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(54) **METHOD FOR PRODUCING A THREE-DIMENSIONAL OBJECT**

VERFAHREN ZUM HERSTELLEN EINES DREIDIMENSIONALEN OBJEKTS

PROCÉDÉ DE PRODUCTION D’UN OBJET TRIDIMENSIONNEL

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(56) References cited:
US-A1- 2008 174 050 **US-A1- 2009 020 901**
US-A1- 2010 262 272

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Description

[0001] The present invention concerns a stereolithography method for the production of a three-dimensional object.

[0002] As is known, a stereolithography machine comprises a container for a liquid substance suited to be solidified through exposure to predefined radiation, typically light radiation.

[0003] The above mentioned radiation is produced by radiation emitting means suited to selectively irradiate a layer of the liquid substance having a predefined thickness and arranged adjacent to the bottom of the container, so as to solidify it.

[0004] The machine also comprises a modelling plate facing the bottom of the container and provided with a supporting surface for the three-dimensional object to be made.

[0005] The above mentioned modelling plate is associated with moving means that are suited to move it according to a direction perpendicular to the bottom of the container.

[0006] In order to produce a three-dimensional object using a machine of the type described above, the shape of the object is schematized as a sequence of layers having a predefined thickness.

[0007] According to the production method, the modelling plate is arranged with the supporting surface immersed in the liquid substance, at a distance from the bottom of the container that is equal to the thickness of the first layer of the object.

[0008] A layer of liquid substance is thus formed that is adjacent to the bottom of the container and that is selectively irradiated by the emitting means in the parts corresponding to the surface area of the first layer, so as to form a corresponding solidified layer that adheres to the supporting surface of the modelling plate.

[0009] Successively, the modelling plate is first moved away from the bottom of the container, so as to separate the solidified layer from the bottom itself and thus allow the liquid substance to flow back under the modelling plate and the liquid layer necessary to form a successive layer of the object to be consequently restored.

[0010] Successively, the modelling plate is moved near the bottom of the container, so as to arrange it at a distance from the bottom that corresponds to its distance as it was during the formation of the first layer, increased by the thickness of the successive layer.

[0011] The new layer of the object is thus formed analogously to the previous one and this process is repeated until all the layers forming the object have been produced.

[0012] Document US 2010/0262272 discloses a method according to the preamble of claim 1 and similar to the one described above, except that the layers are formed and solidified between the modelling plate and a solidification substrate located above it, instead of using the bottom of the container.

[0013] The method described above poses the drawback that the detachment of the solidified layer from the bottom of the container while the plate is being moved away generates a certain resistance.

[0014] This resistance to detachment is mainly due to the suction effect caused by the contact between the solidified layer and the bottom of the container and partly to the adhesion of the solidified layer to the bottom of the container.

[0015] Said resistance to detachment produces traction forces on the three-dimensional object being formed and on the bottom of the container, whose amount mainly depends on the speed with which the plate is moved away, on the surface area of the solidified layer and on the physical properties of the liquid substance.

[0016] Due to the above mentioned traction forces, it is necessary to limit the said speed of the modelling plate, in order to avoid breaking the three-dimensional object that is being formed.

[0017] Consequently, another drawback lies in that the time necessary for the formation of each layer increases, thus increasing also the total time necessary for the production of the object.

[0018] A further drawback lies in that the traction forces generate fatigue stress on the bottom of the container, which over time causes the latter to break down.

[0019] This involves the need to periodically replace the container, with the inconvenience of having to stop production and bear the replacement costs.

[0020] According to a known stereolithography method adopted in the attempt to limit the resistance to detachment described above, the movement of the plate away from the bottom of the container is controlled in such a way that the traction forces acting on the object and on the bottom are limited to a maximum predefined value.

[0021] According to the above mentioned method, it is necessary to determine the traction forces, which requires the use of a suitable sensor, and this makes the stereolithography machine more complex and increases its costs.

[0022] According to a variant application of the above mentioned method, the traction forces are determined using a numerical calculation procedure.

[0023] Even if this variant makes it possible to avoid using a sensor, it however poses the drawback of requiring a complex processing software for calculating the forces.

[0024] Furthermore, said calculation may not correspond to the actual value of the forces, with the inconvenience of reducing the reliability of the system.

[0025] The present invention intends to overcome all the drawbacks of the known art as outlined above.

[0026] In particular, it is a first object of the invention to develop a method for producing a three-dimensional object in layers using a stereolithography machine, which makes it possible to reduce the traction stress between each solidified layer and the bottom of the container while they are separated from each other.

[0027] It is another object of the invention that the above method makes it possible to reduce the extent of the movement of the solidified layer which is necessary to detach it from the bottom of the container to a lower value compared to the value obtainable with the known methods.

[0028] It is another object of the invention to develop the method mentioned above so that it can be easily applied to stereolithography machines of known type.

[0029] The above mentioned objects are achieved by a method for producing a three-dimensional object implemented according to the main claim.

[0030] Further characteristics and details of the method that is the subject of the invention are described in the corresponding dependent claims.

[0031] Advantageously, the reduced resistance to detachment makes it possible to limit the breakages of the object being formed compared to the known methods though maintaining the same geometry of the object.

[0032] Still advantageously, said reduced resistance makes it possible to limit the stress on the container and thus to increase its duration.

[0033] Furthermore, advantageously, the reduced stress to which the layers of the object are subjected makes it possible to obtain objects whose cross section is larger than that of the objects that can be obtained with the known methods, maintaining the same detachment speed and the same physical properties of the liquid substance used.

[0034] Still advantageously, the reduction of the movement of the modelling plate makes it possible to reduce the time necessary for building each layer.

[0035] The said objects and advantages, together with others which will be highlighted below, are illustrated in the description of some preferred embodiments of the invention which are provided by way of non-limiting examples with reference to the attached drawings, wherein:

- Figure 1 shows a stereolithography machine;
- Figure 2 shows the stereolithography machine shown in Figure 1 in a different operating configuration;
- Figure 3 shows a schematic view of the movement of a solidified layer during application of the method that is the subject of the invention;
- Figure 4 shows a schematic view of the movement of a solidified layer during application of a variant implementation of the method that is the subject of the invention.

[0036] The method for producing a three-dimensional object that is the subject of the invention is described with reference to a stereolithography machine that is indicated as a whole by **1** in Figure 1.

[0037] The above mentioned machine **1** comprises a container **2** suited to contain a liquid substance **3** suited to be solidified through exposure to predefined radiation **4.**

[0038] The machine **1** also comprises means **5** suited to emit said predefined radiation **4,** capable of selectively irradiating a layer **6** of the liquid substance **3** having a predefined thickness and arranged adjacent to the bottom **2a** of the container **2,** so as to form a corresponding solidified layer **6a** of the object, as schematically shown in Figure 2.

[0039] Preferably but not necessarily the above mentioned predefined radiation **4** is a laser beam that is selectively directed towards the areas corresponding to the volume of the objectto be produced through said emitting means **5.**

[0040] The machine **1** comprises also actuator means **8** suited to move the solidified layer **6a** with respect to the bottom **2a** of the container 2 at least according to a movement direction **Z** that is perpendicular to the bottom **2a.**

[0041] Said actuator means **8** preferably comprise a modelling plate **7** provided with a supporting surface **7a** for said solidified layer **6a** and facing the bottom **2a** of the container **2.**

[0042] The stereolithography machine **1** also comprises a logic control unit **9,** operatively connected to the emitting means **5** and the actuator means **8** and configured so as to implement a method according to the invention, as described below.

[0043] According to the method of the invention, first of all the layer **6** of liquid substance **3** must be irradiated, as described above.

[0044] Successively, the actuator means **8** separate the solidified layer **6a** obtained in this way from the bottom **2a** of the container **2** through a separation movement **11** having a predefined extent and intended to move the solidified layer **6a** and the bottom **2a** away from each other.

[0045] The diagram shown in Figure 3 illustrates by way of example the movement of the solidified layer **6a** along the movement direction **Z** according to the time **T.** During an initial part of the above mentioned separation movement **11,** the solidified layer **6a** remains adherent to the bottom **2a** owing to the resistance to detachment described above.

[0046] During the above mentioned initial part of the movement **11,** the solidified layer **6a** and the bottom **2a** are subjected to mutual traction stress that causes a certain elastic deformation of the same.

[0047] The complete separation of the solidified layer **6a** from the bottom **2a** takes place exclusively at the level of the final position **20** of the above mentioned initial part of the movement **11,** when the solidified layer **6a** and the bottom **2a** return to the respective non deformed positions.

[0048] In particular, according to the method of the invention the above mentioned separation movement **11** comprises a plurality of separation shifts **12, 12a, 12b, 12c** having respective predefined lengths **13, 13a, 13b, 13c.**

[0049] The above mentioned separation shifts **12,12a, 12b, 12c** are interrupted by intermediate stops **14, 14a,**

14b lasting corresponding predefined time intervals **15, 15a, 15b,** which occur before the solidified layer **6a** has been completely separated from the bottom **2a** of the container **2.**

[0050] Advantageously, during each intermediate stop, the combined effect of the traction and elastic deformation of the solidified layer **6a** and of the bottom **2a** cause them to partially separate at the level of the perimeter of the solidified layer **6a,** thus allowing the penetration of the liquid substance **3** between the solidified layer **6a** and the bottom **2a.**

[0051] The above mentioned penetration reduces the surface area of the solidified layer **6a** that adheres to the bottom **2a,** in such a way as to reduce the traction stress during the successive separation shift **12, 12a, 12b, 12c.**

[0052] Therefore, the above mentioned intermediate stops **14, 14a, 14b** have the effect of limiting the traction stress on the solidified layer **6a** and on the bottom **2a** of the container **2** to lower values than those that would result if the separation movement **11** were a continuous movement, thus achieving one of the objects of the invention.

[0053] Furthermore, to advantage, the intermittent separation movement **11** ensures more gradual penetration of the liquid substance **3** between the solidified layer **6a** and the bottom **2a,** avoiding the sudden detachment movements that are typical of the stereolithography machines of known type and that may cause the object being formed to break.

[0054] Still advantageously, the stop intervals **15, 15a, 15b** allow the inner stress to be redistributed in the solidified layer **6a** and in the bottom **2a** of the container 2, further limiting the harmful effects of said stress.

[0055] Consequently, to advantage, the method of the invention makes it possible to reduce the number of production rejects compared to that obtained with the known methods.

[0056] Furthermore, to advantage, the reduced stress obtained with the method of the invention makes it possible to produce objects having larger cross section than those obtainable with the known methods using an equivalent stereolithography machine.

[0057] Analogously, the fatigue stress on the bottom **2a** of the container **2** is reduced, advantageously increasing the duration of the latter.

[0058] The intermediate stops **14, 14a, 14b** and the consequent penetration of the liquid substance **3** bring the further advantage of accelerating the separation of the solidified layer **6a** from the bottom **2a,** making it possible to achieve the object of reducing the predefined extent of the separation movement **11.**

[0059] It should be observed that all the above mentioned advantages are obtained thanks to the intermediate stops **14, 14a, 14b,** with no need to modify the speed of the actuator means **8.**

[0060] Therefore, the method of the invention can be used in a stereolithography machine of known type with a simple modification of the software of the logic control unit **9,** with no need to make mechanical modifications or to add complex systems for adjusting the speed of the actuator means **8,** thus achieving a further object of the invention.

[0061] Preferably, each intermediate stop **14, 14a, 14b** takes place when the solidified layer **6a** is still at least partially immersed in the liquid substance **3.**

[0062] Advantageously, this makes it possible to use the pressure of the liquid substance **3** to force it to penetrate between the solidified layer **6a** and the bottom **2a,** thus accelerating the separation process.

[0063] Preferably, the predefined extent of the separation movement **11** is such that the solidified layer **6a** never emerges completely from the liquid substance **3.**

[0064] This advantageously makes it possible to avoid the formation of air bubbles between the solidified layer **6a** and the liquid substance **3,** which may affect the correct solidification of the successive layer.

[0065] Obviously, the number of the separation shifts **12, 12a, 12b, 12c** and of the intermediate stops **14, 14a, 14b,** as well as the corresponding predefined lengths **13, 13a, 13b, 13c** and the time intervals **15, 15a, 15b** can be defined in any way.

[0066] For example, the predefined lengths **13, 13a, 13b, 13c** can be such that their sum, corresponding to the extent of the separation movement **11,** exceeds the thickness of the successive layer of the object.

[0067] After the separation movement **11** and before irradiating the successive layer, an approach movement **19** is performed in order to bring the solidified layer **6a** to a position **17** such that the distance from the bottom **2a** is equal to the thickness of the successive layer to be solidified, as indicated in Figure 3.

[0068] Preferably but not necessarily, between the separation movement **11** and the approach movement **19** there is a pause **18,** intended to allow the liquid substance **3** to flow back between the solidified layer **6a** and the bottom **2a,** so as to obtain the complete restoration of the liquid layer.

[0069] Preferably, the number of the separation shifts **12, 12a, 12b, 12c** and of the intermediate stops **14, 14a, 14b,** as well as the corresponding predefined lengths 13, **13a, 13b, 13c** and the time intervals **15, 15a, 15b** are such that the part of the separation movement **11** necessary to obtain the complete separation of the solidified layer **6a** from the bottom **2a** does not exceed the thickness of the successive layer of the object.

[0070] Advantageously, this makes it possible to avoid said approach movement **19** and thus reduces the extent of the overall movement of the solidified layer **6a.**

[0071] In fact, as in this case the solidified layer **6a** comes off before reaching the position **17** corresponding to the successive layer, the solidified layer **6a** can be arranged in the above mentioned position **17** through the last separation shift **12c,** as shown in Figure 4. With the other conditions remaining the same, the predefined extent of the separation movement **11** can be reduced, for example, by means of longer time intervals **15, 15a, 15b**

and/or more intermediate stops **14, 14a, 14b.**

[0072] Preferably, the determination of the value of one or more parameters selected among the lengths of the separation shifts **12, 12a, 12b, 12c,** the number of the intermediate stops **14, 14a, 14b** and the corresponding time intervals **15, 15a, 15b** takes place before starting the separation movement **11.**

[0073] In this way, the above mentioned selected parameters are independent of any feedback actions of the actuator means **8,** avoiding possible delays in the intermediate stops, to the advantage of the precision and reliability of the method.

[0074] Preferably but not necessarily the values of the above mentioned selected parameters are calculated according to the surface area of the layer **6a** to be solidified.

[0075] Advantageously, the above mentioned calculation makes it possible to optimize the separation movement **11** for each layer, so as to minimize the extent of the separation movement **11** and consequently its duration.

[0076] In particular, according to the method a curve should be defined to express each one of the above mentioned selected parameters as a function of the surface area of the layer.

[0077] The above mentioned predefined curve can be stored in the logic control unit **9** of the stereolithography machine **1,** in such a way as to simplify the above mentioned calculation.

[0078] Preferably, the values of the selected parameters are calculated as a function of the ratio between the above mentioned surface area of the layer **6a** to be solidified and its perimeter, representing the shape of the layer itself.

[0079] This, advantageously, makes it possible to include in the calculation the relationship existing between the penetration speed of the liquid substance **3** between the solidified layer **6a** and the bottom **2a** and the perimeter of the solidified layer **6a,** given the same surface area.

[0080] In particular, among all the possible shapes having the same surface area, a circular layer has the minimum perimeter, and so gives the liquid substance 3 fewer chances to penetrate between the solidified layer **6a** and the bottom **2a,** thus making the detachment process slower.

[0081] Vice versa, a layer featuring a longer perimeter compared to a circular layer having the same surface area gives the liquid substance **3** more chances to penetrate and thus favours the detachment process more than the previous circular layer.

[0082] Consequently, the number of intermediate stops **14, 14a, 14b** and/or the corresponding time intervals **15, 15a, 15b** can be reduced as the shape of the layer deviates from the circular shape, while the opposite situation occurs for the lengths of the separation shifts **12, 12a, 12b, 12c.**

[0083] A possible formula for the above mentioned shape ratio is the following:

$$\mathbf{R} = 4\,\pi\,\mathbf{A} / \mathbf{P}^2$$

where R stands for the shape ratio, A for the surface area of the layer and P for its perimeter.

[0084] It is evident that the above mentioned shape ratio assumes a maximum value equal to 1 when the layer has a circular shape and progressively decreases towards 0 (zero) as the layer becomes more flattened.

[0085] According to a variantembodimentofthe invention, the calculation of the above mentioned selected parameters can be made taking in consideration a further shape parameter having a simplified formula compared to the previous one.

[0086] Preferably, the calculation of the above mentioned parameter requires that the surface area of the layer **6a** to be solidified be divided into a plurality of cells having predefined dimensions, each one of which is assigned a weight that is proportional to the number of cells adjacent to it.

[0087] The weights of the cells are summed together in order to obtain the above mentioned shape parameter, which is used to calculate the values of the selected parameters in replacement of said shape ratio.

[0088] Obviously, the calculation of the selected parameters can be carried out even combining the above mentioned methods, that is, using the surface area, the shape ratio and/or the shape parameter in combination with each other.

[0089] Preferably, if the solidified layer **6a** is made up of several separated portions, in the calculation of the selected parameters only the surface areas, the shape ratios and/or the shape parameters are considered that correspond to the portions whose surface area has a predefined value, or only to the portion having the largest surface area.

[0090] Advantageously, this makes it possible to minimize the separation time of the solidified layer **6a** and/or the extent of the corresponding movement, without increasing the risk of breaking the object being formed.

[0091] In fact, it should be considered that each one of said portions becomes detached from the bottom **2a** in a manner that is essentially independent of the other portions, and that, therefore, it will be possible to define the selected parameters only according to the portions for which detachment is more critical, meaning the portions, or portion, with larger surface area.

[0092] It is also evident that in further variants of the method of the invention the lengths of the separation shifts **12, 12a, 12b, 12c,** the number of the intermediate stops **14, 14a, 14b** and/or the corresponding time intervals **15, 15a, 15b** can be determined once and for all before starting the construction of the model and be maintained unchanged for all of the layers.

[0093] In any case, preferably but not necessarily the lengths of the separation shifts **12, 12a, 12b, 12c** are defined so as to be the same, for the sake of calculation simplicity.

[0094] Furthermore, the value of the above mentioned selected parameters can be defined according to other parameters in addition to those described above, for example the viscosity and density of the liquid substance **3, the** movement speed of the actuator means **8,** the maximum depth of the liquid substance **3** present in the container **2,** the mechanical resistance of the bottom **2a** and of the solidified layers **6a,** etc.

[0095] For a stereolithography machine **1** of the known type, a number of intermediate stops included between one and twenty, a length of each separation shift **12, 12a, 12b, 12c** included between 5 and 200 microns and a duration of the time intervals **15, 15a, 15b** included between 0.01 seconds and 1 second can be suitable for most applications.

[0096] According to an example of application of the method described above, a numerical representation of each layer of the object to be produced is processed and supplied to the logic control unit **9,** which controls the actuator means **8** and the emitting means **5** so as to arrange the modelling plate **7** at a suitable distance from the bottom **2a** of the container **2** and, successively, form each solidified layer **6a** according to the description provided above.

[0097] Successively, the logic control unit **9** determines the number of intermediate stops **14, 14a, 14b,** their duration **15, 15a, 15b,** as well as the predefined lengths **13, 13a, 13b, 13c** of the separation shifts **12, 12a, 12b, 12c** consequently activates the actuator means **8.**

[0098] During the separation movement, once having reached the point **20,** the solidified layer **6a** comes off the bottom **2a.**

[0099] The separation movement **11** is completed and if necessary a successive approach movement **19** is carried out, so as to arrange the modelling plate **7** in a suitable position for the solidification of the successive layer.

[0100] The above shows that the method for producing a three-dimensional object of the invention described above achieves all the set objects.

[0101] In particular, the intermittent separation movement makes it possible to reduce the mutual traction stress on the solidified layer and on the bottom of the container before detachment.

[0102] Furthermore, the progressive penetration of the liquid substance between the solidified layer and the bottom of the container makes it possible to reduce the extent of the movement of the solidified layer necessary to cause it to come off the bottom of the container.

[0103] Furthermore, the method of the invention is based on an intermittent movement that is easy to apply to stereolithography machines of known type through simple modifications of their software.

[0104] Upon implementation, the method that is the subject of the invention may be subjected to further changes that, even though not described herein and not illustrated in the drawings, must all be considered protected by the present patent, provided that they fall within the scope of the following claims.

[0105] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly such reference signs do not have any limiting effect on the protection of each element identified by way of example by such reference signs.

Claims

1. Method for producing a three-dimensional object in layers by means of a stereolithography machine (1) of the type comprising:

- a container (2) for containing a liquid substance (3) suited to be solidified through exposure to predefined radiation (4);
- means (5) for emitting said predefined radiation (4), suited to selectively irradiate a layer (6) of said liquid substance (3) having a predefined thickness and arranged adjacent to the bottom (2a) of said container (2) in order to solidify said layer (6);
- actuator means (8) suited to move said solidified layer (6a) with respect to said bottom (2a) at least according to a direction (Z) perpendicular to said bottom (2a);

said method comprising the following operations:

- selectively irradiating said layer (6) of liquid substance in such a way as to obtain said solidified layer (6a);
- separating said solidified layer (6a) from said bottom (2a) through a mutual separation movement (11) having a predefined extent,

characterized in that said separation movement (11) comprises a plurality of separation shifts (12, 12a, 12b, 12c) of corresponding predefined lengths (13, 13a, 13b, 13c), spaced by corresponding intermediate stops (14, 14a, 14b) of corresponding predefined time intervals (15, 15a, 15b), said intermediate stops (14, 14a, 14b) being carried out before said solidified layer (6a) has become completely detached from said bottom (2a),
and further **characterized in that** the number of said intermediate stops (14, 14a, 14b) is included between 1 and 20, said predefined length of each of said separation shifts (12, 12a, 12b, 12c) is included between 5 and 200 microns, and the duration of said time intervals (15, 15a, 15b) is included between 0.01 seconds and 1 second.

2. Method according to claim 1), **characterized in that** each one of said intermediate stops (14, 14a, 14b) takes place when said solidified layer (6a) is at least partially immersed in said liquid substance (3).

3. Method according to claim 1) or 2), **characterized in that** said lengths (13, 13a, 13b, 13c) of said separation shifts (12, 12a, 12b, 12c), the number of said intermediate stops (14, 14a, 14b) and the duration of said time intervals (15, 15a, 15b) are defined so that the predefined extent of said separation movement (11) necessary to obtain said complete separation of said solidified layer (6a) from said bottom (2a) does not exceed the thickness of the successive layer of said object.

4. Method according to any of the preceding claims, **characterized in that** the determination of the value of at least one parameter selected among the lengths (13, 13a, 13b, 13c) of said separation shifts (12, 12a, 12b, 12c), the numberof intermediate stops (14, 14a, 14b) and the corresponding time intervals (15, 15a, 15b) takes place before starting said separation movement (11).

5. Method according to claim 4), **characterized in that** the values of said selected parameters (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) are calculated as a function of the surface area of the layer to be solidified (6a).

6. Method according to claim 5), **characterized in that** the values of said selected parameters (13,13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) are calculated as a function of the ratio between said surface area and the perimeter of said layer to be solidified (6a).

7. Method according to claim 5) or 6), **characterized in that** said calculation of said selected parameters (13, 13a, 13b, 13c, 14, 14a, 14b, 15,15a, 15b) comprises the following operations:

- dividing the surface area of said layer to be solidified (6a) into a plurality of cells;
- assigning each cell a weight proportional to the number of cells adjacent to said cell;
- summing up said weights in order to obtain a shape parameter;
- calculating the values of said selected parameters (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) according to said shape parameter.

8. Method according to any of the preceding claims, **characterized in that** said lengths (13, 13a, 13b, 13c) of said separation shifts (12, 12a, 12b, 12c) are equal to each other.

9. Method according to any of the preceding claims, **characterized in that** said actuator means (8) comprise a modelling plate (7) provided with a supporting surface (7a) for said solidified layer (6a) facing the bottom (2a) of said container (2).

Patentansprüche

1. Methode zur Herstellung eines dreidimensionalen Objekts in Schichten mittels einer Stereolithographiemaschine (1) des Typs, der Folgendes umfasst:

- einen Behälter (2) zur Aufnahme einer flüssigen Substanz (3), die geeignet ist, unter Einwirkung einer vorbestimmten Strahlung (4) verfestigt zu werden;
- Mittel (5) zur Abgabe der besagten, vorbestimmten Strahlung (4), dazu geeignet, eine Schicht (6) der besagten, flüssigen Substanz (3) von vorbestimmter Dicke, die an dem Boden (2a) des besagten Behälters (2) anliegend angeordnet ist, selektiv zu bestrahlen, um die besagte Schicht (6) zu verfestigen;
- Antriebsmittel (8), dazu geeignet, die besagte, verfestigte Schicht (6a) bezüglich des besagten Bodens (2a) wenigstens gemäß einer lotrecht zu besagtem Boden (2a) liegenden Richtung (Z) zu bewegen;

wobei die besagte Methode folgende Vorgänge umfasst:

- selektive Bestrahlung der besagten Schicht (6) einer flüssigen Substanz derart, dass die besagte, verfestigte Schicht (6a) erzielt wird;
- Trennung der besagten, verfestigten Schicht (6a) von besagtem Boden (2a) durch eine wechselseitige Trennbewegung (11) von vorbestimmtem Ausmaß,

dadurch gekennzeichnet, dass die besagte Trennbewegung (11) eine Vielzahl Trennverschiebungen (12, 12a, 12b, 12c) mit jeweils vorbestimmten Längen (13, 13a, 13b, 13c) umfasst, die durch entsprechende Zwischenhalte (14, 14a, 14b) entsprechender, vorbestimmter Zeitintervalle (15, 15a, 15b) distanziert sind, wobei die besagten Zwischenhalte (14, 14a, 14b) ausgeführt werden, bevor die besagte, verfestigte Schicht (6a) vollständig von besagtem Boden (2a) gelöst wird,
und weiter **dadurch gekennzeichnet, dass** die Anzahl der besagten Zwischenhalte (14, 14a, 14b) zwischen 1 und 20 liegt, wobei die besagte vorbestimmte Länge jeder der besagten Trennverschiebungen (12, 12a, 12b, 12c) zwischen 5 und 200 Mikron liegt, und die Dauer der besagten Zeitintervalle (15, 15a, 15b) zwischen 0,01 und 1 Sekunde liegt.

2. Methode gemäß Patentanspruch 1), **dadurch gekennzeichnet, dass** jeder der besagten Zwischenhalte (14, 14a, 14b) stattfindet, wenn die besagte, verfestigte Schicht (6a) wenigstens teilweise in die besagte, flüssige Substanz (3) eingetaucht ist.

3. Methode gemäß Patentanspruch 1) oder 2), **dadurch gekennzeichnet, dass** die besagten Längen (13, 13a, 13b, 13c) der besagten Trennverschiebungen (12, 12a, 12b, 12c), die Anzahl der besagten Zwischenhalte (14, 14a, 14b) und die Dauer der besagten Zeitintervalle (15, 15a, 15b) so definiert sind, dass das vorbestimmte Ausmaß der besagten, zur vollständigen Trennung der besagten, verfestigten Schicht (6a) von besagtem Boden (2a) erforderlichen Trennbewegung (11) die Dicke der nachfolgenden Schicht des besagten Objekts nicht überschreitet.

4. Methode gemäß eines jeden der vorstehenden Patentansprüche, **dadurch gekennzeichnet, dass** die Bestimmung des Werts von wenigstens einem unter den Längen (13, 13a, 13b, 13c) der besagten Trennverschiebungen (12, 12a, 12b, 12c), der Anzahl der besagten Zwischenhalte (14, 14a, 14b) und der entsprechenden Zeitintervalle (15, 15a, 15b) ausgewählten Parameter vor dem Beginn der besagten Trennbewegung (11) stattfindet.

5. Methode gemäß Patentanspruch 4), **dadurch gekennzeichnet, dass** die Werte der besagten, ausgewählten Parameter (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) als eine Funktion des Oberflächenbereichs der zu verfestigenden Schicht (6a) berechnet werden.

6. Methode gemäß Patentanspruch 5), **dadurch gekennzeichnet, dass** die Werte der besagten, ausgewählten Parameter (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) als eine Funktion des Verhältnisses zwischen dem besagten Oberflächenbereich und dem Umfang der besagten, zu verfestigenden Schicht (6a) berechnet werden.

7. Methode gemäß Patentanspruch 5) oder 6), **dadurch gekennzeichnet, dass** die Berechnung der besagten, ausgewählten Parameter (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) folgende Vorgänge umfasst:

- Teilung des Oberflächenbereichs der besagten, zu verfestigenden Schicht (6a) in eine Vielzahl von Zellen;
- Zuweisung zu jeder Zelle eines zur Anzahl der neben der besagten Zelle liegenden Zellen proportionalen Gewichts;
- Summierung der besagten Gewichte, um einen Formparameter zu erzielen;
- Berechnung der Werte der besagten, ausgewählten Parameter (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) gemäß des besagten Formparameters.

8. Methode gemäß eines jeden der vorstehenden Patentansprüche, **dadurch gekennzeichnet, dass** die besagten Längen (13, 13a, 13b, 13c) der besagten Trennverschiebungen (12, 12a, 12b, 12c) untereinander gleich sind.

9. Methode gemäß eines jeden der vorstehenden Patentansprüche, **dadurch gekennzeichnet, dass** die besagten Antriebsmittel (8) eine Modellplatte (7) mit einer Tragfläche (7a) für die besagte, verfestigte Schicht (6a) umfassen, welche zum Boden (2a) des besagten Behälters (2) ausgerichtet ist.

Revendications

1. Méthode pour la production en couches d'objets en trois dimensions au moyen d'une machine de stéréolitographie (1) du type comprenant:

- un récipient (2) apte à contenir une substance liquide (3) indiquée pour être solidifiée par l'exposition à une radiation prédéfinie (4);
- des moyens (5) pour l'émission de ladite radiation prédéfinie (4), indiqués pour irradier sélectivement une couche (6) de ladite substance liquide (3) ayant une épaisseur prédéfinie et disposée adjacente au fond (2a) dudit récipient (2) de façon à solidifier ladite couche (6);
- des moyens actionneurs (8) indiqués pour déplacer ladite couche solidifiée (6a) par rapport audit fond (2a) au moins selon une direction (Z) perpendiculaire audit fond (2a);

ladite méthode comprenant les opérations suivantes:

- irradiation sélective de ladite couche (6) de substance liquide de manière à obtenir ladite couche solidifiée (6a);
- séparation de ladite couche solidifiée (6a) dudit fond (2a) au moyen d'un mouvement de séparation réciproque (11) ayant une extension prédéfinie,

caractérisée en ce que ledit mouvement de séparation (11) comprend une pluralité de déplacements de séparation (12, 12a, 12b, 12c) de longueurs prédéfinies correspondantes (13, 13a, 13b, 13c), espacées par des arrêts intermédiaires correspondants (14, 14a, 14b) d'intervalles de temps prédéfinis correspondants (15, 15a, 15b), lesdits arrêts intermédiaires (14, 14a, 14b) étant réalisés avant que ladite couche solidifiée (6a) se soit complètement séparée dudit fond (2a), et en outre **caractérisée en ce que** le numéro desdits arrêts intermédiaires (14, 14a, 14b) est compris entre 1 et 20, ladite longueur prédéfinie de chacun desdits déplacements de séparation (12, 12a, 12b, 12c) est comprise entre 5 et 200 microns, et la durée desdits intervalles de temps (15, 15a, 15b) est comprise entre 0,01 secondes et 1 seconde.

2. Méthode selon la revendication 1), **caractérisée en ce que** chacun desdits arrêts intermédiaires (14, 14a, 14b) se vérifie quand ladite couche solidifiée (6a) est au moins partiellement immergée dans ladite substance liquide (3).

3. Méthode selon la revendication 1) ou 2), **caractérisée en ce que** lesdites longueurs (13, 13a, 13b, 13c) desdits déplacements de séparation (12, 12a, 12b, 12c), le nombre desdits arrêts intermédiaires (14, 14a, 14b) et la durée desdits intervalles de temps (15, 15a, 15b) sont définis de manière à ce que l'extension prédéfinie dudit mouvement de séparation (11) nécessaire pour obtenir ladite séparation complète de ladite couche solidifiée (6a) dudit fond (2a) ne dépasse pas l'épaisseur de la couche suivante dudit objet.

4. Méthode selon l'une quelconque des revendications précédentes, **caractérisée en ce que** la détermination de la valeur d'au moins un paramètre sélectionné parmi les longueurs (13, 13a, 13b, 13c) desdits déplacements de séparation (12, 12a, 12b, 12c), du nombre d'arrêts intermédiaires (14, 14a, 14b) et des intervalles de temps correspondants (15, 15a, 15b) se vérifie avant le début dudit mouvement de séparation (11).

5. Méthode selon la revendication 4), **caractérisée en ce que** les valeurs desdits paramètres sélectionnés (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) sont calculées en fonction de la surface de la couche à solidifier (6a).

6. Méthode selon la revendication 5), **caractérisée en ce que** les valeurs desdits paramètres sélectionnés (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) sont calculées en fonction du rapport entre ladite surface et le périmètre de ladite couche à solidifier (6a).

7. Méthode selon la revendication 5) ou 6), **caractérisée en ce que** ledit calcul desdits paramètres sélectionnés (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) comprend les opérations suivantes:

   - division de la surface de ladite couche à solidifier (6a) dans une pluralité de cellules;
   - assignation à chaque cellule d'un poids proportionnel au nombre de cellules adjacentes à ladite cellule;
   - somme desdits poids afin d'obtenir un paramètre de forme;
   - calcul des valeurs desdits paramètres sélectionnés (13, 13a, 13b, 13c, 14, 14a, 14b, 15, 15a, 15b) selon ledit paramètre de forme.

8. Méthode selon l'une quelconque des revendications précédentes, **caractérisée en ce que** lesdites longueurs (13, 13a, 13b, 13c) desdits déplacements de séparation (12, 12a, 12b, 12c) sont égales entre elles.

9. Méthode selon l'une quelconque des revendications précédentes, **caractérisée en ce que** lesdits moyens actionneurs (8) comprennent une plaque de modélisation (7) dotée d'une surface de support (7a) pour ladite couche solidifiée (6a) étant tournée vers le fond (2a) dudit récipient (2).

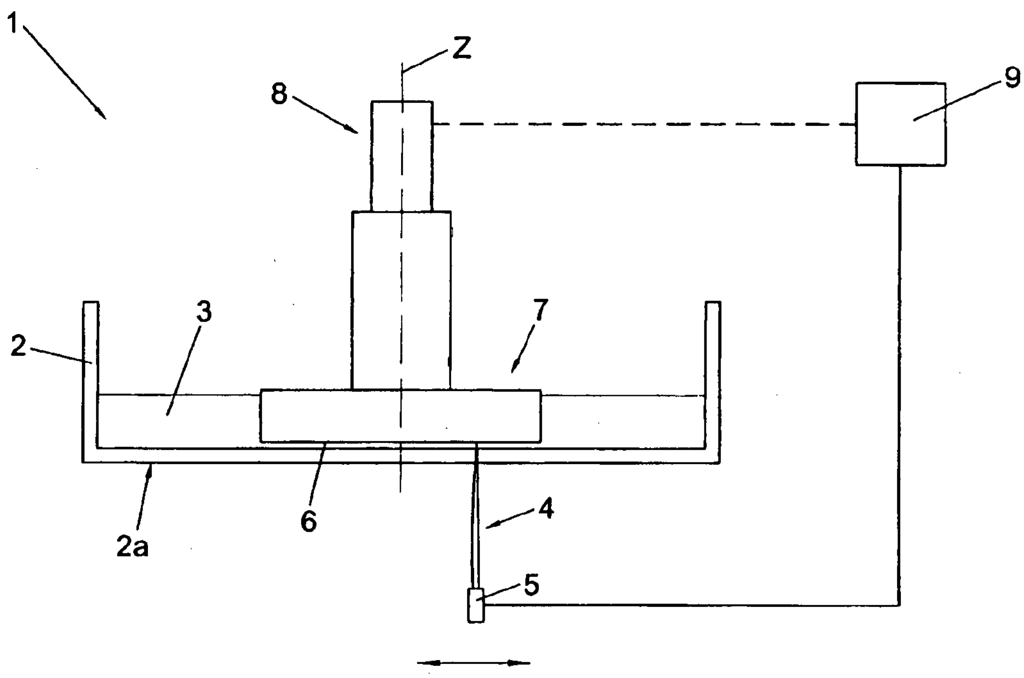

Fig.1

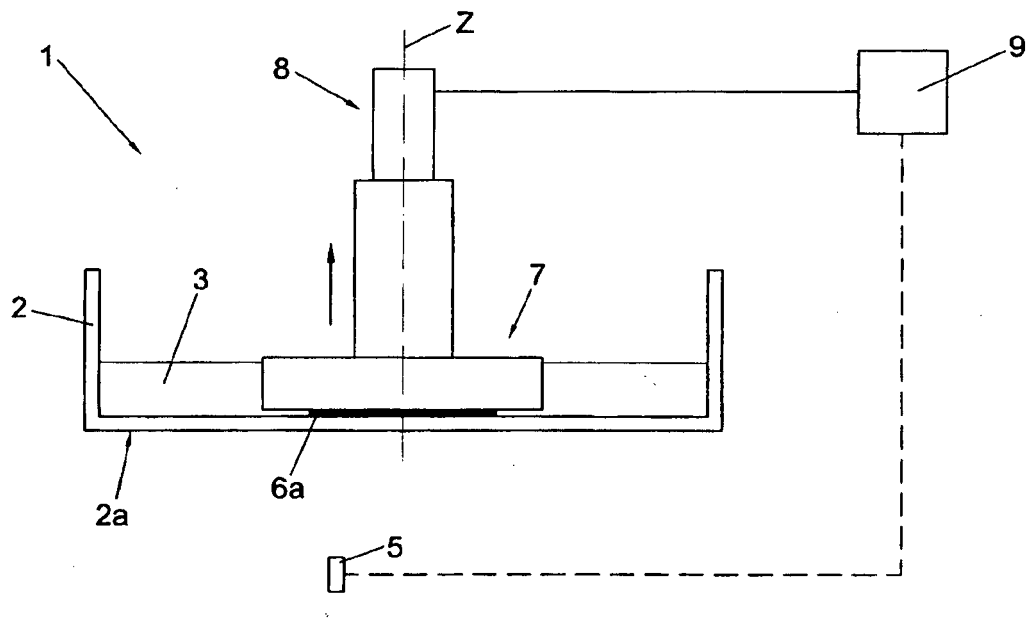

Fig.2

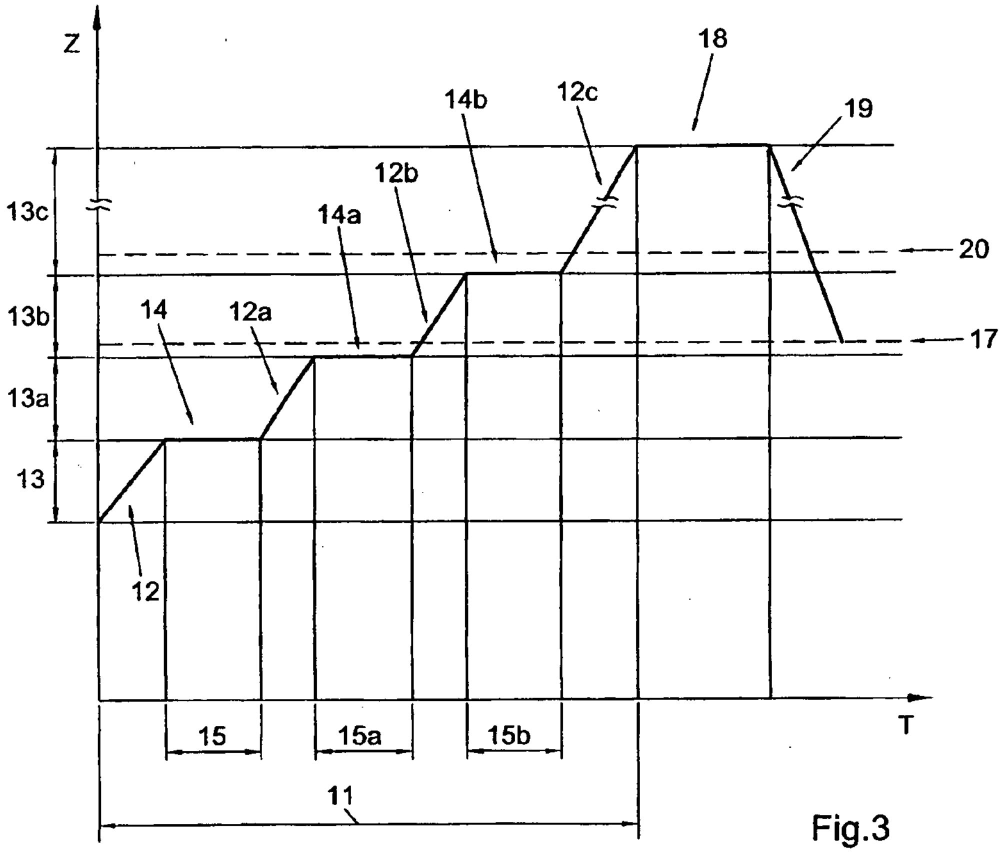
Z
18
14b
12c
19
12b
13c
14a
20
13b
14
12a
17
13a
13
12
T
15
15a
15b
11

Fig.3

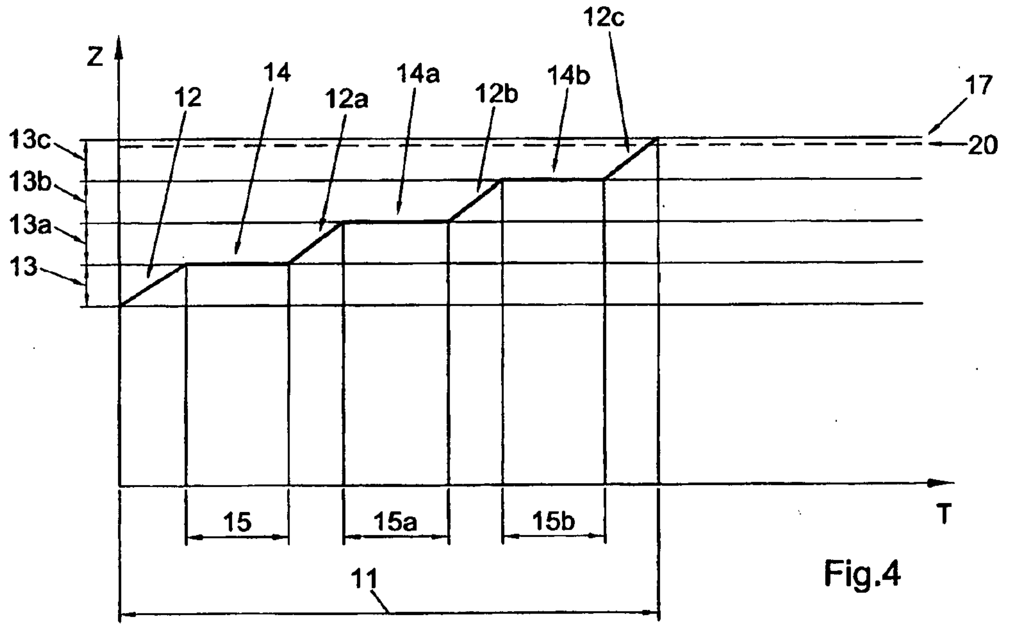
12c
Z
14
14a
14b
17
12
12a
12b
13c
20
13b
13a
13
T
15
15a
15b
11

Fig.4

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 20100262272 A **[0012]**