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(54) QUICK-RELEASE EXTRUDER

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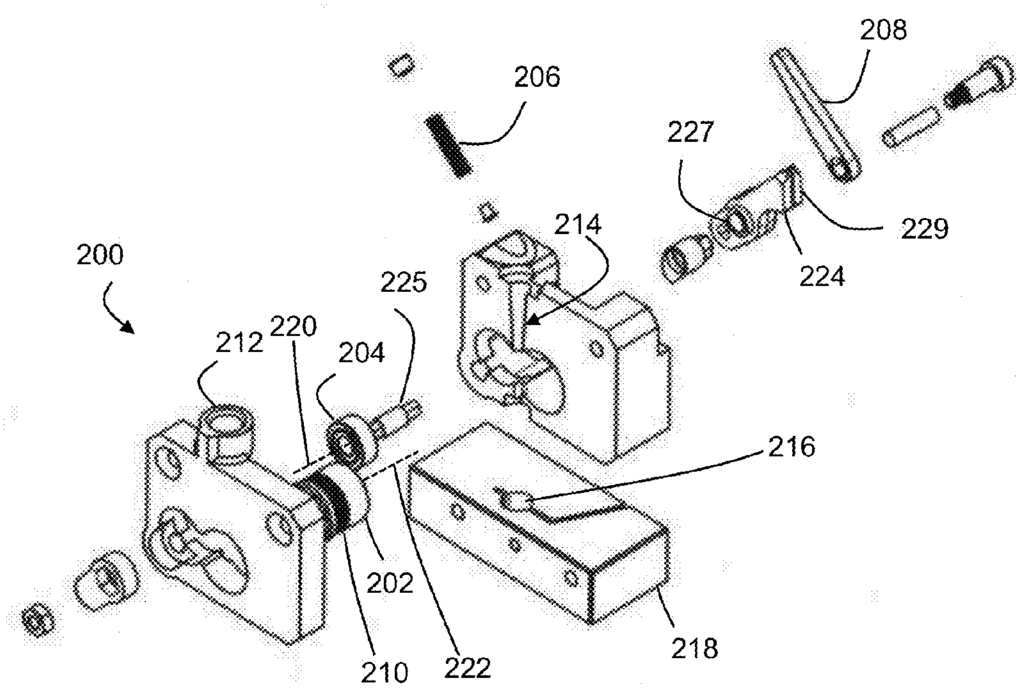
(57) **ABSTRACT**

A bearing that provides contact force to engage a filament with a drive gear has a movable axis that can be controllably moved toward and away from the drive gear in order to engage and disengage the filament. A bearing is spring-biased toward the drive gear, and a bistable lever mechanism is provided with a first stable position in which the bearing is engaged with a filament and a second stable position in which the bearing is disengaged from the filament. By providing a mechanism that locks in both positions, loading and unloading of filament can be facilitated.



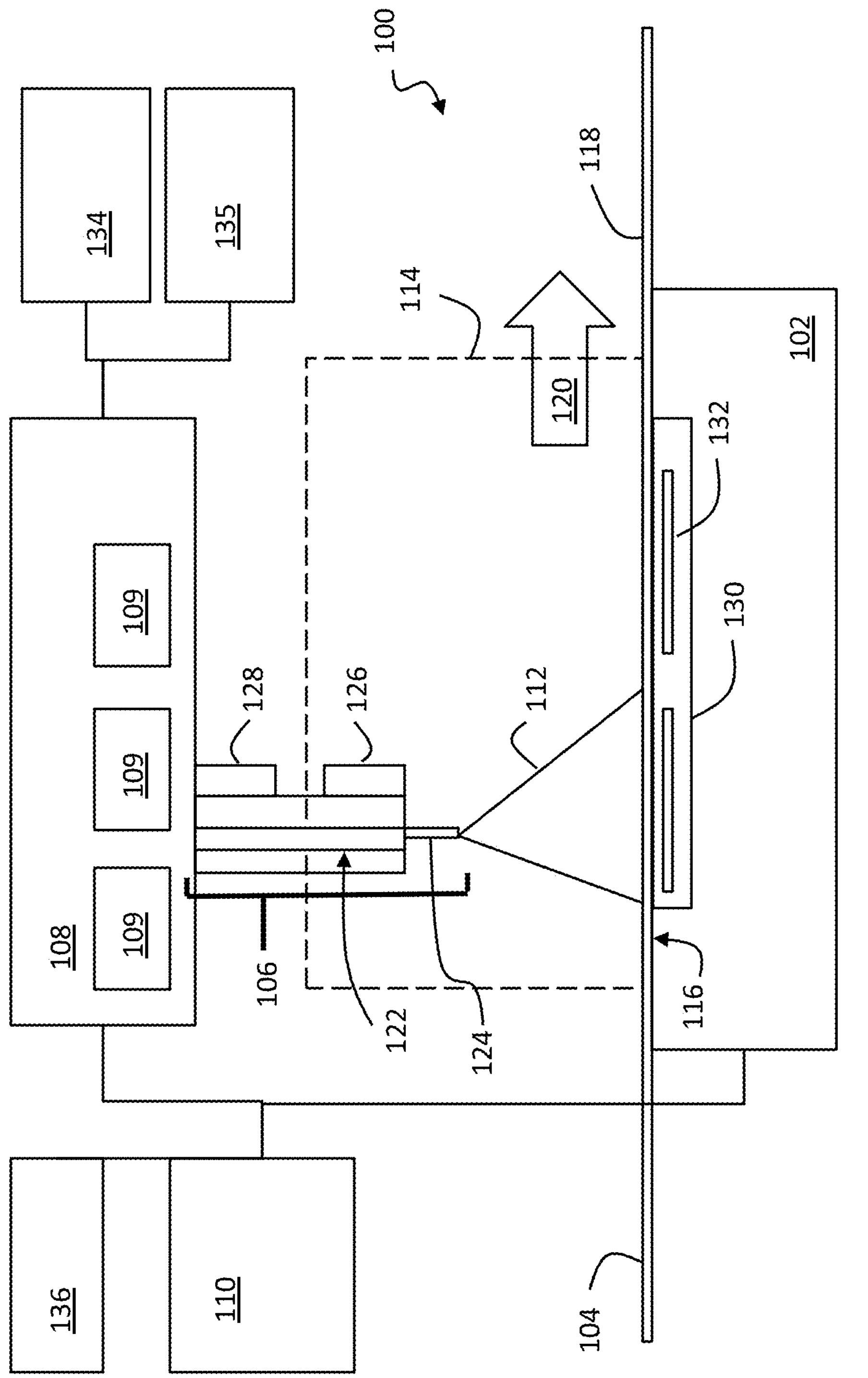

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FIG. 1

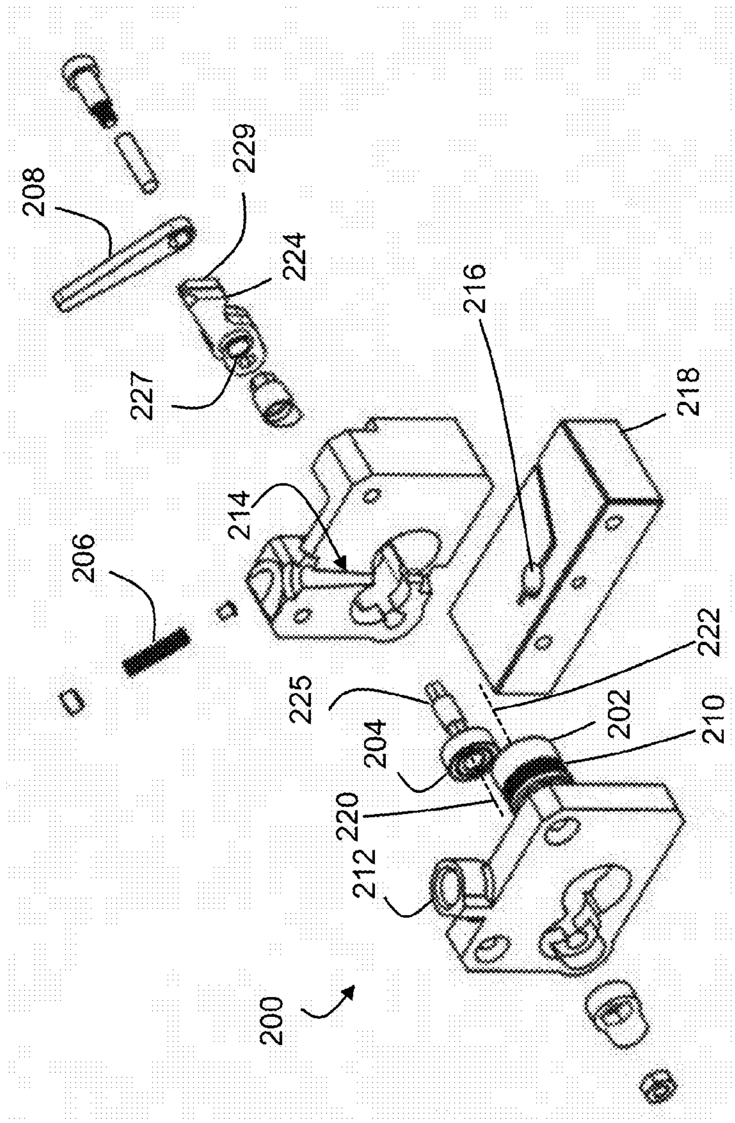

FIG. 2

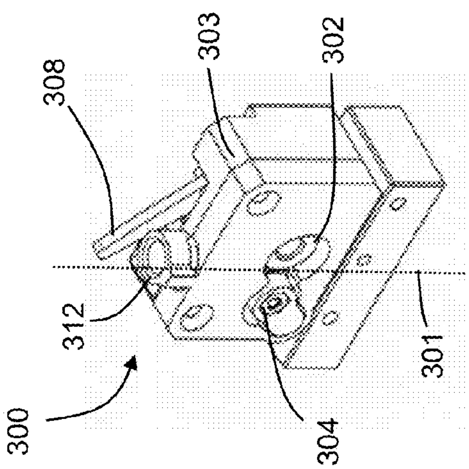

FIG. 3

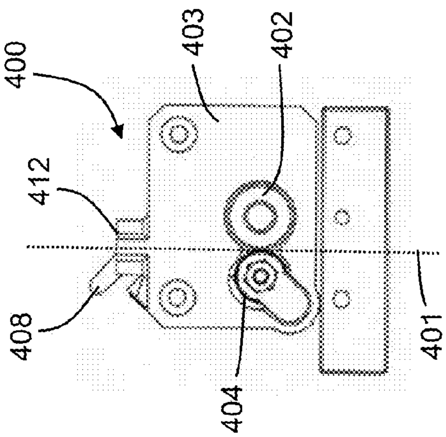

FIG. 4

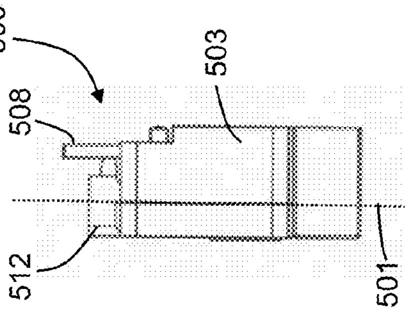

FIG. 5

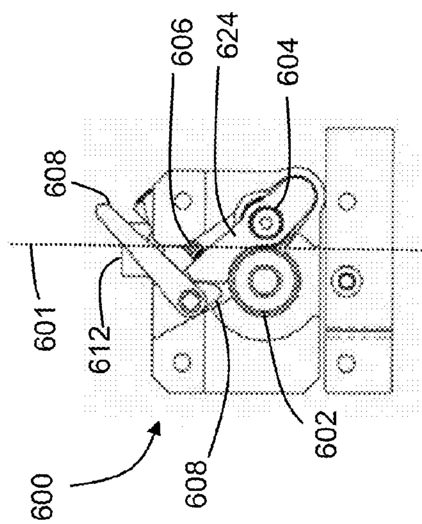

FIG. 6

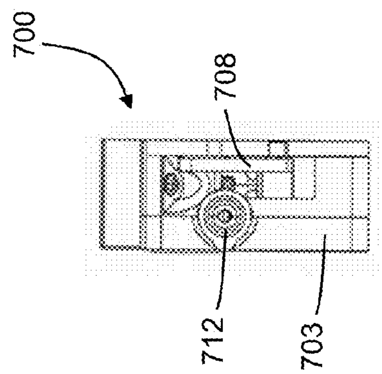

FIG. 7

QUICK-RELEASE EXTRUDER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/719,874 filed on Oct. 29, 2012, the entire content of which is hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The invention generally relates to an extruder assembly, and more specifically an extruder assembly including a quick-release extruder for a device and system for three-dimensional fabrication.

BACKGROUND

[0003] Three-dimensional printing is a process for making a three-dimensional solid object of virtually any shape from a digital model. Three-dimensional printing is achieved using an additive process, where successive layers of build material are laid down in different shapes. The build material may be in the form of a filament, and may include, for example, acrylonitrile butadiene styrene (ABS), high-density polyethylene (HDPL), polylactic acid (PLA), or any other suitable plastic, thermoplastic, or other material that can usefully be extruded to form a three-dimensional object. The filament may be extruded using an extruder, which may include a chamber, an opening at an extruder tip, and a motor to push the filament into the chamber and through the opening in the extruder tip.

[0004] Access to extruders is typically fairly limited. In most three-dimensional printing systems, a user must remove the entire extruder to perform maintenance. To remove the extruder typically requires specific tools and can be a time-consuming process. Also, loading, unloading, and replacement of the filament are difficult and time-consuming because of the lack of easy access to the components of the extruder assembly.

[0005] There is a need for a quick-release extruder that can allow a user access to the components of the extruder assembly for, e.g., maintenance, loading, unloading, and replacement of the filament.

SUMMARY

[0006] A bearing that provides contact force to engage a filament with a drive gear has a movable axis that can be controllably moved toward and away from the drive gear in order to engage and disengage the filament. A bearing is spring-biased toward the drive gear, and a bistable lever mechanism is provided with a first stable position in which the bearing is engaged with a filament and a second stable position in which the bearing is disengaged from the filament. By providing a mechanism that locks in both positions, loading and unloading of filament can be facilitated.

[0007] In one aspect there is disclosed herein an extruder assembly including a drive gear shaped and sized to drive a filament; a bearing having a freely rotating contact surface, the bearing positioned to support the filament against the drive gear with the freely rotating contact surface, where an axis of the bearing is substantially parallel to an axis of the drive gear and where the axis of the bearing is movable toward and away from the axis of the drive gear; a spring configured to bias a position of the axis of the bearing relative to the axis of the drive gear; and a lever positioned to apply a counter-force to the bias of the spring, thereby securing the bearing in a position to apply a constant contact force to the filament by the bearing and the drive gear.

[0008] The extruder assembly may include an extruder as described herein, which may include an input opening aligned to a feedpath. The build material, which may be in the form of a filament, may travel through the opening and thus into the feedpath, which continues into a chamber of the extruder that is shaped and sized to pass the filament along the feedpath. The filament may then travel through an orifice of the extruder, which may discharge the build material during an extrusion.

[0009] The filament may be driven by a drive gear, which may include a number of teeth. The teeth of the drive gear may be positioned to engage the filament before the input opening in the feedpath. Specifically, the filament may be driven into the teeth of the drive gear with enough force to deform the build material, and thus the teeth of the drive gear may grip the filament in this manner. The spring or biasing member may provide the force required to deform the build material into the teeth of the drive gear. The drive gear may then rotate (or otherwise provide movement) such that the teeth drive the filament along the feed path, into the input opening of the extruder, through the chamber, and out of the orifice. It will be apparent that the drive gear may engage the build material in an alternate manner such that the drive gear is configured to drive the build material through the extruder. The drive gear may include a motor that may be integral with the drive gear or coupled to the drive gear such that the motor rotates (or otherwise drives) the drive gear, which may then drive the filament.

[0010] A bearing may be positioned opposite the drive gear, and it may be located along the feedpath. The bearing may be biased by the spring toward the drive gear with a spring force such that the bearing presses the filament against the drive gear. The spring may be coupled to the bearing. The bearing may include a freely rotating contact surface that is able to provide a force against the drive gear and freely rotate with the drive gear without disengaging (when a force maintains the bearing in a position engaged with the drive gear). The spring may maintain a substantially constant contact force of the bearing against a length of the filament between the bearing and the drive gear in the absence of external forces. The bearing may include a smooth surface, and the bearing may be a low friction bearing. The axis of the bearing may be substantially parallel to the axis of the drive gear.

[0011] The extruder assembly may further include a lever that may extend from the extruder assembly. The lever may be configured to manually move the bearing (e.g., against the biasing force of the spring) away from the drive gear and/or away from the feedpath. Thus, the lever may be coupled to the bearing. Alternatively, the lever may be coupled to another mechanical element (or series of elements) and then coupled to the bearing, or the lever may be coupled to the drive gear. The lever may move the axis of the bearing away from the axis of the drive gear. The lever may include a pivot (or several pivots), and the spring may be coupled to the lever away from the pivot. The spring may provide a substantially constant force urging the lever into a first position or a second position. The extruder assembly may also include a locking mechanism to secure the lever in a position (which may be the first position, the second position, or another position) with the bearing moved away from and out of the feedpath and/or drive gear. The locking mechanism may also secure the lever in a position with the bearing moved toward and into the feedpath and/or drive gear. The locking mechanism may include a latch, a clamp, an electrical locking mechanism, a clip, a coupling, a dock, a hook, a pin, a snap, or the like.

[0012] The spring may include a coil spring, a compression spring, a leaf spring, or the like.

[0013] The extruder assembly may further include a heating element to liquefy a length of build material in the chamber of the extruder.

[0014] An extruder assembly may include a manual control extending from the extruder assembly to manually move the bearing against the spring force away from the feedpath. The manual control may include a lever, a knob, a slider, a plunger, a push button, a toggle, an actuator, a screw, a piston, and the like.

[0015] The lever may also be controlled electronically, and may be activated by a user utilizing a control system, or it may be automatically activated by a control system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The foregoing and other objects, features and advantages of the invention will be apparent from the following description of particular embodiments thereof, as illustrated in the accompanying drawings. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

[0017] FIG. **1** is a block diagram of a three-dimensional printer.

[0018] FIG. **2** is an exploded view of an extruder assembly.

[0019] FIG. **3** is a perspective view of an extruder assembly.

[0020] FIG. **4** is a left side view of an extruder assembly.

[0021] FIG. **5** is a front view of an extruder assembly.

[0022] FIG. **6** is a right side view of an extruder assembly.

[0023] FIG. **7** is a top view of an extruder assembly.

DETAILED DESCRIPTION

[0024] The embodiments will now be described more fully hereinafter with reference to the accompanying figures, in which preferred embodiments are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein. Rather, these illustrated embodiments are provided so that this disclosure will convey the scope of the invention to those skilled in the art.

[0025] All documents mentioned herein are hereby incorporated in their entirety by reference. References to items in the singular should be understood to include items in the plural, and vice versa, unless explicitly stated otherwise or clear from the text. Grammatical conjunctions are intended to express any and all disjunctive and conjunctive combinations of conjoined clauses, sentences, words, and the like, unless otherwise stated or clear from the context. Thus, the term "or" should generally be understood to mean "and/or" and so forth.

[0026] Recitation of ranges of values herein are not intended to be limiting, referring instead individually to any and all values falling within the range, unless otherwise indicated herein, and each separate value within such a range is incorporated into the specification as if it were individually recited herein. The word "about," when accompanying a numerical value, is to be construed as indicating a deviation as would be appreciated by one of ordinary skill in the art to operate satisfactorily for an intended purpose. Ranges of values and/or numeric values are provided herein as examples only, and do not constitute a limitation on the scope of the described embodiments. The use of any and all examples, or exemplary language ("e.g.," "such as," or the like) provided herein, is intended merely to better illuminate the embodiments and does not pose a limitation on the scope of the embodiments. No language in the specification should be construed as indicating any unclaimed element as essential to the practice of the embodiments.

[0027] In the following description, it is understood that terms such as "first," "second," "above," "below" and the like, are words of convenience and are not to be construed as limiting terms.

[0028] Described herein are devices, systems, and methods for using an extruder assembly including a quick-release extruder for a three-dimensional printer. It will be understood that while the exemplary embodiments herein emphasize an extruder assembly for a three-dimensional printer, the principles of the invention may be adapted to other fabrication processes. All such variations that can be adapted to use an extruder assembly as described herein are intended to fall within the scope of this disclosure.

[0029] FIG. **1** is a block diagram of a three-dimensional printer. In general, the printer **100** may include a build platform **102**, a conveyor **104**, an extruder **106**, an x-y-z positioning assembly **108**, and a controller **110** that cooperate to fabricate an object **112** within a working volume **114** of the printer **100**.

[0030] The build platform **102** may include a surface **116** that is rigid and substantially planar. The surface **116** may support the conveyer **104** in order to provide a fixed, dimensionally and positionally stable platform on which to build the object **112**.

[0031] The build platform **102** may include a thermal element **130** that controls the temperature of the build platform **102** through one or more active devices **132** such as resistive elements that convert electrical current into heat, Peltier effect devices that can create a heating or cooling affect, or any other thermoelectric heating and/or cooling devices. Thus the thermal element **130** may be a heating element that provides active heating to the build platform **102**, a cooling element that provides active cooling to the build platform **102**, or a combination of these. The heating element **130** may be coupled in a communicating relationship with the controller **110** in order for the controller **110** to controllably impart heat to or remove heat from the surface **116** of the build platform **102**. Thus, the thermal element **130** may include an active cooling element positioned within or adjacent to the build platform **102** to controllably cool the build platform **102**.

[0032] It will be understood that a variety of other techniques may be employed to control a temperature of the build platform **102**. For example, the build platform **102** may use a gas cooling or gas heating device such as a vacuum chamber or the like in an interior thereof, which may be quickly pressurized to heat the build platform **102** or vacated to cool the build platform **102** as desired. As another example, a stream of heated or cooled gas may be applied directly to the build platform **102** before, during, and/or after a build process. Any device or combination of devices suitable for controlling a temperature of the build platform **102** may be adapted to use as the thermal element **130** described herein.

[0033] The conveyer **104** may be formed of a sheet **118** of material that moves in a path **120** through the working volume

114. Within the working volume **114**, the path **120** may pass proximal to the surface **116** of the build platform **102**—that is, resting directly on or otherwise supported by the surface **116**—in order to provide a rigid, positionally stable working surface for a build. It will be understood that while the path **120** is depicted as a unidirectional arrow, the path **120** may be bidirectional, such that the conveyer **104** can move in either of two opposing directions through the working volume **114**. It will also be understood that the path **120** may curve in any of a variety of ways, such as by looping underneath and around the build platform **102**, over and/or under rollers, or around delivery and take up spools for the sheet **118** of material. Thus, while the path **120** may be generally (but not necessarily) uniform through the working volume **114**, the conveyer **104** may move in any direction suitable for moving completed items from the working volume **114**. The conveyor may include a motor or other similar drive mechanism (not shown) coupled to the controller **110** to control movement of the sheet **118** of material along the path **120**. Various drive mechanisms are described in further detail below.

[0034] In general, the sheet **118** may be formed of a flexible material such as a mesh material, a polyamide, a polyethylene terephthalate (commercially available in bi-axial form as MYLAR), a polyimide film (commercially available as KAPTON), or any other suitably strong polymer or other material. The sheet **118** may have a thickness of about three to about seven thousandths of an inch, or any other thickness that permits the sheet **118** to follow the path **120** of the conveyer **104**. For example, with sufficiently strong material, the sheet **118** may have a thickness of about one to about three thousandths of an inch. The sheet **118** may instead be formed of sections of rigid material joined by flexible links.

[0035] A working surface of the sheet **118** (e.g., an area on the top surface of the sheet **118** within the working volume **114**) may be treated in a variety of manners to assist with adhesion of build material to the surface **118** and/or removal of completed objects from the surface **118**. For example, the working surface may be abraded or otherwise textured (e.g., with grooves, protrusions, and the like) to improve adhesion between the working surface and the build material.

[0036] A variety of chemical treatments may be used on the working surface of the sheet **118** of material to further facilitate build processes as described herein. For example, the chemical treatment may include a deposition of material that can be chemically removed from the conveyer **104** by use of water, solvents, or the like. This may facilitate separation of a completed object from the conveyer by dissolving the layer of chemical treatment between the object **112** and the conveyor **104**. The chemical treatments may include deposition of a material that easily separates from the conveyer such as a wax, mild adhesive, or the like. The chemical treatment may include a detachable surface such as an adhesive that is sprayed on to the conveyer **104** prior to fabrication of the object **112**.

[0037] In one aspect, the conveyer **104** may be formed of a sheet of disposable, one-use material that is fed from a dispenser and consumed with each successive build.

[0038] In one aspect, the conveyer **104** may include a number of different working areas with different surface treatments adapted for different build materials or processes. For example, different areas may have different textures (smooth, abraded, grooved, etc.). Different areas may be formed of different materials. Different areas may also have or receive different chemical treatments. Thus a single conveyer **104** may be used in a variety of different build processes by selecting the various working areas as needed or desired.

[0039] The extruder **106** may include a chamber **122** in an interior thereof to receive a build material. The build material may, for example, include acrylonitrile butadiene styrene ("ABS"), high-density polyethylene ("HDPL"), polylactic acid, or any other suitable plastic, thermoplastic, or other material that can usefully be extruded to form a three-dimensional object. The extruder **106** may include an extrusion tip **124** or other opening that includes an exit port with a circular, oval, slotted or other cross-sectional profile that extrudes build material in a desired cross-sectional shape.

[0040] The extruder **106** may include a heater **126** to melt thermoplastic or other meltable build materials within the chamber **122** for extrusion through an extrusion tip **124** in liquid form. While illustrated in block form, it will be understood that the heater **124** may include, e.g., coils of resistive wire wrapped about the extruder **106**, one or more heating blocks with resistive elements to heat the extruder **106** with applied current, an inductive heater, or any other arrangement of heating elements suitable for creating heat within the chamber **122** to melt the build material for extrusion. The extruder **106** may also or instead include a motor **128** or the like to push the build material into the chamber **122** and/or through the extrusion tip **126**.

[0041] In general operation (and by way of example rather than limitation), a build material such as ABS plastic in filament form may be fed into the chamber **122** from a spool or the like by the motor **128**, melted by the heater **126**, and extruded from the extrusion tip **124**. By controlling a rate of the motor **128**, the temperature of the heater **126**, and/or other process parameters, the build material may be extruded at a controlled volumetric rate. It will be understood that a variety of techniques may also or instead be employed to deliver build material at a controlled volumetric rate, which may depend upon the type of build material, the volumetric rate desired, and any other factors. All such techniques that might be suitably adapted to delivery of build material for fabrication of a three-dimensional object are intended to fall within the scope of this disclosure. Other techniques may be employed for three-dimensional printing, including extrusion-based techniques using a build material that is curable and/or a build material of sufficient viscosity to retain shape after extrusion.

[0042] The x-y-z positioning assembly **108** may generally be adapted to three-dimensionally position the extruder **106** and the extrusion tip **124** within the working volume **114**. Thus by controlling the volumetric rate of delivery for the build material and the x, y, z position of the extrusion tip **124**, the object **112** may be fabricated in three dimensions by depositing successive layers of material in two-dimensional patterns derived, for example, from cross-sections of a computer model or other computerized representation of the object **112**. A variety of arrangements and techniques are known in the art to achieve controlled linear movement along one or more axes. The x-y-z positioning assembly **108** may, for example, include a number of stepper motors **109** to independently control a position of the extruder within the working volume along each of an x-axis, a y-axis, and a z-axis. More generally, the x-y-z positioning assembly **108** may include without limitation various combinations of stepper motors, encoded DC motors, gears, belts, pulleys, worm gears, threads, and the like. Any such arrangement suitable for controllably positioning the extruder **106** within the working volume **114** may be adapted to use with the printer **100** described herein.

[0043] By way of example and not limitation, the conveyor **104** may be affixed to a bed that provides x-y positioning within the plane of the conveyor **104**, while the extruder **106** can be independently moved along a z-axis. As another example, the extruder **106** may be stationary while the conveyor **104** is x, y, and z positionable. As another example, the extruder **106** may be x, y, and z positionable while the conveyer **104** remains fixed (relative to the working volume **114**). In yet another example, the conveyer **104** may, by movement of the sheet **118** of material, control movement in one axis (e.g., the y-axis), while the extruder **106** moves in the z-axis as well as one axis in the plane of the sheet **118**. Thus in one aspect, the conveyor **104** may be attached to and move with at least one of an x-axis stage (that controls movement along the x-axis), a y-axis stage (that controls movement along a y-axis), and a z-axis stage (that controls movement along a z-axis) of the x-y-z positioning assembly **108**. More generally, any arrangement of motors and other hardware controllable by the controller **110** may serve as the x-y-z positioning assembly **108** in the printer **100** described herein. Still more generally, while an x, y, z coordinate system serves as a convenient basis for positioning within three dimensions, any other coordinate system or combination of coordinate systems may also or instead be employed, such as a positional controller and assembly that operates according to cylindrical or spherical coordinates.

[0044] The controller **110** may be electrically coupled in a communicating relationship with the build platform **102**, the conveyer **104**, the x-y-z positioning assembly **108**, and the other various components of the printer **100**. In general, the controller **110** is operable to control the components of the printer **100**, such as the build platform **102**, the conveyer **104**, the x-y-z positioning assembly **108**, and any other components of the printer **100** described herein to fabricate the object **112** from the build material. The controller **110** may include any combination of software and/or processing circuitry suitable for controlling the various components of the printer **100** described herein including without limitation microprocessors, microcontrollers, application-specific integrated circuits, programmable gate arrays, and any other digital and/or analog components, as well as combinations of the foregoing, along with inputs and outputs for transceiving control signals, drive signals, power signals, sensor signals, and the like. In one aspect, the controller **110** may include a microprocessor or other processing circuitry with sufficient computational power to provide related functions such as executing an operating system, providing a graphical user interface (e.g., to a display coupled to the controller **110** or printer **100**), convert three-dimensional models into tool instructions, and operate a web server or otherwise host remote users and/or activity through the network interface **136** described below.

[0045] A variety of additional sensors may be usefully incorporated into the printer **100** described above. These are generically depicted as sensor **134** in FIG. **1**, for which the positioning and mechanical/electrical interconnections with other elements of the printer **100** will depend upon the type and purpose of the sensor **134** and will be readily understood and appreciated by one of ordinary skill in the art. The sensor **134** may include a temperature sensor positioned to sense a temperature of the surface of the build platform **102**. This may, for example, include a thermistor or the like embedded within or attached below the surface of the build platform **102**. This may also or instead include an infrared detector or the like directed at the surface **116** of the build platform **102** or the sheet **118** of material of the conveyer **104**. Other sensors that may be usefully incorporated into the printer **100** as the sensor **134** include a heat sensor, a volume flow rate sensor, a weight sensor, a sound sensor, and a light sensor. Certain more specific examples are provided below by way of example and not of limitation.

[0046] The sensor **134** may include a sensor to detect a presence (or absence) of the object **112** at a predetermined location on the conveyer **104**. This may include an optical detector arranged in a beam-breaking configuration to sense the presence of the object **112** at a location such as an end of the conveyer **104**. This may also or instead include an imaging device and image processing circuitry to capture an image of the working volume **114** and analyze the image to evaluate a position of the object **112**. This sensor **134** may be used for example to ensure that the object **112** is removed from the conveyor **104** prior to beginning a new build at that location on the working surface such as the surface **116** of the build platform **102**. Thus the sensor **134** may be used to determine whether an object is present that should not be, or to detect when an object is absent. The feedback from this sensor **134** may be used by the controller **110** to issue processing interrupts or otherwise control operation of the printer **100**.

[0047] The sensor **134** may include a sensor that detects a position of the conveyer **104** along the path. This information may be obtained from an encoder in a motor that drives the conveyer **104**, or using any other suitable technique such as a visual sensor and corresponding fiducials (e.g., visible patterns, holes, or areas with opaque, specular, transparent, or otherwise detectable marking) on the sheet **118**.

[0048] The sensor **134** may include a heater (instead of or in addition to the thermal element **130**) to heat the working volume **114** such as a radiant heater or forced hot air to maintain the object **112** at a fixed, elevated temperature throughout a build. The sensor **134** may also or instead include a cooling element to maintain the object **112** at a predetermined sub-ambient temperature throughout a build.

[0049] The sensor **134** may also or instead include at least one video camera. The video camera may generally capture images of the working volume **114**, the object **112**, or any other hardware associated with the printer **100**. The video camera may provide a remote video feed through the network interface **136**, which feed may be available to remote users through a user interface maintained by, e.g., remote hardware, or within a web page provided by a web server hosted by the three-dimensional printer **100**. Thus, in one aspect there is a user interface adapted to present a video feed from at least one video camera of a three-dimensional printer to a remote user through a user interface.

[0050] The sensor **134** may include may also include more complex sensing and processing systems or subsystems, such as a three-dimensional scanner using optical techniques (e.g., stereoscopic imaging, or shape from motion imaging), structured light techniques, or any other suitable sensing and processing hardware that might extract three-dimensional information from the working volume **114**. In another aspect, the sensor **134** may include a machine vision system that captures images and analyzes image content to obtain information about the status of a job, working volume **114**, or an object **112** therein. The machine vision system may support a variety of imaging-based automatic inspection, process control, and/or robotic guidance functions for the three-dimensional printer **100** including without limitation pass/fail decisions, error detection (and corresponding audible or visual alerts), shape detection, position detection, orientation detection, collision avoidance, and the like.

[0051] Other components, generically depicted as other hardware **135**, may also be included, such as input devices including a keyboard, touchpad, mouse, switches, dials, buttons, motion sensors, and the like, as well as output devices such as a display, a speaker or other audio transducer, light emitting diodes, and the like. Other hardware **135** may also or instead include a variety of cable connections and/or hardware adapters for connecting to, e.g., external computers, external hardware, external instrumentation or data acquisition systems, and the like.

[0052] The printer **100** may include, or be connected in a communicating relationship with, a network interface **136**. The network interface **136** may include any combination of hardware and software suitable for coupling the controller **110** and other components of the printer **100** to a remote computer in a communicating relationship through a data network. By way of example and not limitation, this may include electronics for a wired or wireless Ethernet connection operating according to the IEEE 802.11 standard (or any variation thereof), or any other short or long range wireless networking components or the like. This may include hardware for short range data communications such as BlueTooth or an infrared transceiver, which may be used to couple into a local area network or the like that is in turn coupled to a data network such as the Internet. This may also or instead include hardware/software for a WiMax connection or a cellular network connection (using, e.g., CDMA, GSM, LTE, or any other suitable protocol or combination of protocols). Consistently, the controller **110** may be configured to control participation by the printer **100** in any network to which the network interface **136** is connected, such as by autonomously connecting to the network to retrieve printable content, or responding to a remote request for status or availability.

[0053] An extruder assembly including a quick-release extruder will now be described.

[0054] The extruder assembly with a quick-release extruder may include any of the features described herein including the features described in U.S. Provisional Application No. 61/719,874, which is hereby incorporated by reference in its entirety.

[0055] In a three-dimensional printer, a filament of build material may be supported by and in contact with a drive gear. Also, a filament of build material may be in contact with a drive gear via a bearing, which may be a spring-loaded bearing or the like. The bearing may provide a substantially constant contact force against the filament and toward the drive gear. The bearing may include a quick-release lever or the like to move the bearing away from the drive gear for, e.g., access to and maintenance of an extruder assembly. This arrangement may also permit quick loading, unloading, and replacement of filament of material for a three-dimensional printer.

[0056] FIG. **2** is an exploded view of an extruder assembly **200**. In general, the extruder assembly **200** may include a drive gear **202** with an arrangement of teeth **210** or other protrusions to grip and advance a filament (not shown) through the extruder assembly **200**. The drive gear **202** may be disposed adjacent to a feedpath passing through the extruder assembly **200** along which a filament of build material travels during an extrusion. The feedpath may be defined by the path taken by the filament through the extruder assembly **200**, where the filament enters the feedpath through an input opening **212**, travels through a chamber **214**, engages with a drive gear **202** and a bearing **204**, and travels through an opening **216** in a heating block **218**. Alternatively, the feedpath may be defined as the path taken by the filament before and after engagement with the drive gear **202**. The opening **216** for the feedback may be formed in the heating block **218**, which may include a heating element, thermistors, and so forth for heating the heating block and creating a melt chamber within the opening **216**. An extrusion tip may be formed into a bottom of the opening **216**, or the bottom of the opening **216** may be threaded to removably and replaceably receive a nozzle having on orifice to extrude liquefied material with a desired cross sectional shape. The drive gear **202** may be powered by any suitable electromechanical device such as a stepper motor or the like, and imparts a drive force on a filament by gripping the filament with the teeth **210** and rotating to move the filament along the feedpath.

[0057] A bearing **204** may be any free-rolling contact surface that can apply force normal to the drive gear **202** in order for the teeth **210** to engagement the filament without inhibiting motion of the filament along the feedpath. The bearing **204** may have a smooth, substantially cylindrical exterior, and may be positioned on an axis **220** substantially parallel to an axis **222** of the drive gear **202**. The bearing **204** may also have a different shape than is shown in FIG. **2**, which may be based on the configuration and/or type of the drive gear and/or build material and/or filament used with the extruder assembly **200**. Additionally, the bearing **204** may generally include any suitable mechanical components for relatively low-friction rotation about its axis. A variety of rolling and hydrostatic bearings and the like are known in the art, any of which may be used as the bearing **204** described herein.

[0058] The bearing **204** may be disposed such that it is at a distance where it may apply a force against the drive gear **202** to a filament of suitable diameter that passes between the drive gear **202** and the bearing **204**. A spring **206** may be positioned to apply a substantially constant force to the bearing **204** toward the drive gear **202** so that the drive gear **202** can engage the filament. This arrangement advantageously permits the drive gear **202** and bearing **204** to accommodate defects in a filament and variations in filament diameter while maintaining a consistent gripping force to drive the filament. A coil spring may conveniently be employed as the spring **206**, however a variety of springs and biasing members are known in the art that may be adapted to provide a biasing force to maintain a position of the bearing **204** and/or the drive gear **202** relative to one another. Moreover, the force to maintain a position of the bearing and/or the drive gear relative to one another may be provided by an actuator, a piston, or the like.

[0059] A lever **208** may be provided as a mechanism to position the bearing **204** relative to the drive gear **202**. By operating the lever **208**, the bearing **204** may be moved closer to the drive gear **202** (e.g., in order to engage a filament) or farther from the drive gear **202** (e.g., in order to disengage the filament for removal or other maintenance). It will be understood that the lever may be simple lever, e.g., a spring-loaded lever on a pivot. In an embodiment, when the lever is in a first position the bearing is engaged with the drive gear, and when the lever is in a second position the bearing is disengaged from the drive gear. It will also be understood that the lever

208 may be a bistable lever or the like, where the bistable lever may be associated with a second lever **224** (as shown in FIG. **2**) that is directly coupled to an axle **225** of the bearing **204**. In this configuration, the second lever **224** is urged by the spring **206** toward the drive gear **202** about a pivot **227** in the absence of external forces. The lever **208** can then be operated to contact a beveled surface **229** of the second lever **224** and drive the second lever **224** away from the drive gear **202** against the force of the spring **206**. An arm of the lever **208** may extend from the extruder assembly **200** for hand manipulation. Bistable operation of the lever **208** may be achieved, for example, by forming an L near the pivot point (as illustrated below in FIG. **6**) that locks the bearing **204** in an open (i.e., away from the drive gear) position when the lever **208** is moved beyond a certain rotation. In this respect, the L cooperates with the beveled surface **229** to create a force that retains the open position when the lever **208** is moved to one side. Thus the assembly has a first stable position (a "closed position) in which the bearing engages a filament with the drive gear and a second stable position (an "open position") in which the bearing does not engage a filament with the drive gear.

[0060] An example of a lever is shown in FIG. **2**, but it will be understood that different types of levers and/or mechanical elements may be used to similar affect. For example, the lever may further include additional levers, pivoting links, and the like that cooperate to move the bearing from a first position where it is engaged with the drive gear to a second position where it is disengaged from the drive gear. Similarly, while the bistable lever described above automatically locks in an open or closed position, manual locking mechanism may also or instead be employed, such as with a single spring-loaded lever and an external locking mechanism that can secure the bearing **204** in an open position against the force of a spring.

[0061] Further, it will be understood that a variety of mechanical arrangements may be used to similar affect to release the extruder assembly components. The lever may also or instead include a button, a knob, a slider, or any other mechanical arrangement suitable for moving the bearing **204** into and out of engagement with the drive gear **202**, or more generally farther from or closer to the drive gear **202**, which may include moving the axle **225** of the bearing **204** farther from or closer to the drive gear **202**, preferably while maintaining a generally parallel orientation of the axis **222** of the drive gear with the axis **220** of the bearing. It will be appreciated that the two axes **220**, **222** need not be perfectly parallel at all times and that, by way of example, the axes **220**, **222** may move out of a parallel arrangement when the axis **220** of the bearing is moved away from the axis **222** of the drive gear for loading and unloading of a filament. All such arrangements suitable for tension control and/or quick release may be used with the extruder assemblies described herein, and are intended to fall within the scope of this disclosure.

[0062] FIGS. **3-7** show a number of views of an extruder assembly that may be used as any of the extruder assemblies described above.

[0063] FIG. **3** shows a perspective view of an extruder assembly **300**, where the feedpath **301**, drive gear **302**, bearing **304**, lever **308**, and input opening **312** are visible. Also, as shown in FIG. **3**, the extruder assembly **300** may generally include a housing **303** for the components of the extruder assembly **300**, which may be a two-part housing formed of two portions that can be joined for use as an extruder assembly. While the housing may also be formed as a single integral piece, a two-part construction advantageously facilitates disassembly to service parts within the extruder assembly **300**.

[0064] FIG. **4** shows a left side view of an extruder assembly **400**, where the feedpath **401**, drive gear **402**, bearing **404**, lever **408**, and input opening **412** are visible. Also, as shown in FIG. **4**, the extruder assembly **400** may generally include a housing **403** for the components of the extruder assembly **400**.

[0065] FIG. **5** shows a front view of an extruder assembly **500**, where the feedpath **501**, lever **508**, and input opening **512** are visible. Also, as shown in FIG. **5**, the extruder assembly **500** may generally include a housing **503** for the components of the extruder assembly **500**.

[0066] FIG. **6** shows a right side view of an extruder assembly **600**, where the feedpath **601**, drive gear **602**, bearing **604**, spring **606**, lever **608**, input opening **612**, and second lever **624** are visible. As shown in FIG. **6**, the lever **608** may be disposed in a first position (as shown in FIG. **6**, i.e., where the lever **608** rests on the right side of the extruder assembly **600**), where the bearing **604** is engaged with the drive gear **602**. If the lever **608** is manually moved from the right side of the extruder assembly **600** to the left side of the extruder assembly **600**, the second lever **624** can rotate about a pivot (not shown) against a biasing force of the spring **606** so that the bearing **604** moves out of engagement with the drive wheel **602**. Although not illustrated, it will be noted that an L **630** on the lever **608** can be shaped so that in this second position, an upward force between the L **630** and the beveled end of the second lever **624** retains the lever **608** and the second lever **624** in the open position to provide a bistable lever. In another aspect, the L may be omitted and the bearing **604** may be urged into engagement with the drive gear **602** whenever an external force is removed from the lever **608**.

[0067] FIG. **7** shows a top view of an extruder assembly **700**, where the lever **708** and input opening **712** are visible. Also, as shown in FIG. **7**, the extruder assembly **700** may generally include a housing **703** for the components of the extruder assembly **700**.

[0068] While particular embodiments have been shown and described, it will be apparent to those skilled in the art that various changes and modifications in form and details may be made therein without departing from the spirit and scope of this disclosure and are intended to form a part of the invention as defined by the following claims, which are to be interpreted in the broadest sense allowable by law.

What is claimed is:

1. An extruder assembly comprising:

an extruder comprising an input opening aligned to a feedpath for a filament of build material, a chamber shaped and sized to pass the build material along the feedpath, and an orifice to discharge the build material in an extrusion;

a drive gear having a number of teeth positioned to engage the filament in the feedpath;

a bearing positioned opposite the drive gear along the feedpath;

a spring coupled to the bearing and biasing the bearing toward the drive gear with a spring force;

a lever extending from the extruder assembly to manually move the bearing against the spring force away from the feedpath; and

a locking mechanism to secure the lever in a position with the bearing moved away from and out of the feedpath.

2. The extruder assembly of claim **1** further comprising a motor coupled to the drive gear and operable to rotate the drive gear.

3. The extruder assembly of claim **1** wherein the bearing comprises a freely rotating contact surface.

4. The extruder assembly of claim **1** wherein an axis of the bearing is substantially parallel to an axis of the drive gear.

5. The extruder assembly of claim **4** wherein the lever moves the axis of the bearing away from the axis of the drive gear.

6. The extruder assembly of claim **1** further comprising a pivot for the lever, wherein the spring is coupled to the lever away from the pivot.

7. The extruder assembly of claim **1** wherein the locking mechanism includes a bistable lever including a mechanical linkage to the bearing, the bearing engaged with the drive gear when the bistable lever is in a first position and the bearing disengaged from the drive gear when the bistable lever is in a second position.

8. The extruder assembly of claim **1** wherein the spring is a coil spring.

9. The extruder assembly of claim **1** wherein the spring force provides sufficient force to engage the build material with the drive gear.

10. The extruder of claim **1** wherein the spring force provides sufficient force to deform the build material into the number of teeth of the drive gear.

11. The extruder assembly of claim **10** wherein the build material includes a filament of one or more of acrylonitrile butadiene styrene (ABS), high-density polyethylene (HDPL), and polylactic acid (PLA).

12. The extruder assembly of claim **1** wherein the spring maintains a substantially constant contact force of the bearing against a length of filament between the bearing and the drive gear in an absence of external forces.

13. The extruder assembly of claim **1** wherein the bearing is a low friction bearing.

14. An extruder assembly comprising:

an extruder comprising an input opening aligned to a feedpath for a filament of build material, a chamber shaped and sized to pass the build material along the feedpath, and an orifice to discharge the build material in an extrusion;

a drive gear having a number of teeth positioned to engage the filament before the input opening in the feedpath;

a bearing positioned opposite the drive gear along the feedpath;

a spring element coupled to the bearing and biasing the bearing toward the drive gear with a spring force;

a manual control extending from the extruder assembly to manually move the bearing against the spring force away from the feedpath; and

a locking mechanism to secure the manual control in a position with the bearing moved away from and out of the feedpath.

15. The extruder assembly of claim **14** wherein the manual control includes a lever.

16. The extruder assembly of claim **14** wherein the manual control includes one or more of a knob, a slider, a plunger, and a push button.

17. The extruder assembly of claim **14** wherein the spring element includes a coil spring.

18. The extruder assembly of claim **14** wherein the spring element includes a compression spring.

19. The extruder assembly of claim **14** further comprising a heating element to liquefy a length of build material in the chamber of the extruder.

20. The extruder assembly of claim **14** wherein the locking mechanism includes a bistable lever including a mechanical linkage to the bearing, the bearing engaged with the drive gear when the bistable lever is in a first position and the bearing disengaged from the drive gear when the bistable lever is in a second position.

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