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(54) Title: ADDITIVE MANUFACTURING SYSTEM HAVING FINISH-FOLLOWER

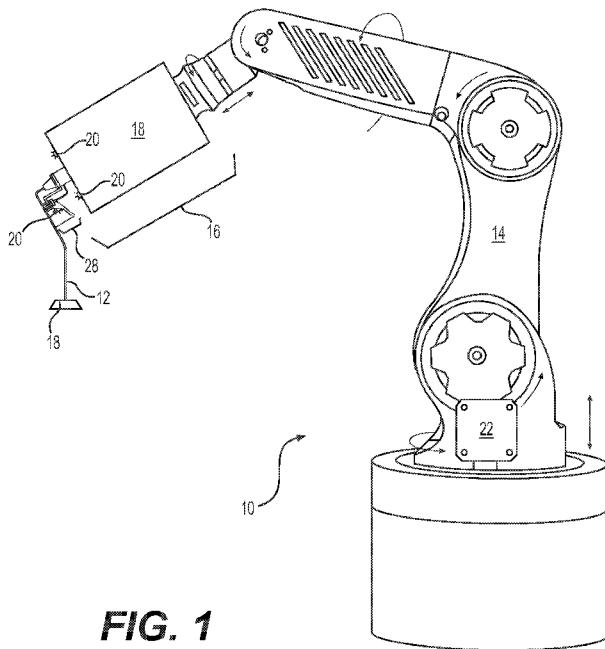


FIG. 1

(57) Abstract: An additive manufacturing system is disclosed. The additive manufacturing system may include a matrix reservoir, a primary nozzle fluidly connected to the matrix reservoir, and a primary cure enhancer operatively connected to at least one of the matrix reservoir and the primary nozzle. The primary cure enhancer may be configured to direct a cure energy toward a tip of the primary nozzle. The additive manufacturing system may also include an auxiliary nozzle, an arm configured to mount the auxiliary nozzle at a trailing side of the primary nozzle, and a passage extending from the matrix reservoir to the auxiliary nozzle.



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

- *with international search report (Art. 21(3))*

DescriptionADDITIVE MANUFACTURING SYSTEM HAVING FINISH-FOLLOWERRelated Applications

[0001] This application is based on and claims the benefit of priority from United States Provisional Application No. 62/449,899 that was filed on January 24, 2017, the contents of which are expressly incorporated herein by reference.

Technical Field

[0002] The present disclosure relates generally to a manufacturing system and, more particularly, to an additive manufacturing system having a finish-follower.

Background

[0003] Extrusion manufacturing is a known process for producing continuous structures. During extrusion manufacturing, a liquid matrix (e.g., a thermoset resin or a heated thermoplastic) is pushed through a die having a desired cross-sectional shape and size. The material, upon exiting the die, cures and hardens into a final form. In some applications, UV light and/or ultrasonic vibrations are used to speed the cure of the liquid matrix as it exits the die. The structures produced by the extrusion manufacturing process can have any continuous length, with a straight or curved profile, a consistent cross-sectional shape, and excellent surface finish. Although extrusion manufacturing can be an efficient way to continuously manufacture structures, the resulting structures may lack the strength required for some applications.

[0004] Pultrusion manufacturing is a known process for producing high-strength structures. During pultrusion manufacturing, individual fiber strands, braids of strands, and/or woven fabrics are coated with or otherwise impregnated with a liquid matrix (e.g., a thermoset resin or a heated thermoplastic) and pulled through a stationary die where the liquid matrix cures and hardens into a final form. As with extrusion manufacturing, UV light and/or ultrasonic vibrations are used in some pultrusion applications to speed the cure of the liquid matrix as it exits the die. The structures produced by the pultrusion manufacturing process have many of the same attributes of extruded structures, as well as increased strength due to the integrated fibers. Although

pultrusion manufacturing can be an efficient way to continuously manufacture high-strength structures, the resulting structures may lack the form (shape, size, and/or precision) and/or surface finish required for some applications.

[0005] The disclosed system is directed at addressing one or more of the problems set forth above and/or other problems of the prior art.

Summary

[0006] In one aspect, the present disclosure is directed to a follower for an additive manufacturing system. The follower may include a matrix inlet passage, and a nozzle connected to a distal end of the matrix inlet passage. The follower may also include a cure enhancer located downstream of the nozzle, and a squeegee blade disposed between the nozzle and the cure enhancer.

[0007] In another aspect, the present disclosure is directed to an additive manufacturing system. The additive manufacturing system may include a matrix reservoir, a primary nozzle fluidly connected to the matrix reservoir, and a primary cure enhancer operatively connected to at least one of the matrix reservoir and the primary nozzle. The primary cure enhancer may be configured to direct a cure energy toward a tip of the primary nozzle. The additive manufacturing system may also include an auxiliary nozzle, an arm configured to mount the auxiliary nozzle at a trailing side of the primary nozzle, and a passage extending from the matrix reservoir to the auxiliary nozzle.

[0008] In yet another aspect, the present disclosure is directed to another additive manufacturing system. This additive manufacturing system may include a moveable support, a print head connected to the moveable support and configured to discharge a matrix-wetted reinforcement, and a follower connected to trail behind the print head. The follower may include a nozzle configured to discharge only a matrix, and a cure enhancer located at a side of the nozzle opposite the print head. The follower may also include a squeegee blade disposed between the nozzle and the cure enhancer.

Brief Description of the Drawings

[0009] Fig. 1 is a diagrammatic illustration of an exemplary disclosed manufacturing system;

[0010] Fig. 2 is a diagrammatic illustration of an exemplary disclosed head that may be utilized with the manufacturing system of Fig. 1; and

[0011] Fig. 3 is a diagrammatic illustration of an exemplary disclosed follower that may be used in conjunction with the head of Fig. 2.

Detailed Description

[0012] Fig. 1 illustrates an exemplary system 10, which may be used to continuously manufacture a composite structure 12 having any desired cross-sectional shape (e.g., circular, polygonal, etc.). System 10 may include at least a support 14 and a head 16. Head 16 may be coupled to and moved by support 14. In the disclosed embodiment of Fig. 1, support 14 is a robotic arm capable of moving head 16 in multiple directions during fabrication of structure 12, such that a resulting longitudinal axis of structure 12 is three-dimensional. It is contemplated, however, that support 14 could alternatively be an overhead gantry or a hybrid gantry/arm also capable of moving head 16 in multiple directions during fabrication of structure 12. Although support 14 is shown as being capable of multi-axis movements, it is contemplated that any other type of support 14 capable of moving head 16 in the same or in a different manner could also be utilized, if desired. In some embodiments, a drive may mechanically couple head 16 to support 14, and may include components that cooperate to move and/or supply power or materials to head 16.

[0013] Head 16 may be configured to receive or otherwise contain a matrix. The matrix may include any type of material (e.g., a liquid resin, such as a zero volatile organic compound resin; a powdered metal; etc.) that is curable. Exemplary matrixes include thermosets, single- or multi-part epoxy resins, polyester resins, cationic epoxies, acrylated epoxies, urethanes, esters, thermoplastics, photopolymers, polyepoxides, thiols, alkenes, thiol-enes, and more. In one embodiment, the matrix inside head 16 may be pressurized, for example by an external device (e.g., an extruder or another type of pump - not shown) that is fluidly connected to head 16 via a corresponding conduit (not shown). In another embodiment, however, the matrix pressure may be generated completely inside of head 16 by a similar type of device. In yet other embodiments, the matrix may be gravity-fed through and/or mixed within head 16. In some instances, the matrix inside head 16 may need to be kept cool and/or dark to inhibit premature curing; while in other instances, the matrix may need to be kept warm for the same reason. In either situation,

head 16 may be specially configured (e.g., insulated, chilled, and/or warmed) to provide for these needs.

[0014] The matrix may be used to coat, encase, or otherwise at least partially surround any number of continuous reinforcements (e.g., separate fibers, tows, rovings, ribbons, and/or sheets of material) and, together with the reinforcements, make up at least a portion (e.g., a wall) of composite structure 12. The reinforcements may be stored within (e.g., on separate internal spools - not shown) or otherwise passed through head 16 (e.g., fed from external spools). When multiple reinforcements are simultaneously used, the reinforcements may be of the same type and have the same diameter and cross-sectional shape (e.g., circular, square, flat, etc.), or of a different type with different diameters and/or cross-sectional shapes. The reinforcements may include, for example, carbon fibers, vegetable fibers, wood fibers, mineral fibers, glass fibers, metallic wires, optical tubes, etc. It should be noted that the term "reinforcement" is meant to encompass both structural and non-structural types of continuous materials that can be at least partially encased in the matrix discharging from head 16.

[0015] The reinforcements may be exposed to (e.g., coated with) the matrix while the reinforcements are inside head 16, while the reinforcements are being passed to head 16 (e.g., as a pre-preg material), and/or while the reinforcements are discharging from head 16, as desired. The matrix, dry reinforcements, and/or reinforcements that are already exposed to the matrix (e.g., wetted reinforcements) may be transported into head 16 in any manner apparent to one skilled in the art.

[0016] The matrix and reinforcement may be discharged from head 16 via at least two different modes of operation. In a first mode of operation, the matrix and reinforcement are extruded (e.g., pushed under pressure and/or mechanical force) from head 16, as head 16 is moved by support 14 to create the 3-dimensional shape of structure 12. In a second mode of operation, at least the reinforcement is pulled from head 16, such that a tensile stress is created in the reinforcement during discharge. In this mode of operation, the matrix may cling to the reinforcement and thereby also be pulled from head 16 along with the reinforcement, and/or the matrix may be discharged from head 16 under pressure along with the pulled reinforcement. In the second mode of operation, where the matrix is being pulled from head 16, the resulting tension in the reinforcement may increase a strength of structure 12, while also allowing for a greater length of

unsupported material to have a straighter trajectory (i.e., the tension may act against the force of gravity to provide free-standing support for structure 12).

[0017] The reinforcement may be pulled from head 16 as a result of head 16 moving away from an anchor point 18. In particular, at the start of structure-formation, a length of matrix-impregnated reinforcement may be pulled and/or pushed from head 16, deposited onto anchor point 18, and cured, such that the discharged material adheres to anchor point 18. Thereafter, head 16 may be moved away from anchor point 18, and the relative movement may cause the reinforcement to be pulled from head 16. It should be noted that the movement of the reinforcement through head 16 could be assisted (e.g., via internal feed mechanisms), if desired. However, the discharge rate of the reinforcement from head 16 may primarily be the result of relative movement between head 16 and anchor point 18, such that tension is created within the reinforcement. It is contemplated that anchor point 18 could be moved away from head 16 instead of or in addition to head 16 being moved away from anchor point 18.

[0018] One or more cure enhancers (e.g., one or more light sources, an ultrasonic emitter, a laser, a heater, a catalyst dispenser, a microwave generator, etc.) 20 may be mounted proximate (e.g., within, on, and/or trailing from) head 16 and configured to enhance a cure rate and/or quality of the matrix as it is discharged from head 16. Cure enhancer 20 may be controlled to selectively expose internal and/or external surfaces of structure 12 to energy (e.g., light energy, electromagnetic radiation, vibrations, heat, a chemical catalyst or hardener, etc.) during the formation of structure 12. The energy may increase a rate of chemical reaction occurring within the matrix, sinter the material, harden the material, or otherwise cause the material to cure as it discharges from head 16.

[0019] A controller 22 may be provided and communicatively coupled with support 14, head 16, and any number and type of cure enhancers 20. Controller 22 may embody a single processor or multiple processors that include a means for controlling an operation of system 10. Controller 22 may include one or more general- or special-purpose processors or microprocessors. Controller 22 may further include or be associated with a memory for storing data such as, for example, design limits, performance characteristics, operational instructions, matrix characteristics, reinforcement characteristics, characteristics of structure 12, and corresponding parameters of each component of system 10. Various other known circuits may be associated with controller 22, including power supply circuitry, signal-conditioning circuitry,

solenoid/motor driver circuitry, communication circuitry, and other appropriate circuitry. Moreover, controller 22 may be capable of communicating with other components of system 10 via wired and/or wireless transmission.

[0020] One or more maps may be stored in the memory of controller 22 and used during fabrication of structure 12. Each of these maps may include a collection of data in the form of models, lookup tables, graphs, and/or equations. In the disclosed embodiment, the maps are used by controller 22 to determine desired characteristics of cure enhancers 20, the associated matrix, and/or the associated reinforcements at different locations within structure 12. The characteristics may include, among others, a type, quantity, and/or configuration of reinforcement and/or matrix to be discharged at a particular location within structure 12, and/or an amount, intensity, shape, and/or location of desired curing. Controller 22 may then correlate operation of support 14 (e.g., the location and/or orientation of head 16) and/or the discharge of material from head 16 (a type of material, desired performance of the material, cross-linking requirements of the material, a discharge rate, etc.) with the operation of cure enhancers 20, such that structure 12 is produced in a desired manner.

[0021] An exemplary head 16 is disclosed in detail in Fig. 2. Head 16 may include, among other things, one or more nozzles 24 that are fluidly connected to the lower end of a matrix reservoir 26. Any number of reinforcements (represented as **R** in Fig. 2) may be received at an opposing upper end of reservoir 26, passed axially through reservoir 26 where at least some matrix-impregnation occurs (matrix represented as **M** in Fig. 2), and discharged from head 16 via any number of separate nozzles 24. In the disclosed embodiment, a single primary nozzle 24 is utilized that has a straight axial or convergent tip. In multi-nozzle applications, however, it may be helpful for a tip of each primary nozzle 24 to have a divergent shape to facilitate coalescing of the different matrix-coated fibers into a ribbon or sheet of composite material.

[0022] As shown in Figs. 2 and 3, head 16 may include a follower 28 connected to a trailing side of head 16 (e.g., a trailing side of primary nozzle 24) by way of a pivoting arm 29. Follower 28 may be an assembly of components that cooperate to create desired surface textures on structure 12. These components may include, among other things, a passage 30 fluidly connected with matrix reservoir 26 (e.g., via primary nozzle 24), and at least one auxiliary nozzle 32 operatively connected to a distal end of passage 30. Passage 30 may be internally provided with matrix from head 16 (and/or a different matrix from another source); and auxiliary nozzle(s)

32 may be configured to discharge the matrix toward structure 12, such that the matrix fills voids within and/or sticks to external surfaces of structure 12. A squeegee 34 may be associated with auxiliary nozzle(s) 32 and configured to wipe over and thereby smooth out the matrix after discharge from auxiliary nozzle(s) 32 and prior to curing by one or more downstream cure enhancers 20.

[0023] Auxiliary nozzle(s) 32 may be configured to apply an outer annular layer or film of matrix to external surfaces of structure 12. For example, each auxiliary nozzle 32 may include one or more orifices 36 located between upstream and downstream blades 34a, 34b of squeegee 34 that are configured to spray or otherwise discharge matrix onto the external surfaces of structure 12. Downstream blade 34b may be spaced away from the external surfaces of structure 12 by a desired distance, and configured to wipe over the matrix applied by orifices 36, thereby pressing the matrix into a smooth layer having a desired and relatively constant thickness (e.g., constant within engineering tolerances). Upstream blade 34a may ride along the outer surface of structure 12 (e.g., in direct or near-direct contact) and be configured to inhibit the matrix from passing to locations further upstream. Upstream blade 34a may be omitted in some embodiments. One or both of upstream and downstream blades 34a, b of squeegee 34 may be position-adjustable, if desired.

[0024] As described above, head 16 may include cure enhancers 20 that function to at least partially cure the composite material as it discharges from primary nozzle 24. In the disclosed embodiment, these cure enhancers 20 are mounted directly to the tip-end of head 16 (e.g., to a lower external surface of matrix reservoir 26. And as also described above, additional downstream cure enhancers 20 may be associated with follower 28 to at least partially cure the additional matrix being applied to structure 12 by auxiliary nozzle(s) 32. These cure enhancers 20 may be mounted within a hood 38 of follower 28. Hood 38 may flare outward and extend downstream to reflect energy from the additional downstream cure enhancers 20 inward toward structure 12.

[0025] As shown in Fig. 3, auxiliary nozzle(s) 32 of follower 28 may include unique features that cooperate to accommodate multi-dimensional print surfaces and/or to produce multi-faceted structures 12. For example, orifices 36 of auxiliary nozzle(s) 32 may be connected to each other by way of a plurality of hinges 40, which allow orifices 36 to be moved out of a straight-line relationship. In particular, hinges 40 may allow for pivoting, raising, and/or lowering orifices 36

relative to each other. When head 16 travels axially relative to a print surface (see, for example, Fig. 2) of structure 12, the raising/lowering of orifices 36 may allow for fabrication of a C-, V-, and/or S-shaped cross-sections in an outer matrix shell of structure 12.

[0026] One or more actuators 42 (e.g., linear and/or rotary actuators) may be associated with hinges 40 and configured to automatically make adjustments to the arrangement of orifices 36 when selectively energized by controller 22. These adjustments may include relative pivoting of hinges 40 and the resulting raising and lowering of orifices 36, as desired. For example, controller 22 may selectively energize one or more actuators 42 based on specifications for structure 12 that are stored in memory and/or in coordination with movements of head 16 caused by support 14. In one embodiment, the adjustments may be implemented to create particular facets of structure 12. In another embodiment, the adjustments may be implemented to discharge material on top of an irregular print surface.

[0027] It is contemplated that auxiliary nozzle(s) 32 may additionally or alternatively be moveable based only on interaction with a print surface (e.g., without the use of any actuators 42), if desired. For example, orifices 36 may be biased (e.g., via a spring or hydraulic pressure) to a baseline position, and moveable away from the baseline position when printing over an uneven surface.

[0028] In one embodiment, squeegee 34 of Fig. 3 includes a flexible outer membrane that surrounds orifices 36. The membrane may be filled with a smart fluid (e.g., a magnetorheological fluid) that, when energized (e.g., when exposed to a magnetic field or a voltage potential), increases in viscosity and can even become a solid. Controller 22 may selectively de-energize the fluid to relax the membrane during movements of actuator(s) 42, and thereafter re-energize the fluid such that the membrane again becomes rigid in the new configuration caused by the movement of actuator(s) 42. In this manner, the membrane may help to provide consistent contour control during fabrication of structure 12.

[0029] It is contemplated that additional functionality could be included within follower 28, if desired. For example, a vibration and/or oscillation inducing member (not shown) could be embedded within and/or near follower 28. This member may be functional to reduce bubbles and/or help to spread out the matrix discharged by primary and/or auxiliary nozzles 24, 32.

Industrial Applicability

[0030] The disclosed system may be used to continuously manufacture composite structures having any desired cross-sectional size, shape, length, density, and/or strength. The composite structures may include any number of different reinforcements of the same or different types, diameters, shapes, configurations, and consists, each coated with a common matrix. In addition, the disclosed head and follower may allow cooperative fabrication of complex structures with high-tolerance surface finish specifications. Operation of system 10 will now be described in detail.

[0031] At a start of a manufacturing event, information regarding a desired structure 12 may be loaded into system 10 (e.g., into controller 22 that is responsible for regulating operations of support 14 and/or head 16). This information may include, among other things, a size (e.g., diameter, wall thickness, length, etc.), a contour (e.g., a trajectory), surface features (e.g., ridge size, location, thickness, length; flange size, location, thickness, length; etc.) and finishes, connection geometry (e.g., locations and sizes of couplings, tees, splices, etc.), location-specific matrix stipulations, location-specific reinforcement stipulations, etc. It should be noted that this information may alternatively or additionally be loaded into system 10 at different times and/or continuously during the manufacturing event, if desired. Based on the component information, one or more different reinforcements and/or matrixes may be selectively installed and/or continuously supplied into system 10.

[0032] Installation of the reinforcements may be performed by passing the reinforcements down through matrix reservoir 26, and then threading the reinforcements through any nozzles 24 that exist. Installation of the matrix may include filling reservoir 26 within head 16 and/or coupling of an extruder (not shown) to head 16.

[0033] Head 16 may then be moved by support 14 under the regulation of controller 22 to cause matrix-coated reinforcements to be placed against or on a corresponding anchor point 18. Cure enhancers 20 within head 16 and/or follower 28 may then be selectively activated to cause hardening of the matrix surrounding the reinforcements, thereby bonding the reinforcements to anchor point 18.

[0034] The component information may then be used to control operation of system 10. For example, the reinforcements may be pulled and/or pushed from head 16 (along with the matrix),

while support 14 selectively moves head 16 in a desired manner during curing, such that an axis of the resulting structure 12 follows a desired trajectory (e.g., a free-space, unsupported, 3-D trajectory). As the separate reinforcements are pulled through head 16, the reinforcements may pass through primary nozzle(s) 24 and under or through follower 28. Auxiliary nozzles 32, the downstream cure enhancers 20, actuator(s) 42, and/or the smart fluid within the membrane of squeegee 34 may be selectively energized by controller 22, such that an outer layer or skin having a desired surface finish and contour is applied to structure 12 and cured. Once structure 12 has grown to a desired length, structure 12 may be disconnected (e.g., severed) from head 16 in any desired manner.

[0035] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed systems and head. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the disclosed systems and heads. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

Claims

What is claimed is:

1. A follower for an additive manufacturing system, comprising:
a matrix inlet passage;
a nozzle connected to a distal end of the matrix inlet passage;
a cure enhancer located downstream of the nozzle; and
a squeegee blade disposed between the nozzle and the cure enhancer.
2. The follower of claim 1, wherein:
the squeegee blade is a first blade; and
the follower further includes a second blade disposed upstream of the nozzle.
3. The follower of claim 1, wherein the squeegee blade includes:
a flexible outer membrane; and
a smart fluid disposed within the flexible outer membrane.
4. The follower of claim 1, wherein the nozzle includes a plurality of orifices.
5. The follower of claim 4, wherein the plurality of orifices are connected together in a chain by way of at least one hinge.
6. The follower of claim 5, further including an actuator configured to move the chain.
7. The follower of claim 1, further including a hood that flare outward around the cure enhancer.
8. The follower of claim 1, further including a pivoting arm configured to connect the nozzle to a trailing side of a print head.
9. An additive manufacturing system, comprising:
a matrix reservoir;
a primary nozzle fluidly connected to the matrix reservoir;

a primary cure enhancer operatively connected to at least one of the matrix reservoir and the primary nozzle, the primary cure enhancer configured to direct a cure energy toward a tip of the primary nozzle;

an auxiliary nozzle;

an arm configured to mount the auxiliary nozzle at a trailing side of the primary nozzle; and

a passage extending from the matrix reservoir to the auxiliary nozzle.

10. The additive manufacturing system of claim 9, further including an auxiliary cure enhancer located downstream of the auxiliary nozzle.

11. The additive manufacturing system of claim 10, further including a squeegee blade disposed between the auxiliary nozzle and the auxiliary cure enhancer.

12. The additive manufacturing system of claim 11, wherein:
the squeegee blade is a first blade; and
the additive manufacturing system further includes a second blade disposed upstream of the auxiliary nozzle.

13. The additive manufacturing system of claim 11, wherein the squeegee blade includes:

a flexible outer membrane; and
a smart fluid disposed within the flexible outer membrane.

14. The additive manufacturing system of claim 10, further including a hood that flare outward around the auxiliary cure enhancer.

15. The additive manufacturing system of claim 9, wherein the auxiliary nozzle includes a plurality of orifices.

16. The additive manufacturing system of claim 15, wherein the plurality of orifices are connected together in a chain by way of at least one hinge.

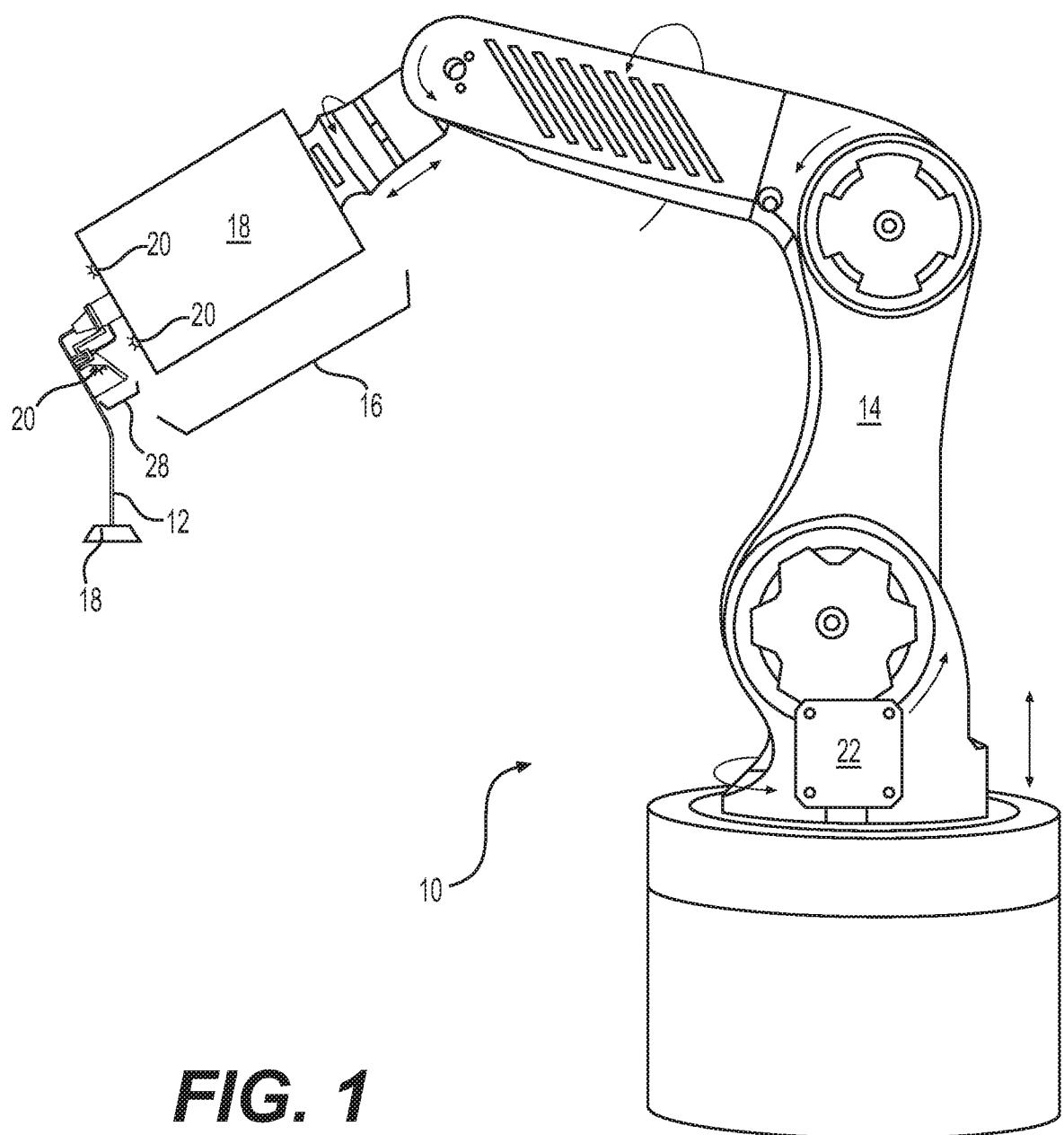
17. The additive manufacturing system of claim 16, further including an actuator configured to move the chain.

18. The additive manufacturing system of claim 9, wherein the arm is configured to pivot the auxiliary nozzle relative to the primary nozzle.

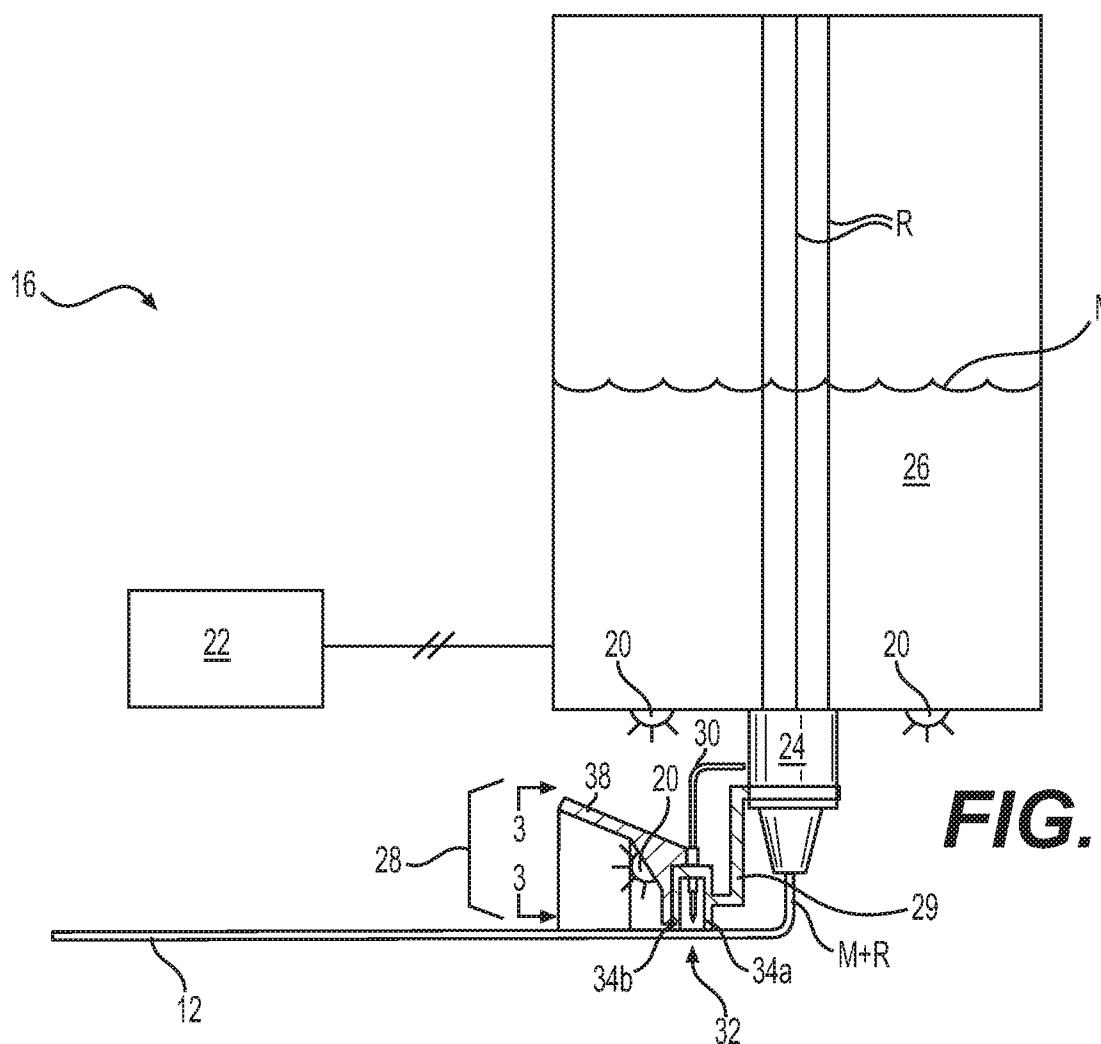
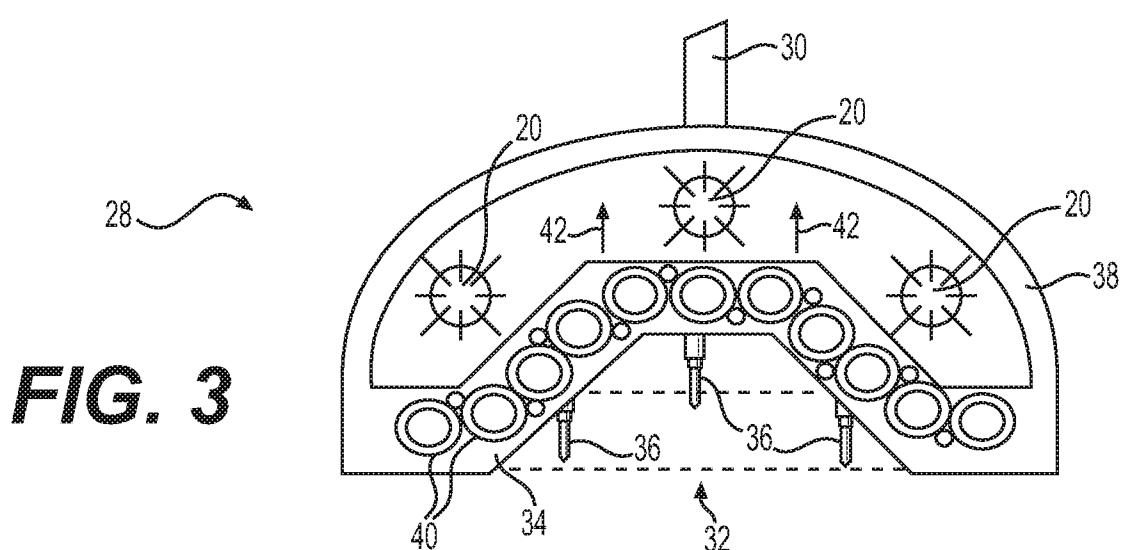
19. The additive manufacturing system of claim 9, wherein:
the primary nozzle is configured to discharge a matrix-wetted reinforcement; and
the auxiliary nozzle is configured to discharge only a matrix.

20. An additive manufacturing system, comprising:
a moveable support;
a print head connected to the moveable support and configured to discharge a matrix-wetted reinforcement; and
a follower connected to trail behind the print head, the follower including:
nozzle configured to discharge only a matrix;
a cure enhancer located at a side of the nozzle opposite the print head; and
a squeegee blade disposed between the nozzle and the cure enhancer.

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**FIG. 1**

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**FIG. 2****FIG. 3**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US17/68020

A. CLASSIFICATION OF SUBJECT MATTER

IPC - B33Y 30/00, B29C 64/20 (2018.01)

CPC -
B33Y 30/00, B29C 64/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/0361873 A1 (MAIER, N.) December 15, 2016; figures 6 and 7; paragraphs [0044-0048].	1, 7
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Y		2-6, 8, 14
X	US 2015/0375457 A1 (MARKFORGED, INC.) December 31, 2015; figures 1A, 1C and 4; paragraphs [0091-0092, 0100, 0101, 0107, 0108, 0117, 0135, 0167, 0188, 0197-0199].	9-12, 18-20
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Y		2, 8, 13-17
Y	DE 10 2012 210 203 A1 (ROBERT BOSCH GMBH) December 19, 2013; see machine translation; figures 1 and 2; paragraph [0001, 0022].	3, 13
Y	US 2015/140147 A1 (KONSTANTINOS, J et al.) May 21, 2015; figure 1; paragraph [0027, 0038, 0042].	4-6, 15-17

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
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 "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search 20 February 2018 (20.02.2018)	Date of mailing of the international search report 08 MAR 2018
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774