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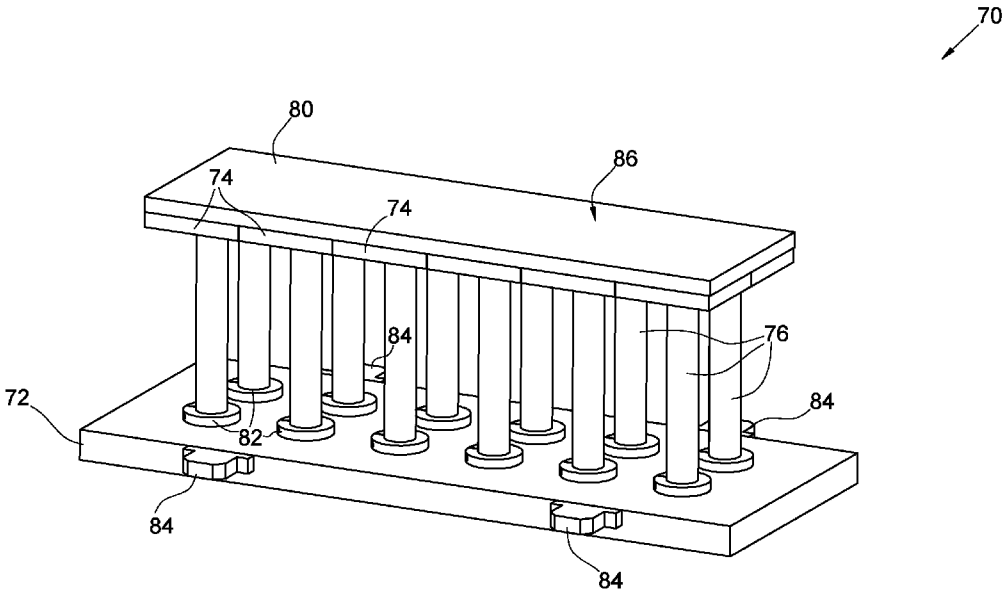

Figure 6

(57) Abstract: This invention relates to an additive manufacturing apparatus which includes a build platform arrangement 70. The build platform arrangement 70 includes a base 72, a plurality of build platform modules 74, a plurality of mounting elements in the form of pillars 76 and a build platform surface element 80. Each one of the build platform modules 74 is configured to be selectively enabled or disabled by locking or unlocking a clamping element 82 associated therewith whereby the associated build platform module 74 can be locked releasably to the base 72. A build platform of a desired configuration can then be selected by enabling the required build platform modules 74. The additive manufacturing apparatus includes a material retaining unit, the configuration of which is adjustable in order to conform to the shape of the support platform.

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Build platform arrangement for an additive manufacturing apparatus

FIELD OF THE INVENTION

This invention relates, broadly, to additive manufacturing. More particularly, the invention relates to a build platform arrangement for an additive manufacturing apparatus and to an additive manufacturing apparatus including such a build platform arrangement. The invention also relates to a material retaining unit for an additive manufacturing apparatus and to an additive manufacturing apparatus including such a material retaining unit.

BACKGROUND OF THE INVENTION

The term "additive manufacturing" (AM) refers to various processes used to synthesise/manufacture a three-dimensional object (hereafter simply referred to as an "object" or "part"). Certain AM techniques are sometimes referred to as "3D printing".

In AM, parts are typically manufactured by digitally slicing a three-dimensional computer-aided design (CAD) model into two-dimensional layers, cross-sections or images. These layers are then sequentially manufactured and joined to each other by curing, consolidating, fusing or otherwise forming these layers from a raw material, typically in the form of a powder or fluid.

In the Inventors' experience, AM generally provides a number of advantages over traditional manufacturing methods. These advantages include the ability to manufacture highly complex parts which allows for weight reduction, integration of

more functionality into parts and part count reduction. The process also obviates the need for tooling, leading to cost, time and/or material saving.

A number of AM processes employ an energy source in the form of a high energy beam (e.g. laser or electron beam) to melt or sinter powdered material in a material bed in layers which are joined ultimately to form a desired part. These processes are hereinafter jointly referred to as "powder bed fusion processes".

In powder bed fusion processes, the energy source is directed by a scanning unit, based on the geometry of a CAD model, to ensure that the desired layers are formed. The material bed is supported on a build platform which is incrementally lowered in one direction (hereinafter generally referred to as "the Z-direction") as each new layer of the object is formed. A fresh layer of material is then added to the material bed before the next layer is scanned and fused.

A number of AM processes also require some form of preheating to be carried out. Preheating strategies are employed to elevate the temperature of raw material before consolidating the raw material into a final form. Preheating may be used in an attempt to ensure that material is more easily processed and/or processed at a more rapid rate, or to remove moisture from the material prior to consolidation (as the presence of moisture may lead to porosity and/or other defects in the object).

Further, when producing AM parts using energy beams, residual stresses form in the material due to solidification shrinkage of a weld pool. In certain materials, these residual stresses are relatively high and, when producing larger parts, can cause the parts to distort and/or crack. Material can be preheated and/or the rate of cooling can be controlled to reduce or relieve such stresses.

Existing AM systems typically employ a build platform which has fixed dimensions. The build platform is generally mounted to an actuating arrangement, e.g. one or more electrically driven linear actuators located below the build platform, which enables

the build platform to be incrementally moved in the Z-direction, thereby permitting the incremental deposition of fresh layers of raw material onto the build platform.

Furthermore, the build platform is typically configured to move within a material retaining unit or housing which also has fixed dimensions. As the build platform moves incrementally in the Z-direction, a material deposition arrangement deposits new layers of material onto the build platform, thereby essentially filling the material retaining unit with material. Preheating is conducted either by heating the build platform or by heating the material deposited on the build platform from the top.

The Inventors have found that known AM systems are generally effective when the build platform is relatively small, i.e. when the build platform defines a generally small area in an X-Y plane. A typical AM system may have a relatively small build platform with dimensions of about 300 mm x 300 mm in the X-Y plane. However, the Inventors believe that known AM systems have a number of drawbacks when relatively large build platforms are employed.

As mentioned above, the build platform and material retaining unit for typical AM systems have fixed sizes. Naturally, a relatively large build platform area may in many cases be provided in order to accommodate larger parts (or larger batches of small parts). It may be necessary to fill the entire surface of the build platform and/or substantially the entire material retaining unit with raw material, even when relatively small parts or relatively few parts are manufactured which do not fill a significant portion of the build platform in the X-Y plane. As a result, upon completion of a production run, the ratio of unused material to used material is high when a small part is produced, and operators are required to have relatively large quantities of raw material available even when only producing small parts.

The presence of a relatively large quantity of unused material may have a negative impact on an AM operation for a number of reasons.

Firstly, unused material may degrade every time an AM apparatus is used, while certain raw materials are only useful for a limited number of production runs and/or have a limited shelf life. The above issues can lead to a significant waste of material and consequential increase in cost.

Secondly, certain raw materials are expensive and large stockpiles are therefore not desirable or feasible.

Thirdly, certain raw materials may be inherently hazardous and large stockpiles may thus lead to safety concerns.

Fourthly, certain materials need to be processed (e.g. sieved or blended) between builds or production runs. Large quantities of unused materials may thus increase overheads associated with material processing and handling.

A further disadvantage associated with conventional, fixed-size build platforms relates to preheating activities. As mentioned above, in typical existing systems, either the entire build platform is preheated or the entire material bed is preheated from the top. In cases where relatively small parts are to be produced, the bulk of input energy required for preheating is wastefully applied to ultimately unused raw material. It is particularly disadvantageous to unnecessarily heat material, because not only does this lead to relatively high energy requirements considering the size of the part to be produced, but it also often accelerates the degradation of the material to the point where it has to be discarded.

The Inventors have also found that it may be difficult to adapt the dimensions of a build platform in an existing AM implementation, as the build platform is typically directly coupled to the actuating arrangement used to displace the build platform along the Z-axis and/or is required to conform to the dimensions of the material retaining unit.

The present invention aims to address the issues identified above, at least to some extent.

SUMMARY OF THE INVENTION

According to one aspect of the invention there is provided an additive manufacturing apparatus, which includes:

an actuating arrangement; and

a build platform arrangement which includes

a base which is attached or attachable to the actuating arrangement, the actuating arrangement being configured to displace the base along a Z-axis; and

a build platform which is mounted or mountable to the base such that operative displacement of the base by the actuating arrangement causes displacement of the build platform, the build platform including a plurality of build platform modules, wherein at least some of the build platform modules are configured to be selectively enabled or disabled, and wherein a working area of the additive manufacturing apparatus is defined by a build platform constituted by the build platform module or modules that is or are operatively enabled.

The working area may be of variable dimensions and/or shape in an X-Y plane of the additive manufacturing apparatus.

Each of the build platform modules may be configured to be selectively enabled or disabled.

The build platform modules may form an array, e.g. a rectangular array, when viewed in the X-Y plane.

The build platform may be spaced apart from the base along the Z-axis of the additive manufacturing apparatus, i.e. the build platform may be located above the base. The base may in turn be located above the actuating arrangement.

At least one heating and/or cooling unit may be provided in a space defined between the base and the build platform. Thermal insulation and/or sensors (e.g. temperature sensor) may also be provided in the space.

One or more of the build platform modules may have a dedicated heating and/or cooling unit associated therewith. The dedicated heating and/or cooling unit associated with a particular build platform module may be activated when the build platform module is enabled and deactivated when the build platform module is disabled. One or more of the build platform modules may be provided with dedicated thermal insulation.

In some embodiments, the build platform modules are mounted or mountable to the base by a plurality of elongate mounting elements. The mounting elements may be pillars. The mounting elements may extend longitudinally along the Z-axis of the apparatus, in use.

Each build platform module may be mounted or mountable to the base by one of the mounting elements ("an associated mounting element").

The build platform modules may be removably mounted or mountable to the base. In some embodiments, when a build platform module is enabled, it is fixed to the base, and when a build platform module is disabled, it is not fixed to the base.

Each of the mounting elements may be actuatable between a locked and an unlocked condition. In some embodiments, each build platform module is configured to be enabled by locking the mounting element associated therewith, and disabled by unlocking the mounting element associated therewith.

In use, a generally planar build platform surface element may be fitted to the build platform module, or modules, that is or are enabled, thereby defining the working area of the additive manufacturing apparatus. The surface element may have a

customizable shape. The working area may be configured to receive material, e.g. powder material, which is to be consolidated, in use.

The build platform modules may be rectangularly shaped. The working area may extend in the X-Y plane.

The actuating arrangement may be provided by one or more linear actuators. The linear actuators may be electrically driven.

The additive manufacturing may include:

at least one material deposition arrangement for depositing layers of material in the working area to form a material bed;

at least one material feeding mechanism for feeding material into the material deposition arrangement; and

a scanning unit spaced operatively above the working area, the scanning unit configured to direct and/or control an energy beam for consolidating material deposited in the material bed.

The additive manufacturing apparatus may include a material retaining unit, the material retaining unit including a plurality of walls which are configured to conform closely to outer side edges of the build platform of the additive manufacturing apparatus so as to retain a material bed operatively deposited in a working area defined by the build platform, wherein the walls are configured to extend generally transversely to the build platform, and wherein at least one of the walls is configured to be adjustably mounted in the additive manufacturing apparatus to permit the material retaining unit to accommodate build platforms of various shapes and/or dimensions.

In some embodiments, the material retaining unit may include four walls. At least one of the walls may be fixedly mountable in the additive manufacturing apparatus, while at least one other wall may be adjustably mountable in the additive manufacturing apparatus.

The walls may extend along a Z-axis of the additive manufacturing apparatus and the build platform may extend in an X-Y plane of the additive manufacturing apparatus.

The material retaining unit may be adjustable so as to accommodate various numbers, arrangements and/or shapes of enabled build platform modules.

According to another aspect of the invention there is provided an an additive manufacturing apparatus including:

a build platform;

an actuating arrangement configured to displace the build platform;

at least one material deposition arrangement for depositing layers of material in a working area defined by the build platform to form a material bed;

at least one material feeding mechanism for feeding material into the material deposition arrangement;

a scanning unit spaced operatively above the working area, the scanning unit configured to direct and/or control an energy beam for consolidating material deposited in the material bed; and

a material retaining unit including a retaining wall which conforms closely to outer side edges of the build platform so as to retain the material bed, wherein the wall extends generally transversely to the build platform, and wherein the configuration of the retaining wall is adjustable to permit the material retaining unit to accommodate build platforms of various dimensions.

The material retaining unit may include four walls. Two of the four walls may be fixedly mounted, while the other two walls are adjustably mounted, the walls being adjusted by moving them between a plurality of positions in an X-Y plane of the apparatus.

At least one of the walls may be removably mounted in the additive manufacturing apparatus to facilitate replacing said at least one wall with another wall of different shape and/or dimensions to said at least one wall.

According to another aspect of the invention there is provided a build platform arrangement for an additive manufacturing apparatus, the build platform arrangement including a plurality of build platform modules, wherein at least some of the build platform modules are configured to be selectively enabled or disabled, and wherein a working area of the additive manufacturing apparatus is defined by a build platform constituted by the build platform module or modules that is or are operatively enabled.

According to still another aspect of the invention there is provided an additive manufacturing apparatus which includes:

an actuating arrangement configured to displace a base of a build platform arrangement along a Z-axis;

at least one material deposition arrangement for depositing layers of material in the working area to form a material bed;

at least one material feeding mechanism for feeding material into the material deposition arrangement;

a scanning unit spaced operatively above the working area, the scanning unit configured to direct and/or control an energy beam for consolidating material deposited in the material bed; and

a material retaining unit including a plurality of walls which are configured to conform closely to outer side edges of the build platform so as to retain a material bed operatively deposited in a working area defined by the build platform, wherein the walls are configured to extend generally transversely to the build platform, and wherein at least one of the walls is configured to be adjustably mounted to permit the material retaining unit to accommodate build platforms of various shapes and/or dimensions.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further described, by way of example, with reference to the accompanying conceptual drawings.

In the drawings:

FIG. 1 shows a sectional front view of an exemplary conventional build platform arrangement for an additive manufacturing apparatus;

FIG. 2 shows a sectional front view of a first embodiment of a build platform arrangement for an additive manufacturing apparatus according to the invention, wherein the build platform arrangement is in a first configuration;

FIG. 3 shows a further sectional front view of the build platform arrangement of FIG. 2 in the first configuration;

FIG. 4 shows a sectional front view of the build platform arrangement of FIG. 2 in a second configuration;

FIG. 5 shows a further sectional front view of the build platform arrangement of FIG. 2 in the second configuration;

FIG. 6 shows a three-dimensional view of a second embodiment of a build platform arrangement for an additive manufacturing apparatus according to the invention;

FIG. 7 shows a three-dimensional view of an embodiment of an additive manufacturing apparatus according to the invention;

FIG. 8 shows a top view of the additive manufacturing apparatus of FIG. 7;

FIG. 9 shows a sectional view of the additive manufacturing apparatus of FIG. 7, taken along the line A-A in FIG. 8;

FIG. 10 shows a three-dimensional view of the additive manufacturing apparatus of FIG. 7, in a second configuration;

FIG. 11 shows a three-dimensional view of the additive manufacturing apparatus of FIG. 7, in a third configuration;

FIG. 12 is a partial front view of the additive manufacturing apparatus of FIG. 7, illustrating the functioning of lockable pillars of the apparatus; and

FIG. 13 is another partial front view of the additive manufacturing apparatus of FIG. 7, further illustrating the functioning of the lockable pillars.

DETAILED DESCRIPTION WITH REFERENCE TO THE DRAWINGS

The following description of the invention is provided as an enabling teaching of the invention. Those skilled in the relevant art will recognise that many changes can be made to the embodiments described, while still attaining the beneficial results of the present invention. It will also be apparent that some of the desired benefits of the present invention can be attained by selecting some of the features of the present invention without utilising other features. Accordingly, those skilled in the art will recognise that modifications and adaptations to the present invention are possible and can even be desirable in certain circumstances, and are a part of the present invention. Thus, the following description is provided as illustrative of the principles of the present invention and not a limitation thereof.

An example of a conventional ("prior art") build platform arrangement 10 used in a powder bed fusion process is illustrated in FIG. 1. The build platform arrangement 10 includes a build platform 12 which is directly mounted to an actuating arrangement 14.

The build platform 12 has a substantially planar shape and is rectangular in top and bottom view. A top surface of the build platform 12 defines a working area 16 in an X-Y plane in which layers of material are operatively deposited to form a material bed 18.

The actuating arrangement 14 is provided by two electrically driven linear actuators 20, 22 located below the build platform 12. In other examples, one or more than two actuators may be employed. Supporting ends 21, 23 of the actuators 20, 22 are directly connected to a bottom surface 24 of the build platform 12.

In use, linear motion of the actuators 20, 22 causes vertical displacement of the build platform 12, i.e. displacement along a Z-axis of an additive manufacturing apparatus (not shown) in which the build platform arrangement 10 is installed. The build

platform 12 is typically displaced incrementally downwardly to permit fresh layers of raw material to be deposited in the working area 16.

The build platform arrangement 10 further includes a material retaining unit 26. The material retaining unit 26 is provided by four walls (two of which are shown in FIG. 1 by reference numerals 28, 30) which are fixedly mounted in the additive manufacturing apparatus so as to conform to outer side edges of the build platform 12. The walls 28, 30 extend transversely to the build platform 12 and their sides abut such that they together provide the material retaining unit 26 with a rectangular shape, when viewed from the top or bottom. In use, the material retaining unit 26 retains the material bed 18 on the build platform 12.

FIGs 2 to 5 illustrate an embodiment of a build platform arrangement 40 forming part of an additive manufacturing apparatus according to the invention. The build platform arrangement 40 includes a base 42 which is attached to an actuating arrangement 44.

The actuating arrangement 44 is provided by two electrically driven linear actuators 46, 48 located below the base 42. Supporting ends 47, 49 of the actuators 46, 48 are directly connected to a bottom surface 50 of the base 42.

In use, linear motion of the actuators 46, 48 causes vertical displacement of the base 42, i.e. displacement along a Z-axis (shown in FIG. 2) of an additive manufacturing apparatus (not shown) in which the build platform arrangement 40 is installed.

While the build platform 12 of the build platform arrangement 10 described with reference to FIG. 1 has fixed dimensions, the build platform arrangement 40 permits the use of build platforms of various dimensions. FIGs 2 and 3 illustrate a first configuration of the build platform arrangement 40 and FIGs 4 and 5 illustrate a second configuration thereof.

In the configuration of FIGs 2 and 3, a build platform 52 is mounted to the base 42 by a mounting element 53 in the form of a steel frame which can be installed or removed

as required. The mounting element is removably fixed to the base 42 and the build platform 52 is in turn removably fixed to the mounting element 53. A conventional heating arrangement 55 is disposed between the build platform 52 and the mounting element 53.

The build platform 52 has a generally planar shape, is rectangular in top and bottom view and covers a substantially smaller area in the X-Y plane than the base 42. The build platform 52 is located above the base and the actuating arrangement 44. In use, therefore, vertical displacement of the base 42 causes displacement of the build platform 52.

The build platform 52 can be displaced downwardly incrementally to permit fresh layers of raw material to be deposited in the working area 54 it defines. FIG. 3 illustrates a condition in which the build platform 52 has been displaced downwardly to permit more raw material to be deposited to increase the volume of the material bed 56. The heating arrangement 55 may be used to heat the build platform 52 (for preheating the material bed 56) and raw material may be consolidated using a high energy beam of a scanning unit (not shown), as will be well understood by those of ordinary skill in the art.

In the configuration of FIGs 4 and 5, a build platform 58 is mounted to the base 42 by two mounting elements 60, 61 of the type described with reference to FIGs 2 and 3 above.

The build platform 58 has a generally planar shape, is rectangular in top and bottom view and covers a substantially larger area in the X-Y plane than the build platform 52 of the first configuration. The mounting elements 60, 61 also cover a substantially larger area in the X-Y plane than the mounting element 53 of the first configuration in order to support the build platform 58 along a length thereof.

As is the case in the first configuration, the build platform 58 can be displaced downwardly incrementally to permit fresh layers of raw material to be deposited in the working area 62 it defines. FIG. 5 illustrates a condition in which the build platform

58 has been displaced downwardly to permit more raw material to be deposited to increase the volume of the material bed 64.

The build platform arrangement 40 is thus scalable in the sense that it allows build platforms of different dimensions to be used in an additive manufacturing apparatus, or allows a single build platform of variable dimensions to be used. The build platform arrangement 40 is also provided with an adjustable material retaining unit 66, which is described in greater detail with reference to FIGs 7 to 11 below.

A second embodiment of a build platform arrangement 70 for an additive manufacturing apparatus according to the invention is illustrated in FIG. 6. The build platform arrangement 70 includes a base 72, a plurality of build platform modules 74, a plurality of mounting elements in the form of pillars 76, and a build platform surface element 80.

The base 72 has a rectangular shape in top and bottom view. A top surface of the base 72 is provided with a 2 x 6 array of evenly spaced apart circular clamping elements 82. The clamping elements 82 are each configured to receive and clamp a lower end of a respective pillar 76 in position such that the pillars 76 extend vertically upwardly from the base 72.

The base 72 also includes supporting elements 84 on two opposing sides thereof. The supporting elements 84 are configured to receive supporting ends of a linear actuating system (e.g. similar to those shown in FIGs 1 to 5) which operatively displaces the base 72 along the Z-axis of the additive manufacturing apparatus.

The build platform modules 74 are tile-shaped and form a 2 x 6 array in the X-Y plane. Each of the build platform modules contains an integral heating unit. Each build platform module 74 is mounted to the base 72 by one of the pillars 76. The pillars 76 extend along the Z-axis. A first or lower end of each pillar 76 can be locked into the base 72 by locking a corresponding one of the clamping elements 82 thereto, while a

second end of each pillar 76 supports a corresponding build platform module 74 from the bottom, as is illustrated in FIG. 6.

In this exemplary embodiment, the build platform modules 74 each cover 300 mm x 300 mm in the X-Y plane and the pitch between the pillars is 300 mm.

Each one of the build platform modules 74 is configured to be selectively enabled or disabled (including its integrated heating unit and a cooling unit, if provided) by locking or unlocking (i.e. clamping or unclamping) the clamping element 82 associated therewith.

The working area 86 of the additive manufacturing apparatus (not shown) in which the build platform arrangement 70 is operatively installed is thus scalable in the sense that it is defined by a build platform that is constituted only by the build platform module or modules 74 that is or are operatively enabled. The build platform modules 74 that are not operatively enabled do not form part of the build platform. An exemplary implementation of the above-described build platform modularity is shown in FIGs 12 and 13, which are referred to below.

The build platform surface element 80 is a plate element which is shaped and dimensioned to be positioned over, and removably fixed to, the build platform modules 74 that are operatively enabled, thereby providing the build platform and defining the working area 86. In this example, the surface element 80 covers all of the build platform modules 74, but it will be appreciated that it may cover any suitable area in use, depending on the number and positions of the enabled build platform modules 74.

The dedicated heating unit of a particular build platform module 74 is only activated when the build platform module 74 is enabled and forms part of the build platform.

The build platform modules 74 can thus be selectively enabled or disabled, depending on the shape and size of the build platform required. A material retaining unit such as

the exemplary material retaining unit described with reference to FIGs 7 to 11 below may be installed with the build platform arrangement 70.

FIGs 7 to 13 illustrate an embodiment of an additive manufacturing apparatus 90 according to the invention. The apparatus 90 is shown primarily for illustrative purposes in order better to describe certain components thereof. It will be understood that, although not shown in the drawings, in addition to the components that are shown, the apparatus 90 may typically include at least one material deposition arrangement for depositing layers of material in a working area to form a material bed, at least one material feeding mechanism for feeding material into the material deposition arrangement, and a scanning unit spaced operatively above the working area for controlling an energy beam consolidating material deposited in the material bed. The apparatus 90 may also include a cover or housing serving to house all of the abovementioned components.

The apparatus 90 includes a supporting platform 92 and four linear actuators 94 extending vertically upwardly from respective lower regions of the supporting platform 92.

The apparatus 90 includes the build platform guiding arrangement 70 of FIG. 6, which in this exemplary apparatus 90 is devoid of the surface element 80 more clearly to illustrate the build platform modules 74. The supporting elements 84 of the arrangement 70 receive supporting ends of the linear actuators 94 for operatively displacing the base 72 along the Z-axis of the additive manufacturing apparatus 90, as described above.

The arrangement 70 is covered along its sides by a material retaining unit 100 which includes four walls 101-104. Two of the walls 101, 102 are fixedly mounted while the positions of the other two walls 103, 104 are adjustable to permit the material retaining unit 100 to accommodate build platforms (and thus working areas) of various shapes and/or dimensions in the X-Y plane. The walls 101-104 are positioned on top of a mounting frame member 105, which is most clearly shown in FIG. 11.

The walls 101-104 extend along the Z-axis of the additive manufacturing apparatus 90 and the two adjustable walls 103, 104 are configured to be moved between a number of positions in the X-Y plane.

In the configuration shown in FIGs 7 to 9, the walls 101-104 are mounted such that the material retaining unit 100 has a rectangular shape in the X-Y plane. In this case, the working area 108 is defined by a 2 x 6 array of enabled build platform modules 74 constituting the build platform. The walls 101-104 extend transversely to the build platform and conform closely to outer side edges of the build platform modules 74 in order to retain a material bed which is operatively deposited in the working area.

In a second configuration shown in FIG. 10, the working area 110 is defined by a 2 x 3 array of enabled build platform modules 74 constituting the build platform. Accordingly, to accommodate these build platform dimensions, the wall 103 is adjusted by moving it towards the wall 101 in the Y-direction in fixing it in the new position shown in FIG. 10.

In a third configuration shown in FIG. 11, the working area 112 is defined by only two adjacent and enabled build platform modules 74 constituting the build platform. The wall 103 is dislocatably mountable in the additive manufacturing apparatus and, in order to accommodate these build platform dimensions, the wall 103 is removed from the material retaining unit 100 and is replaced with a shorter wall 106, while the wall 104 is moved towards the wall 102 in the X-direction and fixed in the new position shown in FIG. 11.

When the apparatus 90 is in use, build platform modules 74 which are not enabled, as well as their associated pillars 76, are unlocked (i.e. unclamped from the clamping elements 82) and dropped to a position below the material retaining unit 100 so as not to interfere with the material retaining unit 100. This is best shown in FIGs 12 and 13.

In the configuration of FIGs 12 and 13, six build platform modules 74A and their associated pillars 76A are locked (i.e. clamped using the clamping elements 82) in position such that the build platform modules 74A form the build platform 114, which is covered by the material retaining unit 110. The modules 74A are locked to the base 72 and move with the base 72 when the linear actuators 94 are actuated from an extended condition (shown in FIG. 12) to a retracted condition (shown in FIG. 13), or vice versa.

The other six build platform modules 74B and their associated pillars 76B are unlocked (i.e. unclamped from the clamping elements 82) and rest on transverse, horizontal bar elements 116 forming part of the supporting platform 92. This resting condition can also be seen in FIGs 10 and 11. The build platform modules 74B are thus clear of the material retaining unit 100 and not locked to the base 72, i.e. the modules 74B do not move with the base 72 when the linear actuators 94 are actuated from the extended condition to the retracted condition, or vice versa.

The Inventors believe that the present invention provides various advantages, a number of which are set out below.

By coupling a build platform indirectly instead of directly to an actuating arrangement, a scalable or customisable build platform may be implemented. Essentially, a platform of any suitable size or shape can be mounted on the base and the material retaining unit can be adjusted accordingly.

The scalable material retaining unit described herein ensures that the deposited raw material is retained in the working area, irrespective of the size and/or shape of the build platform required for a particular application. It will be understood that the build platform need not be rectangular and may, for instance, be arcuate, with the material retaining unit providing a complementary shape.

The present invention may reduce material waste, safety concerns, storage costs and/or the need for relatively large stockpiles of raw material when relatively small parts are manufactured, as less unused raw material will be required.

The build platform arrangement and material retaining unit described herein may also lead to reduced overheads, as less unused material may be required to be processed and handled. Furthermore, productivity may be increased as a result of a reduction in the time it takes to deposit each layer of fresh material.

In cases where build platform modules are provided with dedicated heating units (or cooling units, sensors, or the like), the energy required and costs associated with preheating activities (or the like) may be reduced, as these activities are performed in a dedicated manner in respect of enabled modules only.

The Inventors further believe that build platforms of various shapes or dimensions can be implemented without having an impact on the configuration and layout of the actuation system of an additive manufacturing apparatus.

Furthermore, a substantial space is created between the build platform and its actuators in at least some embodiments of the invention. This may facilitate the incorporation and use of heating systems, cooling systems, insulation and/or sensors within this space.

CLAIMS:

1. An additive manufacturing apparatus, which includes:

an actuating arrangement; and

a build platform arrangement which includes

a base which is attached or attachable to the actuating arrangement, the actuating arrangement being configured to displace the base along a Z-axis; and

a build platform which is mounted or mountable to the base such that operative displacement of the base by the actuating arrangement causes displacement of the build platform, the build platform including a plurality of build platform modules, wherein at least some of the build platform modules are configured to be selectively enabled or disabled, and wherein a working area of the additive manufacturing apparatus is defined by a build platform constituted by the build platform module or modules that is or are operatively enabled.

2. The additive manufacturing apparatus as claimed in claim 1, in which the working area is of variable dimensions and/or shape in an X-Y plane of the additive manufacturing apparatus.

3. The additive manufacturing apparatus as claimed in claim 1 or claim 2, in which each of the build platform modules is configured to be selectively enabled or disabled.

4. The additive manufacturing apparatus as claimed in any one of claims 1 to 3, in which the build platform modules form an array.

5. The additive manufacturing apparatus as claimed in claims 2 to 4, in which the build platform is spaced apart from the base along the Z-axis of the additive

manufacturing apparatus and the base is preferably located above the actuating arrangement.

6. The additive manufacturing apparatus as claimed in claim 5, in which a heating and/or cooling unit is provided in a space defined between the base and the build platform.

7. The additive manufacturing apparatus as claimed in claim 6, in which thermal insulation and/or sensors, such as temperature sensors, are also provided in the space.

8. The additive manufacturing apparatus as claimed in any one of claims 1 to 7, in which one or more of the build platform modules has a dedicated heating and/or cooling unit associated therewith.

9. The additive manufacturing apparatus as claimed in claim 8, in which the dedicated heating and/or cooling unit associated with a particular build platform module is activated when the build platform module is enabled and deactivated when the build platform module is disabled.

10. The additive manufacturing apparatus as claimed in claim 8 or claim 9, in which one or more of the build platform modules is provided with dedicated thermal insulation.

11. The additive manufacturing apparatus as claimed in any one of claims 1 to 10, in which the build platform modules are mounted or mountable to the base by a plurality of elongate mounting elements.

12. The additive manufacturing apparatus as claimed in 11, in which the mounting elements are pillars which extend longitudinally along the Z-axis of the apparatus, in use.

13. The additive manufacturing apparatus as claimed in claim 11 or claim 12, in which each build platform module is mounted or mountable to the base by one of the mounting elements ("an associated mounting element").

14. The additive manufacturing apparatus as claimed in claim 13, in which the build platform modules are removably mounted or mountable to the base.

15. The additive manufacturing apparatus as claimed in claim 14, in which when a build platform module is enabled, it is fixed to the base, and when a build platform module is disabled, it is not fixed to the base.

16. The additive manufacturing apparatus as claimed in any one of claims 13 to 15, in which each of the mounting elements is actuatable between a locked and an unlocked condition, each build platform module being configured to be enabled by locking the mounting element associated therewith, and disabled by unlocking the mounting element associated therewith.

17. The additive manufacturing apparatus as claimed in any one of claims 13 to 16, in which in use, a generally planar build platform surface element is fitted to the build platform module, or modules, that is or are enabled, thereby defining the working area of the additive manufacturing apparatus.

18. The additive manufacturing apparatus as claimed in claim 17, in which the surface element has a customizable shape and the working area is configured to receive material, e.g. powder material, which is to be consolidated, in use.

19. The additive manufacturing apparatus as claimed in any one of claims 1 to 18, in which the build platform modules are rectangularly shaped and the working area extends in the X-Y plane.

20. The additive manufacturing apparatus as claimed in any one of the preceding claims, in which the actuating arrangement is provided by one or more linear actuators, preferably electrically driven linear actuators.

21. The additive manufacturing apparatus as claimed in any one of claims 1 to 20 which includes:

at least one material deposition arrangement for depositing layers of material in the working area to form a material bed;

at least one material feeding mechanism for feeding material into the material deposition arrangement; and

a scanning unit spaced operatively above the working area, the scanning unit configured to direct and/or control an energy beam for consolidating material deposited in the material bed.

22. An additive manufacturing apparatus as claimed in claim 21, which includes a material retaining unit, the material retaining unit including a plurality of walls which are configured to conform closely to outer side edges of the build platform of the additive manufacturing apparatus so as to retain a material bed operatively deposited in a working area defined by the build platform, wherein the walls are configured to extend generally transversely to the build platform, and wherein at least one of the walls is configured to be adjustably mounted in the additive manufacturing apparatus to permit the material retaining unit to accommodate build platforms of various shapes and/or dimensions.

23. An additive manufacturing apparatus as claimed in claim 22, in which the material retaining unit includes four walls, at least one of the walls being fixedly mountable in the additive manufacturing apparatus, while at least one other wall is adjustably mountable in the additive manufacturing apparatus.

24. An additive manufacturing apparatus including:

a build platform;

an actuating arrangement configured to displace the build platform;

at least one material deposition arrangement for depositing layers of material in a working area defined by the build platform to form a material bed;

at least one material feeding mechanism for feeding material into the material deposition arrangement;

a scanning unit spaced operatively above the working area, the scanning unit configured to direct and/or control an energy beam for consolidating material deposited in the material bed; and

a material retaining unit including a retaining wall which conforms closely to outer side edges of the build platform so as to retain the material bed, wherein the wall extends generally transversely to the build platform, and wherein the configuration of the retaining wall is adjustable to permit the material retaining unit to accommodate build platforms of various dimensions.

25. An additive manufacturing apparatus as claimed in claim 24, in which the material retaining unit includes four walls.

26. An additive manufacturing apparatus as claimed in claim 25, in which two of the four walls are fixedly mounted, while the other two walls are adjustably mounted, the walls being adjusted by moving them between a plurality of positions in an X-Y plane of the apparatus.

27. An additive manufacturing apparatus as claimed in claim 26, in which at least one of the walls is removably mounted in the additive manufacturing apparatus to facilitate replacing said at least one wall with another wall of different shape and/or dimensions to said at least one wall.

28. A build platform arrangement for an additive manufacturing apparatus, the build platform arrangement including a plurality of build platform modules, wherein at least some of the build platform modules are configured to be selectively enabled or disabled, and wherein a working area of the additive

manufacturing apparatus is defined by a build platform constituted by the build platform module or modules that is or are operatively enabled.

29. An additive manufacturing apparatus which includes:

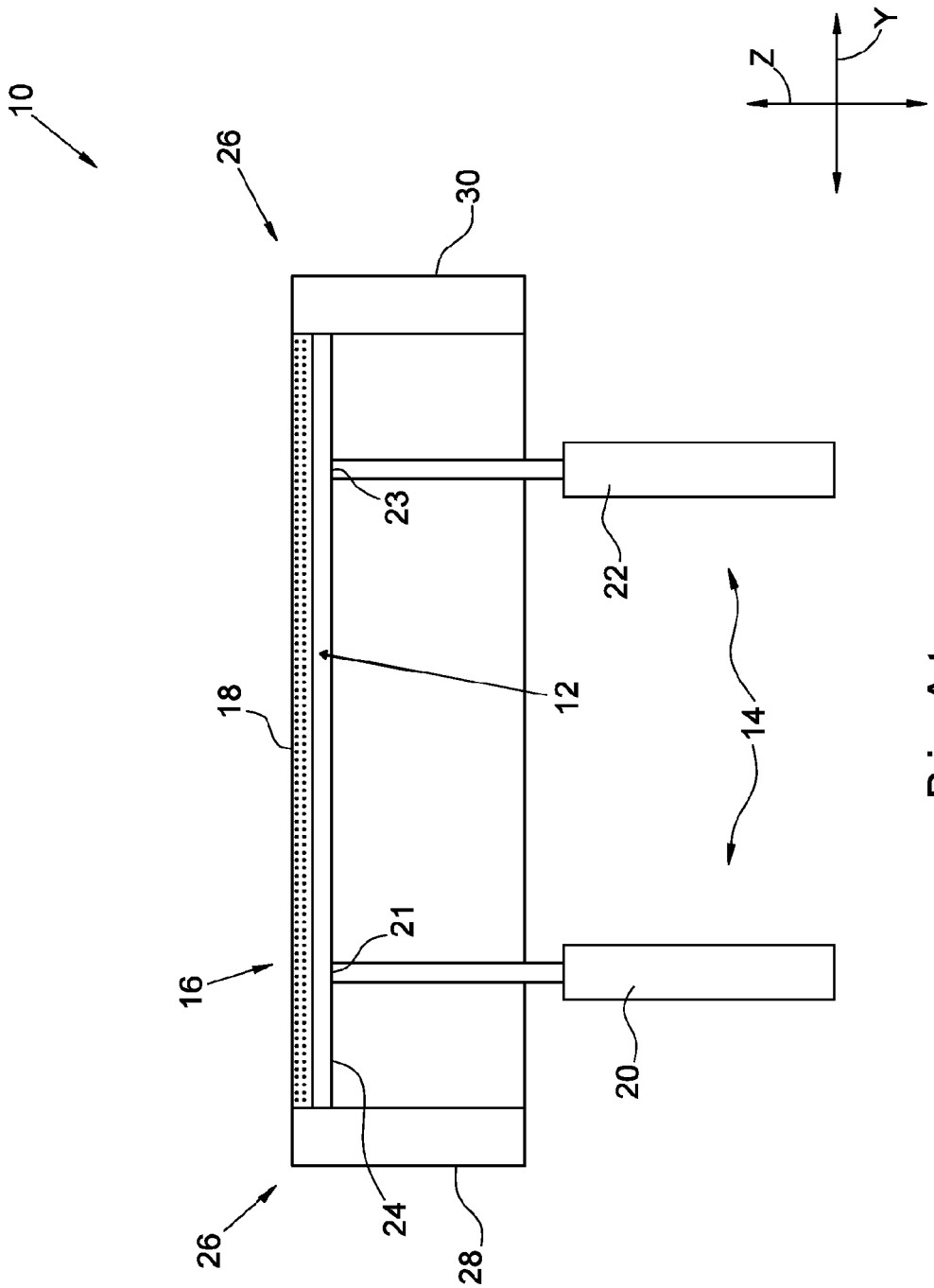
an actuating arrangement configured to displace a base of a build platform arrangement along a Z-axis;

at least one material deposition arrangement for depositing layers of material in the working area to form a material bed;

at least one material feeding mechanism for feeding material into the material deposition arrangement;

a scanning unit spaced operatively above the working area, the scanning unit configured to direct and/or control an energy beam for consolidating material deposited in the material bed; and

a material retaining unit including a plurality of walls which are configured to conform closely to outer side edges of the build platform so as to retain a material bed operatively deposited in a working area defined by the build platform, wherein the walls are configured to extend generally transversely to the build platform, and wherein at least one of the walls is configured to be adjustably mounted to permit the material retaining unit to accommodate build platforms of various shapes and/or dimensions.



Prior Art
Figure 1

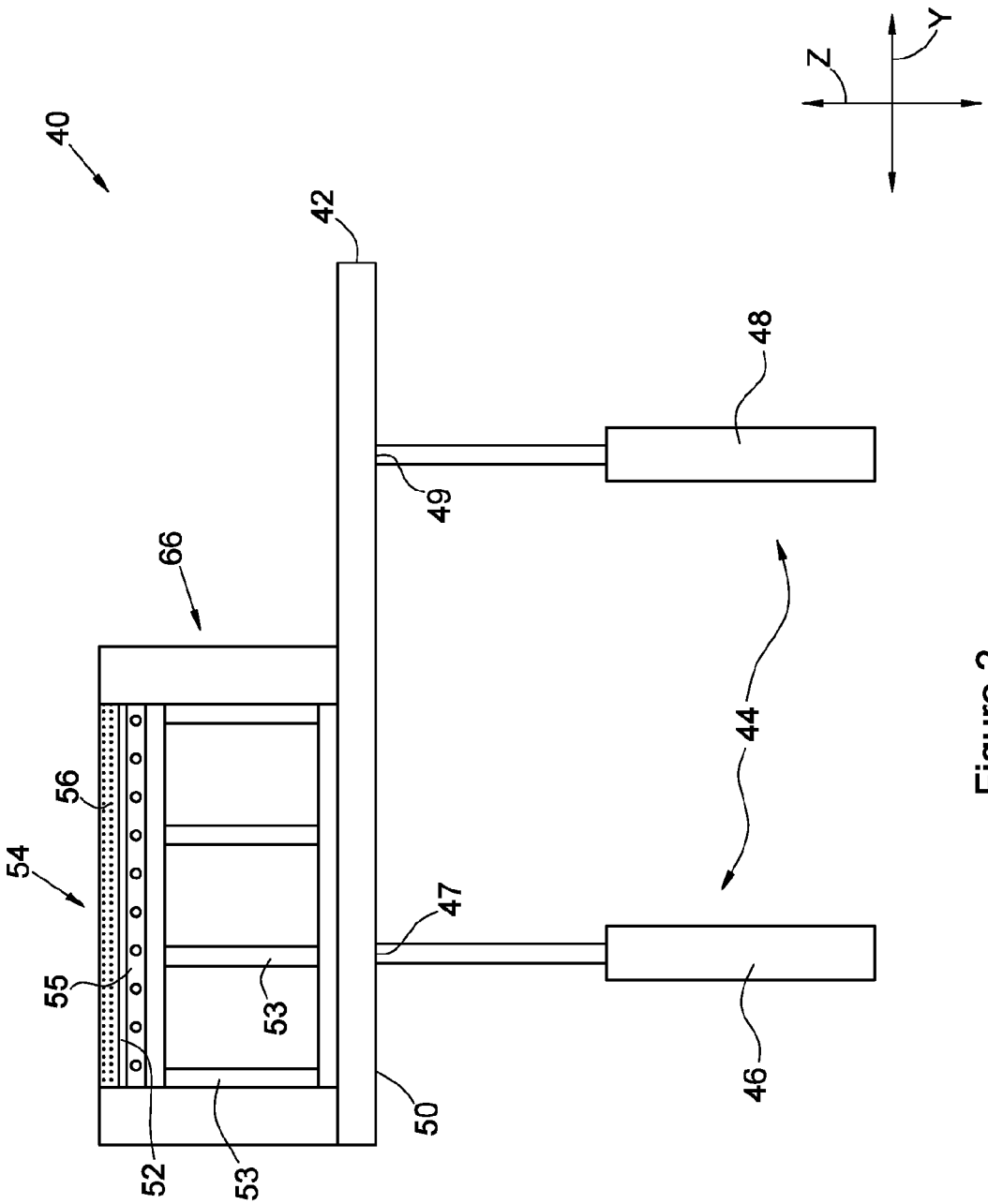


Figure 2

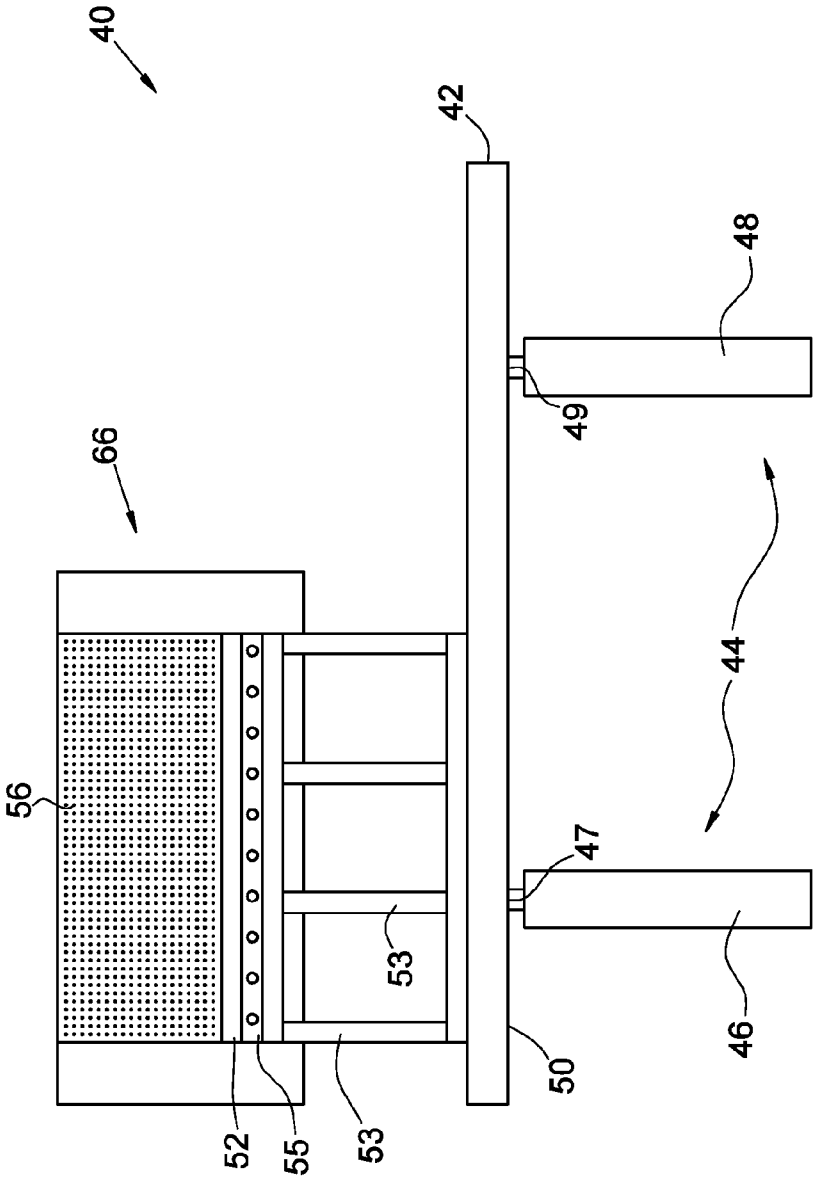


Figure 3

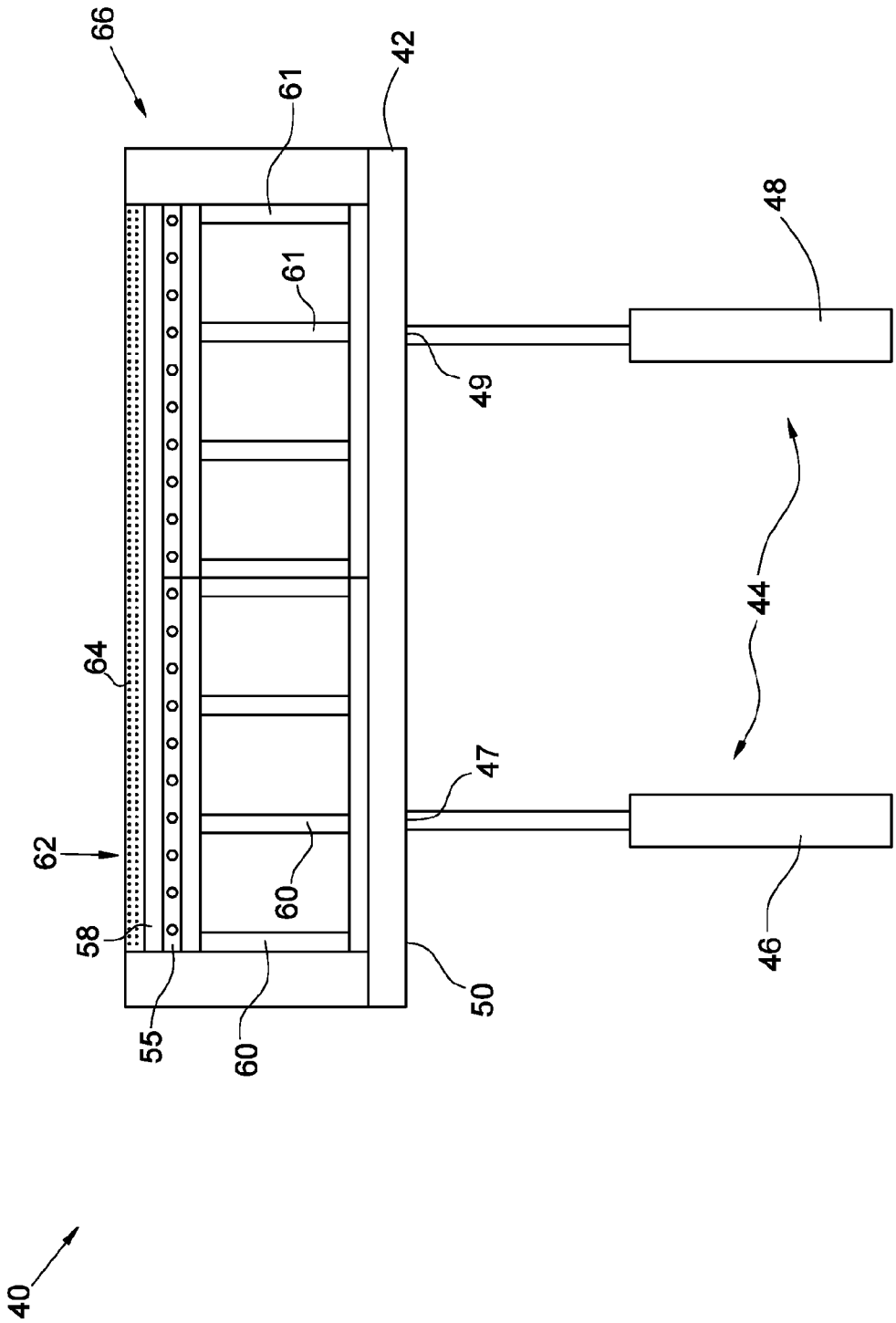


Figure 4

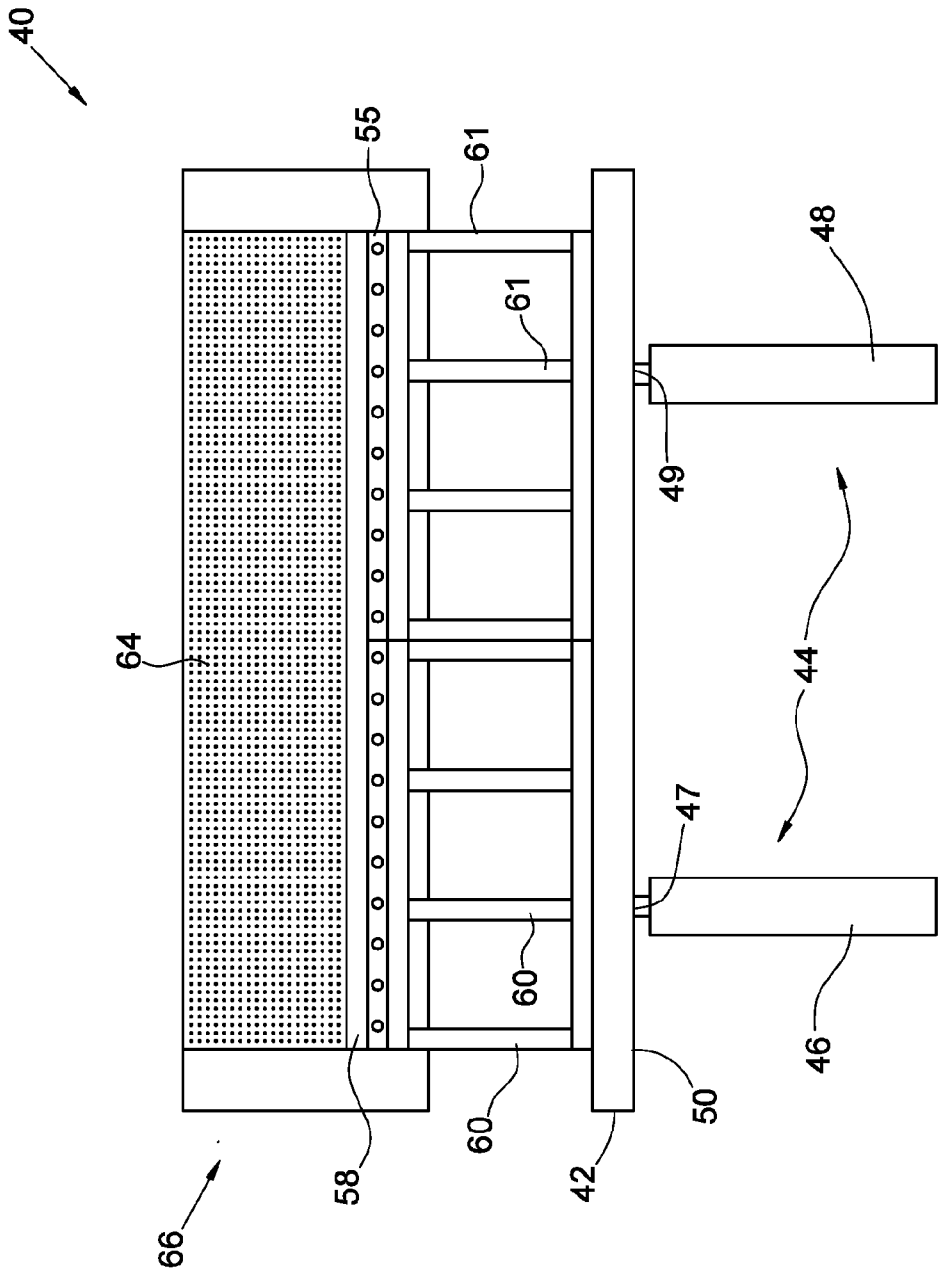


Figure 5

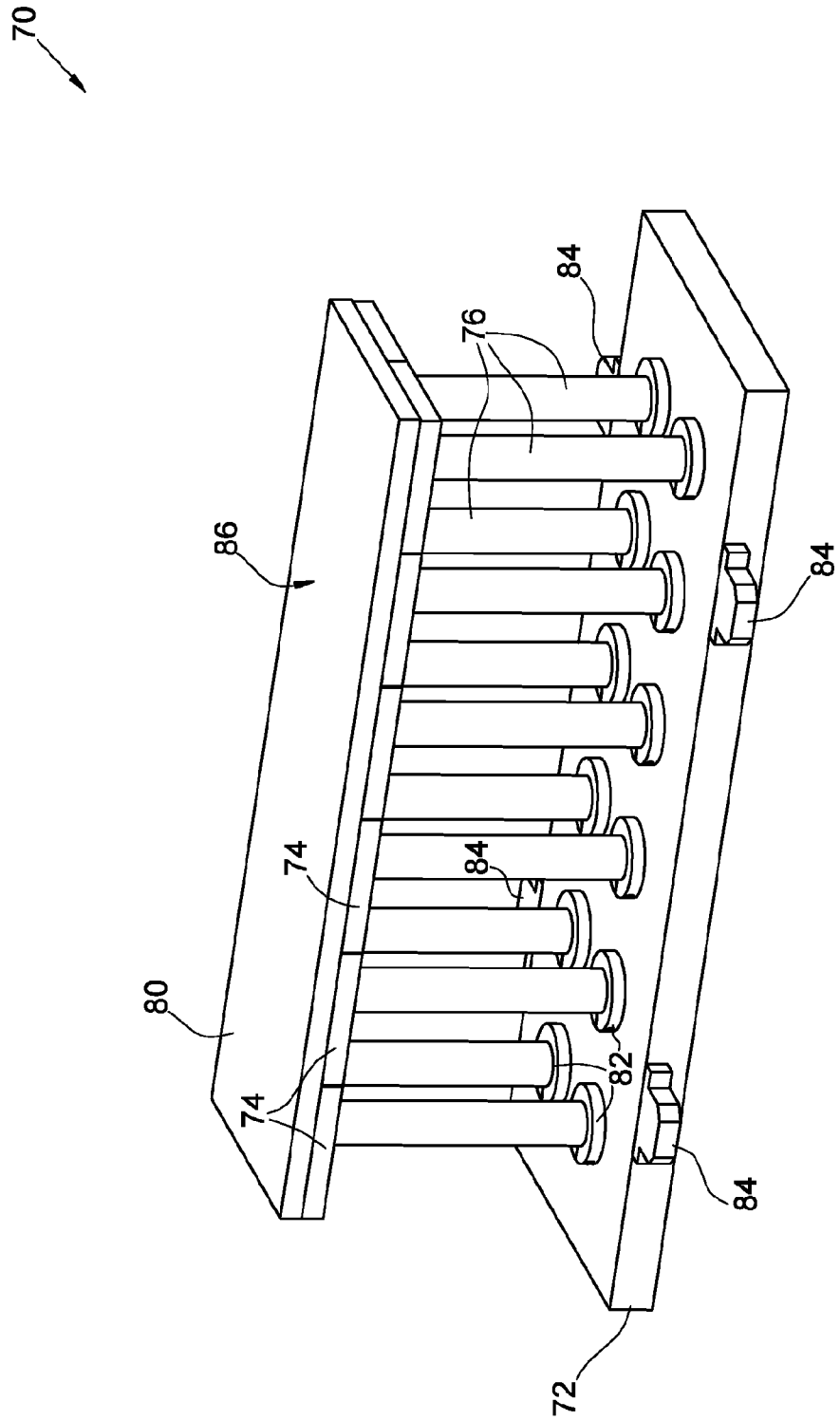


Figure 6

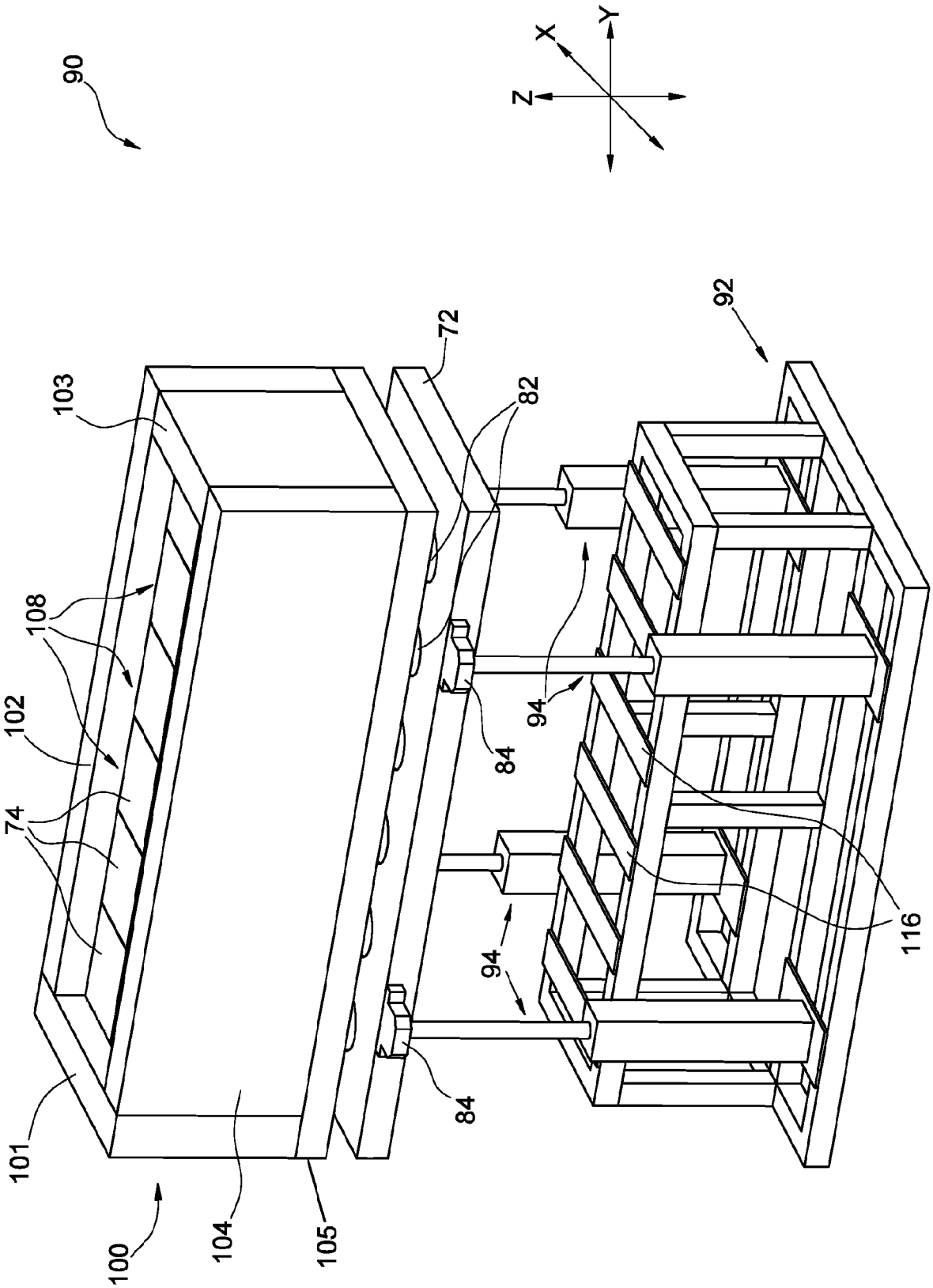


Figure 7

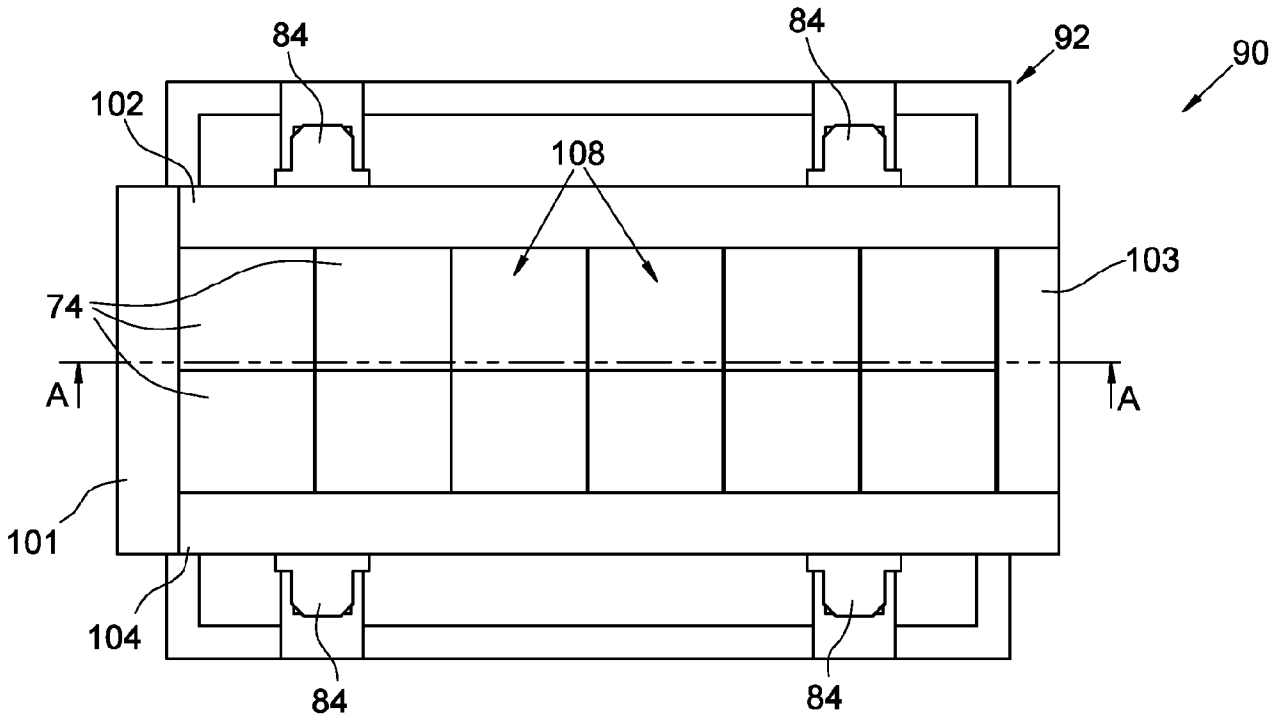


Figure 8

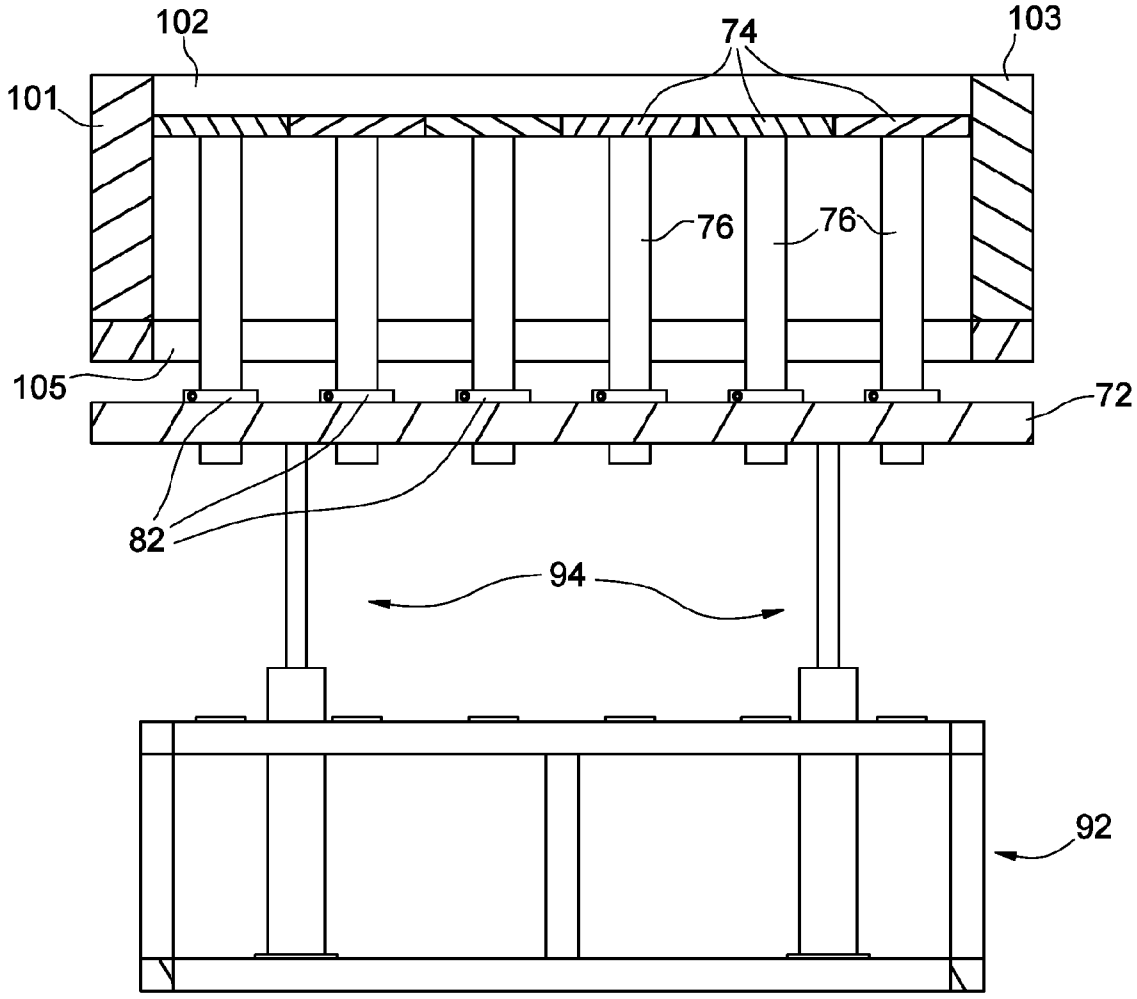


Figure 9

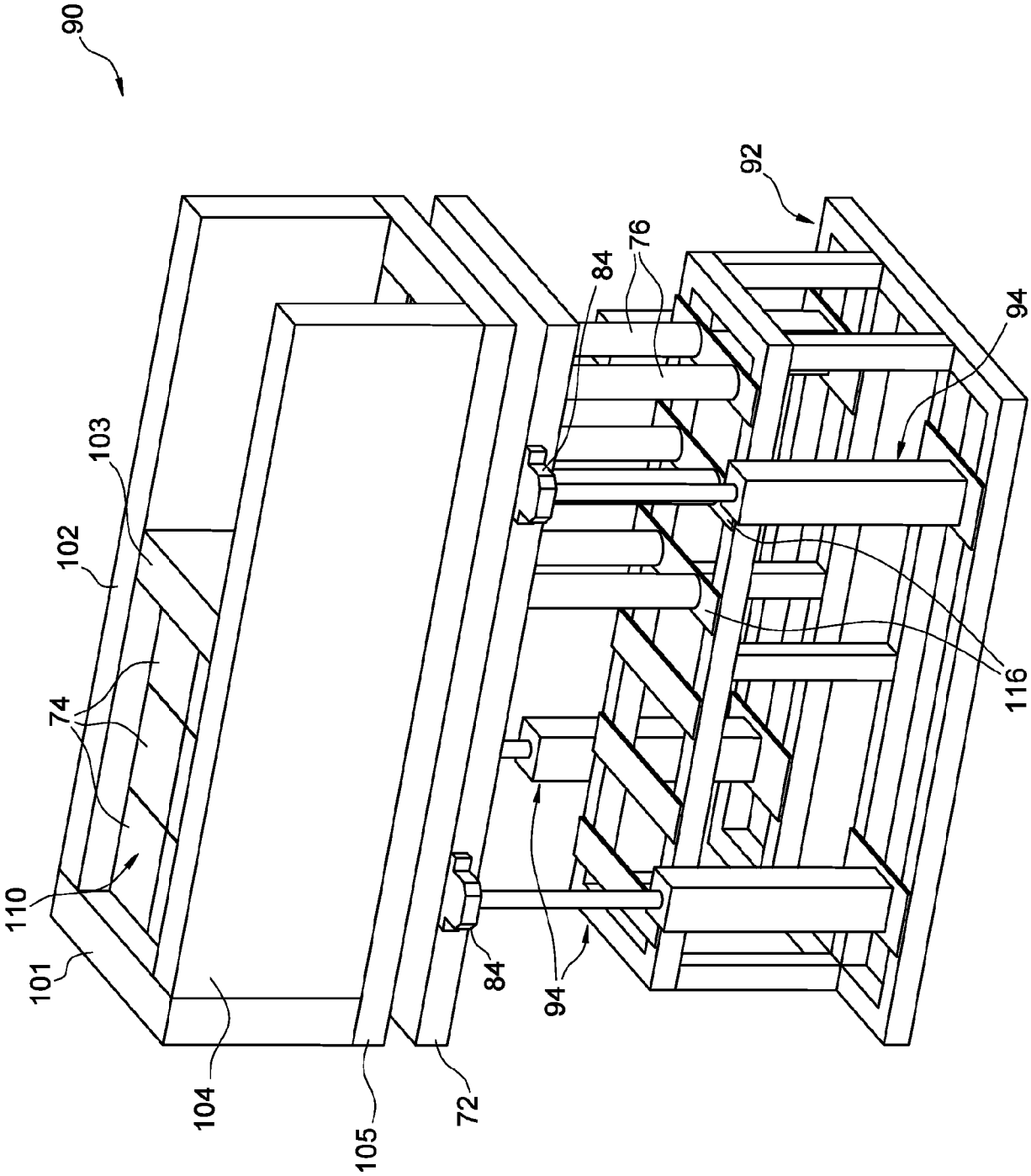


Figure 10

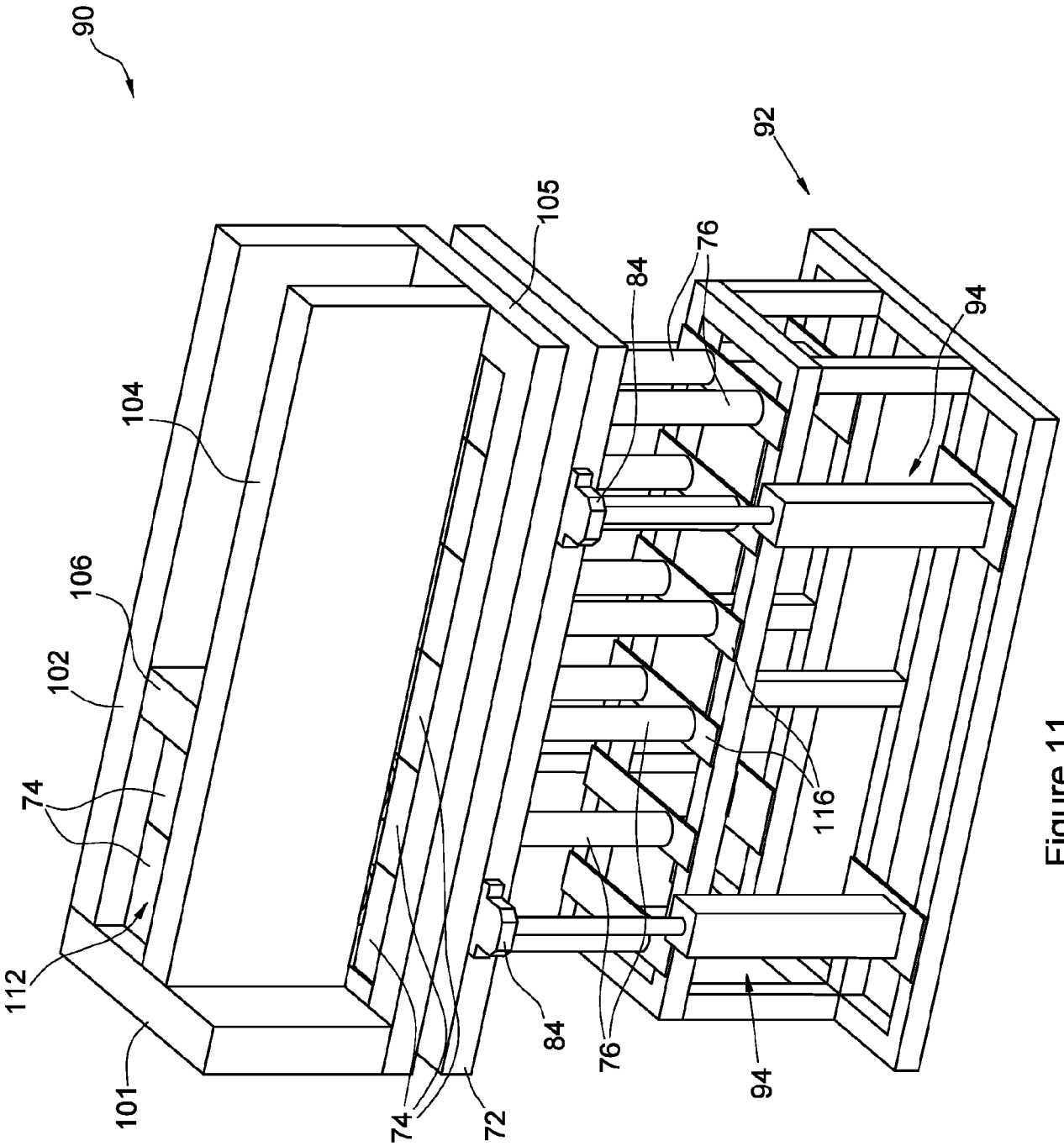


Figure 11

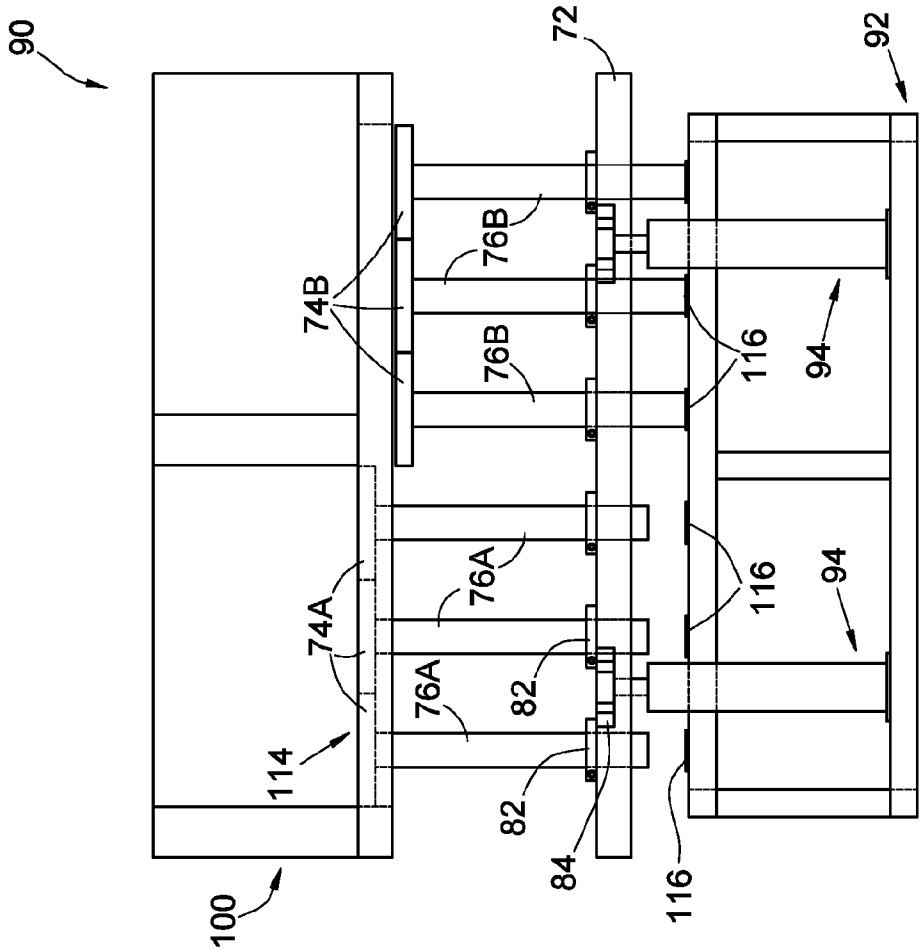


Figure 13

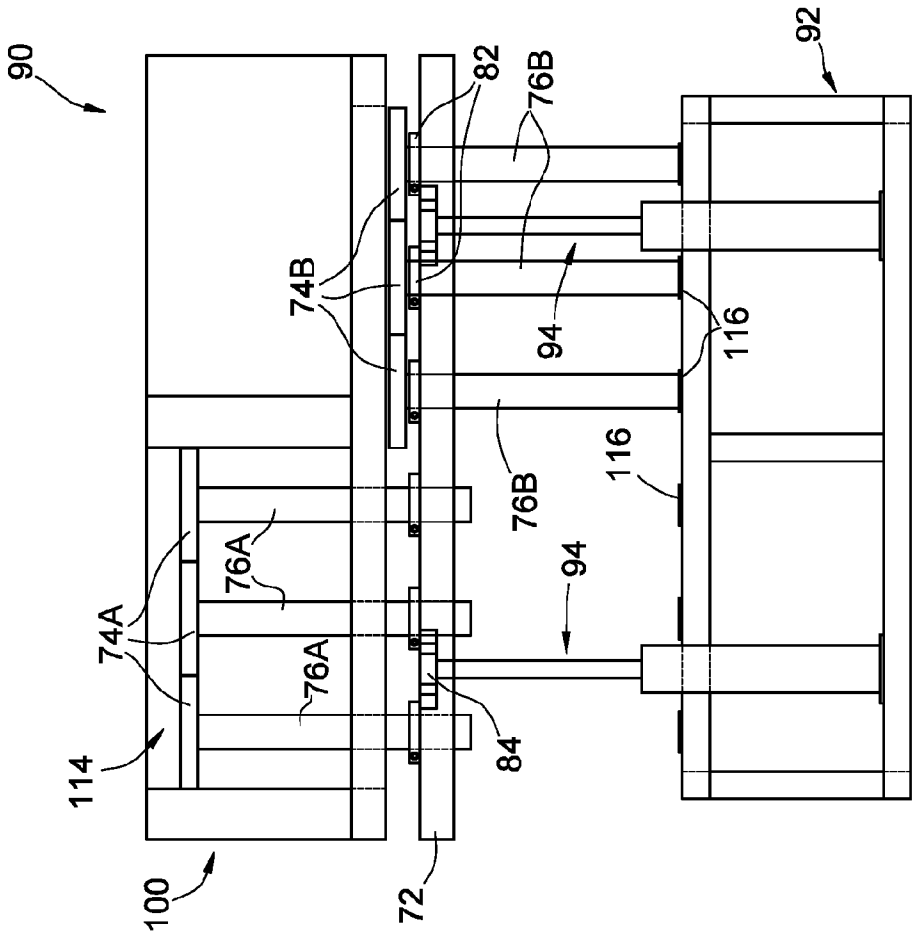


Figure 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2018/058041

A. CLASSIFICATION OF SUBJECT MATTER
INV. B33Y30/00 B29C64/153 B29C64/245
ADD.

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)
B33Y C22C B29C B22F

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2017/051029 A1 (ADDIFAB APS [DK]) 30 March 2017 (2017-03-30) page 3, line 18 - page 23, line 6; figures 1-8	1-6,8,9, 11-21,28 7-10

Y	US 2004/056022 A1 (MEINERS WILHELM [DE] ET AL) 25 March 2004 (2004-03-25) paragraph [0010] - paragraph [0017]; claim 1	7-10

X	US 2002/167101 A1 (TOCHIMOTO SHIGEAKI [JP] ET AL) 14 November 2002 (2002-11-14) paragraph [0117] - paragraph [0119]; figures 1,12 paragraph [0152]	1-6,8,28

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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
4 February 2019	02/04/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Cassiat, Clément

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2018/058041

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2015/081600 A1 (BEIJING TIERTIME TECHNOLOGY CO LTD [CN]; GUO GE [CN]) 11 June 2015 (2015-06-11) claims 1-8; figure 1	7,8
Y,P	WO 2018/109735 A2 (CSIR [ZA]; AEROSUD INNOVATION CENTRE PTY LTD [ZA]) 21 June 2018 (2018-06-21) page 36, line 8 - page 40, line 5; figure 26	7-9
A	US 2010/090374 A1 (DIETRICH DAVID MICHAEL [US] ET AL) 15 April 2010 (2010-04-15) paragraph [0077] - paragraph [0099]; figures 3-7	1,28
A	DE 10 2016 201369 A1 (SIEMENS AG [DE]) 3 August 2017 (2017-08-03) paragraph [0012] - paragraph [0050]; figures 1-5	1,28
A	EP 2 502 730 A1 (BAYERISCHE MOTOREN WERKE AG [DE]) 26 September 2012 (2012-09-26) paragraph [0022] - paragraph [0033]; figures 2-7	1,28
A	EP 2 873 514 A1 (HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN MÜNCHEN [DE]) 20 May 2015 (2015-05-20) figures 1-13	1,28

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2018/058041

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-21, 28

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-21, 28

   Additive manufacturing apparatus with a plurality of build platform modules associated with a dedicated heating/cooling unit.

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2. claims: 22-27, 29

   Additive manufacturing apparatus with an adjustable wall to form the build platform.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2018/058041

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2017051029 A1	30-03-2017	EP 3352970 A1	01-08-2018
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		EP 2873514 A1	20-05-2015