(12) UK Patent Application (19) GB (11) 2543305 (13) A

(43) Date of A Publication 19.04.2017

(21) Application No: 1518164.7

(22) Date of Filing: 14.10.2015

(71) Applicant(s):
**Rolls-Royce plc**
**(Incorporated in the United Kingdom)**
**62 Buckingham Gate, LONDON, SW1E 6AT, United Kingdom**

(72) Inventor(s):
**Daniel Clark**
**Jeffrey Allen**
**Carl Hauser**

(74) Agent and/or Address for Service:
**Rolls-Royce plc**
**IP Department (SinA-48), PO Box 31, DERBY, Derbyshire, DE24 8BJ, United Kingdom**

(51) INT CL:
***B33Y 30/00*** (2015.01) *B22F 3/105* (2006.01)

(56) Documents Cited:
**WO 2014/195068 A**
**WO 2014/018100 A**
**CN 203843169 U**
**CN 104226996 A**
**US 5753274 A**
**US 20150017013 A**
**US 20080317951 A**
**US 20080190905 A**
**US 20060108712 A**

(58) Field of Search:
INT CL **B22F, B23K, B29C, B29D, B33Y, F28B, F28C, F28D, F28F, F28G**
Other: **EPODOC, WPI and Inspec**

(54) Title of the Invention: **Apparatus for building a component**
Abstract Title: **Additive manufacturing apparatus comprising an annular chamber and heating or cooling means**

(57) Apparatus for additive layer manufacturing of an article 7 from a powder bed 3 located in an annular build chamber 6 comprises a radially inner wall 5, a radially outer wall 2 and a build plate 4. The walls 2 & 5 and build plate 4 are rotatable about an axis 34 with the build plate 4 also being vertically moveable along this axis 34. The apparatus further comprises means to heat or cool the inner 5 or outer 2 wall using a jet of fluid from an elongate nozzle. The chamber 6 can be rotated by an actuator 14 which drives the outer wall 2 which in turn drives the build plate 4 which in turn drives the inner wall 5. Alternatively the inner wall 5 and/or the build plate 4 can be independently driven. The chamber 6 can be subdivided to provide a plurality of circumferentially spaced sub-chambers. An insert (40, Fig. 5) can be located in the chamber 6 to reduce its volume. A blade 10 used to level powder in the chamber 6 is curved against the rotation direction of the chamber 6.

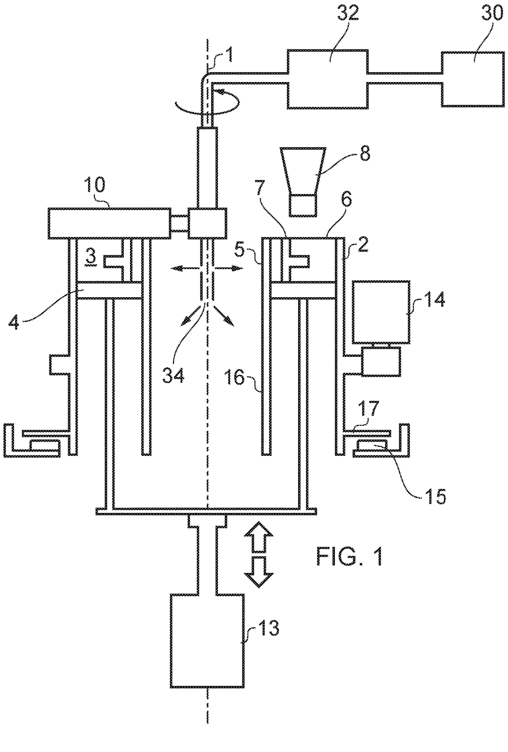


FIG. 1

GB 2543305 A

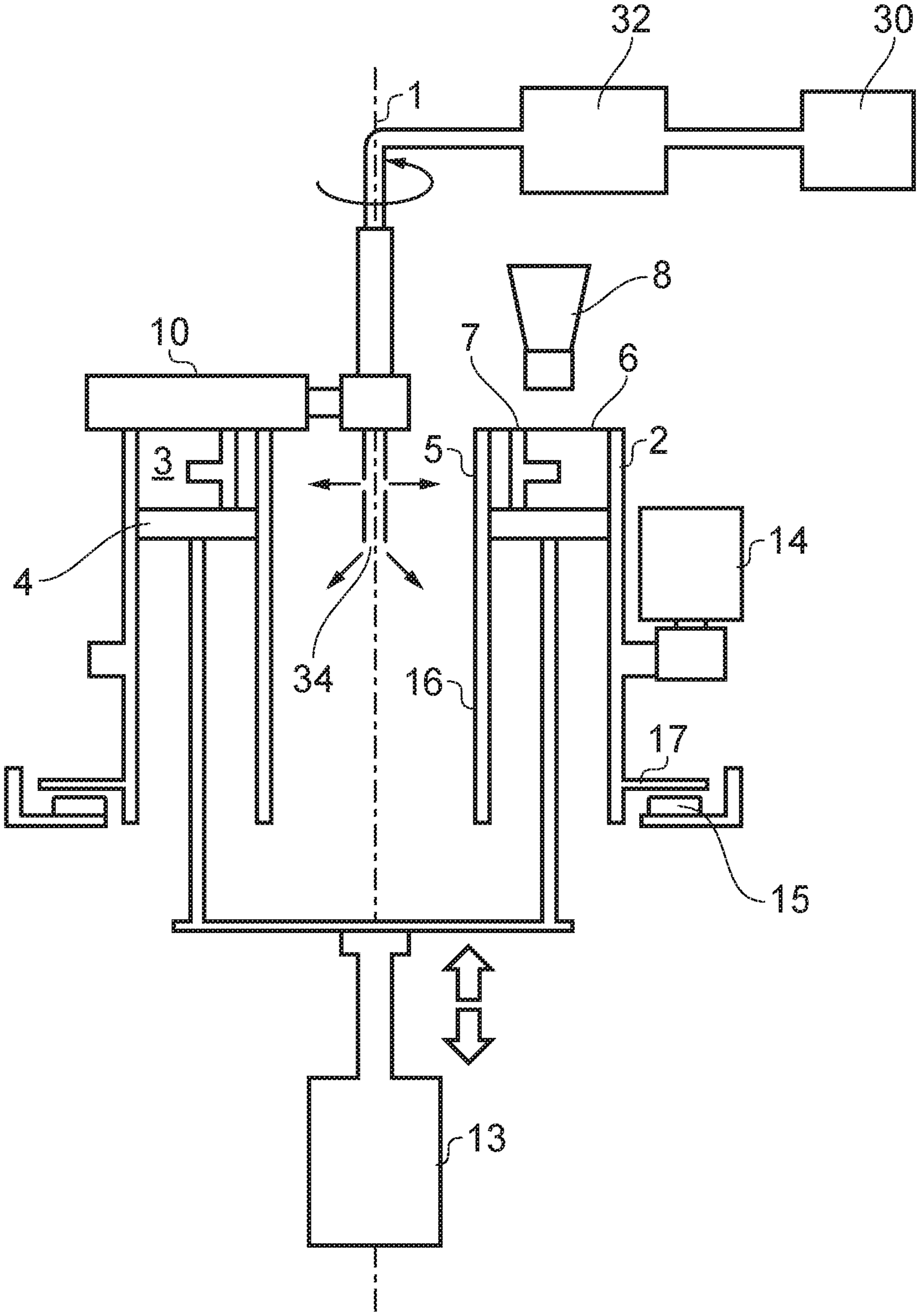


FIG. 1

12 07 16

12 07 16

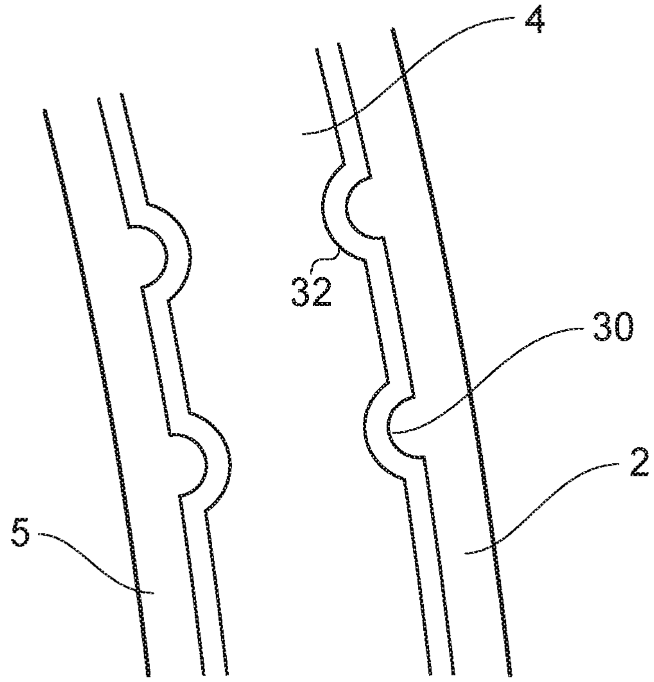


FIG. 2

12 07 16

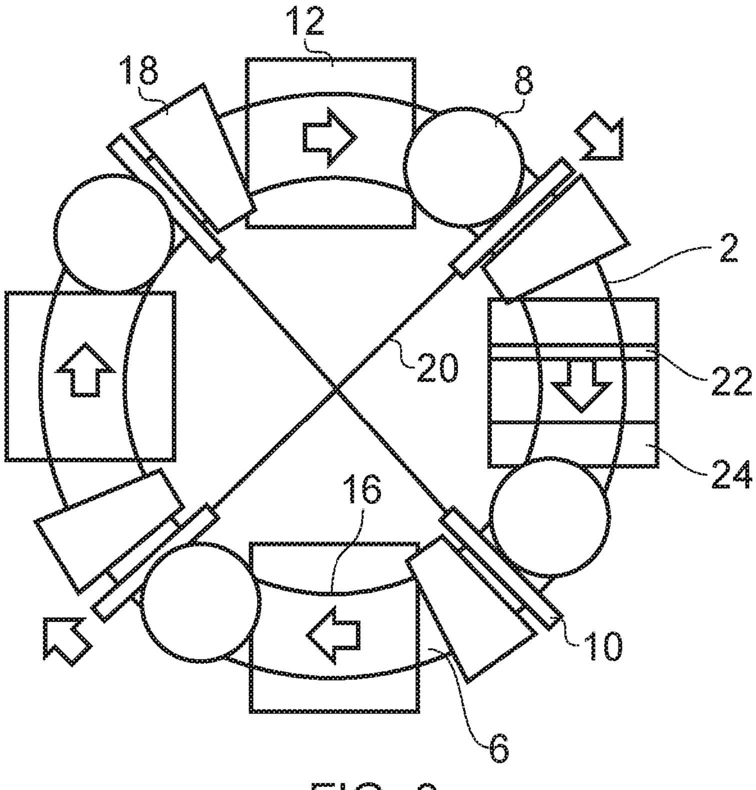


FIG. 3

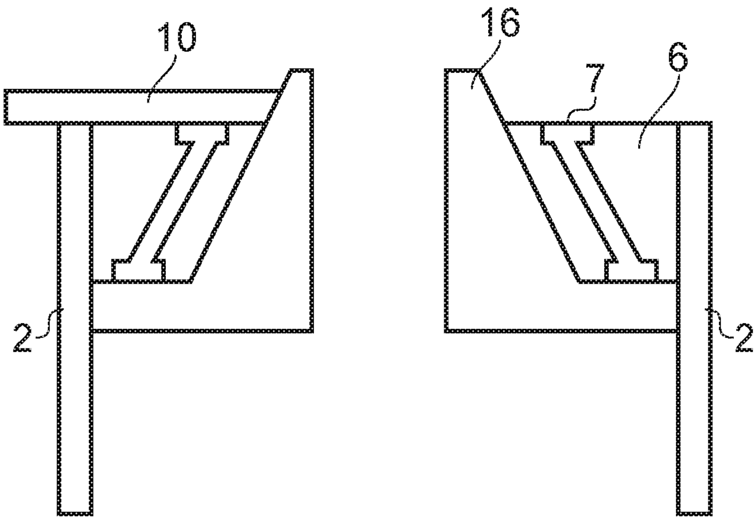


FIG. 4

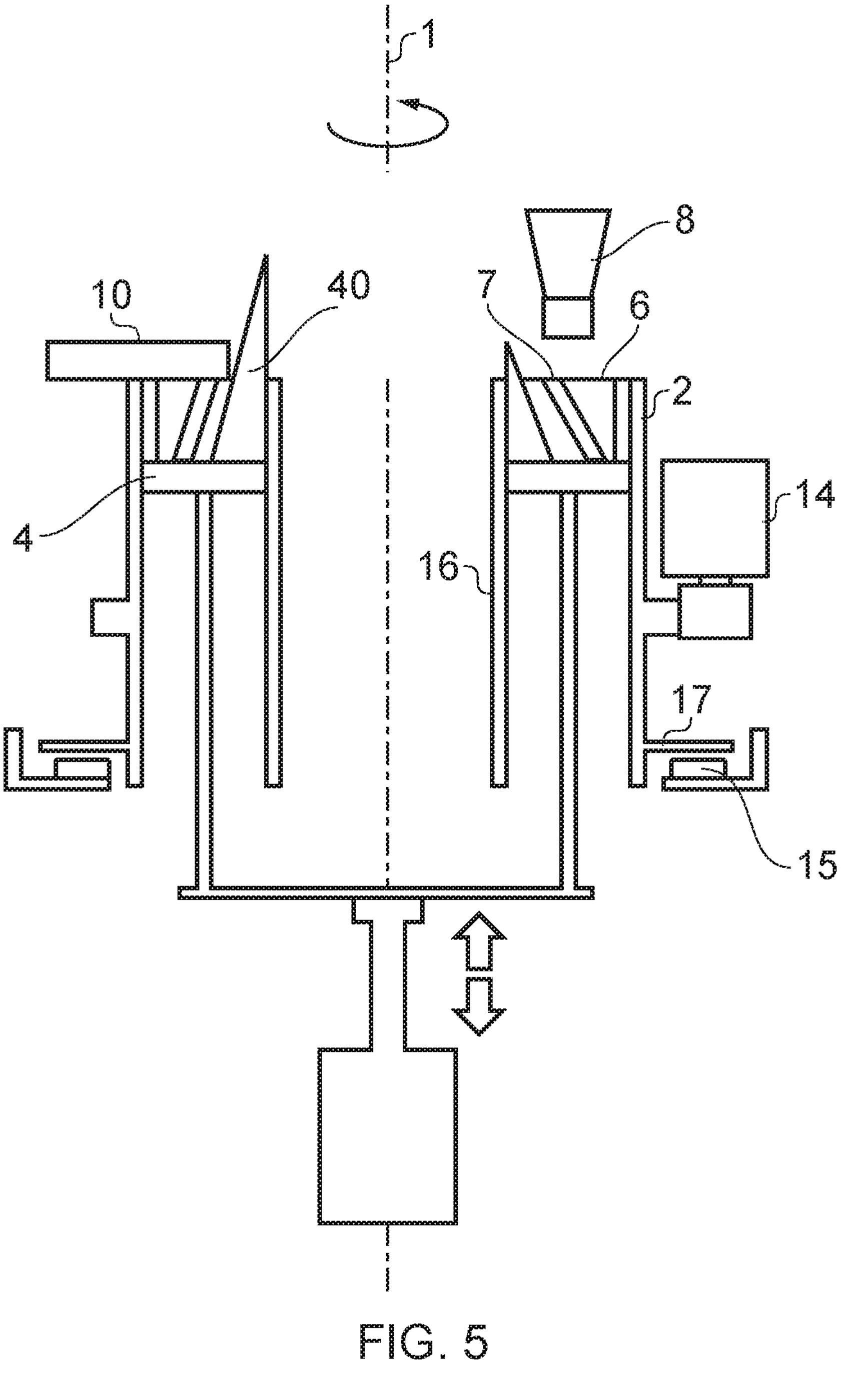


FIG. 5

# Apparatus for Building a Component

## Technical Field of Invention

[001] The present invention relates to methods and apparatus for building components using powder beds. Particular applications are in the manufacture of cylindrical components manufactured from a metallic or polymeric powder.

## Background of Invention

[002] Near net shape manufacturing offers a number of advantages over conventional forging or machining operations, one of which is the ability to manufacture components using less material and post processing steps. One known near net shape manufacturing process is known as powder bed processing.

[003] In conventional powder bed manufacturing methods a bed is supplied onto which a layer of powder is laid. A laser follows a tool path to scan over the surface of the powder and heats and sinters, consolidates or melts the powder at selected locations. The bed is then indexed and a new layer of powdered material laid over the existing layer. The laser repeats its scan either following the same tool path or a further tool path to melt the powder in the new layer at selected locations.

[004] Where the selected locations of adjacent layers overlap, the material is joined. In this way, repeated scanning and layering allows complex components to be built and, since the component is formed layer by layer, complex internal structures that are not possible from some other manufacturing methods can also be formed.

[005] Component definitions can be supplied to the powder bed in a standard form which, when coupled with standard instructions to the powder bed including laser power, path, material type, etc. allows instructions to be sent to machines located anywhere in the world to manufacture the components where they are needed rather than having to deliver the finished article from manufacturing location away from the articles' use.

[006] Powder beds that operate in a rotating manner are known in the art. For example, US2003/0205851 describes a process in which a table is rotatable about a rotational axis and is simultaneously lowered in the direction of the axis so that each radius of its surface

executes a spiral movement the pitch of which corresponds to a layer thickness of material to be melted. Complex slicing algorithms are required since layer heights are inconsistent and angular velocity effects create further difficulties. US 2008/0317951 describes an apparatus in which the build plate is rotated to allow a linear laser scan to be oriented to a predetermined build direction. US 2006/0108712 describes a rotary bed in which the build platform is separately indexable to the bed walls.

**Statements of Invention**

[007] According to a first aspect there is provided apparatus for forming an article by layerwise manufacture, the apparatus comprising: a build tank having a radially inner wall and a radially outer wall and a build plate together providing a chamber within which the article is manufactured; wherein the radially inner wall and the radially outer wall are configured to rotate about an axis; the build plate supporting an article in manufacture and configured to rotate about the axis; the build plate being indexable in the axial direction to increase the volume of the chamber; wherein the build apparatus is provided with a heat exchanger for thermal management of the chamber.

[008] By having an indexable build plate it is possible to rotate the tank walls and build plate a number of times under an energy source which melts a powder within the build tank before indexing the build plate. The powder depth remains constant till each layer has been melted to the extent required in the required locations.

[009] Actuators may be provided to drive rotation of the radially outer wall. Any suitable belt, gear, or other appropriate actuator may be used.

[0010] The radially outer wall may engage the build plate, which may engage the radially inner wall to drive rotation of the radially inner wall. The actuator driving the radially outer wall may thereby drive the radially inner wall through the base plate.

[0011] Engagement may be through a plurality of splines running parallel to the axis of the tank. The splines may engage with a plurality of grooves along an edge of the build plate and aligned with the splines to rotationally drive the build plate from the outer wall.

[0012] The inner wall may have a plurality of splines running parallel to the axis of the tank. The splines may engage with a plurality of grooves along an edge of the build plate. The build plate may have a plurality of grooves along an edge that are aligned with the inner wall splines.

[0013] The build apparatus may have a driving device to rotate the walls independently of the build plate. The walls can be made to rotate faster, slower or at the same velocity as the build apparatus.

[0014] The radially outer wall and the radially inner wall may be cylindrical and together define an annulus. The annulus may be subdivided to provide a plurality of circumferentially spaced build chambers.

[0015] The heat exchanger may comprise a fluid source and one or more nozzles directed towards one or more of the radially inner or radially outer walls.

[0016] The, or each, nozzle may be circumferentially, or axially elongate to deliver a curtain of fluid onto the radially inner wall.

[0017] The build apparatus may further comprise one or more inserts 40 positioned between the radially inner wall and the radially outer wall that reduce the volume of the chamber. The insert may be sloped and extend about the axis of the tank in conical form. The, or each, insert may be thermally conductive and may comprise a porous material the insert having a non-porous exterior barrier for preventing ingress of a powder into the pores.

[0018] The build apparatus may comprise one or more a blade arranged to level powder in the chamber. The blade may be radially indexable. The blade may be curved in a direction opposite the direction of rotation of the radially inner and radially outer walls. A spindle may be connected to the blade to allow the blade to rotate independently of the chamber and / or the base plate.

[0019] The build apparatus may further comprise a powder hopper for supplying powder to the build chamber. The powder hopper may be positioned above the tank to deliver powder via gravity. Multiple hoppers may be provided around the circumference of the build tank. Each hopper may contain a different material and may be indexable into position possibly replacing an existing hopper.

[0020] The build apparatus may further comprise a laser for directing a high energy beam into the chamber for melting a powder supplied to the chamber.

[0021] The laser may have a power modulator such that the high energy beam has a greater power density the further it is from the axis of the build apparatus. The beam may also be pulsed, where the placement of spots (overlap %) might be varied. Alternatively, laser optics may be used to change the spot size.

[0022] According to a further aspect there may be provided a method of operating a build apparatus where the heat exchanger pre-heats the chamber or the powder prior to application of a laser to a build powder.

[0023] The method of operating the build apparatus may use the heat exchanger to cool the chamber during application of a laser to a build powder.

[0024] The method of operating the build apparatus may use the heat exchanger to slow or increase the cooling rate of the chamber after application of a laser to a build powder.

[0025] The method of operating the build apparatus may increase the power density of a high energy beam the further it is from the axis of the build apparatus.

**Description of Drawings**

[0026] Figure 1 depicts a build apparatus;

[0027] Figure 2 depicts a drive arrangement for the radially inner wall.

[0028] Figure 3 is a plan view of the apparatus of Figure 1;

[0029] Figure 4 is an alternative chamber arrangement for the apparatus of Figure 2.

[0030] Figure 5 depicts a further chamber arrangement having inserts.

**Detailed Description of Invention**

[0031] Figure 1 depicts a powder bed manufacturing apparatus that comprises a radially outer external wall 2 a radially inner wall 16 that together provide an annular chamber 6 which rotates about its vertical axis 1 during the building of the component. In this document the term axis is defined with respect to this vertical axis around which the annular chamber rotates and radial is defined with respect to this axis. The base plate 4 is an annular plate that rotates with the inner and outer walls and can be indexed in the axial direction by a suitable actuator e.g. a piston 13. A component 7 is built within a powder bed with powder being supplied from a powder hopper 8 (one is shown). The powder 3 is deposited within the chamber and a levelling blade 10 levels the powder. A laser station 12 (not shown in Fig. 1) is associated with the chamber 6 to provide sufficient energy to melt the powder at the required locations.

[0032] The build plate is mounted to an actuator 13 that allows the build plate 4 to index relative to the chamber walls 2, 16. The actuator may also permit the build plate to rotate about axis 1 independently of the indexing motion.

[0033] The chamber wall is mounted to an actuator 14 that may permit the radially outer chamber wall 2 to rotate about the chamber axis 1 independently of the build plate. The chamber is supported on bearings 15 that carry a flange 17 extending from the chamber wall. One of the advantages of the independently rotating base plate and chamber wall is that the relative velocity of the powder to the wall can be controlled. In practice the chamber wall and the base plate rotate synchronously but if there is any shear effect between the powder and the chamber wall this can be negated or controlled within the powder by having the wall rotate at a faster or slower velocity than the base plate.

[0034] If the inner wall is to be driven at the same velocity as the outer wall and build plate this may be achieved by providing the radially inner 5 and radially outer 2 walls with a series of vertical splines 30 that index a plurality of corresponding splines grooves 32 on the base plate 4 as shown schematically in Figure 2. Drive from the outer wall is transferred through the base plate to the inner wall but the vertical splines that extend the length of the powder bed allow the base plate to rotate with the inner and outer wall but still be indexed in the axial direction. In this arrangement the actuator for the base plate provides simple axial movement rather than having to provide both axial and rotational movement. This simplifies construction of the build apparatus and may allow a relatively large bore to be provided around the axis which may be used, as described later, to cool the build chamber.

[0035] Figure 3 depicts a top view of the build apparatus of Figure 1. Powder is supplied from storage hoppers 8 located above the chamber which feed the powder into the build chamber 6 of the build apparatus. In the exemplary apparatus there are multiple laser 12, re-coater 10 and hopper 8 stations positioned at regular spacing around the chamber annulus. Multiple laser spots are provided at intervals around the annular bed and which are at a fixed position such that the angular component of the laser track speed is provided by the rotation of the bed relative to the laser. An actuator or other raster device 22, such as a galvo head supplies radial and other x-y movement as required with synchronisation between the x-y movement and the rotation of the bed being provided in the software algorithms.

[0036] Although the actuator 22 is shown as being linear across the build chamber there may be benefit in having a curved track to compensate for the difference in rotational speed at the radially inner edge of the build chamber and the radially outer edge of the build chamber. In addition, or alternatively, the density of the energy of the laser (J/mm^2) may be increased as the melt spot generated by the laser moves radially outwards. For an annular bed having a width of 100mm between a radially inner diameter of circa 600mm and a radially outer diameter of 800mm the power may be up to 20% greater at the outer wall.

[0037] The use of multiple lasers and powder hoppers enables different spot sizes and powers or powders to be supplied from the different stations. This would enable, as an example, the external surface of a component to be deposited at one station whilst the body of the component is formed by a further station. Advantageously, where the body and external features require different deposition parameters this can be easily accommodated. Different combinations of deposition parameters can be provided at different scan radial area positions to provide flexibility for optimisation of the material properties and process build rates.

[0038] Other processing stations such as preheat 18, postheat 24, controlled cooling, visual inspection and measurement could be provided in selected circumferential positions.

[0039] Scraper blades 10 may be located on a framework 20 which rotates about the axis of the chamber in a carousel or windmill type arrangement that facilitates a variable re-coater speed compared to track speed even allowing the re-coater blades to rotate in the opposite direction to the laser track scan vector.

[0040] In another arrangement, one or more fixed scraper blades 10 may be provided and acutely angled to the surface of the bed to ensure that the powder is spread into a layer of constant thickness. The scraper blades may extend substantially radially or be angled away from the centre of rotation and may be linear or curved. The recoating speed is equal to the track scan speed.

[0041] The configuration of the scraper blades can be used to control, in part, the way the powder is removed from the surface of the bed. In many environments it is desirable to direct the powder radially outwards where it can be captured and stored for possible further re-use. Directing it inwards towards the axis can lead to an accumulation of powder in a difficult to reach area of the build apparatus and in an area where build-up could cause uneven variation in the weight of the apparatus and this could lead to difficulties in controlling the uniformity of the component build. A scraper with a curvature away from the direction of rotation of the bed and / or scraper will tend to push the powder radially outwards.

[0042] Although a single annular chamber is shown in Figure 3 it is possible to subdivide the single chamber into multiple chambers by inserting one or more spaced walls. Where the drive apparatus of Figure 3 is used, the splines may also be used to locate the dividers. The dividers may protrude through slots in the build plate and protrude through to a level that is equal to, or just below the upper end of the inner or outer wall. Where there is a gap between adjacent chambers in a multiple chamber arrangement, collection hoppers may be provided to collect excess powder for subsequent storage and re-use. The gap also provides thermal insulation between adjacent chambers and provides further surface area around the periphery of a build chamber for better thermal control of the temperature in the build chamber. Cooling or heating may be applied to the gap to facilitate the thermal control.

[0043] As depicted in Figure 1 a heat exchanger arrangement is provided to control the temperature of the build apparatus. The heat exchanger arrangement is used to chill or heat a flow of fluid before its delivery to an external wall of the build apparatus.

[0044] A fluid source 30 directs fluid through a chiller or heater 32 to a nozzle 34. Where the build apparatus in located within an inert atmosphere, such as argon, the source may be a pump or fan within the tank. Alternatively the fluid source may be a cylinder of compressed gas. The fluid is preferably gaseous since a liquid could cause the particles in the build chamber or hopper to agglomerate in a way that could cause blockages or inconsistencies in manufacture of the component.

[0045] The cooled or heated fluid in the embodiment of Figure 1 is directed along the axis of the machine to a nozzle or nozzles that direct the fluid radially on to the radially inner surface of the radially inner wall 5. The flow of fluid may flow as a radial curtain, or knife, around the circumference of the bore defined by the wall, or along an arc close to the position to which the build laser directs its energy.

[0046] The velocity of the fluid is sufficient to create an impingement flow onto the wall. During operation of the build apparatus it is desirable to cool the flow to remove heat from the system. The flow of cooling air may be continued after the built component is complete to enhance the cooling of the bed which will allow the start of a new build process more quickly than if no cooling is applied.

[0047] It may also be desirable to heat the bed before the build process starts. During manufacture of the component the laser inputs significant heat into the powder bed and this can lead to non-uniformity at the start of manufacture compared with later in the manufacture process. Early heating of the bed can minimise the non-uniformity.

[0048] Controlling temperature before build can also help control absorbed moisture in the system as the system may be kept sealed. Using a dry gas, such as argon, helium or other suitable inert gas, or nitrogen which is warmed may counter condensation of any liquid within thesystem.

[0049] The nozzle may have multiple outlets. Some may generate impingement jets whilst others may diffuse an area with fluid at a predetermined temperature. Where an inert gas such as Argon is used a flowrate of around 200l/min minimum may be used.

[0050] The system might be configured to run with two gases, for example nitrogen and argon separately. The system might stand at idle (stand by) and purge using clean dry nitrogen, then use more expensive argon for processing. A dual gas system would add to the control and capital cost however. Nitrogen may also be considered for system cooling once the powder melting phase of the processing is completed, subject to alloy specific controls on oxidation.

[0051] Further nozzles may be used to also apply heating or cooling to the radially outer surface of the radially outer wall. The cooling or heating may be applied to both sides of the build tank simultaneously or separately. Where simultaneous cooling or heating is used there is a reduced temperature distribution across the build tank.

[0052] The annular chamber 6 finds particular advantage when used for the manufacture of annular components such as pipes, drums or annular casings, flanged rings, frusto-conical casings. The articles may have split walls i.e. an inner and outer wall separated by internal fluid passageways, and casings having hangers suitable for mounting protective tiles. The inner and outer walls can be modified by the addition of inserts or sleeves that change the inner or outer diameters of the annular chamber. Doing this ensures that a smaller volume of powder is required to fill the chamber which cuts down on the manufacturing cost. Synchronous rotation of the base plate and the chamber walls mean that the annular chamber can be relatively narrow as shear effects in the powder between the powder and the chamber walls are kept to a minimum.

[0053] In Figure 4 the radially inner wall 16 is provided by a projection extending from the build platform 2. A separate radially inner wall may be provided (as in Figure 1) to lend stability to the wall on the build platform, but this is optional. In these arrangements the levelling blade 10 is not centrally mounted but instead is static with the bed passing beneath it.

[0054] The shape of the projection may be selected to reduce the amount of powder required over that needed for a purely cylindrical bed. The build apparatus of Figure 4 may be used where the component being built 7 is conical. The insert, mounted to the baseplate, is also conical in form with a cone angle selected to match that of the component being built. Where a conical insert is used the levelling blade is provided with an indexing mechanism that moves it radially inwards as the base plate moves lower and the area of the annular chamber increases to level the entire width of the annular chamber.

[0055] The projection 16 may be removable from the build apparatus and replaceable with projections of different sizes and forms. In addition, or alternatively, projections or sleeves may also be used adjacent the radially outer wall of the build apparatus to adjust the size of the chamber and the amount of powder required when building a component or multiple components. Advantageously, the chamber can be built larger than usually required and selectively reduced in size to give flexibility in the type and size of the components that can be manufactured.

[0056] Where sleeves, or projections are used on both the radially inner or radially outer walls they may each be of the same or different forms. Figure 5 depicts an exemplary arrangement with a radially outer insert mounted to the outer wall and a radially inner insert mounted against the radially inner wall of the build chamber. Two forms of radially inner inserts are shown, each provided for a separate build chamber, though it would be appreciated that, depending on the article to be built, a single insert may be used that has a varying cross-section around the circumference of the build apparatus. Practically, in the embodiment of Figure 5, the radially inner inserts 40 may be mounted to the build plate and index with the build plate whilst the radially outer inserts are fixed to the outer wall and do not index. Rotation of the outer walls can help with respect to the extra friction which would otherwise arise from the wall. Where inserts are not indexed, a partially or fully fused wall or dam might be deposited to prevent or limit powder flow underneath. For other configurations of build apparatus e.g. where the levelling blades are mounted closer to the axis the arrangement of inserts may be reversed.

[0057] The inserts, sleeves or projections, may be of a metal, or some other material that is conductive but of low thermal mass. The metal may be foamed, or porous to reduce its mass but have a non-porous facing surface to prevent powder or moisture ingress into the pores. The smooth surfaces are also to control moisture transfer.

[0058] In some embodiments a more complex shape may be applied to the chamber walls. The walls may be bowed or serpentine as the laser can be angled to provide a degree of undercut to the wall provided that the undercut does not block the laser's line of sight. Additionally, where, for example, the manufactured component has re-entrant features the removal of a one piece insert may not be possible. In these situations it may be advisable to form the insert 40 in multiple, arcuate, sections that can be separated to allow the insert parts to pass through or be decomposed or leached out from the finished component.

[0059] Although the base plate could be configured to index relative to the side walls in a helix i.e. for every turn the base plate indexes a predetermined distance this adds to the computing and control complexity required by the whole system to manufacture each component. Accordingly, the base plate performs one, and preferably multiple, complete turns before it is indexed down the distance equivalent to one layer.

[0060] As the annular chamber rotates the, or each, laser directs a beam onto the top layer of the powder to first predetermined pattern. Multiple rotations may be needed to form the completed pattern and advantageously this is facilitated by this arrangement. The laser scans radially across the annular chamber as required till the complete layer is formed. Because the chamber rotates continuously there is no sudden acceleration required by the laser head as may be needed in conventional powder bed processing apparatus.

[0061] As the layer completes the base plate indexes axially and the hoppers supply fresh powder onto the surface of the chamber, the new powder being levelled by the levelling blade before the next layer is melted at the selected locations by the laser.

[0062] As will be understood the laser trajectory does not need to be helical, but could also traverse in a linear or 2-axis traverse across the radial width of the bed. The material can be deposited in a series of circles. Consequently, the linear track speed of the laser could be kept constant to avoid complications of angular velocity constraints. The linear tracks could be but don't have to be radial. They could be linear or 2-axis traverses. A delay, if deemed advantageous for build quality, could be built in after each layer to heat treat, or otherwise, each layer prior to indexing the base plate.

[0063] Multiple laser spots can be provided from stations spaced around the circumference of the annular bed which can speed up the formation of the component and generate higher deposition rates.

[0064] Other forms of actuators could be used to index the base plate. In one arrangement the indexing mechanism is built into the rotating walls e.g. by a series of cam plates, rollers or ratchets. The particular advantage of this arrangement is that the system is substantially continuous as once a component is finished a few layers of virgin powder is deposited before a new base plate is fed onto the surface of the powder and a new component started. Once the first component base plate falls below the lower edge of the chamber walls it can be removed by an unloading station and the component sent for post-processing.

[0065] Rather than feeding a new base plate into the system it is, of course possible to build the next base plate by laser melting one or more complete layers of the powder within the chamber. This finds particular use where the powder is cheap. In other arrangements it is possible to build keying features into the powder layer that engage with the actuators on the sidewalls and help index the components axially.

[0066] As an alternative to an annular component, multiple smaller components may be individually formed within the build chamber. In this alternative arrangement it is possible to divide the bed into multiple sections by providing two or more circumferentially spaced walls. Where there is no inner wall to the build chamber the circumferentially spaced walls may extend radially and intersect at a common axis; where the build chamber is annular the circumferential walls may extend substantially radially between the inner wall and the outer wall of the tank.

[0067] Advantageously, multiple individual build chambers may be formed which can be selectively filled with powder to either save on the use of powder as the entire tank / annular tank need not be filled with powder; or to simultaneously build components of different materials. In some circumstances this may enable laser optical systems on slides to move between build chambers so as to increase their utilisation efficiency whilst the chambers are being loaded and heated or cooled and unloaded. Hoppers containing different powders will be required for this embodiment.

[0068] The material used to build the component is preferably in powder form and may be metallic or plastic. The walls of the tank or the insert may have heaters to control the cooling rate of the manufactured component. The material used to build the component may be in liquid form i.e. a UV or otherwise polymerisable organic. Fibrous reinforcement might also be added in some external configurations.

**Claims:**

1. Build Apparatus for forming an article by layerwise manufacture, the apparatus comprising:

   a build tank having a radially inner wall and a radially outer wall and a build plate together providing a chamber within which the article is manufactured;

   wherein the radially inner wall and the radially outer wall are configured to rotate about an axis;

   the build plate supporting an article in manufacture and configured to rotate about the axis;

   the build plate being indexable in the axial direction to increase the volume of the chamber; wherein the build apparatus is provided with a heat exchanger for thermal management of the chamber.

2. Build apparatus according to claim 1, wherein the build tank has an actuator that drives rotation of the radially outer wall.
3. Build apparatus according to claim 2, wherein the radially outer wall engages the build plate, which engages the radially inner wall to drive rotation of the radially inner wall.
4. Build apparatus according to claim 3, wherein the radially outer wall has one or more features that drive complementary features on the build plate and the build plate has one of more features that drive complementary features on the radially inner wall.
5. Build apparatus according to claim 4, wherein one or more of the features and / or complementary features are axially extending projections that protrude from the radially outer, radially inner wall or the base plate.
6. Build apparatus according to claim 1 or claim 2, wherein the build tank has a driving device to rotate the radially inner wall independently of the build plate or radially outer wall.
7. Build apparatus according to claim 1 or claim 2 or claim 6, wherein the build plate has a driving device to rotate the build plate independently of one or more of the radially inner wall or radially outer wall.

8. Build apparatus according to any preceding claim, wherein the radially outer wall and the radially inner wall are cylindrical and define an annulus.
9. Build apparatus according to claim 8, wherein the annulus is subdivided to provide a plurality of circumferentially spaced build chambers.
10. Build apparatus according to any preceding claim, wherein the heat exchanger comprises a fluid source and one or more nozzles directed towards one or more of the radially inner or radially outer walls.
11. Build apparatus according to claim 10, wherein the one or more nozzles are directed towards the radially inner wall.
12. Build apparatus according to claim 11, wherein the nozzle is circumferentially, or axially elongate to deliver a curtain of fluid onto the radially inner wall.
13. Build apparatus according to any preceding claim, further comprising one or more inserts positioned between the radially inner wall and the radially outer wall that reduce the volume of the chamber.
14. Build apparatus according to claim 13, wherein the insert is sloped and extends about the axis of the tank in conical form.
15. Build apparatus according to claim 13 or claim 14, wherein the, or each, insert is thermally conductive.
16. Build apparatus according to claim 15, wherein the, or each, insert comprises a porous material the insert having a non-porous exterior barrier for preventing ingress of a powder into the pores.
17. Build apparatus according to any preceding claim, comprising a blade arranged to level powder in the chamber.
18. Build apparatus according to claim 17, wherein the blade is radially indexable.
19. Build apparatus according to claim 17 or claim 18, wherein as the blade extends across the build chamber it is curved against the direction of rotation of the radially inner and radially outer walls.
20. Build apparatus according to any preceding claim, the build apparatus further comprising a powder hopper for supplying powder to the build chamber.
21. Build apparatus according to any preceding claim, comprising a laser for directing a high energy beam into the chamber for melting a powder supplied to the chamber.

22. Build apparatus according to claim 21, wherein the laser has a power modulator such that the high energy beam has a greater power density the further it is from the axis of the build apparatus.
23. Build Apparatus substantially as hereinbefore described with reference to the accompanying drawings.
24. A method substantially as hereinbefore described with reference to the accompanying drawings.

Intellectual Property Office

| | | | |
|---|---|---|---|
| **Application No:** | GB1518164.7 | **Examiner:** | Dr Richard Burkitt |
| **Claims searched:** | 1-24 | **Date of search:** | 8 December 2015 |

## Patents Act 1977: Search Report under Section 17

**Documents considered to be relevant:**

| Category | Relevant to claims | Identity of document and passage or figure of particular relevance |
|---|---|---|
| Y | 1-2, 8-10, 15, 17, 20 & 21 | WO 2014/018100 A (PRATT & WHITNEY) - Paragraph [0014] and [0015]. Figure 1, 2 and 4. |
| Y | 1-2, 8-10, 15, 17, 20 & 21 | US 2006/108712 A (MATTES) - Figure 1 and paragraph [0015] and [0016]. |
| Y | 1-2, 8-10, 15, 17, 20 & 21 | US 2015/0017013 A (TOZZI) - Figure 1 paragraph [0042] and [0044] |
| Y | 1-2, 8-10, 15, 17, 20 & 21 | WO 2014/195068 A (SIEMENS) - Figure 1 and WPI Abstract Accession No. 1988-V48798, Page 7, lines 4-15 |
| Y | 1-2, 8-10, 15, 17, 20 & 21 | US 2008/0190905 A (HEINLEIN) - See Figure 2 and Figure 5, paragraph [0014], [0024] and [0030], [0034], [0036] & [0037]. |
| Y | 1-2, 8-10, 15, 17, 20 & 21 | US 5753274 A (WILKENING) - Figure 1 and column 2 lines 27-33. |
| Y | 1-2, 8-10, 15, 17, 20 & 21 | CN 104226996 A (UNIV) See Epodoc abstract and Figure 1. |
| Y | 1-2, 8-10, 15, 17, 20 & 21 | CN 203843169 U (LIU YUANGANG) - EPODOC abstract |
| Y | 1-2, 8-10, 15, 17, 20 & 21 | US 2008/317951 A (GREEN) - Figure 1A paragraph [0008] |

Categories:

| | | | |
|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

Intellectual Property Office

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the $UKC^{X}$ :

| |
|---|
| |

Worldwide search of patent documents classified in the following areas of the IPC

| |
|---|
| B22F; B23K; B29C; B29D; B33Y; F28B; F28C; F28D; F28F; F28G |

The following online and other databases have been used in the preparation of this search report

| |
|---|
| EPODOC, WPI and Inspec |

**International Classification:**

| Subclass | Subgroup | Valid From |
|---|---|---|
| B33Y | 0030/00 | 01/01/2015 |
| B22F | 0003/105 | 01/01/2006 |
| B29C | 0067/00 | 01/01/2006 |