printed units (e.g., in volume, shape, weight, and/or composition). Such systems are also expensive to manufacture and maintain, as well as inefficient and complex to operate.

[0005] In particular, the printing materials required in the pharmaceutical context tend to be of high viscosity and are associated with low printing pressure. Further, when multiple types of printing material are involved in the printing process, nozzles dispensing these different types of printing material need to be operating in a coordinated manner (e.g., opened and closed alternately). Traditional 3D printing systems cannot coordinate the operation of multiple nozzles and control the release of multiple types of material in a precise and consistent manner. Thus, traditional 3D printing systems cannot maintain a high level of consistency among the pharmaceutical dosage units outputted by the nozzles, in the same batch or across multiple batches. The above-described challenges are compounded if the pharmaceutical unit to be manufactured is composed of different materials arranged in a particular structure (e.g., multiple inner parts coated with a shell).

[0006] Further, configuring multiple 3D printers to work together to produce a batch of pharmaceutical dosage units does not produce satisfactory results when conventional 3D printing techniques are used. Specifically, inconsistencies among the multiple 3D printers (e.g., in both hardware configuration and software configuration) can cause the end product to be inconsistent and thus fail to meet the quality standards. Further, system involving the coordination among multiple 3D printers are generally inefficient to operate and expensive to maintain.

[0007] Thus, there is a need for systems and methods for 3D printing pharmaceutical dosage units (e.g., tablets caplets, printlets) in an accurate, precise, and cost-efficient manner, while maintaining high throughput over time. There is also a need for a system that can coordinate the operations of multiple 3D printers to print a batch of pharmaceutical dosage units.

BRIEF SUMMARY

[0008] According to a first aspect, there is provided a system for creating pharmaceutical products by additive manufacturing, including: a material supply module for receiving a set of printing materials for creating the pharmaceutical products; a flow distribution module comprising a flow distribution plate, wherein the material supply module is configured to transport a single flow corresponding to the set of printing materials to the flow distribution plate; wherein the flow distribution plate comprises: a plurality of channels for dividing the single flow into a plurality of flows; a plurality of nozzles; and one or more controllers for

controlling the plurality of nozzles to dispense the plurality of flows based on a plurality of nozzle-specific parameters to create the pharmaceutical products, wherein the set of printing materials for creating the pharmaceutical products is heated to a first temperature in the flow distribution plate and heated to a second temperature higher than the first temperature in the plurality of nozzles.

[0008a] According to a second aspect, there is provided a method for creating pharmaceutical products by additive manufacturing, including: receiving, by a material supply module, a set of printing materials for creating the pharmaceutical products; transporting a single flow corresponding to the set of printing materials to a flow distribution module comprising a flow distribution plate; dividing, by a plurality of channels of the flow distribution plate, the single flow into a plurality of flows, wherein the set of printing materials is heated to a first temperature in the flow distribution plate; receiving, by a plurality of nozzles, the plurality of flows; heating, in the plurality of nozzles, the set of printing materials to a second temperature higher than the first temperature; and controlling, by one or more controllers, the plurality of nozzles to dispense the plurality of flows based on a plurality of nozzle-specific parameters to create the pharmaceutical products.

[0009] In some embodiments, the system further comprises a printing platform configured to receive the dispensed plurality of flows, wherein the printing platform is configured to move to form a batch of the pharmaceutical product.

[0010] In some embodiments, the material supply module is configured to heat the received set of printing materials.

[0011] In some embodiments, the material supply module is configured to plasticize the received set of printing materials.

[0012] In some embodiments, the material supply module comprises a piston mechanism, a screw mechanism, a screw pump mechanism, a cogwheel mechanism, a plunger pump mechanism or any combination thereof.

[0013] In some embodiments, the plurality of channels forms a first juncture configured to dividing the single flow into two flows.

[0014] In some embodiments, wherein the plurality of channels forms a second juncture and a third juncture configured to divide the two flows into 4 flows.

[0015] In some embodiments, the first juncture is positioned higher than the second juncture and the third juncture.

[0016] In some embodiments, the first juncture, the second juncture, and the third juncture are positioned on a same plane.

[0017] In some embodiments, the flow distribution plate is split-table into a plurality of components, wherein the plurality of components are configured to be held together via one or more screws.

[0018] In some embodiments, a nozzle of the plurality of nozzles comprises a heater.

[0019] In some embodiments, a nozzle of the plurality of nozzles comprises a thermal isolation structure.

[0020] In some embodiments, the plurality of nozzles comprises a plurality of needle-valve mechanisms.

[0021] Disclosed herein is a needle-valve mechanism of the plurality of needle-valve mechanisms including: a feed channel extending through the respective nozzle, wherein the feed channel is tapered at a distal end of the nozzle; and a needle, wherein a distal end of the needle is configured to be in contact and seal the feed channel when the needle-valve mechanism is in a closed position, and wherein the distal end of the needle is configured to be retracted to allow a flow of printing materials to be dispensed.

[0022] In some embodiments, movement of the needle is driven by one or more actuators.

[0023] In some embodiments, the one or more actuators include a linear motor.

[0024] In some embodiments, movement of the needle is controlled manually.

[0025] In some embodiments, the needle is a first needle, the plurality of nozzles comprises a single plate coupled to the first needle and a second needle, and wherein movement of the single plate causes movement of the first needle and the second needle.

[0026] In some embodiments, a parameter of the plurality of nozzle-specific parameters comprises an amount of opening of a respective nozzle.

[0027] In some embodiments, the one or more controllers are configured to adjust the amount of opening of the respective nozzle based on a weight of a unit in the batch corresponding to the respective nozzle.

[0028] In some embodiments, the one or more controllers are configured to adjust the amount of opening of the respective nozzle based one or more machine learning algorithms.

[0029] In some embodiments, the one or more controllers are configured to control temperature or pressure at the plurality of the nozzles.

[0030] In some embodiments, the temperature is controlled via a temperature control device comprising one or more heating devices, one or more cooling devices, or a combination thereof.

[0031] In some embodiments, a temperature at the plurality of the nozzles is higher than a temperature at the materials supply module.

[0032] In some embodiments, a temperature at the plurality of the nozzles is higher than a temperature at the flow distribution plate.

[0033] In some embodiments, the one or more controllers are configured to control a feeding speed of the set of printing materials.

[0034] In some embodiments, the plurality of nozzles is a first plurality of nozzles, the printing system further comprising a second plurality of nozzles configured to dispense a different set of materials, wherein the printing system is configured to switch between the first plurality of nozzles and the second plurality of nozzles to print the batch.

[0035] In some embodiments, the pharmaceutical unit is a tablet.

[0036] Disclosed herein is a computer-enabled method for creating pharmaceutical products by additive manufacturing, including: receiving a plurality of unit measurements corresponding to a plurality of pharmaceutical dosage units, wherein the plurality of pharmaceutical dosage units are generated using a plurality of nozzles of an additive manufacturing system; determining whether a sum of the plurality of unit measurements differs from a target batch measurement by more than a predefined threshold; in accordance with a determination that the sum differs from the target batch measurement by more than the predefined threshold, adjusting one or more nozzles of the plurality of nozzles based on an average of the plurality of unit measurements; in accordance with a determination that the sum does not differ from the target batch measurement

by more than the predefined threshold, adjusting one or more nozzles of the plurality of nozzles based on a target unit measurement.

[0037] In some embodiments, the plurality of pharmaceutical unit is a plurality of tablets.

[0038] In some embodiments, the unit measurements are weight measurements of the plurality of pharmaceutical dosage units.

[0039] In some embodiments, the unit measurements are volume measurements of the plurality of pharmaceutical dosage units.

[0040] In some embodiments, the unit measurements are composition measurements of the plurality of pharmaceutical dosage units.

[0041] In some embodiments, the method further comprises: in accordance with a determination that the sum differs from the target batch measurement by more than the predefined threshold, adjusting one or more operation parameters of the additive manufacturing system.

[0042] In some embodiments, the one or more operation parameters include temperature.

[0043] In some embodiments, the one or more operation parameters include pressure.

[0044] In some embodiments, the one or more operation parameters include a speed of feeding printing materials.

[0045] In some embodiments, the predefined threshold is between +/- 0.5 % to +/- 5 %.

[0046] In some embodiments, the method further comprises, after adjusting one or more nozzles of the plurality of nozzles based on a target unit measurement, printing a new batch; determining whether a weight of an unit in the new batch differs from the target unit measurement by more than a second predefined threshold; in accordance with a determination that the weight of the unit in the new batch differs from the target unit measurement by more than the second predefined threshold, adjusting one or more operation parameters of the additive manufacturing system.

[0047] In some embodiments, the one or more operation parameters include temperature.

[0048] In some embodiments, the one or more operation parameters include an amount of opening of a nozzle.

[0049] In some embodiments, the second predefined threshold is less than 5%.

[0050] Disclosed herein is a method for manufacturing pharmaceutical products by additive manufacturing comprises: receiving, using a material supply module, a set of printing materials; transporting, using the material supply module, a single flow corresponding to the set of printing materials to a flow distribution plate, wherein the flow distribution plate comprises a plurality of channels; dividing, via the plurality of channels of the flow distribution plate, the single flow into a plurality of flows; causing a plurality of nozzles to dispense the plurality of flows based on a plurality of nozzle-specific parameters.

[0051] Disclosed herein is a non-transitory computer-readable storage medium stores one or more programs, the one or more programs comprising instructions, which when executed by one or more processors of an electronic device having a display, cause the electronic device to: receive a plurality of weight measurements corresponding to a plurality of pharmaceutical dosage units, wherein the plurality of pharmaceutical dosage units are generated using a plurality of nozzles of a 3D printing system; determine whether a sum of the plurality of weight measurements differs from a target batch weight by more than a predefined threshold; in accordance with a determination that the sum differs from the target batch weight by more than the predefined threshold, adjust one or more nozzles of the plurality of nozzles based on an average weight measurement of the plurality of weight measurements; in accordance with a determination that the sum does not differ from the target batch weight by more than the predefined threshold, adjust one or more nozzles of the plurality of nozzles based on a target weight measurement.

[0052] Disclosed herein is a system for manufacturing a plurality of pharmaceutical products by additive manufacturing comprises a first printing station comprising: a first printing platform; and a first plurality of nozzles; a second printing station comprising: a second printing platform; and a second plurality of nozzles; a plate transport mechanism; a printing plate; wherein the system is configured to: while the printing plate is positioned on the first printing platform, determining whether printing of a first portion of each pharmaceutical product in the plurality of pharmaceutical products is complete at the first printing station; in accordance with a determination that the printing of the first portion is complete at the first printing station, identifying the second printing station; transporting the printing plate from the first printing platform to the second printing platform via the plate transport mechanism; and

CLAIMS

1. A system for creating pharmaceutical products by additive manufacturing, comprising:

a material supply module for receiving a set of printing materials for creating the pharmaceutical products;

a flow distribution module comprising a flow distribution plate,

wherein the material supply module is configured to transport a single flow corresponding to the set of printing materials to the flow distribution plate;

wherein the flow distribution plate comprises: a plurality of channels for dividing the single flow into a plurality of flows;

a plurality of nozzles; and

one or more controllers for controlling the plurality of nozzles to dispense the plurality of flows based on a plurality of nozzle-specific parameters to create the pharmaceutical products, wherein the set of printing materials for creating the pharmaceutical products is heated to a first temperature in the flow distribution plate and heated to a second temperature higher than the first temperature in the plurality of nozzles.

2. The system of claim 1, further comprising a printing platform configured to receive the dispensed plurality of flows, wherein the printing platform is configured to move to form the pharmaceutical products.

3. The system of claim 1, wherein the material supply module is configured to plasticize the received set of printing materials and wherein the material supply module comprises a piston mechanism, a screw mechanism, a screw pump mechanism, a cogwheel mechanism, a plunger pump mechanism or any combination thereof.

4. The system of claim 1, wherein the plurality of channels forms a first juncture configured to divide the single flow into two flows.

5. The system of claim 4, wherein the plurality of channels forms a second juncture and a third juncture configured to divide the two flows into 4 flows.

6. The system of claim 1, wherein the flow distribution plate is split-able into a plurality of components to expose inner surfaces of the plurality of channels, wherein the plurality of components are configured to be held together via one or more screws.

7. The system of claim 1, wherein a nozzle of the plurality of nozzles comprises a heater, or wherein a nozzle of the plurality of nozzles comprises a thermal isolation structure.

8. The system of claim 1, wherein the plurality of nozzles comprises a plurality of needle-valve mechanisms, and wherein a needle-valve mechanism of the plurality of needle-valve mechanisms comprises:

a feed channel extending through the respective nozzle, wherein the feed channel is tapered at a distal end of the nozzle; and

a needle, wherein a distal end of the needle is configured to be in contact and seal the feed channel when the needle-valve mechanism is in a closed position, and wherein the distal end of the needle is configured to be retracted to allow a flow of printing materials to be dispensed.

9. The system of claim 8, wherein movement of the needle is driven by one or more actuators, or wherein the one or more actuators include a linear motor.

10. The system of claim 8, wherein the needle is a first needle, wherein the plurality of nozzles comprises a single plate coupled to the first needle and a second needle, and wherein movement of the single plate causes movement of the first needle and the second needle.

11. The system of claim 1, wherein a parameter of the plurality of nozzle-specific parameters comprises an amount of opening of a respective nozzle.

12. The system of claim 11, wherein the one or more controllers are configured to adjust the amount of opening of the respective nozzle based on a weight of a pharmaceutical product corresponding to the respective nozzle.

13. The system of claim 1, wherein the one or more controllers are configured to control temperature or pressure at the plurality of the nozzles.

14. The system of claim 1, wherein a temperature at the plurality of the nozzles is higher than a temperature at the materials supply module, or wherein a temperature at the plurality of the nozzles is higher than a temperature at the flow distribution plate.

15. The system of claim 1, wherein flow paths of the plurality of flows are geometrically symmetrical.

16. The system of claim 8, wherein the diameter of the plurality of channels of the flow distribution plate is larger than the diameter of feed channels of the plurality of nozzles.

17. The system of claim 16, wherein the material supply module is configured to transport the single flow to the flow distribution plate via a supply channel, and wherein the diameter of the supply channel is larger than the diameter of the plurality of channels of the flow distribution plate.

18. The system of claim 1, wherein the flow distribution plate is split-able and comprises a plurality of modules, wherein each module of the plurality of modules is configured to receive a flow and divide the flow into four flows to be dispensed by four nozzles of the plurality of nozzles.

19. A method for creating pharmaceutical products by additive manufacturing, comprising:

receiving, by a material supply module, a set of printing materials for creating the pharmaceutical products;

transporting a single flow corresponding to the set of printing materials to a flow distribution module comprising a flow distribution plate;

dividing, by a plurality of channels of the flow distribution plate, the single flow into a plurality of flows, wherein the set of printing materials is heated to a first temperature in the flow distribution plate;

receiving, by a plurality of nozzles, the plurality of flows;

heating, in the plurality of nozzles, the set of printing materials to a second temperature higher than the first temperature; and

controlling, by one or more controllers, the plurality of nozzles to dispense the plurality of flows based on a plurality of nozzle-specific parameters to create the pharmaceutical products.

20. The method of claim 19, further comprising:

receiving, by a printing platform, the dispensed plurality of flows, and

moving the printing platform to form the pharmaceutical products.

21. The method of claim 19, wherein the flow distribution plate is split-able into a plurality of components to expose inner surfaces of the plurality of channels, wherein the plurality of components are configured to be held together via one or more screws.

22. The method of claim 19, wherein the plurality of nozzles comprises a plurality of needle-valve mechanisms, and wherein a needle-valve mechanism of the plurality of needle-valve mechanisms comprises:

a feed channel extending through the respective nozzle, wherein the feed channel is tapered at a distal end of the nozzle; and

a needle, wherein a distal end of the needle is configured to be in contact and seal the feed channel when the needle-valve mechanism is in a closed position, and wherein the distal end of the needle is configured to be retracted to allow a flow of printing materials to be dispensed.

23. The method of claim 19, wherein a parameter of the plurality of nozzle-specific parameters comprises an amount of opening of a respective nozzle.

24. The method of claim 23, further comprising: adjusting, by the one or more controllers, the amount of opening of the respective nozzle based on a weight of a pharmaceutical product corresponding to the respective nozzle.

25. The method of claim 19, further comprising: controlling, by the one or more controllers, temperature or pressure at the plurality of the nozzles.

26. The method of claim 19, wherein a temperature at the plurality of the nozzles is higher than a temperature at the materials supply module.

27. The method of claim 19, wherein flow paths of the plurality of flows are geometrically symmetrical.

28. The method of claim 22, wherein the diameter of the plurality of channels of the flow distribution plate is larger than the diameter of feed channels of the plurality of nozzles.

29. The method of claim 28, wherein the material supply module is configured to transport the single flow to the flow distribution plate via a supply channel, and wherein the diameter of the supply channel is larger than the diameter of the plurality of channels of the flow distribution plate.

30. The method of claim 19, wherein the flow distribution plate is split-able and comprises a plurality of modules, wherein each module of the plurality of modules is configured to receive a flow and divide the flow into four flows to be dispensed by four nozzles of the plurality of nozzles.