configured to receive a third powder;

a third conduit connecting a bottom of the third hopper to the third groove and defining a third feeding path for the third powder;

a third suction head having a first end connected to the third groove and a second end connected to the mixer unit; and

a third motor configured to rotate the third wheel so that the third powder is transferred from the third hopper to the third groove via the third conduit and then to the mixer unit via the third suction head, wherein

the mixer unit is configured to mix the first powder, the second powder and the third powder.

20. The system of claim **19**, further comprising:

a shaft extending through a center of the first wheel and a center of the second wheel, wherein

the first wheel, the second wheel and the third wheel are co-axial,

the first wheel is positioned above the second wheel which is positioned above the third wheel, and

the first wheel has a smaller circumference than the second wheel which has a smaller circumference than the third wheel.

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