

**TITLE: "A PUMP ASSEMBLY FOR A THREE-DIMENSIONAL PRINTING
SYSTEM"**

TECHNICAL FIELD

Present disclosure relates to a field of construction. Particularly, but not exclusively, the present disclosure relates to a three-dimensional printing system used for construction. Further, embodiments of the present disclosures relate to a pump assembly for the three-dimensional printing system.

BACKGROUND OF THE DISCLOSURE

Generally, buildings are constructed using bricks/building blocks with the help of mortar. Such a method includes laying of bricks in courses and numerous patterns. The bricks are further plastered together by the mortar in order to create a durable structure. Sometimes, buildings are also constructed by pouring concrete into metal forms, which hold the concrete in place. Steel rods of various thickness are further placed inside the metal forms to reinforce the concrete. The concrete may be poured into the metal forms by suitable means and allowed to cure for a predetermined amount of time. Such conventional methods of construction of buildings using bricks or by pouring concrete into metal forms is expensive and time-consuming process. Also, these conventional processes require more manpower and requires constant monitoring and supervision.

Over the last few years, 3D printing has emerged as a solution to various manufacturing processes including construction. In the recent years, 3D printing has been widely used in the field of construction for the construction of buildings or structures. A 3D printed building is a structure that is constructed by depositing material, layer-by-layer. One of the primary tools that is used for the 3D printing of buildings is a 3D printer that comprises of a robotic arm with a nozzle. The nozzle of the printer extrudes specially formulated cement at a predetermined pressure by means of a pump. Such 3D printing technologies enable the buildings to be constructed in reduced amount of time, with less material and negligible wastage. As a result, the construction of buildings has become much cheaper, faster than conventional processes.

Conventional 3D printers use pumps which provide a non-continuous and a pulsating pumping action. As a result, while laying of the building material there exists a disturbance in the pattern of deposition. Such a disturbance may be a sinusoidal wave-like pattern that appears on printed concrete or building material. In order to pump material without pulsation, progressive cavity-

based pumps are used in 3D printers. However, the progressive cavity-based pumps have the inability to pump non-slurry mixes and large aggregate mixes having high viscosity. Further, to expedite the setting of printed concrete structures, the concrete mixture is usually formulated to rapidly gain strength and hardness. However, the currently utilized pumps for concrete 3D printing are not capable of mustering sufficient pressure for pumping hardened mixes.

The present disclosure is directed to overcome one or more limitations stated above or any other limitation associated with the conventional arts.

SUMMARY OF THE DISCLOSURE

One or more shortcomings of conventional pumping systems employed in the three-dimensional printing systems are overcome, and additional advantages are provided through the pumping system as claimed in the present disclosure. Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein and are considered as a part of the claimed disclosure.

In a non-limiting embodiment of the present disclosure, a pump assembly for a three-dimensional printing system is disclosed. The pump assembly includes a plurality of pumping cylinders, each configured to encase at least one first piston. Further, the pump assembly includes at least one first actuator coupled to each of the at least one first piston. The at least one first actuator is configured to displace the at least one first piston between a first position and a second position, within a corresponding pumping cylinder. Furthermore, the pump assembly includes a plurality of valves, each associated with at least one of the plurality of pumping cylinders. Each of the plurality of valves is defined with an inlet port and an outlet port for fluidly connecting the corresponding pumping cylinder with at least one primer chamber in a primer arrangement and a print nozzle. The pump assembly, further includes one or more sensors associated with the at least one first actuator. The one or more sensors are configured to generate an input signal corresponding to a position of the at least one first piston within each of the plurality of pumping cylinders. Additionally, the pump assembly includes a control unit, communicatively coupled to each of the one or more sensors. The control unit is configured to selectively operate the inlet port and the outlet port of each of the plurality of valves, based on the input signal received from the one or more sensors, such that a pumping cycle is initiated in one pumping cylinder of the plurality of pumping cylinders, and

simultaneously a loading cycle is initiated in another pumping cylinder of the plurality of pumping cylinders.

In an embodiment, the primer arrangement includes at least one primer chamber configured to hold print material. The at least one primer chamber is in fluid communication with each of the plurality of pumping cylinders. Further, the at least one primer chamber includes a second piston disposed in the at least one primer chamber. The second piston is coupled to a second actuator and is configured to reciprocate to displace the print material from the at least one primer chamber into the corresponding pumping cylinder during loading cycle.

In an embodiment, the primer arrangement comprises a plurality of guiding pillars oriented vertically and, the plurality of guiding pillars is configured to guide reciprocatory movement of the second piston.

In an embodiment, the at least one first actuator and the second actuator is one of a hydraulic actuator, an electrical actuator and a pneumatic actuator.

In an embodiment, the loading cycle corresponds to flow of a print material from the at least one primer chamber into the corresponding pumping cylinder of the plurality of pumping cylinders.

In an embodiment, the pumping cycle corresponds to flow of pressurized print material from the corresponding pumping cylinder of the plurality of pumping cylinders into the print nozzle of the three-dimensional printing system.

In an embodiment, the pump assembly includes a first passage for interconnecting inlet ports of each of the plurality of valves with the at least one primer chamber.

In an embodiment, the pump assembly includes a second passage for interconnecting outlet ports of each of the plurality of valves with the print nozzle.

In an embodiment, each of the plurality of valves includes a hollow tube defined with the inlet port and the outlet port and a piston disposed within the hollow tube. The piston is defined with a through hole and is configured to displace for selectively operating the inlet port and the outlet port. Further, the valve includes a drain port, to facilitate cleaning of each of the plurality of pumping cylinders.

In an embodiment, the pump assembly includes comprises at least one non-return valve disposed between each of the plurality of valves and the at least one primer chamber, to

selectively allow and stop flow of the print material into each of the plurality of pumping cylinders.

In an embodiment, the control unit is configured to generate a signal to operate the inlet port of the valve associated with one pumping cylinder of the plurality of pumping cylinders, to enable the loading cycle of one pumping cylinder of the plurality of pumping cylinders, based on the input signal generated by the one or more sensors which correspond to the first position of the at least one first piston.

In an embodiment, the control unit is configured to generate a signal to operate the outlet port of the valve associated with one pumping cylinder of the plurality of pumping cylinders to enable pumping cycle of one pumping cylinder, based on the input signal generated by the one or more sensors which correspond to completion of the loading cycle in one pumping cylinder of the plurality of pumping cylinders.

In another non-limiting embodiment of the present disclosure, a pumping system for a three-dimensional printing system is disclosed. The pumping system includes a primer arrangement comprising at least one primer chamber configured to hold print material and a second piston disposed in the at least one primer chamber, wherein the second piston is coupled to a second actuator and a pump assembly in fluid communication with the primer arrangement. The pump assembly includes a plurality of pumping cylinders, configured to encase at least one first piston coupled to at least one first actuator. Each of the of the pumping cylinders of the plurality of pumping cylinders is associated with at least one primer chamber. Further, the pump assembly includes a plurality of valves, each associated with at least one of the plurality of pumping cylinders. Each of the plurality of valves is defined with an inlet port and an outlet port for fluidly connecting the corresponding pumping cylinder with the at least one primer chamber and a print nozzle. Furthermore, the pumping system includes one or more sensors associated with the at least one first actuator and the second actuator, wherein the one or more sensors are configured to generate an input signal corresponding to a position of the at least one first piston within each of the plurality of pumping cylinders and position of the second piston in the at least one primer chamber. Additionally, the pumping system includes a control unit, communicatively coupled to each of the one or more sensors. The control unit is configured to selectively operate the inlet port and the outlet port of each of the plurality of valves, based on input signal received from the one or more sensors, such that a pumping cycle

is initiated in one pumping cylinder of the plurality of pumping cylinders, and a loading cycle is initiated in another pumping cylinder of the plurality of pumping cylinders.

It is to be understood that the aspects and embodiments of the disclosure described above may be used in any combination with each other. Several of the aspects and embodiments may be combined together to form a further embodiment of the disclosure.

The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The novel features and characteristic of the disclosure are set forth in the appended claims. The disclosure itself, however, as well as a mode of use, further objectives, and advantages thereof, will best be understood by reference to the following detailed description of an embodiment when read in conjunction with the accompanying drawings. One or more embodiments are now described, by way of example only, with reference to the accompanying drawings wherein like reference numerals represent like elements and in which:

Figure. 1 illustrates a perspective view of a pumping system for a three-dimensional printing system, in accordance with an embodiment of the present disclosure.

Figure. 2 illustrates a perspective view of a primer arrangement of the pumping system of Figure. 1, in accordance with an embodiment of the present disclosure.

Figure. 3 illustrates a perspective view of a pump assembly of the pumping system of Figure. 1, in accordance with an embodiment of the present disclosure.

Figure. 4 illustrates an exploded view of a pumping cylinder of a pump assembly, in accordance with an embodiment of the present disclosure.

Figure. 5 illustrates an exploded view of a valve of the pump assembly of Figure. 3.

Figure. 6 is a block diagram depicting working of the pumping system of Figure. 1, in accordance with an embodiment of the present disclosure.

The figures depict embodiments of the disclosure for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles of the disclosure described herein.

DETAILED DESCRIPTION

While the embodiments in the disclosure are subject to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the figures and will be described below. It should be understood, however, that it is not intended to limit the disclosure to the particular forms disclosed, but on the contrary, the disclosure is to cover all modifications, equivalents, and alternative falling within the scope of the disclosure.

It is to be noted that a person skilled in the art would be motivated from the present disclosure and modify various features of the pumping system for the three-dimensional printing system. Therefore, such modifications are considered to be part of the disclosure. Accordingly, the drawings show only those specific details that are pertinent to understand the embodiments of the present disclosure, so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skilled in the art having benefit of the description herein.

The terms “comprises”, “comprising”, or any other variations thereof used in the disclosure, are intended to cover a non-exclusive inclusions, such that an assembly or a system that comprises a list of components does not include only those components but may include other components not expressly listed or inherent to such system, method, or assembly, or device. In other words, one or more elements in a system or device preceded by “comprises... a” does not, without more constraints, preclude the existence of other elements or additional elements in the system or device.

Embodiment of the present disclosure discloses a pumping system for a three-dimensional printing system. Usually, the printing material such as concrete mixture is an aggregate of rock or gravels and sand along with water and cement. When the concrete mixture is pumped in the conventional pumps, a sinusoidal wave-like pattern appears on printed concrete due the

intrinsic inability of the conventional pumps to dispense concrete in continuous and a non-impulsive manner. Further, the currently utilized pumps for concrete 3D Printing are not capable of mustering sufficient pressure for pumping hardened, non-slurry mixes with large aggregate particles.

Accordingly, the present disclosure discloses a pumping system for a three-dimensional printing system. The pumping system of the present disclosure facilitates in catering uninterrupted flow of high-pressure print material (thus, concrete mixture) to the three-dimensional printing system for carrying printing operation.

The pumping system may broadly include a primer arrangement and a pump assembly. The primer arrangement and the pump assembly may be fluidly connected to each other using suitable piping arrangement. The primer arrangement may include at least one primer chamber, which may be configured to hold the print material. Further, the primer arrangement may include a second piston coupled to a second actuator. The second piston may be disposed in the at least one primer chamber and configured to displace the printing material from the primer chamber at relatively high pressure into the pump assembly.

The pump assembly may include a plurality of pumping cylinders, configured to encase at least one first piston coupled to at least one first actuator. Each of the of the pumping cylinders of the plurality of pumping cylinders is associated with at least one primer chamber. Further, the pump assembly may include a plurality of valves, each associated with at least one of the plurality of pumping cylinders. Each of the plurality of valves comprises an inlet port and an outlet port for fluidly connecting the corresponding pumping cylinder with the at least one primer chamber and a print nozzle. Furthermore, the pumping system includes one or more sensors associated with the at least one first actuator and the second actuator. The one or more sensors are configured to generate an input signal corresponding to a position of the at least one first piston within each of the plurality of pumping cylinders and position of the second piston in the at least one primer chamber. Additionally, the pumping system includes a control unit, which may be communicatively coupled to each of the one or more sensors. The control unit is configured to selectively operate [thus open or close] the inlet port and the outlet port of each of the plurality of valves, based on input signal received from the one or more sensors, such that a pumping cycle is initiated in one pumping cylinder of the plurality of pumping cylinders and, simultaneously a loading cycle is initiated in another pumping cylinder of the plurality of pumping cylinders. This configuration of alternate loading and pumping cycles in

the pumping cylinders results in uninterrupted flow of print material into the three-dimensional printing system.

In the following detailed description, embodiments of the disclosure are explained with reference to accompanying figures that form a part hereof, and in which are shown by way of illustration specific embodiments in which the disclosure may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the disclosure, and it is to be understood that other embodiments may be utilized and that changes may be made without departing from the scope of the present disclosure. The following description is, therefore, not to be taken in a limiting sense.

Figure. 1 illustrates a perspective view of a pumping system (200) for a three-dimensional printing system. The pumping system (200) may be configured to pump high viscous print material such as concrete (3D) mixture/slurry at high pressure into the three-dimensional printing system, in accordance with some embodiments of the present disclosure.

As seen in **Figure. 1**, the pumping system (200) may broadly include a primer arrangement (110) and a pump assembly (100). In an embodiment, the primer arrangement (110) and the pump assembly (100) fluidly connected to each other by suitable piping arrangements. As apparent from **Figure. 2**, the primer arrangement (110) may include at least one primer chamber (105), which may be supported on a platform (125). In an embodiment, the at least one primer chamber (105) may be configured to hold the printing material. Further, the primer arrangement (110) may include a second piston (107), which may be coupled to a second actuator (108). As apparent from **Figure. 2**, the second piston (107) may be supported by a plurality of guiding pillars (109), which may orient vertically. The plurality of guiding pillars (109) may be configured to allow reciprocatory movement of the second piston (107) during operation, for displacing the printing material into the pump assembly (100) at relatively higher pressure from the at least one primer chamber (105). In an illustrated embodiment, the primer arrangement (110) includes a pair of primer chamber (105) and the same cannot be construed as a limitation, as the primer arrangement (110) may include a number of primer chambers (105) based on the requirement.

Now referring to **Figure. 3**, the pump assembly (100) may include a plurality of pumping cylinders (101), which may be configured to encase at least one first piston (102). In an embodiment, each of the plurality of pumping cylinders (101) may be fluidly connected with the at least one primer chamber (105) of the primer arrangement (110) [best seen in **Figure. 1**].

As seen in **Figure. 4**, which illustrates an exploded view of the pumping cylinders (101), the pumping cylinder (101) may include an outer casing (126) having a substantially cylindrical profile. The outer casing (126) may be configured to encase at least one first actuator (103), which may be coupled to the at least one first piston (102). The at least one first actuator (103) may be configured to displace the at least one first piston (102) between a first position and a second position, within the corresponding pumping cylinder (101). As apparent from **Figure. 4**, one end of the outer casing (126) may be configured to receive a nozzle (121). The nozzle (121) may be configured to guide the print material flowing from the pumping cylinder (101) at higher pressure. Further, the outer casing (126) of the pumping cylinder (101) may be defined with an inlet (122) for receiving cleaning fluid to perform cleaning of the pumping cylinders (101).

In an embodiment, the pump assembly (100) may further include a plurality of valves (104), where each valve (104) of the plurality of valves (104) may be associated with the at least one of the plurality of pumping cylinders (101). Referring to **Figure. 5**, each of the plurality of valves (104) may include a hollow tube (113) defined with an inlet port (115), an outlet port (116) and a drain port (119). Further, the valve (104) may include a selection rod (114), which may be defined with a first port (117) and a second port (118). The selection rod (114) may be disposed within the hollow tube (113) and may be configured to displace within the hollow tube (113) for selectively aligning the first port (117) and the second port (118) with one of the inlet port (115) and outlet port (116) during operation of the pumping system (200). In an embodiment, the selection rod (114) may be coupled to a third actuator (123) which may displace the selection rod (114) within the hollow tube (113) to selectively align either of the first port (117) or the second port (118) with the inlet port (115) or the outlet port (116) for allowing flow of print material into and from the pumping cylinders (101). As an example, the first port (117) may align with the inlet port (115) for allowing flow of print material into the pumping cylinder (101), and the second port (118) may align with the outlet port (116) for allowing flow of print material from the pumping cylinder (101). In an embodiment, aligning of the first port (117) and the inlet port (115), the second port (118) and the outlet port (116) takes place, alternatively or selectively. As a working example, when the first port (117) and the inlet port (115) are aligned, the second port (118) and the outlet port (116) are misaligned and vice-versa. In an embodiment and as apparent from **Figure. 3**, the inlet ports (115) of the plurality of valves (104) associated with the pumping cylinders (101) are connected to each other by a first passage (111) for connecting each of the plurality of valves (104) with the at

least one primer chamber (105). Further, the outlet ports of the plurality of valves (104) may be connected by a second passage (112) for connecting the outlet ports of the plurality of valves (104) with a print nozzle (121) (not shown in figures) of the three-dimensional printing system.

In an embodiment, the drain port (119) may facilitate in allowing flow of cleaning fluid from the pumping cylinders (101). That is, the drain port (119) is configured to egress cleaning fluid such as water from the pumping cylinder (101) for cleaning the pumping cylinders (101).

In an embodiment, the pumping system (200) may include at least one non-return valve (127). The at least one non-return valve (127) may be disposed between each of the plurality of valves (104) associated with the pumping cylinders (101) and the at least one primer chamber (105). The at least one non-return valve (127) may be configured to selectively allow and stop flow of printing material into each of the plurality of pumping cylinders (101) from the at least one primer chamber (105). As an example, the at least one non-return valve (127) may be a shut-off valve (104). However, same shall not be considered as a limitation, as any other type of valve which performs the same functions may be used.

Turning back to **Figure. 1**, the pumping system (200) may include one or more sensors (106). The one or more sensors (106) may be associated with the at least one first actuator (103) and a second actuator (108). In an embodiment, the one or more sensors (106) may be configured to generate an input signal corresponding to a position of the at least one first piston (102) in corresponding pumping cylinder (101) and the second piston (107) in corresponding primer chamber (105). As an example, the one or more sensors (106) may be but not limiting toAs apparent from **Figure. 1**, the pumping system (200) may further include a control unit which may be communicatively coupled to the one or more sensors (106). In an embodiment, the control unit (130) may be configured to selectively operate the valves (104) i.e. to selectively operate the inlet port (115) and the outlet port (116) of the valve (104), based on the input signal from the one or more sensors (106), which corresponds to position of the at least one first position and the second position, to initiate a loading cycle in one pumping cylinder (101) of the plurality of pumping cylinders (101) and corresponding at least one primer chamber (105) and, initiate pumping cycle in another pumping cylinder (101) of the plurality of pumping cylinders (101).

In an embodiment, the at least one first actuator (103) and the second actuator (108) and the third actuator may be one of a hydraulic actuators, an electric actuator and a pneumatic actuator.

Referring now to **Figure. 6**, which is a block diagram illustrating working of the pumping system (200). In an embodiment, working of the pumping system (200) is described with the pump assembly (100) having a pair of pumping cylinders (101) and the primer arrangement (110) having a pair of primer chambers (105). The same cannot be considered as a limitation, since the pumping system (200) may include several pumping cylinders (101) and the primer chambers (105) based on the requirement.

As seen in **Figure. 6**, the print material i.e. high viscous concrete (3D) mixture may be loaded into a first primer chamber (201) and the second primer chamber (202) of the primer arrangement (110). Now referring to **Figure. 6** in tandem with **Figure. 1**, in an embodiment, initially, the at least one first piston (102) may be positioned at the first position within the first pumping cylinder (203). As an example, the first position may correspond to fully retracted condition of the at least one first piston (102) within the pumping cylinder (101, 203). The one or more sensors (106) may generate an input signal corresponding to the first position of the at least one first piston (102). Based on the input signal, the control unit (130) may operate the valve (104) [i.e. displace the selection rod (114) such that the first port (117) is aligned with the inlet port (115)], to initiate a loading cycle. In the loading cycle, the print material flows from the first primer chamber (201) into the first pumping cylinder (203). In an embodiment, the second piston (107) is disposed within the first primer chamber (201) may reciprocate to apply force for displacing the print material [i.e. high viscous print material] from the first primer chamber (201) into the first pumping cylinder (203) at relatively higher pressure. Upon completion of loading cycle in the first pumping cylinder (203), the control unit (130) may operate the valve (104) (i.e. displace the selection rod (114) such that the first port (117) is aligned with the outlet port (117)), to initiate pumping cycle in the first pumping cylinder (203). In an embodiment, in the pumping cycle the at least one first actuator (103) disposed in the at least one first pumping cylinder (203) may displace from the first position towards the second position to egress the printing material out of the first pumping cylinder (203) at higher pressure into the print nozzle (121) of the three-dimensional printing system.

In an embodiment, during initiation of the pumping cycle in the first pumping cylinder (203), the control unit (130) based on the input signal from the one or more sensors (106) associated with the second pumping cylinder (204) [thus, the at least one first actuator (103)] may operate the valve (104) associated with the second pumping cylinder (204) to initiate loading cycle in the second pumping cylinder (204). In the loading cycle of the second pumping cylinder (204),

the print material flows from the second primer chamber (202) into the second pumping cylinder (204) through the valve.

Further referring to **Figure. 4**, upon completion of printing of the required structure, a cleaning process may be initiated. As seen in **Figure. 3**, valve (104) associated with the first pumping cylinder (203) and the second pumping cylinder (204) is defined with a drain port (119). In an embodiment, cleaning fluid typically water may be fed into the first pumping cylinder (203) and the second pumping cylinder (204) through an inlet (122). Once, the pumping cylinders (203, 204) are filled with cleaning fluid, the at least one first actuator (103) may be operated to displace the first piston (102) from the first position to egress the cleaning fluid along with hardened concrete (3D) through the drain port (119) and, thus cleaning the pumping cylinders (203, 204).

In an embodiment, the at least one first pumping cylinder (203) and the second pumping cylinder (204) may be subjected to alternate loading cycle and the pumping cycle to cater uninterrupted supply of print material into the three-dimensional print system. In other words, when the first pumping cylinder (203) is under pumping cycle, the second pumping cylinder (204) may be under loading cycle and vice-versa to cater uninterrupted supply of print material into the three-dimensional print system.

In an embodiment, configuration of the pumping system (200) aids in achieving a low-frequency, high volume pumping with minimized sinusoidal wave-like structures during printing operation.

In an embodiment, a cleaning ball (not shown in figures) may be inserted into the drain port (119). The cleaning ball may be configured to brush the surface to remove the sediments and hardened concrete (3D) that remain in the passages of the pumping system (200).

In an embodiment, an air relief valve (104) (not shown in figures) may be provided at the nozzle (121) to relieve air trapped in the passages, for ensuring concrete (3D) compaction and its consistent flow and deposition from the print nozzle (121).

In an embodiment, the print material may be directly supplied to the print nozzle (121) of the three-dimensional printing system for carrying out printing operations which require print material of low pressure.

In an embodiment, one primer chamber (105) may be configured to deliver print material into the multiple pumping cylinders (101).

Equivalents:

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as “open” terms (e.g., the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at least,” the term “includes” should be interpreted as “includes but is not limited to,” etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases “at least one” and “one or more” to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to inventions containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an” (e.g., “a” and/or “an” should typically be interpreted to mean “at least one” or “one or more”); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation *is* explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean *at least* the recited number (e.g., the bare recitation of “two recitations,” without other modifiers, typically means *at least* two recitations, or *two or more* recitations). Furthermore, in those instances where a convention analogous to “at least one of A, B, and C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, and C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances, where a convention analogous to “at least one of A, B, or C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, or C” would include but

not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase “A or B” will be understood to include the possibilities of “A” or “B” or “A and B.” While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

Table of Referral Numerals:

Referral numerals	Description
100	Pump assembly
101	Pumping cylinders
102	First piston
103	First actuator
104	Valves
105	Primer chamber
106	One or more sensors
107	Second piston
108	Second actuator
109	Guiding pillars
110	Primer arrangement
111	First passage
112	Second passage
113	Hollow tube
114	Selection rod
115	Inlet port
116	Outlet port
117	First port
118	Second port
119	Drain port
121	Nozzle
122	Cleaning fluid inlet

123	Third actuator
124	Platform for a pump assembly
125	Platform for a primer arrangement
126	Outer casing
130	Control unit
200	Pumping system

We Claim:

1. A pump assembly (100) for a three-dimensional printing system, comprising:
 - a plurality of pumping cylinders (101), each configured to encase at least one first piston (102);
 - at least one first actuator (103) coupled to each of the at least one first piston (102), wherein the at least one first actuator (103) is configured to displace the at least one first piston (102) between a first position and a second position, within a corresponding pumping cylinder of the plurality of pumping cylinders (101);
 - a plurality of valves (104), each associated with at least one of the plurality of pumping cylinders (101), wherein each of the plurality of valves (104) is defined with an inlet port (115) and an outlet port (116) for fluidly connecting the corresponding pumping cylinder (101) with at least one primer chamber (105) in a primer arrangement (110) and a print nozzle (121);
 - one or more sensors (106) associated with the at least one first actuator (103), wherein the one or more sensors (106) are configured to generate an input signal corresponding to a position of the at least one first piston (102) within each of the plurality of pumping cylinders (101); and
 - a control unit (130), communicatively coupled to each of the one or more sensors (106), wherein the control unit (130) is configured to selectively operate the inlet port (115) and the outlet port (116) of each of the plurality of valves (104), based on the input signal received from the one or more sensors (106), such that a pumping cycle is initiated in one pumping cylinder (101) of the plurality of pumping cylinders (101), and, simultaneously a loading cycle is initiated in another pumping cylinder (204) of the plurality of pumping cylinders (101).
2. The pump assembly (100) as claimed in claim 1, wherein the primer arrangement (110) comprising:
 - at least one primer chamber (105) configured to hold print material, wherein the at least one primer chamber (105) is in fluid communication with each of the plurality of pumping cylinders (101); and

a second piston (107) disposed in the at least one primer chamber (105), wherein the second piston (107) is coupled to a second actuator (108) and is configured to reciprocate, to displace the print material from the at least one primer chamber (105) into the corresponding pumping cylinder (101) during loading cycle.

3. The pump assembly (100) as claimed in claims 1 and 2, wherein the primer arrangement (110) comprises a plurality of guiding pillars (109) oriented vertically and, the plurality of guiding pillars (109) is configured to guide reciprocatory movement of the second piston (107).
4. The pump assembly (100) as claimed in claim 1, wherein the at least one first actuator (103) and the second actuator (108) is one of a hydraulic actuator, an electrical actuator and a pneumatic actuator.
5. The pump assembly (100) as claimed in claim 1, wherein the loading cycle corresponds to flow of a print material from the at least one primer chamber (105) into the corresponding pumping cylinder (101) of the plurality of pumping cylinders (101).
6. The pump assembly (100) as claimed in claim 1, wherein the pumping cycle corresponds to flow of pressurized print material from the corresponding pumping cylinder (101) of the plurality of pumping cylinders (101) into the print nozzle (121).
7. The pump assembly (100) as claimed in claim 1, comprises a nozzle (121) coupled to an end of each of the plurality of pumping cylinders (101), wherein the nozzle (121) is configured to guide the print material flowing out of the corresponding pumping cylinder (101) of the plurality of pumping cylinders (101).
8. The pump assembly (100) as claimed in claim 1, comprises a first passage (111) for interconnecting inlet ports (115) of each of the plurality of valves (104) with the at least one primer chamber (105).
9. The pump assembly (100) as claimed in claim 1, comprises a second passage (112) for interconnecting outlet port (116) of each of the plurality of valves (104) with the print nozzle (121).
10. The pump assembly (100) as claimed in claim 1, wherein each of the plurality of valves (104) comprises:

a hollow tube (113) defined with the inlet port (115) and the outlet port (116);
and

a selection rod (114) disposed within the hollow tube (113) and defined with a first port (117) and a second port (118), wherein the selection rod (114) is configured to displace to selectively align the first port (117) and the second port (118) with the inlet port (115) and the outlet port (116).

11. The pump assembly (100) as claimed in claim 1, wherein each of the plurality of valves (104) comprises a drain port (119), to facilitate cleaning of each of the plurality of pumping cylinders (101).
12. The pump assembly (100) as claimed in claim 1, comprises at least one non-return valve (127) disposed between each of the plurality of valves (104) and the at least one primer chamber (105), to selectively allow and stop flow of the print material into each of the plurality of pumping cylinders (101).
13. The pump assembly (100) as claimed in claim 1, wherein the control unit (130) is configured to generate a signal to operate the inlet port (115) of the valve (104) associated with one pumping cylinder (101) of the plurality of pumping cylinders (101), to enable the loading cycle of one pumping cylinder (101) of the plurality of pumping cylinders (101), based on the input signal generated by the one or more sensors (106) which correspond to the first position of the at least one first piston (102).
14. The pump assembly (100) as claimed in claim 1, wherein the control unit (130) is configured to generate a signal to operate the outlet port (116) of the valve (104) associated with one pumping cylinder (101) of the plurality of pumping cylinders (101) to enable pumping cycle of one pumping cylinder (101), based on the input signal generated by the one or more sensors (106) which correspond to completion of the loading cycle in one pumping cylinder (101) of the plurality of pumping cylinders (101).
15. A pumping system (200) for a three-dimensional printing system, comprising:
 - a primer arrangement (110) comprising at least one primer chamber (105) configured to hold print material and a second piston (107) disposed in the at least one primer chamber (105), wherein the second piston (107) is coupled to a second actuator (108);

a pump assembly (100) in fluid communication with the primer arrangement (110);

the pump assembly (100) comprises a plurality of pumping cylinders (101), configured to encase at least one first piston (102) coupled to at least one first actuator (103), wherein each of the of the pumping cylinders (101) of the plurality of pumping cylinders (101) is associated with at least one primer chamber (105);

a plurality of valves (104), each associated with at least one of the plurality of pumping cylinders (101), wherein each of the plurality of valves (104) comprises an inlet port (115) and an outlet port (116) for fluidly connecting the corresponding pumping cylinder (101) with the at least one primer chamber (105) and a print nozzle (121);

one or more sensors (106) associated with the at least one first actuator (103) and the second actuator (108), wherein the one or more sensors (106) are configured to generate an input signal corresponding to a position of the at least one first piston (102) within each of the plurality of pumping cylinders (101) and position of the second piston (107) in the at least one primer chamber (105); and

a control unit (130), communicatively coupled to each of the one or more sensors (106), wherein the control unit (130) is configured to selectively operate the inlet port (115) and the outlet port (116) of each of the plurality of valves (104), based on input signal received from the one or more sensors (106), such that a pumping cycle is initiated in one pumping cylinder (101) of the plurality of pumping cylinders (101), and simultaneously a loading cycle is initiated in another pumping cylinder (101) of the plurality of pumping cylinders (101).

16. The pumping system (200) as claimed in claim 15, wherein the at least one first actuator (103) and the second actuator (108) is one of a hydraulic actuator, an electrical actuator and a pneumatic actuator.
17. The pumping system (200) as claimed in claim 15, wherein the loading cycle corresponds to flow of a print material from at least one primer chamber (105) into the corresponding pumping cylinder (101) of the plurality of pumping cylinders (101).
18. The pumping system (200) as claimed in claim 15, wherein the pumping cycle corresponds to flow of pressurized print material from the corresponding pumping

cylinder (101) of the plurality of pumping cylinders (101) into the print nozzle (121) of the three-dimensional printing system.