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(54) SYSTEM FOR FABRICATING FIBER-REINFORCED STRUCTURES

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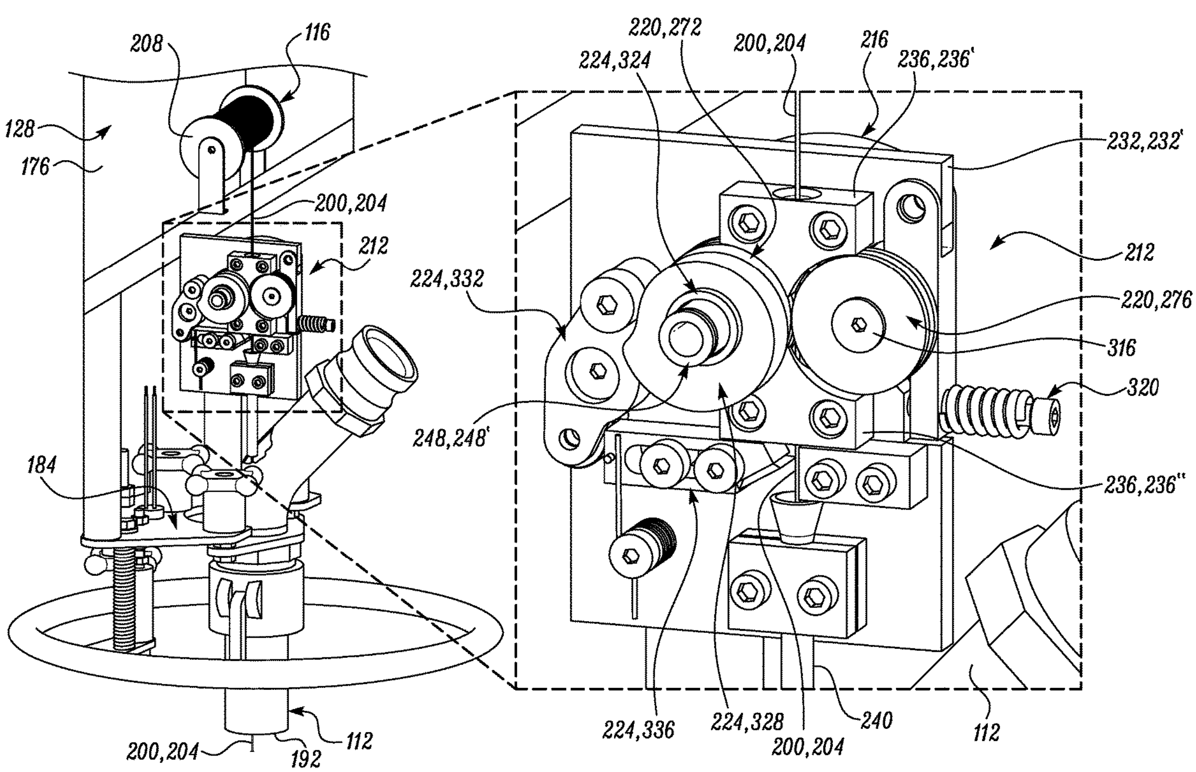
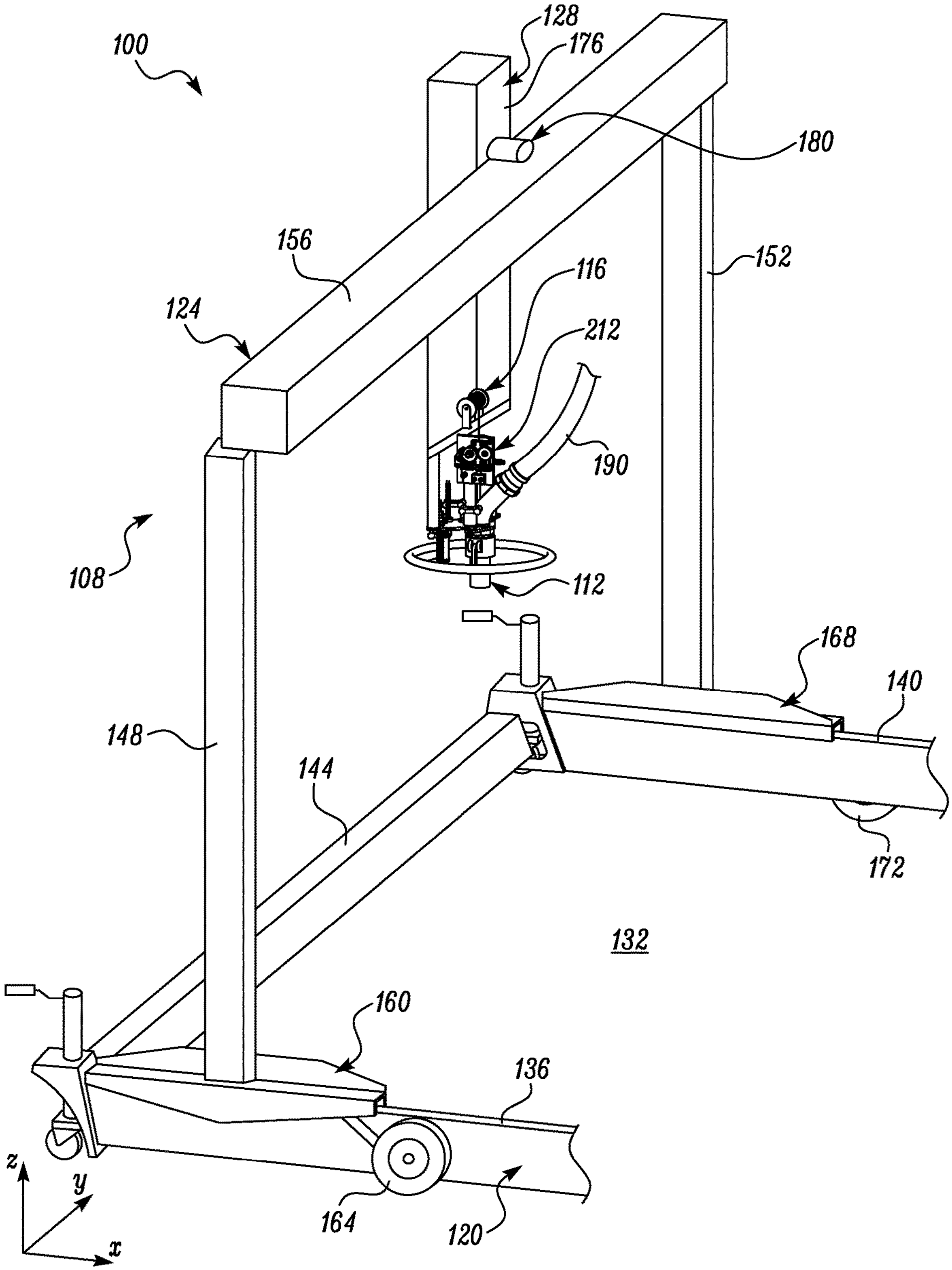
(57) **ABSTRACT**

A system, for controlling a supply of a reinforcement member into a printable material extruded from a nozzle of an additive manufacturing system, includes a motor with a driveshaft defining a drive axis and an engagement portion, a feed roller mountable on the driveshaft and including a first coupler engageable with the engagement portion, an actuator including a second coupler engageable with the engagement portion, and a controller configured to actuate the motor to rotate the driveshaft about the drive axis: in a first direction to engage the engagement portion with the first coupler and transfer torque from the driveshaft to the feed roller to supply the reinforcement member into the printable material; and in a second direction to engage the engagement portion with the second coupler and transfer torque from the driveshaft to the actuator to cut-off the supply of the reinforcement member into the printable material.

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128
176
180
156
152
124
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172
132
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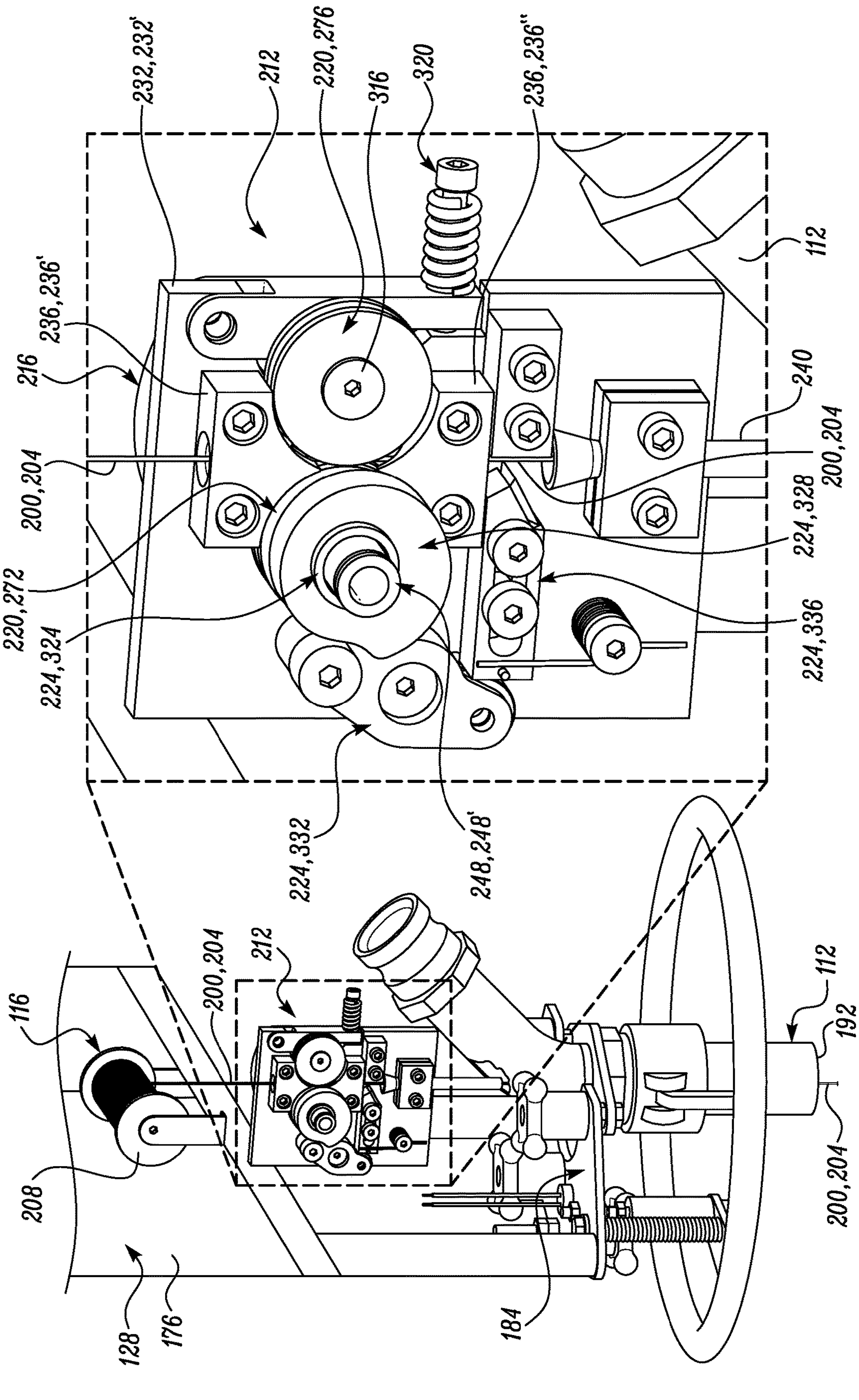
164
120
z
y
x

FIG. 1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220,276
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112
216
236,236'
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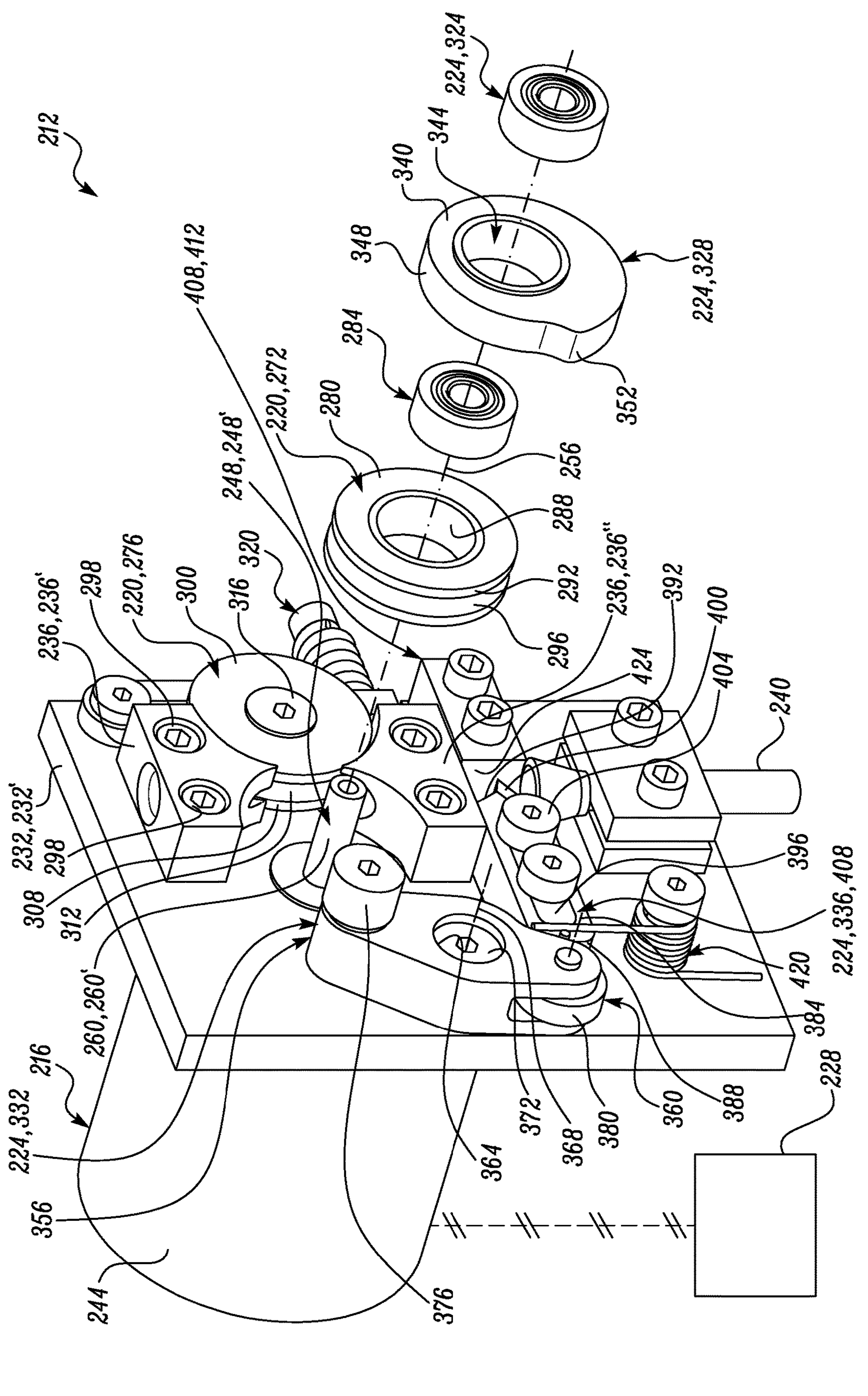
200,204
200,204
224,328
220,272
224,324
224,336
224,332
248,248'
116
200,204
212
208
112
192
200,204
128
176
184

FIG. 2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224,324
344
340
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248,248'
288
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300
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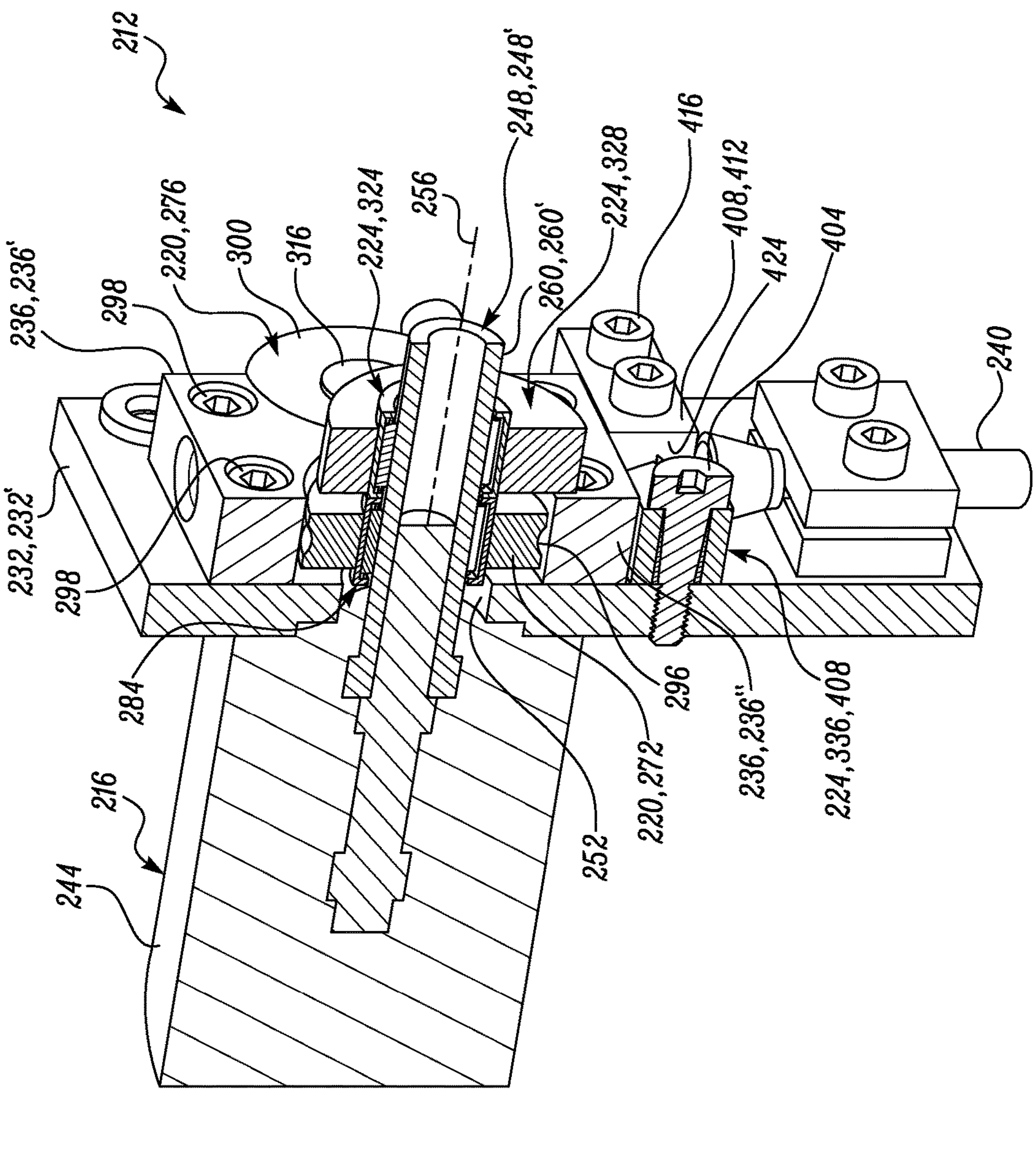
298
236,236'
236,236''
292
296
392
400
424
404
240
232,232'
298
308
312
260,260'
396
224,336,408
420
384
388
360
380
368
372
364
216
224,332
356
228
244
376

FIG. 3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300
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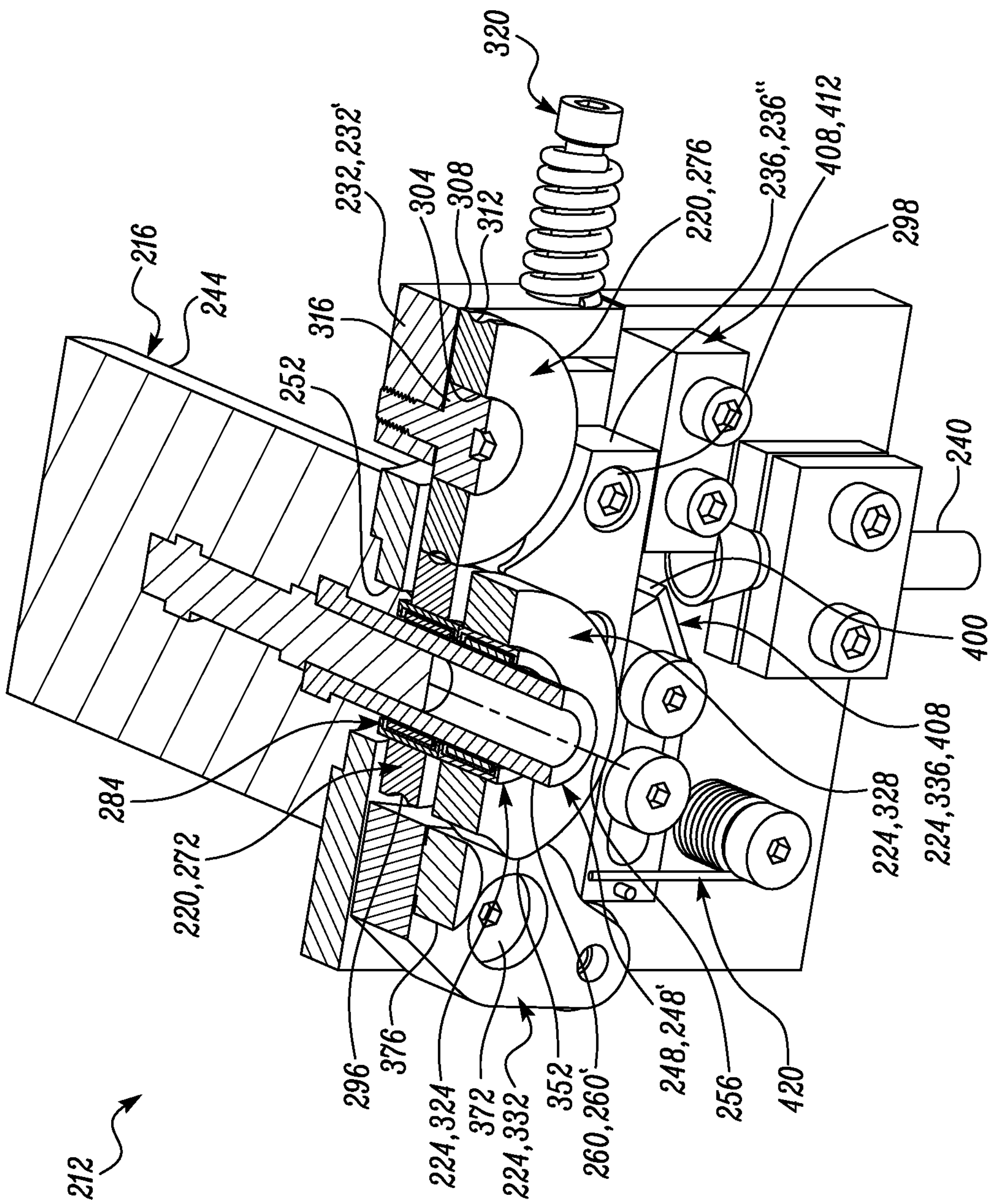
224,328
416
408,412
424
404
240
232,232'
298
284
216
244
252
220,272
296
236,236''
224,336,408
408

FIG. 4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216
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236,236''
408,412
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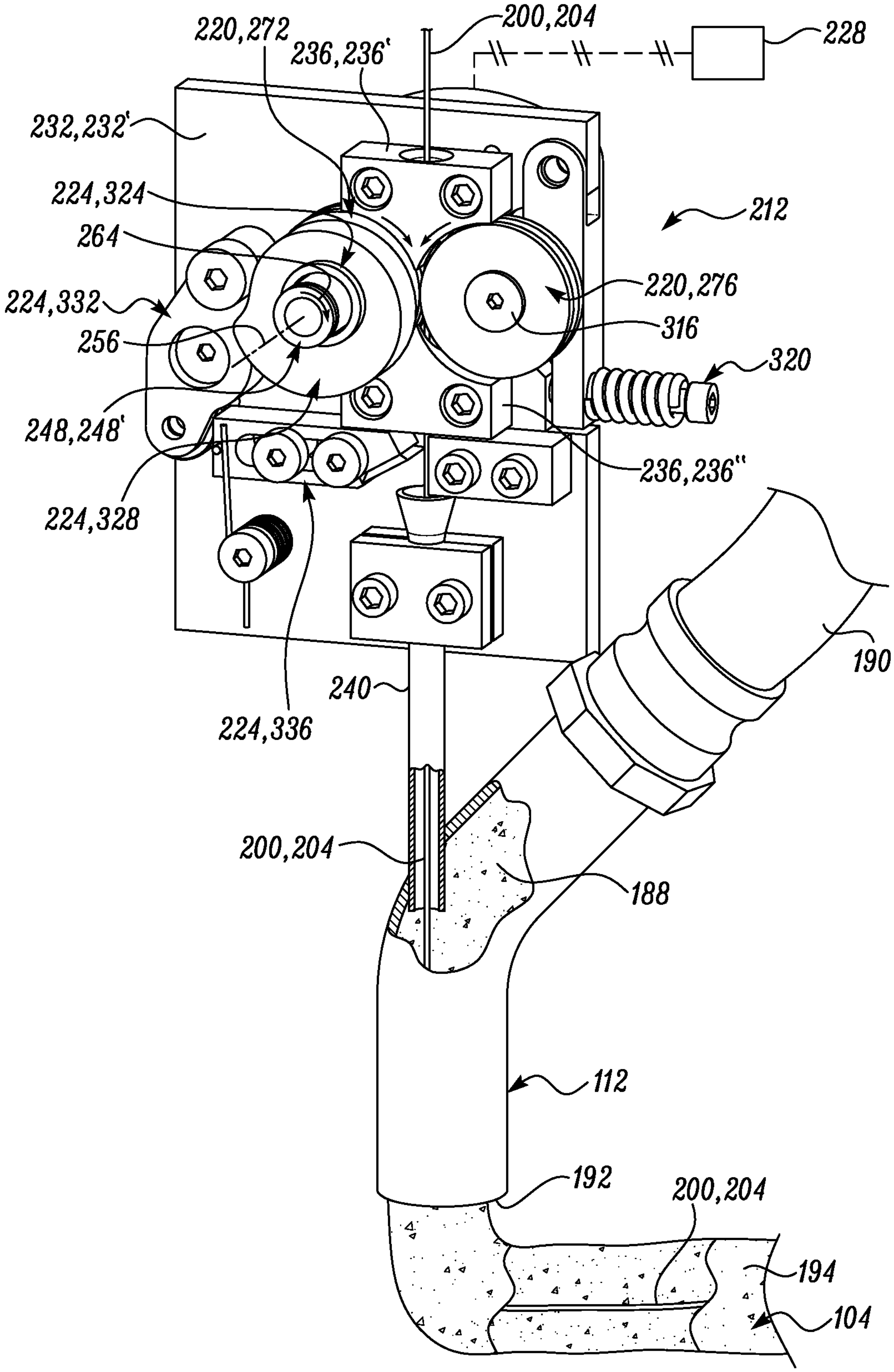
240
400
408
224,336,408
224,328
420
256
248,248'
260,260'
352
224,332
372
224,324
376
296
220,272
284
212

FIG. 5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224,332
316
256
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236,236''
224,328
190
224,336
240
200,204
188
112
192
200,204
194
104

FIG. 6

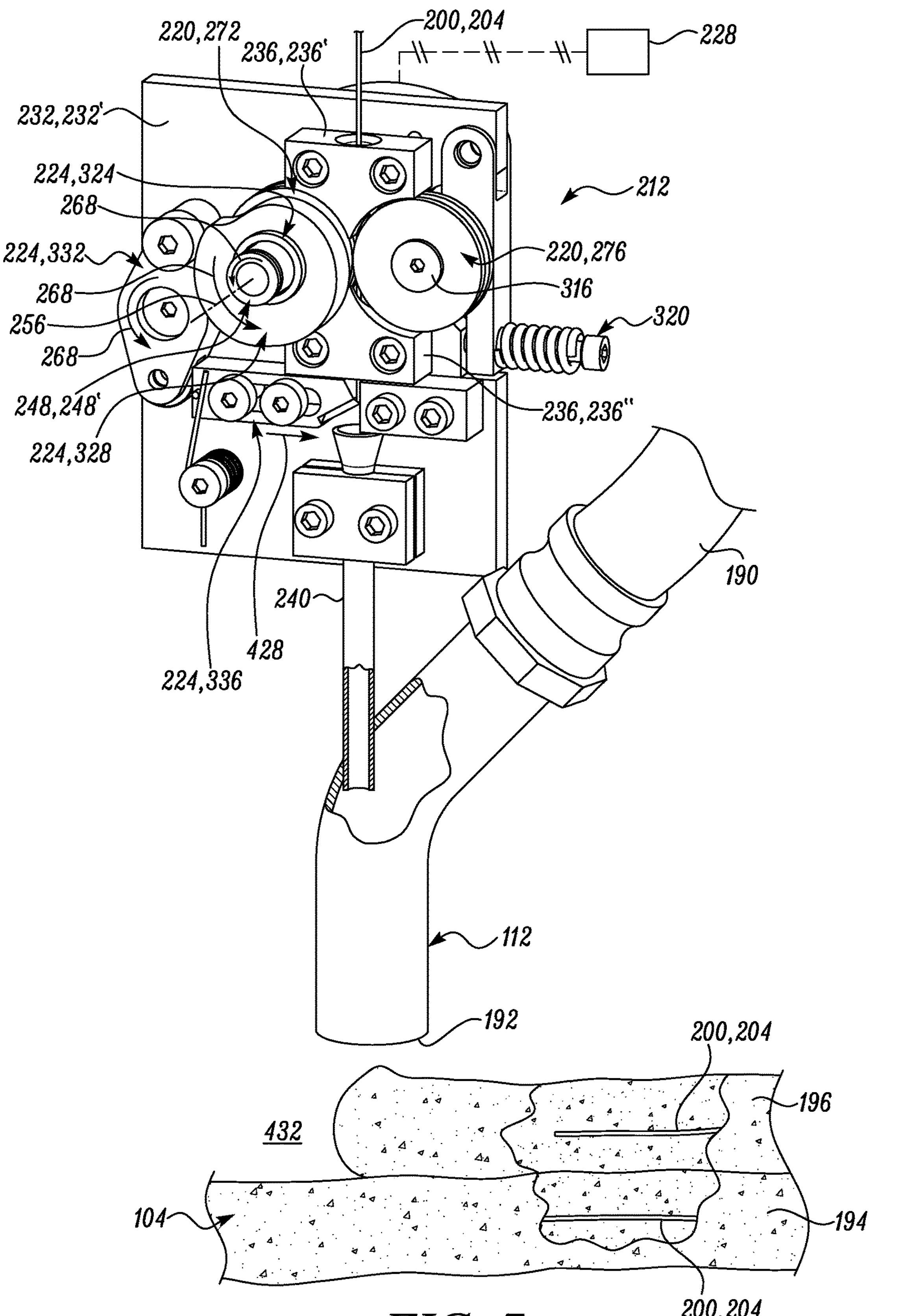
200,204
220,272
236,236'
228
232,232'
224,324
212
268
224,332
220,276
268
316
256
320
268
248,248'
236,236''
224,328
190
240
428
224,336
112
192
200,204
196
432
104
194
200,204

FIG. 7

SYSTEM FOR FABRICATING FIBER-REINFORCED STRUCTURES

TECHNICAL FIELD

[0001] The present disclosure relates to additive construction of fiber-reinforced structures. More particularly, the present disclosure relates to a system for controlling a supply of a reinforcement member into a printable material to be extruded from an additive manufacturing system to fabricate a fiber-reinforced structure.

BACKGROUND

[0002] Additive construction may be implemented to fabricate large-scale, three-dimensional structures (e.g., walls, buildings, barracks, etc.,) on worksites. A typical additive construction involves extruding, via a nozzle of an additive manufacturing system, a printable material (e.g., concrete, cement, asphalt, etc.,) in a layer-by-layer manner to fabricate a structure. In addition, the additive construction involves embedding reinforcement members, such as reinforced-fiber roving, within or in-between the deposited layers of the printable material to enhance the strength of the structure. Embedding the reinforcement members within or in-between the deposited layers may be labor-intensive, error-prone, and unsafe for construction workers present in the vicinity of the operating additive manufacturing system.

[0003] U.S. patent publication no. 2022/0176586 discloses a method and an apparatus for producing a concrete component, including concrete and a textile reinforcement composed of a reinforcement fiber strand. A yarn is saturated with a mineral suspension and forms the at least one reinforcement fiber strand. The reinforcement fiber strand is fed by means of a moving device, so that the reinforcement fiber strand is placed in a concrete strand, placed on a concrete layer, or placed on a vertical side surface of a plurality of concrete layers placed on top of each other, so that a perpendicular reinforcement is produced when arranged on the outside. The reinforcement fiber strand is further enclosed by the concrete immediately upon placement or subsequently before the mineral suspension has cured.

SUMMARY OF THE INVENTION

[0004] In one aspect, the disclosure relates to a system for controlling a supply of a reinforcement member into a printable material to be extruded from a nozzle of an additive manufacturing system to fabricate a fiber-reinforced structure. The system includes a motor, a pair of feed rollers, an actuator, and a controller. The motor includes a driveshaft defining a drive axis and an engagement portion. A feed roller of the pair of feed rollers is mountable on the driveshaft. The feed roller includes a first coupler engageable with the engagement portion. the actuator includes a second coupler engageable with the engagement portion. The controller is configured to actuate the motor to rotate the driveshaft about the drive axis in a first direction to engage the engagement portion with the first coupler and transfer torque from the driveshaft to the feed roller to supply the reinforcement member into the printable material and to disengage the engagement portion with the second coupler to allow the driveshaft to rotate with respect to the actuator. Also, the controller is configured to rotate the driveshaft about the drive axis in a second direction (opposite to the first direction) to engage the engagement portion with the second coupler and transfer torque from the driveshaft to the actuator to cut-off the supply of the reinforcement member into the printable material and to disengage the engagement portion with the first coupler to allow the driveshaft to rotate with respect to the feed roller.

[0005] In another aspect, the disclosure is directed to an additive manufacturing system for fabricating a fiber-reinforced structure. The additive manufacturing system includes a support structure, a nozzle supported on the support structure and configured to extrude a printable material, a dispenser configured to dispense a reinforcement member, and a system for controlling a supply of the reinforcement member from the dispenser into the printable material flowing through the nozzle. The system includes a motor, a pair of feed rollers, an actuator, and a controller. The motor includes a driveshaft defining a drive axis and an engagement portion. A feed roller of the pair of feed rollers is mountable on the driveshaft. The feed roller includes a first coupler engageable with the engagement portion. the actuator includes a second coupler engageable with the engagement portion. The controller is configured to actuate the motor to rotate the driveshaft about the drive axis in a first direction to engage the engagement portion with the first coupler and transfer torque from the driveshaft to the feed roller to supply the reinforcement member into the printable material and to disengage the engagement portion with the second coupler to allow the driveshaft to rotate with respect to the actuator. Also, the controller is configured to rotate the driveshaft about the drive axis in a second direction (opposite to the first direction) to engage the engagement portion with the second coupler and transfer torque from the driveshaft to the actuator to cut-off the supply of the reinforcement member into the printable material and to disengage the engagement portion with the first coupler to allow the driveshaft to rotate with respect to the feed roller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** is a perspective view of an exemplary additive manufacturing system including a nozzle for extruding a printable material, in accordance with an embodiment of the present disclosure;

[0007] FIG. **2** is a perspective view of an exemplary system for controlling a supply of a reinforcement member into the printable material to be extruded from the nozzle, in accordance with an embodiment of the present disclosure;

[0008] FIG. **3** is an exploded view of the system, in accordance with an embodiment of the present disclosure;

[0009] FIG. **4** is a cross-sectional view of the system, in accordance with an embodiment of the present disclosure;

[0010] FIG. **5** is a cross-sectional view of the system, in accordance with an embodiment of the present disclosure;

[0011] FIG. **6** illustrates an operating state of the system for supplying the reinforcement member into the printable material, in accordance with an embodiment of the present disclosure; and

[0012] FIG. **7** illustrates an operating state of the system for cutting-off the supply of reinforcement member into the printable material, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0013] Reference will now be made in detail to specific embodiments or features, examples of which are illustrated in the accompanying drawings. Generally, corresponding reference numbers may be used throughout the drawings to refer to the same or corresponding parts, e.g., **1**, **1'**, **1"**, **101** and **201** could refer to one or more comparable components used in the same and/or different depicted embodiments.

[0014] Referring to FIG. **1**, an exemplary additive manufacturing system **100** is disclosed. The additive manufacturing system **100** is used to construct various types of structures (e.g., barracks, enclosures), portions of structures (e.g., walls), or other products utilizing additive manufacturing processes. In an exemplary additive manufacturing process, a printable material (e.g., concrete, cement, asphalt, etc.,) may be laid in a layer-by-layer manner to fabricate fiber-reinforced structures (e.g., a structure **104**, as shown in FIGS. **6** and **7**) and/or portions thereof. In an embodiment, the additive manufacturing system **100** may be a stationary system, for example, fixed to the ground of a worksite. In another embodiment, the additive manufacturing system **100** may be a portable system, for example, attached to a mobile work machine.

[0015] The additive manufacturing system **100** includes a support structure **108**, a nozzle **112**, and a dispenser **116**. The support structure **108** accommodates and/or supports the nozzle **112** and the dispenser **116**, although other known components and structures of the additive manufacturing system **100** may be supported by the support structure **108**, as well. The support structure **108** facilitates relatively free movement of the nozzle **112**, e.g., along x axis, y axis, and z axis, to accomplish the additive construction of the structure **104**.

[0016] In an exemplary embodiment, as shown in FIG. **1**, the support structure **108** includes a gantry frame **120**, a gantry bridge **124**, and a vertical arm **128**. The gantry frame **120** may be configured to rest (or traverse) on a ground surface **132**. The gantry frame **120** may include multiple components coupled together to impart a generally horizontal, substantially U-shaped profile, to the gantry frame **120**. For example, as shown in FIG. **1**, the gantry frame **120** includes two spaced-apart longitudinal trusses **136**, **140**, and a transverse truss **144**. Each of the longitudinal trusses **136**, **140** may extend along the x-axis. The transverse truss **144** may extend between the longitudinal trusses, along the y-axis.

[0017] The gantry bridge **124** may be supported by the gantry frame **120**. For example, as shown in FIG. **1**, the gantry bridge **124** includes a first vertical truss **148**, a second vertical truss **152**, and a horizontal truss **156**. The first vertical truss **148** may be supported by (and is coupled to) the longitudinal truss **136** of the gantry frame **120**. The second vertical truss **152** may be supported by (and is coupled to) the longitudinal truss **140** of the gantry frame **120**. In an example, the first vertical truss **148** is attached to a first carriage assembly **160** that is movably secured (e.g., via guide wheels **164**) to the longitudinal truss **136** of the gantry frame **120**. The second vertical truss **152** is attached to a second carriage assembly **168** that is movably secured (e.g., via guide wheels **172**) to the longitudinal truss **140** of the gantry frame **120**. The first carriage assembly **160** and the second carriage assembly **168** facilitate movement of the gantry bridge **124** along the x-axis. The horizontal truss **156** may span a distance between and is coupled on opposite ends of the first vertical truss **148** and the second vertical truss **152**.

[0018] The vertical arm **128** may be operatively coupled to the horizontal truss **156** to move with respect to the horizontal truss **156**. In an example, as shown in FIG. **1**, the vertical arm **128** is a gantry truss **176** operatively coupled to the horizontal truss **156**, via a trolley **180**. The trolley **180** may allow the gantry truss **176** to move with respect to the horizontal truss **156**, for example, along y-axis and z-axis to position the nozzle **112** and the dispenser **116** at a desired location.

[0019] The nozzle **112** is supported on the support structure **108**. In an example, as shown in FIGS. **1** and **2**, the nozzle **112** is mounted to an end portion **184** of the vertical arm **128** of the support structure **108**. The nozzle **112** may be fluidly coupled with a source (not shown) of printable material **188**, for example, via a conduit **190** (e.g., a hose, a pipe, etc.,) (as shown in FIGS. **1**, **6**, and **7**). The source of printable material **188** may be a mixer, hopper, tank, vessel, etc. that is configured to prepare, store, and/or contain a volume of the printable material **188**. In an exemplary additive manufacturing process, the nozzle **112** receives the printable material **188** (pumped through the conduit **190**) and extrudes the printable material **188**, via an outlet **192**, to form one or more layers (e.g., a first layer **194**, a second layer **196**, shown in FIG. **6** and FIG. **7**) of the structure **104** and/or a portion thereof. The outlet **192** may facilitate the nozzle **112** to extrude the printable material **188** in a direction perpendicular to at least one of a preceding layers (e.g., the first layer **194**, or the second layer **196**), or a base surface (e.g., ground surface **132**).

[0020] The dispenser **116** may be supported on the support structure **108**. The dispenser **116** is configured to hold and dispense a reinforcement member **200** to be supplied and mixed with the printable material **188** within the nozzle **112**. In an example, as shown in FIGS. **2**, **6**, and **7**, the reinforcement member **200** includes a reinforced fiber roving **204**, and the dispenser **116** includes a spool **208** of reinforced fiber roving **204** mounted on the vertical arm **128** of the support structure **108** at a location, for example, above the nozzle **112**. Examples of the reinforced fiber roving **204** may include, but not limited to, basalt fiber roving, fiberglass roving, carbon fiber roving, aramid fiber roving, and glass-carbon hybrid roving.

[0021] To control (e.g., allow, or cut-off) a supply of the reinforcement member **200** (e.g., the reinforced fiber roving **204**) from the dispenser **116** into the printable material **188** flowing through the nozzle **112**, in one or more aspects of the present disclosure, a system **212** is provided. The system **212** includes a motor **216**, a pair of feed rollers **220**, an actuator **224**, and a controller **228**. In addition, the system **212** may include a base plate **232**, a pair of guide blocks **236**, and a guiding tube **240**. Each of the base plate **232**, the motor **216**, the pair of feed rollers **220**, the actuator **224**, the pair of guide blocks **236**, the guiding tube **240**, and the controller **228** is discussed in detail with reference to the FIGS. **2-5**.

[0022] The base plate **232** may be a flat rectangular plate **232**. The base plate **232** may be mounted to the vertical arm **128** of the support structure **108**. In an exemplary embodiment, as shown in FIG. **2**, the base plate **232** is mounted on the gantry truss **176**, for example, at a location between the dispenser **116** and the nozzle **112**. The base plate **232** may be configured to support the motor **216**, the pair of feed rollers **220**, the actuator **224**, the pair of guide blocks **236**, and the guiding tube **240**.

[0023] The motor **216** includes a housing **244** and a driveshaft **248**. The housing **244** may be mounted to the base plate **232**, for example, through a mounting plate (not shown) that is secured to the base plate **232**. The driveshaft **248** may be rotatably supported on one or more bearings (not shown) within the housing **244**. Although not limited, the driveshaft **248** may include a cylindrical structure **248**. The driveshaft **248** may be at least partly received into a hollow opening **252** (shown in FIGS. **4** and **5**) defined at the base plate **232** to facilitate the mounting of the motor **216** onto the base plate **232**. The driveshaft **248** defines a drive axis **256** and an engagement portion **260**. In an exemplary embodiment, as shown in FIGS. **3-5**, the engagement portion **260** is an outer circumferential surface **260** of the driveshaft **248**. In other embodiments, the engagement portion **260** may be any protruded portion or depression portion, or any other known geometry, formed on the outer circumferential surface **260** of the driveshaft **248**.

[0024] The motor **216** is a reversible motor **216'** configured to be actuated to selectively rotate the driveshaft **248** in a first direction **264** (e.g., clockwise direction) about the drive axis **256**, and in a second direction **268** opposite to the first direction **264** (e.g., an anticlockwise direction) about the drive axis **256**. Further, the motor **216** may be an electrical motor (i.e., powered by one or more electrical power sources, such as batteries), or may be a hydraulic motor (i.e., powered by pressurized flow of fluid).

[0025] The pair of feed rollers **220** includes a first feed roller **272** and a second feed roller **276**. The first feed roller **272** may include an annular body **280** and a first coupler **284**. The annular body **280** may be a monolithic body defining a central bore **288** and an outer circumferential surface **292**. In addition, the annular body **280** may define a groove **296** extending circumferentially along the outer circumferential surface **292** of the annular body **280**. The groove **296** may be configured to receive the reinforcement member **200** from a first guide block **236** (of the pair of guide blocks **236**) and direct the reinforcement member **200** towards a second guide block **236"** (of the pair of guide blocks **236**). The first guide block **236'** and the second guide block **236"** may be secured to the base plate **232**, for example, via fasteners **298** (as shown in FIG. **3**).

[0026] The first coupler **284** is configured to be received and fixedly coupled to the central bore **288** of the annular body **280**. The first coupler **284** facilitates the first feed roller **272** to be mounted on to the driveshaft **248**. Once mounted on the driveshaft **248**, the first coupler **284** is engageable or disengageable with the corresponding engagement portion **260** (e.g., the outer circumferential surface **260'**) of the driveshaft **248** to selectively transfer torque between the driveshaft **248** and the first feed roller **272**. In an exemplary embodiment, the first coupler **284** is a one-way clutch configured to engage with the engagement portion **260** of the driveshaft **248** upon rotation of the driveshaft **248** in the first direction **264** about the drive axis **256**, and disengage with the engagement portion **260** upon rotation of the driveshaft **248** in the second direction **268** about the drive axis **256**. Examples of the one-way clutch may include, but not limited to, a sprag-type one-way clutch, roller-type one-way clutch, ratchet-type one-way clutch, and pawl-type one-way clutch.

[0027] The second feed roller **276** may include an annular body **300**. The annular body **300** may be a monolithic body defining a central bore **304** (see FIG. **5**) and an outer circumferential surface **308**. In addition, the annular body **300** may define a groove **312** extending circumferentially along the outer circumferential surface **308** of the annular body **300**. The second feed roller **276** may be rotatably coupled, for example, via a fastener **316**, to the base plate **232** adjacent to the first feed roller **272**. Once rotatably coupled to the base plate **232**, the groove **312** of the second feed roller **276** may be aligned and abutted (e.g., via a tensioner **320**) against the corresponding groove **296** (of the first feed roller **272**). Accordingly, the groove **312** (along with the groove **296**) may receive the reinforcement member **200** from the first guide block **236'** and direct the reinforcement member **200** towards the second guide block **236"**.

[0028] The actuator **224** is now discussed. The actuator **224** is configured to move between a released position (shown in FIG. **6**) and an actuated position (shown in FIG. **7**). In the released position, the actuator **224** allows the supply of the reinforcement member **200** into the printable material **188** flowing through the nozzle **112**. In the actuated position, the actuator **224** cut-off the supply of the reinforcement member **200** into the printable material **188** flowing through the nozzle **112**. The actuator **224** includes a second coupler **324**. In addition, the actuator **224** may include a cam lobe **328**, a lever **332**, and a cutter **336**.

[0029] The second coupler **324** is a one-way clutch configured to engage with the engagement portion **260** of the driveshaft **248** upon rotation of the driveshaft **248** in the second direction **268** about the drive axis **256**, and disengage with the engagement portion **260** upon rotation of the driveshaft **248** in the first direction **264** about the drive axis **256**. Examples of the one-way clutch may include, but not limited to, a sprag-type one-way clutch, roller-type one-way clutch, ratchet-type one-way clutch, and pawl-type one-way clutch. The cam lobe **328** may include an annular body **340**. The annular body **340** may define an opening **344** and an outer peripheral surface **348**. In addition, the annular body **340** may define a contacting portion **352** extending outwardly from the outer peripheral surface **348**.

[0030] In an assembly of the second coupler **324** and the cam lobe **328**, the second coupler **324** is received and fixedly coupled to the opening **344** of the cam lobe. Once the second coupler **324** and the cam lobe **328** are assembled together, the second coupler **324** (along with the cam lobe **328**) may be mounted to the driveshaft **248**. Once mounted to the driveshaft **248**, the second coupler **324** is engageable with corresponding engagement portion **260** (e.g., the outer circumferential surface **260'**) of the driveshaft **248** upon rotation of the driveshaft in the second direction **268** about the drive axis **256**, and disengageable with the corresponding engagement portion **260** of the driveshaft **248** upon rotation of the driveshaft in the first direction **264** about the drive axis **256**.

[0031] The lever **332** may define a first end portion **356** and a second end portion **360** opposite to the first end portion **356**. The lever **332** may also define a shaft bore **364** defining a pivoting axis **368** (shown in FIG. **3**). In an exemplary embodiment, the pivoting axis **368** is parallel to the drive axis **256**. The shaft bore **364** may be formed between the first end portion **356** and the second end portion **360**. The shaft bore **364** may be configured to receive a shaft **372** (secured on the base plate **232**, as shown in FIG. **3**) to pivotally support the lever **332** about the pivoting axis **368**.

[0032] Further, the lever **332** may define a cam following portion **376** at the first end portion **356**. The cam following portion **376** may be configured to contact the contacting portion **352** of the cam lobe **328**. Furthermore, the lever **332** may include a roller **380** at the second end portion **360**. The roller **380** is rotatable about an axis **384** to facilitate a rolling engagement between the second end portion **360** (of the lever **332**) and the cutter **336** upon pivoting of the lever **332** about the pivoting axis **368**.

[0033] The cutter **336** defines a first end **388**, a second end **392**, and a slot **396** extending between the first end **388** and the second end **392**. Also, the cutter **336** includes a blade **400** located at the second end **392**. The cutter **336** is slidably secured to the base plate **232**, for example, via fasteners **404** received within the slot **396** and into the base plate **232**. Also, the cutter **336** is operably engaged with the second end portion **360** of the lever **332**. For example, the first end **388** of the cutter **336** is in rolling engagement with the roller **380** of the lever **332**. In the illustrated embodiment, the cutter **336** is a part of a cutting assembly **408**, that also includes a stationary block **412** secured to the base plate **232**, for example, via fasteners **416**.

[0034] The cutter **336** is configured to be actuated (e.g., upon pivoting of the lever **332** about the pivoting axis **368**) to move (e.g., slide) from a biased position (e.g., a spring-biased position, via a spring **420**, as shown in FIG. **6**) to an actuated position (as shown in FIG. **7**) to cut-off the supply of the reinforcement member **200**. In an example, as the cutter **336** moves toward the actuated position, the blade **400** may push and abut the reinforcement member **200** against a surface **424** of the stationary block **412** to apply a shearing force on the reinforcement member **200** and cut-off the supply of the reinforcement member **200**. In an exemplary embodiment, as shown in FIGS. **6** and **7**, the cutter **336** moves reciprocally between the biased position and the actuated position in a third direction **428** (shown in FIG. **7**). The third direction **428** may be defined at an angle with respect to the drive axis **256**. In an example, the third direction **428** may be defined perpendicular to the drive axis **256**.

[0035] The controller **228** is now discussed. The controller **228** may be an electronic controller that operates in a logical fashion to perform operations, execute control algorithms, store, and retrieve data and other desired operations. The controller **228** may include or access memory, secondary storage devices, processors, and any other components for running an application. The memory and secondary storage devices may be in the form of read-only memory (ROM) or random-access memory (RAM) or integrated circuitry that is accessible by the controller **228**. Various other circuits may be associated with the controller **228** such as power supply circuitry, signal conditioning circuitry, driver circuitry, and other types of circuitry.

[0036] The controller **228** may be a single controller or may include more than one controller disposed to control various functions and/or features of the system **212** and/or the additive manufacturing system **100**. The term "controller" is meant to be used in its broadest sense to include one or more controllers and/or microprocessors that may be associated with the system **212** and/or the additive manufacturing system **100**, and that may cooperate in controlling various functions and operations of the system **212** and/or the additive manufacturing system **100**. The functionality of the controller **228** may be implemented in hardware and/or software without regard to the functionality. The controller **228** may rely on one or more data maps relating to the operating conditions and the operating environment of the additive manufacturing system **100** that may be stored in the memory of or associated with the controller **228**. Each of these data maps may include a collection of data in the form of tables, graphs, and/or equations.

[0037] The controller **228** is communicably coupled with the motor **216** of the system **212**. As an example, by way of the controller's **228** communicable coupling with the motor **216**, the controller **228** is configured to control (e.g., actuate) the motor **216** to rotate the driveshaft **248** about the drive axis **256** either in the first direction **264** (e.g., clockwise direction) or in the second direction **268** (e.g., anticlockwise direction). The controller **228** actuates the motor **216** to rotate the driveshaft **248** in the first direction **264** to engage the engagement portion **260** (of the driveshaft **248**) with the first coupler **284** and to disengage the engagement portion **260** with the second coupler **324**. The engagement of the driveshaft **248** with the first coupler **284** may allow the driveshaft **248** to transfer torque to the first coupler **284** to supply the reinforcement member **200** into the printable material **188** flowing through the nozzle **112**. At this stage, the disengagement of the driveshaft **248** with the second coupler **324** may allow the driveshaft **248** to rotate freely with respect to the second coupler **324** (of the actuator **224**) about the drive axis **256**.

[0038] Alternatively, the controller **228** actuates the motor **216** to rotate the driveshaft **248** in the second direction **268** to engage the engagement portion **260** (of the driveshaft **248**) with the second coupler **324** and to disengage the engagement portion **260** with the first coupler **284**. The engagement of the driveshaft **248** with the second coupler **324** may allow the driveshaft **248** to transfer torque to the second coupler **324** to cut-off the supply of the reinforcement member **200** into the printable material **188** flowing through the nozzle **112**. At this stage, the disengagement of the driveshaft **248** with the first coupler **284** may allow the driveshaft **248** to rotate freely with respect to the first coupler **284** about the drive axis **256**. At this point, rotation of the feed rollers **220** (i.e., of both the first feed roller **272** and the second feed roller **276**) may be stopped resulting in termination of the supply of the reinforcement member **200**.

[0039] In some embodiments, the controller **228** may also control a pump or pump system (not shown) that is configured to pump the printable material **188** (stored within the source of the printable material **188**) through the conduit **190** and the nozzle **112** during the additive manufacturing process. For example, the controller **228** may receive one or more inputs (or instructions stored on the memory of the controller **228**) associated with a start of extrusion or an end of extrusion of the printable material **188** from the nozzle **112**. Based on receipt of such inputs, the controller **228** may start or stop the pump (or the pump system) to control the extrusion of the printable material **188** from the nozzle **112**.

[0040] Further, the controller **228** may be configured to control the supply of the reinforcement member **200** based on the receipt of the inputs (or instructions) associated with the start or end of extrusion of the printable material **188** from the nozzle **112**. For instance, upon receipt of an input indicative of the start of extrusion of the printable material **188** from the nozzle **112**, the controller **228** may actuate the motor **216** to rotate the driveshaft **248** in the first direction **264** to facilitate the supply of the reinforcement member **200** into the printable material **188** within the nozzle **112**. In an example, the controller **228** may simultaneously send signals to the pump in order to start pumping the printable material **188** through the conduit **190** and into the nozzle **112**, and to the motor in order to rotate the driveshaft **248** in the first direction **264** to start the supply the reinforcement member **200**.

[0041] In another instance, upon receipt of an input indicative of approaching the end of extrusion of the printable material **188** from the nozzle **112**, the controller **228** may actuate the motor **216** to rotate the driveshaft **248** in the second direction **268** so as to cut-off the supply of the reinforcement member **200** into the printable material **188** before the end of extrusion of the printable material **188** from the nozzle **112**. In an example, upon receipt of an input indicative of approaching the end of extrusion of the printable material **188** from the nozzle **112**, the controller **228** may actuate the motor **216** (to rotate the driveshaft **248** in the second direction **268**) so as to cut-off the supply of the reinforcement member **200** into the printable material **188** five seconds before the end of extrusion of the printable material **188** from the nozzle **112**. This may prevent the reinforcement member **200** to extend out from the layer(s) (e.g., from the second layer **196**, as shown in FIG. **7**) of the printable material **188**.

[0042] Additionally, in some embodiments, the controller **228** may control position (and/or orientation) of the nozzle **112** in the three-dimensional space to form desired shape or geometry of the structure **104**. In the illustrated embodiment, the nozzle **112** is oriented in a manner such that its outlet **192** extrudes the printable material **188** and the reinforcement member **200** in a direction perpendicular to at least one of a preceding layer (e.g., the first layer **194**) of the printable material **188** (including the reinforcement member **200**) and the base surface (e.g., ground surface **132**). In order to control the positioning and orientation of the nozzle **112**, the controller **228** may be configured to control movement of various components of the additive manufacturing system **100**. For example, the controller **228** may be configured to control movement of the gantry bridge **124** with respect to the gantry frame **120** along the x-axis. In addition, the controller **228** may be configured to control movement of the vertical arm **128** with respect to the horizontal truss **156** along the y-axis and z-axis.

INDUSTRIAL APPLICABILITY

[0043] The present disclosure provides the additive manufacturing system **100** for constructing various types of fiber-reinforced structures (such as the structure **104**), portions of structure(s), or other products utilizing additive manufacturing processes. During a fabrication of a structure (e.g., the structure **104**) using the additive manufacturing process, there may be a need to start or stop the supply of reinforcement member **200** (e.g., the reinforced fiber roving **204** dispensed from the dispenser **116**) into the printable material **188** to be extruded from the nozzle **112** of the additive manufacturing system **100**. For example, to fabricate a window portion **432** (shown in FIG. **7**) of the structure **104** (e.g., wall), the extrusion of the printable material **188** and the reinforcement member **200** (from the nozzle **112**) needs to be halted for a period (e.g. to correspondingly form a desired width of the window portion **432**) while the nozzle **112** moves along a length of the structure **104**. During the movement of the nozzle **112** along the length of the structure **104**, upon completion of the halt period, there may be a need to resume the extrusion of the printable material **188** and the reinforcement member **200** (from the nozzle **112**) to fabricate the remaining portion of the structure **104**.

[0044] In order to control (e.g., allow, or cut-off) the supply of the reinforcement member **200** from the dispenser **116** into the printable material **188** flowing through the nozzle **112**, for example, upon start and end of extrusion of the printable material **188** from the nozzle **112**, the additive manufacturing system **100** is provided with the system **212**. In an exemplary process of fabricating the structure **104** with the window portion **432** (shown in FIG. **7**) using the additive manufacturing system **100**, the controller **228** may initially receive an input (e.g., instruction pre-stored in the memory of the controller **228**) indicative of the start of extrusion of the printable material **188** from the nozzle **112**, for example, to lay-down the first layer **194** associated with the structure **104** (as shown in FIG. **6**). In response to the input, the controller **228** may actuate the motor **216** to rotate the driveshaft **248** in the first direction **264** about the drive axis **256**.

[0045] As the driveshaft **248** rotates in the first direction **264**, the engagement portion **260** (of the driveshaft **248**) engages with the first coupler **284** and disengages with the second coupler **324**. This engagement between the engagement portion **260** (of the driveshaft **248**) and the first coupler **284** facilitates torque transfer from the driveshaft **248** to the feed roller **220** (e.g., to the first feed roller **272**). As a result, the first feed roller **272** may co-rotate with the driveshaft **248** in the first direction **264**. The first feed roller **272** (rotating in the first direction **264**) drives the second feed roller **276** to rotate in the second direction **268** to correspondingly receive the supply of reinforcement member **200** (dispensed from the dispenser **116**) and direct the supply of reinforcement member **200** (through the grooves **296**, **312**) towards the second guide block **236"** (and the guiding tube **240**) and into the printable material **188** flowing within the nozzle **112**. The printable material **188** along with the reinforcement member **200** is then extruded from the nozzle **112** to lay-down the (reinforced) first layer **194** of the structure **104**. At this stage, the driveshaft **248** rotates freely with respect to the second coupler **324** due to disengagement between the engagement portion **260** (of the driveshaft **248**) and the second coupler **324**.

[0046] Upon completion of the first layer **194**, the nozzle **112** may be controlled (e.g., via the controller **228**) to move and extrude the printable material **188** (with the reinforcement member **200**) to lay-down the second layer **196** over the first layer **194**. During movement of the nozzle **112** laying the second layer **196** over the first layer **194**, the controller **228** may receive an input indicative of approaching end of extrusion of the printable material **188** from the nozzle **112**. In response to the input associated with the end of extrusion, the controller **228** may actuate the motor **216** to rotate the driveshaft **248** in the second direction **268**.

[0047] As the driveshaft **248** rotates in the second direction **268**, the engagement portion **260** (of the driveshaft **248**) engages with the second coupler **324** and disengages with the first coupler **284**. This engagement of the driveshaft **248** with the second coupler **324** may allow the driveshaft **248** to transfer torque to the second coupler **324** to rotate the second coupler **324** in the second direction **268**. This may result in rotation of the cam lobe **328** (fixedly coupled with the second coupler **324**) in the second direction **268** about the drive axis **256**. During the rotation of the cam lobe **328** in the second direction **268**, the contacting portion **352** (of the cam lobe **328**) may contact the cam following portion **376** (of the lever **332**) to pivot the lever **332** in the second direction **268** about the pivoting axis **368**. Upon pivoting of the lever **332** about the pivoting axis **368** in the second direction **268**, the second end portion **360** (e.g., roller **380**) may engage and actuate the cutter **336** from the biased position to the actuated position in the third direction **428**. Upon actuation, the blade **400** (of the cutter **336**) may push and abut the reinforcement member **200** against the surface **424** (of the stationary block **412**) to apply the shearing force on the reinforcement member **200** and cut-off the supply of the reinforcement member **200**. At this stage, the driveshaft **248** rotates freely with respect to the first coupler **284** due to disengagement between the engagement portion **260** (of the driveshaft **248**) and the first coupler **284**. Once the nozzle **112** moves past the desired width of the window portion **432**, the controller **228** may control the pump and the motor **216** in a manner as discussed above to resume extrusion of the printable material **188** and the reinforcement member **200** from the nozzle **112** for example, to continue laying-down the second layer **196** over the first layer **194**.

[0048] The system **212** offers automatedly cutting and re-feeding of the reinforcement member **200** (e.g., reinforced fiber roving **204**) into the printable material **188** to be extruded from the nozzle **112** to form structures. Accordingly, the system **212** eliminates need of additional labor for placing reinforcement members (such as the reinforcement member **200**) within or in-between the layers of the printable material **188** extruded by the moving nozzle **112**, thereby reducing labor requirement, effort, and manufacturing cost of the structure **104**, and at the same time, improving labor safety.

[0049] Unless explicitly excluded, the use of the singular to describe a component, structure, or operation does not exclude the use of plural such components, structures, or operations or their equivalents. The use of the terms “a” and “an” and “the” and “at least one” or the term “one or more,” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The use of the term “at least one” followed by a list of one or more items (for example, “at least one of A and B” or one or more of A and B") is to be construed to mean one item selected from the listed items (A or B) or any combination of two or more of the listed items (A and B; A, A and B; A, B and B), unless otherwise indicated herein or clearly contradicted by context. Similarly, as used herein, the word “or” refers to any possible permutation of a set of items. For example, the phrase “A, B, or C” refers to at least one of A, B, C, or any combination thereof, such as any of: A; B; C; A and B; A and C; B and C; A, B, and C; or multiple of any item such as A and A; B, B, and C; A, A, B, C, and C; etc.

[0050] It will be apparent to those skilled in the art that various modifications and variations can be made to the compression pad, the battery module, and/or the method of the present disclosure without departing from the scope of the disclosure. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the compression pad, the battery module, and/or the method disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims and their equivalent.

What is claimed is:

1. A system for controlling a supply of a reinforcement member into a printable material to be extruded from a nozzle of an additive manufacturing system to fabricate a fiber-reinforced structure, the system comprising:

a motor comprising a driveshaft defining a drive axis and an engagement portion;

a pair of feed rollers, a feed roller of the pair of feed rollers mountable on the driveshaft and comprising a first coupler engageable with the engagement portion;

an actuator comprising a second coupler engageable with the engagement portion; and

a controller configured to actuate the motor to rotate the driveshaft about the drive axis:

in a first direction to engage the engagement portion with the first coupler and transfer torque from the driveshaft to the feed roller to supply the reinforcement member into the printable material and to disengage the engagement portion with the second coupler to allow the driveshaft to rotate with respect to the actuator, and

in a second direction opposite to the first direction to engage the engagement portion with the second coupler and transfer torque from the driveshaft to the actuator to cut-off the supply of the reinforcement member into the printable material and to disengage the engagement portion with the first coupler to allow the driveshaft to rotate with respect to the feed roller.

2. The system of claim **1**, wherein the controller is configured to actuate the motor to rotate the driveshaft in the second direction to cut-off the supply of the reinforcement member into the printable material before an end of extrusion of the printable material from the nozzle.

3. The system of claim **1**, wherein the controller is configured to actuate the motor to rotate the driveshaft in the first direction to supply the reinforcement member into the printable material upon receipt of an input indicative of a start of extrusion of the printable material from the nozzle.

4. The system of claim **1**, wherein the first coupler is a one-way clutch configured to engage with the engagement portion of the driveshaft in the first direction and disengage with the engagement portion of the driveshaft in the second direction.

5. The system of claim **1**, wherein the second coupled is a one-way clutch configured to engage with the engagement portion of the driveshaft in the second direction and disengage with the engagement portion of the driveshaft in the first direction.

6. The system of claim **1**, wherein the actuator includes:

a cam lobe defining an opening configured to receive the second coupler to co-rotate the cam lobe with the second coupler when the driveshaft is rotated in the second direction about the drive axis;

a lever defining a first end portion engageable with the cam lobe to pivot the lever about a pivoting axis and a second end portion opposite to the first end portion; and

a cutter operably engaged with the second end portion, the cutter is configured to move from a biased position to an actuated position to cut-off the supply of the reinforcement member upon pivoting of the lever about the pivoting axis.

7. The system of claim **6**, wherein the pivoting axis is parallel to the drive axis.

8. The system of claim **6**, wherein the cutter moves reciprocally between the biased position and the actuated position in a third direction at an angle with respect to the drive axis.

9. The system of claim **6**, wherein the second end portion includes a roller rotatable about an axis to facilitate a rolling engagement between the second end portion of the lever and the cutter upon pivoting of the lever about the pivoting axis.

10. The system of claim **1**, wherein the reinforcement member includes a reinforced fiber roving.

11. An additive manufacturing system for fabricating a fiber-reinforced structure, the additive manufacturing system comprising:

a support structure;

a nozzle supported on the support structure and configured to extrude a printable material;

a dispenser configured to dispense a reinforcement member; and

a system for controlling a supply of the reinforcement member from the dispenser into the printable material flowing through the nozzle, the system comprising:

a motor comprising a driveshaft defining a drive axis and an engagement portion;

a pair of feed rollers, a feed roller of the pair of feed rollers mountable on the driveshaft and comprising a first coupler engageable with the engagement portion;

an actuator comprising a second coupler engageable with the engagement portion; and

a controller configured to actuate the motor to rotate the driveshaft about the drive axis:

in a first direction to engage the engagement portion with the first coupler and transfer torque from the driveshaft to the feed roller to supply the reinforcement member into the printable material and to disengage the engagement portion with the second coupler to allow the driveshaft to rotate with respect to the actuator, and

in a second direction opposite to the first direction to engage the engagement portion with the second coupler and transfer torque from the driveshaft to the actuator to cut-off the supply of the reinforcement member into the printable material and to disengage the engagement portion with the first coupler to allow the driveshaft to rotate with respect to the feed roller.

12. The additive manufacturing system of claim **11**, wherein the controller is configured to actuate the motor to rotate the driveshaft in the second direction to cut-off the supply of the reinforcement member into the printable material before an end of extrusion of the printable material from the nozzle.

13. The additive manufacturing system of claim **11**, wherein the controller is configured to actuate the motor to rotate the driveshaft in the first direction to supply the reinforcement member into the printable material upon receipt of an input indicative of a start of extrusion of the printable material from the nozzle.

14. The additive manufacturing system of claim **11**, wherein the first coupler includes a one-way clutch configured to engage with the engagement portion of the driveshaft in the first direction and disengage with the engagement portion of the driveshaft in the second direction.

15. The additive manufacturing system of claim **11**, wherein the second coupler includes a one-way clutch configured to engage with the engagement portion of the driveshaft in the second direction and disengage with the engagement portion of the driveshaft in the first direction.

16. The additive manufacturing system of claim **11**, wherein the actuator includes:

a cam lobe defining an opening configured to receive the second coupler to co-rotate the cam lobe with the second coupler when the driveshaft is rotated in the second direction about the drive axis;

a lever defining a first end portion engageable with the cam lobe to pivot the lever about a pivoting axis and a second end portion opposite to the first end portion; and

a cutter operably engaged with the second end portion, the cutter is configured to move from a biased position to an actuated position to cut-off the supply of the reinforcement member upon pivoting of the lever about the pivoting axis.

17. The additive manufacturing system of claim **16**, wherein the pivoting axis is parallel to the drive axis.

18. The additive manufacturing system of claim **16**, wherein the cutter moves reciprocally between the biased position and the actuated position in a third direction at an angle with respect to the drive axis.

19. The additive manufacturing system of claim **16**, wherein the second end portion includes a roller rotatable about an axis to facilitate a rolling engagement between the second end portion of the lever and the cutter upon pivoting of the lever about the pivoting axis.

20. The additive manufacturing system of claim **11**, wherein the nozzle defines an outlet configured to extrude the printable material and the reinforcement member in a direction perpendicular to at least one of a preceding layer formed of the printable material and the reinforcement member and a base surface.

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