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Inventor(s) Barnhill; Christopher David et al.

ATTACHMENT STRUCTURE FOR ADDITIVE MANUFACTURING

Abstract

An additive manufacturing apparatus includes a build module. A feed module is configured to support a first portion of a resin support. The first portion of the resin support is supported by a feed mounting panel. A take-up module is configured to support a second portion of the resin support. The second portion of the resin support is supported by a take-up mounting panel and is positioned on an opposing side of the radiant energy device from the feed module. An adjustment assembly is configured to adjust a position of at least one of a feed mandrel within the feed module or a take-up mandrel within the take-up module.

Inventors: **Barnhill; Christopher David (Cincinnati, OH), Liu; Zhen (Niskayuna, NY), Muhlenkamp; Trent William (Cincinnati, OH)**

Applicant: **General Electric Company** (Evendale, OH)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] The present application claims priority to, and is a continuation of, U.S. patent application Ser. No. 17/410,314, titled "ATTACHMENT STRUCTURE FOR ADDITIVE MANUFACTURING," and filed on Aug. 24, 2021. The entire contents of the above-referenced application is hereby incorporated by reference in its entirety for all purposes.

FIELD

[0002] The present subject matter relates generally to an additive manufacturing apparatus, and more particularly to attachment structures for mounting various modules of the additive manufacturing apparatus relative to one another.

BACKGROUND

[0003] Additive manufacturing is a process in which material is built up layer-by-layer to form a component. Stereolithography (SLA) is a type of additive manufacturing process, which employs a tank of radiant-energy curable photopolymer "resin" and a curing energy source such as a laser. Similarly, Digital Light Processing (DLP) three-dimensional (3D) printing employs a two-dimensional image projector to build components one layer at a time. For each layer, the energy source draws or flashes a radiation image of the cross section of the component onto the surface of the resin. Exposure to the radiation cures and solidifies the pattern in the resin and joins it to a previously-cured layer.

[0004] In some instances, additive manufacturing may be accomplished through a "tape casting" process. In this process, a resin is deposited onto a flexible radiotransparent resin support, such as tape or foil, that is fed out from a supply reel to a build zone. Radiant energy is used to cure the resin to a component that is supported by a stage in the build zone. Once the curing of the first layer is complete, the stage and the resin support are separated from one another. The resin support is then advanced and fresh resin is provided to the build zone. In turn, the first layer of the cured resin is placed onto the fresh resin and cured through the energy device to form an additional layer of the component. Subsequent layers are added to each previous layer until the component is completed.

[0005] In some instances, various components of the additive manufacturing apparatus may be provided as separate modules. Accordingly, it may be beneficial to develop an attachment structure for the various modules such that the modules may be aligned with one another.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] A full and enabling disclosure of the present disclosure, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures.

[0007] FIG. **1** is a schematic side view of an additive manufacturing apparatus in accordance with various aspects of the present disclosure;

[0008] FIG. **2**A is a front perspective view of the manufacturing apparatus in accordance with various aspects of the present disclosure;

[0009] FIG. **2**B is an enhanced view of section IIA of FIG. **2**A;

[0010] FIG. **3** is a top schematic view of a plurality of print modules positioned within a build module in accordance with various aspects of the present disclosure;
[0011] FIG. **4** is a front perspective view of a feed mounting panel configured to support one or more components of a feed module in accordance with various aspects of the present disclosure;
[0012] FIG. **5** is a rear perspective view of the feed mounting panel of the feed module in accordance with various aspects of the present disclosure;
[0013] FIG. **6** is a front perspective view of a take-up mounting panel configured to support one or more components of a take-up module in accordance with various aspects of the present disclosure;
[0014] FIG. **7** is a rear perspective view of the take-up mounting panel of the take-up module in accordance with various aspects of the present disclosure;
[0015] FIG. **8** is a front perspective view of a plurality of build panels of the build module in accordance with various aspects of the present disclosure;
[0016] FIG. **9** is a front perspective view of a feed frame of the feed module in accordance with various aspects of the present disclosure;
[0017] FIG. **10** is a front perspective view of the feed frame operably coupled with the feed mounting panel in accordance with various aspects of the present disclosure;
[0018] FIG. **11** is a front perspective view of an alignment pad of the feed frame in accordance with various aspects of the present disclosure;
[0019] FIG. **12** is a front perspective view of an attachment location of the feed mounting panel in accordance with various aspects of the present disclosure;
[0020] FIG. **13** is a front perspective view of a take-up frame of the take-up module in accordance with various aspects of the present disclosure;
[0021] FIG. **14** is a front perspective view of the take-up frame operably coupled with the take-up mounting panel in accordance with various aspects of the present disclosure;
[0022] FIG. **15** is a front perspective view of an alignment pad of the take-up frame in accordance with various aspects of the present disclosure;
[0023] FIG. **16** is a front perspective view of an attachment location of the take-up mounting panel in accordance with various aspects of the present disclosure;
[0024] FIG. **17** is a front perspective view of a build frame of a build module in accordance with various aspects of the present disclosure;
[0025] FIG. **18** is a front perspective view of the build frame operably coupled with a plurality of build panels in accordance with various aspects of the present disclosure;
[0026] FIG. **19** is a front perspective view of an alignment pad of the build frame in accordance with various aspects of the present disclosure;
[0027] FIG. **20** is a front perspective view of an attachment location of two adjacent build panels in accordance with various aspects of the present disclosure;
[0028] FIG. **21** is a method of assembling the manufacturing apparatus in accordance with various aspects of the present disclosure;
[0029] FIG. **22** is a method of assembling the manufacturing apparatus in accordance with various aspects of the present disclosure; and
[0030] FIG. **23** depicts an exemplary computing system for an additive manufacturing apparatus in accordance with various aspects of the present disclosure.
[0031] Repeat use of reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the present disclosure.

DETAILED DESCRIPTION

[0032] Reference will now be made in detail to present embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the invention.
[0033] As used herein, the terms “first,” “second,” and “third” may be used interchangeably to

distinguish one component from another and are not intended to signify a location or importance of the individual components. Moreover, for purposes of convenience and clarity only, directional terms, such as top, bottom, left, right, up, down, over, above, below, beneath, rear, back, and front, may be used with respect to the accompanying drawings. These and similar directional terms should not be construed to limit the scope of the disclosure in any manner. Thus, it will be appreciated that the apparatus and/or any component described here may be oriented in one or more orientations that are rotationally offset from those illustrated without departing from the scope of the present disclosure.

[0034] The terms “coupled,” “fixed,” “attached to,” and the like refer to both direct coupling, fixing, or attaching, as well as indirect coupling, fixing, or attaching through one or more intermediate components or features, unless otherwise specified herein. The terms “upstream” and “downstream” refer to the relative direction with respect to a resin support movement along the manufacturing apparatus. For example, “upstream” refers to the direction from which the resin support moves, and “downstream” refers to the direction to which the resin support moves. The term “selectively” refers to a component's ability to operate in various states (e.g., an ON state and an OFF state) based on manual and/or automatic control of the component.

[0035] The singular forms “a,” “an,” and “the” include plural references unless the context clearly dictates otherwise.

[0036] Approximating language, as used herein throughout the specification and claims, is applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as “about,” “approximately,” “generally,” and “substantially,” is not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or apparatus for constructing or manufacturing the components and/or systems. For example, the approximating language may refer to being within a ten percent margin.

[0037] Moreover, the technology of the present application will be described in relation to exemplary embodiments. The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any embodiment described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments. Additionally, unless specifically identified otherwise, all embodiments described herein should be considered exemplary.

[0038] Here and throughout the specification and claims, range limitations are combined and interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. For example, all ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other.

[0039] As used herein, the term “and/or,” when used in a list of two or more items, means that any one of the listed items can be employed by itself, or any combination of two or more of the listed items can be employed. For example, if a composition or assembly is described as containing components A, B, and/or C, the composition or assembly can contain A alone; B alone; C alone; A and B in combination; A and C in combination; B and C in combination; or A, B, and C in combination.

[0040] The present disclosure is generally directed to an additive manufacturing apparatus that implements various manufacturing processes such that successive layers of material(s) (e.g., resins) are provided on each other to “build-up,” layer-by-layer, a three-dimensional component. The successive layers generally cure together to form a monolithic component that may have a variety of integral sub-components. Although additive manufacturing technology is described herein as enabling the fabrication of complex objects by building objects point-by-point, layer-by-layer, variations of the described additive manufacturing apparatus and technology are possible and within the scope of the present subject matter.

[0041] The additive manufacturing apparatus can include a support plate, a window supported by the support plate, and a stage moveable relative to the window. The additive manufacturing apparatus can further include a flexible tape or resin support that supports a resin. The resin support, with the resin thereon, is positioned between the stage and the support plate. A radiant energy device is configured to cure a portion of the resin forming the component, which is translated towards and away from the resin support by the stage between successive curing operations.

[0042] In some instances, the stage may be positioned within a build module and may be supported on a build panel that is fixed within the build module in a predefined position.

[0043] A separable feed module may be operably coupled with the build module. The feed module can be configured to support a first portion of the resin support. The feed module may include a feed frame. A feed mounting panel may be affixed to the feed frame. One or more components of the feed module are supported by the feed mounting panel to ensure that each of the components is aligned in a predetermined position relative to the build module or a component of the build module.

[0044] A separable take-up module may also be operably coupled with the build module. The take-up module can be positioned on an opposing side of the radiant energy device from the feed module. The take-up module can be configured to support a second portion of the resin support. The take-up module may include a take-up frame. A take-up mounting panel may be affixed to the take-up frame. One or more components of the take-up module are supported by the take-up mounting panel to ensure each of the components is aligned with the feed module and/or the build module in a predefined manner. By aligning the various components, and consequently, the first and second portions of the resin support, various operational faults may be avoided and/or minimized.

[0045] Referring to the drawings wherein identical reference numerals denote the similar elements throughout the various views, FIG. **1** schematically illustrates an example of one type of suitable apparatus **10** for forming a component **12** created from one or more layers of resin R. The apparatus **10** can include one or more of a support plate **14**, a window **16**, a stage **18** that is movable relative to the window **16**, and a radiant energy device **20**, which, in combination, may be used to form any number (e.g., one or more) of additively manufactured components **12** within one or more build modules **22**.

[0046] In the illustrated example, the apparatus **10** includes a feed module **24**, which may include a feed mandrel **24**A, and a take-up module **26**, which may include a take-up mandrel **26**A that are spaced-apart and configured to couple with respective end portions of a resin support **28**, such as a flexible tape or foil or another type of the resin support **28** extending therebetween. A portion of the resin support **28** between the feed mandrel **24**A and the take-up mandrel **26**A can be supported from underneath by the support plate **14**. Suitable mechanical supports (frames, brackets, etc.) may be provided for the mandrels **24**A, **26**A, and the support plate **14**.

[0047] The feed mandrel **24**A and/or the take-up mandrel **26**A can be configured to control the speed and direction of the resin support **28** such that the desired tension and speed is maintained in the resin support **28** through a drive system **30**. In various examples, the drive system **30** can be configured as individual first and second control devices **32**, **34** respectively associated with the feed mandrel **24**A and/or the take-up mandrel **26**A. Moreover, the control devices **32**, **34** may include various components, such as motors, actuators, feedback sensors, and/or controls can be provided for driving the mandrels **24**A, **26**A in such a manner so as to move at least a portion of the resin support **28** between the mandrels **24**A, **26**A.

[0048] In various embodiments, the window **16** is transparent and can be operably supported by the support plate **14**. Further, the window **16** and the support plate **14** can be integrally formed such that one or more windows **16** are integrated within the support plate **14**. Likewise, the resin support **28** is also transparent or includes portions that are transparent. As used herein, the terms “transparent” and “radiotransparent” refer to a material that allows at least a portion of radiant energy of a selected wavelength to pass through. For example, the radiant energy that passes through the window **16** and the resin support **28** can be in the ultraviolet spectrum, the infrared spectrum, the visible spectrum, or any other practicable radiant energy. Non-limiting examples of transparent materials include polymers, glass, and crystalline minerals, such as sapphire or quartz.

[0049] The resin support **28** extends between the feed module **24** and the take-up module **26** and defines a “resin surface” **36**, which is shown as being planar, but could alternatively be arcuate. In some instances, the resin surface **36** may be defined by a first side of the resin support **28** and may be positioned to face the stage **18** with the window **16** on an opposing, second side of the resin support **28** from the stage **18**. For purposes of convenient description, the resin surface **36** may be considered to be oriented parallel to an X-Y plane of the apparatus **10**, and a direction perpendicular to the X-Y plane is denoted as a Z-axis direction (X, Y, and Z being three mutually perpendicular directions). As used herein, the X-axis refers to the machine direction along the length of the resin support **28**. As used herein, the Y-axis refers to the transverse direction across the width of the resin support **28** and generally perpendicular to the machine direction. As used herein, the Z-axis refers to the stage direction that can be defined as the direction of movement of the stage **18** relative to the window **16**.

[0050] The resin surface **36** may be configured to be “non-stick,” that is, resistant to adhesion of a cured resin R. The non-stick properties may be embodied by a combination of variables such as the chemistry of the resin support **28**, its surface finish, and/or applied coatings. For instance, a permanent or semi-permanent non-stick coating may be applied. One non-limiting example of a suitable coating is polytetrafluoroethylene (“PTFE”). In some examples, all or a portion of the resin surface **36** may incorporate a controlled roughness or surface texture (e.g. protrusions, dimples, grooves, ridges, etc.) with nonstick properties. Additionally or alternatively, the resin support **28** may be made in whole or in part from an oxygen-permeable material.

[0051] For reference purposes, an area or volume immediately surrounding the location of the resin support **28** and the window **16** or transparent portion defined by the support plate **14** may be defined as a “build zone,” labeled **38**.

[0052] In some instances, the apparatus **10** may further include a material deposition assembly **40** and/or a reclamation system **72**. The material deposition assembly **40** may be any device or combination of devices that is operable to apply a layer of the resin R on the resin support **28**. The material deposition assembly **40** may optionally include a device or combination of devices to define a height of the resin R on the resin support **28** and/or to level the resin R on the resin support **28**. Nonlimiting examples of suitable material deposition assemblies include chutes, hoppers, pumps, spray nozzles, spray bars, or printheads (e.g. inkjets).

[0053] In the illustrated embodiment, the material deposition assembly **40** includes a vessel **41**A and a reservoir **41**B. A conduit **43** extends from the vessel **41**A to direct resin from the vessel **41**A to the reservoir **41**B. The conduit **43** may be positioned along a bottom portion of the vessel **41**A such that the resin R may be gravity fed from the vessel **41**A to the conduit **43**, which may generally prevent the introduction of air to the resin R as the air is transferred into and/or through the conduit **43**. In some instances, a filter may be positioned upstream, downstream, and/or within the conduit **43** with respect to the flow of resin from the vessel **41**A to the reservoir **41**B. In such instances, the resin may be gravity fed through the filter prior to entering the reservoir **41**B to catch various agglomerates, partially cured resin pieces, and/or other foreign objects that may affect the resin once it is thinned out on the resin support **28** or may affect the quality of the component **12**.

[0054] The reservoir **41**B may include any assembly to control the thickness of the resin R applied to the resin support **28**, as the resin support **28** passes under and/or through the reservoir **41**B. The reservoir **41**B may be configured to maintain a first volume of the resin R and define a thickness of the resin R on the resin support **28** as the resin support **28** is translated in an X-axis direction. The vessel **41**A may be positioned above the reservoir **41**B in a Z-axis direction, or in any other position, and configured to store a second volume of the resin R. In various embodiments, when the first volume of the resin R deviates from a predefined range, additional resin R is supplied from the vessel **41**A to the reservoir **41**B.

[0055] In some embodiments, the reclamation system **72** may be configured to remove at least a portion of the resin R that remains on the resin support **28** after the resin support **28** is removed from a build zone **38**. For example, the reclamation system **72** may include a wiper assembly, a blade assembly, and/or any other removal assembly.

[0056] The resin R includes any radiant-energy curable material, which is capable of adhering or binding together the filler (if used) in the cured state. As used herein, the term “radiant-energy curable” refers to any material which solidifies or partially solidifies in response to the application of radiant energy of a particular frequency and energy level. For example, the resin R may include a photopolymer resin containing photo-initiator compounds functioning to trigger a polymerization reaction, causing the resin R to change from a liquid (or powdered) state to a solid state. Alternatively, the resin R may include a material that contains a solvent that may be evaporated out by the application of radiant energy. The uncured resin R may be provided in solid (e.g. granular) or liquid form, including a paste or slurry.

[0057] Furthermore, the resin R can have a relatively high viscosity fluid that will not “slump” or run off during the build process. The composition of the resin R may be selected as desired to suit a particular application. Mixtures of different compositions may be used. The resin R may be selected to have the ability to out-gas or burn off during further processing, such as a sintering process.

[0058] The resin R may incorporate a filler. The filler may be pre-mixed with the resin R, then loaded into the material deposition assembly **40**. The filler may include any material that is chemically and physically compatible with the selected resin R. The particles may be regular or irregular in shape, may be uniform or non-uniform in size, and may have variable aspect ratios. For example, the particles may take the form of powder, of small spheres or granules, or may be shaped like small rods or fibers.

[0059] The composition of the filler, including its chemistry and microstructure, may be selected as desired to suit a particular application. The filler includes particles, which are conventionally defined as “a small bit of matter.” For example, the filler may be metallic, ceramic, polymeric, and/or organic. Other examples of potential fillers include diamond, silicon, and graphite. Mixtures of different compositions may be used. In some examples, the filler composition may be selected for its electrical or electromagnetic properties, e.g. it may specifically be an electrical insulator, a dielectric material, an electrical conductor, and/or magnetic.

[0060] The filler may be “fusible,” meaning it is capable of consolidation into a mass upon via application of sufficient energy. For example, fusibility is a characteristic of many available powders including, but not limited to, polymeric, ceramic, glass, and/or metallic materials. The proportion of filler to resin R may be selected to suit a particular application. Generally, any amount of filler may be used so long as the combined material is capable of flowing and being leveled, and there is sufficient resin R to hold together the particles of the filler in the cured state.

[0061] With further reference to FIG. **1**, the stage **18** is capable of being oriented parallel to the resin surface **36**. Various devices may be provided for moving the stage **18** relative to the window **16** parallel to the Z-axis direction. For example, as illustrated in FIG. **1**, the movement may be provided through an actuator **44** operably coupled with a static anchor **46** and configured to change a relative position of the stage **18** relative to the radiant energy device **20**, the support plate **14**, the window **16**, and/or any other static component of the apparatus **10**. The actuator **44** may be configured as a ballscrew electric actuator, a linear electric actuator, a pneumatic cylinder, a hydraulic cylinder, a delta drive, or any other practicable device may additionally or alternatively be used for this purpose. In addition to, or as an alternative to, making the stage **18** movable, the resin support **28** could be movable parallel to the Z-axis direction.

[0062] The radiant energy device **20** may be configured as any device or combination of devices operable to generate and project radiant energy on the resin R in a suitable pattern and with a suitable energy level and other operating characteristics to cure the resin R during the build process. For example, as shown in FIG. **1**, the radiant energy device **20** may include a projector **48**, which may generally refer to any device operable to generate a radiant energy patterned image of suitable energy level and other operating characteristics to cure the resin R. As used herein, the term “patterned image” refers to a projection of radiant energy comprising an array of one or more individual pixels. Non-limiting examples of patterned imaged devices include a DLP projector or another digital micromirror device, a two-dimensional array of LEDs, a two-dimensional array of lasers, and/or optically addressed light valves. In the illustrated example, the projector **48** includes a radiant energy source **50** such as a UV lamp, an image forming apparatus **52** operable to receive a source beam **54** from the radiant energy source **50** and generate a patterned image **56** to be projected onto the surface of the resin R, and optionally focusing optics **58**, such as one or more lenses.

[0063] The image forming apparatus **52** may include one or more mirrors, prisms, and/or lenses and is provided with suitable actuators, and arranged so that the source beam **54** from the radiant energy source **50** can be transformed into a pixelated image in an X-Y plane coincident with the surface of the resin R. In the illustrated example, the image forming apparatus **52** may be a digital micro-mirror device.

[0064] The projector **48** may incorporate additional components, such as actuators, mirrors, etc. configured to selectively move the image forming apparatus **52** or other part of the projector **48** with the effect of rastering or shifting the location of the patterned image on the resin surface **36**. Stated another way, the patterned image may be moved away from a nominal or starting location.

[0065] In addition to other types of radiant energy devices **20**, the radiant energy device **20** may include a “scanned beam apparatus” used herein to refer generally to any device operable to generate a radiant energy beam of suitable energy level and other operating characteristics to cure the resin R and to scan the beam over the surface of the resin R in a desired pattern. For example, the scanned beam apparatus can include a radiant energy source **50** and a beam steering apparatus. The radiant energy source **50** may include any device operable to generate a beam of suitable power and other operating characteristics to cure the resin R. Non-limiting examples of suitable radiant energy sources **50** include lasers or electron beam guns.

[0066] The apparatus **10** may be operably coupled with a computing system **60**. The computing system **60** in FIG. **1** is a generalized representation of the hardware and software that may be implemented to control the operation of the apparatus **10**, including some or all of the stage **18**, the radiant energy device **20**, the actuator **44**, and the various parts of the apparatus **10** described herein. The computing system **60** may be embodied, for example, by software running on one or more processors embodied in one or more devices such as a programmable logic controller (“PLC”) or a microcomputer. Such processors may be coupled to process sensors and operating components, for example, through wired or wireless connections. The same processor or processors may be used to retrieve and analyze sensor data, for statistical analysis, and for feedback control. Numerous aspects of the apparatus **10** may be subject to closed-loop control.

[0067] In some embodiments, one or more of the support plate **14**, the window **16**, the stage **18**, and/or the radiant energy device **20**, which, in combination, may be used to form the additively manufactured component **12**, may be positioned within the build module **22**. The build module **22** can include a build frame **62** supporting any one or more of the one or more of the support plate **14**, the window **16**, the stage **18**, and/or the radiant energy device **20**. Further, the feed module **24** can include a feed frame **66** that is capable of supporting any of the components provided therein, such as the feed mandrel **24**A, which may be carried on a feed mounting panel **68**, and/or the vessel **41**A, which may be carried on the vessel panel **42**. Similarly, the take-up module **26** may include a take-up frame **70** that is capable of supporting any of the components provided therein, such as the take-up mandrel **26**A and/or a material reclamation system **72**, either of which may be carried on a take-up mounting panel **74**. The feed frame **66** and/or the take-up frame **70** may also support various components of the apparatus **10**.

[0068] Referring to FIG. **2**A, a perspective view of the manufacturing apparatus **10** is provided in accordance with various exemplary embodiments of the present disclosure. As illustrated, the apparatus **10** includes a pair of build modules **22**, the feed module **24**, and a take-up module **26**. It will be appreciated, however, that the apparatus **10** may include any number (e.g., one or more) of build modules **22**. As will be described in greater detail below, each of the components within the build modules **22**, the feed module **24**, and a take-up module **26** may be anchored to various panels **42**, **68**, **74**, **162** (FIG. **8**) with the various panels **42**, **68**, **74**, **162** being mounted to at least one of the feed frame **66**, the build frame(s) **62**, and/or the take-up frame. In addition, in various embodiments, an adjustment assembly may be configured to adjust a position of at least one of a feed mandrel **24**A within the feed module **24** or a take-up mandrel **26**A within the take-up module **26**, which may assist in preventing foil translation issues due to misalignment of the feed mandrel **24**A relative to the take-up mandrel **26**A.

[0069] In some embodiments, the feed frame **66** may include one or more alignment pads **124** that may be attached to the feed frame **66** and/or integrally formed with various portions of the feed frame **66** that act as datums for coupling various components thereto. Similarly, the build frame **62** may include one or more alignment pads **124** that may be attached to the build frame **62** and/or integrally formed with various portions of the build frame **62** that act as datums for coupling various components thereto. Likewise, the take-up frame **70** may include one or more alignment pads **124** that may be attached to the take-up frame **70** and/or integrally formed with various portions of the take-up frame **70** that act as datums for coupling various components thereto.

[0070] In some instances, one or more panels within the feed module **24** may be operably coupled with the alignment pads **124**. For example, a vessel panel **42** and/or a feed mounting panel **68** may be coupled with the feed module alignment pads **124**. Similarly, one or more panels within the build module **22** may be operably coupled with the alignment pads **124**. For example, one or more build panels **162** (FIG. **8**) each supporting a print module **116** thereon may be coupled with the build module alignment pads **124**. Likewise, one or more panels within the take-up module **26** may be operably coupled with the alignment pads **124**. For example, a take-up mounting panel **74** may be coupled with the take-up module alignment pads **124**. Each of the panels **42**, **68**, **74**, **162** described herein may be formed from any practical material, such as, but not limited to, a metallic material, a composite material, a polymeric material, an elastomeric material, a combination thereof, and/or another material.

[0071] In various examples, coupling of the panels **42**, **68**, **74**, **162** (FIG. **8**) described herein to one of the feed frame **66**, the build frame **62**, and/or the take-up frame to define a mounting plane **142**, **144**, **146** of each respective module. In some embodiments, each of the mounting planes **142**, **144**, **146** are also aligned relative to one another to define an alignment plane **118**. In some instances, the alignment plane **118** may be formed by each of the mounting planes **142**, **144**, **146** of the modules being positioned in a co-planar orientation, parallel, and/or otherwise aligned.

[0072] With reference to FIGS. **2**A and **2**B, to align each of the modules relative to one another along the alignment plane **118**, the build frame **62**, the feed frame **66**, and/or the take-up frame may each include one or more mounts **138** to drive higher functionality and alignment. For instance, each of the feed module **24**, the one or more build modules **22**, and the take-up module **26** include one or more mounts **138**. The one or more mounts **138** may be used to align each of the feed frame **66**, the one or more build frames **62**, and the take-up frame **70** relative to one another.

[0073] In various embodiments, the build module **22** includes the build frame **62** having a first mount **138** operably coupled (e.g., welded) on a first side thereof and a second mount **138** operably coupled (e.g., welded) on a second side thereof. The feed module **24** includes the feed frame **66** having a third mount **138** operably coupled (e.g., welded) thereto. The take-up module **26** includes the take-up frame **70** having a fourth mount operably coupled (e.g., welded) thereto. In such

examples, the first mount can be operably coupled with the third mount and the second mount can be operably coupled with the fourth mount.
[0074] In some examples, the first mount **138** and the second mount **138** are welded to the build frame **62** and machined in place to define a plane of respective outer surfaces of the first mount **138** and the second mount **138** relative to the build frame **62**. Similarly, the third mount **138** is welded to the feed frame **66** and machined in place to define a plane of an outer surface of the third mount **138** relative to the feed frame **66**. Likewise, the fourth mount **138** is welded to the take-up frame **70** and machined in place to define a plane of an outer surface of the fourth mount **138** relative to the take-up frame **70**. As such, each of the mounts **138** may define a planar surface that aligns with another of the mounts **138** to ensure that the build frame **62**, the feed frame **66**, and the take-up frame **70** are generally aligned in a predefined orientation relative to one another.
[0075] In some embodiments, the mounts **138** may be positioned such that each of the mounts **138** is coupled with a pair of frame elements of the respective frame, which in the illustrated embodiment in FIGS. **2**A and **2**B, is a bottom frame element **150** and a vertically extending frame element **152**. However, it will be appreciated that the mounts **138** may be positioned in any other location without departing from the scope of the present disclosure.
[0076] As illustrated, the mounts **138** may be configured to extend generally in a first direction (e.g., in the Y-axis direction in FIG. **2**A) while the various panels **42**, **68**, **74**, **162** (FIG. **8**) of the apparatus **10** may extend in a second, offset direction (e.g., in the X-axis direction in FIG. **2**A). In some examples, such as the those illustrated in FIGS. **2**A, the first and second directions may be perpendicular to one another.
[0077] With reference to FIG. **3**, in various embodiments, the build module **22** may include one or more print modules **116**. Each print module **116** may include a support plate **14**, a window **16**, a stage **18**, an actuator **44**, and/or a radiant energy device **20**. As generally illustrated in FIG. **3**, the resin support **28** may be maintained in a position in which the resin support **28** generally extends through each print module **116** and covers the one or more windows **16** of the print modules **116**. Moreover, the mounts **138** may allow for the resin support **28** to be aligned such that the resin support **28** remains in its original position **154** rather than sliding to a misalignment position **156** in the Y-axis direction during operation, which may occur when one or more components are misaligned and/or the feed mandrel **24**A and the take-up mandrel **26**A have non-parallel axes of rotation.
[0078] Referring to FIGS. **4** and **5**, exemplary perspective views of the feed mounting panel **68** are illustrated in accordance with exemplary embodiments of the present disclosure. As illustrated, the feed mandrel **24**A can be anchored to the feed mounting panel **68** and may support and rotate a first portion **76** (FIG. **1**) of the resin support **28** (FIG. **1**). In various embodiments, the feed mandrel **24**A includes a front portion **78** on a first side **80** of the feed mounting panel **68** and a rear portion **82** on a second, opposing side **84** of the feed mounting panel **68**. In some instances, a bearing **86** may be positioned along the front portion **78**, the rear portion **82**, and/or between the front and rear portions **78**, **82**.
[0079] The front portion **78** of the feed mandrel **24**A may include a cylindrical portion **88** that is configured to accept the first portion **76** of the resin support **28** thereabout. In various instances, the resin support **28** may be operably coupled to a feed spool **158** (FIG. **1**) (e.g., cardboard spool, polymeric spool, metallic spool, paper-based spool, etc.), and the feed spool **158** may be positioned about the feed mandrel **24**A.
[0080] A stop **90** may be positioned between the cylindrical portion **88** and the feed mounting panel **68**. As such, when the resin support **28** is positioned about the feed mandrel **24**A, the stop **90** defines a first distance d.sub.1 between an inner edge of the feed spool **158** and the feed mounting panel **68**. In some examples, the feed mandrel **24**A may be configured to move between a disengaged position and an engaged position. In operation, the feed mandrel **24**A may be placed in the disengaged position to allow the feed spool **158**, and the resin support **28** wound thereabout, to

be slid along the feed mandrel **24**A to a position in which an end portion of the feed spool **158** is in contact or close proximity to the stop **90**. Once the feed spool **158** is positioned about the feed mandrel **24**A, the feed mandrel **24**A may be placed in the engaged position causing the feed spool **158**, and, consequently, the first portion **76** of the resin support **28** to rotate with the feed mandrel **24**A.

[0081] In some embodiments, the drive system **30** (FIG. **1**) may include a first control device **32** operably coupled with the rear portion **82** of the feed mandrel **24**A. The first control device **32** may be configured as one or more motors, actuators, or any other device that may rotate the feed mandrel **24**A. Further, as illustrated in FIG. **5**, the first control device **32** may include a transmission **92** in the form of a belt system, a gear system, and/or any other practicable system.

[0082] With further reference to FIGS. **4** and **5**, one or more rollers **94**A, **94**B, and/or a tension sensor **96**, such as a load cell, may be anchored to the first side **80** of the feed mounting panel **68**. For example, a pair of rollers **94**A, **94**B may be positioned above the feed mandrel **24**A in the Z-axis direction. In some instances, the pair of rollers **94**A, **94**B may have an axis of rotation **98**A that is generally parallel to an axis of rotation **98**B of the feed mandrel **24**A.

[0083] The tension sensor **96** may be positioned between the pair of rollers **94**A, **94**B and the feed mandrel **24**A in the Z-axis direction. The tension sensor **96** may be configured as a force transducer that converts a tension or torque provided by the resin support **28** onto the tension sensor **96** into an electrical signal that can be measured by the computing system **60** to determine a tension of the resin support **28**. In some embodiments, the resin support **28** may be provided from the feed mandrel **24**A around a first roller **94**A, around the tension sensor **96**, and around a second roller **94**B.

[0084] As illustrated in FIG. **4**, a cover **64** may be anchored to the first side **80** of the feed mounting panel **68**. In various instances, the cover **64** may be configured to prevent any resin that might drip from dripping onto the first portion **76** (FIG. **1**) of the resin support **28** and/or any other component of the apparatus **10**. Additionally or alternatively, the cover **64** may also prevent damage to various components of the apparatus **10** while loading the first portion **76** (FIG. **1**) of the resin support **28** onto and/or off of the apparatus **10**.

[0085] Referring to FIGS. **6** and **7**, respective front and rear perspective views of the take-up mounting panel **74** are illustrated in accordance with exemplary embodiments of the present disclosure. As illustrated, the take-up mounting panel **74** may define a generally planar front surface. The take-up mandrel **26**A may be anchored to the take-up mounting panel **74** and configured to support a second portion **100** (FIG. **1**) of the resin support **28**.

[0086] In various embodiments, the take-up mandrel **26**A includes a front portion **102** on a first side **104** of the take-up mounting panel **74** and a rear portion **106** on a second, opposing side **108** of the take-up mounting panel **74**. In some instances, a bearing **110** may be positioned along the front portion **102**, the rear portion **106**, and/or between the first and second portions **102**, **106** of the take-up mandrel **26**A.

[0087] The front portion **102** of the take-up mandrel **26**A may include a cylindrical portion **112** that is configured to accept the second portion **100** of the resin support **28** thereabout. In various instances, the resin support **28** may be operably coupled to a take-up spool **160** (FIG. **1**) (e.g., cardboard spool, polymeric spool, paper-based spool, etc.), and the take-up spool **160** may be positioned about the take-up mandrel **26**A.

[0088] A stop **114** may be positioned between the cylindrical portion **112** and the take-up mounting panel **74**. As such, the resin support **28** is wrapped about the feed mandrel **24**A, the stop **114** defines a second distance d.sub.2 between the inner edge of the take-up spool **160** and the take-up mounting panel **74**. In some examples, the take-up mandrel **26**A may be configured to move between a disengaged position and an engaged position. In operation, the take-up mandrel **26**A may be placed in the disengaged position to allow the take-up spool **160** to be slid along the take-up mandrel **26**A to a position in which an end portion of the take-up spool **160** is in contact or close proximity to the stop **114**. Once the take-up spool **160** is positioned about the take-up mandrel **26**A, the take-up mandrel **26**A may be placed in the engaged position causing the take-up spool **160**, and, consequently, the second portion **100** of the resin support **28** to rotate with the take-up mandrel **26**A.

[0089] In some examples, once the vessel panel **42** and/or the feed mounting panel **68** are coupled to the feed frame, the one or more build panels **162** are mounted to the build frame **62**, and/or the take-up mounting panel **74** is coupled to the take-up frame **70**, the stop **90** of the feed module and/or the stop **114** of the take-up module may be adjusted to alter a position of the foil.

[0090] Similar to the feed module **24**, the second control device **34** may be operably coupled with the rear portion **106** of the feed mandrel **24**A. The second control device **34** may be configured as one or more motors, actuators, or any other device that may rotate the feed mandrel **24**A. Further, as illustrated in FIG. **6**, the second control device **34** may include a transmission **120** in the form of a belt system, a gear system, and/or any other practicable system. Moreover, the first control device **32** and the second control device **34** may be operably coupled with feedback sensors and/or controls that can be provided for driving the mandrels **24**A, **26**A in such a manner so as to maintain the resin support **28** tensioned between the mandrels **24**A, **26**A and to wind the resin support **28** from the feed mandrel **24**A to the take-up mandrel **26**A.

[0091] With further reference to FIGS. **5** and **6**, one or more rollers may be anchored to the first side **104** of the take-up mounting panel **74**. For example, a set of three rollers **122**A, **122**B, **122**C may be positioned on various portions of the take-up mounting panel **74**. In some instances, each roller **122**A, **122**B, **122**C may have an axis of rotation **123**A that is generally parallel to an axis of rotation **123**B of the take-up mandrel **26**A.

[0092] Referring to FIG. **8**, the build module **22** may include any number (e.g., one or more) of print modules **116** may each be used to form an additively manufactured component **12** (FIG. **1**). Each print module **116** may include a support plate **14**, a window **16**, a stage **18**, an actuator **44**, and/or a radiant energy device **20**. In addition, each print module **116** may be coupled to individual build panels **162**, which may aid in assembly and manufacturing, as well as in serviceability. As illustrated, the print modules **116** may be placed in an upstream/downstream orientation such that the resin support **28** translates between each subsequent print module **116** as the resin support **28** is moved from the feed module **24** to the take-up module **26**.

[0093] With further reference to FIG. **8**, each of the build panels **162** may define a plurality of attachment locations **164**. The attachment locations **164** are configured to align with respective alignment pads **124** to attach each respective build panel **162** to the build frame **62**.

[0094] Referring to FIGS. **9** and **10**, exemplary perspective views of the feed module **24** are illustrated in accordance with exemplary embodiments of the present disclosure. In the illustrated embodiments, the feed frame **66** may include one or more alignment pads **124** that may be attached to the feed frame **66** and/or integrally formed with various portions of the feed frame **66**. The alignment pads **124** can act as datums to align the feed mounting panel **68** with a defined position relative to the feed frame **66**, which, in turn, may align the first portion **76** (FIG. **1**) of the resin support **28** within the feed module **24** (FIG. **1**) to various components of the apparatus **10**.

[0095] As illustrated, the feed mounting panel **68** may define attachment locations **126** for attaching the feed mounting panel **68** to the feed frame **66** through alignment with the alignment pads **124**. In some embodiments, the feed mounting panel **68** may include at least a distal upper location **126**A, an intermediate upper location **126**B, and a proximal upper location **126**C. In some instances, the distal upper location **126**A and the intermediate upper location **126**B may be separated by a first length l.sub.1. Further, the intermediate upper **126**B location and the proximal upper location **126**C may be separated by a second length l.sub.2. In various embodiments, the first and second lengths l.sub.1, l.sub.2 may be different from one another, which may provide a poka-yoke (or error-proofed) design for assembly. Additionally or alternatively, the alignment pads **124** may also provide for a more rigid structure to keep the weight of the resin support **28** from causing

deflection in the feed mounting panel **68**. To this end, various attachment locations (e.g., **126**B, **126**E) may be positioned on opposing sides of the feed mandrel **24**A of the feed module **24**.
[0096] In some embodiments, the feed mounting panel **68** may further include at least a distal lower location **126**D, an intermediate lower location **126**E, and a proximal lower location **126**F. In some instances, the distal lower location **126**D and the intermediate lower location **126**E may be separated by a third length l.sub.3. Further, the intermediate lower location **126**E and the proximal lower location **126**F may be separated by a fourth length l.sub.4. In various embodiments, the third and fourth lengths l.sub.3, l.sub.4 may be different from one another.
[0097] Further still, the feed mounting panel **68** may additionally or alternatively each include additional attachment locations **126**G generally between the distal upper location **126**A and the distal lower locations **126**D and/or between the proximal upper location **126**C and the proximal lower locations **126**F. It will be appreciated, however, that the feed module **24** may include any number of attachment locations **126** without departing from the scope of the present disclosure.
[0098] Referring to FIGS. **11** and **12**, front perspective views of an alignment pad **121** of the feed module **24** and an attachment location **126** of the feed mounting panel **68** are illustrated in accordance with various exemplary embodiments of the present disclosure. In some embodiments, the alignment pads **124** may define an attachment void **168** that may be offset on the alignment pad in the X-axis and/or Z-axis direction. The feed mounting panel **68** can define first and second apertures **130**, **132**. In several embodiments, a coupling fastener **134** can be positioned in the first aperture **130** and into the attachment void **168** of the alignment pad. The coupling fastener **134** can be a mounting bolt that is configured to removably anchor the feed mounting panel **68** to the feed frame **66**. An adjustment fastener **136** can be positioned through the second aperture **132** and contact and/or press against the alignment pad. As such, the adjustment fastener **136** can be an adjustment screw (e.g., a jack screw) that is configured to allow for fine adjustment of the feed mounting panel **68** relative to the feed frame **66**.
[0099] Referring to FIGS. **13** and **14**, exemplary perspective views of the take-up frame **70** are illustrated in accordance with exemplary embodiments of the present disclosure. In the illustrated embodiments, the take-up frame **70** may include one or more alignment pads **124** that may be attached to the take-up frame **70** and/or integrally formed with various portions of the take-up frame **70**. The alignment pads **124** can act as datums to align the take-up mounting panel **74** with a defined position relative to the take-up frame **70**, which, in turn, may align the first portion **76** of the resin support **28** within the take-up module **26** to various components of the apparatus **10**.
[0100] In some embodiments, the take-up mounting panel **74** may include at least a distal upper location **128**A, an intermediate upper location **128**B, and a proximal upper location **128**C. In some instances, the distal upper location **128**A and the intermediate upper location **128**B may be separated by a fifth length l.sub.5. Further, the intermediate upper location **128**B and the proximal upper location **128**C may be separated by a sixth length l.sub.6. In various embodiments, the fifth and sixth lengths l.sub.5, l.sub.6 may be different from one another, which may provide a poka-yoke design. Moreover, the first and fifth lengths l.sub.1, l.sub.5 may be generally equal or different from one another, the first and sixth lengths l.sub.1, l.sub.6 may be generally equal or different from one another, the second and fifth lengths l.sub.2, l.sub.5 may be generally equal or different from one another, and/or the second and sixth l.sub.2, l.sub.6 lengths may be generally equal or different from one another.
[0101] In various embodiments, the take-up mounting panel **74** may include at least a distal lower location **128**D, an intermediate lower location **128**E, and a proximal lower location **128**F. In some instances, the distal lower location **128**D and the intermediate lower location **128**E may be separated by a seventh length l.sub.7. Further, the intermediate lower location **128**E and the proximal lower location **128**F may be separated by an eighth length l.sub.8. In various embodiments, the seventh and eighth lengths l.sub.7, l.sub.8 may be different from one another. Moreover, the third and seventh lengths l.sub.3, l.sub.7 may be generally equal or different from

one another, the third and eighth lengths l.sub.3, l.sub.8 may be generally equal or different from one another, the fourth and seventh lengths l.sub.4, l.sub.7 may be generally equal or different from one another, and/or the fourth and eighth lengths l.sub.4, l.sub.8 may be generally equal or different from one another.

[0102] Further still, the take-up mounting panel **74** may additionally or alternatively include additional attachment locations **128**G generally between the distal upper location **128**A and the distal lower locations **128**D and/or between the proximal upper location **128**C and the proximal lower locations **128**F. It will be appreciated, however, that the take-up module **26** may include any number of attachment locations **128** without departing from the scope of the present disclosure.

[0103] Referring to FIGS. **15** and **16**, front perspective views of an alignment pad of the take-up module **26** and an attachment location **128** of the take-up mounting panel **74** are illustrated in accordance with various exemplary embodiments of the present disclosure. In some embodiments, the alignment pads **124** may define an attachment void **168** that may be offset on the alignment pad. The take-up mounting panel **74** can define first and second apertures **130**, **132**. In several embodiments, a coupling fastener **134** can be positioned in the first aperture **130** and into the attachment void **168** of the alignment pad. The coupling fastener **134** can be a mounting bolt that is configured to removably anchor the take-up mounting panel **74** to the take-up frame **70**. An adjustment fastener **136** can be positioned through the second aperture **132** and contact and/or press against the alignment pad. As such, the adjustment fastener **136** can be an adjustment screw (e.g., a jack screw) that is configured to allow for adjustment of the take-up mounting panel **74** relative to the take-up frame **70**.

[0104] Referring now to FIGS. **17** and **18**, front perspective view of the build module **22** is illustrated in accordance with various exemplary embodiments of the present disclosure. In the illustrated embodiment, the build frame **62** may include one or more alignment pads **124** that may be attached to the build frame **62** and/or integrally formed with various portions of the build frame **62**. The alignment pads **124** can act as datums to align one or more build panels **162** with a defined position relative to the build frame **62**, which, in turn, may align each print module **116** (FIG. **3**) relative to the other components of the apparatus **10**.

[0105] In some embodiments, the build frame **62** may support five build panels **162**. Each build panel **162** may include a pair of upper attachment locations and a pair of lower attachment locations. It will be appreciated, however, that the take-up module **26** may include any number of attachment locations **128** without departing from the scope of the present disclosure.

[0106] Referring to FIGS. **19** and **20**, front perspective views of an alignment pad of the build module **22** and an attachment location **164** (FIG. **18**) of a pair of build panels **162** are illustrated in accordance with various exemplary embodiments of the present disclosure. In some embodiments, the alignment pads **124** may define a pair of attachment voids **168**. The build panels **162** may define a single aperture within each attachment location. In several embodiments, a coupling fastener **134** can be positioned in the first aperture **130** of each build panel **162** and into the attachment void **168** of the alignment pad. As illustrated, in some instances, adjacently positioned build panels **162** may be operably coupled with a common alignment pad **124**.

[0107] In various examples, once each panel of the apparatus is coupled with an associated frame (e.g., the feed frame **66**, the build frame **62**, or the take-up frame **70**) with one or more fasteners **134**, an adjustment assembly may be utilized to adjust a position of at least one of a feed mandrel within the feed module or a take-up mandrel within the take-up module. For example, one or more adjustment fasteners **136** can be used to rotate and/or aligned the feed mandrel **24**A and the take-up mandrel **26**A in a defined orientation. In addition, the stop **90** of the feed module and/or the stop **114** of the take-up module may be adjusted, which can prevent resin support **28** walking (or other issues).

[0108] Now that the construction and configuration of the additive manufacturing apparatus has been described according to various examples of the present subject matter, methods **200**, **300** for assembling an additive manufacturing apparatus are respectively provided with reference to FIGS. **21** and **22**. It should be appreciated that the example methods **200** is discussed herein only to describe example aspects of the present subject matter and is not intended to be limiting. Any of the steps within FIG. **21** may be omitted or rearranged in any other order without departing from the scope of the present disclosure.

[0109] Referring now to FIG. **21**, a method of aligning the resin can include installing one or more components within the feed frame at step **202**. As provided herein, the one or more components may be operably coupled to a feed mounting panel. The feed frame panel may be mounted to the feed frame.

[0110] At step **204**, the method **200** can include installing one or more components within the take-up frame. As provided herein, the one or more components may be operably coupled to a take-up mounting panel. The take-up frame panel may be mounted to the take-up frame.

[0111] At step **206**, the method **200** can include installing one or more print modules within a build frame. As provided herein, the one or more print modules may be mounted to one or more build panels. For instance, each print module may be mounted to a respective build panel. However, it will be appreciated that more than one print module may be mounted to a common build panel. The build panels may then be mounted to the build frame.

[0112] At step **208**, the method **200** can include aligning and attaching the feed frame, the build frame, and the take-up frame relative to one another. In some instances, to align each of the modules relative to one another along the alignment plane, the build frame, the feed frame, and/or the take-up frame may each include one or more one or more mounts. Once the one or more mounts of the feed frame are aligned with the build frame, a coupling fastener may be positioned within the one or more mounts to retain the position of the frames relative to one another. Likewise, once the one or more mounts of the take-up frame are aligned with the build module on an opposing side of the build frame from the feed frame, a coupling fastener may be positioned within the one or more mount to retain the position of the frames relative to one another. As provided herein, the apparatus may include any number of build frames. As such, in instances in which more than one build frame is implemented, the feed frame may be coupled to a first build module and the take-up module may be coupled with a second build module. In addition, the first build frame may be coupled with the second build frame on an opposite side of the first build frame from the feed frame and on an opposite side of the second build frame from the take-up frame.

[0113] At step **210**, the method **200** can include installing a resin support through the apparatus. In various embodiments, the resin support may have a first portion operably coupled with a feed spool and a second portion operably coupled with a take-up spool. The feed spool may be positioned about a feed mandrel within the feed module. The take-up spool may be positioned about a take-up mandrel within the take-up module. An intermediate portion of the resin support may extend through the build module and along one or more print modules within the build module.

[0114] At step **212**, the method **200** can include translating the resin support from the feed module to the take-up module. As the resin support is translated, at step **214**, the method includes determining whether any misalignment characteristics are present. For example, determining whether any misalignment characteristics are present may include determining whether the resin support is generally moving from its original position in the Y-axis direction indicating misalignment of one or more components and/or the feed mandrel and the take-up mandrel have non-parallel axes of rotation. Additionally or alternatively, determining whether any misalignment characteristics are present may include determining whether any ripples or other variations are present along the resin support.

[0115] If any misalignment characteristics are present, at step **216**, the method **200** can include adjusting an orientation of the feed panel, the one or more build panels, and/or the take-up panel. As provided herein, each of the feed panel, the one or more build panels, and/or the take-up panel may have their respective orientation adjusted through one or more adjustment screws. Once the orientation of the feed panel, the one or more build panels, and/or the take-up panel is adjusted, the method **200** can return to step **212**.

[0116] If no misalignment characteristics are present (or a negligible amount of misalignment is present), at step **218**, the method includes determining whether the resin provided on the resin support is positioned over the window of each respective print module in a Z-axis direction.

[0117] If the resin is not positioned over one or more window, at step **220**, the method can include adjusting a stop positioned on a mandrel of the apparatus. For example, a stop of the feed mandrel and/or a stop positioned on a take-up mandrel may be adjusted to align the resin support. Once a stop positioned on a mandrel of the apparatus is adjusted, the method **200** can return to step **212**.

[0118] If the resin is positioned over each of the one or more windows, at step **222**, the method **200** may include initiating a build process.

[0119] Referring now to FIG. **22**, an alternatively method may be implemented for aligning the resin support within the apparatus. For instance, the method **300**, at step **302**, can include aligning the feed frame, the build frame, and the take-up frame to one another. In some instances, to align each of the modules relative to one another along the alignment plane, the build frame, the feed frame, and/or the take-up frame may each include one or more one or more mounts. Once the one or more mounts of the feed frame are aligned with the build module, a coupling fastener may be positioned within the one or more mount to retain the position of the frames relative to one another. Likewise, once the one or more mounts of the take-up frame are aligned with the build module on an opposing side of the build frame from the feed frame, a coupling fastener may be positioned within the one or more mount to retain the position of the frames relative to one another. As provided herein, the apparatus may include any number of build frames. As such, in instances in which more than one build frame is implemented, the feed frame may be coupled to a first build module and the take-up module may be coupled with a second build module.

[0120] At step **304**, the method **300** can include installing a feed mounting panel and components onto the feed frame such that each of the components is mounted within the feed module relative to a feed module mounting plane defined by one or more datums within the feed module. As provided herein, the feed mounting panel may support various components such as a feed mandrel, one or more rollers, a cover, a tension sensor, etc. that can each be positioned on the feed mounting panel.

[0121] At step **306**, the method **300** can include installing a take-up mounting panel and components onto the take-up frame such that each of the components is mounted within the take-up module relative to a take-up module mounting plane defined by one or more datums within the take-up module. As provided herein, the take-up mounting panel may support various components such as a take-up mandrel, one or more rollers, a reclamation system, etc. that can each be positioned on the take-up mounting panel.

[0122] At step **308**, the method **300** can include installing a one or more build panels and print modules onto the build frame such that each of the one or more build panels is mounted within the build module relative to a module module mounting plane defined by one or more datums within the build module. As provided herein, each of the build panels may support a print module. Each print module may include a support panel, a window, a stage, an actuator, and/or a radiant energy device.

[0123] At step **310**, the method **300** can include aligning each of the mounting planes to form an alignment plane. Once the panels within each module are aligned with to define respective mounting planes, the mounting planes are aligned in a co-planar manner to define the alignment plane.

[0124] At step **312**, the method **300** includes installing a resin support through the apparatus. In various embodiments, the resin support may have a first portion operably coupled with a feed spool and a second portion operably coupled with a take-up spool. The feed spool may be positioned about a feed mandrel within the feed module. The take-up spool may be positioned about a take-up mandrel within the take-up module. An intermediate portion of the resin support may extend through the build module and along one or more print modules within the build module.

[0125] At step **314**, the method **300** can include translating the resin support from the feed module to the take-up module. As the resin support is translated, at step **316**, the method includes determining whether the resin support is generally moving from its original position in the Y-axis direction indicating misalignment of one or more components and/or the feed mandrel and the take-up mandrel have non-parallel axes of rotation.

[0126] If the resin support moves from its original position in a longitudinal direction as the resin support is translated in a longitudinal direction, the method **300**, at step **318**, can include making modification to the feed module, the build module, and/or the take-up module. The modifications can include altering a position of one or more panels within the modules of the apparatus by altering a fastener, which may be in the form of a coupling fastener (e.g., mounting bolt) and/or an adjustment fastener (e.g., a jack screw). If the resin support does not move or moves within a predefined range from its original position as it is translated, the build process may be initiated at step **320**.

[0127] FIG. **23** depicts certain components of computing system **60** according to example embodiments of the present disclosure. The computing system **60** can include one or more computing device(s) **60**A which may be used to implement the methods **200**, **300** described herein. The computing device(s) **60**A can include one or more processor(s) **60**B and one or more memory device(s) **60**C. The one or more processor(s) **60**B can include any suitable processing device, such as a microprocessor, microcontroller, integrated circuit, an application specific integrated circuit (ASIC), a digital signal processor (DSP), a field-programmable gate array (FPGA), logic device, one or more central processing units (CPUs), graphics processing units (GPUs) (e.g., dedicated to efficiently rendering images), processing units performing other specialized calculations, etc. The memory device(s) **60**C can include one or more non-transitory computer-readable storage medium(s), such as RAM, ROM, EEPROM, EPROM, flash memory devices, magnetic disks, etc., and/or combinations thereof.

[0128] The memory device(s) **60**C can include one or more computer-readable media and can store information accessible by the one or more processor(s) **60**B, including instructions **60**D that can be executed by the one or more processor(s) **60**B. The instructions **60**D may execute operations of the additive manufacturing apparatus **10** described above. For instance, the memory device(s) **60**C can store instructions **60**D for running one or more software applications, displaying a user interface, receiving user input, processing user input, etc. In some implementations, the instructions **60**D can be executed by the one or more processor(s) **60**B to cause the one or more processor(s) **60**B to perform operations. The instructions **60**D can be software written in any suitable programming language or can be implemented in hardware. Additionally, and/or alternatively, the instructions **60**D can be executed in logically and/or virtually separate threads on processor(s) **60**B.

[0129] The one or more memory device(s) **60**C can also store data **60**E that can be retrieved, manipulated, created, or stored by the one or more processor(s) **60**B. The data **60**E can include, for instance, data to facilitate performance of the apparatus **10** described herein. The data **60**E can be stored in one or more database(s). The one or more database(s) can be connected to computing system **60** by a high bandwidth LAN or WAN, or can also be connected to the computing system **60** through network(s) (not shown). The one or more database(s) can be split up so that they are located in multiple locales. In some implementations, the data **60**E can be received from another device.

[0130] The computing device(s) **60**A can also include a communication module or interface **60**F used to communicate with one or more other component(s) of computing system **60** or the additive manufacturing apparatus **10** over the network(s). The communication interface **60**F can include any suitable components for interfacing with one or more network(s), including for example, transmitters, receivers, ports, controllers, antennas, or other suitable components.

[0131] It should be appreciated that the additive manufacturing apparatus is described herein only for the purpose of explaining aspects of the present subject matter. In other example embodiments, the additive manufacturing apparatus may have any other suitable configuration and may use any other suitable additive manufacturing technology. Further, the additive manufacturing apparatus and processes or methods described herein may be used for forming components using any suitable material. For example, the material may be plastic, metal, concrete, ceramic, polymer, epoxy, photopolymer resin, or any other suitable material that may be embodied in a layer of slurry, resin, or any other suitable form of sheet material having any suitable consistency, viscosity, or material properties. For example, according to various embodiments of the present subject matter, the additively manufactured components described herein may be formed in part, in whole, or in some combination of materials including but not limited to pure metals, nickel alloys, chrome alloys, titanium, titanium alloys, magnesium, magnesium alloys, aluminum, aluminum alloys, iron, iron alloys, stainless steel, and nickel or cobalt based superalloys (e.g., those available under the name Inconel® available from Special Metals Corporation). These materials are examples of materials suitable for use in the additive manufacturing processes described herein, and may be generally referred to as "additive materials."

[0132] Aspects of the invention(s) are provided by the subject matter of the following clauses, which are intended to cover all suitable combinations unless dictated otherwise based on logic or the context of the clauses and/or associated figures and description:

[0133] An additive manufacturing apparatus comprising: a build module; a feed module configured to support a first portion of a resin support, the first portion of the resin support supported by a feed mounting panel; a take-up module configured to support a second portion of the resin support, the second portion of the resin support maintained by a take-up mounting panel and positioned on an opposing side of the build module from the feed module; and an adjustment assembly configured to adjust a position of at least one of a feed mandrel within the feed module or a take-up mandrel within the take-up module.

[0134] The additive manufacturing apparatus of one or more of these clauses, wherein the feed mandrel is anchored to the feed mounting panel and configured to maintain the resin support at a first distance from the feed mounting panel.

[0135] The additive manufacturing apparatus of one or more of these clauses, wherein the take-up mandrel is anchored to the take-up mounting panel and configured to maintain the resin support at a second distance from the take-up mounting panel.

[0136] The additive manufacturing apparatus of one or more of these clauses, wherein the first distance and the second distance are generally equal.

[0137] The additive manufacturing apparatus of one or more of these clauses, further comprising: a build frame supporting a first stage; a feed frame supporting the feed mounting panel; and a take-up frame supporting the take-up mounting panel, wherein one or more one or more mounts are positioned on opposing sides of the build frame for aligning the build frame to the feed frame and to the take-up frame.

[0138] The additive manufacturing apparatus of one or more of these clauses, further comprising: a first set of alignment pads defined by the feed frame; and a second set of alignment pads defined by the take-up frame, wherein each of the alignment pads within the first set of alignment pads and the second set of alignment pads defines a respective attachment void.

[0139] The additive manufacturing apparatus of one or more of these clauses, wherein a first set of attachment locations and a second set of attachment locations each includes a first aperture and a second aperture.

[0140] The additive manufacturing apparatus of one or more of these clauses, wherein a coupling fastener is positioned through the first aperture and into the attachment void of the first set of alignment pads or the second set of alignment pads.

[0141] The additive manufacturing apparatus of one or more of these clauses, wherein the adjustment assembly includes an adjustment fastener positioned through the second aperture and contacts the alignment pads within the first set of alignment pads and the second set of alignment pads, and wherein the adjustment fastener is configured to provide fine adjustment of one or more mounting planes.

[0142] The additive manufacturing apparatus of one or more of these clauses, further comprising: a first mount operably coupled with the feed module; and a second mount operably coupled with the build module, wherein a fastener is positioned through the first and second mounts to fix the position of the feed module relative to the build module, and wherein the first and second mounts extend in a parallel direction to one another, the parallel direction being offset from a mounting plane of the feed module or the build module.

[0143] The additive manufacturing apparatus of one or more of these clauses, further comprising: a second stage positioned between the first stage and the take-up module.

[0144] A method of assembling an additive manufacturing apparatus, the method comprising: aligning a feed frame, a build frame, and a take-up frame to one another; installing a feed mounting panel and components onto the feed frame to define a feed module mounting plane; installing a take-up mounting panel onto the take-up frame to define a take-up module mounting plane; installing a one or more build panels onto the build frame to define a build module mounting plane; and aligning each of the mounting planes to form an alignment plane.

[0145] The method of one or more of these clauses, further comprising: positioning a fastener within a mount of the feed frame and a first mount of the build frame to operably couple the feed frame to a first side of the build frame; and positioning a fastener within a mount of the take-up frame and a second mount of the build frame to operably couple the take-up frame to a second side of the build frame.

[0146] The method of one or more of these clauses, further comprising: installing a resin support through the apparatus, wherein the resin support has a first portion operably coupled with a feed spool and a second portion operably coupled with a take-up spool, and wherein an intermediate portion of the resin support extends through the build frame.

[0147] The method of one or more of these clauses, wherein the one or more build panels includes a first build panel and a second build panel, the first build panel supporting a first print module and the second build panel supporting a second print module, and wherein the first print module is upstream of the second print module.

[0148] The method of one or more of these clauses, further comprising: altering at least one of the feed module mounting plane, the take-up module mounting plane, or the build module mounting plane when a resin support moves from an original position to a misaligned position in a Y-axis direction as the resin support is translated from the feed frame to the take-up frame.

[0149] An additive manufacturing apparatus comprising: a build module including a build frame having a first mount on a first side thereof and a second mount on a second side thereof; a feed module including a feed frame, the feed frame including a third mount; and a take-up module including a take-up frame, the take-up frame including a fourth mount, wherein the first mount is operably coupled with the third mount and the second mount is operably coupled with the fourth mount.

[0150] The additive manufacturing apparatus of one or more of these clauses, further comprising: a resin support that defines a resin surface to support an uncured layer of resin, a first portion of the resin support position about a feed mandrel and a second portion of the resin support positioned about a take-up mandrel; and a first print module and a second print module within the build module, wherein the first print module is positioned upstream of the second print module, wherein the feed module and the take-up module each adjustable in a Y-axis direction to align the resin support at opposing ends of the build module along the first print module and the second print module.

[0151] The additive manufacturing apparatus of one or more of these clauses, further comprising: an alignment pad within a feed frame, the alignment pad defining an attachment void; a coupling

fastener positioned through a first aperture defined by a feed mounting panel and within the attachment void; and an adjustment fastener positioned through a second aperture defined by the feed mounting panel, the adjustment fastener configured to contact an alignment pad.
[0152] The additive manufacturing apparatus of one or more of these clauses, wherein the first mount and the second mount are welded to the build frame and machined in place to define a plane of an outer surface of the first mount and the second mount relative to the build frame, wherein the third mount is welded to the feed frame and machined in place to define a plane of an outer surface of the third mount relative to the feed frame, and wherein the fourth mount is welded to the take-up frame and machined in place to define a plane of an outer surface of the fourth mount relative to the take-up frame.
[0153] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Claims

1. An additive manufacturing apparatus comprising: a build module; a feed module configured to support a first portion of a resin support, the first portion of the resin support supported by a feed mandrel operably coupled to a feed mounting panel; a take-up module configured to support a second portion of the resin support, the second portion of the resin support supported by a take-up mandrel operably coupled to a take-up mounting panel, the take-up module positioned on an opposing side of the build module from the feed module; a first stop positioned between the first portion of a resin support and the feed mounting panel, the first stop defining a first distance between an inner edge of the first portion of the resin support and the feed mounting panel; and a second stop positioned between the second portion of a resin support and the take-up mounting panel, the second stop defining a second distance between an inner edge of the second portion of the resin support and the take-up mounting panel.
2. The additive manufacturing apparatus of claim 1, wherein the feed mandrel is configured to be placed in an engaged position or a disengaged position, and wherein a feed spool operably coupled with the first portion of the resin support is configured to rotate with the feed mandrel in the engaged position.
3. The additive manufacturing apparatus of claim 1, wherein the take-up mandrel is configured to be placed in an engaged position or a disengaged position, and wherein a take-up spool operably coupled with the second portion of the resin support is configured to rotate with the take-up mandrel in the engaged position.
4. The additive manufacturing apparatus of claim 1, wherein the first distance and the second distance are generally equal.
5. The additive manufacturing apparatus of claim 1, further comprising: a build frame supporting a first stage; a feed frame supporting the feed mounting panel; and a take-up frame supporting the take-up mounting panel, wherein one or more one or more mounts are positioned on opposing sides of the build frame for aligning the build frame to the feed frame and to the take-up frame.
6. The additive manufacturing apparatus of claim 5, further comprising: a first set of alignment pads defined by the feed frame; and a second set of alignment pads defined by the take-up frame, wherein each of the alignment pads within the first set of alignment pads and the second set of alignment pads defines a respective attachment void.

7. The additive manufacturing apparatus of claim 6, wherein the first set of alignment pads defined by the feed frame each includes a first aperture and a second aperture.
8. The additive manufacturing apparatus of claim 7, further comprising: a coupling fastener is positioned through the first aperture and into one of the attachment voids of the first set of alignment pads or the second set of alignment pads.
9. The additive manufacturing apparatus of claim 7, further comprising: an adjustment fastener is positioned through the second aperture and contacts one of the alignment pads within the first set of alignment pads and the second set of alignment pads, and wherein the adjustment fastener is configured to provide fine adjustment of one or more mounting planes.
10. An additive manufacturing apparatus comprising: a build module; a feed module configured to support a first portion of a resin support, the first portion of the resin support operably coupled with a feed spool supported by a feed mandrel; a take-up module configured to support a second portion of the resin support, the second portion of the resin support operably coupled with a take-up spool supported by a take-up mandrel; a first stop extending outwardly of the feed mandrel; and a second stop extending outwardly of the take-up mandrel.
11. The additive manufacturing apparatus of claim 10, wherein the take-up module positioned on an opposing side of the build module from the feed module.
12. The additive manufacturing apparatus of claim 10, further comprising: a feed mounting panel operably coupled with a feed frame, the feed mounting panel supporting the feed mandrel.
13. The additive manufacturing apparatus of claim 12, wherein the first stop is positioned between the first portion of the resin support and the feed mounting panel, the first stop defining a first distance between an inner edge of the first portion of the resin support and the feed mounting panel.
14. The additive manufacturing apparatus of claim 10, further comprising: a take-up mounting panel operably coupled with a take-up frame, the take-up mounting panel supporting the take-up mandrel.
15. The additive manufacturing apparatus of claim 14, wherein the second stop is positioned between the second portion of a resin support and the take-up mounting panel, the second stop defining a second distance between an inner edge of the second portion of the resin support and the take-up mounting panel.
16. An additive manufacturing apparatus comprising: a build frame supporting a first stage; a feed frame supporting operably supporting a feed mounting panel, the feed frame selectively couplable to a first side of the build frame; a feed mandrel operably coupled to a feed mounting panel and configured to support a first portion of a resin support, the feed mandrel rotatably about a first axis of rotation; a take-up frame supporting operably supporting a take-up mounting panel, the take-up frame selectively couplable to a second side of the build frame; and a take-up mandrel operably coupled to a take-up mounting panel and configured to support a second portion of a resin support, the feed mandrel rotatably about a second axis of rotation, wherein the second axis of rotation is parallel to the second axis of rotation.
17. The additive manufacturing apparatus of claim 16, further comprising: a first stop positioned between the first portion of a resin support and the feed mounting panel, the first stop defining a first distance between an inner edge of the first portion of the resin support and the feed mounting panel.
18. The additive manufacturing apparatus of claim 17, further comprising: a second stop positioned between the second portion of a resin support and the take-up mounting panel, the second stop defining a second distance between an inner edge of the second portion of the resin support and the take-up mounting panel.
19. The additive manufacturing apparatus of claim 16, wherein the feed mandrel is configured to be placed in an engaged position or a disengaged position, and wherein a feed spool operably coupled with the first portion of the resin support is configured to rotate with the feed mandrel in the engaged position.

20. The additive manufacturing apparatus of claim 16, wherein the take-up mandrel is configured to be placed in an engaged position or a disengaged position, and wherein a take-up spool operably coupled with the second portion of the resin support is configured to rotate with the take-up mandrel in the engaged position.