

Description

Method and arrangement for separating excess material from an additively manufactured component

Additive manufacturing is becoming increasingly more important in contemporary production processes. It allows the production of products with outlines and topologies of virtually arbitrary complexity with comparatively little outlay. In comparison with conventional manufacturing methods, only a few structural constraints have to be observed within the scope of additive manufacturing.

The so-called powder bed method, which finds use in the production of metallic components in particular, is a known type of additive manufacturing technology. In this context, the material for the component to be produced is provided layer-by-layer in the form of a powder bed, fluid bed, or material bed. For the purposes of producing the component, the individual particles of the material are then connected together layer by layer. In this case, the material can be a metal, a polymer powder, an inorganic material, or any other powdery or liquid material. The material particles can be connected by physical or chemical processes, sintering, adhesive bonding, fusing, freezing, or other connection methods. Known methods include laser melting and laser sintering, and the application of UV radiation for curing liquid materials.

The non-connected, that is to say excess material serves as a passive support structure during the manufacturing process such that, for example, overhanging geometries can be realized. A similar statement also applies to fluids or fluidizable materials, for example UV-beam curable monomers. After the manufacturing process has been completed, the non-connected material frequently completely or at least partially fills the

component and has to be removed from the cavities of the final component after the said component has been taken from the material bed.

Until now, the excess material has been removed manually or by machine-based rotating or shaking of the component. However, such a procedure can be very long-winded - especially if the component has cavities of complex geometry.

Document EP 3527304 A1 has disclosed a method in which emptying of the excess workpiece is simulated and optimized emptying is carried out on the basis thereof. However, a sufficiently accurate simulation of the emptying procedure requires a great amount of computational outlay.

It is an object of the present invention to create a method and an arrangement which allow efficient separation of excess material from an additively manufactured component.

This object is achieved by a method having the features of patent claim 1, by an arrangement having the features of patent claim 10, by a computer program product having the features of patent claim 11, and by a computer-readable storage medium having the features of patent claim 12.

To separate excess material from an additively manufactured component, spatially resolved structure data of the component are received. The structure data are used to divide a cavity in the component into grid cells by way of a virtual spatial grid, with a spatial alignment of the grid relative to the component being specified by an alignment specification. A discrete pattern of spatial orientations of the component is ascertained on the basis of the alignment specification. Furthermore, the grid cells of the cavity are filled with a virtual material in a simulation. The structure data are then used to simulate an

emptying procedure of the virtual material from the component for spatial orientations restricted to the discrete pattern, with a temporal sequence of orientations that are restricted to the discrete pattern being ascertained. The component then is successively rotated into the orientations of the temporal sequence on the basis of the simulated emptying procedure.

An arrangement for separating a material from an additively manufactured component, a computer program product, and a computer-readable, preferably non-volatile storage medium are provided to carry out the method according to the invention.

By way of example, the method according to the invention and the arrangement according to the invention can be respectively carried out and implemented by means of one or more computers, processors, application-specific integrated circuits (ASICs), digital signal processors (DSPs), and/or what are known as "field programmable gate arrays" (FPGAs).

An advantage of the invention can be seen in the fact that, in particular, a computational outlay required for the simulation can generally be significantly reduced as a result of the restriction to a discrete pattern of spatial orientations. To the extent that the real movement of the component is also restricted to the discrete pattern, the simulation results are also sufficiently accurate in most cases. Moreover, as a result of simulating the emptying procedure and a movement of the component into advantageous emptying poses based thereon, the excess material can generally be very effectively separated from the component.

Advantageous embodiments and developments of the invention are specified in the dependent claims.

According to an advantageous embodiment of the invention, a respective movement step of the simulation can be restricted to discrete movements of the virtual material from a respective grid cell to an adjacent grid cell. In the process, the discrete movements of the virtual material can be simulated by movements of virtual material particles from a respective grid cell to a respectively adjacent grid cell. In particular, movements within a grid cell and/or continuous movements of the virtual material can be excluded.

Accordingly, a movement direction of the virtual material in the simulation can be restricted to directions leading from a respective grid cell to an adjacent grid cell.

In particular, the simulation can be carried out by means of a grid-based three-dimensional cellular automaton.

As a rule, the restriction to discrete movements from grid cell to grid cell, the restriction to discrete movement directions, and/or the use of a cellular automaton simplifies the simulation significantly and usually leads to a significant reduction in computational outlay required. It is actually found that a computational outlay can be reduced by at least one order of magnitude in many cases.

According to a further advantageous embodiment of the invention, directions leading from a grid cell to adjacent grid cells can be included in the discrete pattern of spatial orientations. For these directions, material movements can in many cases already be simulated sufficiently accurately and with little computational outlay by way of simple simulation models.

Preferably, the discrete pattern can be formed by spatial orientations whose angular values are substantially discretized in 45° steps.

Furthermore, a grid cell which is filled with more virtual material than an adjacent grid cell can be ascertained. Hence, a direction leading from the ascertained grid cell to the adjacent grid cell can be included in the temporal sequence of the orientations.

According to an advantageous development of the invention, a respective material movement can be detected by one or more sensors for a respective orientation of the ascertained temporal sequence. A trigger signal can then be generated as a result of detecting an abating of the material movement, the trigger signal causing a rotation of the component into a subsequent orientation of the temporal sequence. In particular, the trigger signal can in this context be considered predominantly prior to the simulated emptying procedure. As a result of the predominantly triggered rotation into the subsequent orientation, it is possible to avoid delays that are based on an overestimation of the emptying duration as a result of the simulation.

An exemplary embodiment of the invention is described in more detail below on the basis of the drawing. In this case, in a respective schematic illustration:

Figure 1 shows an arrangement according to the invention,

Figure 2 shows a simulation of an emptying procedure,

Figure 3 shows a discrete pattern of directions leading into adjacent grid cells, and

Figure 4 shows a flowchart of a method according to the invention.

To the extent that the same or corresponding reference signs are used in the figures, these denote the same or corresponding entities which are preferably implemented or realized as described in the context of the relevant figures.

Figure 1 shows a schematic illustration of an arrangement A according to the invention for separating excess material WS from an additively manufactured component BT, that is to say a component produced by means of an additive manufacturing method. The component BT is preferably manufactured by a 3-D printer using the powder bed method, within the scope of which, as presented at the outset, individual particles of a powdery or fluid material are interconnected layer by layer. The material WS that is not connected during the additive manufacture and hence is excess should be removed accordingly. Figure 1 shows the component BT following the completion of the layer-by-layer manufacturing process, but still before the excess, non-connected material WS has been removed.

The arrangement A comprises a vibration apparatus SV, a positioning apparatus PV, a controller CTL, and a sensor system S.

The component BT is mechanically coupled to the vibration apparatus SV, which in turn is mechanically coupled to the positioning apparatus PV. The positioning apparatus PV, which is preferably in the form of a robotic arm, serves to put the component BT into different poses. A pose denotes a spatial situation of the component and comprises its position and spatial orientation or alignment. Thus, the component can be moved or rotated into different positions and spatial orientations by way of the positioning apparatus PV. According to the invention, the spatial orientations into which the component BT is brought by the positioning apparatus PV are restricted in this context to a discrete pattern of a few

directions. Advantageously, the discrete direction pattern is formed by spatial orientations whose angular values are substantially discretized in 45° steps.

The vibration apparatus SV serves to put the component BT into mechanical vibrations. Amplitude, frequency, and/or vibration direction of the mechanical vibrations are preferably variable in this context. Together with the vibration apparatus SV, the positioning apparatus PV can rotate the component BT about one or more axes of rotation and can displace the said component translationally. Preferably, the component BT can be taken from a 3-D manufacturing environment, for example a 3-D printer, by way of a positioning apparatus PV in the form of a robotic arm and can be fastened to the vibration apparatus SV. The positioning apparatus PV and the vibration apparatus SV are part of a movement apparatus BV for moving the component BT.

The sensor system S, the positioning apparatus PV, the vibration apparatus SV, and the movement apparatus BV are coupled to the controller CTL. The controller CTL serves to control the movement apparatus BV, that is to say control the positioning and alignment of the component BT by the positioning apparatus PV and to control the vibrations to be brought about by the vibration apparatus SV.

In particular, the movement apparatus BV is controlled so that the component BT is successively rotated into various discretized spatial orientations, in which the excess material WS is emptied as quickly and/or as completely as possible. Ideally, the time required cumulatively for emptying the excess material WS, that is to say for vacating the component, should be minimized in the process.

This minimization is implemented on the basis of a simulation of one or more emptying procedures. In the process, the time

required for emptying is ascertained by simulation for different emptying poses, that is to say in particular for discretized spatial orientations of the component BT. The cumulative time required is then minimized by means of an optimization method. In the process, a temporal sequence of emptying poses which leads to the shortest possible emptying time is ascertained in a targeted manner. A multiplicity of standard optimization methods are available for such optimizations.

The simulation is carried out on the basis of a volumetric model CAD of the component BT by means of a three-dimensional cellular automaton ZA of the controller CTL. In this case, the volumetric model CAD is represented by spatially resolved structure data of the component BT, which are transmitted to the controller CTL. On the basis of this simulation, the controller CTL ascertains suitable movement data BD for driving the positioning apparatus PV and the vibration apparatus SV or for driving the movement apparatus BV. Spatial orientations and positions to be adopted by the component BT and frequency, amplitude, and/or vibration directions of vibrations are quantified by the movement data BD. A respective emptying pose of the component BT can preferably be specified by a position specification which quantifies a position of the component BT together with discretized angular specifications which quantify a spatial orientation of the component BT. In particular, Euler angles can be used as angular specifications.

The movement apparatus BV receives the movement data BD from the controller CTL and is controlled by the movement data BD. In this way, the positioning apparatus PV is prompted to move the component BT into an emptying pose, in which the excess material WS is emptied as quickly and as effectively as possible. Moreover, the vibration apparatus SV is prompted to put the component BT into mechanical vibrations, in such a way that the emptying procedure is accelerated where possible. As it were,

the material WS is shaken out of the component BT to a certain extent.

Material WS falling or emptied out of the component BT during the emptying procedure is detected by the sensor system S. In particular, the sensor system S serves to detect a movement of the material WS caused by the emptying procedure and, specifically, an abating of this movement. The sensor system S may have different sensors for this purpose. In particular, it is possible to provide scales W, by means of which the material WS emptied from the component BT is weighed continuously. In place of or in addition to the scales W, any other rate sensor may also be provided to sense the emptied material WS. Further, an optical sensor OS, for example a camera or a photoelectric barrier, can be used to detect the emptied material WS, preferably in conjunction with a laser L for illuminating the emptied material WS. Further, the noise of the material WS falling from the component BT or the noise of the material WS moving within the component BT can be detected by means of an acoustic sensor AS. Moreover, movements of the material WS within the component BT can be detected by means of a motion sensor BS, for example by means of a laser interferometer or by means of what is known as a MEMS (micro-electromechanical system).

As soon as a lack of noticeable material movement is determined by means of the sensor system S, it is possible, as a rule, to assume that the movements of the material WS within the interior of the component BT have also decayed. As soon as this state occurs, the emptying of the component and also possible tipping procedures in the interior of the component BT stop for the current pose. Inasmuch as many simulations overestimate the duration of emptying procedures, it is found to be very advantageous to bring the component into the next emptying pose immediately after the detection of the material movement

abating, without waiting for the elapse of a period of time ascertained by the simulation.

Accordingly, a trigger signal TR is generated by the sensor system S as a consequence of the detection of the material movement abating, and the said trigger signal is transmitted to the controller CTL. In particular, the trigger signal TR can then be generated as soon as a weight of the emptied material WS, as measured by the scales W, remains at least approximately stationary, that is to say no longer changes or no longer changes substantially. In the case of the other sensors OS, AS, and BS, the trigger signal TR can be generated as soon as a detection result drops below a specified threshold value.

As a consequence of receiving the trigger signal TR, the movement apparatus BV is prompted by the controller CTL to move the component BT into the next emptying pose.

Figure 2 elucidates a simulation of a procedure for emptying excess material WS from the component BT.

To simulate the emptying procedure, method steps S1 to S7 are preferably carried out by the controller CTL.

In method step S1, a volumetric model CAD of the component BT in the form of spatially resolved structure data of the component BT is read by the controller CTL. The volumetric model CAD can be available, in particular, as what is known as a CAD (computer-aided design) model. A cavity H in the component BT which is filled with excess material WS following the additive manufacture of the component BT and which should be emptied through an opening E in the component BT is determined on the basis of the volumetric model CAD.

To simulate the emptying procedure, the component BT and, in particular, its cavity H are divided into a multiplicity of grid cells GZ by way of a virtual spatial, that is to say three-dimensional grid G on the basis of the structure data CAD. For reasons of clarity, only a few of these grid cells GZ have been provided with a reference sign in figure 2.

In the present exemplary embodiment, the grid G is spanned by orthogonal basis vectors such that the grid cells GZ are cuboid or die-shaped. As an alternative or in addition, a tetrahedron or a hexahedron grid G may also be provided. The alignment of the grid G, as defined by the basis vectors, vis-à-vis the component G is specified by an alignment specification RA, preferably in relation to a body-fixed coordinate system of the component BT. In particular, the alignment specification RA may comprise one or more of the basis vectors in the process.

A discrete pattern R of spatial orientations of the component BT is ascertained on the basis of the alignment specification RA. The discrete pattern R is elucidated by figure 3. In the present exemplary embodiment, the discrete pattern R orients itself with respect to the preferred directions of the simulation specified by the grid G. Naturally, when specifying a grid G that discretizes the component BT, the respective material movements in the component BT which lead from one grid cell GZ to an adjacent grid cell BGZ can be simulated particularly well and/or particularly easily. By contrast, movements in other directions would have to be approximated in cell-overarching fashion or treated by a finer simulation of material movements within a grid cell. However, this would significantly increase the computational outlay required.

Consequently, the discrete pattern R is formed precisely by the directions leading from a grid cell GZ to an adjacent grid cell BGZ or is restricted to these directions. In the case of a two-

dimensional grid, a respective (interior) grid cell GZ is surrounded by eight adjacent grid cells BGZ. In such a case, the pattern R would consist of those discrete directions that are inclined in 45° steps vis-à-vis the basis vectors of the two-dimensional grid. In the real three-dimensional case, a respective (interior) grid cell GZ is surrounded by 26 adjacent grid cells BGZ. To the extent that a direction of the three-dimensional grid G can be specified by two angular values, the discrete pattern R in the three-dimensional case can be formed by those 26 directions whose angular values are respectively inclined in 45° steps vis-à-vis grid planes spanned by two basis vectors of the grid G in each case.

In the further method step S2 depicted in figure 2, a respective path length of a path extending in the cavity H to the opening E is determined for a respective grid cell GZ on the basis of the volumetric model CAD. The respective path lengths are depicted with hatching in the upper right-hand part of figure 2, with darker regions being arranged closer to the opening E than brighter regions. Advantageously, the path lengths can be ascertained with the aid of what is known as a fast-marching method, by means of which a shortest path from a grid cell to the opening E is ascertained for each respective grid cell GZ.

Furthermore, a respective local emptying direction, which leads from a grid cell GZ to that adjacent grid cell BGZ which has the shortest local path length to the opening E, is selected or ascertained for a respective grid cell GZ from the discrete pattern R. The respectively ascertained emptying direction and the respectively ascertained shortest local path length are assigned to the respective grid cell GZ.

In method step S3, the cavity H is fully or partially filled with virtual material particles VWP on the basis of the volumetric model CAD in a simulation. In this case, a virtual

material particle VWP can represent a multiplicity of real material particles in a simulation. When using other simulations, filling with the virtual material can be realized accordingly differently.

Furthermore, a counter K for a temporal sequence of emptying poses $AP(K)$ to be ascertained is initialized as $K=1$. As already explained above, such an emptying pose $AP(K)$ in each case specifies a discretized spatial orientation and a position of the component BT.

In method step S4, an emptying pose $AP(K)$ that is advantageous for a current fill level of the component BT with virtual material particles VWP and a suitable vibration of the component BT are ascertained. The choice of the current emptying pose $AP(K)$ determines the emptying process, in which gravity is a driving force and is assisted by shaking the component BT. The choice of the emptying pose $AP(K)$ is based on an analysis of the current fill level of the component BT and the ascertained path lengths and local emptying directions. In this case, the emptying pose $AP(K)$ comprises an orientation and a position of the component BT in particular.

To ascertain advantageous emptying pose $AP(K)$, there is a search for a grid cell GZ, which is currently filled with more virtual material particles VWP than an adjacent grid cell BGZ and which is assigned a short path length, more particularly a shortest possible path length to the opening E. Optionally, a fill parameter can be ascertained for a respective grid cell GZ, in which an amount of virtual material particles VWP currently contained in the said cell is combined by calculation with the assigned path length, for example in the form of a weighted sum. Preferably, such a fill parameter is increased by a shorter path length and by a greater number of currently contained virtual material particles VWP, and otherwise it is reduced. In this

case, a grid cell having the highest fill parameter can be selected from the grid cells GZ.

Subsequently, a local tilt direction assigned to the found or selected grid cell is selected as global tilt direction. The selected tilt direction is used to define an emptying pose $AP(K)$, by means of which the component BT would be oriented in such a way that the global tilt direction points downward in the direction of gravity. To the extent that the local tilt directions are restricted to the discrete pattern R, this also applies to the orientation specified by the emptying pose $AP(K)$.

Furthermore, movement data that quantify the ascertained emptying pose $AP(K)$ are determined. Moreover, further movement data are ascertained, by means of which the component BT would be put into vibrations that accelerate the emptying procedure. The further movement data can specify amplitude, frequency, and vibration direction of these vibrations in particular. The ascertained movement data are combined in a data set $BD(K)$, which quantifies a specific movement for the component BT.

In method step S5, the procedure of emptying virtual material particles VWP from the opening E of the component BT that is specifically induced by this movement is physically simulated. The simulation is carried out by means of a three-dimensional cellular automaton ZA on the basis of the volumetric model CAD. Per movement step of the simulation, the cellular automaton only considers or simulates discrete movements of material particles VWP from a respective grid cell GZ into an adjacent grid cell BGZ. As a rule, a required computational outlay can be significantly reduced as a result of this simplification. Accordingly, the movement direction of the material particles VWP per movement step of the simulation is restricted to directions leading from a respective grid cell GZ to an adjacent

grid cell BGZ, that is to say restricted to the discrete pattern R.

Within the scope of the simulation, the component BT is virtually brought into the emptying pose AP(K) ascertained in method step S4 and made to vibrate. In particular, a distribution of the virtual material particles VWP in the component BT caused by movements is simulated in this case. As already mentioned above, the emptying procedure is driven by gravity and assisted by the vibrations.

As a result of the simulation of the specific movement of the component BT, that is to say the specific emptying procedure in the emptying pose AP(K), a temporal progression of a distribution of the virtual material particles VWP in the component BT resultant therefrom is ascertained. The current emptying pose AP(K) and the resultant progression of the distribution of the virtual material particles VWP are assigned to the respective movement of the component BT.

Whether the cavity H has been emptied virtually is checked in method step S6. To this end, a target value for the emptying may be specified, for example a residual degree of fill which, if undershot, means that the component BT is considered emptied or ready for use. To the extent that the cavity H has not been emptied, the counter K is increased by an increment and there is a jump back to method step S4, in which the next emptying pose AP(K+1) is ascertained. Otherwise, method step S7 is carried out.

The simulation results are documented and a control file based thereon is generated in method step S7. The control file contains a temporal sequence of the ascertained emptying poses AP(1), ..., AP(N), associated movement data BD(1), ..., BD(N) for controlling the movement apparatus BV, and further simulation results. In

the present exemplary embodiment, the control file contains, for a K-th simulated movement of the component BT, the associated emptying pose $AP(K)$, the movement data $BD(K)$ specifying the movement, and the progression of the distribution of the virtual material particles VWP in the component BT resulting from the movement.

Figure 4 shows a flowchart of a method according to the invention for separating excess material WS from the component BT.

In an initial method step S10, an emptying procedure as described in the context of figure 2 is simulated on the basis of the volumetric model CAD by method steps S1 to S7. As described above, the result of the simulation is generation of a control file which contains the temporal sequence of the ascertained emptying poses $AP(1)$, ..., $AP(N)$, the associated movement data $BD(1)$, ..., $BD(N)$ for driving the movement apparatus BV, and, for a respective emptying pose $AP(K)$, the resultant temporal progression of the distribution of the virtual material particles VWP in the component BT. The simulation can preferably be carried out in advance or offline.

The counter K for the emptying poses is initialized as $K = 1$ before a next method step S11 is carried out.

In method step S11, the movement apparatus BV is prompted on the basis of the movement data $BD(K)$ to move the component BT into the emptying pose $AP(K)$, which has been discretized in respect of its orientation, and to make the said component vibrate. In this case, the movement of the component BT or its temporal progression is oriented on the temporal progression of the simulated material distribution.

In a further method step S12, the material WS emptied from the component BT in the emptying pose $AP(K)$ is continuously detected

by the sensor system S - as explained in the context of figure 1. In the process, a movement of the emptied material WS is detected in particular.

In a method step S13 related thereto, a check is carried out as to whether the detected material movement is abating, that is to say is becoming significantly weaker or coming to a standstill. As soon as it is determined that there is no noticeable material movement left, a trigger signal TR is generated and transmitted to the controller CTL - as described in the context of figure 1. The trigger signal TR prompts the controller CTL to carry out an emptying test S14 and optionally jump back to method step S11. By contrast, if there is no detection of the material movement abating, there is a return to method step S12.

A check as to whether the component BT has already been emptied is carried out within the scope of the emptying test S14. In particular, this test can be implemented by virtue of a weight of the emptied material WS being compared to a weight of the material WS originally contained in the component BT. By way of example, the latter can be ascertained on the basis of the volumetric model CAD. Should the test yield that the component BT has been emptied, the separation according to the invention is successfully terminated, and reaches a target state ST.

By contrast, if the test yields that the component BT has not yet been emptied, the counter K is increased by an increment and there is a return to method step S11, within the scope of which the component BT is moved to the next emptying pose AP(K+1). Optionally, a predetermined time interval can be awaited before the start of the movement into the next emptying pose AP(K), in order to ensure that even possible residual movements of the material WS in the interior of the component BT have come to a standstill, or in order to increase the probability thereof.

As already mentioned above, the return to method step S11 is prompted by the trigger signal TR. In this case, the trigger signal TR is predominantly taken into account prior to the temporal progress of the simulated material distribution. In particular, a period of time for the decay of the material movement in the emptying pose $AP(K)$, as ascertained by the simulation, is not awaited; instead, the actually measured abating of the material movement is targeted. That is to say, in a deviation from the simulation-driven control of the movement device BV by the controller CTL, the movement into the next emptying pose $AP(K+1)$ is prompted as soon as it is determined by means of the sensor system S that there is no longer a noticeable material movement. To the extent that the decay time is frequently overestimated by simulations, this allows the emptying procedure to be significantly accelerated in general.

As a result of the restriction according to the invention to a discrete pattern of a few spatial orientations of the component BT, a computational outlay required for the simulation can be significantly reduced as a rule. This applies in particular since this pattern is specifically matched to the grid G underlying the simulation. In this context, the simulation is found to be particularly accurate if the real emptying directions or orientations of the component are within this grid-induced pattern. Consequently, a high simulation accuracy can also be ensured by restricting the poses to be adopted for the purposes of emptying the component BT to the same pattern.

Claims

1. A method for separating excess material (WS) from an additively manufactured component (BT), wherein

a) spatially resolved structure data (CAD) of the component (BT) are received,

b) the structure data (CAD) are used to divide a cavity (H) in the component (BT) into grid cells (GZ) by way of a virtual spatial grid (G), with a spatial alignment of the grid (G) relative to the component (BT) being specified by an alignment specification (RA),

c) a discrete pattern (R) of spatial orientations of the component (BT) is ascertained on the basis of the alignment specification (RA),

d) the grid cells (GZ) of the cavity (H) are filled with a virtual material (VWP) in a simulation,

e) the structure data (CAD) are used to simulate an emptying procedure of the virtual material (VWP) from the component (BT) for spatial orientations restricted to the discrete pattern (R), with a temporal sequence of orientations (AP(1), ..., AP(N)) that are restricted to the discrete pattern (R) being ascertained, and

f) the component (BT) is successively rotated into the orientations (AP(1), ..., AP(N)) of the temporal sequence on the basis of the simulated emptying procedure.

2. The method as claimed in claim 1, characterized in that the component (BT) is rotated into the orientations (AP(1), ..., AP(N)) of the temporal sequence and/or made to mechanically vibrate by a movement apparatus (BV).

3. The method as claimed in either of the preceding claims, characterized in that a respective movement step of the simulation is restricted to discrete movements of the virtual

material (VWP) from a respective grid cell (GZ) to an adjacent grid cell (BGZ).

4. The method as claimed in any one of the preceding claims, characterized in that a movement direction of the virtual material (VWP) in the simulation is restricted to directions leading from a respective grid cell (GZ) to an adjacent grid cell (BGZ).

5. The method as claimed in any one of the preceding claims, characterized in that the simulation is carried out by means of a grid-based three-dimensional cellular automaton (ZA).

6. The method as claimed in any one of the preceding claims, characterized in that directions leading from a grid cell (GZ) to adjacent grid cells (BGZ) are included in the discrete pattern of spatial orientations.

7. The method as claimed in any one of the preceding claims, characterized in that the discrete pattern is formed by spatial orientations whose angular values are substantially discretized in 45° steps.

8. The method as claimed in any one of the preceding claims, characterized in that a grid cell (GZ) which is filled with more virtual material (VWP) than an adjacent grid cell (BGZ) is ascertained and
in that a direction leading from the ascertained grid cell (GZ) to the adjacent grid cell (BGZ) is included in the temporal sequence of the orientations (AP(1), ..., AP(N)).

9. The method as claimed in any one of the preceding claims, characterized in that, for a respective orientation (AP(K)) of the ascertained temporal sequence:

- a material movement is detected by one or more sensors,

- a trigger signal (TR) is generated as a result of detecting an abating of the material movement, and
- a rotation of the component (BT) into a subsequent orientation (AP(K+1)) of the temporal sequence is caused by the trigger signal (TR).

10. An arrangement (A) for separating a material (WS) from an additively manufactured component (BT), configured to carry out a method as claimed in any one of the preceding claims.

11. A computer program product configured to carry out a method as claimed in any one of claims 1 to 9.

12. A computer-readable storage medium having a computer program product as claimed in claim 11.