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(54) Title: METHOD AND APPARATUS FOR LAYERWISE PRODUCTION OF A 3D OBJECT

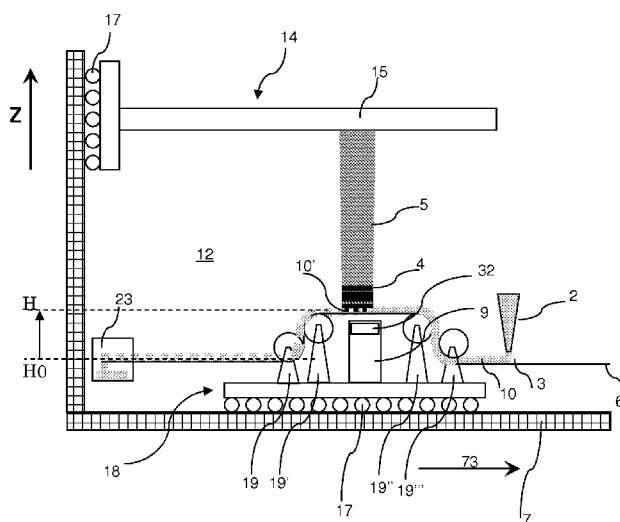


Figure 1

(57) Abstract: A system and method for layerwise production of a tangible object (5), the system comprising: a construction shape (6) to form a liquid layer to be brought in contact with the tangible object; solidifying means (9) for solidifying a predetermined area of a layer (10) of the liquid (3), so as to obtain a solid layer (14) of the tangible object (5), the solid layer thus having a predetermined shape; separating means (18; 19'; 19'') for separating said solid layer from said construction shape; moving means (18) for moving, relative to one another, the construction shape (6) to a predetermined position relative to the tangible object (5), for carrying out a successive such method cycle for solidifying a predetermined area of a successive such liquid layer; the system is arranged to provide a limited volume of liquid adhered to the construction shape to form a liquid layer of limited height that does not contact the tangible object; wherein said moving of said construction shape and said solidifying of said predetermined area are carried out to take place simultaneously.



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Title: METHOD AND APPARATUS FOR LAYERWISE PRODUCTION OF A 3D OBJECT

FIELD AND BACKGROUND OF THE INVENTION

The invention relates to a method for layerwise production of a tangible object according to the preamble of claim 1. The invention also relates to a system for layerwise production of a tangible object.

5 Such a method is known. For example it is known from US6547552 a small volume of liquid is pressed between a foil and a tangible object to provide a thin liquid layer than can be solidified. The flexible foil is transmittent to curing radiation. A firstly formed solid layer of the tangible object is adhered to the underside of the carrier plate by selectively solidifying the liquid.

10 Consecutively formed solid layers are each adhered to a previously formed solid layer, respectively.

Each time after solidification of a new layer, a foil guiding stage is moved to peel off the foil from the earlier solidified layers adhered thereon in order to separate the last formed solid layer from the foil.

15 A desire exists to increase the speed of the production process.

SUMMARY OF THE INVENTION

20 It is an object of the invention to enable a faster production of a tangible object.

Therefore, according to a first aspect of the invention, a method according to claim 1 is provided.

In this method according to the first aspect of the invention, a construction shape is provided; and method cycles are repeatedly performed,
25 each method cycle comprising the steps of:

providing a liquid layer on the construction shape of limited height that does not contact the tangible object;

moving, relative to one another, the construction shape to a predetermined position relative to the tangible object, for carrying out a successive such method cycle for solidifying a predetermined area of a successive such liquid layer;

5 solidifying a predetermined area of a layer of the liquid so as to obtain a solid layer of the tangible object, the solid layer thus having a predetermined shape; and

separating said solid layer from said construction shape;

wherein for at least one of said method cycles said moving of said
10 construction shape and said solidifying of said predetermined area are carried out to take place simultaneously. Favourable effects of such simultaneous movement and solidifying are elucidated as follows.

At first, the simultaneous movement and solidifying provides a speed gain of the process in itself. That is, the start of solidifying a layer does not
15 have to wait until all parts of the layer have been provided with the liquid. Hence, there is little or no downtime of the solidifying means. Furthermore, operation is simplified and material cost can be decreased.

Furthermore, according to a second aspect of the invention, a system
20 according to claim 8 is provided.

Specific embodiments of the invention are set forth in the dependent claims.

These and other aspects of the invention will be apparent from and
25 elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

Further details, aspects and embodiments of the invention will be described, by way of example only, with reference to the drawings.

Fig. 1 schematically shows a sectional side view of an example of an embodiment of a system according to the invention;

Fig. 2 schematically shows a sectional side view of another example of an embodiment of a system according to the invention;

5 Figs. 3 -5 schematically show sectional sides of further examples of yet other embodiments of a system according to the invention;

Figure 6: Schematic representation of an embodiment of an apparatus according to the present invention;

10 Figure 7: illustration of lift effects for an object having large cross-section;

Figure 8: illustration of residual foil lifting;

Figure 9: a schematic embodiment including a perforated plate;

Figure 10: a schematic embodiment minimizing resin evaporation;

Figure 11: a schematic embodiment including resin heaters;

15 Figure 12: a detail of a roller assembly;

Figure 13: optical transmission details of a foil;

Figure 14: bidirectional solidification processing; and

Figure 15: the embodiment of Figure 14 in reverse modes.

20

DETAILED DESCRIPTION

Each of the examples of Figs. 1-6 relates to a system according to claim 8 that can perform an example of a method according to claim 1. In the respective figures sometimes the same reference signs are used for similar or
25 identical parts or aspects of the systems.

Hence, each of the examples of Figs. 1-6 relates to an example embodiment of a system for layerwise production of a tangible object 5. The systems may comprise: a construction shape 6 onto which a liquid layer is applied; a solidifier 9 for solidifying a predetermined area of a layer 10 of the liquid 3, so
30 as to obtain a solid layer 4 of the tangible object 5, the solid layer thus having

a predetermined shape; a separator 18; 19'; 19" for separating said solid layer from said construction shape; and a mover 18 for moving, relative to one another, the construction shape 6 to a predetermined position relative to the tangible object 5, for carrying out a successive such method cycle for solidifying
5 a predetermined area of a successive such liquid layer. Preferably but not necessarily the system comprises a dispenser 2 to dispense a limited volume of liquid adhered to the construction shape and adjust the volume to form a liquid layer of limited height. Before moving of the construction shape to the tangible object, the liquid layer does not contact the tangible object.
10 Additionally, the liquid layer may be formed by dispensing of said layer from a reservoir; and said moving of said construction shape and said dispensing of said liquid layer may be carried out to take place simultaneously.

Reference is now made to Fig. 1, which shows a system 12 according to
15 the invention.

In this embodiment, the system 12 comprises a liquid applicator 2 which, in the shown example, is filled with a liquid 3. The system 12 further comprises a construction shape in the form of a flexible foil 6. On the foil 6, a liquid layer is formed of limited height to be brought in contact with the
20 tangible object 5. The system 1 further comprises a solidifier 9 for solidifying a predetermined area 10 of a layer of the liquid 3, said liquid layer 10 adjoining the construction shape 6, so as to obtain a solid layer 4 of the tangible object 5, the solid layer thus having a predetermined shape.

In one embodiment, the solidifier 9 is an energy source arranged to
25 project a pattern through the foil 6 when the liquid layer 3 contacts the tangible object 5. In particular, the energy source 9 is arranged for at least partially curing at least part of an intersection pattern in the liquid layer. To enable the light or other radiation of the solidifier 9 to solidify the liquid layer 3, the construction shape 6 (flexible foil 6) is preferably substantially
30 transparent to the radiation.

As will be explained somewhat further below, the system 1 may further comprise a separator for separating said solid layer 4 from said construction shape 6. Additionally, the separator removes unsolidified parts from the tangible object so as to obtain a solid layer (14) of the tangible object (5), the
5 solid layer thus having a predetermined shape.

The system 1 further comprises a mover 18 arranged to move, relative to one another, the construction shape 6 to a predetermined position relative to the tangible object 5, for carrying out a successive such method cycle for solidifying a predetermined area of a successive such layer 4. In this way the
10 mover can position the construction form in successive steps to form multiple layers of the tangible object.

In one embodiment, the mover comprises a movable foil guiding stage 18 located below the construction shape 6. Further, in the shown example embodiment, the energy source 9 is positioned on the movable foil guiding
15 stage 18, between foil guiding elements 19, to expose the layer of uncured material through the foil 6.

In one embodiment, each time after solidification and separation of a new layer, carrier plate (z-stage) 15 together with the tangible object 5 including solidified layers adhered thereon are moved upwards. Hence, the
20 method for layerwise production of a tangible object is a cyclic method, wherein the described steps of positioning, solidifying, and separating together are comprised in a single cycle step of the method.

In one embodiment, the system is arranged in such a way, that for at least one of said method cycles, a limited volume of liquid 3 is dispensed
25 adhered to the construction shape 6 and adjusted to form a liquid layer 10 of limited height that does not contact the tangible object. This is explained in an example embodiment as follows:

The flexible foil 6 has a liquid contacting side for being in contact with the liquid 3 to form liquid layer 10. At least upper parts in Fig. 1 of the guide
30 18 are in pressing contact with a side of the flexible foil 6 opposite to the liquid

contacting side. In the shown example, said pressing contact is realized by a sliding or rolling movement of the guide 18 along said opposite side of the flexible foil 6. Lower parts in Fig. 1 of the guide 18 are in rolling contact with a support platform by means of rollers 17. Both the guide 18 and the solidifier 9
5 are movable relative to the platform 7 via these rollers 17 in either or both directions indicated by arrow 73 in Fig. 1. The solidifier may be movable relative to the guide 18.

In the shown example, the foil 6 is transparent to radiation from solidifier 9. As an example it is now assumed that, in the course of time during
10 the performing of a method cycle, the guide 18 and the solidifier 9 are synchronously moving in the right-hand direction of arrow 73 in Fig. 1. Then, at the instantaneous moment in time shown in Fig. 1, there are contacting parts of the layer 10 contacting the tangible object 5 for solidifying certain parts of the layer 10'. During the movement of the guide 18 and the solidifier 9,
15 these contacting parts 10 are time-dependently varying. Thus, over time, the contacting parts 10 may vary depending, in particular, of the position of the guide 18 relative to the tangible object 5.

In Fig. 1 on the left-hand side of the figure, these contacting parts 10 have been separated from said other, already solidified parts of the layer 10.

20 Movable z-stage 14 can be moved in a z-direction before a new layer of curable material is provided to the tangible object 5. With z-direction is meant the direction transverse to the layer of curable material 3 positioned on the foil 6. The z-stage 14 may be raised while the foil guiding stage 18 is not moving. In this embodiment, rolling elements 17 enable movement of the z-stage 14.
25 Tangible object 5 is connected to the z-stage 15 and in each method cycle a new layer is stacked from below. For sake of clarity, the layer of curable material is shown with an exaggerated thickness.

The apparatus 12 may include a guide in the form of a foil guiding stage 18, for providing a layer of curable material to the tangible object 5. The
30 apparatus 12 may further comprise a remover for removing the uncured

material from the layer outside the intersection pattern. In the embodiment of FIG. 1, the foil guiding stage 18 is arranged for dispensing a layer of curable material to the foil, illuminating the layer to solidify a further patterned layer to the tangible object 5, and for removing the uncured material from the layer outside the pattern. As an alternative, removing the uncured material from the layer outside the intersection pattern may be performed by e.g. removing the uncured material with a blower. This is especially suitable when the uncured material has a dry, powder like structure or is a low viscosity liquid.

The foil guiding stage 18 may be movable transverse to the z-direction. In one embodiment, the movement of the foil guiding stage 18 is enabled by rolling elements 17. Other ways of moving, like sliding are also possible. The foil guiding stage 18 further comprises foil guiding elements 19, 19', 19'' and 19''' protruding from the stage 18 for guiding a foil 6 along the tangible object 5 so as to apply a layer of curable material to the tangible object 5. In illustrated embodiment 1, the foil guiding elements 19 comprise rollers. The foil guiding stage 18 can be reciprocable. Two foil guiding elements (19, 19') arranged on the stage 18 define a contact height defined by a height H where the tangible object 5 contacts the liquid layer 10 and at least one position H0 distanced from the contact height H, for guiding the foil 6 to or from the contact height to contact the tangible object 5 by movement along the tangible object 5 while keeping the foil fixed relative to the tangible object 5 at least during contacting.

The foil 6 can be arranged for carrying the curable layer material supplied from a dispenser 2 to the tangible object 5 and for carrying the removed uncured material away from the tangible object 5, possibly to a residue reservoir 23. Typically, the uncured material outside the intersection pattern sticks to the moving foil 6 because the adhesive force between the uncured material and the foil 6 are larger than the adhesive force between the uncured material and the tangible object 5.

The foil 6 and the foil guiding stage 18 may be moved independently. In one operating mode, in a first step, the foil 6 is moved so as to provide a layer of curable material beneath the tangible object 5. The curable material is, at that time, not yet in contact with the tangible object 5. In a second step, the foil guiding stage 18 moves along the tangible object 5 to apply the layer of curable material to the tangible object 5, expose the curable material and remove the uncured material. In the second step, the foil 6 does not substantially move relative to the tangible object 5 transverse to the z-direction.

10 The apparatus 12 may comprise an energy source 9 arranged for at least partially curing at least part of an intersection pattern in the layer of curable material 3. In the embodiment of Figure 1 the energy source 9 comprises a plurality of individually operable LEDs arranged in rows and columns (not shown). The energy source 9 may be moveably disposed relative to the layer of curable material 3, such that it can move in a direction 8 parallel to the layer of curable material 3. The motion of the energy source 9 may be controlled by a controller, which also controls the lighting of the LEDs. In use, the energy source 9 may be moved rectilinearly in a direction that extends at an angle with the directions of the rows and columns of the LED array 32 to enhance the effective resolution of the system. This technique is described in more detail in copending application EP 07150447.6 in the name of applicant, which is incorporated herein by reference for further information regarding this aspect. The energy source 9 may be positioned on the movable foil guiding stage 18, between the protruding foil guiding elements 19 so as to expose the layer of uncured material through the foil 6. The energy source may be covered by a transparent plate, e.g. a glass plate to improve the guidance of the foil 6.

20 The combination of using a LED light source comprising a plurality of individually operable LEDs and partially curing at least part of the intersection pattern may be advantageous. Before explaining this further, the LED light source as used in this embodiment will be described in some detail.

The LED light source may comprise a two dimensional matrix of typically about 80 x 120 light emitting diodes (LEDs); that are imaged via a multilens array (not shown) to the layer of curable material 3. The length of the matrix is typically about 60 centimetres. The LED's are individually
5 operable to write the intersection pattern with a control speed of an individual LED typically in the order of nanoseconds, by a plurality of electrical pathways, selectively connected to the respective LEDs. In this example, accordingly, the energy source 9 may be provided by a two-dimensional array of LEDs extending in a plane parallel to the layer of curable material 3.

10 When the complete intersection pattern is fully cured, the LED light source may typically move over the layer of uncured material with a scanning speed of about 10 centimeters per second.

Figure 2 shows a further detailed embodiment wherein the subprocesses 'layer provision' 20 and 'solidifying' 30 may be carried out simultaneously. In
15 addition, the separating step 40 may also be carried out in the same operational movement of foil guiding stage 180. Furthermore additional subprocesses can be carried out simultaneously, which could include simultaneous execution of other process steps (besides coating - lifting - exposing - peeling) such as foil cleaning, object cleaning, post curing, heating, cooling
20 (compensate for exothermic reaction), and pre-curing). Pre - and post curing steps can be carried out by applying heat or specific radiation as further exemplified in Figure 6.

The functional process units that carry out these process steps are preferably kept with a limited extension in the movement direction which
25 enhances the simultaneity and thus the overall efficiency. It is noted that the subsystems layer provision and layer removal will be interchanged when reversing movement of stage 180; in Figure 2, the movement is from left to right (arrow 73). Such a reciprocal solidification process is further exemplified in Figures Figure 14 and Figure 15. However, it is also possible that a
30 unidirectional solidification process is performed, wherein, in only a single

direction a layer is provided and solidified; and a 'fly back' movement is performed by the stage 180 without performing layer provision and solidification. This may depend on how fast the exposure unit 90 can perform a fly-back movement from end point to start point.

5 The solidifying means, in the example formed by 'exposure unit' 90 for carrying out the solidification can have a dimension that is limited in the direction of the foil guiding stage 180, since in this direction, by scanning movement, a full length dimension of the tangible object 5 can be built. The simultaneity of the layer provision 20 and solidifying 30 processes can be used
10 to achieve an additional gain in required process time.

As an additional advantage, in contrast to sequential operation, the layer provision 20 and exposure unit 30 used for carrying out said subprocesses can be used more efficiently (close to 100% of the time). In addition, since all of the machine parts for separate process steps can be
15 dimensioned relatively small, high process speed can be provided which diminishes process time for all sub processes.

The figure illustrates a machine in which the product is built by adding layers successively to the underside of the product 50 which is attached to the 'product holder' 150.

20 The 'working area' is large enough to accommodate the product 50 to be made. The present invention is especially useful when the working area is relatively large, e.g. about 50 x 50 cm².

In figure 2 the 'product holder' 150 defines a working area of at least about 50 cm long (from left to right in the figure) and about 50 cm wide
25 (perpendicular to the plane of the drawing).

- In one embodiment, for each layer two process steps are always required (1) providing (20) a layer of resin 10, exposure (30) of the resin 10; in many applications there is also releasing (40) the unexposed resin 10 from the building surface ('peeling' in the example of the drawing).

- Conventionally these processes may be carried out on the entire working area.

In one aspect of the invention, the processes may be performed on only a small part of the working area at a time. So process equipment (e.g. exposure
5 unit) is required that can address a part of the working area at any instant of time.

Thus, while figure 2 illustrates a single foil guiding stage 180 covering at least one length dimension of the working area, a multi stage arrangement can be provided where the processes are carried out in parallel, simultaneously
10 on different parts of the working area. This may considerably reduce a total process time:

- In one embodiment, each of the 3 processes requires a process time $TP(i)$, $i=1..3$ that is determined by:

- the net process time $TP(i)$: e.g. the required exposure time (e.g.
15 lower light output results in a longer exposure time) or the speed at which the process can be carried out: movement [m/s] from left to right. This in turn is determined by properties of e.g. the resin and the product (e.g. the product can only withstand small forces resulting in lower movement speed).

- the lead in and lead out time. In the example of the Figure 2
20 arrangement, wherein a moving process is depicted by moving a reciprocable guide stage 18, as opposed to stationary process equipment, the distance to be travelled is the length of the working area + the length of the guide stage $LPE(i)$ resulting in an additional process time $TPE(i) = LPE(i) / v$ (where v is the travelling speed).

25 - so the total time for one layer will be:

conventionally for stationary systems: $TP1 + TP2 + TP3$.

with the moving stage: $\max (TP1, TP2, TP3) + TPE1 + TPE2 + TPE3$.

It follows that $TP1$, $TP2$ and $TP3$ are preferably comparable, and when the process equipment can be made small compared to the working area. For

large working area, an arrangement comprising a moving foil guiding stage thus may provide process time reduction.

To shorten the length direction of the stage, an exposure unit 9 is typically limited in length, for example, for working areas of about 50 cm, only
5 about 6 cm length can be realised with elements ('pixels', each having a LED+microlens) of 2 x 2 mm², and still provide a high resolution of about 15 pixels per mm of working-area-width.

In addition, the coater 20 and peeler 40 mechanisms are preferably limited in length, also typically about a few cm. For the coater rollers
10 preferably knurled rollers 190 are used as an example of a profiled applicator for flattening and adjusting the layer volume provided from the dispenser. A carefully designed profile allows the liquid to evenly spread to the foil by urging the profile to the foil and allowing the liquid in the recesses of the profile and thus form a layer of uniform height. The system 120 is provided
15 with vibration damping 200 and a protective cap 250. A controller can be arranged to control the method steps carried out by the system 120.

Figure 3 shows a schematic example wherein a schematically foil guiding carriage 181. In one embodiment, the foil guiding stage comprises at least two foil guiding elements 19 arranged thereon defining a contact height
20 H and at least one position distanced from the contact height, for guiding the foil 6 to or from the contact height to contact the tangible object 5 by movement along the tangible object 5 while having opposite ends fixed relative to the tangible object at least during contacting. The stage is operative in both directions to be used either as a coater or as a peeler, so the machine can be
25 operated with a bi-directional movement; in such an embodiment, moving back the complete mechanism from the end-of-scan position to the start-of-scan position is not needed. Accordingly, two layers can be produced in a cycle where the carriage returns to its initial position.

Figure 4 shows an alternative embodiment, wherein carriage 182 is operated in a unidirectional way: Here a back and forth movement results in the production of a single layer.

Figure 5 shows a foil guiding stage arrangement 183 wherein the foil
5 guiding elements comprise a separator guide 192 and an applicator guide 191, the separator guide 192 having a smaller bending radius than the applicator guide. The operating movement is indicated by arrow 73. Preferably, in bidirectional mode, this system comprises a changing system to change the separator guide 192 and the applicator guide 191 relative to the guiding stage
10 direction 73.

While the embodiments detail construction shapes in the form of a flexible foil, other construction shapes are possible without departing from the scope of the invention, in particular, rigid shapes, such as drums, planar shapes etc. Furthermore, while the moving means are typically provided as a
15 carriage 18, 180, 181, 182, 183, other systems, in particular, drum actuating designs may provide movement of the construction shape to the tangible object.

According to a further aspect, an apparatus is provided for building a 3D
20 model by stacking layers in a rapid prototyping or rapid manufacturing process, the apparatus comprising a stage 14 arranged for holding the model, an applicator 18 arranged for providing a layer of curable material to the model, a first energy source 9 arranged for at least partially curing at least part of an intersection pattern in the layer of curable material, a remover for
25 removing the uncured material from the layer outside the intersection pattern, and a second energy source 100 for post-curing the layer, wherein the second energy source may comprise a wide-range energy source. Figure 6 further illustrates an embodiment, wherein, according to one aspect of the present invention, the system 12 comprises a movable foil guiding stage 18, said foil
30 guiding stage 18 being movable transverse to the z-direction, said foil guiding

stage 18 comprising foil guiding elements 19 protruding from the stage 18 for guiding a foil 6 along the model 5 so as to apply a layer of curable material 3 to the model 5.

According to a further aspect, the first energy source 9 can be positioned
5 on the movable foil guiding stage 18, between the protruding foil guiding elements 19 so as to expose the layer of uncured material through the foil 6.

As used herein, the term 'curable material' includes any material which is curable (i.e., which can be polymerized and/or cross-linked) by, for example,
10 a UV light, a laser, ionizing radiation (including but not limited to an electron beam, gamma rays or x-rays), or a combination of any of the foregoing. The term 'curable material' shall also be construed to mean a composite material comprising a mixture of both curable and non-curable materials, such as a resin in which fibers and/or fillers are intermixed.

15

Partially curing comprises curing to such a degree that the intersection pattern remains stable while removing the uncured material from the layer outside the intersection pattern. The curable material is not fully cured, but only to such an extent that the material is sufficiently stabilized that it is not
20 removed with the uncured material during the step of removing the uncured material outside the intersection pattern.

In the shown embodiment of Figure 6, the extra energy needed for fully curing may be provided in a post-curing step in a cost-effective way by a wide-range energy source 100. The use of a wide-range energy source 100 is feasible
25 because the uncured material outside the intersection pattern may be removed first.

Fully curing an intersection pattern needs a certain exposure time.
30 Partially curing the intersection pattern means curing the pattern to a lower

degree. When the energy source operates at the same power with which the full curing is done, the exposure may be shorter and the speed of the RM and RP processes increases.

5 The transition of a resin cured by UV from liquid to solid passes a so-called gel-point. At this point all monomers are chemically bonded to form one big molecule. More curing forms more bonds, e.g. cross links, to realize a higher E-modulus of the material. The degree of curing desired in partially curing may be defined by curing the curable material to a degree on or near
10 the gel-point degree of the material, where the intersection pattern remains stable while removing the uncured material from the layer outside the intersection pattern. In practice, curing to a degree on or near the gel-point degree may be interpreted as a degree within a range of about 80% - 120% of the gel-point degree.

15

 This gel-point degree of curing p_c is defined by the formula $p_c = 2 / f_{avg}$. In this formula, f_{avg} is the parameter average 'functionality' related to the number of chemical bonds per monomer, a property of the resin. Typically, values of f_{avg} are in the range of about 3 to 6. This means the gel-point is
20 reached at a curing degree p_c between about $2/3$ and $1/3$.

 The curing degree used for regular production may be about 0.9. The potential productivity gain by partially curing may then be between about 35% and 170%. A characteristic of typical curable materials that are used in RP
25 and RM is that they may be partially cured up to a certain degree and if energy is provided within a certain time after the partial curing, this energy will add up to the energy for the partial curing until the material is fully cured. The energy provided during the partial curing is not lost, or is at least substantially preserved.

30

Curing at least part of the intersection pattern includes fully curing as well, as opposed to the partially curing being described above, of a raster pattern in the layer of curable material 3, said raster pattern being dimensioned to hold uncured material. The material may thus be fully cured,
5 but only a raster pattern is cured instead of the complete intersection pattern.

The amount of material that has to be exposed for curing a raster pattern is less than for curing the complete intersection pattern. A laser source may e.g. travel a shorter path, which increases the RP and RM speed. The raster patterns may be further optimized for improving the on and off duty
10 sequence of the individual LED's of the LED light source. This may further improve the output power of the LED's and the building speed.

A combination of partially curing and curing at least part of an intersection pattern, for example, curing a raster of the intersection pattern to
15 a certain degree only, is also possible. This may further speed up the RP and RM process.

One way of removing the uncured material outside the intersection pattern is to blow the material away. This way is especially suitable when the
20 uncured material has a dry, powder like structure or is a low viscosity liquid.

One possibility to hold uncured material inside the raster pattern during the step of removing the uncured material may be realised by dimensioning the raster pattern to provide capillaries for holding the uncured
25 material. When using the mechanism of capillarity, the dimensions of the raster are, for example, related to the viscosity of the uncured material.

Another possibility to hold uncured material inside the raster pattern during the step of removing the uncured material is to provide additional
30 material inside the raster pattern after having first removed substantially all

the uncured material from the layer. This introduces an extra process step. However, it also creates the opportunity to fill the object with an additional material that differs from the curable material of the layer if the required characteristics of the surface of the model differ from the characteristics of the
5 inside. The surface may, for example, be smooth or soft, while the inside is desired to be light or rigid. The additional material may be sticky to hold the material inside the raster pattern.

After at least partially curing at least part of the intersection pattern
10 and removing the uncured material outside the raster pattern, the layer may be post-cured with a wide-range energy source 100. The wide-range energy source 100 is typically a wide-range UV light source, for example, but not restricted to, a UV TL light source. However, the use of a wide-range thermal source is also contemplated.

15

Figure 6 shows an embodiment of an apparatus 12 for building a 3D model by stacking layers in a rapid prototyping or rapid manufacturing process according to the present invention. The apparatus 12 comprises a stage 14 for holding the model. In this embodiment, the stage 14 is a movable z-stage
20 15 that may be moved in a z-direction before the applicator 18 provides a layer of curable material to the model. Movement in the z-direction the direction can be transverse to the layer of curable material. The stage 14 may be raised while the applicator 18 is not moving, but it is also possible to lower the applicator 18 as long as the distance between the model 5 and the applicator
25 18 is increased. In this embodiment, rolling elements 17 enable movement of the z-stage 15.

Figure 6 shows that the model 5 is connected under the z-stage 15 and that a new layer is stacked from below. For sake of clarity, the layer of curable
30 material is shown with an exaggerated thickness.

In one embodiment, the apparatus 12 comprises an applicator 18 for providing a layer of curable material to the model 5. The apparatus 12 further comprises a remover for removing the uncured material from the layer outside the intersection pattern. In the embodiment of Figure 6, the applicator 18 is
5 arranged for both providing a layer of curable material to the model 5 and for removing the uncured material from the layer outside the intersection pattern. This is convenient but alternatives for removing the uncured material from the layer outside the intersection pattern are possible, for example, removing the uncured material with a blower. This is especially suitable when the uncured
10 material has a dry, powder like structure or is a low viscosity liquid.

In this embodiment the applicator 18 is formed by a movable foil guiding stage. The foil guiding stage 18 is movable transverse to the z-direction. The movement of the foil guiding stage 18 may be enabled by rolling elements 17.
15 Other ways of moving, like sliding are also possible. The foil guiding stage 18 further comprises foil guiding elements 19, 19', 19'' and 19''' protruding from the stage 18 for guiding a foil 20 along the model 5 so as to apply a layer of curable material to the model 5. In one embodiment, the foil guiding elements 19 comprise four rollers 21.

20

In the embodiment illustrated in Figure 6, the foil 6 is arranged for carrying the curable material supplied from a supply reservoir 2 to the model 5 and for carrying the removed uncured material from the model 5 to a residue reservoir 23. Typically, the uncured material outside the intersection pattern
25 sticks to the moving foil 6 because the adhesive force between the uncured material and the foil 6 are larger than the adhesive force between the uncured material and the model 5.

The applicator 18 may further comprise a supply reservoir 2 for storing
30 the curable material and a residue reservoir 23 for storing the uncured

material removed from the layer outside the intersection pattern. The reservoirs may be open or closed. Open may have the advantage that filling or emptying is easier. In a closed reservoir, keeping the curable material under certain operating conditions before using or recycling it may be easier. In this
5 embodiment, the foil 6 may be arranged for carrying the curable material supplied from a closed supply reservoir 2 to the model 5 and for carrying the removed uncured material from the model 5 to the residue reservoir 23. In this embodiment, the applicator 18 may further comprise an actuator (not shown) for moving the foil 6 to and from the model 5.

10

The foil 6 and the foil guiding stage 18 may be moved independently. In one operating mode, in a first step, the foil 6 is moved so as to provide a layer of curable material beneath the model 5. The curable material is, at that time, not yet in contact with the model 5. In a second step, the foil guiding stage 18
15 moves along the model 5 to apply the layer of curable material to the model 5, expose the curable material and remove the uncured material. In the second step, the foil 6 does not substantially move relative to the model 5 transverse to the z-direction.

20 In one embodiment, the apparatus 12 according to the present invention comprises a first energy source 9 arranged for at least partially curing at least part of an intersection pattern in the layer of curable material 3. In the embodiment of Figure 6 the first energy source 9 comprises a plurality of individually operable LEDs arranged in rows and columns (not shown). The
25 first energy source 9 may be moveably disposed below the layer of curable material 3, such that it can move in a direction parallel to the layer of curable material 3. The motion of the first energy source 9 may be controlled by a controller, which also controls the lighting of the LEDs. In use, the first energy source 9 may be moved rectilinearly in a direction that extends at an angle
30 with the directions of the rows and columns of the LED array 32 to enhance

the effective resolution of the system. This technique is described in more detail in copending application EP 07150447.6 in the name of applicant, which is incorporated herein by reference for further information regarding this aspect. The first energy source 9 may be positioned on the movable foil guiding
5 stage 18, between the protruding foil guiding elements 19 so as to expose the layer of uncured material through the foil 6. The energy source may be covered by a transparent plate, e.g. a glass plate to improve the guidance of the foil 6.

The combination of using a LED light source comprising a plurality of
10 individually operable LEDs and partially curing at least part of the intersection pattern may be advantageous. Before explaining this further, an example of a LED light source as used in an embodiment of the present invention will be described in some detail.

15 In one embodiment, the LED light source 32 comprises a two dimensional matrix of typically about 80 x 120 light emitting diodes (LEDs); that are imaged via a multilens array (not shown) to the layer of curable material 3. The length of the matrix is typically about 60 centimetres. The LEDs may be individually operable to write the intersection pattern with a
20 control speed of an individual LED typically in the order of nanoseconds, by a plurality of electrical pathways, selectively connected to the respective LEDs. In this example, accordingly, the first energy source 9 may be provided by a two-dimensional array of LEDs extending in a plane parallel to the layer of curable material 3, and in between the multi-lens-array and the substrate.

25 When the complete intersection pattern is fully cured, the LED light source typically moves over the layer of uncured material with a scanning speed of about 10 centimeters per second.

Figure 7 illustrates a problem that can arise when the cross section of
30 the object is large: the capillary forces in the narrow slit between foil 6 and

object 50 cause this slit to be narrowed. This may lift the foil from its intended position P to a higher position Q, and makes the layer at the positions to be exposed 1010 thinner. Thus the new layer is too thin. This effect can accumulate during a number of layers, and the accuracy of the product can be severely compromised. Even the building process can be interrupted if the accumulated thickness loss is such that at a certain layer no contact is made any more between the liquid layer moved towards the product and the product itself. A solution for this problem is to apply a compensating downward force on the foil, by creating a pressure difference across the foil.

10 This can be done by adding a vacuum chamber 210 underneath the foil, more specifically around the exposure unit. An underpressure is applied to the inside 212 of the chamber by applying suction 213 at the connection tubing 211.

15 In an embodiment, the chamber 210 fits closely (slit of e.g. 1 mm width) around the exposure head 30, to prevent bulging downward of the foil at the slit. Surprisingly, notwithstanding the narrowness of the slit, the required underpressure to prevent the problem of foil lifting is very small, typically 10 mbar or less. Upon analysis it was found that the underpressure is effectively acting on the full area of the exposure head 30.

20 In Figure 8 some residual foil lifting 66 is shown. This does not normally occur because the resin has already been exposed there (in this figure the exposure head is moving right to left) and is strong enough to withstand the capillary forces, but in case lifting yet occurs (depending on e.g. curing speed of the resin used) it can be remedied by extending the vacuum chamber or adding an additional vacuum chamber, always taking care that the slits for letting the underpressure pass from the chamber to underneath the foil are small (~1 mm) in order to keep the foil from bulging downward.

25 Figure 9 shows as an example a perforated plate forming a top side 901 of an exposure head extension 900.

It will be clear to a person skilled in the art that the above way of keeping a large area of foil under control with a very small underpressure can be applied in different embodiments, not necessarily only around the exposure head, but in all those cases where spurious forces tend to move the foil away
5 from its intended position. For example, a very small underpressure can be applied, e.g., through a vacuum or a vacuum chamber used at or near the point of the peeling roller or at or near the point where the foil 6 is separated from the last-cured layer of the object (50). In order to stabilize the underpressure preferably, vacuum chamber extension 900 has walls close to foil, to keep leaks
10 here small.

Figure 10 shows an embodiment wherein resin evaporation is minimized. To reduce evaporation, it is favorable to remove the resin from the foil in areas where the foil has just been separated (or peeled) from the object
50. This can be done by adding a remover or squeegee 1001 that moves
15 together with coater assembly 20 or peeler assembly 40, thus forming a reservoir of material 1002. Preferably this squeegee makes an angle α of approximately 10 degrees with the foil 6. This approximate angle was found to have the best scraping capability in one direction and the capability to allow resin to pass in the opposite direction, thus retrieving any resin left on the foil
20 rather than pushing it to the edge of the machine.

Note that 1002 forms a reservoir, because it is enclosed all around: by the squeegee 1001 and by the upward running part of the foil 6. The squeegee 1001 may include extensions having openings for passing shafts of lower roller 190, and seals around the shaft passings. In a bidirectional embodiment, a
25 reservoir 1002 is formed on each side of the carriage 180. And there may be liquid layer providing roller (e.g., a Meyer bar) 190 also on each side of the foil guiding stage.

In an embodiment, the thickness of the liquid layer provided by the coater bars (Meyer bars) is at least equal to the thickness of the next layer, but
30 preferably a bit more. For example, for building with layers of 50 μm , a good

value for the liquid layer thickness is around 70 - 80 μm . Thus when the foil with the liquid layer is moved towards the object, the space of 50 μm between the foil and the previous layer on the object is completely filled with liquid resin. The surplus of resin (20 - 30 μm) is pressed forward in front of the roller
5 that lifts the foil towards the object, or sideways into spaces that may be present in the object as built so far.

The rollers that provide the liquid layer (e.g., Meyer bars) are preferably knurled, or profiled, so that the amount of resin that is transported in the
10 recesses of the Meyer bar from the reservoir side of the Meyer bar to the exposure unit side of the Meyer bar is sufficient to provide the desired (in the example: 70 - 80 μm) thickness of liquid layer. It is to be noted that the liquid in the recesses only partly remains on the foil behind the Meyer bars, and part stays on the Meyer bar. Therefore the size of the recesses has to be determined
15 experimentally.

Figure 11 exemplifies an embodiment, where the resin is heated and discloses equipment used for heating and placement to improve the operational temperature conditions of the resin.

20 For the building process to work well, between the exposure and the separation from the foil, the resin should be cured to a certain extent, in order for the newly formed layer to adhere to the previously built layers of the object. For many resins, e.g. DSM Somos 8120 (an epoxy acrylate), exposed at 365 nm, curing is faster at a higher temperature. In fact, the mentioned resin is found
25 in an embodiment to work well when used above room temperature, preferably approximately between 30 and 40 $^{\circ}\text{C}$. Thus it is beneficial (allows shorter time between exposure and separation) to have a provision to heat the resin to above room temperature. Surprisingly an elegant solution was found to include a small heating bar 301a, 301b to be kept in thermal contact with the
30 underside (non-liquid-contacting side) of the foil, in close proximity of the

exposure head. For bidirectional operation, a second heater 301b on the opposite side of the exposure head 30 may be added.

The heater bar 301 is preferably close to the exposure head, to keep the heated area small, and to keep the total system compact (and thereby fast). In
5 case there is also a vacuum chamber, the heater bar(s) can be either inside or outside the vacuum chamber.

At first sight, one might think that such a small bar would not give sufficient temperature increase, because the foil is only in contact with the bar for a very short time, e.g. 0.2 s (heater bar width 2 cm, movement speed 10
10 cm/s); but we found it does. Analysis showed that this time is sufficient for the heat of the bar to penetrate the foil with resin layer, because the resin and foil are thin (e.g. 0.2 mm in total). The temperature of the bar does not even have to be much above the target temperature to achieve this. E.g. to achieve a foil and resin temperature of 30 °C typically a heater bar temperature of about 40
15 °C is required.

The heater bar is preferably of a material with high heat conductivity. E.g. it can be an aluminum housing (e.g. a square tube of approximately 2 x 2 cm), heated e.g. by an electric heater inside.

20 In an embodiment, the underside of the object built so far, and the top of the exposure unit, are at or around the target temperature (30 °C in the example). This state arises automatically after a number of cycles have been performed. Thus, the building process in this embodiment can be started by performing a number of 'dummy' cycles, i.e. cycles where no exposure is
25 performed, and no vertical movement of the z-stage 150 is performed. This heats up the underside of the platform 150 and the top of the exposure unit to the required process temperature. Alternatively, other heating means can be used to pre-heat these parts before starting the actual building process.

For example, a heating element can be built into the platform 150, and
30 the pre heating of both the platform and the top of the exposure unit are

carried out with the platform close to the exposure head (e.g. 1 mm distance or less).

Exothermic resins:

5 The curing process of most resins is exothermic, i.e. heat is generated in the curing process. Thus the required amount of heating by the heating bars will vary depending on the resin being processed. Even some cooling may be required to keep the process temperature from rising too much. Thus the heater bars may be provided with a cooling element inside, and the amount of
10 heating/cooling may be controlled (automatically or manually), based on a temperature sensor, that is e.g. built into the top of the exposure unit. Similarly, the object platform may contain not only a heater but also a cooling element.

 This heating method is much preferable over a larger heating system,
15 e.g. one which keeps the several moving units of the machine, and the resin reservoir, at an increased temperature. The invented heating method keeps the heated part of the total system as small as possible, and thus requires much less power. Another advantage is that the resin is only at increased temperature during the process phase when this is useful (from exposure
20 through separation); it can cool down immediately afterward, thus preventing any unwanted effects in the unexposed resin, such as aging, evaporation, or thermal curing.

 Figure 12 discloses a drawing wherein a radius of the roller is disclosed specifically. In addition, Figure 12 illustrates bearings 198 provided on the
25 outside of the roller. An optimum radius r of peeling rollers is provided in a range smaller than 10 mm. While a large radius r might be supposed to give a gradual, 'gentle' peeling and thus allow sufficient time for the last-cured layer to separate from the foil, surprisingly, it is found that a small radius works better: it allows for a higher separation speed, without damaging the last-
30 cured layer.

A radius of approximately 10 mm or smaller is preferred, typically even approximately 6 mm or smaller. In addition, with a small diameter, in combination with the large width of the working area (e.g. 50 cm), the stiffness of the roller construction may be challenging. The roller has to withstand the
5 tension force of the foil, and still remain straight. A shaft through the centre of the roller typically is not stiff enough. Advantageously the peeling roller is supported by bearings on the outside. These can be positioned at as many positions along the length of the roller as is necessary to achieve the desired straightness. In fig. 12 outside bearings are shown as friction bearings 198,
10 supported on the stiff peeling unit frame 195; of course any other type of bearing can also be used, in particular roller bearings. In an embodiment, at least four bearings are used. In another embodiment, at least one bearing is located on the horizontal floor of the peeling unit frame and at least one bearing is located on the vertical wall of the peeling unit frame.

15

The foil may be clamped lengthwise by the clamps 501 in fig.11. A mechanism may be provided (not shown) to keep the length of the foil under a predefined tension. The optimum tension depends on the type and thickness of the foil, but may typically be around 10 N per cm of foil width (500 N for a foil
20 width of 50 cm). This tension may keep the foil flat over the area where this is necessary: the part that is at the object contacting height (H in fig. 1). Significantly lengthwise tension can be sufficient to keep the foil flat over the whole of this area, including its side edges and not require clamps or other tension devices on the side edges.

25 In another embodiment of the invention, there are also types of foil, typically (but not exclusively; it is not fully understood which foil properties exactly are determining in this respect) those with lower modulus of elasticity, where the lengthwise tension by the clamps 501 is insufficient to keep the foil flat over the whole of the relevant area. In particular the side edges in this
30 embodiment can show a tendency to move up or down or wrinkle from the

intended plane. In such cases a solution can be found in the addition of side clamps, which may take one of the following forms or other forms:

The edge of the foil is perforated with holes at regular intervals, e.g. 2 cm; on the exposure unit carriage corresponding sprocket wheels are provided, at least one for each side of the foil, the teeth of which engage in the perforation and which sprocket wheels are forced outward by means of e.g. a spring, so that they exert an outward force on the foil edge, and thus provide a widthwise tension in the foil above the exposure unit.

In an embodiment, an improvement over simple sprocket wheels are toothed belts, the teeth of which engage in the foil perforation and which have a certain length (e.g. 5 - 20 cm) running parallel to the foil plane.

A number of movable mechanical grippers may be positioned on the machine frame along the sides of the foil. Each gripper comes forward, grips the edge of the foil, and exerts an outward force on the foil edge, for as long as the foil in front of the gripper is at the high level H. So from the moment the lifting roller 19 has passed in front of the gripper until just before the peeling roller 19 arrives in front of the gripper.

A suction clamp may be provided above the foil. The clamp is a long, narrow device on each side of the working area, having a length about equal to the length of the work area (object building area). The bottom surface of each clamp is a suction face, typically realised by a porous material backed by an underpressure chamber.

As soon as part of the foil edge is lifted from the lower lever to the level H where it touches the suction clamp, this piece of foil may be kept sucked against the clamp and it cannot move any more. At the lifting roller, the foil is under tension and thereby is also stretched sideways, and in this sideways-stretched condition both edges are fixed against the suction clamps. Due to the clamps the foil remains stretched sideways even after the lifting roller has passed.

The same effect as with the suction clamp can be realised by a sticky surface in stead of a suction surface. For example a clean soft silicone sheet of e.g. 1 mm thickness acts sticky with respect to many foil materials. If such sticky material is mounted on a stiff clamp frame, and positioned such that the
5 lifting rollers lifts and presses the foil edges against the sticky material, we obtain the desired sideways stretching effect.

Figure 13 discloses an interesting detail since it was found that only the side of the film away from the liquid layer 10 needs to be optically clear; the side facing the liquid layer 10 can be allowed to be diffusive, since surprisingly
10 its diffusiveness is removed by the wetting by the resin that is applied on the surface. This may reduce the manufacturing requirements for the foils.

The foil 6 forms an optical path between the exposure head 38 and the resin to be exposed and thereby influences the optical transmission. In an embodiment illustrated in Figure 13a, the exposure head can be arranged to
15 give a sharp focus 401 halfway in the resin layer 10 (see figure 13a). In such an embodiment diffusive (matte) structures in the optical path are unfavorable. E.g. matte bottom or top surfaces of the foil would give light scattering as illustrated in Figure 13b. Similarly, diffusiveness of the foil's bulk material (Figure 13c) would lead to light scattering that could destroy the sharp focus
20 401.

Experiments were run with foil that was matte on one side. With Figure 13b in mind we put the matte side upward, to keep the effect of the scattering smaller. Surprisingly we observed that the scattering at the matte top surface was eliminated at the moment the resin layer was applied to the top surface.
25 Surprisingly, in certain embodiments of the invention, only one of the foil surfaces (and the bulk) needs to be optically clear (non-diffusive), the other surface can be allowed to be matte. The matte side is then to be used as the resin-contacting side. This finding is important, since it is much more difficult to produce foil that is optically clear on both surfaces.

It is noted that the foil side facing the liquid layer should easily separate from (fully or partially) cured resin. Materials that meet this condition include but are not limited to TPX (bulk), silicone (applied as a coating on a foil of different material) and other materials that allow for easy separation.

5 The method and system of the invention have been tested successfully with acrylate and epoxy (and epoxy-acrylate) resins, using exposure with UV light around 365-375 nm. The following commercial types are among these:

DSM Somos 8120 (epoxy-acrylate)

Envisiontec R5 Profactory (acrylate)

10 To prevent sticking between underside of foil and topside of exposure head, which can occur due to van der Waals forces when these surfaces are very smooth, a very light rubbing with talcum powder or similar may be applied.

Figure 14 provides additional disclosure of a bidirectional embodiment. While
15 the solidifying method can be applied either in a unidirectional way or in a bidirectional way as previously discussed, an advantage of bidirectional **use** may be that process time can be gained by avoiding to have to return all the process carriages back to their start position before a new cycle can be started. Instead, after a pass in one direction, the carriage(s) can reverse instantly and
20 start the process in the opposite direction.

In one example of a bidirectional embodiment, certain elements of the machine may be configured in mirror-like symmetry so that such elements can switch functions when the direction is switched. Referring to Figure 14 this can be explained as follows:

- 25 - As shown here a first process step is carried out in the right-to-left direction 74. Lower roller 19 aL has the function of providing the liquid layer, upper roller 19aH has the function of lifting the coated foil up to the level H;
- On the side of the exposure head 30 opposite rollers 19 aL and 19aH, upper roller 19 bH has the function of peeling roller, and the lower roller 19 bL

has the function of guiding the foil back to the lower level H0 (shown in Figure 1).

- After a single cycle has been completely performed from right to left (the foil has been completely peeled off from the product), a new cycle can be started immediately from left to right. Now the functions of 19 bH and 19 aH are interchanged, and the functions of 19 bL and 19 aL are interchanged.

- So upper rollers 19 bH and 19 aH can be designed to be suitable for both the lifting and the peeling function. This constraint may lead to a compromise design w.r.t. e.g. the roller radius, as the peeler roller radius is preferably small, as explained in conjunction with fig. 12.

- In that case the switchable solution discussed in conjunction with Figure 5 can be used. Additionally, lower rollers 19 aL and 19 bL can be arranged to be suitable for both providing a liquid layer of correct thickness, and for guiding the foil. A reservoir can be present on either sides (X2a and X2b).

Note that the squeegees X4a and X4b are preferably both present even in the case of unidirectional use (even in that case the resin must preferably be retained within the space defined by the squeegees).

In one example of a bidirectional embodiment, separate carriages for the exposure unit (180 c) and for the equipment on either side of the exposure unit (180a and 180b) can be used in contrast to previously disclosed single carriages.

This has the advantage that the distances between the carriages can be optimized for the movement direction, in dependency of the times required for the different subprocesses.

One example is that some curing time is required between exposure and peeling, to give the resin sufficient strength to withstand the peeling process. So one preferable configuration is to have the exposure unit following the coating unit immediately, but the peeler roller following the exposure unit at a

certain distance, corresponding to the required curing time before peeling. The different distances between the units for the two process directions 74 and 73 are shown in Figure 15.

5 The detailed drawings, specific examples and particular formulations given serve the purpose of illustration only. While the specific embodiments of the apparatus 12, 120 described and shown herein concern building the model 5, 50 upside down, the teachings of the present invention may be applied to apparatuses that build models right side up or even any other orientation. The
10 aspects of the present invention can also be applied in apparatuses for conventional RP and RM techniques like Selective Laser Sintering (SLS) and Stereo Lithography (SLA). In the foregoing specification, the invention has been described with reference to specific examples of embodiments of the invention. It will, however, be evident that various modifications and changes
15 may be made therein without departing from the broader spirit and scope of the invention as set forth in the appended claims. Furthermore, the object may have any suitable size and shape. Also, the invention is not limited to physical devices or units implemented in non-programmable hardware but can also be applied in programmable devices or units able to perform the desired device
20 functions by operating in accordance with suitable program code. Furthermore, the devices may be physically distributed over a number of apparatuses, while functionally operating as a single device. Also, devices functionally forming separate devices may be integrated in a single physical device. However, other modifications, variations and alternatives are also possible. The specifications
25 and drawings are, accordingly, to be regarded in an illustrative rather than in a restrictive sense. While certain embodiments detail certain optional features as further aspects of the invention, the description is meant to encompass and specifically disclose all combinations of these features unless specifically indicated otherwise or physically impossible.

Claims

1. A method for layerwise production of a tangible object (5), the method comprising:
- providing a construction shape (6); and
 - repeatedly performing method cycles, each method cycle comprising the
- 5 steps of:
- providing a liquid layer on the construction shape of limited height that does not contact the tangible object;
 - moving, relative to one another, the construction shape to a predetermined position relative to the tangible object, for carrying out a
- 10 successive such method cycle for solidifying a predetermined area of a successive such liquid layer;
- solidifying a predetermined area of a layer (10) of the liquid (3);
 - removing unsolidified parts from the tangible object so as to obtain a solid layer (14) of the tangible object (5), the solid layer thus having a
- 15 predetermined shape;
- wherein for at least one of said method cycles, said moving of said construction shape and said solidifying of said predetermined area are carried out to take place simultaneously.
2. A method according to claim 1, wherein, in addition, said layer provision
- 20 and said solidifying are carried out such that solidifying of certain parts of the layer (14) takes place simultaneously with provision of the liquid layer on the construction shape.
3. A method according to claim 1, wherein the construction shape comprises a flexible foil (6) that is bent such that time-dependently varying
- 25 contacting parts of the liquid contacting side of the flexible foil (6) are in contact with the tangible object for solidifying said certain parts of the layer (10).

4. A method according to claim 3, wherein guiding means (18) are brought in pressing contact with the side of the flexible foil (6) opposite to the liquid contacting side for defining the time-dependently varying contacting parts of the liquid contacting side of the flexible foil.
- 5 5. A method according to claim 4, wherein said pressing contact is realized by means of sliding of the guiding means (18) along the flexible foil (6) having opposite ends fixed relative to the tangible object.
6. A method according to claim 1, further comprising
- solidifying at least part of an intersection pattern (5) of the object in the
 - 10 liquid layer with a first energy source (6) so as to stabilize the at least part of the intersection pattern (5);
 - removing the unsolidified material from the layer outside the intersection pattern (5); and
 - post-solidifying the layer with a second energy source (9), wherein the
 - 15 second energy source (9) is a wide-range energy source (10).
7. The method according to claim 6, wherein the solidifying of at least part of the intersection pattern (5) comprises the curing of a raster pattern (11) in the layer of curable material (3), said raster pattern (11) being dimensioned to hold uncured material.
- 20 8. A system for layerwise production of a tangible object (5), the system comprising:
- a construction shape (6) arranged to provide a liquid layer of limited height that does not contact the tangible object, to be brought in contact with the tangible object;
 - 25 solidifying means (9) for solidifying a predetermined area of a layer (10) of the liquid (3), so as to obtain a solid layer 14 of the tangible object 5, the solid layer thus having a predetermined shape;

removing means for removing uncured material from the layer outside the intersection pattern;

moving means (18) for moving, relative to one another, the construction shape to a predetermined position relative to the tangible object,
5 for solidifying a predetermined area of a successive such liquid layer;
characterized in that
the system is arranged to move said construction shape (6) and said solidifying means (9) simultaneously to contact the liquid layer with the tangible object (5) while solidifying a predetermined area of such layer.

10 9. A system according to claim 8, wherein the system is further arranged to carry out said layer provision and said solidifying such that solidifying of certain parts of the layer (14) takes place simultaneously with provision of the liquid layer on the construction shape.

10. A system according to claim 8, wherein the construction shape
15 comprises a flexible foil (6) that is bent such that time-dependently varying contacting parts of the liquid contacting side of the flexible foil (6) are in contact with the tangible object for solidifying said certain parts of the layer (10).

11. A system according to claim 8, wherein the construction shape (6)
20 comprises guiding means (18) and wherein the guiding means are brought in pressing contact with the side of the flexible foil (6) opposite to the liquid contacting side for defining the time-dependently varying contacting parts of the liquid contacting side of the flexible foil.

12. The system according to claim 11, wherein the guiding means (18)
25 comprises a foil guiding stage comprising at least two foil guiding elements (19) arranged thereon defining a contact height H and at least one position distanced from the contact height, for guiding the foil (6) to or from the contact

height to contact the tangible object (5) by movement along the tangible object (5) while having opposite ends fixed relative to the tangible object at least during contacting.

13. The system according to claim 12, wherein the foil guiding stage further
5 comprises an applicator system for flattening and adjusting the layer volume.

14. The system according to claim 8, further comprising: a stage (14) arranged for holding the tangible object (5), the stage being a movable z-stage (15) for moving the tangible object (5) in a z-direction before providing the layer of curable material (3).

10 15. The system according to claim 12, said solidifying means (9) further comprising:
a first energy source (6) arranged for at least partially curing at least part of an intersection pattern in the layer of curable material (3), wherein the energy source (6) is positioned on the movable foil guiding stage (18), between the
15 protruding foil guiding elements (19) so as to expose the layer of uncured material through the foil (20).

16. The apparatus according to claim 15, said solidifying means (9) further comprising:

- separating means (18; 19'; 19'') for separating said solid layer from said
20 construction shape, and
- a second energy source (9) for post-curing the layer, wherein the second energy source (9) comprises a wide-range energy source (10) that is positioned on the movable foil guiding stage (18) for post-curing the layer.

25 17. The apparatus according to anyone of claims– 15, wherein the first energy source (6) comprises a plurality of individually operable LED's.

Figure 2

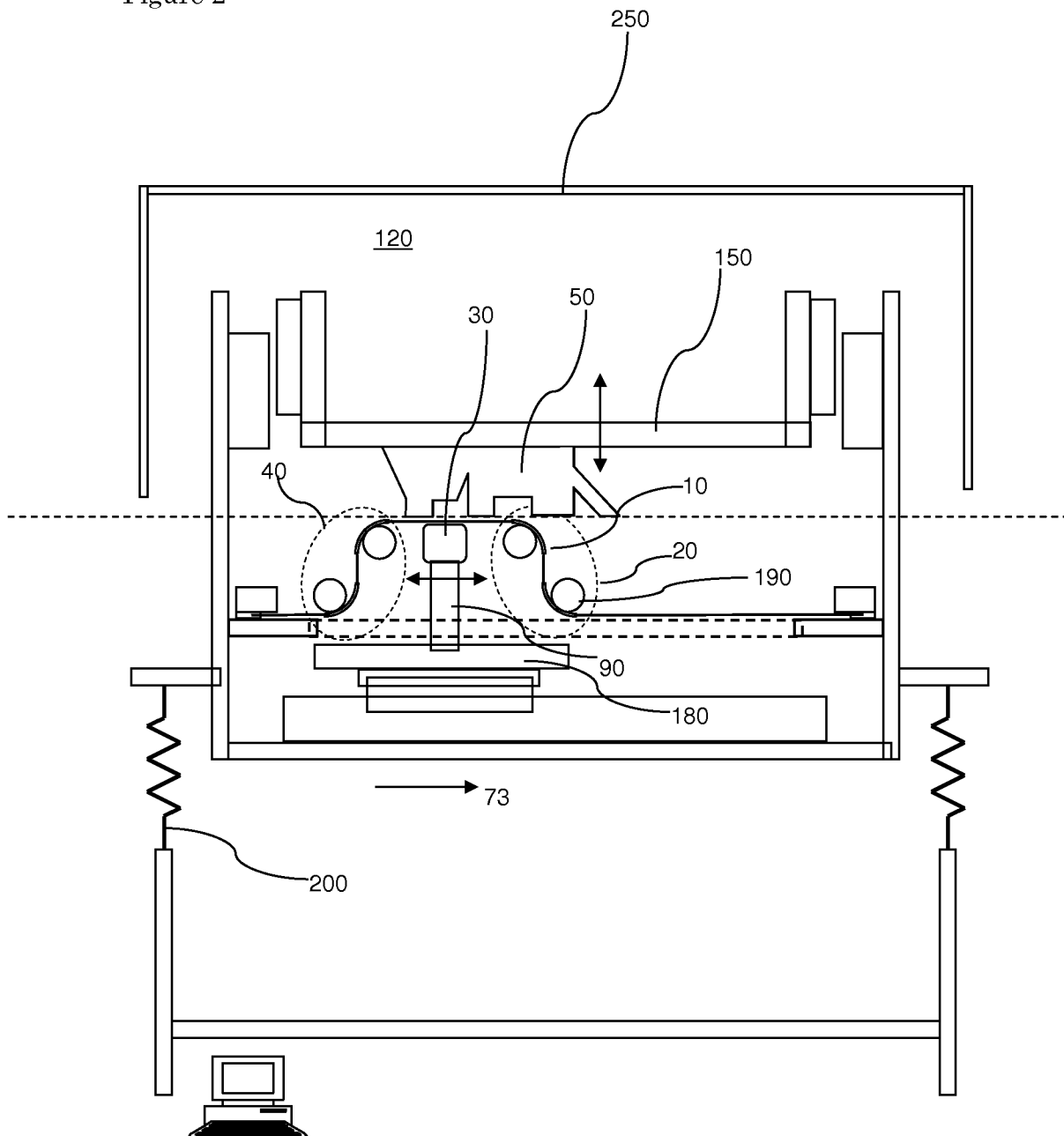


Figure 3

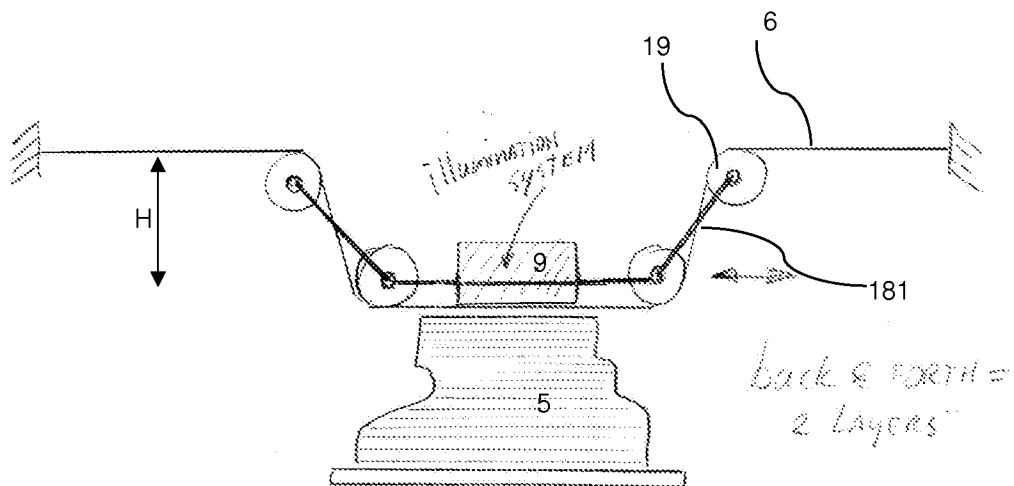


Figure 4

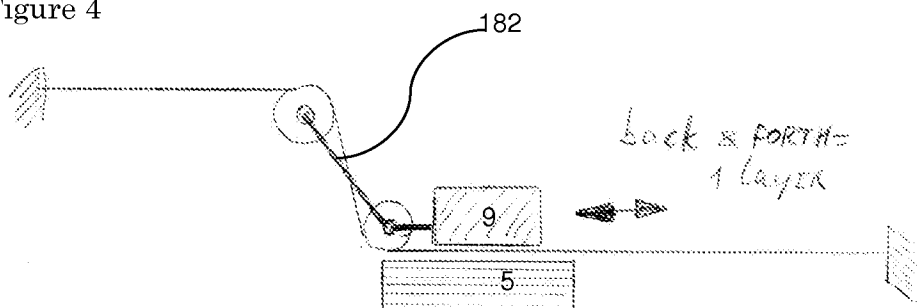


Figure 5

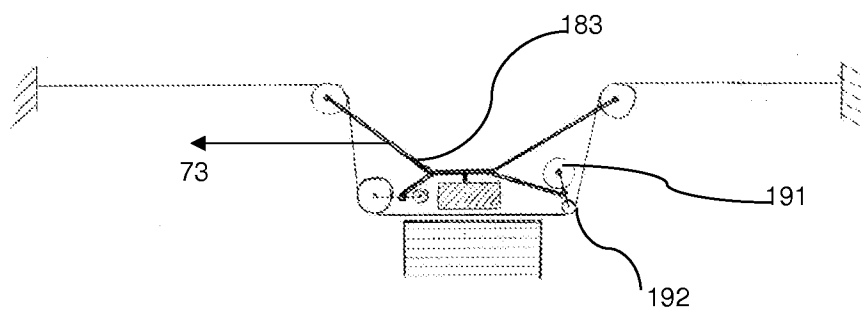


Figure 6

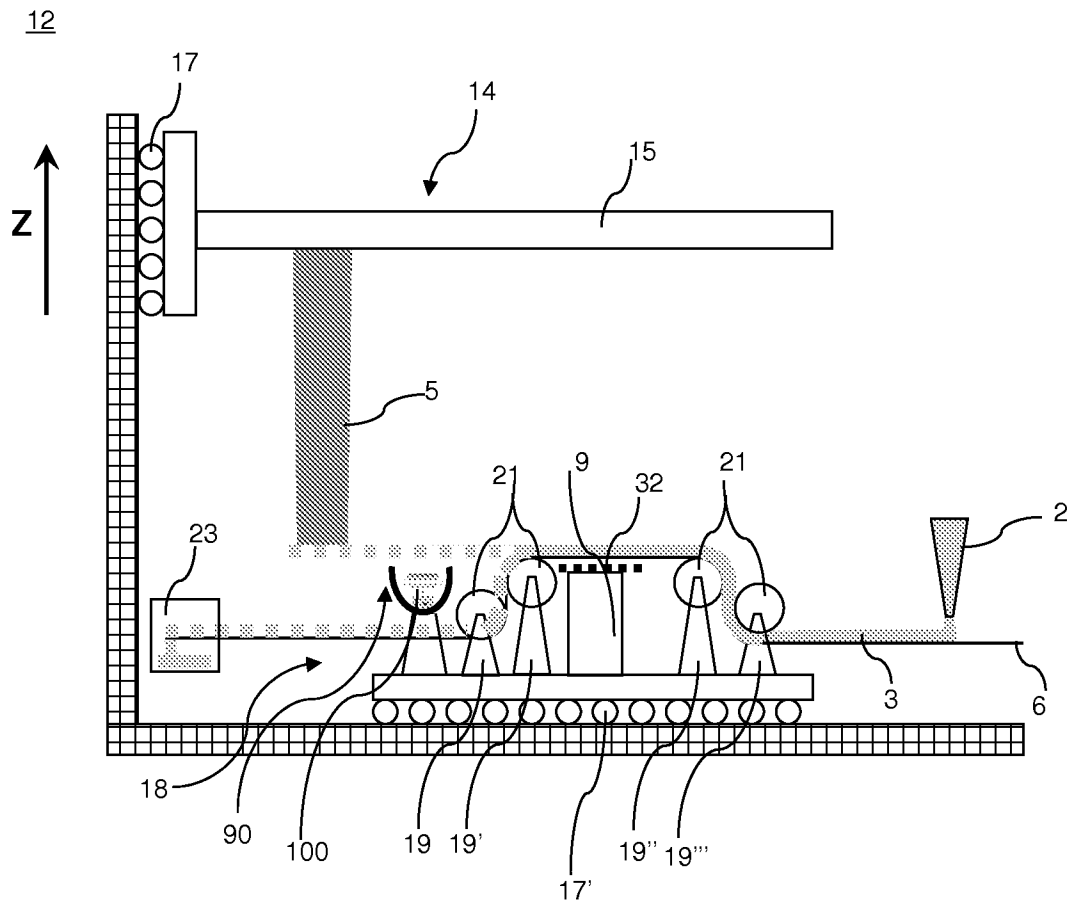


Figure 7

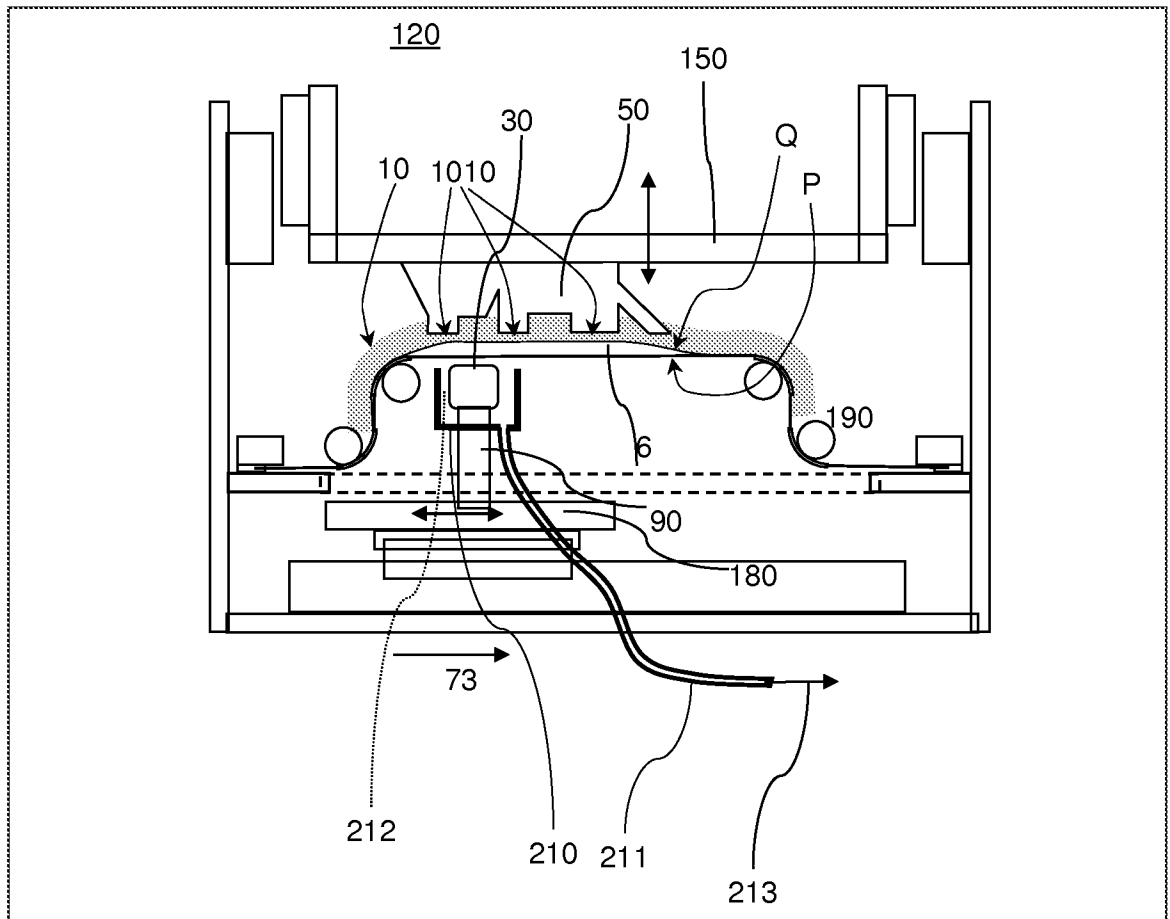


Figure 8

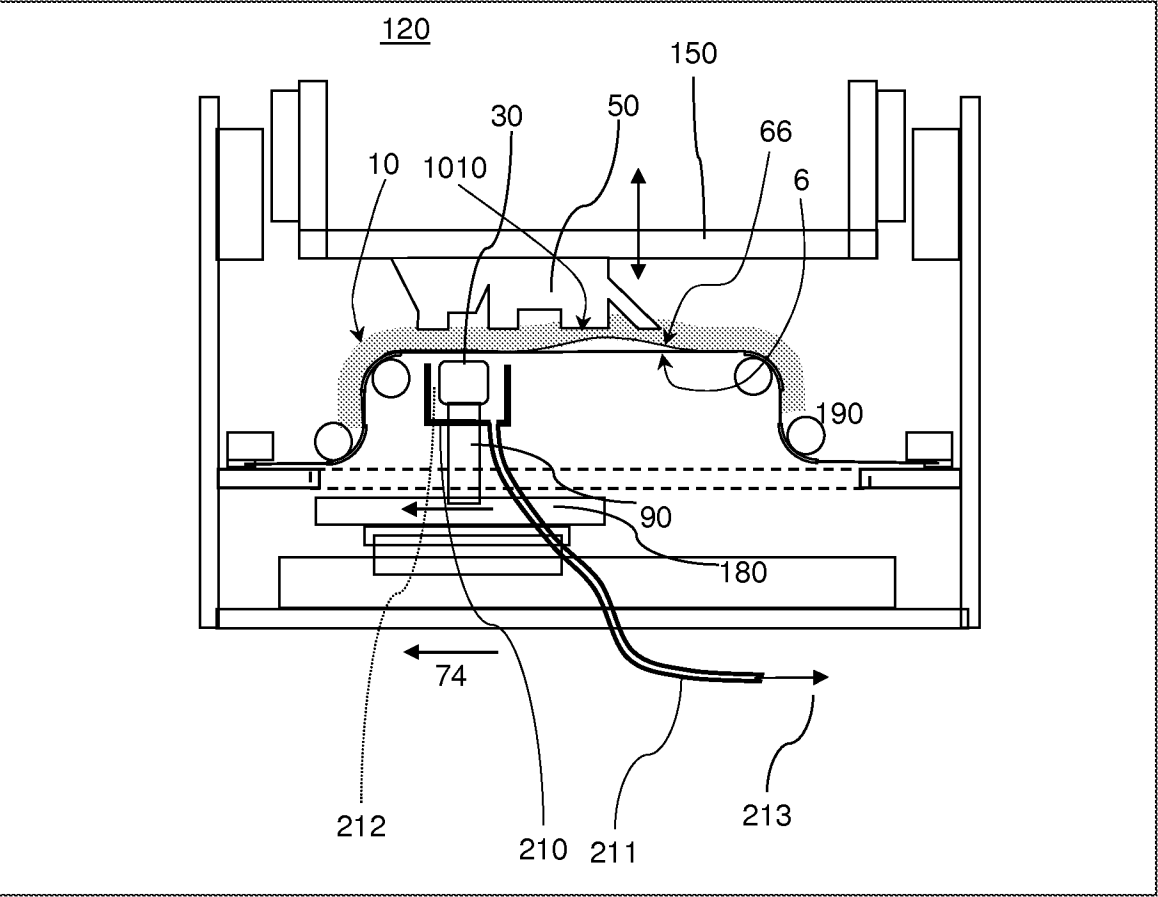


Figure 9

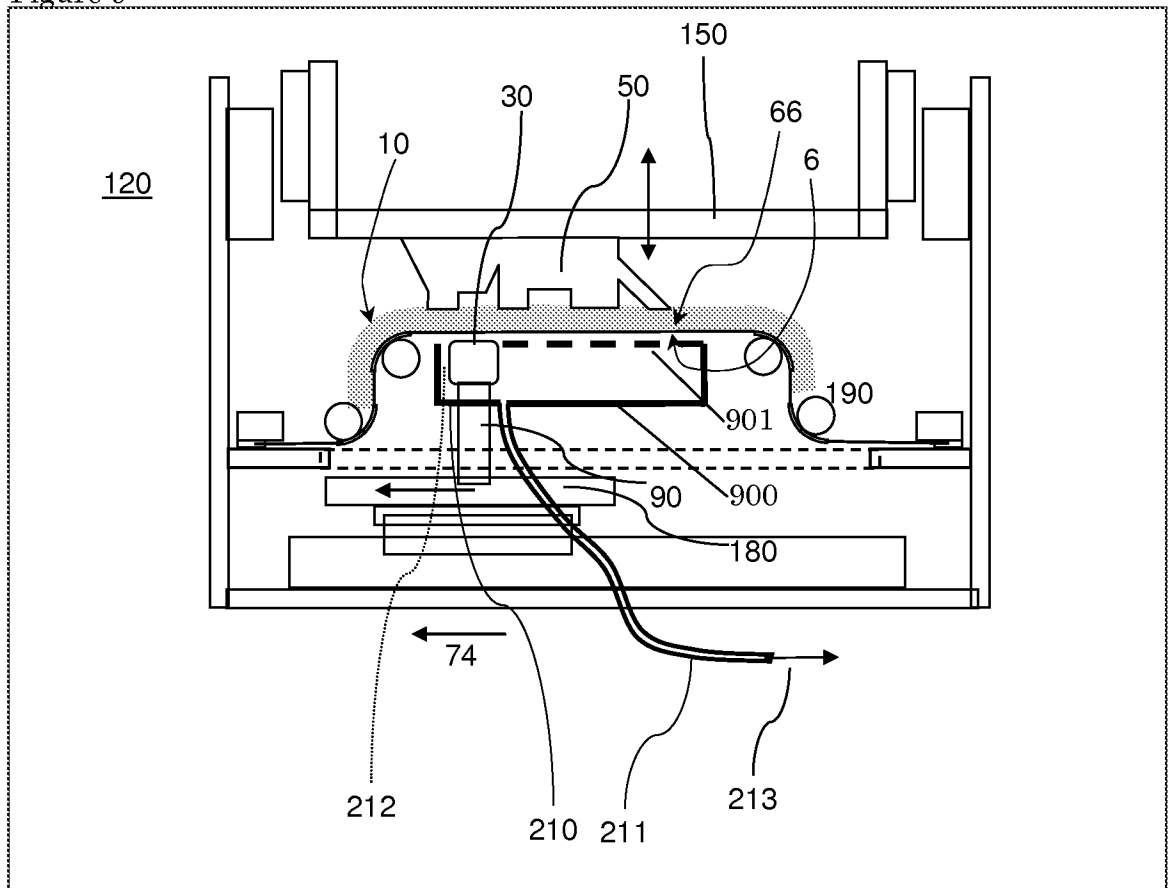


Figure 10

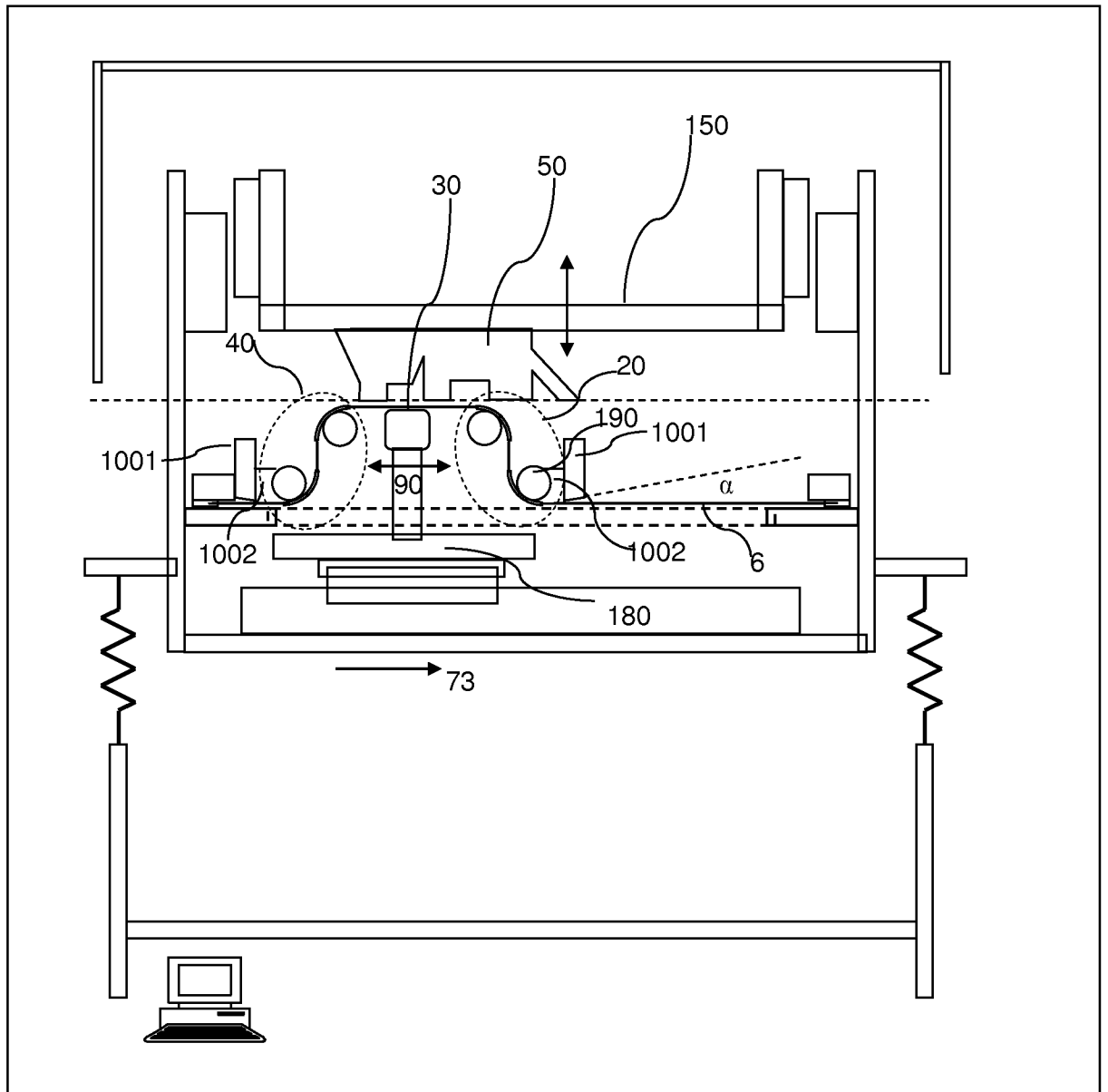


Figure 11

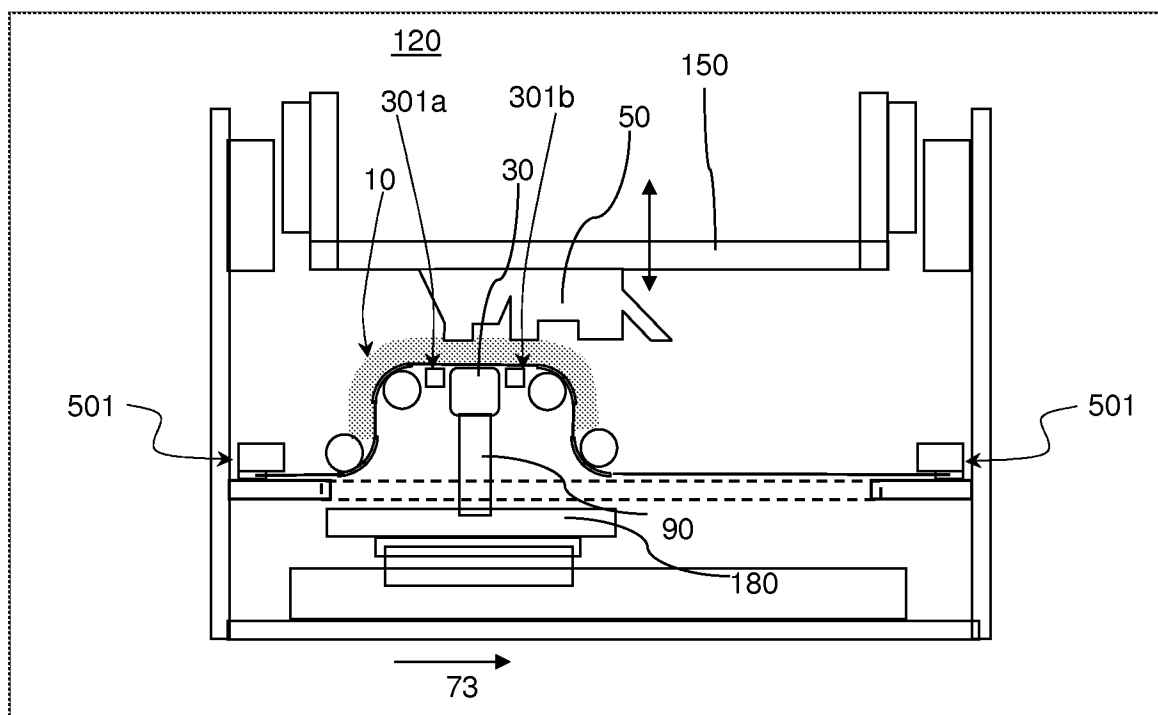


Figure 12

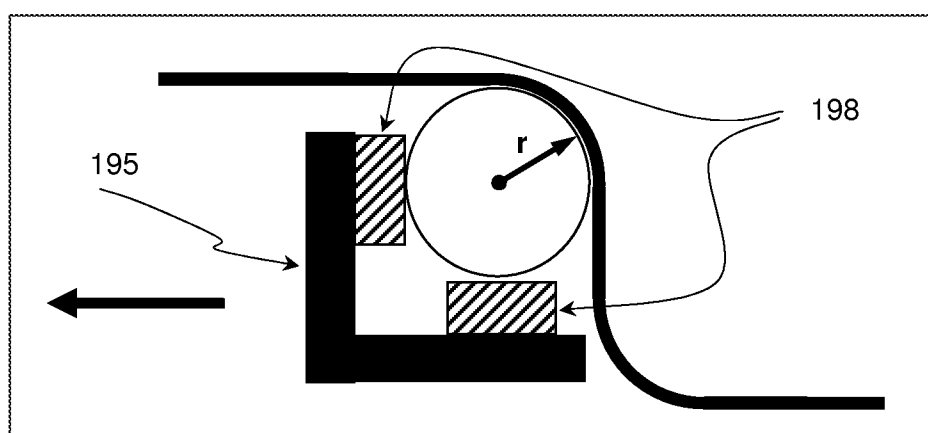


Figure 13

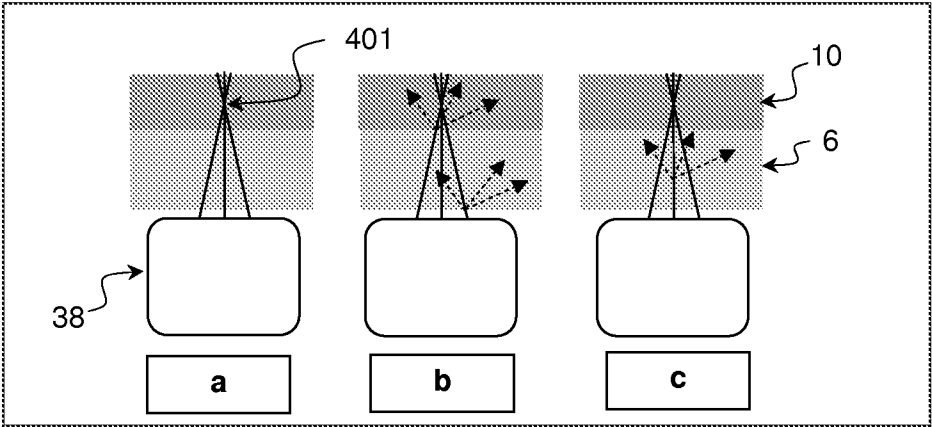


Figure 14

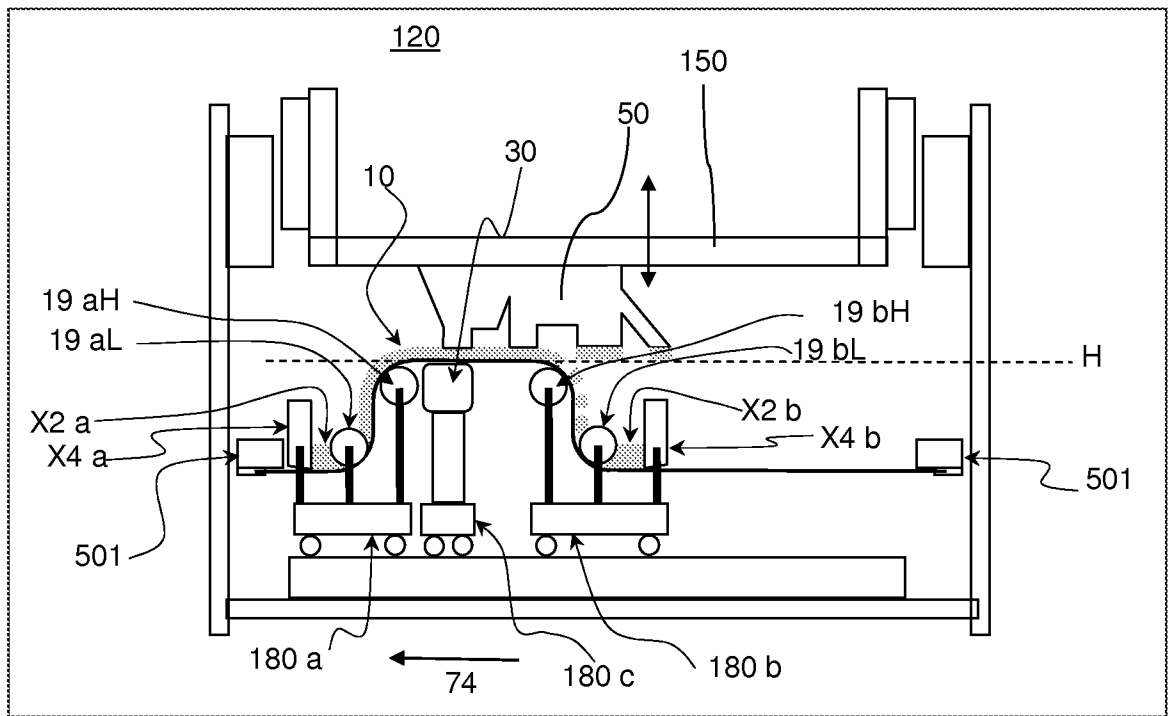
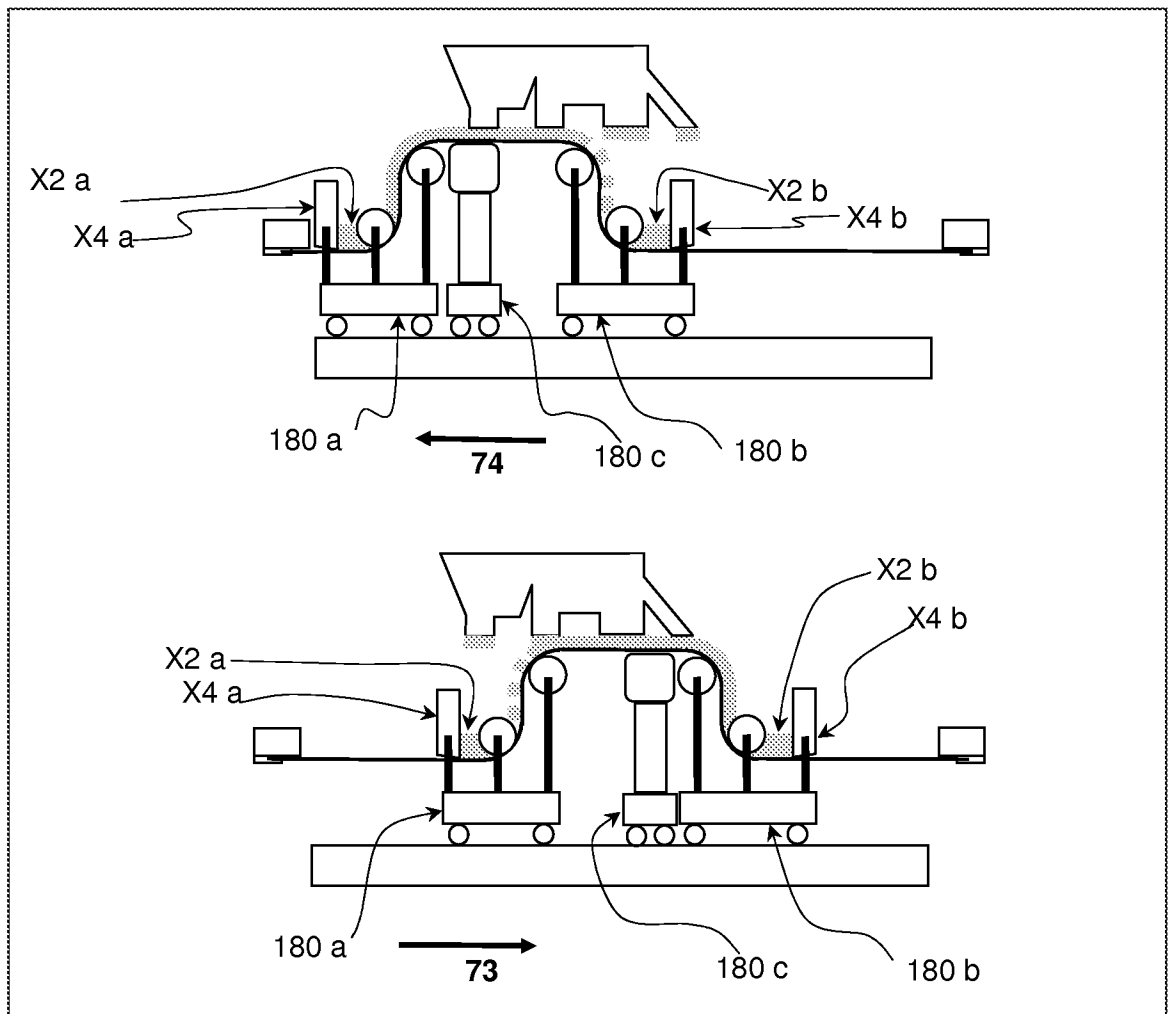


Figure 15



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2009/050783

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C67/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B29C

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 practical, 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 A A A A	US 5 637 169 A (HULL CHARLES W [US] ET AL) 10 June 1997 (1997-06-10) column 13, line 18 - column 15, line 32; figure 3 ----- WO 01/40866 A2 (FRUTH CARL JOHANNES [DE]) 7 June 2001 (2001-06-07) figures 6,7 ----- EP 1 719 607 A1 (3D SYSTEMS INC [US]) 8 November 2006 (2006-11-08) figure 1 ----- WO 00/30834 A1 (AFIT CORP [JP]; KAIEDA SHOZO [JP]; SUZUKI NORIYUKI [JP]) 2 June 2000 (2000-06-02) abstract; figures 1a, 1b ----- -/--	1-2,7-9, 14,17 3-6, 10-13, 15-16 1-17 1-17 1-17

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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

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

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Date of the actual completion of the international search

5 February 2010

Date of mailing of the international search report

15/02/2010

Name and mailing address of the ISA/

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Authorized officer

Pierre, Nathalie

INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2009/050783

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 025 981 A2 (3D SYSTEMS INC [US]) 9 August 2000 (2000-08-09) claims 1, 18 -----	6, 16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2009/050783

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EP 1719607	A1	08-11-2006	DE 102006019860 A1 EP 2143552 A1 JP 2006312318 A US 2006249884 A1	30-11-2006 13-01-2010 16-11-2006 09-11-2006
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