



(51) International Patent Classification:

B29C 67/00 (2006.01) B33Y 30/00 (2015.01)
B33Y 10/00 (2015.01) B33Y 50/02 (2015.01)

(21) International Application Number:

PCT/JP2015/005843

(22) International Filing Date:

24 November 2015 (24.11.2015)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2014-242141 28 November 2014 (28.11.2014) JP
2015-215979 2 November 2015 (02.11.2015) JP

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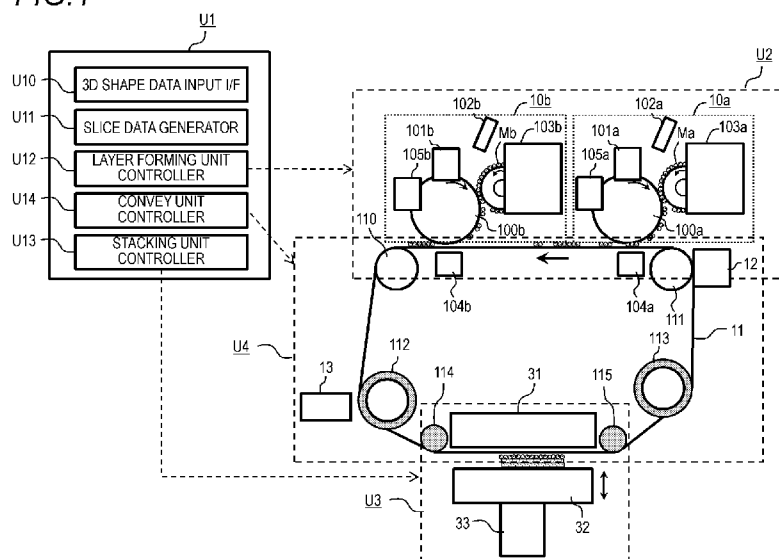
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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(54) Title: THREE-DIMENSIONAL SHAPING APPARATUS AND THREE-DIMENSIONAL SHAPED ARTICLE MANUFACTURING METHOD

FIG. 1



(57) Abstract: A three-dimensional shaped article manufacturing method includes: forming particle images using different types of particle materials; sequentially transferring the particle images to a layer bearing member (100), thereby forming a particle-layer which is one layer of materials; softening the particle-layer by implementing temperature control to a first target temperature in a state in which the particle-layer borne on the layer bearing member (100) is in contact with a three-dimensional shaped article under manufacturing; and solidifying the particle-layer by implementing temperature control to a second target temperature lower than the first target temperature and fixing the particle-layer to the three-dimensional shaped article under manufacturing.

Published:

— *with international search report (Art. 21(3))*

Description

Title of Invention: THREE-DIMENSIONAL SHAPING APPARATUS AND THREE-DIMENSIONAL SHAPED ARTICLE MANUFACTURING METHOD

Technical Field

[0001] The present invention relates to a three-dimensional shaping apparatus and a three-dimensional shaped article manufacturing method.

Background Art

[0002] In recent years, three-dimensional shaping techniques referred to as additive manufacturing (AM) or 3-dimensional printers are gathering attention (in the present specification, these techniques will be collectively referred to as an AM technique). The AM technique is a technique of shaping a solid object by slicing 3-dimensional shape data of the solid object to create a plurality of items of slice shape data, forming layers using a shaping material based on the respective items of slice shape data, and sequentially stacking and fixing the shaping material layers. In 1980s, stereolithography apparatuses which use photocurable resins have been developed and productized, and presently, various shaping techniques such as a vat photopolymerization scheme, a material jetting scheme, and a material extrusion scheme are known.

[0003] The AM technique provides such convenience that a mold is not necessary and a complex shape can be created. Thus, the AM technique is desirably used for manufacturing a prototype for examining the quality of the operation and shape of parts, a part of a welfare apparatus such as a hearing aid which is a single product or a small-lot product, a personal dental shaped article, or an aircraft part. Moreover, since the AM technique can manufacture complex-shape parts which cannot be formed using a mold and can create time-consuming sophisticated design shapes, the AM technique is also used for manufacturing parts and shaped articles that are difficult to manufacture using a conventional processing method and manufacturing apparel with a sophisticated design. Patent Literature (PTL) 1, 2, and 3 are known as prior techniques related to the AM technique.

Citation List

Patent Literature

- [0004] [PTL1] US5088047
[PTL2] WO95/26871
[PTL3] WO2014/092205

Summary of Invention

Technical Problem

[0005] In the conventional AM technique, the type of materials that can be used for each shaping technique is limited. Thus, even if users want to obtain material properties (mechanical strength, heat resistance, texture, and the like) equivalent to those of an object created by injection molding, machining, or the like, the AM technique cannot freely use materials used in injection molding, machining, or the like. Development of a material that can be applied to respective shaping techniques and exhibit desired properties is one of the technical issues of the AM technique.

[0006] Moreover, in the AM technique, there is a strong demand to mix a plurality of types of materials into one three-dimensional shaped article. When it is easy to combine different materials, various applications may occur in such a manner to manufacture a color shaped article using materials of different colors or incorporating parts having different texture and strength in a portion of a shaped article. Moreover, although a support portion is sometimes provided so as to prevent a portion of a shaped article from floating during stacking, if the support portion can be formed of a material that is easily removed, an operation of removing the support portion after stacking becomes easy. However, according to the vat photopolymerization scheme, for example, of the conventional AM technique, it is in principle not possible to use a plurality of types of materials. Moreover, although some apparatuses which employ the material jetting scheme or the material extrusion scheme can use a plurality of materials, it is necessary to use materials of which the properties are adjusted so that the materials can be stacked under the same conditions. Thus, the usable materials are limited and it is difficult to develop such materials.

[0007] The present invention aims to solve at least one of the problems of the AM technique. For example, an object of the present invention is to provide a three-dimensional shaping apparatus in which the degree of freedom in selecting usable materials is higher than that of the conventional AM technique. Another object of the present invention is to provide a three-dimensional shaping apparatus capable of stacking a plurality of materials having different properties in a simple sequence.

Solution to Problem

[0008] According to a first aspect of the present invention, there is provided a three-dimensional shaping apparatus that manufactures a three-dimensional shaped article by stacking materials, including: a plurality of particle image forming units that form particle images, using different types of particle materials, respectively; a layer bearing member that bears a particle-layer which is one layer of materials formed by combining a plurality of particle images formed by the plurality of particle image forming units; and a stacking unit that stacks the particle-layer, borne on the layer

bearing member, on a three-dimensional shaped article under manufacturing, wherein the stacking unit includes: a stage that holds the three-dimensional shaped article under manufacturing; and a temperature control unit that controls a temperature of the particle-layer borne on the layer bearing member, and in a state in which the three-dimensional shaped article under manufacturing held on the stage and the particle-layer borne on the layer bearing member are in contact with each other, after the temperature is controlled to a first target temperature by the temperature control unit, the temperature is controlled to a second target temperature lower than the first target temperature, whereby the particle-layer is fixed to the three-dimensional shaped article under manufacturing.

[0009] According to a second aspect of the present invention, there is provided a three-dimensional shaped article manufacturing method of manufacturing a three-dimensional shaped article by stacking materials, the method including: causing a plurality of particle image forming units to form particle images, using different types of particle materials; causing the plurality of particle image forming units to sequentially transfer the particle images to a layer bearing member, thereby forming a particle-layer which is one layer of materials; softening the particle-layer by implementing temperature control to a first target temperature in a state in which the particle-layer borne on the layer bearing member is in contact with a three-dimensional shaped article under manufacturing; and solidifying the particle-layer by implementing temperature control to a second target temperature lower than the first target temperature and fixing the particle-layer to the three-dimensional shaped article under manufacturing.

Advantageous Effects of Invention

[0010] According to the present invention, it is possible to improve the degree of freedom in selecting usable materials as compared to the conventional AM technique. Moreover, it is possible to provide a three-dimensional shaping apparatus capable of stacking a plurality of materials having different properties in a simple sequence.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

Brief Description of Drawings

[0011] [fig.1]Fig. 1 is a diagram schematically illustrating an overall configuration of a three-dimensional shaping apparatus according to a first embodiment.
 [fig.2]Fig. 2 is a diagram illustrating a modified example of a layer forming unit.
 [fig.3]Figs. 3A and 3B are diagrams illustrating the configuration of a particle image forming portion and a developing device.
 [fig.4]Fig. 4 is a flowchart illustrating an operation sequence of the three-dimensional

shaping apparatus according to the first embodiment.

[fig.5] Figs. 5A to 5D are diagrams schematically illustrating the operation of a stacking process.

[fig.6] Fig. 6 is a diagram illustrating a change in state when a thermoplastic substance is heated and cooled.

[fig.7] Fig. 7 is a diagram illustrating an example of a change in the temperature and elasticity of an amorphous substance.

[fig.8] Fig. 8 is a diagram for describing an example of a temperature control sequence according to the first embodiment.

[fig.9] Fig. 9 is a diagram illustrating an example of a change in the temperature and elasticity of a crystalline substance.

[fig.10] Fig. 10 is a diagram illustrating an example of a temperature control sequence according to a second embodiment.

[fig.11] Fig. 11 is a diagram illustrating an example of a temperature control sequence according to a third embodiment.

[fig.12] Figs. 12A and 12B are diagrams illustrating an example of a parameter table used in a fourth embodiment.

[fig.13] Fig. 13 is a flowchart illustrating a parameter switching process according to the fourth embodiment.

[fig.14] Fig. 14 is a diagram schematically illustrating an overall configuration of a three-dimensional shaping apparatus according to a fifth embodiment.

[fig.15] Fig. 15 is a diagram schematically illustrating an overall configuration of a three-dimensional shaping apparatus according to a sixth embodiment.

[fig.16] Fig. 16 is a diagram schematically illustrating an overall configuration of a three-dimensional shaping apparatus according to a seventh embodiment.

[fig.17] Fig. 17 is a diagram schematically illustrating a modified example of the three-dimensional shaping apparatus according to the seventh embodiment.

Description of Embodiments

[0012] Hereinafter, exemplary embodiments of the present invention will be described with reference to the drawings. Dimensions, materials, shapes, relative arrangements, and the like of respective members described in the following embodiments and the sequences, control parameters, target values, and the like of various control processes are not intended to limit the scope of the present invention unless specifically stated otherwise.

[0013] <First Embodiment>

<<Overall Configuration of Three-Dimensional Shaping Apparatus>>

Referring to Fig. 1, an overall configuration of a three-dimensional shaping apparatus

according to a first embodiment of the present invention will be described. Fig. 1 is a diagram schematically illustrating an overall configuration of a three-dimensional shaping apparatus according to a first embodiment.

[0014] The three-dimensional shaping apparatus of the present embodiment is an additive manufacturing system of such a scheme that manufactures a three-dimensional shaped article by stacking thin layers (referred to as particle-layers) having a particle material arranged two-dimensionally or thin films obtained by fusing the thin layers.

[0015] As illustrated in Fig. 1, the three-dimensional shaping apparatus is generally configured to include a control unit U1, a layer forming unit (also referred to as an image forming unit) U2, a stacking unit U3, and a convey unit U4. The control unit U1 is a unit that performs a process of generating a plurality of layers of slice data (cross-section data) from three-dimensional shape data of a solid object (shaping object) to be shaped and controls respective units of the three-dimensional shaping apparatus. The layer forming unit U2 is a unit that forms a particle-layer formed of a particle material. The stacking unit U3 is a unit that forms a three-dimensional shaped article by sequentially stacking and fixing a plurality of particle-layers formed by the layer forming unit U2. The convey unit U4 is a unit that carries a particle-layer from the layer forming unit U2 to the stacking unit U3.

[0016] These units U1 to U4 may be accommodated in a plurality of housings or may be accommodated in one housing. When the units U1 to U4 are accommodated in respective housings, the units can be easily combined or replaced according to the use, required performance, materials to be used, installed space, failures, or the like of the three-dimensional shaping apparatus. Thus, it is possible to improve the convenience and the degree of freedom of the apparatus configuration. On the other hand, when all units are accommodated in one housing, it is possible to reduce the size of the entire apparatus and the cost. The unit configuration illustrated in Fig. 1 is an example only, and other configurations may be employed.

[0017] <<Control Unit>>

The configuration of the control unit U1 will be described. As illustrated in Fig. 1, the control unit U1 includes, as its functions, a three-dimensional shape data input interface U10, a slice data generator U11, a layer forming unit controller U12, a stacking unit controller U13, a convey unit controller U14, and the like.

[0018] The three-dimensional shape data input interface U10 has a function of receiving three-dimensional shape data of a shaping object from an external apparatus (for example, a PC or the like). Data created and output by a three-dimensional CAD, a three-dimensional modeler, a three-dimensional scanner, or the like can be used as the three-dimensional shape data. Although the file format is not particularly limited, a stereolithography (STL) file format, for example, can be preferably used.

- [0019] The slice data generator U11 has a function of slicing a shaping object expressed by three-dimensional shape data at a predetermined pitch to compute a cross-sectional shape of each layer and generating image data (also referred to as slice data) used for image formation in the layer forming unit U2 based on the cross-sectional shape. For example, the slice data can be generated by adding a support portion required for shaping to the shaping object expressed by three-dimensional shape data and then computing the cross-sectional shape.
- [0020] The layer forming unit U2 of the present embodiment can form images using a plurality of types of materials, which will be described in detail later. Thus, data corresponding to the images of respective materials is generated as the slice data. In this case, it is preferable to adjust the position and shape of the image in the respective items of slice data so that the image of different materials do not overlap as much as possible. This is because, when the images overlap and the amount of particles in the overlapping portion is large, the thickness of the particle-layer may vary greatly, which leads to a decrease in the dimensional accuracy of a three-dimensional shaped article. For example, multi-valued image data (each value indicates the type of a material) or multi-plane image data (each plane corresponds to the type of a material) can be used as the file format of the slice data. Hereinafter, a material that forms a solid object to be shaped will be referred to as a “structure material”, a material that forms a support portion will be referred to as a “support material”, and the structure material and the support material will be collectively referred to as a “shaping material”.
- [0021] The layer forming unit controller U12 is a function of controlling a layer forming process of the layer forming unit U2 based on the slice data generated by the slice data generator U11. Moreover, the stacking unit controller U13 is a function of controlling a stacking process of the stacking unit U3. The convey unit controller U14 is a function of controlling switching between driving/stopping, a conveyance speed, and the like of the convey unit U4. Specific content of the control of the respective units will be described later.
- [0022] Moreover, the control unit U1 includes an operating portion, a display portion, and a storage portion, which are not illustrated in the drawing. The operating portion performs a function of receiving instructions from users. For example, users can turn the power on/off, change various settings of the apparatus, and input operation instructions and the like. The display portion presents information to users. For example, the display portion can present various setting screens, error messages, operation states, and the like. The storage portion stores the three-dimensional shape data, the slice data, and various setting values (for example, parameters for determining the conditions of the layer forming process and the stacking process).
- [0023] The control unit U1 can be configured in hardware by a computer that includes a

central processing unit (CPU), a memory, an auxiliary storage device (a hard disk, a flash memory, or the like), an input device, a display device, and various I/F units. The respective functions U10 to U13 are implemented by a CPU reading and executing a program stored in the auxiliary storage device or the like and controlling necessary devices. A portion or all of the functions may be implemented by a circuit such as an ASIC or an FPGA or may be executed by another computer using techniques such as cloud computing or grid computing.

[0024] <<Layer Forming Unit>>

Next, a configuration of the layer forming unit U2 will be described. The layer forming unit U2 is a unit that forms a particle-layer from a particle material using an electrophotography process, for example. The electrophotography process is a method of forming a desired image by a series of processes of charging a photoconductor, forming a latent image by exposure, and allowing a developer particle to adhere to the latent image to form a developer image. The principle of the electrophotography process is the same as that used in a 2D printer such as a copier. However, since the three-dimensional shaping apparatus uses a particle material having a different property from a toner material as the developer, it is often not possible to use the process control and the member structure used in the 2D printer as they are. Although Fig. 1 illustrates a case of using the electrophotography process, an inkjet scheme as disclosed in PTL3 (WO2014/092205) may be used.

[0025] As illustrated in Fig. 1, the layer forming unit U2 includes a first particle image forming portion 10a and a second particle image forming portion 10b. The first particle image forming portion 10a is a particle image forming unit that forms a particle image using a first particle material Ma and includes an image bearing member 100a, a charging device 101a, an exposure device 102a, a developing device 103a, a transfer device 104a, and a cleaning device 105a. Moreover, the second particle image forming portion 10b is a particle image forming unit that forms a particle image using a second particle material Mb and includes an image bearing member 100b, a charging device 101b, an exposure device 102b, a developing device 103b, a transfer device 104b, and a cleaning device 105b.

[0026] In the present embodiment, a structure material formed of a thermoplastic resin or the like is used as the first particle material Ma, and a support material having thermoplastic and water-soluble properties is used as the second particle material Mb. Polyethylene (PE), polypropylene (PP), ABS, polystyrene (PS), and the like, for example, can be used as the structure material. Moreover, glucides, polylactic acid (PLA), polyvinyl alcohol (PVA), polyethylene glycol (PEG), and the like can be used as the support material. A volume average diameter of the particles of the respective materials is preferably between 5 micrometers and 50 micrometers, and is more

preferably between 15 micrometers and 25 micrometers when shaping accuracy and shaping speed are considered. Moreover, the volume average diameter in the present invention is a value obtained by measurement according to the known laser diffraction and scattering method (micro-track method).

[0027] These particle image forming portions 10a and 10b are disposed along a surface of a conveyance belt 11. In Fig. 1, although the particle image forming portion 10a of the structure material is arranged on the upstream side in the conveyance direction, the order of arranging the particle image forming portions is optional. Moreover, the number of particle image forming portions may larger than two, and the number of particle image forming portions may be increased appropriately depending on the type of the shaping material used. For example, Fig. 2 illustrates an example in which four particle image forming portions 10a to 10d are arranged. In this case, images may be formed using four structure materials or images may be formed using three structure materials and one support material. When a plurality of types of materials having different qualities, colors, hardness, properties, and the like are combined, a number of variations of three-dimensional shaped articles can be created. Such excellent extensibility is one of the advantages of three-dimensional shaping apparatuses which use the electrophotography process.

[0028] Hereinafter, the configuration of each portion of the layer forming unit U2 will be described in detail. However, the suffixes a to d appended to reference numerals of the constituent members in the description common to the particle image forming portions 10a to 10d will be omitted and the particle image forming portions and image bearing members will be referred to as a particle image forming portion 10 and an image bearing member 100, respectively, for example.

[0029] (Image Bearing Member)

Fig. 3A is a diagram illustrating a configuration of the particle image forming portion 10, and Fig. 3B is a diagram illustrating a detailed configuration of the developing device 103.

[0030] The image bearing member 100 is a member for bearing an electrostatic latent image. In this example, a photoconductor drum in which a photoconductor layer having a photoconductive property is formed on an outer circumferential surface of a metal cylindrical formed of aluminum or the like is used. An organic photoconductor (OPC), an amorphous silicon photoconductor, a selenium photoconductor, or the like can be used as the photoconductor, and the type of the photoconductor can be appropriately selected depending on the use and required performance of the three-dimensional shaping apparatus. The image bearing member 100 is rotatably supported on a frame (not illustrated) and rotates at a constant velocity in the clockwise direction in the drawing during image formation with the aid of a motor (not illustrated).

[0031] (Charging Device)

The charging device 101 is a charging unit that uniformly charges the surface of the image bearing member 100. In the present embodiment, although a non-contact charging scheme which uses corona discharge is used, other charging schemes such as a roller charging scheme in which a charge roller makes contact with the surface of the image bearing member 100 may be used.

[0032] (Exposure Device)

The exposure device 102 is an exposure unit that exposes the image bearing member 100 according to image information (slice data) to form an electrostatic latent image on the surface of the image bearing member 100. The exposure device 102 is configured to include a light source such as a semiconductor laser or a light-emitting diode, a scanning mechanism formed of a polygon mirror that rotates at a high speed, and an optical member such as an imaging lens.

[0033] (Developing Assembly)

The developing device 103 is a developing unit that visualizes an electrostatic latent image by supplying developer (in this example, particles of the structure material or the support material) to the image bearing member 100 (in the present specification, an image visualized by the developer is referred to as a particle image). Fig. 3B illustrates a detailed configuration of the developing device 103. The developing device 103 includes a container 1030 that stores developer, a supply roller 1031 provided inside the container 1030, a developing roller 1032 that bears developer and supplies the developer to the image bearing member 100, and a regulating member 1033 that regulates the thickness of the developer. The supply roller 1031 and the developing roller 1032 are rotatably supported on the container 1030 and rotate at a constant velocity in the counterclockwise direction in the drawing during image formation with the aid of a motor (not illustrated). Developer particles stirred and charged by the supply roller 1031 are supplied to the developing roller 1032 and the thickness thereof is regulated to the thickness of approximately one particle by the regulating member 1033. After that, the electrostatic latent image at a portion at which the developing roller 1032 and the image bearing member 100 face each other is developed. Although a developing scheme includes a reverse developing scheme in which developer adheres to a portion where charges are removed by exposure and a normal developing scheme in which developer adheres to a non-exposed portion, any of the two schemes may be used.

[0034] The developing device 103 may have a so-called developing cartridge structure and may be detachably attached to the layer forming unit U2. This is because it is easy to add or change developer (the structure material and the support material) by replacing the cartridge. Alternatively, the image bearing member 100, the developing device

103, the cleaning device 105, and the like may be accommodated in one cartridge (so-called a process cartridge) so that the image bearing member itself can be replaced. When a problem arises, in particular, in relation to wear and life span of the image bearing member 100 depending on the type, hardness, and size of the structure material and the support material, the structure of a process cartridge is superior in terms of practicality and convenience.

[0035] (Transfer Device)

The transfer device 104 is a transfer unit that transfers the particle image on the image bearing member 100 to the surface of the conveyance belt 11. The transfer device 104 is disposed opposite the image bearing member 100 with the conveyance belt 11 interposed. The transfer device 104 electrostatically transfers the particle image to the conveyance belt 11 by applying a voltage of the opposite polarity to the particle image on the image bearing member 100. The transfer from the image bearing member 100 to the conveyance belt 11 is also referred to primary transfer. In the present embodiment, although a transfer scheme which uses corona discharge is used, other transfer schemes such as a roller transfer scheme or transfer schemes other than an electrostatic transfer scheme may be used.

[0036] (Cleaning Device)

The cleaning device 105 is a unit that collects developer particles remaining on the image bearing member 100 without being transferred to clean the surface of the image bearing member 100. In the present embodiment, although the cleaning device 105 of a blade scheme in which developer particles are scraped off by a cleaning blade that makes contact with the image bearing member 100 in a counter direction is employed, a cleaning device of a brush scheme or an electrostatic adsorption scheme may be used.

[0037] <<Convey Unit>>

Next, the configuration of the convey unit U4 will be described. The convey unit U4 is a unit that carries a particle-layer from the layer forming unit U2 to the stacking unit U3 and includes the conveyance belt 11, a belt cleaning device 12, and an image detection sensor 13.

[0038] (Conveyance Belt)

The conveyance belt 11 functions as a transfer target member to which the particle images are transferred from the respective particle image forming portions 10, a layer bearing member that bears a particle-layer formed of a plurality of particle images, and conveyance means that carries the particle-layer to the stacking unit U3. After a particle image of the structure material is transferred from the particle image forming portion 10a on the upstream side, a particle image of the support material is transferred from the particle image forming portion 10b on the downstream side in synchronism

with the transfer, whereby one particle-layer is formed on the surface of the conveyance belt 11.

[0039] The conveyance belt 11 is an endless belt formed of a material such as a resin or polyimide, and as illustrated in Fig. 1, is wound around a plurality of rollers 110, 111, 112, 113, 114, and 115. At least one of the rollers is a driver roller which rotates the conveyance belt 11 in the counterclockwise direction in the drawing during image formation with driving force of a motor (not illustrated). Moreover, at least one of the rollers is a tension roller and has a function of adjusting tension of the conveyance belt 11.

[0040] (Belt Cleaning Device)

The belt cleaning device 12 is a unit that cleans materials adhering to the surface of the conveyance belt 11. In the present embodiment, although the cleaning device of a blade scheme in which materials are scraped off by a cleaning blade that makes contact with the conveyance belt 11 in a counter direction is employed, a cleaning device of a brush scheme or an electrostatic adsorption scheme may be used.

[0041] (Image Detection Sensor)

The image detection sensor 13 is a detection unit that reads a particle-layer borne on the surface of the conveyance belt 11. A detection result obtained by the image detection sensor 13 is used for alignment of the particle-layer, control of timing relative to the stacking unit U3 on the subsequent stage, and detection of abnormalities (a desired image is not formed, an image is not present, the thickness fluctuation is large, or a positional shift of the image is large) in the particle-layer.

[0042] <<Stacking Unit>>

Next, a configuration of the stacking unit U3 will be described. The stacking unit U3 is a unit that forms a three-dimensional shaped article by sequentially stacking and fixing the particle-layers carried by the convey unit U4.

[0043] As illustrated in Fig. 1, the stacking unit U3 includes a temperature control device 31, a stage 32, and a stage moving mechanism 33. Hereinafter, the configuration of each portion of the stacking unit U3 will be described in detail. In the present embodiment, the conveyance belt 11 of the convey unit U4 also serves as conveyance means that carries the particle-layer to a stacking position. A stacking position is a position at which stacking of a particle-layer (on a three-dimensional shaped article under manufacturing) is performed, and in the configuration of Fig. 1, a portion in which the conveyance belt 11 is sandwiched between the temperature control device 31 and the stage 32 corresponds to the stacking position. The two rollers 114 and 115 disposed before and after the stacking position perform the role of maintaining the conveyance belt 11 (that is, the particle-layer during stacking) passing through the stacking position flat.

[0044] (Temperature Control Device)

The temperature control device 31 is a temperature control unit that controls the temperature of the particle-layer conveyed to the stacking position. A heating device such as a ceramic heater or a halogen heater can be used as the temperature control device 31. Moreover, a configuration for actively decreasing the temperature of the particle-layer by heat radiation or cooling may be provided in the temperature control device 31 as well as the configuration for heating. The lower surface (the belt-side surface) of the temperature control device 31 is configured as a flat surface and thus also functions as a guide for the conveyance belt 11 that passes through the stacking position and a pressing member that applies uniform pressure to the particle-layer.

[0045] (Stage)

The stage 32 is a flat table on which a three-dimensional shaped article is stacked. The stage 32 can move in an up-down direction (the direction vertical to the belt surface at the stacking position) with the aid of the moving mechanism 33 configured as a linear actuator or the like. By performing heating and pressing (as well as heat radiation and cooling as necessary) with the particle-layer borne and carried to the stacking position sandwiched between the temperature control device 31 and the stage 32, the particle-layer is transferred from the conveyance belt 11 toward the stage 32. The first particle-layer is directly transferred to the stage 32, and the second and subsequent particle-layers are stacked on a three-dimensional shaped article (under manufacturing) on the stage 32. As described above, in the present embodiment, the temperature control device 31 and the stage 32 form a stacking unit that stacks a particle-layer.

[0046] <<Operation of Three-Dimensional Shaping Apparatus>>

Next, an operation of the three-dimensional shaping apparatus having the above-described configuration will be described. In this example, it is assumed that a process of generating slice data by the control unit U1 is already completed, and the process of forming particle-layers and the process of stacking the particle-layer will be described in that order. Fig. 4 is a flowchart illustrating an operation sequence of the three-dimensional shaping apparatus of the present embodiment and Fig. 5 is a diagram schematically illustrating the operation of the stacking process.

[0047] (Layer Forming Process)

First, the control unit U1 controls a driving source such as a motor so that the image bearing member 100 and the conveyance belt 11 of the respective particle image forming portions 10 rotate at the same circumferential velocity (process speed) in synchronism (S500).

[0048] After the rotating velocity is stabilized, the particle image forming portion 10a on the uppermost stream side starts image formation (S501). That is, the control unit U1

controls the charging device 101a so that the entire surface of the image bearing member 100a is substantially uniformly charged with a predetermined polarity and a predetermined charging potential. Subsequently, the control unit U1 exposes the surface of the charged image bearing member 100a with the aid of the exposure device 102a. In this example, charges are removed by exposure to form a potential difference between an exposure portion and a non-exposed portion. An image formed by the potential difference is the electrostatic latent image. On the other hand, the control unit U1 drives the developing device 103a to allow the particles of the structure material to adhere to the latent image on the image bearing member 100a to form a particle image of the structure material. This particle image is primarily transferred to the conveyance belt 11 by the transfer device 104a.

[0049] Moreover, the control unit U1 allows the particle image forming portion 10b on the downstream side to start image formation with a predetermined time difference from the start of the image formation of the particle image forming portion 10a (S502). The image formation in the particle image forming portion 10b is performed in the same order as the image formation in the particle image forming portion 10a. Here, the time difference in the start of image formation is set to a value obtained by dividing the distance between a primary transfer nip in the particle image forming portion 10a on the upstream side and a primary transfer nip in the particle image forming portion 10b on the downstream side by the process speed. In this way, the two particle images formed by the respective particle image forming portions 10a and 10b are aligned and disposed on the conveyance belt 11 and one particle-layer formed of the structure material and the support material is formed (S503). In the case of a cross-section which does not have an overhanging portion and does not require a support portion, the image formation of the particle image forming portion 10b is not performed. In this case, the particle-layer is formed of only the particle images of the structure material.

[0050] (Stacking Process)

The conveyance belt 11 continues rotating at the process speed to transfer the particle-layer in the direction indicated by an arrow in Fig. 1. At a timing at which the particle-layer arrives at the stacking position, the control unit U1 stops the conveyance belt 11 to align the particle-layer at the stacking position (S504). The conveyance and stopping timing of the conveyance belt 11 may be controlled based on a detection result obtained by the image detection sensor 13 detecting the position of a leading end of the particle-layer. This is because, in the case of a three-dimensional shaping apparatus, the position, size, and shape of an image (the particle-layer) may be different from layer to layer, and the timing of arriving at the stacking position and the positional relation with the temperature control device may change from layer to layer. In this respect, it is necessary to perform different control from that of a 2D printer in

which the position and size of an image is determined depending on a sheet size.

[0051] After that, as illustrated in Fig. 5A, the control unit U1 raises the stage 32 (to approach the belt surface). In this way, the stage surface (in the case of the first layer) or the upper surface (in the case of the second and subsequent layers) of the three-dimensional shaped article 41 formed on the stage 32 makes contact with the particle-layer 40 on the conveyance belt 11 (S505).

[0052] In this state, the control unit U1 controls the temperature of the temperature control device 31 according to a predetermined temperature control sequence. Specifically, first, a first temperature control mode of heating to a first target temperature is performed for a predetermined period to fuse the particle material of the particle-layer 40 (S506: Fig. 5B). In this way, the particle-layer softens, and the sheet-shaped layer 40 is closely attached to the stage surface or the upper surface of the three-dimensional shaped article 41. After that, a second temperature control mode of controlling the temperature to a second target temperature lower than the first target temperature is performed for a predetermined period to solidify the fused material (S507: Fig. 5C). After the second temperature control mode ends, the control unit U1 lowers the stage 32 (to be separated from the belt surface) (S508: Fig. 5D). In this way, stacking of the sheet-shaped layer is completed. Here, the temperature control period of the first and second temperature control modes is set appropriately to a value (for example, several milliseconds to several tens of seconds) based on the thickness of the particle-layer, the temperature characteristics of the material, the thickness and the thermal capacity of the conveyance belt 11, and the like. The values of the target temperature, the temperature control period, and the like are set in advance in the storage portion of the control unit U1 according to the type of the shaping material.

[0053] After the stacking of the particle-layer ends, execution of the layer forming process for the next layer begins (S501 and subsequent steps). When the layer forming process and the stacking process are repeated for a necessary number of times, a desired intermediate three-dimensional shaped article is formed on the stage 32. Finally, the intermediate three-dimensional shaped article is separated from the stage 32 and the water-soluble support material is removed using warm water or the like. In this way, a shaped article can be obtained. After the support material is removed, a predetermined process such as a surface treatment or assembling may be performed on the shaped article to obtain a final product.

[0054] <<Temperature Control Sequence>>

Next, a temperature control sequence (S506 and S507 in Fig. 4) during stacking in the stacking unit U3 will be described in detail.

[0055] The temperature characteristics (softening or solidification temperature range) of a shaping material are different from substance to substance. Thus, the three-dimensional

shaping apparatus of the present embodiment performs appropriate temperature control corresponding to a shaping material used in order to reliably stack a particle-layer in which a plurality of types of shaping materials are mixed in one stacking process. In other words, a temperature control sequence which uses a temperature condition that can soften or solidify all shaping materials used is used so that a plurality of shaping materials having different temperature characteristics can be stacked simultaneously. In this way, the stacking process is simplified and the process efficiency is improved.

[0056] Fig. 6 illustrates a change in the state of a substance in relation to temperature when a general thermoplastic substance was heated and cooled. As illustrated in Fig. 6, a thermoplastic substance is in a solid state (elastic state) before heating. For example, an amorphous substance is in a solid state in which several polymers are entangled in a glass state in a disordered manner.

[0057] When an amorphous substance in the solid state is heated, polymers become movable at the glass transition point T_g , and the amorphous substance enters a viscoelastic state from the solid state and then changes to a liquid state (viscous state). Conversely, when an amorphous substance in the liquid state (viscous state) is cooled, the amorphous substance gradually becomes immovable, and the amorphous substance enters a viscoelastic state. When the amorphous substance is cooled to a temperature lower than the glass transition point T_g , the amorphous substance enters a glass state which is an elastic state.

[0058] An example of a change in temperature and elasticity of an amorphous substance is illustrated in Fig. 7. The elasticity is highest in a glass-state region. When the amorphous substance is heated, the elasticity decreases gradually, and the elasticity decreases greatly in a temperature range (referred to as a transition region) including the glass transition point T_g . After that, the amorphous substance enters a rubber-like state (supercooled liquid) which is a fused state with high viscosity. The elasticity decreases gently in the rubber-state region. When the amorphous substance is heated further from the rubber-state region, the elasticity decreases further and the amorphous substance enters a flowable state (liquid) with low viscosity. The glass transition point can be measured by a general method such as differential scanning calorimetry (DSC), thermal simulated current (TSC), or viscoelasticity measurement. In the present invention, an intermediate glass transition point obtained by measuring according to ASTM D3418-82 using DSC-7 (product of PerkinElmer Corporation) which is a differential scanning calorimetry apparatus (DSC meter) is used as the glass transition point.

[0059] When the elasticity is high (in the case of the glass state), even when two members are brought into contact and are pressed, if the pressure is released, the deformed members return to the original positions before pressing and the respective members

will not be mixed together. However, when the members are heated to reach a high viscosity state (the rubber state or the liquid state) and are brought into contact and are pressed, the respective members are mixed together at the contacting portion and will not return to the original positions even if the pressure is released. Moreover, when an object in which the fused members are partially mixed together is cooled, the members enter a glass state in which materials do not flow, and the two members are combined.

[0060] In the three-dimensional shaping apparatus of the present embodiment, since the respective particle image forming portions 10 use different types of shaping materials, materials having different temperature characteristics are mixed in one particle-layer. Thus, the target temperature in the temperature control sequence is set by taking the glass transition points T_g of the respective shaping materials used into consideration. Specifically, in the first temperature control mode for fusing or softening the particle-layer, the first target temperature is set to a value equal to or higher than a lower limit which is the highest temperature of the glass transition points of the respective materials. On the other hand, in the second temperature control mode for solidifying the particle-layer, the second target temperature is set to a value equal to or lower than an upper limit which is the lowest temperature of the glass transition points of the respective materials. By performing such temperature control, after the entire particle-layer in which materials having different temperature characteristics are mixed is fused or softened in a common fusing temperature region, the entire particle-layer can be solidified in a common solidification temperature region. Thus, a particle-layer in which a plurality of types of amorphous materials are mixed can be stably fused and solidified in a simple sequence.

[0061] In the first and second temperature control modes, if the temperature control range is too wide, it takes a considerable time to stabilize the temperature control and the stacking process takes a longer period than necessary. Thus, the control range of the first target temperature may be set such that the highest temperature of the glass transition points of the respective materials is a lower-limit temperature and an upper-limit temperature is approximately 70°C higher than the lower-limit temperature. Similarly, the control range of the second target temperature may be set such that the lowest temperature of the glass transition points of the respective materials is an upper-limit temperature and a lower-limit temperature is approximately 50°C lower than the upper-limit temperature.

[0062] As an example, the temperature control sequence when different types of amorphous materials A and B have such temperature characteristics (viscoelasticity characteristics) as illustrated in Fig. 8, and the glass transition points of the materials A and B are T_{gA} and T_{gB} ($T_{gA} > T_{gB}$) will be described. This example corresponds to a case in which maltotetraose (glass transition point: 156°C) which is an amorphous material is

used as the support material A, and ABS (glass transition point: 130°C) which is an amorphous resin is used as the structure material B.

[0063] The particle-layer on the conveyance belt 11 is formed of the particle image of the material A and the particle image of the material B. In a state in which the upper surface of the shaped article on the stage 32 is in contact with the particle-layer, the particle-layer is maintained for a predetermined period while controlling the temperature within a temperature range between the lower-limit temperature (T_{gA}) and the upper-limit temperature ($T_{gA} + 70^{\circ}\text{C}$). By doing so, since both materials A and B are softened, the entire particle-layer enters a fused state without causing a disorder (deformation or muddiness) of the particle images of different types of materials. The upper surface of the shaped article on the stage 32 being in contact with the particle-layer also enters the fused state in a similar manner. After that, in a state in which the fused particle-layer and the upper surface of the shaped article are in contact with each other, the particle-layer is maintained for a predetermined period within a temperature range between the lower-limit temperature ($T_{gB} - 50^{\circ}\text{C}$) and the upper-limit temperature (T_{gB}). By doing so, since both the fused materials A and B are solidified, the particle-layer is fixed (integrated) to the shaped article without causing a disorder (deformation or muddiness) of the particle images of different types of materials. After this series of temperature control sequences are executed, when the stage 32 is lowered, the shaped article is separated from the surface of the conveyance belt 11.

[0064] (Advantages of Present Embodiment)

According to the three-dimensional shaping apparatus of the present embodiment described above, since image formation can be performed layer by layer, dramatic improvement in the processing speed can be expected as compared to the conventional AM technique. Moreover, since any materials suitable for the process can be used, the degree of freedom in selecting materials is higher than the conventional AM technique. Further, since the unit is divided for respective processes such as the layer forming unit U2 and the stacking unit U3, the degree of freedom in the apparatus configuration and the extensibility are high.

[0065] Further, in the stacking process of the present embodiment, after the particle-layer is sandwiched between the belt surface and the three-dimensional shaped article, the particle-layer is fused or softened at a temperature at which all types of materials are fused, the temperature is decreased to a temperature at which all types of materials are solidified, and then, the three-dimensional shaped article (the stage) is separated from the belt surface. As a result, the particle-layer in which a plurality of types of materials having different characteristics are mixed can be stacked stably while securing high quality. In the present embodiment, although an example of combining two types of amorphous materials has been illustrated, the temperature control of the present em-

bodiment can be applied to a combination of three or more types of amorphous materials.

[0066] <Second Embodiment>

In the first embodiment, although two types of amorphous materials were used, a combination of materials is not limited thereto. In a second embodiment, an example of combining a plurality of types of crystalline materials to manufacture a three-dimensional shaped article will be described. Since the configuration of the three-dimensional shaping apparatus itself is the same as that of the first embodiment (Fig. 1), a configuration unique to the second embodiment only will be described.

[0067] As illustrated in Fig. 6, a thermoplastic substance is in a solid state (elastic state) before heating. In the case of a crystalline substance, the crystalline substance is in a solid state in which polymers are arranged in a crystalline state in a well-ordered manner. When a crystalline substance is heated, since molecules moves greatly with thermal energy, deformation occurs if pressure is applied. When the temperature is increased further, polymers become movable at a melting point T_m , and the crystalline substance enters a liquid state from the solid state. Conversely, when the crystalline substance in the liquid state (viscous state) is cooled, the crystalline substance begins to solidify when the temperature becomes equal to or lower than a crystallization temperature T_c rather than solidifying immediately even if the temperature is lower than the melting point T_m . When the temperature is decreased further, since a thermal vibration range of polymers decreases, the crystalline substance enters a solid state with high elasticity.

[0068] An example of a change in temperature and elasticity of a crystalline substance is illustrated in Fig. 9. The elasticity is highest in a solid region (crystal region). When the crystalline substance is heated, the elasticity decreases gradually. When the temperature exceeds the melting point T_m , the crystalline substance becomes liquid (viscous state) and the elasticity decreases greatly. Subsequently, when the fused and liquid crystalline substance (viscous state) is cooled, since the crystalline substance does not solidify immediately even when the temperature becomes equal to or lower than the melting point T_m , the elasticity does not increase immediately. Moreover, when the temperature reaches the crystallization temperature T_c or lower, the elasticity increases greatly and the crystalline substance enters a solid state (elastic state).

[0069] In the three-dimensional shaping apparatus of the present embodiment, the respective particle image forming portions 10 use different types of crystalline materials. Thus, the target temperature in the temperature control sequence is set by taking the melting points T_m and the crystallization temperatures T_c of the respective crystalline materials used into consideration. Specifically, in the first temperature control mode for fusing (softening) the particle-layer, the first target temperature is set to a value

equal to or higher than the highest temperature of the melting points of the respective materials. On the other hand, in the second temperature control mode for solidifying the particle-layer, the second target temperature is set to a value equal to or lower than the lowest temperature of the crystallization temperatures of the respective materials. By performing such temperature control, after the entire particle-layer in which materials having different temperature characteristics are mixed is fused or softened in a common fusing temperature region, the entire particle-layer can be solidified in a common solidification temperature region. Thus, a particle-layer in which a plurality of types of amorphous materials are mixed can be stably fused and solidified in a simple sequence.

- [0070] In the first and second temperature control modes, if the temperature control range is too wide, it takes a considerable time to stabilize the temperature control and the stacking process takes a longer period than necessary. Thus, the control range of the first target temperature may be set such that the highest temperature of the melting points of the respective materials is a lower-limit temperature and an upper-limit temperature is approximately 50°C higher than the lower-limit temperature. Similarly, the control range of the second target temperature may be set such that the lowest temperature of the crystallization temperatures of the respective materials is an upper-limit temperature and a lower-limit temperature is approximately 50°C lower than the upper-limit temperature.
- [0071] As an example, the temperature control sequence when different types of crystalline materials A and B have such temperature characteristics (viscoelasticity characteristics) as illustrated in Fig. 10 will be described. The glass transition points of the materials A and B are T_{gA} and T_{gB} , the crystallization temperatures thereof are T_{cA} and T_{cB} , the melting points thereof are T_{mA} and T_{mB} , and these temperatures are in the relation of $T_{gA} < T_{gB}$, $T_{cA} < T_{cB}$, and $T_{mA} < T_{mB}$. This example corresponds to a case in which polypropylene (melting point: 160°C) which is a crystalline resin is used as the structure material A, and polyethylene glycol (melting point: 65°C) which is a crystalline material is used as the support material B.
- [0072] The particle-layer on the conveyance belt 11 is formed of the particle image of the material A and the particle image of the material B. In a state in which the upper surface of the shaped article on the stage 32 is in contact with the particle-layer, the particle-layer is maintained for a predetermined period while controlling the temperature within a temperature range between the lower-limit temperature (T_{mA}) and the upper-limit temperature ($T_{mA} + 50^{\circ}\text{C}$). By doing so, since both materials A and B are softened, the entire particle-layer enters a fused state without causing a disorder (deformation or muddiness) of the particle images of different types of materials. The upper surface of the shaped article on the stage 32 being in contact with the particle-

layer also enters the fused state in a similar manner. After that, in a state in which the fused particle-layer and the upper surface of the shaped article are in contact with each other, the particle-layer is maintained for a predetermined period within a temperature range between the lower-limit temperature ($T_{cA} - 50^{\circ}\text{C}$) and the upper-limit temperature (T_{cA}). By doing so, since both the fused materials A and B are solidified, the particle-layer is fixed (integrated) to the shaped article without causing a disorder (deformation or muddiness) of the particle images of different types of materials. After this series of temperature control sequences are executed, when the stage 32 is lowered, the shaped article is separated from the surface of the conveyance belt 11.

[0073] With the configuration of the present embodiment described above, it is possible to obtain the same advantages as those of the first embodiment. In the present embodiment, although an example of combining two types of crystalline materials has been illustrated, the temperature control of the present embodiment can be applied to a combination of three or more types of crystalline materials.

[0074] <Third Embodiment>

In a third embodiment, an example in which a three-dimensional shaped article is manufactured by combining a crystalline material and an amorphous material will be described. Practically, it is difficult to clearly distinguish a crystalline material and an amorphous material. In many cases, a crystalline material indicates a material (a crystalline material containing amorphous portions) having high crystallinity and an amorphous material indicates a material (an amorphous material containing crystalline portions) having high amorphism. The same temperature control can be applied to when such materials are combined. Since the configuration of the three-dimensional shaping apparatus itself is the same as that of the first embodiment (Fig. 1), a configuration unique to the third embodiment only will be described.

[0075] As described with reference to Fig. 6, a crystalline thermoplastic substance and an amorphous thermoplastic substance exhibit different changes in elasticity when the substances are heated and cooled. Thus, in the first temperature control mode of the present embodiment, the first target temperature is set to a value equal to or higher than the highest temperature of the melting point of the crystalline material used and the glass transition point of the amorphous material used. On the other hand, in the second temperature control mode, the second target temperature is set to a value equal to or lower than the lowest temperature of the crystallization temperature of the crystalline material used and the glass transition point of the amorphous material used. By performing such temperature control, after the entire particle-layer in which a crystalline material and an amorphous material are mixed is fused or softened in a common fusing temperature region, the entire particle-layer can be solidified in a common solidification temperature region. Thus, a particle-layer in which a crystalline

material and an amorphous material are mixed can be stably fused and solidified in a simple sequence.

- [0076] The control range of the first target temperature may be set such that the highest temperature of the melting point of the crystalline material used and the glass transition point of the amorphous material used is a lower-limit temperature and an upper-limit temperature is approximately 50°C higher than the lower-limit temperature. Similarly, the control range of the second target temperature may be set such that the lowest temperature of the crystallization temperature of the crystalline material used and the glass transition point of the amorphous material used is an upper-limit temperature and a lower-limit temperature is approximately 50°C lower than the upper-limit temperature.
- [0077] As an example, the temperature control sequence when a crystalline material A and an amorphous material B have such temperature characteristics (viscoelasticity characteristics) as illustrated in Fig. 11 will be described. The glass transition points of the materials A and B are T_{gA} and T_{gB} , the crystallization temperature of the material A is T_{cA} , the melting point of the material A is T_{mA} , and these temperatures are in the relation of $T_{gA} < T_{gB} < T_{cA} < T_{mA}$. This example corresponds to a case in which polypropylene (melting point: 160°C) which is a crystalline resin is used as the structure material A, and maltotetraose (glass transition point: 156°C) which is an amorphous material is used as the support material B.
- [0078] The particle-layer on the conveyance belt 11 is formed of the particle image of the material A and the particle image of the material B. In a state in which the upper surface of the shaped article on the stage 32 is in contact with the particle-layer, the particle-layer is maintained for a predetermined period while controlling the temperature within a temperature range between the lower-limit temperature (T_{mA}) and the upper-limit temperature ($T_{mA} + 50^{\circ}\text{C}$). By doing so, since both materials A and B are fused or softened, the entire particle-layer enters a fused state without causing a disorder (deformation or muddiness) of the particle images of different types of materials. The upper surface of the shaped article on the stage 32 being in contact with the particle-layer also enters the fused state in a similar manner. After that, in a state in which the fused particle-layer and the upper surface of the shaped article are in contact with each other, the particle-layer is maintained for a predetermined period within a temperature range between the lower-limit temperature ($T_{gA} - 50^{\circ}\text{C}$) and the upper-limit temperature (T_{gA}). By doing so, since both the fused materials A and B are solidified, the particle-layer is fixed (integrated) to the shaped article without causing a disorder (deformation or muddiness) of the particle images of different types of materials. After this series of temperature control sequences are executed, when the stage 32 is lowered, the shaped article is separated from the surface of the conveyance belt 11.

[0079] Moreover, when the crystallization temperature T_{cA} and the melting point T_{mA} of the material A and the glass transition point T_{gB} of the material B are in the relation of $T_{cA} < T_{mA} < T_{gB}$, the particle-layer is maintained for a predetermined period while controlling the temperature within a temperature range between the lower-limit temperature (T_{gB}) and the upper-limit temperature ($T_{gB} + 70^{\circ}\text{C}$), whereby both materials A and B are fused or softened. After that, in a state in which the fused particle-layer and the upper surface of the shaped article are in contact with each other, the particle-layer is maintained for a predetermined period within a temperature range between the lower-limit temperature ($T_{cA} - 50^{\circ}\text{C}$) and the upper-limit temperature (T_{cA}), whereby both materials A and B can be solidified.

[0080] With the configuration of the present embodiment described above, it is possible to obtain the same advantages as those of the first embodiment. In the present embodiment, although an example of combining two types of materials has been illustrated, the temperature control of the present embodiment can be applied to a combination of three or more types of materials.

[0081] <Fourth Embodiment>

Next, a three-dimensional shaping apparatus according to a fourth embodiment of the present invention will be described. In the fourth embodiment, a configuration in which parameters (a target temperature, a temperature control period, and the like) of the temperature control sequence are changed according to the type of a shaping material used in formation of the particle-layer in the layer forming unit U2 will be described.

[0082] Fig. 12A is an example of a parameter table stored in the storage portion of the control unit U1. In this table, the value of four parameters of a “softening temperature”, a “softening period”, a “solidification temperature”, and a “solidification period” are stored for each type of shaping materials. The softening temperature is a temperature (lower-limit value) required for softening (fusing) a material and is the melting point of a crystalline material and the glass transition point of an amorphous material. The softening period is the temperature control period of the first temperature control mode. Moreover, the solidification temperature is a temperature (upper-limit value) required for solidifying a material and is the crystallization temperature of a crystalline material and the glass transition point of an amorphous material. The solidification period is the temperature control period of the second temperature control mode.

[0083] The flow of a process of switching parameters according to the type of shaping materials will be described with reference to the flowchart of Fig. 13. The process of Fig. 13 may be executed only once when the three-dimensional shaping apparatus is activated or manufacturing of a three-dimensional shaped article starts. Alternatively,

when there is a possibility that the shaping material is changed in each layer, the process may be executed each time before the particle-layer is formed or stacked.

[0084] First, the control unit U1 (the stacking unit controller U13) acquires information indicating the type of the shaping materials used in the respective particle image forming portions 10 mounted in the layer forming unit U2 (step S1300). It is assumed that the type of the shaping material is set (registered) in advance by a user, and the information is stored in the storage portion of the control unit U1. Alternatively, a storage medium that stores the type of a shaping material may preferably be provided in a cartridge used in the particle image forming portion 10 and the type information of the shaping material may preferably be read from the storage medium. Moreover, the shape or structure of the cartridge may be changed for each type of the shaping material, and the type of the shaping material may be determined by detecting the shape or structure of the cartridge.

[0085] Subsequently, the control unit U1 reads parameters corresponding to the shaping materials obtained in step S1300 from the parameter table (step S1301). For example, when a material A is used as the structure material and a material B is used as the support material, the parameters corresponding to the materials A and B are read from the parameter table of Fig. 12A.

[0086] Subsequently, the control unit U1 determines the first target temperature used in the first temperature control mode based on the highest temperature of the softening temperatures of the shaping materials read in step S1301 (step S1302). A specific determination method is the same as that of the embodiments described above. Moreover, the control unit U1 sets the longest period of the softening periods of the shaping materials read in step S1301 as the temperature control period of the first temperature control mode (step S1303).

[0087] Subsequently, the control unit U1 determines the second target temperature used in the second temperature control mode based on the lowest temperature of the solidification temperatures of the shaping materials read in step S1301 (step S1304). A specific determination method is the same as that of the embodiments described above. Moreover, the control unit U1 sets the longest period of the solidification periods of the shaping materials read in step S1301 as the temperature control period of the second temperature control mode (step S1305).

[0088] By performing the above-described processes, the parameters (a target temperature, a temperature control period, and the like) of the temperature control sequence can be set to appropriate values according to the shaping material actually used for creation of the particle-layer. Moreover, the parameters are automatically updated when the shaping material used in the particle image forming portion 10 is changed. Thus, it is possible to provide a three-dimensional shaping apparatus which has an excellent degree of

freedom and extensibility and which can use various types of shaping materials having different characteristics.

[0089] The structure of the parameter table is not limited to that illustrated in Fig. 12A. For example, as illustrated in Fig. 12B, a table in which parameters such as a target temperature, a temperature control period, and the like are set for each combination of shaping materials may be used. In this case, the parameters corresponding to a combination of the shaping materials used in the layer forming unit U2 are read from the table. Moreover, in Figs. 12A and 12B, although two parameters of the temperature and the period are illustrated, other parameters may be added and the temperature parameter only may be used if the temperature control period is not changed.

[0090] <Fifth Embodiment>

Fig. 14 schematically illustrates an overall configuration of a three-dimensional shaping apparatus according to a fifth embodiment of the present invention. In the first embodiment (Fig. 1), the temperature of the fixed temperature control device 31 is controlled. However, in the fifth embodiment, the temperature control device 31 includes a first temperature controller 31A controlled to the first target temperature and a second temperature controller 31B controlled to the second target temperature. Hereinafter, the description of the same portions as those of the above-described embodiments will not be provided, and a configuration unique to the fifth embodiment only will be described.

[0091] As illustrated in Fig. 14, the temperature control device 31 of the present embodiment has a structure in which the first temperature controller 31A and the second temperature controller 31B are disposed in parallel, and the temperature control device 31 can be moved in a direction (the horizontal direction in the drawing) parallel to the stage surface by a moving mechanism 34. The moving mechanism 34 is configured as a linear actuator or the like.

[0092] When the particle-layer is conveyed and aligned at the stacking position by the conveyance belt 11, the control unit U1 raises the stage 32 to allow the stage surface or the upper surface of the three-dimensional shaped article on the stage to make contact with the particle-layer. In a state in which the first temperature controller 31A is maintained to the first target temperature and the second temperature controller 31B is maintained to the second target temperature, the temperature control device 31 is moved at a predetermined velocity along the belt surface by the moving mechanism 34. In this case, the temperature control device 31 is moved so that the particle-layer on the conveyance belt 11 first passes through the region of the first temperature controller 31A and then passes through the region of the second temperature controller 31B. In this way, similarly to the first embodiment, the entire particle-layer is softened at the first target temperature, and then, the entire particle-layer is solidified at the

second target temperature. After that, when the stage 32 is separated from the belt surface, the three-dimensional shaped article to which the particle-layer is fixed is separated from the belt surface.

[0093] With the configuration of the present embodiment described above, it is possible to obtain the same advantages as those of the first embodiment. Further, since the temperature controllers 31A and 31B controlled to different temperatures are moved, it is possible to decrease the size of the temperature control device.

[0094] <Sixth Embodiment>

Fig. 15 schematically illustrates an entire configuration of a three-dimensional shaping apparatus according to a sixth embodiment of the present invention. The stacking unit U3 according to the first to fifth embodiments is configured to raise the stage 32 in a stopping state of the conveyance belt 11 and performs stacking with the particle-layer sandwiched between the conveyance belt 11 and the stage 32. In contrast, the stacking unit U3 of the sixth embodiment is configured to stack the particle-layer while horizontally moving the stage 32 in the same direction as the conveyance belt 11. In the present specification, the stacking scheme used in the first to fifth embodiments will be referred to as “stop-and-stacking” and the stacking scheme used in the sixth embodiment will be referred to as “convey-and-stacking”. Hereinafter, the description of the same portions as those of the above-described embodiments will not be provided, and a configuration unique to the sixth embodiment only will be described.

[0095] As illustrated in Fig. 15, the stacking unit U3 of the present embodiment includes a moving mechanism 35 for moving the stage 32. The moving mechanism 35 can control at least two directions of an up-down direction (the direction vertical to the belt surface at the stacking position) and a horizontal direction (the direction parallel to a belt conveyance direction at the stacking position) and is configured as a biaxial linear actuator or the like. Moreover, the temperature control device 31 has a structure in which the first temperature controller 31A and the second temperature controller 31B are disposed in parallel similarly to the fifth embodiment.

[0096] The operation of a three-dimensional shaping apparatus of a convey-and-stacking scheme will be described. The stage 32 is in a standby state at a home position (the position indicated by a broken line in Fig. 15) until one particle-layer is formed by the layer forming unit U2 and is conveyed to the stacking position by the convey unit U4.

[0097] When the image detection sensor 13 detects a leading end of the particle-layer on the conveyance belt 11, the control unit U1 calculates the timing at which the leading end of the particle-layer arrives at the stacking position (the position of the roller 114) based on the detection result. Moreover, the control unit U1 controls the driving of the stage 32 so that the three-dimensional shaped article on the stage 32 enters the stacking

position at the same timing and at the same velocity as the particle-layer. It is assumed that the height position of the stage 32 is aligned at such a height that the upper surface of the three-dimensional shaped article makes exact contact with the particle-layer. In this way, the particle-layer is superimposed on the upper surface of the three-dimensional shaped article on the downstream side of the roller 114.

[0098] On the other hand, prior to arrival of the particle-layer, the first temperature controller 31A disposed on the upstream side is maintained to the first target temperature, and the second temperature controller 31B disposed on the downstream side is maintained to the second target temperature. When the conveyance belt 11 and the stage 32 are moved in a horizontal direction (the rightward direction in the drawing) at the same velocity, the three-dimensional shaped article and the particle-layer pass through the temperature controllers 31A and 31B in a closely attached state. In this case, the entire particle-layer is first softened when passing through the first temperature controller 31A, and subsequently, the entire particle-layer is solidified when passing through the second temperature controller 31B. In this way, the particle-layer is fixed to the upper surface of the three-dimensional shaped article. When the stage 32 passes through the roller 115 on the lowermost stream side of the stacking position, the three-dimensional shaped article is separated from the surface of the conveyance belt 11 and the stacking is completed. After stacking ends, the stage 32 moves to the home position and waits until the next particle-layer arrives.

[0099] With the configuration of the present embodiment described above, it is possible to obtain the same advantages as those of the above-described embodiments. Further, since stacking is performed while conveying the particle-layer, it is possible to improve the efficiency and the processing speed of the stacking process as compared to the stop-and-stacking scheme.

[0100] <Seventh Embodiment>

Fig. 16 schematically illustrates an entire configuration of a three-dimensional shaping apparatus according to a seventh embodiment of the present invention. In the above-described embodiments, the convey unit U4 includes one conveyance belt 11. In contrast, in the present embodiment, the convey unit U4 is configured to include a conveyance belt 11 (also referred to as a first belt) disposed close to the layer forming unit U2 and a conveyance belt 30 (also referred to as a second belt) disposed close to the stacking unit U3. In this configuration, a state in which the first and second belts 11 and 30 operate in synchronism in contact with each other and a state in which the first and second belts 11 and 30 operate independently by being separated from each other may be switched.

[0101] For example, by putting the two belts 11 and 30 in a normally separated state except when it is necessary to do otherwise, it is possible to prevent heat of the stacking unit

U3 from being transmitted to the layer forming unit U2 and to perform image formation stably. Alternatively, for example, by putting the two belts 11 and 30 in a separated state and performing the layer forming process and the stacking process in parallel, it is possible to shorten the time required for manufacturing the three-dimensional shaped article.

[0102] The configuration of the convey unit U4 of the present embodiment may be combined with the three-dimensional shaping apparatuses of the second to sixth embodiments. As an example, Fig. 17 illustrates an example in which the convey unit U4 of the three-dimensional shaping apparatus of the convey-and-stacking scheme of the sixth embodiment includes the first belt 11 and the second belt 30.

[0103] <Others>

The configuration of the above-described embodiments illustrate specific examples of the present invention and are not intended to limit the scope of the present invention. Various specific configurations may occur without departing from the technical scope of the present invention. Moreover, the configurations and operations (control) of the respective embodiments may be combined with each other unless such combinations incur technical contradictions.

[0104] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2014-242141, filed on November 28, 2014 and Japanese Patent Application No. 2015-215979, filed on November 2, 2015, which are hereby incorporated by reference herein in their entirety.

Claims

- [Claim 1] A three-dimensional shaping apparatus that manufactures a three-dimensional shaped article by stacking materials, comprising:
a plurality of particle image forming units that form particle images, using different types of particle materials, respectively;
a layer bearing member that bears a particle-layer which is one layer of materials formed by combining a plurality of particle images formed by the plurality of particle image forming units; and
a stacking unit that stacks the particle-layer, borne on the layer bearing member, on a three-dimensional shaped article under manufacturing, wherein
the stacking unit includes:
a stage that holds the three-dimensional shaped article under manufacturing; and
a temperature control unit that controls a temperature of the particle-layer borne on the layer bearing member, and
in a state in which the three-dimensional shaped article under manufacturing held on the stage and the particle-layer borne on the layer bearing member are in contact with each other, after the temperature is controlled to a first target temperature by the temperature control unit, the temperature is controlled to a second target temperature lower than the first target temperature, whereby the particle-layer is fixed to the three-dimensional shaped article under manufacturing.
- [Claim 2] The three-dimensional shaping apparatus according to claim 1, wherein the stacking unit controls the temperature to the second target temperature by means of the temperature control unit and then separates the three-dimensional shaped article, to which the particle-layer is fixed, from the layer bearing member.
- [Claim 3] The three-dimensional shaping apparatus according to claim 1 or 2, wherein
the first target temperature is a temperature at which all of a plurality of types of particle materials that form the particle-layer are softened, and
the second target temperature is a temperature at which all of the plurality of types of particle materials that form the particle-layer are solidified.
- [Claim 4] The three-dimensional shaping apparatus according to claim 3, wherein the particle-layer is formed of a plurality of types of amorphous

materials,

the first target temperature is set to a value equal to or higher than a highest temperature of glass transition points of the amorphous materials, and

the second target temperature is set to a value equal to or lower than a lowest temperature of glass transition points of the amorphous materials.

[Claim 5] The three-dimensional shaping apparatus according to claim 3, wherein the particle-layer is formed of a plurality of types of crystalline materials,

the first target temperature is set to a value equal to or higher than a highest temperature of melting points of the crystalline materials, and the second target temperature is set to a value equal to or lower than a lowest temperature of crystallization temperatures of the crystalline materials.

[Claim 6] The three-dimensional shaping apparatus according to claim 3, wherein the particle-layer is formed of a crystalline material and an amorphous material,

the first target temperature is set to a value equal to or higher than a highest temperature of a melting point of the crystalline material and a glass transition point of the amorphous material, and

the second target temperature is set to a value equal to or lower than a lowest temperature of a crystallization temperature of the crystalline material and a glass transition point of the amorphous material.

[Claim 7] The three-dimensional shaping apparatus according to any one of claims 1 to 6, further comprising:

a control unit that changes the first target temperature and the second target temperature according to the types of particle materials used in formation of the particle-layer.

[Claim 8] The three-dimensional shaping apparatus according to any one of claims 1 to 7, wherein

the temperature control unit includes a first temperature controller that is controlled to the first target temperature and a second temperature controller that is controlled to the second target temperature, and the stacking unit moves the temperature control unit or the stage so that the three-dimensional shaped article under manufacturing held on the stage and the particle-layer borne on the layer bearing member, which are in a state of being in contact with each other, pass through the first

temperature controller and then pass through the second temperature controller, thereby fixing the particle-layer to the three-dimensional shaped article under manufacturing.

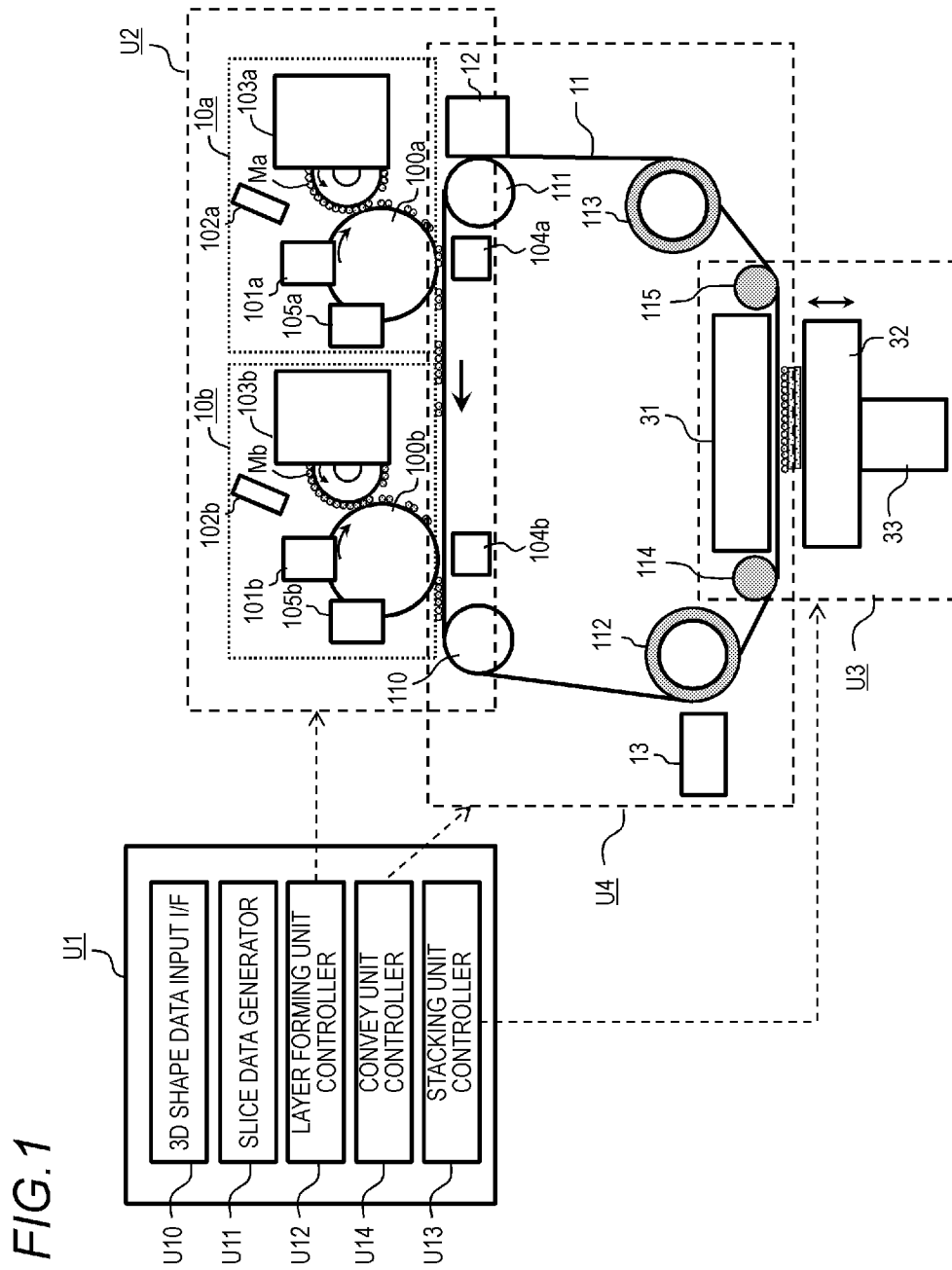
[Claim 9] The three-dimensional shaping apparatus according to any one of claims 1 to 8, wherein
the different types of particle materials include a structure material that forms the three-dimensional shaped article and a support material that forms a support portion that supports an overhanging portion of the three-dimensional shaped article.

[Claim 10] The three-dimensional shaping apparatus according to any one of claims 1 to 9, wherein
the particle image forming unit forms the particle image by an electrophotography process.

[Claim 11] A three-dimensional shaped article manufacturing method of manufacturing a three-dimensional shaped article by stacking materials, the method comprising:
causing a plurality of particle image forming units to form particle images using different types of particle materials;
causing the plurality of particle image forming units to sequentially transfer the particle images to a layer bearing member, thereby forming a particle-layer which is one layer of materials;
softening the particle-layer by implementing temperature control to a first target temperature in a state in which the particle-layer borne on the layer bearing member is in contact with a three-dimensional shaped article under manufacturing; and
solidifying the particle-layer by implementing temperature control to a second target temperature lower than the first target temperature and fixing the particle-layer to the three-dimensional shaped article under manufacturing.

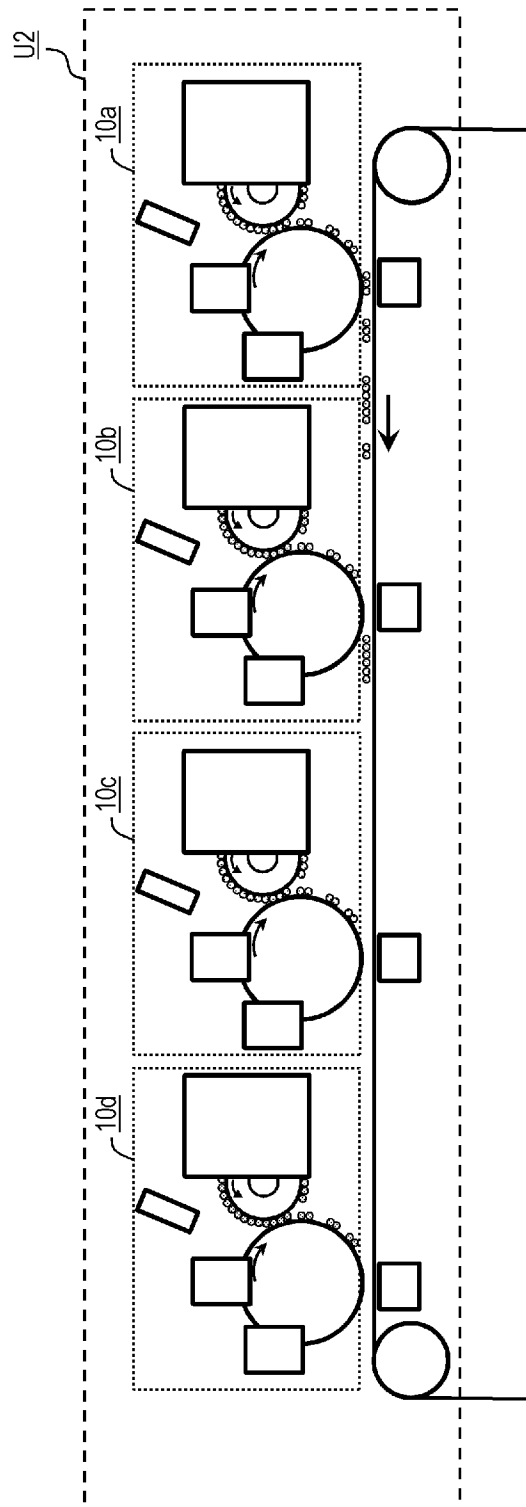
[Claim 12] The three-dimensional shaped article manufacturing method according to claim 11, wherein
the particle image forming unit forms the particle image by an electrophotography process.

[Fig. 1]



[Fig. 2]

FIG. 2



[Fig. 3]

FIG. 3A

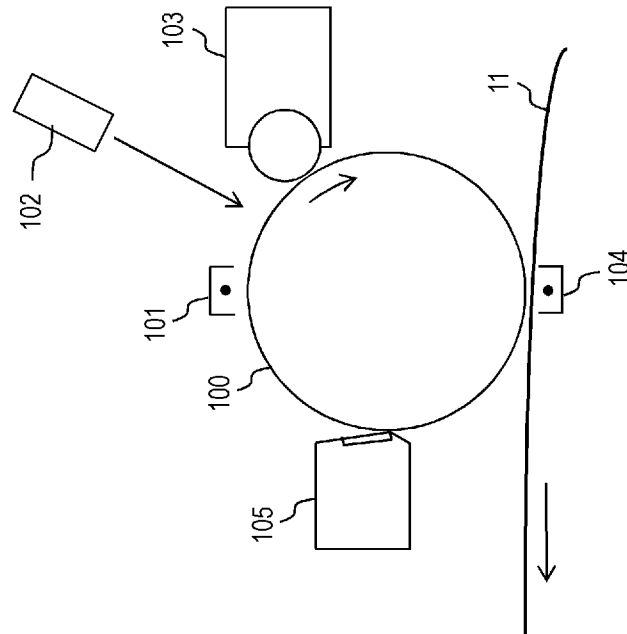
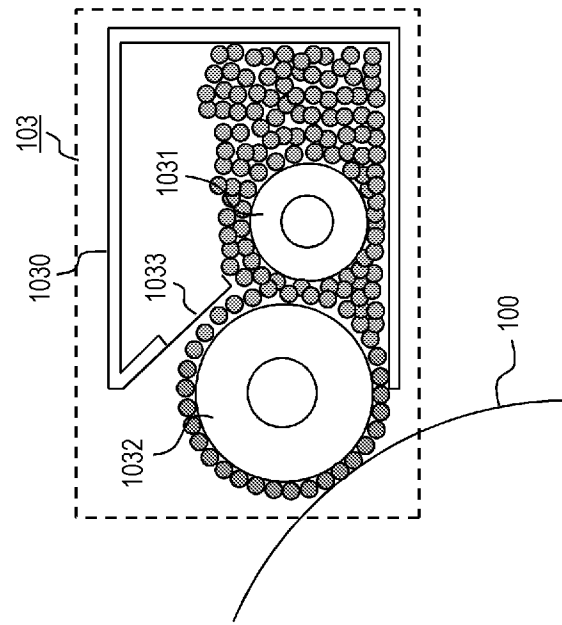
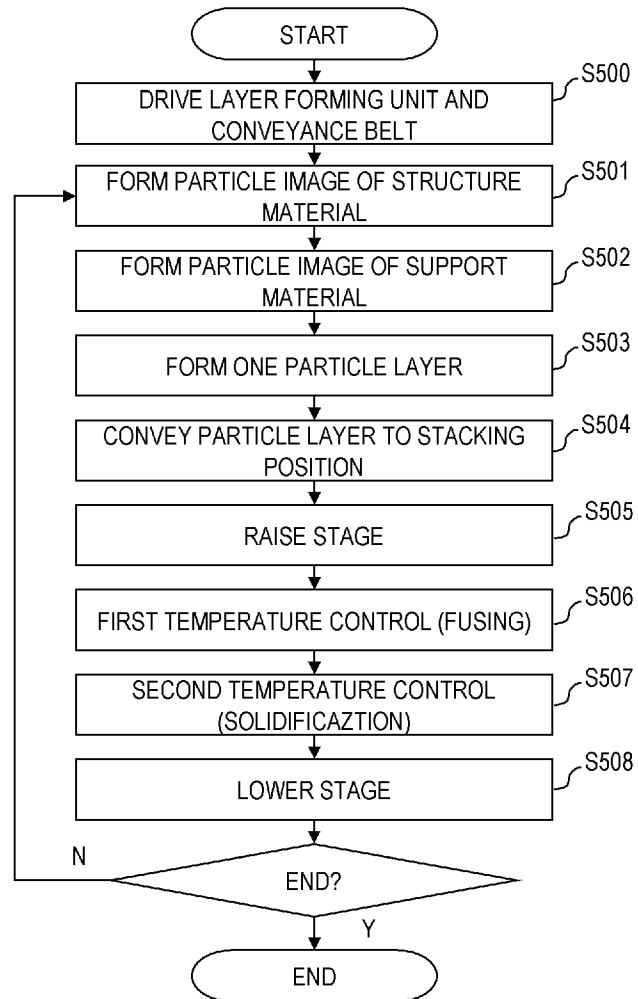


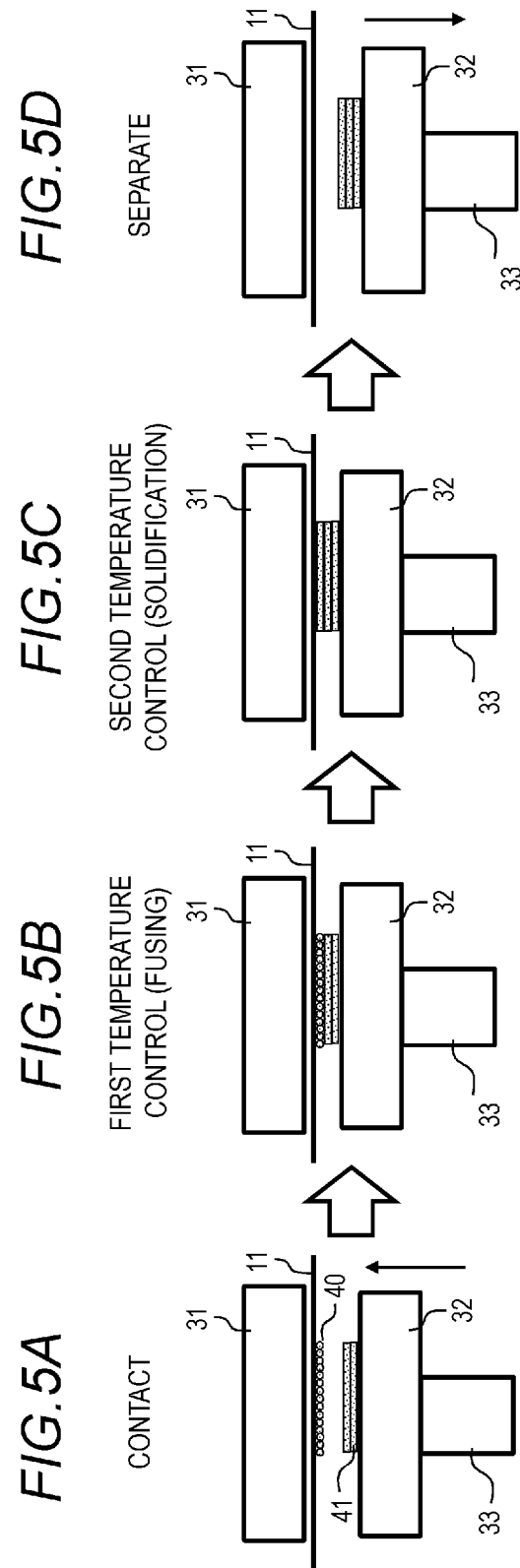
FIG. 3B



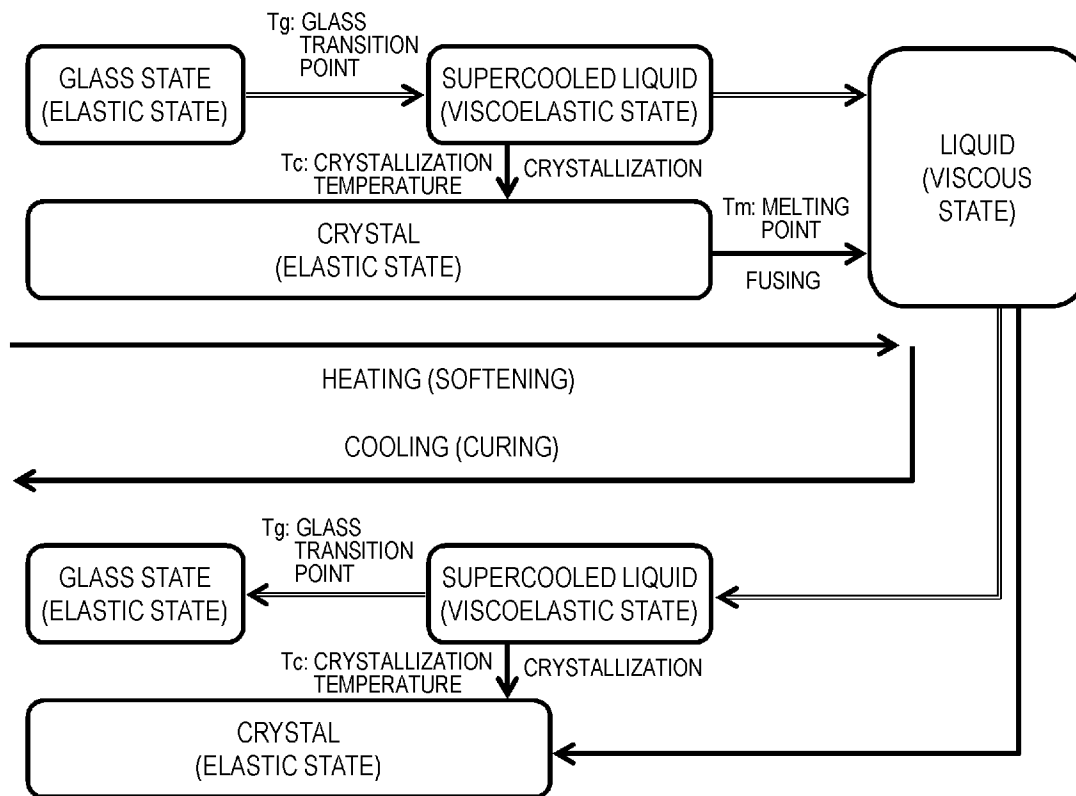
[Fig. 4]

FIG.4

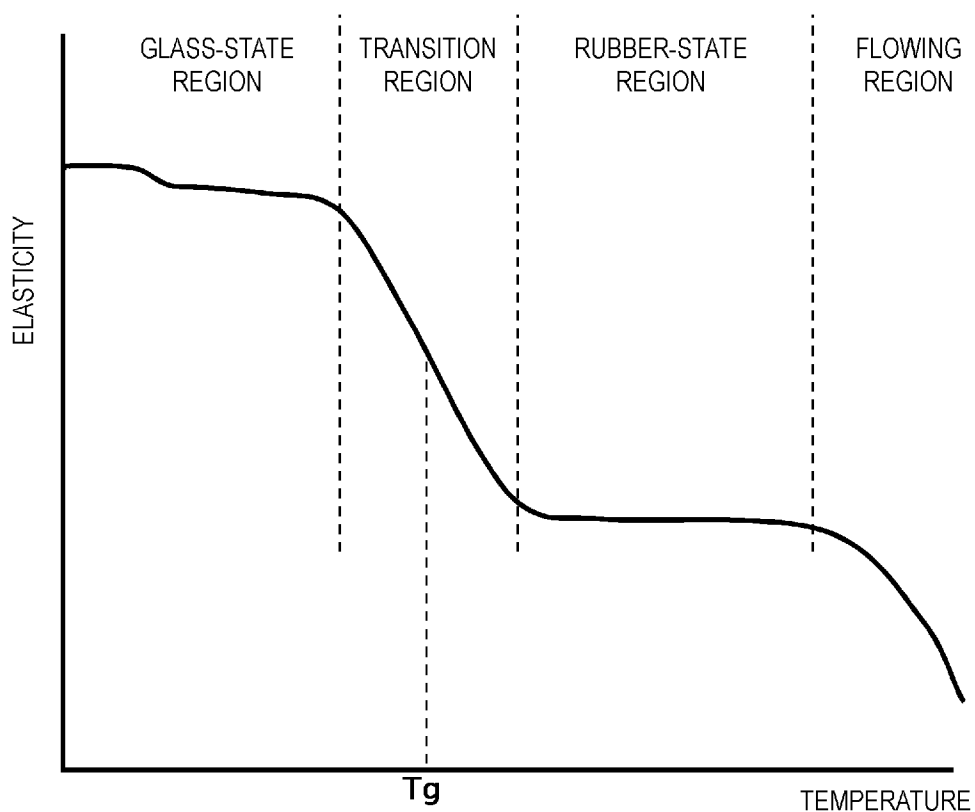
[Fig. 5]



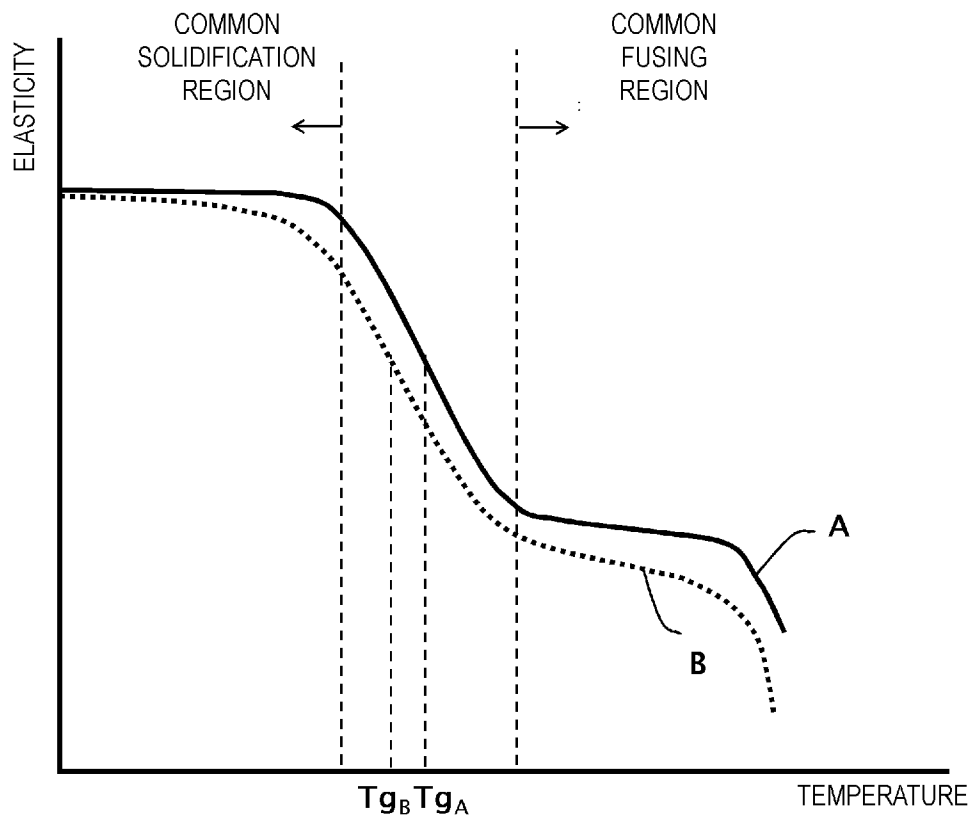
[Fig. 6]

FIG. 6

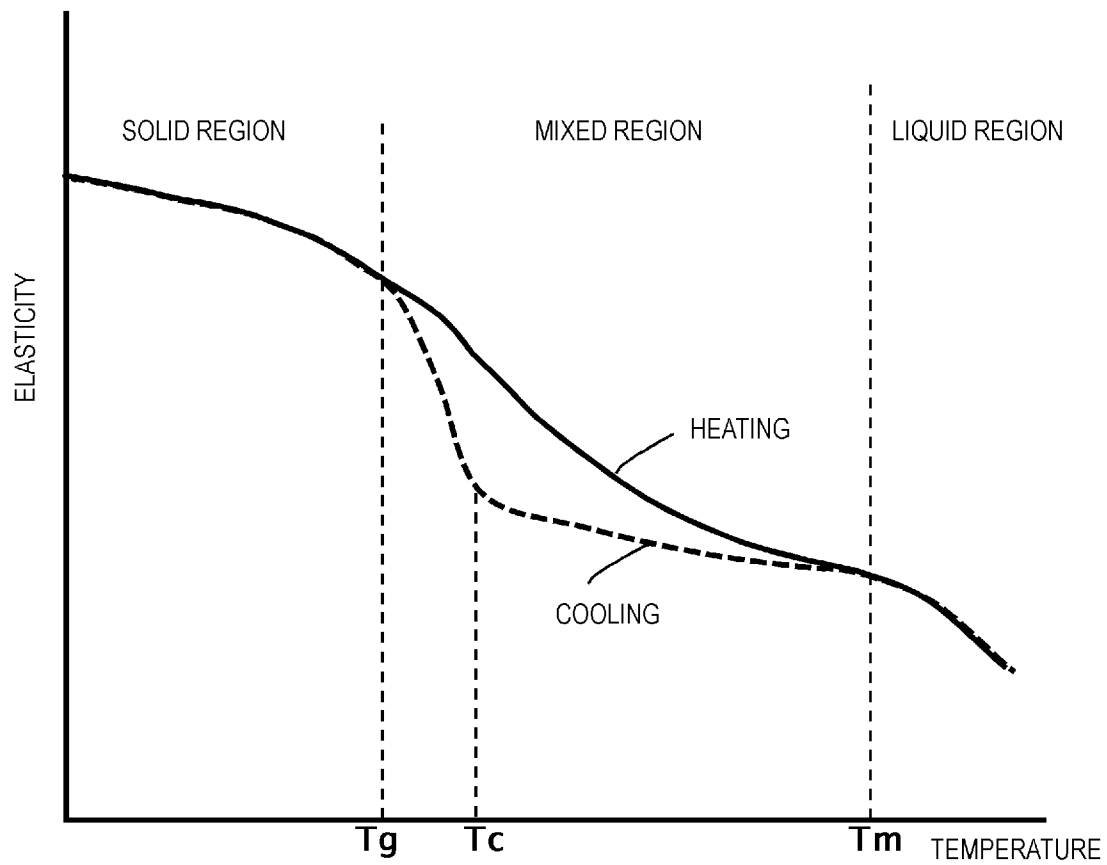
[Fig. 7]

FIG. 7

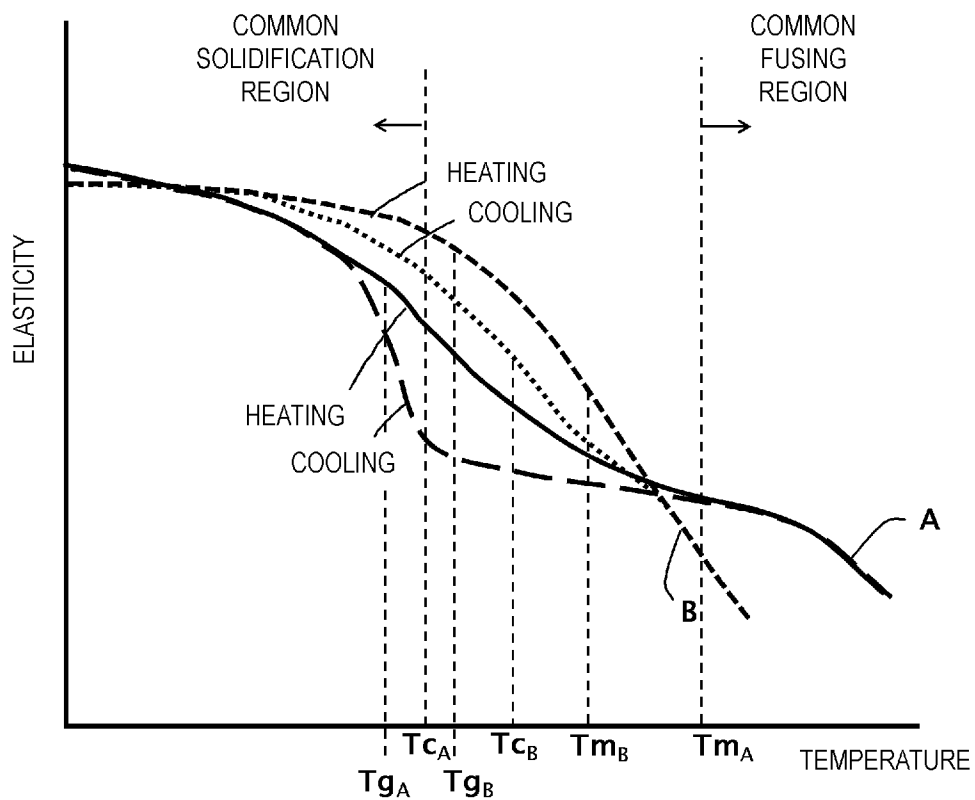
[Fig. 8]

FIG.8

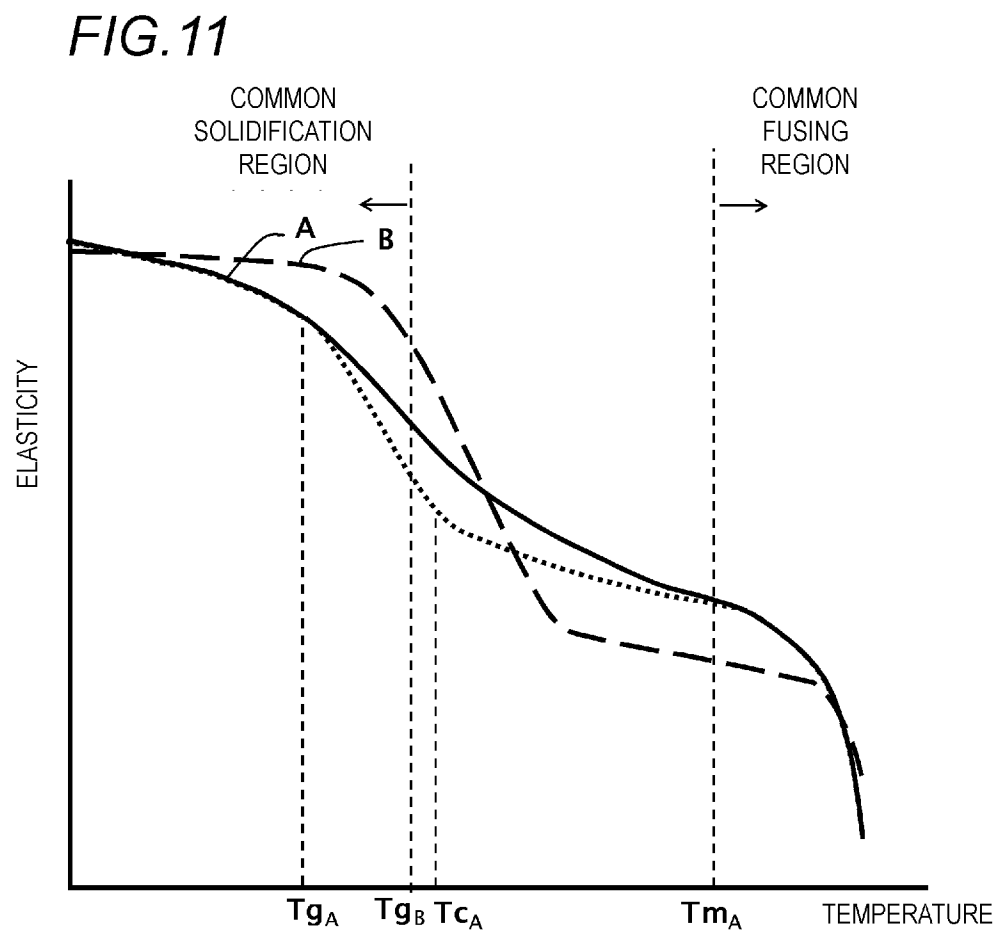
[Fig. 9]

FIG.9

[Fig. 10]

FIG.10

[Fig. 11]



[Fig. 12]

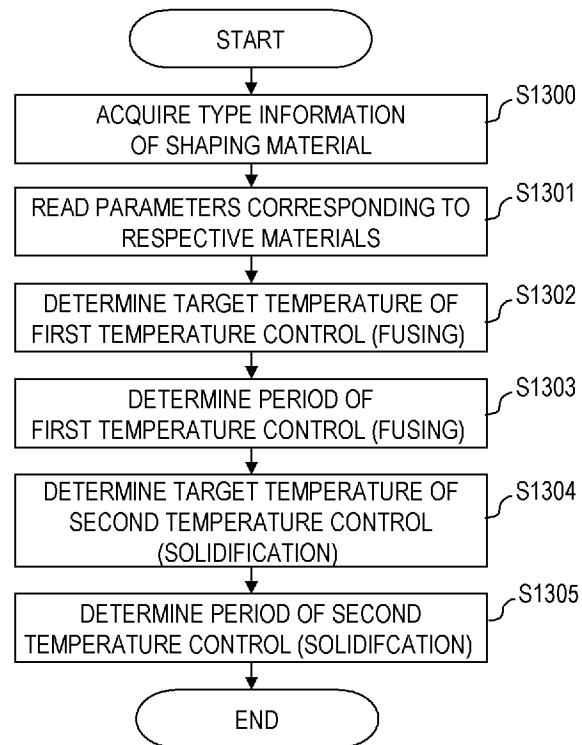
FIG. 12A

	SOFTENING TEMPERATURE (°C)	SOFTENING PERIOD (SEC)	SOLIDIFICATION TEMPERATURE (°C)	SOLIDIFICATION PERIOD (SEC)
MATERIAL A	XXX	XXX	XXX	XXX
MATERIAL B	XXX	XXX	XXX	XXX
MATERIAL C	XXX	XXX	XXX	XXX
...	...	...	...	...

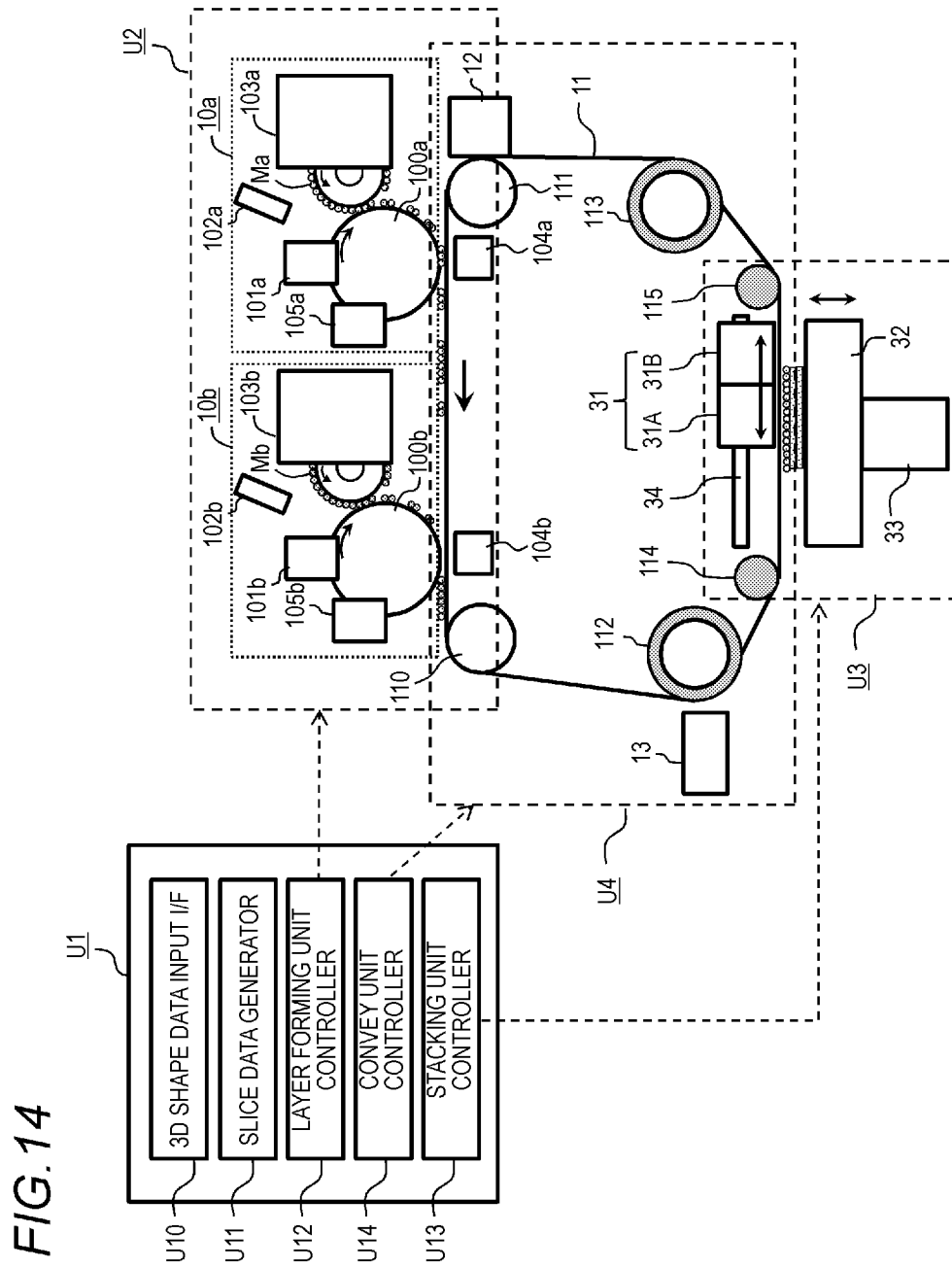
FIG. 12B

	FIRST TEMPERATURE CONTROL (SOFTENING)		SECOND TEMPERATURE CONTROL (SOLIDIFICATION)	
	TARGET TEMPERATURE (°C)	TEMPERATURE CONTROL PERIOD (SEC)	TARGET TEMPERATURE (°C)	TEMPERATURE CONTROL PERIOD (SEC)
MATERIAL A,B	XXX	XXX	XXX	XXX
MATERIAL A,C	XXX	XXX	XXX	XXX
MATERIAL D,E,F	XXX	XXX	XXX	XXX
...	...	...	...	...

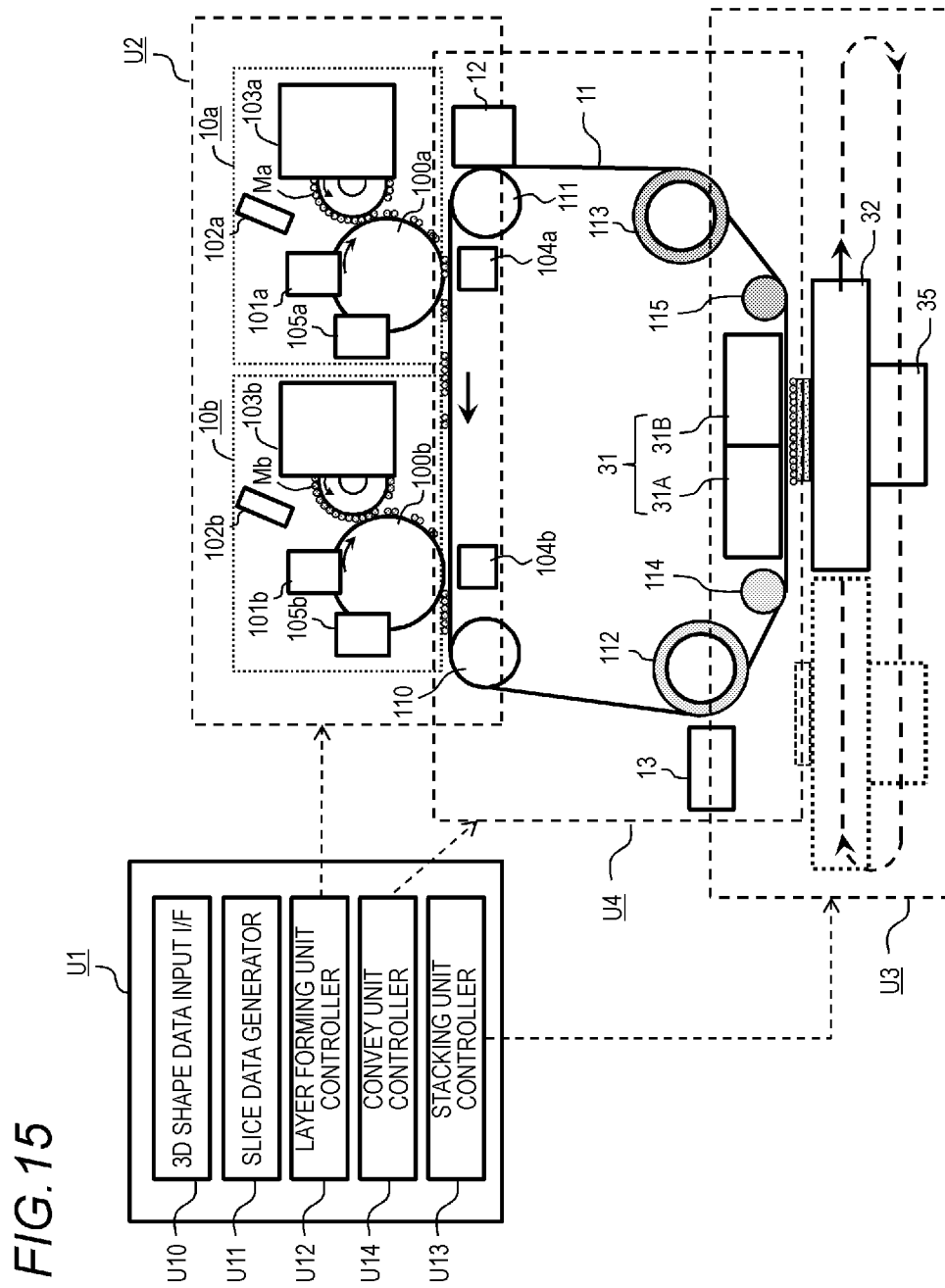
[Fig. 13]

FIG. 13

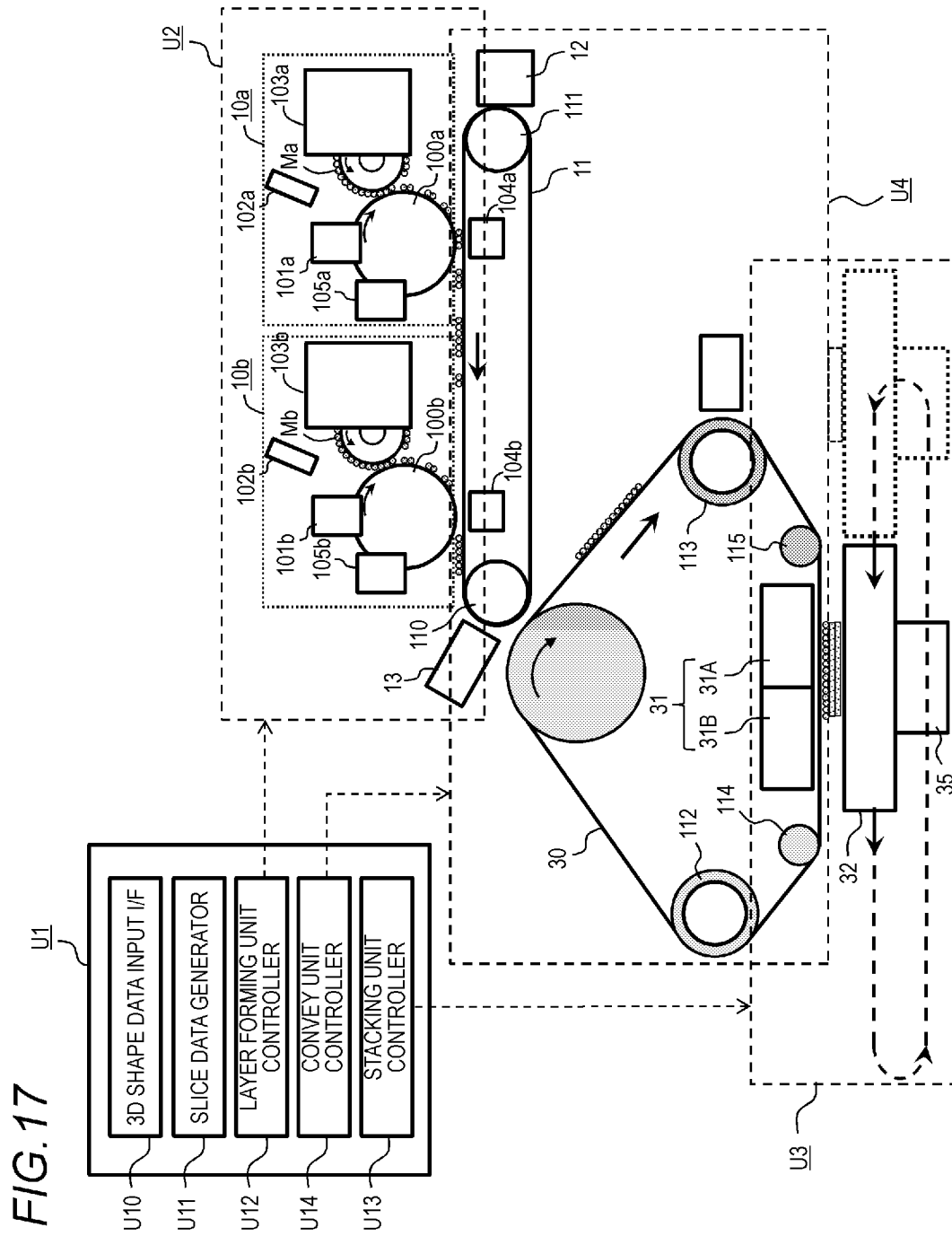
[Fig. 14]



[Fig. 15]



[Fig. 17]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2015/005843

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C67/00 B33Y10/00 B33Y30/00 B33Y50/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G03G B29C B33Y

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/186558 A1 (COMB JAMES W [US] ET AL) 25 July 2013 (2013-07-25) figures 2A, 4A-4C page 1, paragraph [0008] page 3, paragraph [0040] page 4, paragraph [0058] page 5, paragraph [0064] page 6, paragraph [0072] page 7, paragraphs [0084], [0085], [0087]	1-12
A	WO 95/26871 A1 (GREND A EDWARD P [US]) 12 October 1995 (1995-10-12) cited in the application figure 4 page 18, lines 8-20	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

9 February 2016

Date of mailing of the international search report

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Authorized officer

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/JP2015/005843

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013186558	A1	25-07-2013	NONE

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