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(54) **Title:** ADDITIVE MANUFACTURING POST-PROCESSING SYSTEM

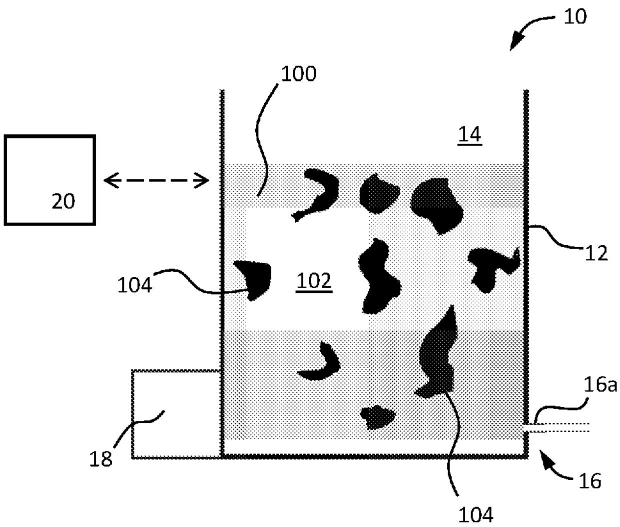

Figure 1

(57) **Abstract:** In certain examples, a build volume post-processing system comprises a container, a fluid delivery system, and an agitation system. The container may comprise a cavity, the cavity to receive a build volume comprising build material and at least one three-dimensional object. The fluid delivery system may deliver a fluid into the cavity. The agitation system may, in use, cause agitation of the fluid to separate the build material from the at least one printed three-dimensional object window.

[Continued on next page]

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ADDITIVE MANUFACTURING POST-PROCESSING SYSTEM

BACKGROUND

[0001] Additive manufacturing systems, including those commonly referred to as ‘3D printers’, build three-dimensional (3D) objects from selective addition of build material. In one example of additive manufacturing, an object may be generated by solidifying portions of layers of build material. In examples, the build material may be in the form of a slurry or a powder. In certain examples, energy may be applied to solidify the portions. To control the solidification process and the quality of the built three-dimensional objects, functional agents may be selectively deposited onto the layers.

[0002] Once the three-dimensional objects have been built, they must be removed, or ‘unpacked’, from the surrounding build material. In some cases, the three-dimensional objects may be cleaned to remove stubborn build material and/or functional agents. The removal and/or cleaning processes can be laborious and/or time consuming.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Various features of the present disclosure will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate features of the present disclosure, and wherein:

[0004] Figure 1 is a schematic diagram of an example build volume post-processing system.

[0005] Figure 2 is a schematic diagram of an example build volume post-processing system.

[0006] Figure 3 schematically illustrates a build volume post-processing operation according to one example.

[0007] Figure 4 schematically illustrates a build volume post-processing operation according to one example.

[0008] Figure 5 schematically illustrates a build volume post-processing operation according to one example.

[0009] Figure 6 schematically illustrates a build volume post-processing operation according to one example.

[0010] Figure 7 schematically illustrates a build volume post-processing operation according to one example.

[0011] Figure 8 schematically illustrates a build volume post-processing operation according to one example.

[0012] Figure 9 schematically illustrates a build volume post-processing operation according to one example.

[0013] Figure 10 schematically illustrates a build volume post-processing operation according to one example.

[0014] Figure 11 is a flow chart of an example method of post-processing a build volume according to one example.

[0015] Figure 12 is a flow chart of an example method of post-processing a build volume according to one example.

[0016] Figure 13 is a schematic diagram of an example build volume post-processing system according to one example.

DETAILED DESCRIPTION

[0017] Three-dimensional (3D) objects can be generated using additive manufacturing techniques.

[0018] The objects may be generated by solidifying portions of successive layers of build material. The portions of build material to be solidified on each layer may be determined by solidification areas mapped out on each layer of build material. The build material may be powder-based and the material properties of generated objects may be dependent on the type of build material and the type of solidification. For example, various plastic powder types can be used as the raw build material. In other examples, metal powders may be used. In other examples, other build materials may be used. In certain examples, the build material includes paste material, slurry material or liquid material. In certain additive manufacturing systems, the build material may be changed between builds.

[0019] In certain additive manufacturing techniques, the objects may be generated using fused deposition modeling (FDM) where a molten build material is extruded from a movable nozzle to build the 3D object. The nozzle is moved in two-dimensions as the molten build material is forced through the nozzle such that the 3D object is build up by depositing a molten filament of the build material layer-by-layer. In certain examples, the 3D object may be supported as it is built by support structures that have also been built with the movable nozzle. The support structures may need to be removed once the 3D object is completed. For example, the support structures may be dissolved by a solvent once the 3D object is built.

[0020] Suitable build materials for additive manufacturing include polymers, crystalline plastics, semi-crystalline plastics, polyethylene (PE), polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), thermoplastic polyurethane (TPU), amorphous plastics, Polyvinyl Alcohol Plastic (PVA), Polyamide (such as polyamide (PA) 11, PA12), thermo(setting) plastics, resins, transparent powders, colored powders, metallic powder (for example, a metal, metal alloy, or metalloid powder), ceramics powder such as for example glass particles, and/or a combination of at least two of these or other materials wherein such combination may include different particles each of different materials or different materials in a single compound particle. Examples of blended build materials include alumide, which may include a blend of aluminum and polyamide, multi-color powder, and plastics/ceramics blends.

[0021] According to one example, a suitable build material may be PA12 build material commercially known as V1R10A ‘HP PA12’ available from HP Inc. There exist more build materials and blends of build materials that can be managed by example apparatuses disclosed herein and that are not mentioned in this disclosure.

[0022] In certain examples, solidification of the build material is enabled and controlled using functional agents.

[0023] In some examples, solidification of the build material may be enabled by the selective addition of functional agents that bind the build material together at the selected portions.

[0024] In certain examples, functional agents such as a binding agent may be selectively applied to the build material. For example, a binding agent may be a material that, when applied to a portion of the build material, causes the portion of the build material to bind together. The binding agent may cause the portion of the build material to solidify. For example, the portion of the build material may bond together on the application of the binding agent.

[0025] The binding agent may be applied to any suitable build material, such as, for example, any of the build materials above. For instance, in one example, the binding agent may be selectively applied to a metallic powder as described herein to bind portions of the metallic powder together. In some examples, the binding agent may be fired onto the build material by jet nozzles. In some cases, this may be termed metal binder jetting.

[0026] In certain examples, the applied binding agent may define the solidification areas of a layer of build material, which correspond to the portions of a layer of build material that are to be solidified. In certain examples, the binding agent causes a chemical reaction that causes the portion of build material to bind together. In certain examples, the binding agent causes the particles of the portion of the build material to bind together by sticking together.

[0027] One example of a binding agent is a latex binder. In some examples, metal 3D objects may be formed from solidifying portions of a metal powder build material layer. In some examples, a latex binder may be used to bind portions of the metal build material layer.

[0028] In some examples, additional treatments may be applied to the binding agent treated build material to 'set', or 'cure', the portion of build material. This may be so that the completed 3D object has sufficient strength to be handled and/or used. For example, the portion of build material and/or a completely built three-dimensional object may be treated with heat or light to cure the binding agent and/or the build material. In other examples, no further treatment will be applied to the build material to which the binding agent has been applied. In some cases, the cured 3D object may be called a 'green' object. For example, where portions of a metal build material are bound together to form the 3D object, the cured 3D object may be called a 'green' metal object. Further post-processing may take place on the 'green' 3D object, for example the 'green' 3D object may be heated or sintered. In an example, where a latex binder is used to bind portions of a metal build material together, the latex binder may be dried and/or cured to provide the 3D object with sufficient strength to be a 'green' 3D object. For example, the latex binder may be heat cured.

[0029] In certain examples, solidification of the build material may be enabled by temporary application of energy to selected portions of the build material. The applied energy may, for example, cause the selected portions of the build material to melt or soften, and then re-solidify such that the particles of the build material stick together. In some examples, the particles of the build material may be sintered together.

[0030] In certain examples, functional agents such as fusing agents are applied to the build material. In an example, a fusing agent is a material that, when a suitable amount of energy is applied to a combination of build material and fusing agent, causes the build material to heat up sufficiently to melt, coalesce, sinter, or otherwise fuse, and to solidify upon cooling.

[0031] The fusing agent may be, for example, an energy absorber. According to one example, a suitable fusing agent may be an ink-type formulation comprising carbon black, such as, for example, the fusing agent formulation commercially known as V1Q60A, 'HP fusing agent', available from HP Inc. In one example, such a fusing agent may additionally comprise an infrared light absorber. In one example, such an ink may additionally comprise a near infrared light absorber. In one example, such a fusing agent may additionally comprise a visible light absorber. In one example, such an ink may additionally comprise a UV light absorber. Examples of inks comprising visible light enhancers are dye based colored ink and pigment based colored ink, such as inks commercially known as CE039A and CE042A, available from HP Inc.

[0032] The fusing of the build material may be by melting or sintering of the build material, for example. In certain examples, the applied fusing agent may define the solidification areas of a layer of build material, which correspond to the portions of a layer of build material that are to be solidified. In cases where solidification is achieved by the temporary application of energy, the fusing agent aids the absorption of the energy into the portions of a build material to be solidified. In certain examples, the energy may be radiatively applied to the layer of build material. For example, the thermal radiation may be applied to the layer of build material. For example, the energy may be applied to the layer of build material by infrared lamps. For example, the energy may be applied to the layer of build material by the direct application of heat to the build material by a laser.

[0033] In an example, the fusing agent may be a liquid that is applied to the layer of build material. In an example, the fusing agent may be printed onto the layer of build material. For example, the fusing agent may be an ink-type formulation printed on the layer of build material. In certain examples, the fusing agent may be printed onto the layer of build material by jet nozzles.

[0034] In certain examples, the solidification of the build material may be controlled using detailing agent. In an example, the detailing agent may be selectively applied to a layer of build material where the fusing action is to be reduced. For example, a detailing agent may be applied to reduce fusing at an object boundary to produce a part with distinct and smooth edges. The detailing agent may aid the definition of the 3D object borders and/or surfaces. The detailing agent may reduce thermal distortion in the printed 3D object layer. In an example, a detailing agent may be selectively applied to regions of a layer of build material that are not to be fused. The detailing agent may be printed on the build material. The detailing agent may be water-based. The detailing agent may be arranged to absorb thermal energy. According to one example, a suitable detailing agent may be a formulation commercially known as V1Q61A ‘HP detailing agent’ available from HP Inc.

[0035] In certain examples, a combination of binding and fusing agents may be used. In other examples, other methods of solidification may be used.

[0036] In certain examples, a filler material may selectively replace the build material in certain portions of the layers of build material. The filler material may be beneficial because it reduces the use of the build material in the additive manufacturing techniques. In some build processes, the build material may degrade during the process. This may be, for example, due to the heat or humidity to which the build material is exposed during the build process. The non-solidified build material may become contaminated, for example due to oxidization during the build process. In some cases, the contamination may be prevalent when the build material is recycled and used in multiple build processes. For example, non-solidified metallic build material may be oxidized during the build process. Due to the contamination, the non-solidified build material may not easily reused in a subsequent build process. Thus, where a filler material replaces certain portions of the build material, less build material may be degraded compared with a build process where the filler material is not used. Hence, a smaller inventory of build material may be carried and fewer resources are expended on recycling. In this way, for example, the cost associated with the use of build material may be reduced.

[0037] Where portions of the successive layers of build material are not located near to areas of the layer of build material that are to be solidified, the filler material can be used instead of the build material. A buffer zone, or suitable margin of error, of non-solidified build material can be used around the areas of the layer or build material that are to be solidified to prevent any build errors occurring in the built 3D object(s).

[0038] Suitable filler materials for additive manufacturing may be any material having the properties to act as a filler. The filler material may be beneficially chosen to possess properties that complement the build material and/or functional agents. Such properties may include being able to withstand the treatments applied to neighbouring build materials in a build layer during a build process. For example, the filler material may be a material that can withstand the energy applied during a fusing process. For example, the filler material may not react when coming into contact with a binding agent, such as, for example, any of the binding agents described above. In some examples, the filler material may be a material having a low thermal conduction. In some examples, the filler material may be a material having a relatively high electrical resistance. In some examples, the filler material may be a thermal energy absorbing material. For example, the filler material may be used to insulate 3D objects so as to prevent residual heat from the build process transferring between the 3D objects. For example, where the build material is a plastics material, the temperature of the build plastic 3D objects may be maintained at an acceptable level by the insulating and/or energy absorbing effect of the filler material. In another example, the filler material may operate in conjunction with the detailing agent to prevent surrounding build material from sticking to 3D objects. In some examples, the filler material may be chosen to absorb excess functional agents. For example, the filler material may be selected to absorb residual solvents from functional or print agents applied during the build process so as to prevent the solvents weakening the completed 3D objects and/or prevent solvents leaking into portions of build material not intended for solidification causing that build material to stick to the 3D object surface.

[0039] For example, the filler material may be selected from one or more of the following: a ceramic material, a plastics material, or a glass material. The filler material may be provided in any suitable form, for example, as a powder, as a paste, or as a liquid.

[0040] Additive manufacturing systems may comprise different units. An example of an additive manufacturing system may comprise a controller and a build unit. The controller may comprise a storage module encoded with instructions executable by a processor as described further below. In certain examples, the build unit may be a component that is separate from the remaining components of the additive manufacturing system. For example, the build unit may be a removable or interchangeable unit that is separate from the controller. For example, the build unit may be interchangeable with other build units which have different operating parameters, such as being to build with different build materials. In an example, the build unit may be interchangeable with another build unit so that further 3D objects can be built as the first used build unit is removed for post-processing which may involve any one more of removing 3D object(s) in the build unit, cooling, removing excess build material, and cleaning. In some cases, the build unit may be interchangeable with another build unit for the sake of regular maintenance of the build unit(s).

[0041] The build unit may comprise a build platform that provides a working area on which a 3D object may be built. The additive manufacturing system may comprise a printing system. In certain examples, the printing system may be a separate component of the additive manufacturing system. For example, the printing system may be a removable or interchangeable system that is separate from the build unit. For example, the printing system may be interchangeable with other printing systems which have different operating parameters, such as being to deposit a different range of materials.

[0042] The printing system may comprise a build material deposit system for depositing a layer of build material on the build platform. A build material store may contain build material from which a 3D object may be built. In certain examples, the build unit may comprise the build material store. In certain examples, the printing system may comprise a filler material deposit system for depositing a filler material in portions of the layer of build material. A filler material store may be provided to contain and supply filler material.

[0043] In certain examples, the printing system may comprise a functional agent application system to apply functional agent(s) to the layer of build material. For example, the functional agent application system may comprise a set of printheads with nozzles that fire the functional agent(s) onto the layer of build material. The functional agent(s) may be any of the functional agents described above. For example, the functional agent application system may comprise a set of printheads with nozzles that print ink on the layer of build material.

[0044] In certain examples, the printing system may comprise a binding agent application system to apply binding agent to the layer of build material. In certain examples, the printing system may comprise a fusing agent application system to apply fusing agent to the layer of build material. And certain examples, the printing system may comprise a detailing agent application system to apply detailing agent to the layer of material.

[0045] The additive manufacturing system may comprise a fusing system. In certain examples, the printing system may be integrated with the fusing system. In an example, the fusing system may temporarily apply energy to a layer of build material deposited on the build platform. In certain examples, the energy may be applied substantially uniformly across the whole layer of build material. For example, the energy source of the fusing system may be 'scanned' over the width of the layer of build material to apply energy to the whole of the layer of build material. For example, the fusing system may temporarily apply energy to solidification areas of the layer of build material defined by fusing agent applied to the layer of build material.

[0046] It should be understood that the additive manufacturing system may comprise all of, or some of, or one of, the units, components, and/or systems described above. For example, the additive manufacturing system comprising a controller and a printing system may be supplied to a user separately of a build unit. Such an additive manufacturing system may be to operate with a range of different build units, for example. In an example, the additive manufacturing system comprising the controller having a storage module encoded with executable instructions, as described further below, may be supplied to a user separately of a printing system, and/or a build unit.

[0047] An example build process will now be described. In certain examples, the build process may be performed in the build unit of the additive manufacturing system based on data derived from a 3D object model of a 3D object, such as the 3D object identified above.

[0048] The build process may involve forming, in the build unit, a build volume comprising the 3D object and build material. In some examples, it may be desirable to build more than one 3D object with the build unit at the same time; hence, the build process may involve forming a build volume comprising a plurality of 3D objects. At the end of the build process, the completed build volume may comprise solidified and non-solidified build material from layers of build material.

[0049] The build process may be performed in the build unit of the additive manufacturing system based on build data derived from a virtual build volume of the build volume. Depending on whether the build process is to build one 3D object or a plurality of 3D objects, the virtual build volume may comprise a corresponding 3D object model or a plurality of corresponding 3D object models. For example, the virtual build volume may be a virtual build volume of the working area of the build unit in which several 3D object models are spatially arranged for the purposes of deriving build data for the build volume. In certain examples, the controller of the additive manufacturing system may instruct the build unit to perform the build process based on the build data derived from the virtual build volume.

[0050] In certain examples, the build data may include build data relating to each build layer to be formed on the built platform to fabricate the build volume. For example, the build data relating to each build layer includes build data defining the solidification area(s) for each build layer. The build data may define the boundary(ies), and therefore the size and position, of the solidification area(s) with respect to the build platform of the build unit.

[0051] In certain examples, the build data relating to each build layer includes build data defining areas of each build layer in which the build material is replaced with filler material. The build data may define the boundaries, and therefore the size and position with respect to the build platform, of the areas in which build material is to be replaced with filler material.

[0052] The build data relating to each build layer may be derived by slicing the virtual build volume at regular intervals along one of its axes to define a series of cross-sectional virtual slices through the virtual build volume. The series of cross-sectional virtual slices may be parallel cross-sectional slices. The size of the interval may correspond with the desired thickness of each build layer, which may be determined by such factors as desired resolution of the built 3D object(s).

[0053] Each cross-sectional virtual slice may define those portions of each respective build layer of build material which are to be solidified. Where a slice through the virtual build volume intersects an outer surface of a 3D object model, the intersection of the slice and the outer surface may define the boundary(ies) of the solidification area(s) defined in the build data.

[0054] In certain examples, each cross-sectional virtual slice may also define the areas of each layer in which build material is to be replaced by filler material may be derived. In certain examples, the boundaries of the areas from which build material to be replaced by filler material can be calculated based on the boundaries of the solidification areas defined in the build data for each respective build layer. In some examples, a tolerance, or margin, of build material around the boundaries of the solidification areas can be provided for to ensure that no filler material is deposited in, or near to, any areas that are to be solidified in each respective layer.

[0055] To build a three-dimensional (3D) object, or a plurality of 3D objects, with, for example, the additive manufacturing system above, a series of build layers are successively added to the build platform or added to an existing layer on the build platform, during a build process. Each build layer comprises a layer of build material deposited on the build platform or deposited on an existing layer on the build platform. In certain examples, functional agents may selectively applied to the layer of build material, based on build data as discussed above. In certain examples, filler material may be deposited on the build platform to replace build material in selected areas of the build layer.

[0056] In certain examples, binding agent is selectively applied to the layer of building material to define solidification areas of the build layer where the build material is to be bound together. The action of the binding agent binds together those portions of the build material to which it is applied. For example, portions of the build material, corresponding to the solidification areas of the build layer, may be bound together by the binding agent. The bound portions define one solidified layer of the 3D object.

[0057] In certain examples, fusing agent is selectively applied to the layer of build material to define solidification areas of the build layer where the build material is to be fused together. Energy may, in some examples, then be applied to the build layer by the fusing system. In certain examples, detailing agent may be applied to regions of the layer of build material. In certain examples, following the application of functional agents, the subsequent application of energy fuses portions of the build material according to the agents that have been applied. For example, portions of the build material, where fusing agent was applied, may be fused by the absorption of the applied energy. The fused portions define one solidified layer of the 3D object. In certain examples, where detailing agent has been applied to regions of the layer of build material, the fusing action may be reduced or completely nullified by absorbing the energy without fusing the build material.

[0058] In certain examples, the build platform may be moved so that another layer may be added on top of the completed layer. For example, the build platform may be moved vertically downwards so that another layer of build material may be deposited on top of the previous build layer. The build process may continue by building the next build layer in the series thereby adding another layer to the build volume. The build process may continue adding build layers and selectively solidifying portions of them until the build volume is completed. The build volume may be completed once all the solidified layers of the 3D object, or the plurality of 3D objects, are built. The completed build volume comprises completed 3D object(s) and non-solidified build material that surrounds the 3D object(s).

[0059] As noted above, in certain examples, a filler material may selectively replace the build material in certain portions of the build layer(s). In some examples, the completed build volume may comprise completed 3D object(s), non-solidified build material, and filler material. In some instances, the completed build volume may comprise completed 3D object(s) and filler material.

[0060] Once the build volume is completed, the completed 3D object(s) can then be removed, or ‘unpacked’, from the build volume. In some examples, the completed build volume can be removed from the build platform and the completed 3D object(s) can then be removed from the build volume. In other examples, the completed 3D object(s) can then be removed from the build volume whilst in situ on the build platform.

[0061] To remove the completed 3D object(s) from the build volume, the non-solidified build material may be removed from around the completed 3D object(s). In certain examples, the build volume may be post-processed once completed in order to remove the build material from around the 3D object(s). Some methods of post-processing build volumes are complex and laborious. The method chosen depends on the selected build material used to form the build volume and the methods chosen to solidify the 3D object(s) in the build volume.

[0062] For instance, where the build material has been fused to together as described above for example, the 3D object(s) may be sandblasted to remove the build material from around the 3D object. In other cases, where the build material has been bound together by a binding agent, the 3D object(s) may be carefully removed from the surrounding non-solidified build material using brushes before the 3D object(s) are removed for further cleaning.

[0063] In certain examples, the bulk of the build material surrounding the 3D object(s) may be removed first. For example, the bulk of the build material surrounding the 3D object(s) may be removed by vacuuming around the 3D object(s) using a vacuum hose. In other examples, the bulk of the build material surrounding the 3D object(s) may be removed by dislodging the build material with compressed air. In some examples, the bulk of the build material surrounding the 3D object(s) may be removed by sieving the build material from the 3D object(s). However, whilst vacuuming, for example, can remove the bulk of the build material without too much effort, some build material will remain between 3D object(s) in the build volume and, furthermore, in some cases, between complex surfaces of the 3D object(s) themselves. Moreover, it can be difficult to reach the lower build layers of the build volume beneath the 3D object(s) to remove the build material. Vacuuming from the underside of the build volume does not improve the situation since the layers above the completed 3D object(s) are also obstructed. Such post-processing methods often involve much manual labour and are therefore time-consuming, inefficient, and expensive.

[0064] Vacuuming around the 3D object(s) in the build volume in this manner can present other difficulties. The build material may be in a very fine powder form and, as such, can pose risks such as respiratory difficulties for those working with the additive manufacturing systems. Furthermore, depending on the build material, the fine powder can present an explosion risk, which may involve careful management and, therefore, added processing expense.

[0065] Furthermore, due to the nature of the build process, which involves binding and/or fusing material, for example, build material can remain stuck, or more strongly attached, to the surfaces of the 3D object(s). In some instances, a firmer cleaning approach may be required. The build material stuck to the surface of 3D object(s) may be post-processed to remove it by, for example, sandblasting, bead-blasting, or brushing the 3D object(s). For example, detailing agent may remain on the surfaces of the 3D object(s) causing excess build material to stick to the 3D object(s).

[0066] In the case of build processes that use binding agent, various remaining solvents used in the binding agent can cause build material to stick like wet clay to the 3D object(s).

[0067] In some instances, residues of functional agents may also remain on the surfaces of the 3D object(s). In some build processes, residual compounds may remain on the surfaces of the 3D objects, or in the build material that clings to the surfaces of the 3D objects. For example, residual solvents and/or surfactants may remain proximal to the 3D object surfaces, which can weaken the completed 3D objects. In metal-based build processes, where a latex-based binder is used, for example, the solvents and surfactants may prevent the latex from hardening, which can weaken the completed 3D objects. For example, in some examples of metal binder jetting, a latex residue may remain on the surfaces of the 3D objects.

[0068] In certain examples, the build volume may be heated in order to evaporate any residual functional agents. The heating may be done at a slow rate, for example, such that heat is gradually transferred towards the centre of the build volume. The drawback of heating the build volume in this way is that the temperature distribution in the build volume is not uniform. For example, the outer regions of the build volume will be hotter than the centre of the build volume. In addition to this method not being very effective at removing residual functional agents, the process can also affect the mechanical properties of the 3D object(s) depending on their location in the build volume.

[0069] The Applicants have developed a build volume post-processing system that removes many of the laborious manual tasks associated with removing the build material from around completed 3D object(s) in the build volume.

[0070] An example of a build volume post-processing system 10 is shown in Figure 1. The build volume post-processing system 10 comprises a container 12. The container 12 comprises a cavity 14. The cavity 14 may comprise a bottom portion that comprises the lowermost, or deepest, part of the cavity 14. The cavity

14 may comprise a top portion that comprises the uppermost part of the cavity 14.

[0071] In use, the cavity 14 may receive a build volume 100 that comprises build material 102 and at least one three-dimensional (3D) object 104. The at least one (3D) object 104 may be a built 3D object 104. In some examples, the build volume 100 may comprise a plurality of 3D objects 104. In some examples, the build volume 100 may also comprise filler material as discussed above.

[0072] The build volume post-processing system 10 further comprises a fluid delivery system 16. In use, the fluid delivery system 16 may deliver a fluid into the cavity 14. The fluid may be any suitable fluid that can be used for post-processing a build volume. For example, the fluid may be a liquid, a gel, or a paste. For example, the fluid may be a liquid such as a water-based liquid. In some examples, the fluid may be water. In some examples, the fluid may contain agents that aid the separation of the build material from 3D object(s). For example, the fluid may be a liquid that contains solvents that act to dissolve the functional agents, or components thereof, that cause non-solidified build material to remain attached to completed 3D object(s). For example, the liquid may be water that contains water-soluble solvents. In certain examples, the fluid may be a colourant that imparts a colour to the surfaces of the 3D object. For example, the fluid may be a paint. The fluid may be a liquid paint, for example. The fluid may be a colour powdercoat, for example. In some examples, the fluid may be a varnish to varnish the surfaces of the 3D object(s).

[0073] In some examples, the fluid may be selected so that it does not compromise the strength of the completed 3D object(s). In some examples, where a binding agent has been used to bind together portions of a build material, the fluid may be chosen so as to not adversely affect the properties of the binding agent. For example, where a latex binder has been used to bind together a metal build material to form a ‘green’ 3D object, the fluid may be selected so as to not adversely affect the latex binder.

[0074] In some examples, the container 12 may comprise a heating system to heat the fluid delivered into the cavity 14. For example, the container 12 may comprise heater elements located in the walls of the cavity 14. In other examples, the build volume post-processing system 10 may comprise a heating system to heat the fluid before it is delivered into the cavity 14.

[0075] The build volume post-processing system 10 further comprises an agitation system 18. In use, the agitation system 18 causes agitation of the fluid to separate build material from the at least one 3D object 104. In certain examples, the agitation system 18 may cause agitation of the fluid and the build volume 102 to separate build material from the at least one 3D object 104. In certain examples, the agitation system 18 may cause agitation of the fluid and the at least one 3D object 104 to separate build material from the at least one 3D object 104.

[0076] In certain examples, where filler material has been used in the build process for building the build volume, the agitation system 18 may cause agitation of the fluid to dislodge the filler material from the build volume. In certain examples, where filler material has been used in the build process for building the build volume, the agitation system 18 may cause agitation of the fluid to dislodge the filler material from the 3D object(s). In certain examples, the agitation system 18 may cause agitation of the fluid and the filler material to dislodge the filler material from the build volume. In certain examples, the agitation system 18 may cause agitation of the fluid and the filler material to dislodge the filler material from the 3D object(s).

[0077] The build volume post-processing system 10 may further comprise a controller 20. In use, the controller 20 may control functions of the build volume post processing system 10. For example, and as discussed further below, the controller 20 may control the delivery of fluid into the cavity 14 by the fluid delivery system 16. In some examples, the controller 20 may be co-located with the container 12, fluid delivery system 16, and agitation system 18. In other examples the controller 20 may be remotely located from the rest of the build volume post-processing system 10.

[0078] In certain examples, the build volume post-processing system 10 may form a part of another system. For example, an additive manufacturing system, such as the additive manufacturing system described above, may comprise the build volume post-processing system 10. For example, the build volume post-processing system 10 may form a part of a build unit in which the 3D object(s) is formed, such as any of the build units described above. For example, the build volume post-processing system 10 may form a part of a removable or interchangeable build unit as described above. In certain examples, the build unit of the additive manufacturing system may comprise the container 12. For example, the container 12 and the build platform may be assembled together in the build unit. For example, the cavity of the container 12 may surround and/or support the build platform on which a build volume, such as any of the build volumes described above, is formed. In such examples, the build volume may be formed inside the cavity of the container 12. This arrangement may allow a build volume to be post-processed immediately by the build volume post-processing system 10 as soon as the build volume is completed. In some cases, the controller 20 may be a controller of the additive manufacturing system. For example, the controller 20 may be the build unit controller described above.

[0079] In certain examples, the build volume post-processing system 10 may be a standalone system. For example, a build volume, such as any of the build volumes described above, may be transferred to the cavity 14 of the container 12 once the build volume has been completed in a build unit, m, such as any of the build units described above. In certain examples, the completed build volume may be transferred on the build platform to the cavity 14 of the container 12. For example, the cavity 14 of the container 12 may comprise a receptacle to accommodate the build platform of the build unit. In some examples, the build volume may be removed from the build platform of the build unit and placed into the cavity 14 of the container 12 for post-processing.

[0080] In certain examples, the fluid delivery system 16 may comprise a fluid inlet 16a and a fluid delivery conduit that delivers the fluid to the cavity 14 through the fluid inlet 16a. In some examples, and is shown in Figure 1, the fluid inlet 16a may be located near the bottom portion of the cavity 14 thereby allowing the cavity 14 to be filled with fluid from its bottom. In some examples, the fluid delivery system 16 may comprise a fluid reservoir.

[0081] In some examples, the fluid delivery system 16 may comprise a dispensing system that dispenses the fluid into the cavity 14 of the container 12 through an opening at the top of the cavity. For example, the dispensing system may comprise a hose that is placed near or at the top of the cavity 14 to deliver the fluid.

[0082] In certain examples, the agitation system 18 may comprise a vibration system. In use, the vibration system may vibrate the fluid when it has been delivered into the cavity 14 of the container 12. In certain examples, the vibration system may vibrate the fluid and the build volume 102.

[0083] In some examples, the vibration system may comprise an ultrasonic wave generator. The ultrasonic wave generator may ultrasonically vibrate the fluid by transmitting ultrasonic waves into the fluid inside the cavity 14. The ultrasonic waves transmitted to the fluid may vibrate any non-solidified build material stuck to the 3D object thereby releasing it from the surface of the 3D object. In some examples, where filler material has been used in the build process, the ultrasonic waves transmitted to the fluid may also dislodge any filler material in the build volume.

[0084] Another example of a build volume post-processing system 10 is shown in Figure 2. As with the example shown in Figure 1, the build volume post-processing system 10 comprises a container 12 and the container 12 comprises a cavity 14. In use, the cavity 14 may receive a build volume 100 that comprises build material 102 and at least one three-dimensional (3D) object. The at least one three-dimensional (3D) object 104 may be a built three-dimensional (3D) object 104. As shown in Figure 2, in some examples, the build volume 100 may comprise a plurality of 3D objects 104.

[0085] As also shown in Figure 2, in some examples, the build volume 100 may comprise a filler material 106. As Figure 2 illustrates, and as discussed above, the filler material 106 may surround portions of non-solidified build material 102 that, in turn, surround the build 3D object(s) 104. a greater proportion of filler material 106 than build material 102.

[0086] In certain examples, agitation system 18 may comprise a compressed gas injection system. In use, the compressed gas injection system may agitate the fluid as compressed gas is delivered into the cavity 14 of the container 12. In certain examples, the compressed gas injection system may agitate the fluid and the build volume 102. In some examples, the compressed gas injection system may also agitate the filler material 106. In some examples, the delivery of the compressed gas into the cavity 14 creates bubbles of gas in the fluid. The motion of the bubbles of gas through the fluid, for instance as they rise from the bottom of the cavity to the top of the cavity, may agitate the fluid and thereby separate build material from the least one 3D object. In some examples, the motion of the bubbles of gas through the fluid may cause the filler material 106 to be dislodged.

[0087] In certain examples, the agitation system 18 may comprise a porous surface located in the cavity 14 of the container 12. In some cases, the porous surface may be located, in use, beneath the build volume 102 when it is received in the cavity 14. The compressed gas may be injectable into the cavity through the porous surface. By injecting the compressed gas through the porous surface, the size of the bubbles of gas created in the fluid in the cavity 14 can be controlled. For example, the porosity of the porous surface can be defined such that the bubbles of gas created in the fluid are small thereby increasing the effectiveness of the agitation of the fluid and thereby the separation of the build material from the at least one 3D object.

[0088] In certain examples, the porous surface may comprise a surface of a plate located in the cavity 14 of the container 12. For example, the porous surface may comprise the top surface of a plate 182 located in the bottom portion of the cavity 14. The plate 182 may comprise a plurality of holes 183 that render the plate 182 porous. The holes 183 through the plate 182 define channels through which the compressed gas may be injected.

[0089] The agitation system 18 may comprise at least one compressed gas inlet 184. As Figure 2 shows, the agitation system 18 may comprise a plurality of compressed gas inlets 184. Any suitable number of compressed gas inlets 184 may be provided. The at least one compressed gas inlet 184 may deliver the compressed gas into a plenum 186 located beneath the plate 182. As illustrated in Figure 2, the plenum 186 may be defined by the bottom surface of the plate 182 and the lowest surface of the cavity 14. In use, the plenum 186 allows the compressed gas to be delivered from the inlet 184 through the holes 183 and into the fluid in the cavity 14. In some examples, the plate 182 may be sealed against the immediately adjacent surfaces of the cavity 14 to prevent gas escaping around the edges of the plate and/or prevent fluid entering the plenum 106. In some examples, the agitation system 18 may comprise compressed gas supply 188. For example, the compressed gas supply 188 may comprise a compressor, a reservoir, or a compressed gas supply outlet.

[0090] In certain examples, the build volume post-processing system 10 may comprise a fluid removal system. The fluid removal system may, in use, remove fluid from the cavity 14 of the container 12. For example, the fluid removal system may be used to remove fluid from the cavity 14 once the agitation system 18 is determined to have completed agitating the fluid that has been delivered to the cavity 14. In certain examples, the fluid removal system may be used to remove build material 102 from the cavity 14. In some examples, the fluid removal system may be used to remove filler material 106 from the cavity 14.

[0091] In some examples, the fluid removal system may comprise at least one fluid outlet in fluid communication with the cavity 14. In certain examples, the fluid removal system may comprise a plurality of fluid outlets in fluid communication with the cavity 14. For example, at least one of, or a plurality of, fluid outlets may be provided in fluid communication with the bottom portion of the cavity 14. For example, at least one of, or a plurality of, fluid outlets may be provided in fluid communication with the top portion of the cavity 14. In certain examples, the at least one fluid outlet may be connected to a suction system. The suction system may be used to removing fluid and other materials, from the cavity 14.

[0092] In some examples, and as shown in Figure 2, the fluid removal system may comprise at least one fluid outlet 22 located in the bottom portion of the cavity 14. In the example, shown in Figure 2 the at least one fluid outlet 22 passes through the plate 182 and plenum 186 and out through the lower surface of the cavity 14. Any suitable number of fluid outlets 22 may be provided in the bottom portion of the cavity 14. In some cases, the at least one fluid outlet 22 may be connected to a fluid outlet conduit 22a. In some examples, the at least one fluid outlet 22 may be used to remove build material 102 and/or filler material 106 from the cavity 14.

[0093] In some examples, and as shown in Figure 2, the fluid removal system may comprise at least one fluid outlet 24 located in a top portion of the cavity 14. In some examples, the at least one fluid outlet 24 may be located at container lid 26 that may be used to close an opening into the cavity 14 of the container 12. The opening may be used, in some cases where the build volume post-processing system 10 is not a component of a build unit, to place the build volume into the cavity 14. The opening may also be used to access the post-processed 3D object(s). Any suitable number of fluid outlets 24 may be provided in the top portion of the cavity 14. In some cases, the at least one fluid outlet 24 may be connected to a fluid outlet conduit 24a. In some examples, the at least one fluid outlet 24 may be used to remove build material 102 and/or filler material 106 from the cavity 14.

[0094] The cavity 14 of the container 12 may be constructed so that the cavity 14 has a large enough volume to accommodate the build volume. In certain examples, the cavity 14 of the container 12 may be constructed so that an empty volume 108 is provided above a build volume received in the cavity 14. The empty volume 108 may allow additional space in the cavity so that the build volume post-processing system 10 may perform the functions as described below.

[0095] With reference to Figures 3 and 4, the operation of a build volume post-processing system, for example any of the build volume post-processing systems 10 as described herein, will now be described.

[0096] In certain examples, to post-process a build volume with the build volume post-processing system 10, a completed build volume may be received within the cavity 14 of the container 12. For example, the build volume may be placed into the cavity 14 of the container 12. In other examples, a build volume may be received in the cavity 14 by being completed on the build platform of a build unit that comprises the container 12 and, hence the build volume is in situ in the cavity 14 of the container 12 once completed.

[0097] Once the build volume is located in the cavity 14 of the container 12, a fluid may be delivered, or applied, to the cavity 14. As discussed above, the fluid may be any fluid suitable for use in separating the non-solidified build material from the 3D object(s). The fluid may be delivered, or applied, to the cavity 14 by the fluid delivery system 16. In the example shown in Figure 3, a fluid 200, such as any of the fluids described herein, is fed to the cavity through the fluid inlet 16a located in the bottom portion of the cavity 14. Thus, in this example, the fluid 200 floods the build volume 100 from below as it is injected into the cavity 14.

[0098] In certain examples, a predetermined amount of fluid may be applied, or delivered, to the cavity 14. In other examples, a fluid may be continuously applied to the cavity 14. For example, the fluid may be injected into the cavity 14 and then drained from the cavity 14 before being recirculated and re-injected into the cavity 14.

[0099] Figure 3 shows a container 12 in which the cavity 14 has been injected with the fluid 200 such that the fluid 200 begins to separate the build material 102 from the 3D object(s) 104 of a build volume 100 that is located in the cavity 14. In some examples, the fluid may be injected into the cavity 14 to, at least partially, immerse a build volume 100 that is located in the cavity 14. In some examples, the fluid may be injected into the cavity 14 and not begin separating the build material 102 from the 3D object(s) 104 of a build volume 100 that is located in the cavity 14. In the case of the example shown in Figure 3, the build volume 100 also comprises filler material 106 that has replaced the build material 102 in certain portions of the build volume 100 during the build process. As discussed above, in other examples build volume may comprise build material and 3D object(s) but not be composed of any filler material.

[00100] In certain examples, the fluid can be preheated before it is injected into the cavity 14 to aid the post-processing of the build volume. In other examples, the fluid may be heated by heater elements located in the build volume post-processing system. For example, heater elements may be located in the walls of the cavity 14 or in the plate 182.

[00101] In the example shown in Figure 3, the injection of the fluid 200 causes the build volume 100 to partially collapse. In this instance, the filler material 106 is buoyant and therefore floats on, or near, the top of the fluid 200 injected into the cavity 14. In this instance, the build material 102 has a density such that it remains on, or sinks towards, the bottom portion of the cavity 14. The dislodged filler material 106 that is not trapped by build material 102 floats. As Figure 3 shows, some filler material 106a remains trapped under 3D object(s) and/or build material 102. Furthermore, the trapped filler material 106a, in turn, prevents some portions of the build material 102a from sinking to the bottom of the cavity 14. The trapped build material 102 and filler material 106 cannot be reached by the vacuuming methods described hereinabove. The filler material 106 that has travelled to the top portion of the cavity 14 may be mixed with a portion of the fluid 200 that has been injected into the cavity 14. Similarly, the build material 102 may be mixed with a portion of the fluid 200 that has been injected into the cavity. For example, the build material 102 that has sunk to the bottom of the cavity 14 may be mixed with the fluid 200.

[00102] Figure 3 shows one example of how the materials, of which the build volume is composed, react when the fluid is injected into the cavity 14. For example, a filler material utilised in the build process may have a density that is greater than that of the fluid injected into the cavity 14 and, therefore, the filler material may sink to the bottom of the cavity 14. Similarly, a build material used in the build process may be buoyant with respect to the fluid injected into the cavity 14 and, therefore float to the top of the fluid.

[00103] In certain examples, a fluid that is injected cavity 14 may begin to act upon the build material and/or the functional agents that have been used in the build process. For example, the fluid may begin to dissolve one or more of

the functional agents that have been used in the build process. In some examples, the fluid that is injected into the cavity 14 may aid in curing, or setting, the solidified build material making up the build 3D object(s). This may be an osmotic process, for example, where the fluid is drawn into the solidified build material of the 3D object(s) and acts to extract undesirable functional agents. In other examples, a fluid that is injected cavity 14 may not act upon the build material and/or the functional agents that have been used in the build process.

[00104] In certain examples, such as build material comprising a metal powder that has been bound by a binding agent that includes latex, for example, and where the fluid is water, the latex acts to protect the 3D object because the latex forms a watertight film around the particles making up the 3D object and the strength of the latex is not affected by the injected water.

[00105] In certain examples, the injected fluid may be left for a predetermined time in the cavity 14 to maximise the effectiveness of the fluid acting upon the building material and/or the functional agents that have been used build process.

[00106] The agitation system 18 may be used to cause agitation of the applied fluid. In certain examples, the agitation system 18 may be used to cause agitation of the fluid after the injected fluid has been left for a predetermined time in the cavity 14. In some examples, the agitation is system 18 may be used to cause agitation of the fluid at the same time as the fluid is applied to the cavity 14. For example, the agitation system may activate his soon as fluid begins to be injected into the cavity 14. For example, the agitation system may cause agitation of a fluid continuously applied to the cavity 14.

[00107] The agitation system 18 may, in certain examples, agitate the build material. The agitation of the build material may be caused directly by the agitation system 18 and/or or indirectly by the agitated fluid. In some examples, the agitation system 18 may agitate the 3D object(s). In some examples, where the build volume comprises a filler material, the agitation system 18 may agitate the filler material. The agitation of the filler material may be caused directly by the agitation system 18 and/or or indirectly by the agitated fluid.

[00108] In certain examples, the agitation system 18 may cause agitation of the fluid by vibrating the fluid in the cavity 14. In some cases, the agitation system 18 may cause agitation of the build volume by vibrating the build volume in the cavity 14. In some cases, the agitation system 18 may cause agitation of the filler material in the cavity 14. In some examples, the agitation system 18 may cause agitation of the fluid and/or build material by ultrasonically vibrating the fluid and/or build material and/or the filler material.

[00109] In certain examples, the agitation system 18 may cause agitation of the fluid by injecting a compressed gas into the fluid. In certain examples, the compressed gas may be injected into the fluid through a porous surface. In certain examples, the compressed gas may be injected into the fluid from beneath the build volume. Injecting a gas into the fluid through a porous surface may cause small gas bubbles to form and rise through the fluid. As the bubbles rise through the fluid in the cavity 14 they cause vibrations in the fluid. The bubbles rising through the fluid may also agitate the non-solidified build material that surrounds the completed 3D object(s). The bubbles rising through the fluid may also agitate the completed 3D object(s). In some examples, where present, the bubbles rising through the fluid may also agitate the filler material of the build volume.

[00110] Figure 4 shows an example of agitation being caused in the fluid 200 in the cavity 14. In Figure 4, compressed gas is injected through the compressed gas inlets 184 in the direction of arrows 300 and into the plenum 186. The gas passes through the holes 183 in the plate 182 thereby being injected into the fluid 200 through the porous top surface of the plate 182. The injected compressed gas forms gas bubbles 302 as it passes out from the porous top surface of the plate 182. The gas bubbles 302 rise through the fluid 200 and the materials composing the build volume 100. The gas bubbles 302 may rise from below the build volume 100. The gas bubbles 302 may rise through a mixture of the fluid 200 and the build material 102. The gas bubbles may rise through a mixture of the fluid 200 and the filler material 106.

[00111] As they rise, the gas bubbles 302 agitate the fluid 200 thereby causing the build material 102 to separate from the 3D object(s) 104. In some cases, the rising gas bubbles 302 may also agitate the build material 102. In some cases, the rising gas bubbles 302 may also agitate the 3D object(s) 104 directly. Where the build volume 100 is also composed of a filler material 106, the rising gas bubbles 302 may also agitate filler material 106 thereby causing the filler material 106 to be dislodged.

[00112] The agitation caused by the agitation system 18 may cause the materials of which the build volume 100 is composed to be redistributed inside the cavity 14. For example, where the build volume 100 comprises a filler material 106 and the filler material 106 is buoyant with respect to the fluid 200, as is shown in Figures 3 and 4, the filler material 106 will float to, or near to, the top of the fluid 200 in the cavity 14. In other examples, where the filler material is denser than the applied fluid, the filler material will sink to the bottom of the cavity 14. Similarly, the build material may be buoyant with respect to the fluid and will, therefore, float to, or near to, the top of the applied fluid in the cavity 14. Conversely, where the build material 102 is denser than the fluid, as is shown in Figures 3 and 4, then the build material 102 will sink to the bottom of the cavity 14.

[00113] The benefit of choosing a filler material 106 that is buoyant with respect to the fluid in the cavity 14, and a build material 102 that is denser than the fluid in the cavity 14, is that these two materials composing the build volume may be more readily separated from each other in the 3D post-processing system examples described. Similarly, choosing a build material that is buoyant with respect to the fluid in the cavity 14, and a filler material that is denser than the fluid in the cavity 14 also means that these two materials composing the build volume may be more readily separated from each other.

[00114] Thus, in certain examples where the build volume is composed of a filler material, the densities of the build material and the filler material can be selected with separation from each other in mind.

[00115] In some examples, where the build volume is composed of a filler material, the filler material and the build material may both have densities such that they are buoyant with respect to the fluid injected into the cavity 14. In other examples, the filler material in the will material may both be denser than the fluid injected the cavity 14 so that both materials sink to the bottom of the cavity.

[00116] In some examples, where the filler material and the build material may both have densities such that they are buoyant with respect to the fluid injected into the cavity 14, the filler material may be selected to have a density that is more, or less, dense than the build material. In this way, both the filler material and the build material will float to, or near to, the top of the fluid in the cavity 14 and form two floating layers with one material layer on top of the other material layer, the orientation of which would depend on their respective material densities. This allows the filler material and the build material to be separated easily by drawing one material out of the cavity 14 after the other. Since the volume of each material in the build volume is known, the volume in each layer can be estimated.

[00117] In certain examples, the relative particle size of the filler material and build material may be selected to aid the separation and/or recycling process. For example, the relative particle size of the filler material and the build material may be selected such that the two materials can be passed through a sieve to separate them. For example, the filler particle size may be coarser than the build material particle size.

[00118] As the agitation caused by the agitation system 18 causes the materials of which the build volume 100 is composed to be redistributed within the cavity 14, the agitation may also cause the 3D object(s) to settle towards the bottom portion of the cavity 14 as the build material 102 is separated from their outer surfaces.

[00119] Figure 5 shows one example of the distribution of the materials of which the build volume 100 is composed following agitation caused by the agitation system 18. In certain cases, the fluid 200 and the materials composing the build volume 100 may be allowed to settle for a period following agitation caused by the education system eating.

[00120] In Figure 5, following the agitation caused by the dictation system 18, and since in this example the build material 102 is denser than the fluid 200, the build material 102 and the 3D object(s) have settled in the bottom portion of the cavity 14. The build material 102 may be mixed with a portion of the fluid 200. Also in Figure 5, since the filler material 106 is buoyant with respect to the fluid injected into the cavity 14, the filler material 106 resides in the top portion of the cavity 14. The filler material 106 may be mixed with a portion of the fluid 200. In certain examples, a portion of the fluid 200 may be located between the filler material at the top of the cavity 14 and the build material 102 at the bottom of the cavity 14.

[00121] At least one of the materials of which the build volume is composed may be removed from the cavity 14. For example, the separated build material may be removed from the cavity 14. In some examples, whether build volume comprises a filler material, the dislodged filler material may be removed from the cavity 14. In some examples, a mixture of the separated build material and the dislodged filler material may be removed from the cavity 14 together. In certain examples, a mixture of the fluid and the build material and/or the filler material may be removed from the cavity 14 together.

[00122] In certain examples, additional fluid may be delivered into the cavity 14 in order to facilitate the removal of one of the materials from which the build volume is composed from the cavity 14.

[00123] In certain examples, one of the materials of which the build volume is composed may be removed from the top portion of the cavity 14. For example, where a filler material is buoyant with respect to the fluid in the cavity 14, the filler material may be removed from the top portion of the cavity 14. Similarly, for example, where the build material is buoyant with respect to the fluid in the cavity, the build material may be removed from the top portion of the cavity 14. In certain examples, where the build material and a filler material are used together in the build process and are both are buoyant with respect to the fluid in the cavity 14, a mixture of the build material and the filler material may be removed from the top portion of the cavity 14. In certain examples, a mixture of the fluid and the build material and/or the filler material may be removed from the top portion of the cavity 14 together.

[00124] Figure 6 shows one example of the filler material 106 being removed from the top portion of the cavity 14. Since the filler material 106 is buoyant with respect to the fluid 200 it can be removed from the top portion of the cavity 14. The filler material 106 may be drawn through the at least one fluid outlet 24 via fluid outlet conduit 24a. The filler material 106 may be drawn towards the at least one fluid outlet 24 and through the fluid outlet conduit 24a in the direction of arrows F. The at least one fluid outlet conduit 24a may be in fluid communication with a filler material 106 waste depository. Following removal from the cavity 14 the waste filler material 160 may be reused in another build process. Since the filler material 106 has been separated from the build material 102, the filler material 106 may be reusable with minimal or no further treatment. In certain examples, where the build material is buoyant with respect to the fluid 200, it can also be removed from the top portion of the cavity 14 in the same manner. In some examples, the build material and the filler material 106 may be removed from the top portion of the cavity 14 in the same manner. In certain examples, the build volume post-processing system 10 may include systems that apply suction to the fluid outlet conduit 24a thereby aiding the removal of the filler material 106 and/or the build material from the cavity 14.

[00125] In certain examples, the filler material 106 may be mixed with the fluid 200 in the top portion of the cavity 14. Accordingly, a mixture of the filler material 106 and the fluid 200 may be drawn through the at least one fluid outlet 24 and into the fluid outlet conduit 24a. Similarly, where the build material is buoyant with respect to the fluid 200, a mixture of the build material and the fluid 200 may be drawn through the at least one fluid outlet 24.

[00126] Figure 6 also shows an example in which additional fluid 200 is delivered into the cavity 14 to facilitate the removal of the filler material 106 from the top portion cavity 14. Additional fluid 200 may be injected through the fluid inlet 16a. The additional fluid 200 increases the volume of fluid 200 in the cavity 14 thereby forcing the filler material 106 towards the fluid outlet conduit 24.

[00127] In certain examples, one of the materials of which the build volume is composed may be removed from the bottom portion of the cavity 14. For example, where the build material has a density that is higher than the applied fluid, the build material may be removed from the bottom portion of the cavity 14. Similarly, for example, where the filler material has a density that is higher than the applied fluid, the filler material may be removed from the bottom portion of the cavity 40. In certain examples, where the build material and a filler material are used together in the build process and are both denser than the applied fluid in the cavity 14, a mixture of the build material and the filler material may be removed from the bottom portion of the cavity 14. In certain examples, a mixture of the fluid and the build material and/or the filler material may be removed from the bottom portion of the cavity 14 together.

[00128] Figure 7 shows one example of the filler material 106 being removed from the bottom portion of the cavity 14. Since the build material 102 is denser than the fluid 200 it can be removed from the bottom portion of the cavity 14. The build material 10 may be drawn out through the fluid outlet conduit 22a by draining the fluid 200 from the cavity 14 through the at least one fluid outlet 22 via fluid outlet conduit 22a. Figure 7 shows that the fluid 200 is drained from the cavity 14 through the at least one fluid outlet 22 and through the fluid outlet conduit 22a in the direction of arrows B. In some examples, the build material 102 may be mixed with the fluid 200 in the bottom portion of the cavity 14 such that the build material 102 is drained through the at least one fluid outlet 22 and through the fluid outlet conduit 22a with the fluid 200. The at least one fluid outlet conduit 22a may be in fluid communication with a build material 102 waste depository. Following removal from the cavity 14 the waste build material 102 may be reused in another build process. Since the build material 102 has been separated from the filler material 106, the build material 102 may be reusable with minimal or no further treatment. In certain examples, where the filler material is denser than the fluid 200, it can also be removed from the bottom portion of the cavity 14 in the same manner. In some examples, the build material 102 and the filler material may be removed from the bottom portion of the cavity 14 in the same manner. In certain examples, the build volume post-processing system 10 may include systems that apply suction to the fluid outlet conduit 22a thereby aiding the removal of the filler material 106 and/or the build material from the cavity 14.

[00129] In some examples, additional fluid 200 may be delivered into the cavity 14 to maximise the removal of the build material 102 from the top portion cavity 14. For example, additional fluid 200 may be injected through the fluid inlet 16a. The additional fluid 200 may be used to flush the cavity 14 and remaining 3D object(s) to remove the build material 200 completely. As many cycles of additional fluid 200 may be applied as desired.

[00130] In certain examples, the amount of fluid injected into the cavity 14 may be determined based on the known volumes of build material and/or filler material that were used to form the build volume. For example, in the case where the build material and the filler material are both buoyant with respect to the fluid applied to the cavity 14, the amount of fluid to be injected into the cavity 14 may be determined from the known exact volumes of each of the materials of which the build volume is composed.

[00131] Figure 8 shows the container 12 once the build material 102 has been drained through the fluid outlet conduit 22a. The 3D object(s) rest on the plate 182 in the bottom portion of the cavity 14 and may be removed ready for use.

[00132] In some examples, a fluid may be reapplied to the cavity 14. In some examples, the reapplied fluid may be a different fluid from that which was initially applied to the cavity 14. In other examples, the same type of fluid may be reapplied to the cavity 14. Once a fluid has been reapplied to the cavity 14, the agitation system 18 may cause agitation of the newly applied fluid.

[00133] An example is shown in Figure 9, which illustrates how once another dose of fluid 201 has been delivered to the cavity 14, the agitation system 18 may cause agitation of the newly applied fluid 201. The fluid 201 may be applied through the fluid inlet 16a. Once the fluid 201 is located in the cavity 14, compressed gas may be injected through the at least one compressed gas inlet 184. As they compressed gas passes through the porous top surface plate 182,

the compressed gas forms bubbles of gas 303. The bubbles of gas 303 may, for example, be a different size to the first set of bubbles of gas 302, for example. For example, the bubbles of gas 303 may be smaller than the first set of bubbles of gas 302.

[00134] As many cycles of agitated fluid as desired may be applied successively to the 3D object(s). For example, different types of fluids may be successively applied to the 3D object(s). For example, each of the different fluids applied may have a different function. For example, each fluid applied successive fluid applied may remove or dissolve a different functional agent. Furthermore, different levels of agitation may be caused by the agitation system 18 depending on the desired treatment of the 3D object(s). For example, different size of vibrational waves may be applied with each respective fluid. In other examples, the size of gas bubbles generated by the injected compressed gas may be changed for each respective applied fluid.

[00135] Applying several cycles of agitated fluid to the 3D object(s) may maximise the amount of build material and/or functional agents removed from the surfaces of the 3D object(s).

[00136] In some cases, additional processes may be applied to the 3D object(s). For example, the 3D object(s) may be allowed to air dry in the cavity 14 of the container 12 for a period following the removal of the fluid and/or build material and/or filler material. In some examples, as illustrated in the example shown Figure 10, air may be injected through the at least one compressed gas inlet 184 to aid in drying 3D object(s). In the case of figure 10, the air permeates through the porous top surface of the plate as indicated by the arrows H. In some examples the air injected through the compressed gas inlet 184 may be heated prior to injection thereby improving the efficiency of the drying process.

[00137] In some examples, the build volume post-processing system 10 can be used to control the post-build temperature of the build volume. For instance, a fluid can be injected through the fluid delivery system 16 to cool down the 3D object(s) at a controlled rate. For instance, successively cooler doses of fluid can be injected into the cavity 14 in a controlled manner.

[00138] In the case where a mixture of build material and filler material are removed from the cavity 14, the materials can be separated from each other once they are removed. For instance, the mixture of materials can be sieved to separate one material from the other. The separated materials can then be dried so they can be used in a later build process.

[00139] In certain examples, the compressed gas may be compressed air. In other examples, the compressed gas may be any other suitable compressed gas. For example, it may be desirable that the compressed gas comprises an inert gas to limit the chances of explosive reactions with build material and/or filler material. In some examples, an inert compressed gas may be used that reduces oxidation of the build material. For example, the compresses gas may be selected from at least one of: nitrogen, argon, carbon dioxide.

[00140] Certain examples of methods of post-processing a build volume will now be described. The build volume may be, for example, any of the example build volumes described herein. The example method(s) will be described with respect to the flow charts of Figures 11 and 12.

[00141] In certain examples, the method(s) may be executed by any of the build volume post-processing systems described herein. In certain examples, the example method(s) may be performed in the controller of an example build volume post-processing system as described herein. In some cases, the example method(s) may be performed in the controller of an example additive manufacturing system. In certain examples, the example method(s) may be performed remotely from an example build volume post-processing system and instructions be transmitted to the build volume post-processing system.

[00142] Referring to Figure 11, at block 502, a method comprises applying a fluid to a three-dimensional (3D) build comprising build material and at least one three-dimensional (3D) object. The at least one three-dimensional (3D) object 104 may be a built three-dimensional (3D) object 104.

[00143] The 3D object may have been built by the build process that was used to form the build volume. In some examples, the build volume may also comprise filler material. In certain examples, the build volume may comprise a

plurality of 3D object(s). In certain examples, the fluid may be applied to the build volume in a cavity in which the build volume is received. A container may comprise the cavity. In some examples, the fluid may be applied to the build volume by delivering the fluid into the cavity from a fluid delivery system. In certain examples, the fluid may be applied to the build volume in the cavity continuously. In some examples, the fluid may be injected into the cavity.

[00144] In certain examples, the build volume may remain in the fluid for a predetermined period. In some examples, the fluid may be heated inside the cavity. In other examples the fluid may be heated prior to being applied to the build volume.

[00145] At block 504, the method comprises agitating the fluid to separate the build material from the at least one 3D object.

[00146] In certain examples, the build material may be agitated to separate the build material from the at least one 3D object. In certain examples, the at least one 3D object may be agitated to separate the build material from the at least one 3D object. In some examples, where build volume comprises filler material, the filler material may be agitated to dislodge it from the build volume.

[00147] In certain examples, the agitation may be performed by an agitation system.

[00148] In some examples, the agitation system may comprise a vibration system and the agitation may be performed by the vibration system. Thus, agitating the fluid and/or the build material and/or the filler material may comprise vibrating the fluid and/or the build material and/or the filler material. For example, the vibration system may comprise an ultrasonic wave generator and the agitation may be performed by the ultrasonic wave generator.

[00149] In certain examples, the agitation may be performed by injecting a compressed gas into the fluid. Thus, agitating the fluid and/or the build material and/or the filler material may comprise injecting a compressed gas into the fluid. Injecting the compressed gas into the fluid may comprise forming gas bubbles in the fluid. The gas bubbles agitate the fluid and/or the build material and/or the filler material. In some examples, the compressed gas may be injected into the fluid through a porous surface. In some examples, the porous surface may be located beneath build volume.

[00150] Certain further method(s) of post-processing a build volume will now be described with respect to Figure 12.

[00151] In certain examples, the method may comprise removing a material of which the build volume is composed from the cavity. For example, the method may comprise removing the separated build material from the cavity. In some examples, where the build volume is composed of a filler material, the method may comprise removing the dislodged filler material from the cavity.

[00152] In one example, at block 602, for example, the method may comprise removing the filler material from the cavity. In some examples, removing the filler material from the cavity may comprise removing the filler material from a top portion of the cavity. For example, removing the filler material from the top portion of the cavity may comprise forcing the filler material through at least one fluid outlet located substantially in the top portion of the cavity. In certain examples, removing the filler material from the top portion of the cavity may comprise forcing a mixture of the fluid and the filler material through the at least one fluid outlet located substantially in the top of the portion of the cavity. In some examples, removing the filler material from the top portion of the cavity may comprise sucking a mixture of the fluid and the filler material through the at least one fluid outlet located substantially in the top portion of the cavity. In certain examples the method may comprise removing the filler material and/or the build material from the top portion of the cavity.

[00153] In one example, at block 604, the method may comprise removing the separated build material from the cavity. In some examples, removing the separated build material from the cavity may comprise removing the separated build material from a bottom portion of the cavity. For example, removing the separated build material from the bottom portion of the cavity may comprise extracting the separated build material through at least one fluid outlet located substantially in the bottom portion of the cavity. In certain examples removing the

separated build material from the bottom portion of the cavity may comprise draining a mixture of the fluid and the separated build material through the at least one fluid outlet located substantially in the bottom portion of the cavity. In some examples, removing the filament build material from the bottom portion of the cavity may comprise sucking a mixture of the fluid and the separated build material through the at least one fluid outlet located substantially in the bottom portion of the cavity. In certain examples the method may comprise removing the filler material and/or the build material from the bottom portion of the cavity.

[00154] In certain examples, the build material and, where used, the filler material may be allowed to settle before being removed from the cavity. In some examples, the fluid may be drained continuously from the cavity at the same rate as it is correspondingly continuously delivered to the cavity. In certain examples, additional fluid delivered to the cavity to flush remaining build material and/or filler material from the cavity. Any suitable number of cycles of additional fluid may be delivered to the cavity.

[00155] In an example, at block 606, the method may comprise reapplying a fluid to the cavity. The fluid may be effectively reapplied to the 3D object(s) remaining in the cavity. The fluid may be the same fluid as applied at block 502, or may be a different fluid with different material properties.

[00156] At block 608, in certain examples, the method may comprise agitating the newly applied fluid. Agitating the newly applied fluid may comprise injecting a compressed gas into the fluid to generate gas bubbles in the fluid.

[00157] The any number any suitable number of cycles of blocks 606 and/or 608 may be performed. The number of cycles of blocks 606 and/or 608 that are performed may depend on the desired level of cleanliness of the post-processed 3D object(s).

[00158] In an example, at block 610, the method may comprise injecting air into the cavity. In certain examples, the injected air may be permitted to permeate through the porous surface into the cavity. In certain examples, the injected air may be heated prior to being injected into the cavity.

[00159] The method may comprise, at block 612, recycling the material is removed from the cavity. For example, the build material and/or filler material may be cleaned for reuse in a subsequent build process.

[00160] The example methods described above may be performed in any of the example build volume post-processing systems described herein and illustrated in any of the Figures.

[00161] For example, the method(s) described above may be performed in the example build volume post-processing system 10 shown in Figure 13. In certain examples, the method described above may be performed in a 3D post-processing system 10 that is a part of a build unit, for example the build unit 800 illustrated by a dashed line in Figure 13. An additive manufacturing system may comprise the build unit 800. The build unit 800 may comprise a build platform 12 as described above (not shown in Figure 13).

[00162] The build volume post-processing system 10 may comprise at least one controller 20. In other examples, the build unit 800 may comprise a controller that controls the build volume post-processing system 10. In some examples, the controller 20 of the build volume post-processing system 10 may cooperate with a controller of the build unit 800. The controller(s) may comprise a computer.

[00163] The controller 20 may be communicatively connected 704 with the fluid delivery system 16 and the agitation system 18. The controller 20 may control other features of the container 12, such as heating elements for example. The controller 20 and the fluid delivery system 16 and the agitation system 18 may be communicatively connected with one another via communications interfaces. For example, the controller 20 may be electrically connected by way of communication cabling. However, it will be appreciated that a wireless communication protocol could be used instead.

[00164] The controller 20 of the build volume post-processing system 10 may be communicatively connected to other system, such as the additive manufacturing system.

[00165] In some examples, the controller(s) may be remote from the build volume post-processing system 10. For example, the controller(s) may be remotely connected to the build volume post-processing system 10 over a network, which would allow the controller(s) and the other features of the build volume post-processing system 10 to be located separately from each other, including the possibility of being separate by large distances. The connection may be a network connection.

[00166] The controller 20 may comprise a processor 700. The processor 700 may carry out any of the processes or methods described herein or instruct they be carried out in the build volume post-processing system 10. The controller 20 may comprise a storage module 702. The storage module 702 may comprise a non-transitory storage medium. The non-transitory machine-readable storage medium 702 may be encoded with instructions executable by the processor. Some examples of non-transitory storage media are disks, thumb drives, memory cards and do not include propagated signals.

[00167] Any of the example processes or methods described herein may be encoded in machine readable form on the non-transitory storage medium. For example, the example processes or methods above may be in the form of a computer program comprising computer program code. For example, the non-transitory machine-readable storage medium may be encoded with instructions for performing all, or any of, the blocks described herein. For example, the processor 700 may retrieve and execute the encoded instructions and perform any of the blocks described herein or instruct another device, such as the build unit 800, to perform any of the blocks described herein. The processor 700 may retrieve and execute encoded instructions and perform additional blocks relating to other functions of the printing system.

[00168] The processor 700 may be a parallel processor or a serial processor. The processor 700 may execute the instructions may be carried out in any suitable order, or simultaneously.

[00169] In certain examples, the non-transitory machine-readable storage medium 702 may be encoded with instructions which, when executed by a processor, control the processor to: cause fluid to be injected into a cavity of a container in which is received a build volume comprising build material and at least one three-dimensional object; and, cause an agitator to agitate the fluid in the cavity.

[00170] The non-transitory machine-readable storage medium may be encoded with the other instructions relating to the functioning of the additive manufacturing system.

[00171] It will be appreciated that the example blocks may be implemented at various locations throughout the build volume post-processing system, for instance in the controller 20, agitation system 18, or in some cases, in the build unit 800. As described above, the build volume post-processing system 10 and the build unit 800 may be combined into a single unit and the blocks may be implemented in one location.

[00172] It will be appreciated that the example blocks may be implemented at various locations across a network. For example, a remote computer may store encoded instructions for performing an example of the calibration process described above. A local or terminal computer may access the remote computer and access the encoded instructions. It will be appreciated that the example blocks may be implemented by a dedicated circuit, for example a DSP or a programmable logic array.

[00173] The preceding description has been presented to illustrate and describe examples of the principles described. This description is not intended to be exhaustive or to limit these principles to any precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is to be understood that any feature described in relation to any one example may be used alone, or in combination with other features described, and may also be used in combination with any features of any other of the examples, or any combination of any other of the examples.

CLAIMS

What is claimed is:

1. A build volume post-processing system, the post-processing system comprising:
   a container comprising a cavity, the cavity to receive a build volume comprising build material and at least one three-dimensional object;
   a fluid delivery system to deliver a fluid into the cavity; and
   an agitation system to, in use, cause agitation of the fluid to separate the build material from the at least one three-dimensional object.

2. A build volume post-processing system according to claim 1, wherein the agitation system comprises a compressed gas injection system.

3. A build volume post-processing system according to claim 2, wherein the agitation system comprises a porous surface located, in use, beneath the build volume and through which the compressed gas is injectable.

4. A build volume post-processing system according to claim 1, wherein the agitation system comprises a vibration system to vibrate the fluid.

5. A build volume post-processing system according to claim 4, wherein the vibration system comprises an ultrasonic wave generator.

6. A build volume post-processing system according to claim 1 comprising a fluid removal system, wherein the fluid removal system comprises at least one fluid outlet from the cavity.

7. A build volume post-processing system according to claim 6, wherein the cavity comprises a bottom portion and the at least one fluid outlet is located substantially in the bottom portion of the cavity.

8. A build volume post-processing system according to claim 6, wherein the cavity comprises a top portion and the at least one fluid outlet is located substantially in the top portion of the cavity.

9. A method comprising:

applying a fluid to a build volume comprising build material and at least one three-dimensional object; and

agitating the fluid to separate the build material from the at least one three-dimensional object.

10. A method according to claim 9, wherein the agitating of the fluid comprises injecting a compressed gas into the fluid.

11. A method according to claim 10, wherein the agitating the fluid comprises injecting the compressed gas into the fluid through a porous surface located beneath the build volume.

12. A method according to claim 9, wherein the fluid is applied into a cavity in which the three-dimensional object is received, and wherein the method comprises removing a material of which the build volume is composed from the cavity.

13. A method according to claim 9, and wherein the cavity comprises a top portion, and wherein method comprises removing the build material and/or a filler material the top portion of the cavity.

14. A method according to claim 9, wherein the cavity comprises a bottom portion, and wherein the method comprises removing the build material from the bottom portion of the cavity.

15. A non-transitory machine-readable storage medium comprising instructions executable by a processor, the storage medium comprising:

instructions to cause fluid to be injected into a cavity of a container in which is received a build volume comprising build material and at least one three-dimensional object; and

instructions to cause an agitator to agitate the fluid in the cavity.

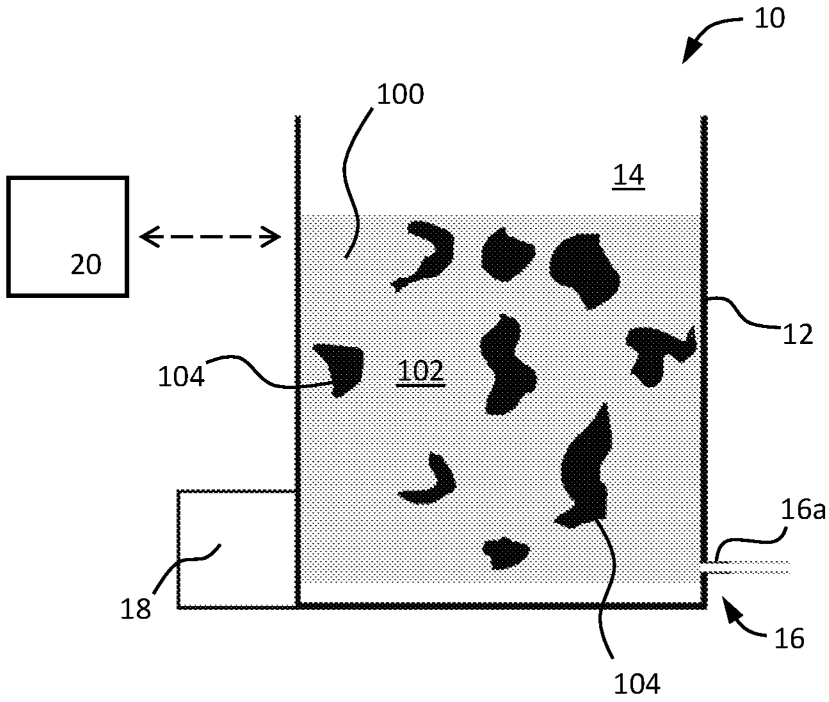


Figure 1

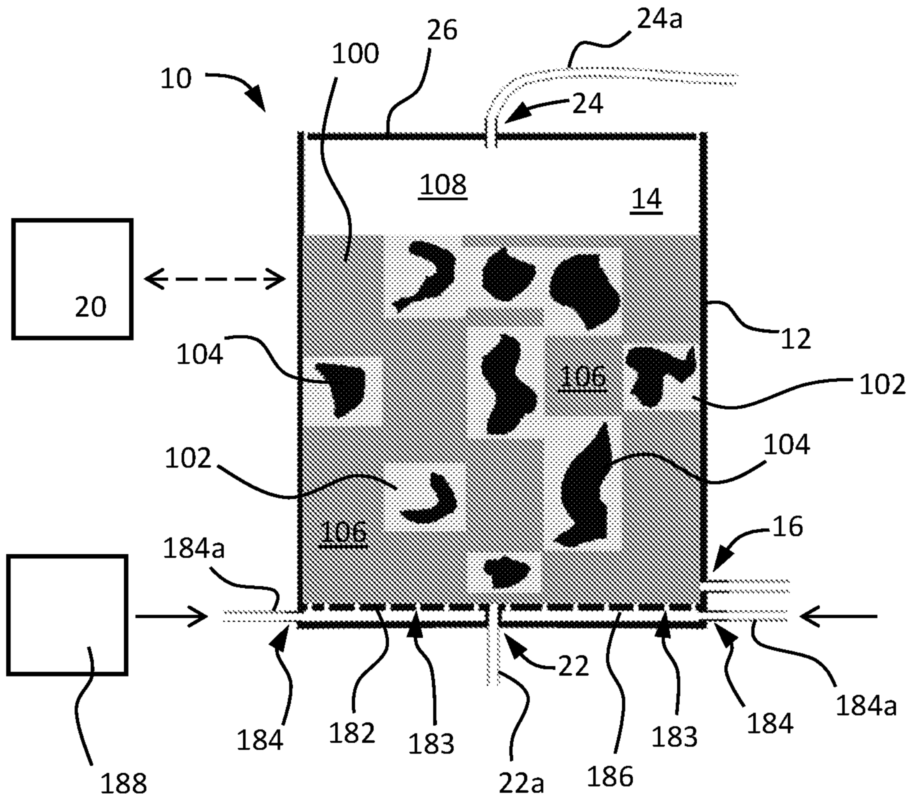


Figure 2

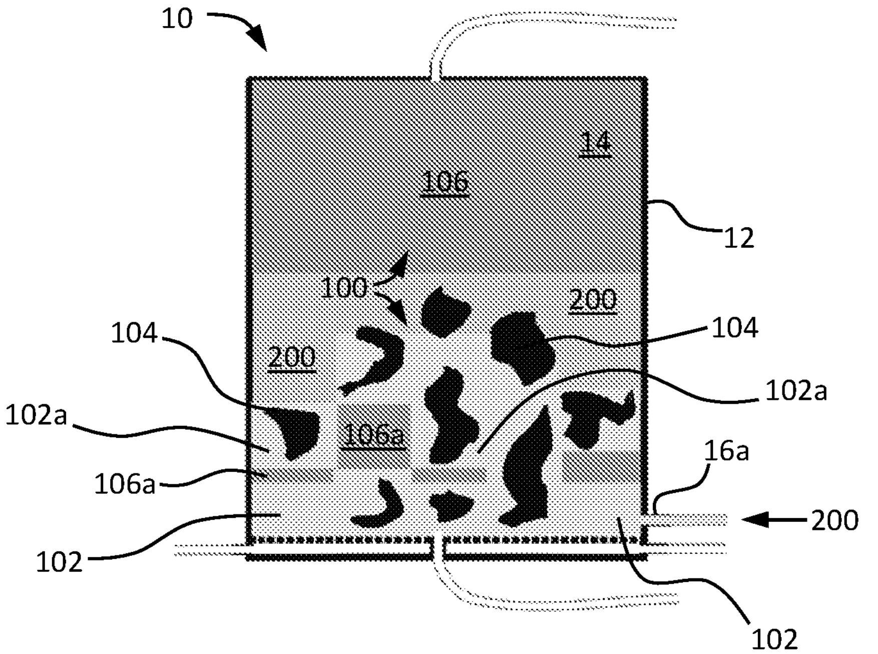


Figure 3

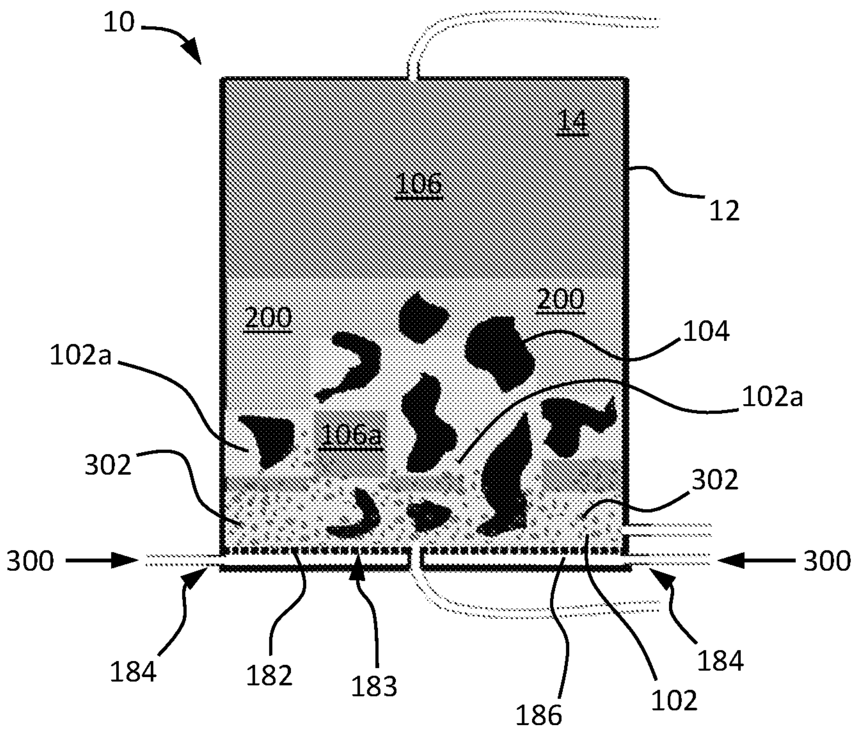


Figure 4

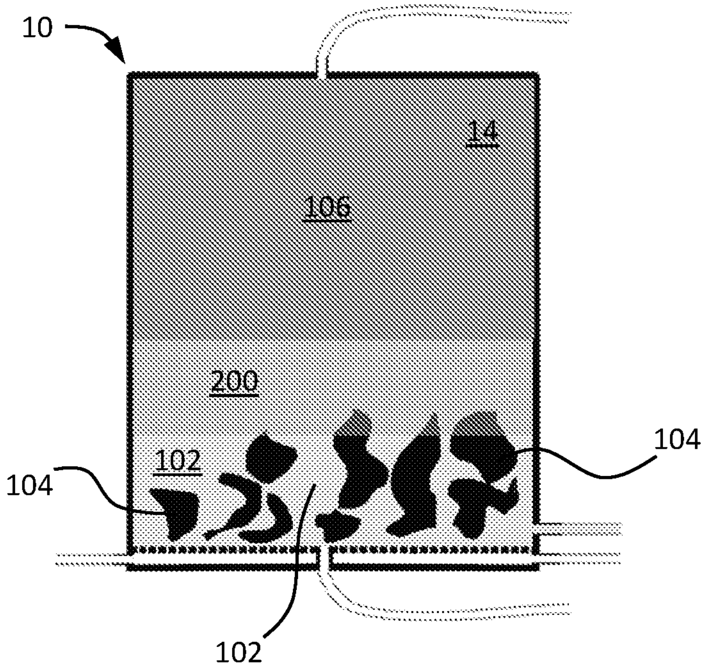


Figure 5

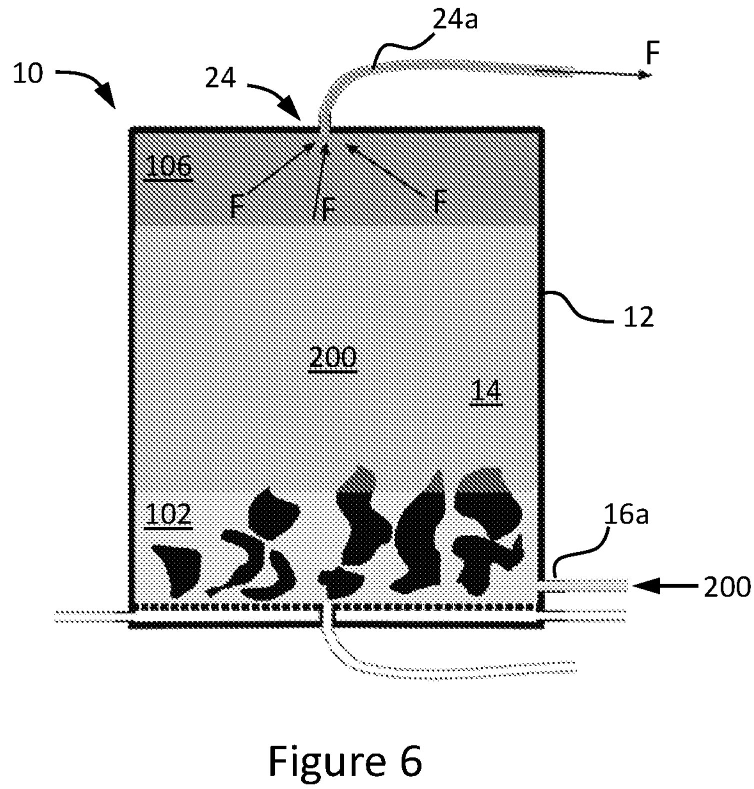


Figure 6

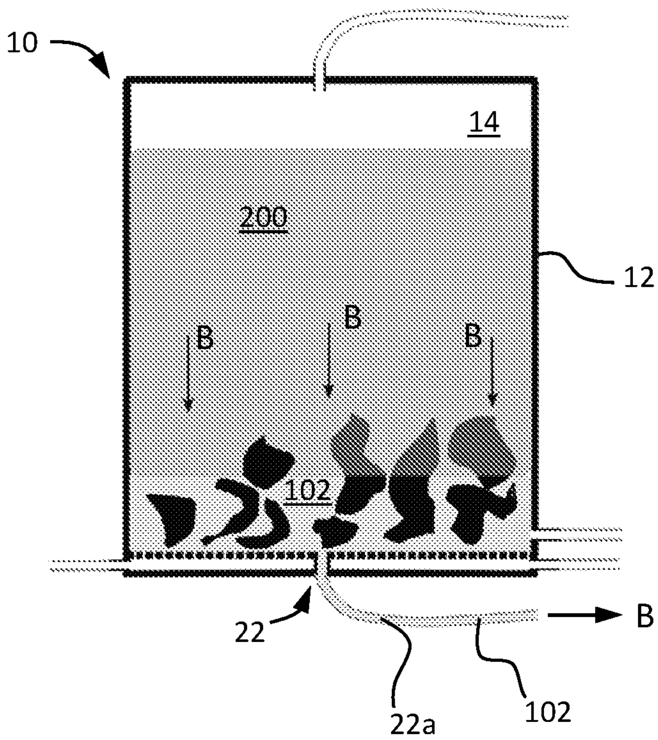


Figure 7

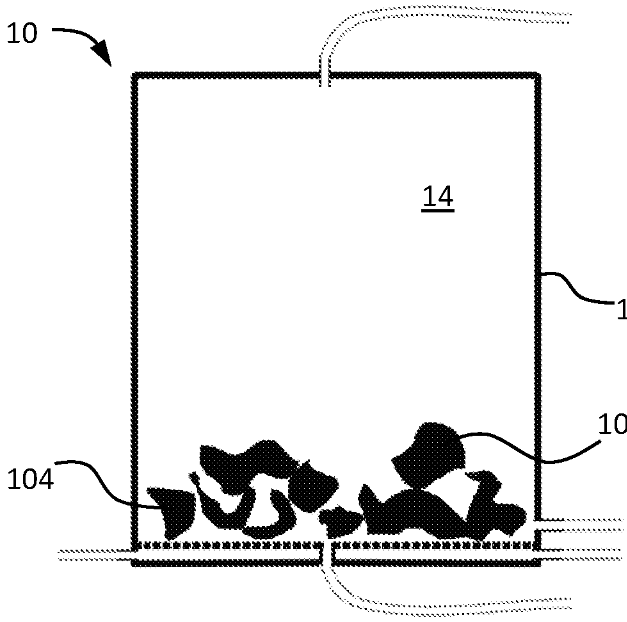


Figure 8

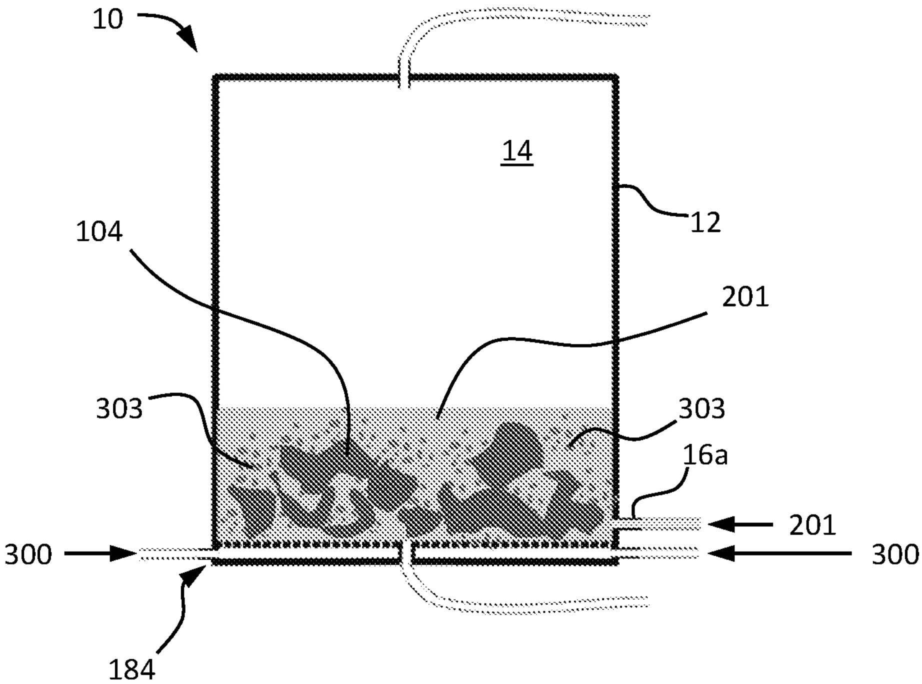


Figure 9

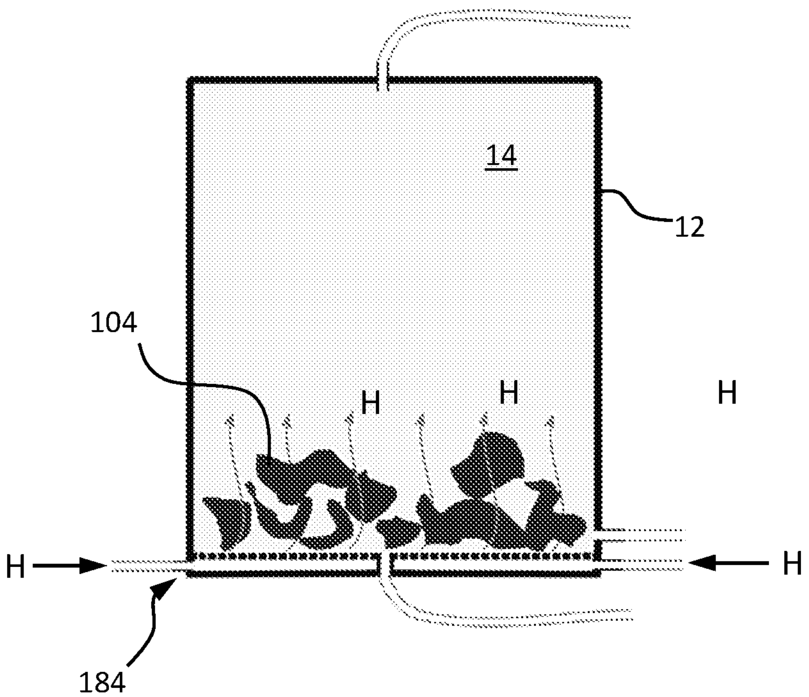


Figure 10

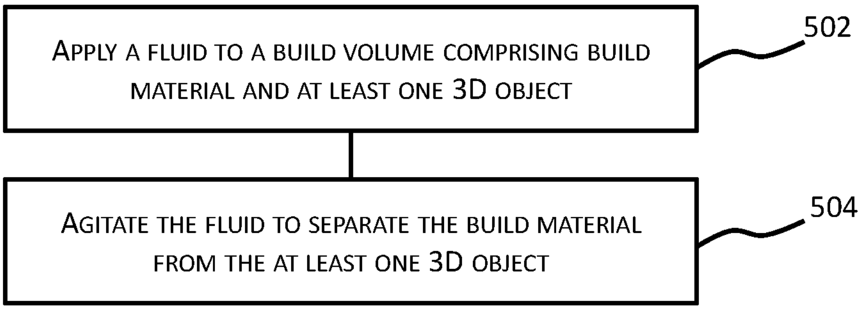


Figure 11

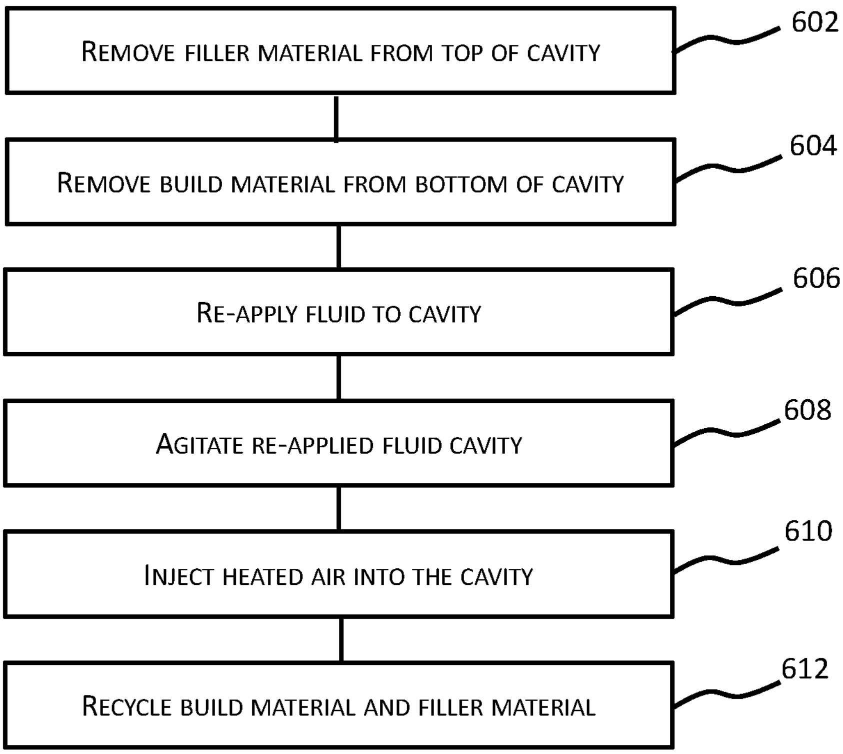
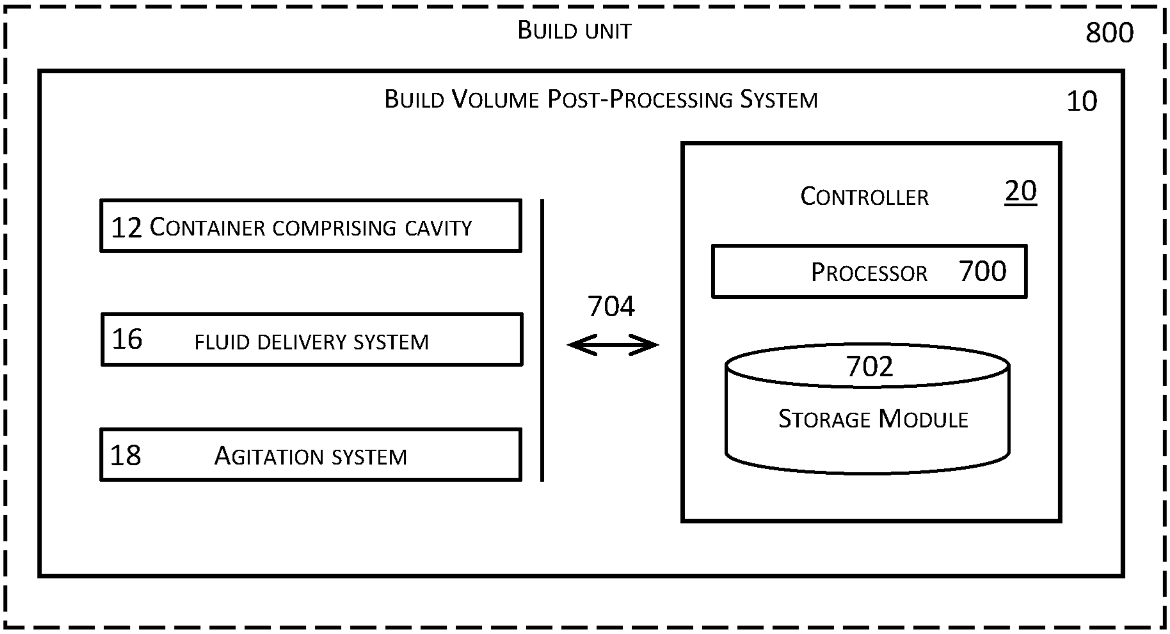


Figure 12



Build unit
800
Build Volume Post-Processing System
10
12 Container comprising cavity
16 fluid delivery system
18 Agitation system
704
Controller
20
Processor 700
702
Storage Module

Figure 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2018/056036

A. CLASSIFICATION OF SUBJECT MATTER

B29C 64/35 *(2017.01)*
B29C 64/379 *(2017.01)*
B33Y 40/00 *(2015.01)*
B08B 3/12 *(2006.01)*

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B29C 64/35, 64/393, B33Y 50/02, 40/00, B29C 67/00-67/24, 64/379, B08B 3/12

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

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

PatSearch (RUPTO Internal), USPTO, PAJ, Espacenet, Information Retrieval System of FIPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017/196355 A1 (HEWLETT-PACKARD DEVELOPMENT COMPANY L.P.) 16.11.2017, paragraphs [0001], [0038], [0041], [0080] - [0082], [0087], fig. 2A, 3, 4	1-3, 6-15
Y		4, 5
Y	WO 2017/18018 A1 (HEWLETT-PACKARD DEVELOPMENT COMPANY L.P.) 19.10.2017, paragraphs [0082], [0084], [0085]	4
Y	EP 2910363 A1 (SEIKO EPSON CORPORATION) 26.08.2015, paragraph [0054]	5
A	US 2004/084814 A1 (BOYD MELISSA D et al.) 06.05.2004, abstract	1-15

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 June 2019 (14.06.2019)	27 June 2019 (27.06.2019)

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