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(71) Applicant: **CANON KABUSHIKI KAISHA** [JP/JP]; 30-2, Shimomaruko 3-chome, Ohta-ku, Tokyo, 1468501 (JP).

(72) Inventors: **USAMI, Hirokazu**; C/O CANON KABUSHIKI KAISHA, 30-2,Shimomaruko 3-chome, Ohta-ku, Tokyo, 1468501 (JP). **TADA, Tatsuya**; C/O CANON KABUSHIKI KAISHA, 30-2,Shimomaruko 3-chome, Ohta-ku, Tokyo, 1468501 (JP). **KARASHIMA, Kenji**; C/O CANON KABUSHIKI KAISHA, 30-2,Shimomaruko 3-chome, Ohta-ku, Tokyo, 1468501 (JP). **KASE, Takashi**; C/O CANON KABUSHIKI KAISHA, 30-2,Shimomaruko 3-chome, Ohta-ku, Tokyo, 1468501 (JP). **YAMANAKA, Satoru**; C/O CANON KABUSHIKI KAISHA, 30-2,Shimomaruko 3-chome, Ohta-ku, Tokyo, 1468501 (JP). **WAKABAYASHI, Yuji**; C/O CANON KABUSHIKI KAISHA, 30-2,Shimomaruko 3-chome, Ohta-ku, Tokyo, 1468501 (JP).

(74) Agents: **ABE, Takuma** et al.; C/O CANON KABUSHIKI KAISHA, 30-2,Shimomaruko 3-chome, Ohta-ku, Tokyo, 1468501 (JP).

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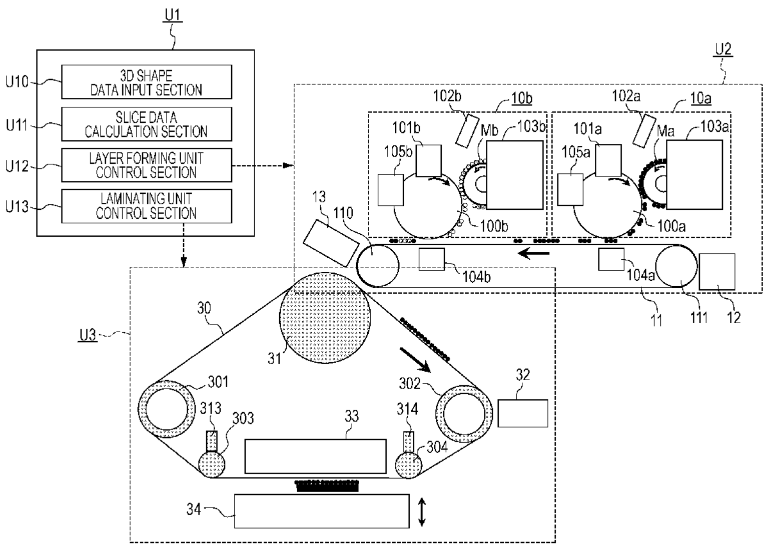
(54) Title: THREE-DIMENSIONAL MODELING APPARATUS, THREE-DIMENSIONAL MODELING METHOD, AND ARTICLE MANUFACTURING METHOD



(57) Abstract: A three-dimensional modeling apparatus used to produce a three-dimensional object includes a layer forming unit (U2) configured to form a layer on a conveying member (11, 30), and a laminating unit (U3) configured to laminate, at a lamination position, the layer having been conveyed by the conveying member (11, 30) to the lamination position. The laminating unit (U3) includes a changing device (313, 314) configured to change an inclination or a shape of a surface of the conveying member (30) at the lamination position.

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— *with amended claims (Art. 19(1))*

Description

Title of Invention: THREE-DIMENSIONAL MODELING APPARATUS, THREE-DIMENSIONAL MODELING METHOD, AND ARTICLE MANUFACTURING METHOD

Technical Field

[0001] The present invention relates to a three-dimensional modeling apparatus, a three-dimensional modeling method, and an article manufacturing method.

Background Art

[0002] Recently, attention has been focused on three-dimensional modeling techniques called, for example, additive manufacturing (AM), 3D printers, or rapid prototyping (RP) (in this Description, those techniques are collectively referred to as the AM technique). The AM technique is a technique of modeling a three-dimensional object through the steps of slicing 3D shape data of a three-dimensional object to generate plural sets of slice shape data, forming each layer with a modeling material in accordance with each set of slide shape data, successively laminating layers of the modeling material, and fixating the laminated layers. After beginning with development of a practical product in 1980s as an apparatus for carrying out an optical modeling method using a photo-curable resin, various techniques have been developed so far. At the present, the following seven modeling techniques are mainly classified by ASTM (American Society for Testing and Materials).

(1) Vat photopolymerization (VP): optical modeling method

(2) Powder bed fusion (PBF): laser sintering method, laser fusion method, electron-beam fusion method, etc.

(3) Binder jetting (BJ)

(4) Material extrusion (ME): fusion deposition modeling (FDM)

(5) Material jetting (MJ)

(6) Directed energy deposition (DED)

(7) Sheet lamination (SL)

[0003] The AM technique has simplicity in not requiring molds or dies, and convenience in a capability of molding a complicated shape. Therefore, the AM technique is used in fabricating a trial product (prototype) to check whether the operation or the shape of a part is good or not, welfare equipment, such as a hearing aid, which is a single item or a small lot item, dental modeled objects for personal uses (such as parts for orthodontic therapy, artificial teeth, and crowns), finally modeled objects of airplane parts, etc. Furthermore, because the AM technique makes it possible to fabricate not only parts having complicated shapes, which cannot be fabricated using molds, but also parts being sophisticated in design, which take a lot of time and labor, the AM technique is further used in fabricating parts and modeled objects, which are difficult to fabricate by the related-art processing methods, and finally modeled products of clothing ornaments having high aesthetics, etc.

[0004] However, because the AM technique is a method of additively laminating the material layer by layer, it is known that, from the viewpoint of productivity, the AM technique takes a longer time to fabricate one three-dimensional object than the prior art technique that produces objects having the same shape in a large amount.

[0005] Furthermore, when layers of structural materials are laminated successively in fabricating a modeled object with the AM technique, a support portion for supporting a layer needs to be formed in addition to a modeling material portion at the same time in such a manner that an overlying layer will not come into a partly floating state. The support portion has to be removed after the end of modeling steps. A working time necessary to remove the support portion is also added to a total time to manufacture the finally modeled object. Thus, it is further known that, in the AM technique of the type taking a time to remove the support portion, productivity is further reduced in comparison with other types of AM techniques. Here, the term "structural material" implies a material of the finally modeled object. A material of the support portion is called a support material, and the structural material and the support material are called together a modeling material.

[0006] Moreover, it is known that, in the AM technique, because the types of usable materials are limited, materials necessary for achieving desired characteristics regarding mechanical strength, heat resistance, and texture of the additive-manufactured object cannot be used freely.

[0007] Three-dimensional modeling apparatuses of sheet lamination type are also proposed (Patent Literatures (PTL) 1 to 3).

Citation List

Patent Literature

[0008] PTL 1: U.S. Patent No. 5088047

PTL 2: PCT Japanese Translation Patent Publication No. 8-511217

PTL 3: Japanese Patent Laid-Open No. 10-207194

PTL 4: PCT Japanese Translation Patent Publication No. 2014-533210

PTL 5: Japanese Patent Laid-Open No. 2014-162009

PTL 6: Japanese Patent Laid-Open No. 2013-140214

Summary of Invention

Technical Problem

[0009] In PTLs 1 to 3, a conveying member (transfer belt) and a stage are brought into an indirectly contacted state with a layer interposed between them. Thereafter, the layer is laminated on the stage by moving the conveying member and the stage away from each other. However, when the conveying member and the stage are moved away from each other, the layer may be firmly stuck to the conveying member and the layer may be disordered in some cases. The disorder of the layer may lead to a possibility that accuracy or strength of a three-dimensional object is reduced.

[0010] The present invention provides a three-dimensional modeling apparatus that can suppress the layer from being disordered when the conveying member and the stage are moved away from each other.

[0011] PTLs 4 to 6 disclose three-dimensional modeling apparatuses in which the layer is separated from the conveying member with the aid of the curvature of the conveying member.

[0012] According to one aspect of the present invention, there is provided a three-dimensional modeling apparatus used to model a three-dimensional object, the apparatus including a layer forming unit configured to form a layer on a conveying member, and a laminating unit configured to laminate, at a lamination position, the layer having been conveyed to the lamination position by the conveying member, wherein the laminating unit includes a changing device configured to change an inclination or a shape of a surface of the conveying member at the lamination position.

[0013] Further features of the present invention will become apparent from the following description of an exemplary embodiment with reference to the attached drawings.

Brief Description of Drawings

[0014] [fig.1]Fig. 1 is a schematic diagram illustrating an overall configuration of a three-dimensional modeling apparatus according to a first embodiment.

[fig.2]Fig. 2 is a schematic view of a layer forming unit.

[fig.3A]Fig. 3A illustrates a configuration of a particle image forming section.

[fig.3B]Fig. 3B illustrates a configuration of a developing apparatus.

[fig.4A]Fig. 4A is an illustration referenced to explain the reason why particle layers are to be formed such that the particle images will not overlap with each other.

[fig.4B]Fig. 4B is an illustration referenced to explain the reason why particle layers are to be formed such that the particle images will not overlap with each other.

[fig.5]Fig. 5 is a flowchart representing an operation sequence of the three-dimensional modeling apparatus according to the first embodiment.

[fig.6]Fig. 6 is an enlarged perspective view of the surroundings of a lamination position in the three-dimensional modeling apparatus according to the first embodiment.

[fig.7]Fig. 7 is an enlarged perspective view of the surroundings of a lamination

position in a three-dimensional modeling apparatus according to a second embodiment.
[fig.8]Fig. 8 is a schematic diagram illustrating an overall configuration of a three-dimensional modeling apparatus according to a third embodiment.
[fig.9]Fig. 9 is an enlarged perspective view of the surroundings of a lamination position in the three-dimensional modeling apparatus according to the third embodiment.
[fig.10]Fig. 10 is an enlarged perspective view of the surroundings of a lamination position in a three-dimensional modeling apparatus according to a fourth embodiment.
[fig.11]Fig. 11 is a schematic diagram illustrating an overall configuration of a three-dimensional modeling apparatus according to a fifth embodiment.
[fig.12]Fig. 12 is an enlarged perspective view of the surroundings of a sheet forming position in the three-dimensional modeling apparatus according to the fifth embodiment.
[fig.13]Fig. 13 is a schematic diagram illustrating an overall configuration of a three-dimensional modeling apparatus according to a sixth embodiment.
[fig.14]Fig. 14 is an enlarged perspective view of the surroundings of a lamination position in the three-dimensional modeling apparatus according to the sixth embodiment.

Description of Embodiments

[0015] Embodiments of the present invention will be described below by way of example with reference to the drawings. It is, however, to be noted that not only dimensions, materials, shapes, relative positional relations, etc. of individual members, but also procedures, control parameters, target values in various types of control, which are described in the following embodiments, are not intended to limit the scope of the present invention thereto unless otherwise specified.

First Embodiment

[0016]

Overall Configuration of Three-Dimensional Modeling Apparatus

[0017] An overall configuration of a three-dimensional modeling apparatus according to a first embodiment of the present invention is described with reference to Fig. 1. Fig. 1 is a schematic diagram illustrating the overall configuration of a three-dimensional modeling apparatus according to a first embodiment.

[0018] The three-dimensional modeling apparatus of this embodiment is constituted as an AM (Additive Manufacturing) system of the type of modeling a three-dimensional object by laminating (additive-forming) layers in each of which a particulate material is two-dimensionally arrayed. The three-dimensional modeling apparatus is also called, e.g., a 3D printer, an RP (Rapid Prototyping) system.

[0019] As illustrated in Fig. 1, the three-dimensional modeling apparatus mainly includes a control unit U1, a layer forming unit (also called an image forming unit) U2, and a laminating unit U3. The control unit U1 is configured to execute, e.g., not only a process of generating slice data (section data) of plural layers from 3D shape data of a modeling object, but also control of individual sections of the three-dimensional modeling apparatus. The layer forming unit U2 is configured to form a particle layer made of a particulate material by utilizing an electrophotographic process. The laminating unit U3 is configured to model a three-dimensional object by successively laminating the plurality of particle layers each of which has been formed in the layer forming unit U2, and by fixating the laminated particle layers.

[0020] The above-mentioned units U1 to U3 may have different housings, or they may be disposed in a single housing. The configuration of the units U1 to U3 being separately disposed in different housings is advantageous in that the units can be easily combined or replaced depending on, for example, the use of the three-dimensional modeling apparatus, the performance demanded, materials to be used, an installation space, and the occurrence of a failure, and that a degree of freedom and convenience in configuration of the apparatus are increased. On the other hand, the configuration of all the units being disposed in a single housing is advantageous in reducing the size of the entire apparatus and realizing reduction of the cost. The unit configuration of Fig. 1 is merely illustrative, and other configurations may be optionally adopted.

Control Unit

[0021] A configuration of the control unit U1 is described. As illustrated in Fig. 1, the control unit U1 includes, e.g., a 3D shape data input section U10, a slice data calculation section U11, a layer forming unit control section U12, and a laminating unit control section U13 in terms of functions.

[0022] The 3D shape data input section U10 has the function of receiving 3D shape data of the modeling object from an external device (e.g., a personal computer). The 3D shape data can be given as data that is generated and output by 3D CAD, a 3D modeler, or a 3D scanner, for example. The file format of the 3D shape data is freely selected, but, for example, the STL (StereoLithography) file format can be preferably used.

[0023] The slice data calculation section U11 has the function of slicing the modeling object, which is expressed by the 3D shape data, at a predetermined pitch, calculating a section shape of each layer, and generating image data (also called slice data) that is used in the layer forming unit U2 to form an image on the basis of the calculated section shape. The slice data calculation section U11 further has the function of analyzing the 3D shape data or the slice data of upper and lower layers, determining whether an overhang portion (or a floating portion) is present, and adding an image for a support material to the slice data if required.

[0024] Though described later in detail, the layer forming unit U2 in this embodiment is able to perform image formation using plural types of materials. Thus, the slice data is generated as data corresponding to an image to be formed of each material. On that occasion, positions and shapes of images expressed by different sets of slice data are preferably adjusted such that the images to be formed of different materials will not overlap with each other. The reason is that, if the images are overlapped with each other, a variation would occur in thickness of the particle layer, and dimensional accuracy of the modeled three-dimensional object would degrade. The file format of the slice data may be, for example, a multi-value image data (each value representing the type of material) or multi-plane image data (each plane representing the type of material).

[0025] The layer forming unit control section U12 has the function of controlling a layer forming process in the layer forming unit U2 in accordance with the slice data generated in the slice data calculation section U11. The laminating unit control section U13 further has the function of controlling a lamination process in the laminating unit U13. Details of practical control in the individual units are described later.

[0026] Though not illustrated, the control unit U1 further includes an operating section, a display section, and a storage section. The operating section has the function of receiving an instruction from a user. For example, instructions regarding power on/off and various settings and operations in the apparatus can be entered through the operating section. The display section has the function of presenting information to the user. For example, various setting screens, error messages, operation statuses, etc. can be presented through the display section. The storage section has the function of storing the 3D shape data, the slice data, various setting values, etc.

[0027] The control unit U1 can be constituted, in terms of hardware, by a computer including a CPU (central processing unit), a memory, auxiliary storages (e.g., a hard disk and a flash memory), an input device, a display device, and various I/F's. The above-described functions U10 to U13 are realized by the CPU that reads programs stored in, e.g., the auxiliary storages, executes the programs, and controls the associated devices as required. It is to be noted that a part or the whole of the above-described functions may be constituted by one or more circuits, such as ASIC and FPGA, or may be executed by another computer with the use of cloud computing, grid computing, or other adapted techniques.

Layer Forming Unit

[0028] A configuration of the layer forming unit U2 will be described below. The layer forming unit U2 is configured to form the particle layer made of the particulate material by utilizing an electrophotographic process. Herein, the term "electrophotographic process" implies a series of processes of uniformly charging a photosensitive member (image bearing member), exposing the charged photosensitive member (image bearing member) in accordance with image information, and forming an electrostatic latent image corresponding to the image information on the photosensitive member. The electrophotographic process further includes a continued series of processes of attaching developer particles to the electrostatic latent image, and forming a developer image on the photosensitive member, thereby forming a desired image on the photosensitive member. The principle of the electrophotographic process is in common to that used in a 2D printer, such as a copying machine. In the three-dimensional modeling apparatus, however, because a particulate material (modeling material) having a particle diameter larger than that of toner by one order of magnitude or more is used, process control and component structures in the 2D printer cannot be used as they are in some cases. In this embodiment, the particle diameter of the modeling material can be optionally selected.

[0029] As illustrated in Fig. 1, the layer forming unit U2 includes a first particle image forming section 10a, a second particle image forming section 10b, an intermediate bearing and conveying belt 11, a belt cleaning apparatus 12, and an image sensor 13. The first particle image forming section 10a is configured to form a particle image by employing a first particulate material (modeling material) Ma. The first particle image forming section 10a includes an image bearing member (photosensitive member) 100a, a charging apparatus 101a that charges the image bearing member 100a, an exposure apparatus 102a that exposes the image bearing member 100a, and a developing apparatus 103a that develops an electrostatic latent image with the particulate material Ma and forms a particle image. The first particle image forming section 10a further includes a transfer apparatus 104a that transfers the particle image onto the intermediate bearing and conveying belt 11, and a cleaning apparatus 105a that cleans the image bearing member 100a. The second particle image forming section 10b is configured to form a particle image by employing a second particulate material Mb. The second particle image forming section 10b includes an image bearing member 100b, a charging apparatus 101b, an exposure apparatus 102b, a developing apparatus 103b, a transfer apparatus 104b, and a cleaning apparatus 105b, which execute respectively similar functions to those of the above-described corresponding components in the first particle image forming section 10a.

[0030] In this embodiment, a structural material (modeling material) made of, e.g., a thermoplastic resin is used as the first particulate material Ma, and a support material (modeling material) having thermal plasticity and water solubility is used as the second particulate material Mb. When a section does not include the overhang portion and hence does not require the support portion, an image is not formed in the second particle image forming section 10b. In such a case, the particle layer is formed using only the particle image of the structural material. The structural material may be, for example, PE (polyethylene), PP (polypropylene), ABS, and PS (polystyrene). The support material may be, for example, carbohydrate, polylactate (PLA), PVA (polyvinyl alcohol), and PEG (polyethylene glycol). Particles of the structural material and the support material preferably have diameters of 5 μm or more and 50 μm or less. In this embodiment, particles having diameters of about 20 μm are used.

[0031] The particle image forming sections 10a and 10b are arranged along the surface of the intermediate bearing and conveying belt 11. While, in Fig. 1, the particle image forming section 10a for the structural material is arranged on the upstream side in a conveying direction, the order in arrangement of the particle image forming sections can be optionally determined. The number of the particle image forming sections may be more than two and can be increased, as required, depending on the types of modeling materials used. As another example, Fig. 2 illustrates the case where four particle image forming sections 10a to 10d are arranged. In that case, it is possible to adopt a configuration of performing image formation with four types of structural materials, or a configuration of performing image formation with three types of structural materials and one type of support material. The variety of three-dimensional objects to be formed can be increased by combining plural types of materials that are different in material properties, color, hardness, physical properties, etc. Such superiority in extensibility is also one advantage of the three-dimensional modeling apparatus utilizing the electrophotographic process.

[0032] Configurations of individual components of the layer forming unit U2 will be described in detail below. It is to be noted that, in description common to the particle image forming sections 10a to 10d, alphabets a to d suffixed to reference signs of the components are omitted, and the components are denoted, for example, as represented by the particle image forming section 10 and the image bearing member 100.

Image Bearing Member

[0033] Fig. 3A illustrates a configuration of the particle image forming section 10, and Fig. 3B illustrates a detailed configuration of the developing apparatus 103.

[0034] The image bearing member 100 is configured to bear the electrostatic latent image. In this embodiment, a photosensitive drum including a photoconductor layer having a photoconductivity and formed on an outer circumferential surface of a metal cylinder made of aluminum, for example, is used as the image bearing member 100. The photoconductor layer may be made of an organic photoconductor (OPC), an amorphous silicon photoconductor, or a selenium photoconductor. The type of photoconductor may be optionally selected depending on the use of the three-dimensional modeling apparatus and the performance demanded. The image bearing member 100 is rotatably supported by a frame body (not illustrated) and is rotated clockwise in the drawing by a motor (not illustrated) at a constant speed during the image formation.

Charging Apparatus

[0035] The charging apparatus 101 is configured to uniformly charge the surface of the image bearing member 100. While a non-contact charging technique utilizing corona discharge is employed in this embodiment, another type of charging, such as a roller charging technique of contacting a charged roller with the surface of the image bearing member 100, may also be used.

Exposure Apparatus

[0036] The exposure apparatus 102 is configured to expose the image bearing member 100 in accordance with image information (slice data) and to form the electrostatic latent image on the surface of the image bearing member 100. The exposure apparatus 102 includes, for example, a light source such as a semiconductor laser or a light-emitting diode, a scanning unit including a polygon mirror that is rotated at a high speed, and an optical member such as a focusing lens.

Developing Apparatus

[0037] The developing apparatus 103 is configured to supply a developer (in the form of particles of the structural material or the support material herein) to the image bearing member 100, thereby visualizing the electrostatic latent image (in this Description, an image visualized with the developer is called a particle image). Fig. 3B illustrates a detailed configuration of the developing apparatus 103. The developing apparatus 103 includes a container 1030 that contains the developer, a supply roller 1031 disposed inside the container 1030, a developing roller 1032 that bears the developer and supplies the developer to the image bearing member 100, and a restricting member 1033 that restricts a thickness of the developer. The supply roller 1031 and the developing roller 1032 are rotatably supported by the container 1030 and are each rotated counterclockwise in the drawing by a motor (not illustrated) at a constant speed during the image formation. The developer particles agitated and charged by the supply roller 1031 are supplied to the developing roller 1032, and a layer thickness of the developer particles is restricted by the restricting member 1033 to a value substantially corresponding to one particle. Thereafter, the electrostatic latent image is developed in a zone where the developing roller 1032 and the image bearing member 100 are opposed to each other. As developing techniques, there are a reversal developing technique of attaching the developer to a region where charges have been removed by exposure, and a normal developing technique of attaching the developer to a region that has not been exposed. One of those techniques may be optionally used.

[0038] Preferably, the developing apparatus 103 has a structure of the so-called developing cartridge and is removably mounted to the layer forming unit U2. The reason is that replenishment and change of the developer (including the structural material and the support material) can be easily made through replacement of a cartridge. As an alternative, the image bearing member 100, the developing apparatus 103, the cleaning apparatus 105, and so on may be constituted into an integral cartridge (so-called process cartridge) such that the image bearing member 100 may be replaced in itself. When wear and a lifetime of the image bearing member 100 are particularly matters of concern due to types, hardness, and particle diameters of the structural material and the support material, the configuration using the process cartridge is more practical and convenient.

Transfer Apparatus

[0039] The transfer apparatus 104 is configured to transfer the particle image, which has been formed on the circumferential surface of the image bearing member 100, onto the surface of the intermediate bearing and conveying belt 11. The transfer apparatus 104 is arranged on the side opposite to the image bearing member 100 with the intermediate bearing and conveying belt 11 interposed between them. The particle image is electrostatically transferred to the intermediate bearing and conveying belt 11 by applying a voltage having a polarity reversed to that of the particle image on the image bearing member 100. The transfer from the image bearing member 100 to the intermediate bearing and conveying belt 11 is also called primary transfer. While a transfer technique utilizing corona discharge is used in this embodiment, a different transfer technique other than the electrostatic transfer technique, such as a roller transfer technique, may also be used.

Cleaning Apparatus

[0040] The cleaning apparatus 105 is configured to recover the developer particles that remain on the image bearing member 100 without being transferred, and to clean the surface of the image bearing member 100. The cleaning apparatus 105 used in this embodiment is of the blade type scraping off the developer particles by a cleaning blade that is held in contact with the image bearing member 100 from a counter direction. However, a cleaning apparatus of the brush type or the electrostatic absorption type may also be used.

First Intermediate Bearing and Conveying Belt

[0041] The intermediate bearing and conveying belt (first intermediate bearing and conveying belt) 11 is a conveying member (intermediate conveying member) to which the particle image having been formed by each particle image forming section 10 is transferred. The particle image of the structural material is transferred from the particle image forming section 10a on the upstream side, and thereafter the particle image of the support material is transferred from the particle image forming section 10b on the downstream side in alignment with the particle image of the structural material. As a result, one particle layer is formed on the surface of the intermediate bearing and conveying belt 11. At that time, as illustrated in Fig. 4A, if the particle images are overlapped with each other on the intermediate bearing and conveying belt 11, a variation would occur in thickness of the particle layer. Even when the variation is about 10-odd to several tens microns, the accumulated variations may affect the dimensional accuracy of a finally modeled object in view of the fact that several hundreds to several tens of thousands of particle layers are laminated to model one three-dimensional object. In this embodiment, therefore, the variation in thickness of the particle layer is suppressed, as illustrated in Fig. 4B, by adjusting positions and sizes of respective particle images of individual materials (the adjustment being made when the slice data for each material is generated) such that the particle images will not overlap with each other. Thus, the three-dimensional modeling apparatus cannot be practiced by directly employing an electrophotographic method of expressing a full-color image with a subtractive mixture technique of superimposing toner images in four colors of C, M, Y and K, which is used in many full-color 2D printers.

[0042] The intermediate bearing and conveying belt 11 is an endless belt made of resin or polyimide. As illustrated in Fig. 1, the intermediate bearing and conveying belt 11 is arranged to extend over a plurality of rollers 110 and 111. A tension roller may be disposed in addition to the rollers 110 and 111 for adjustment of tension of the intermediate bearing and conveying belt 11. At least one of the rollers 110 and 111 is a driving roller that rotates the intermediate bearing and conveying belt 11 counterclockwise in the drawing with a driving force from a motor (not illustrated) during the image formation. The roller 110 serves also as a roller constituting a secondary transfer section in cooperation with a secondary transfer roller 31 in the laminating unit U3.

Belt Cleaning Apparatus

[0043] The belt cleaning apparatus 12 is configured to clean the material adhering to the surface of the intermediate bearing and conveying belt 11. The belt cleaning apparatus 12 used in this embodiment is of the blade type scraping off the material by a cleaning blade that is held in contact with the intermediate bearing and conveying belt 11 from a counter direction. However, a cleaning apparatus of the brush type or the electrostatic absorption type may also be used.

Image Sensor 13

[0044] The image sensor 13 is configured to read the particle layer borne on the surface of the intermediate bearing and conveying belt 11. A detection result of the image sensor 13 is utilized in, e.g., alignment of the particle layer, timing control with respect to the laminating unit U3 in a subsequent stage, and detection of abnormality of the particle layer (detection of an abnormal state that the desired image is not formed, that there is no image, that the variation in thickness is large, or that a deviation of an image position is large).

Laminating Unit

[0045] The laminating unit U3 will be described below. The laminating unit U3 is configured to form a three-dimensional object by receiving the particle layers, which have been formed in the layer forming unit U2, from the intermediate bearing and conveying belt 11, successively laminating the received particle layers, and fixating the laminated particle layers.

[0046] As illustrated in Fig. 1, the laminating unit U3 includes a second intermediate bearing and conveying belt 30, a secondary transfer roller 31, an image sensor 32, a heater 33, and a stage 34. Detailed configurations of the individual components of the laminating unit U3 will be described below.

Second Intermediate Bearing and Conveying Belt

[0047] The second intermediate bearing and conveying belt 30 is a second conveying member that receives each of the particle layers, which have been formed in the layer forming unit U2, from the first intermediate bearing and conveying belt 11, and that bears and conveys the received particle layer to a lamination position. The lamination position is a position at which the particle layers are laminated (namely, they are successively overlaid onto the three-dimensional object under additive manufacturing). In the configuration of Fig. 1, the lamination position corresponds to a region where the second intermediate bearing and conveying belt 30 is sandwiched between the heater 33 and the stage 34.

[0048] The second intermediate bearing and conveying belt 30 is an endless belt made of resin or polyimide. As illustrated in Fig. 1, the second intermediate bearing and conveying belt 30 is arranged to extend over the secondary transfer roller 31 and a plurality of rollers 301, 302, 303 and 304. At least one of the rollers 31, 301 and 302 is a driving roller that rotates the second intermediate bearing and conveying belt 30 clockwise in the drawing with a driving force from a motor (not illustrated). The rollers 303 and 304 are a roller pair that serves to adjust tension of the second intermediate bearing and conveying belt 30, and to keep flat the second intermediate bearing and conveying belt 30 passing the lamination position (i.e., the particle layer while it is being laminated).

Secondary Transfer Roller

[0049] The secondary transfer roller 31 is configured to transfer the particle layer from the first intermediate bearing and conveying belt 11 in the layer forming unit U2 to the second intermediate bearing and conveying belt 30 in the laminating unit U3. The secondary transfer roller 31 sandwiches the first intermediate bearing and conveying belt 11 and the second intermediate bearing and conveying belt 30 between itself and the opposing roller 110 in the layer forming unit U2, thereby forming a secondary transfer nip between both the belts. The particle layer is transferred to the second intermediate bearing and conveying belt 30 by applying a bias, which has a polarity reversed to that of the particle layer, to the secondary transfer roller 31 from a power supply (not illustrated).

Image Sensor 32

[0050] The image sensor 32 is configured to read the particle layer borne on the surface of the second intermediate bearing and conveying belt 30. A detection result of the image sensor 32 is utilized in, e.g., alignment of the particle layer and timing control in conveyance to the lamination position.

Heater

[0051] The heater 33 is a temperature control unit that controls a temperature of the particle layer conveyed to the lamination position. For example, a ceramic heater or a halogen heater can be used as the heater 33. A unit of positively lowering the temperature of the particle layer through heat dissipation or cooling may be further disposed in addition to a heating unit. A lower surface (i.e., a surface facing the belt) of the heater 33 is flat and serves as not only a guide for the second intermediate bearing and conveying belt 30 passing the lamination position, but also a pressing member that applies uniform pressure to the particle layer.

Stage

[0052] The stage 34 is a flat bench on which the three-dimensional object is formed by the additive manufacturing. The stage 34 is movable by an actuator (not illustrated) in a vertical direction (i.e., a direction perpendicular to a belt surface in the lamination position). The particle layer borne on and conveyed by the second intermediate bearing and conveying belt 30 to the lamination position is sandwiched between the stage 34 and the heater 33. In such a state, the stage 34 applies heat and pressure (including heat dissipation or cooling as required) to the particle layer, whereby the particle layer is transferred from the second intermediate bearing and conveying belt 30 to the stage 34. The particle layer for the first layer is transferred directly onto the stage 34, and the particle layers for the second and subsequent layers are successively laminated on the three-dimensional object (under the additive manufacturing) on the stage 34. Thus, in this embodiment, the heater 33 and the stage 34 constitute a laminating apparatus that laminates the particle layers.

Driving Device

[0053] Driving devices 313 and 314 are actuators and move a roller 303 (first roller) and a roller 304 (second roller), respectively, from a state where the rollers 303 and 304 co-operatively form the surface of the second intermediate bearing and conveying belt 30 as a flat surface that is parallel to the surface of the stage 34. More specifically, as illustrated in Fig. 6, the driving device 313 changes an inclination of a rotation axis of the roller 303 to incline (as denoted by a dotted line), relative to the surface of the stage 34, the rotation axis of the roller 303 that has been set parallel (as denoted by a one-dot-chain line) to the surface of the stage 34. The driving device 314 changes an inclination of a rotation axis of the roller 304 to incline (as denoted by a dotted line), relative to the surface of the stage 34, the rotation axis of the roller 304 that has been set parallel (as denoted by a one-dot-chain line) to the surface of the stage 34.

[0054] By moving the rollers 303 and 304 in such a manner, the surface of the second intermediate bearing and conveying belt 30 is twisted to change the surface shape thereof at the lamination position from a flat surface to a non-flat surface, thus making the surface shape of the stage 34 and the surface shape of the second intermediate bearing and conveying belt 30 different from each other. Fig. 6 is an enlarged perspective view of the surroundings of the lamination position in the three-dimensional modeling apparatus.

[0055] While the particle layer is being conveyed and when the lamination of the particle layer is started, the rollers 303 and 304 are each positioned (as denoted by the one-dot-chain line) perpendicularly to an advancing direction of the second intermediate bearing and conveying belt 30. At the timing when the particle layer departs away from the second intermediate bearing and conveying belt 30 after the lamination of the particle layer, the rollers 303 and 304 are each inclined (as denoted by the dotted line) from an ordinary set position (denoted by the one-dot-chain line). After the particle layer has completely departed away from the second intermediate bearing and conveying belt 30, the rollers 303 and 304 are each returned to the ordinary set position (denoted by the one-dot-chain line).

[0056] For example, a piezoelectric element, a screw mechanism, a cylinder mechanism, a piston mechanism, or a motor can be used as the driving device. Thus, in this embodiment, the driving devices 313 and 314 constitute a unit that changes the shape or the inclination of the surface of the second intermediate bearing and conveying belt 30 at the lamination position. In this Description, the lamination position is defined as a position at which the conveying member and the stage are in an indirectly contacted state with the particle layer (or the three-dimensional object) interposed between them. Stated in another way, in this embodiment, the lamination position corresponds to a region of the second intermediate bearing and conveying belt 30 between the rollers 303 and 304 (specifically, in that region, the second intermediate bearing and conveying belt 30 is not contacted with the rollers 303 and 304).

[0057] While the plural rollers are moved in this embodiment, only one roller (i.e., the roller 303 or 304) may be moved. While the plural rollers are inclined in different directions in this embodiment, the plural rollers may be inclined in the same direction. However, a deviation of the second intermediate bearing and conveying belt 30 can be reduced with a simple configuration in the case of inclining the rollers 303 and 304 in reversed directions as in this embodiment. When the rollers 303 and 304 are inclined in the same direction through the same angle, the inclination of the surface of the second intermediate bearing and conveying belt 30 is changed. Such a configuration may also be adopted. Furthermore, while, in this embodiment, the rollers 303 and 304 are each inclined in a plane perpendicular to the advancing direction of the second intermediate bearing and conveying belt 30, the present invention is not limited to that configuration. For example, the roller 303 may be inclined in a plane including the second intermediate bearing and conveying belt 30 similarly to the configuration of a fourth embodiment described later.

Operation of Three-Dimensional Modeling Apparatus

[0058] The operation of the three-dimensional modeling apparatus having the above configuration will be described below. The following description is made in order of a process of forming the particle layer for each layer and a process of laminating the particle layers on an assumption that the process of generating the slice data in the control unit U1 has been completed. Fig. 5 is a flowchart representing an operation sequence of the three-dimensional modeling apparatus according to this embodiment.

Layer Forming Process

[0059] First, the control unit U1 controls driving sources, e.g., motors, such that the image bearing member 100, the first intermediate bearing and conveying belts 11, and the second intermediate bearing and conveying belts 30 of the individual particle image forming sections 10 are rotated at the same peripheral speed (process speed) in synchronism.

[0060] After the rotation speed has stabilized, the image formation in the particle image forming section 10a at the most upstream side is started (S501). More specifically, the control unit U1 controls the charging apparatus 101a to uniformly charge the entire surface of the image bearing member 100a in a predetermined polarity and at a predetermined charging potential. Then, the control unit U1 controls the exposure apparatus 102a to expose the surface of the charged image bearing member 100a in accordance with information that represents an image to be formed. Here, a potential difference between an exposed region and a not-exposed region is formed by removing charges through the exposure. An image corresponding to the potential difference is an electrostatic latent image. Moreover, the control unit U1 drives the developing apparatus

103a to form a particle image of the structural material by attaching particles of the structural material to the latent image on the image bearing member 100a. The formed particle image is primary-transferred onto the intermediate bearing and conveying belt 11 by the transfer apparatus 104a.

[0061] At a predetermined time lag from the start of the image formation in the particle image forming section 10a, the control unit U1 starts the image formation in the particle image forming section 10b on the downstream side (S502). The image formation in the particle image forming section 10b is performed through similar procedures to those in the image formation in the particle image forming section 10a. Here, the time lag in the start of the image formation is set to a value resulting from dividing the distance from a primary transfer nip in the particle image forming section 10a on the upstream side to a primary transfer nip in the particle image forming section 10b on the downstream side by the process speed. As a result, two particle images having been formed in the particle image forming sections 10a and 10b are arranged on the intermediate bearing and conveying belt 11 in a state aligned with each other, and a particle layer corresponding to one layer, the particle layer being made of the structural material and the support material, is formed (S503). (In the case of a section that does not include the overhang portion and hence does not require the support portion, the image formation in the particle image forming section 10b is not performed. In that case, the particle layer is formed only by the particle image of the structural material.) Thereafter, the particle layer is conveyed to the laminating unit U3 by the first intermediate bearing and conveying belt 11.

Lamination Process

[0062] During a period in which the operation of forming the particle layer is performed as described above, the second intermediate bearing and conveying belt 30 in the laminating unit U3 is rotated in a state contacting the first intermediate bearing and conveying belt 11 at the same outer circumferential speed (process speed) as that of the first intermediate bearing and conveying belt 11 in a synchronous relation. At the timing when a front end of the particle layer on the first intermediate bearing and conveying belt 11 reaches the secondary transfer nip, the control unit U1 applies a predetermined transfer bias to the secondary transfer roller 31, whereby the particle layer is transferred to the second intermediate bearing and conveying belt 30 (S506).

[0063] The second intermediate bearing and conveying belt 30 continues to rotate at the same process speed and conveys the particle layer in a direction denoted by an arrow in Fig. 1. The image sensor 32 detects a position of the particle layer on the belt 30, and the control unit U1 conveys the particle layer to a predetermined lamination position in accordance with the detection result (S508). At the timing when the particle layer reaches the lamination position, the control unit U1 stops the second intermediate bearing and conveying belt 30 and exactly positions the particle layer to the lamination position (S509). Then, the control unit U1 ascends the stage 34 (to come closer to the belt surface) to such an extent that a stage surface (in the case forming a first layer) or an upper surface of a three-dimensional object formed on the stage surface (in the case forming a second or subsequent layer) is brought into contact with the particle layer on the belt 30 (S510).

[0064] While keeping the above-described contact state, the control unit U1 controls a temperature of the heater 33 in accordance with a predetermined temperature control sequence. More specifically, the control unit U1 first executes a first mode of heating the heater 33 up to a first target temperature for a predetermined time, thereby thermally melting the particle material of the particle layer (S511). With the first mode, the particle layer is softened and the particle layer in the form of a sheet is closely contacted with the stage surface or the upper surface of the three-dimensional object. Then, the control unit U1 executes a second mode of controlling the heater 33 to a second target temperature lower than the first target temperature for a predetermined time, thereby solidifying the softened particle layer (S512).

[0065] Here, the temperature control sequence, the target temperatures, the heating times, and so on are set depending on respective characteristics of the structural material and the support material, which are used in forming the particle layer. For example, the first target temperature in the first mode is set to a value higher than the highest temperature between the meting points or the glass transition points of the materials, which are used in forming the particle layer. On the other hand, the second target temperature in the second mode is set to a value lower than the lowest temperature between the crystallization temperatures or the glass transition points (in the case of amorphous materials) of the materials, which are used in forming the particle layer. By performing the temperature control as described above, it is possible to thermally plasticize (soften) the entire particle layer, which contains plural types of particle materials having thermal fusion characteristics different from each other, in a common fusion temperature range, and then to solidify the entire material layer in a common solidification temperature range. Accordingly, the fusion and the solidification of the particle layer containing plural types of particle materials can be performed in a stable manner.

[0066] In each of the first mode and the second mode, if a temperature control range is too wide, a time would be taken to stabilize the temperature control, and a lamination process time would be increased excessively. For that reason, a control range of the first target temperature is preferably set such that the highest temperature between the meting points or the glass transition points of the materials, which are used in forming the particle layer, is set as a lower limit temperature, and that an upper limit temperature is set to a value of the lower limit value + about 50°C. Similarly, a control range of the second target temperature is preferably set such that the lowest temperature between the crystallization temperatures or the glass transition points (in the case of amorphous materials) of the materials, which are used in forming the particle layer, is set as an upper limit temperature, and that a lower limit temperature is set to a value of the upper limit value - about 50°C. For example, when ABS (glass transition point: 130°C) is used as the structural material and maltotetraose (glass transition point: 156°C) is used as the support material, the control ranges are preferably set as follows. The control range of the first target temperature is set with the lower limit being 156°C or higher and the upper limit being 206°C or lower, and the control range of the second target temperature is set with the lower limit being 80°C or higher and the upper limit being 130°C or lower.

[0067] After the end of the second mode, the control unit U1 descends the stage 34 (S513). Then, the control unit U1 drives the rollers 303 and 304 through the respective driving devices to deform the surface of the second intermediate bearing and conveying belt 30 (S514). As a result, the surface shape of the stage 34 and the surface shape of the second intermediate bearing and conveying belt 30 can be made different from each other such that the particle layer is easier to peel off from the surface of the second intermediate bearing and conveying belt 30. Hence damage of the particle layer can be suppressed. While, in the flowchart of Fig. 5, the surface of the second intermediate bearing and conveying belt 30 is started to deform after starting the descent of the stage 34, the deformation of the belt surface and the descent of the stage 34 may be started at the same time by controlling the stage and the driving devices in synchronism with each other. Alternatively, the surface of the second intermediate bearing and conveying belt 30 may be started to deform before starting the descent of the stage 34.

[0068] When the entire particle layer is peeled off from the surface of the second intermediate bearing and conveying belt 30 and the lamination of the particle layer is completed, the control unit U1 drives the rollers 303 and 304 through the respective driving devices to return the surface shape of the second intermediate bearing and conveying belt 30 to the original flat state (S515).

[0069] Thereafter, execution of the layer forming processing for a next layer is started (S501 and so on). A desired three-dimensional object is formed on the stage 34 by repeating the above-described layer forming process and lamination process in the required number of times. A finally modeled object (article) can be obtained by, in the last step, removing the three-dimensional object from the stage 34 and removing the support material, which is water soluble, with hot water, for example. The finally modeled object (article) may be finished by further executing additional predetermined processes (such as cleaning and assembly) on the three-dimensional object.

Advantages of This Embodiment

[0070] According to the above-described three-dimensional modeling apparatus of this embodiment, the apparatus executes an operation of making the surface shape of the stage different from the surface shape of the conveying member (or making the surface of the stage nonparallel to the surface of the conveying member). With the execution of such an operation, the particle layer (three-dimensional object) is easier to peel off from the surface of the conveying member, and damage of the particle layer (three-dimensional object) can be suppressed.

Second Embodiment

[0071] Fig. 7 is an enlarged perspective view of the surroundings of a lamination position in a three-dimensional modeling apparatus according to a second embodiment of the present invention. In the first embodiment (Fig. 1), the particle layer is laminated on the stage 34 by vertically moving the stage 34 in a state where the second intermediate bearing and conveying belt 30 is stopped. On the other hand, in the second embodiment, the particle layer is laminated on a stage 340 in a state where the second intermediate bearing and conveying belt 30 and the stage 340 are moved in synchronism with each other. Only the features specific to the second embodiment will be described below while description of components in common to those in the first embodiment is omitted.

[0072] The stage 340 is held in contact with the second intermediate bearing and conveying belt 30 in a state where the stage 340 is moved in the same direction and at the same speed as those of the second intermediate bearing and conveying belt 30. By repeating such a synchronous operation, the particle layers are successively laminated on the stage 340. The stage 340 is movable by an actuator (not illustrated) not only in a vertical direction (i.e., a direction perpendicular to a belt surface at the lamination position), but also in a horizontal direction (i.e., a direction parallel to the belt surface at the lamination position). In other words, the stage 340 is moved in an up-and-down direction and a right-and-left direction as denoted by a dotted line in Fig. 7.

[0073] The above-described second embodiment can also provide similar advantageous effects to those in the first embodiment. In addition, since there is no necessity of stopping the conveying member during the lamination process of the particle layer, the throughput of the three-dimensional modeling apparatus can be increased.

[0074] Moreover, in the second embodiment, since the particle layer is laminated on the stage 340 in a state where the second intermediate bearing and conveying belt 30 is moved, a zigzag motion of the second intermediate bearing and conveying belt 30 can be suppressed by inclining the rollers 303 and 304 through the same angle in opposite directions.

Third Embodiment

[0075] Fig. 8 is a schematic diagram illustrating an overall configuration of a three-dimensional modeling apparatus according to a third embodiment of the present invention. Fig. 9 is an enlarged perspective view of the surroundings of a lamination position in the three-dimensional modeling apparatus according to the third embodiment. In the first embodiment (Fig. 1), the rollers are inclined to change the shape or the inclination of the surface of the second intermediate bearing and conveying belt 30. On the other hand, in the third embodiment, one of the rollers is translated (namely, moved parallel). Only the features specific to the third embodiment will be described below while description of components in common to those in the first embodiment is omitted.

[0076] A laminating unit in this embodiment includes a pair of rollers 3030 and 3040. The pair of rollers 3030 and 3040 act to keep flat the surface of the second intermediate bearing and conveying belt 30 at the lamination position. The roller 3040 is constituted to be movable in a direction perpendicular to a rotation axis of the roller 3040. The laminating unit in this embodiment further includes a driving device 3140. The driving device 3140 is an actuator, and it moves the roller 3040 in the direction perpendicular to the rotation axis of the roller 3040 in accordance with an instruction from the laminating unit control section U13. For example, a piezoelectric element, a screw mechanism, a cylinder mechanism, a piston mechanism, or a motor can be used as the driving device 3140. Thus, in this embodiment, the driving devices 3140 constitutes a unit that changes the inclination of the surface of the second intermediate bearing and conveying belt 30 at the lamination position.

[0077] While the particle layer is being conveyed and when the lamination of the particle layer is started, the rollers 3030 and 3040 are each held at an ordinary set position (denoted by a one-dot-chain line in Fig. 9) where the surface of the second intermediate bearing and conveying belt 30 at the lamination position is parallel to the surface of the stage 34. At the timing when the particle layer departs away from the second intermediate bearing and conveying belt 30 after the lamination of the particle layer, the roller 3040 is translated from the ordinary set position (as denoted by a dotted line in Fig. 9) such that the surface of the second intermediate bearing and conveying belt 30 at the lamination position and the surface of the stage 34 are non-parallel to each other. After the particle layer has completely departed away from the second intermediate bearing and conveying belt 30, the roller 3040 is returned to the ordinary set position (denoted by the one-dot-chain line in Fig. 9). The roller 3040 is preferably moved in synchronism with the descent of the stage 34.

[0078] While only one roller is moved in this embodiment, the surface of the second intermediate bearing and conveying belt 30 at the lamination position and the surface of the stage 34 may be made nonparallel to each other by moving a plurality of rollers (e.g., the rollers 3030 and 3040).

[0079] According to the above-described three-dimensional modeling apparatus of this embodiment, the apparatus executes an operation of making the surface of the stage nonparallel to the surface of the conveying member. With the execution of such an operation, the particle layer (three-dimensional object) is easier to peel off from the surface of the conveying member, and damage of the particle layer (three-dimensional object) can be suppressed.

Fourth Embodiment

[0080] Fig. 10 is an enlarged perspective view of the surroundings of a lamination position in a three-dimensional modeling apparatus according to a fourth embodiment of the present invention. In the second embodiment (Fig. 7), the rollers are driven by the driving devices. On the other hand, in the fourth embodiment, the rollers are fixedly positioned without being driven (although the rollers are allowed to rotate about their own axes corresponding to the movement of the second intermediate bearing and conveying belt 30). Only the features specific to the fourth embodiment will be described below while description of components in common to those in the second embodiment is omitted.

[0081] A laminating unit in this embodiment includes rollers 3031, 3032, 3010, and 3041. The rollers 3032 and 3041 act to keep flat the surface of the second intermediate bearing and conveying belt 30 at the lamination position. Here, the roller 3041 (first roller) positioned upstream of the lamination position is arranged such that a rotation axis of the roller 3041 is parallel to the surface of the second intermediate bearing and conveying belt 30 and further parallel to a direction (denoted by a one-dot-chain line) perpendicular the advancing direction of the belt 30. On the other hand, the roller 3032 (second roller) positioned downstream of the lamination position is arranged such that a rotation axis of the roller 3032 is parallel to the surface of the second intermediate bearing and conveying belt 30, but not parallel to the direction (denoted by the one-dot-chain line) perpendicular the advancing direction of the belt 30. Thus, the rotation axis of the roller 3032 is inclined relative to the rotation axis of the roller 3041. The roller 3031 (third roller) positioned downstream of the roller 3032 and the roller 3010 (fourth roller) positioned downstream of the roller 3031 are arranged such that respective rotation axes of the rollers 3031 and 3010 are parallel to the rotation axis of the roller 3032 (as denoted by dotted lines). With the roller arrangement described above, the belt 30 can be rotated without causing a zigzag motion.

[0082] Since the roller 3032 is located at the end (exit) of a region defining the lamination position and the rotation axis of the roller 3032 is not perpendicular to the advancing direction of the second intermediate bearing and conveying belt 30, the particle layer starts to peel off at its portion (one corner when the particle layer is rectangular) from the second intermediate bearing and conveying belt 30 with the advance of the belt 30. Therefore, the particle layer is easier to peel off from the surface of the second intermediate bearing and conveying belt 30, and damage of the particle layer (three-dimensional object) can be suppressed.

[0083] According to the above-described three-dimensional modeling apparatus of this embodiment, the rollers positioned downstream of the lamination position are inclined relative to the direction perpendicular to the advancing direction of the conveying member. With such an arrangement, the region defining the lamination position has the exit that is inclined relative to a leading side of the particle layer. As a result, the particle layer (three-dimensional object) is easier to peel off from the surface of the conveying member, and damage of the particle layer (three-dimensional object) can be suppressed. In addition, since there is no necessity of driving the roller, the three-dimensional modeling apparatus can be provided in which control is facilitated.

Fifth Embodiment

[0084] Fig. 11 is a schematic diagram illustrating an overall configuration of a three-dimensional modeling apparatus according to a fifth embodiment of the present invention. Fig. 12 is an enlarged perspective view of the surroundings of a sheet forming position in the three-dimensional modeling apparatus according to the fifth embodiment. In the fifth embodiment, the present invention is applied to a sheet forming apparatus instead of the laminating unit.

[0085] A laminating unit in the fifth embodiment includes the sheet forming apparatus that forms the particle layer into a sheet. The sheet forming apparatus includes a pressing member 410 and a heater 420. The pressing member 410 is a component similar to the stage 34, and the heater 420 is a component similar to the heater 33. The particle layer having been transferred to the second intermediate bearing and conveying belt 30 is borne on and conveyed by the belt 30 to the lamination position via the sheet forming position. At the sheet forming position, the particle layer is heated and melted to be formed into a sheet-like thin film. At the lamination position, the sheet-like thin film is heated and melted again to be laminated on the stage 34.

[0086] Rollers 3051 and 3052 are tension rollers that act to keep flat the surface of the second intermediate bearing and conveying belt 30 at the sheet forming position. Thus, the rollers 3051 and 3052 are components similar to the rollers 303 and 304. Driving devices 315 and 316 are components that drive the rollers 3051 and 3052, respectively. Thus, the driving devices 315 and 316 are components similar to the driving devices 313 and 314. In this embodiment, the driving devices 315 and 316 constitute a unit that changes the shape or the inclination of the surface of the second intermediate bearing and conveying belt 30 at the sheet forming position. In this Description, the sheet forming position is defined as a position at which the conveying member and the pressing member are in an indirectly contacted state with the particle layer interposed between them. Stated in another way, in this embodiment, the sheet forming position corresponds to a region of the second intermediate bearing and conveying belt 30 between the rollers 3051 and 3052 (specifically, in that region, the second intermediate bearing and conveying belt 30 is not contacted with the rollers 3051 and 3052).

[0087] According to the above-described three-dimensional modeling apparatus of this embodiment, the apparatus executes an operation of making the surface shape of the pressing member different from the surface shape of the conveying member (or making the surface of the pressing member nonparallel to the surface of the conveying member). With the execution of such an operation, the particle layer is easier to peel off from the surface of the conveying member, and damage of the particle layer can be suppressed.

[0088] Instead of the technique of the laminating unit in the first embodiment, the technique of the laminating unit in at least one of the second to fourth embodiments may be applied to the sheet forming apparatus in the fifth embodiment. Such a modification is also involved in the present invention.

Sixth Embodiment

[0089] Fig. 13 is a schematic diagram illustrating an overall configuration of a three-dimensional modeling apparatus according to a sixth embodiment of the present invention. Fig. 14 is an enlarged perspective view of the surroundings of a lamination position in the three-dimensional modeling apparatus according to the sixth embodiment of the present invention. In the third embodiment (Fig. 8), the roller 3040 over which the second intermediate bearing and conveying belt 30 is arranged to extend is translated in order to change the shape or the inclination of the surface of the second intermediate bearing and conveying belt 30. On the other hand, in the sixth embodiment, a member other than the roller over which the second intermediate bearing and conveying belt 30 is arranged to extend is pressed against the belt 30. Only the features specific to the sixth embodiment will be described below while description of components in common to those in the third embodiment is omitted.

[0090] A laminating unit in this embodiment includes a member (pressing member) 3060 that is pressed against the second intermediate bearing and conveying belt 30. The pressing member 3060 is movable in the direction perpendicular to the surface of the second intermediate bearing and conveying belt 30. A width of the pressing member 3060 is smaller than that of the second intermediate bearing and conveying belt 30.

[0091] The laminating unit in this embodiment further includes a driving device 3160. The driving device 3160 is an actuator and moves the pressing member 3060 in the direction perpendicular to the surface of the second intermediate bearing and conveying belt 30 in accordance with an instruction from the laminating unit control section U13. In this embodiment, the driving device 3160 corresponds to the unit that changes the inclination of the surface of the second intermediate bearing and conveying belt 30 at the lamination position.

[0092] While the particle layer is being conveyed and when the lamination of the particle layer is started, the roller 3060 is held at an ordinary set position (denoted by a one-dot-chain line in Fig. 14) where the pressing member 3060 is not contacted with the second intermediate bearing and conveying belt 30. At the timing when the particle layer departs away from the second intermediate bearing and conveying belt 30 after the lamination of the particle layer, the roller 3060 is translated from the ordinary set position (as denoted by a dotted line in Fig. 14). In other words, the pressing member 3060 is pressed against the second intermediate bearing and conveying belt 30 to make the surface of the second intermediate bearing and conveying belt 30 at the lamination position and the surface of the stage 34 nonparallel to each other. After the particle layer has completely departed away from the second intermediate bearing and conveying belt 30, the pressing member 3060 is returned to the ordinary set position.

[0093] While only one pressing member is moved in this embodiment, the surface of the second intermediate bearing and conveying belt 30 at the lamination position and the surface of the stage 34 may be made nonparallel to each other by moving a plurality of pressing members. While the width of the pressing member 3060 is preferably smaller than that of the second intermediate bearing and conveying belt 30, the former may be larger than the latter.

[0094] According to the above-described three-dimensional modeling apparatus of this embodiment, the apparatus executes an operation of making the surface of the stage nonparallel to the surface of the conveying member. With the execution of such an operation, the particle layer (three-dimensional object) is easier to peel off from the surface of the conveying member, and damage of the particle layer (three-dimensional object) can be suppressed.

[0095] While the preferred embodiments of the present invention have been described above, the present invention is not limited to those embodiments, and the present invention can be variously modified and altered within the scope not departing from the gist of the invention.

[0096] For example, while a plurality of conveying members (first and second conveying members) are used in each of the above-described embodiments, the layer forming unit may be constituted to form a layer directly on the second conveying member with omission of the first conveying member.

[0097] Furthermore, in the first embodiment and the third embodiment, the inclination or the shape of the belt surface is changed by driving at least one roller. However, the inclination or the shape of the belt surface may be changed by additionally providing a member separate from the roller and pressing the member against the belt, as in the sixth embodiment.

[0098] The inclination or the shape of the belt surface may be changed by combining the first embodiment and the third embodiment with each other.

[0099] While, in the above-described embodiments, the layer is formed on the conveying member by employing the electrophotographic process, the layer may be formed on the conveying member by employing suitable one of other processes instead of the electrophotographic process. The other processes include, e.g., an ink jet process. Thus, the present invention can be further applied to a system disclosed in WO2014/092205, for example.

[0100] 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.

[0101] This application claims the benefit of Japanese Patent Application No. 2014-242512, filed November 28, 2014 and No. 2015-203192, filed October 14, 2015, which are hereby incorporated by reference herein in their entirety.

Claims

[Claim 1] A three-dimensional modeling apparatus used to model a three-dimensional object, the apparatus comprising:
a layer forming unit configured to form a layer on a conveying member; and
a laminating unit configured to laminate, at a lamination position, the layer having been conveyed by the conveying member to the lamination position,
wherein the laminating unit includes a changing device configured to change an inclination or a shape of a surface of the conveying member at the lamination position.

[Claim 2] The three-dimensional modeling apparatus according to Claim 1, wherein the layer forming unit forms the layer through an electrophotographic process.

[Claim 3] The three-dimensional modeling apparatus according to Claim 1 or 2, wherein the layer forming unit includes a particle image forming apparatus configured to form a particle image through an electrophotographic process, and a first conveying member to which the particle image having been formed by the particle image forming apparatus is transferred, the particle image forming apparatus forming the layer including the particle image on the first conveying member,
the laminating unit includes a second conveying member arranged to receive the layer having been formed on the first conveying member, and to convey the layer to the lamination position, and a laminating apparatus configured to laminate the layer having been conveyed by the second conveying member,
the laminating apparatus includes a stage on which the layer is laminated, and
the changing device changes an inclination or a shape of a surface of the second conveying member at the lamination position.

[Claim 4] The three-dimensional modeling apparatus according to Claim 3, wherein the changing device changes the inclination of the surface of the second conveying member in a way of making the surface of the second conveying member nonparallel to a surface of the stage at the lamination position.

[Claim 5] The three-dimensional modeling apparatus according to Claim 3 or 4, wherein the changing device changes the shape of the surface of the second conveying member in a way of making the surface of the second conveying member and a surface of the stage different in shape from each other at the lamination position.

[Claim 6] The three-dimensional modeling apparatus according to any one of Claims 3 to 5, wherein the changing device changes the inclination or the shape of the surface of the second conveying member in synchronism with movement of the stage.

[Claim 7] The three-dimensional modeling apparatus according to any one of Claims 3 to 6, wherein the laminating unit includes a plurality of rollers over which the second conveying member is arranged to extend, and the changing device includes a driving device configured to drive at least one of the plural rollers.

[Claim 8] The three-dimensional modeling apparatus according to Claim 7, wherein the driving device changes an inclination of the roller.

[Claim 9] The three-dimensional modeling apparatus according to Claim 8, wherein the driving device inclines a rotation axis of the roller relative to a surface of the stage.

[Claim 10] The three-dimensional modeling apparatus according to any one of Claims 7 to 9, wherein the plural rollers includes first and second rollers, and
the driving device inclines the first roller and the second roller in different directions.

[Claim 11] The three-dimensional modeling apparatus according to any one of Claims 7 to 10, wherein the driving device moves the roller.

[Claim 12] The three-dimensional modeling apparatus according to Claim 11, wherein the driving device moves the roller in a direction perpendicular to a rotation axis of the roller.

[Claim 13] The three-dimensional modeling apparatus according to any one of Claims 3 to 6, wherein the laminating unit includes a plurality of rollers over which the second conveying member is arranged to extend,
the plural rollers include a first roller arranged upstream of the lamination position, and a second roller arranged downstream of the lamination position, and
the changing device includes a pressing member that is pressed against the second conveying member, and a driving device configured to drive the pressing member.

[Claim 14] A three-dimensional modeling apparatus used to model a three-dimensional object, the apparatus comprising:

a layer forming unit configured to form a layer on a conveying member; and
a laminating unit configured to laminate, at a lamination position, the layer having been conveyed by the conveying member to the lamination position,
wherein the laminating unit includes a plurality of rollers over which the conveying member is arranged to extend,
the plural rollers include a first roller arranged upstream of the lamination position, and a second roller arranged downstream of the lamination position, and
a rotation axis of the second roller is inclined relative to a rotation axis of the first roller.

[Claim 15] The three-dimensional modeling apparatus according to Claim 14, wherein the layer forming unit includes a particle image forming apparatus configured to form a particle image through an electrophotographic process, and a first conveying member to which the particle image having been formed by the particle image forming apparatus is transferred, the particle image forming apparatus forming the layer including the particle image on the first conveying member, and
the laminating unit includes a second conveying member arranged to receive the layer having been formed on the first conveying member, and to convey the layer to the lamination position, and a laminating apparatus configured to laminate the layer having been conveyed by the second conveying member.

[Claim 16] The three-dimensional modeling apparatus according to Claim 15, wherein the plural rollers include a third roller arranged downstream of the second roller, and a fourth roller arranged downstream of the third roller, and
respective rotation axes of the second to fourth rollers are inclined relative to the rotation axis of the first roller.

[Claim 17] The three-dimensional modeling apparatus according to Claim 16, wherein the rotation axes of the second to fourth rollers are parallel to each other.

[Claim 18] A three-dimensional modeling apparatus used to produce a three-dimensional object, the apparatus comprising:
a layer forming unit configured to form a layer on a conveying member; and
a laminating unit configured to laminate the layer having been

conveyed by the conveying member to a lamination position via a sheet forming position,
wherein the laminating unit includes a changing device configured to change an inclination or a shape of a surface of the conveying member at the sheet forming position.

[Claim 19] The three-dimensional modeling apparatus according to Claim 18, wherein the layer forming unit includes a particle image forming apparatus configured to form a particle image through an electrophotographic process, and a first conveying member to which the particle image having been formed by the particle image forming apparatus is transferred, the particle image forming apparatus forming the layer including the particle image on the first conveying member,
the laminating unit includes a second conveying member arranged to receive the layer having been formed on the first conveying member, and to convey the layer to the sheet forming position and to the lamination position, a sheet forming apparatus configured to form the layer having been conveyed by the second conveying member into a sheet, and a laminating apparatus configured to laminate the layer having been formed into the sheet,
the laminating apparatus includes a changing device configured to change an inclination or a shape of a surface of the second conveying member at the sheet forming position.

[Claim 20] An article manufacturing method comprising the steps of:
manufacturing a three-dimensional object by employing the three-dimensional modeling apparatus according to any one of Claims 1 to 19, and
removing a support material from the three-dimensional object.

AMENDED CLAIMS
received by the International Bureau on 30 March 2016 (30.03.2016)

[Claim 1] (Amended) A three-dimensional modeling apparatus used to model a three-dimensional object, the apparatus comprising:

a layer forming unit configured to form a layer on a conveying member; and

a laminating unit configured to laminate, at a lamination position, the layer having been conveyed by the conveying member to the lamination position,

wherein the layer forming unit includes a particle image forming apparatus configured to form a particle image, and a first conveying member to which the particle image having been formed by the particle image forming apparatus is transferred, the particle image forming apparatus forming the layer including the particle image on the first conveying member,

the laminating unit includes a second conveying member arranged to receive the layer having been formed on the first conveying member, and to convey the layer to the lamination position, and a laminating apparatus configured to laminate the layer having been conveyed by the second conveying member,

the laminating apparatus includes a stage on which the layer is laminated, and

a changing device changes an inclination or a shape of a surface of the second conveying member at the lamination position.

[Claim 2] The three-dimensional modeling apparatus according to Claim 1, wherein the layer forming unit forms the layer through an electrophotographic process.

[Claim 3] (Deleted)

[Claim 4] (Amended) The three-dimensional modeling apparatus according to Claim 1,

wherein the changing device changes the inclination of the surface of the second conveying member in a way of making the surface of the second conveying member nonparallel to a surface of the stage at the lamination position.

[Claim 5] (Amended) The three-dimensional modeling apparatus according to any one of Claims 1, 2 and 4,

wherein the changing device changes the shape of the surface of the second conveying member in a way of making the surface of the second conveying member and a surface of the stage different in shape from each other at the lamination position.

[Claim 6] (Amended) The three-dimensional modeling apparatus according to any one of Claims 1, 2, 4 and 5, wherein the changing device changes the inclination or the shape of the surface of the second conveying member in synchronism with movement of the stage.

[Claim 7] (Amended) The three-dimensional modeling apparatus according to any one of Claims 1, 2, 4 to 6,

wherein the laminating unit includes a plurality of rollers over which the second conveying member is arranged to extend, and

the changing device includes a driving device configured to drive at least one of the plural rollers.

[Claim 8] The three-dimensional modeling apparatus according to Claim 7,

wherein the driving device changes an inclination of the roller.

[Claim 9] The three-dimensional modeling apparatus according to Claim 8,

wherein the driving device inclines a rotation axis of the roller relative to a surface of the stage.

[Claim 10] The three-dimensional modeling apparatus according to any one of Claims 7 to 9,

wherein the plural rollers includes first and second rollers, and

the driving device inclines the first roller and the second roller in different directions.

[Claim 11] The three-dimensional modeling apparatus according to any one of Claims 7 to 10, wherein the driving device moves the roller.

[Claim 12] The three-dimensional modeling apparatus according to Claim 11,

wherein the driving device moves the roller in a direction perpendicular to a rotation axis of the roller.

[Claim 13] (Amended) The three-dimensional modeling apparatus according to any one of Claims 1, 2, 4 to 6,

wherein the laminating unit includes a plurality of rollers over which the second conveying member is arranged to extend,

the plural rollers include a first roller arranged upstream of the lamination position, and a second roller arranged downstream of the lamination position, and

the changing device includes a pressing member that is pressed against the second conveying member, and a driving device configured to drive the pressing member.

[Claim 14] A three-dimensional modeling apparatus used to model a three-dimensional object, the apparatus comprising:

a layer forming unit configured to form a layer on a conveying member; and a laminating unit configured to laminate, at a lamination position, the layer having been conveyed by the conveying member to the lamination position,

wherein the laminating unit includes a plurality of rollers over which the conveying member is arranged to extend,

the plural rollers include a first roller arranged upstream of the lamination position, and a second roller arranged downstream of the lamination position, and

a rotation axis of the second roller is inclined relative to a rotation axis of the first roller.

[Claim 15] The three-dimensional modeling apparatus according to Claim 14,

wherein the layer forming unit includes a particle image forming apparatus configured to form a particle image through an electrophotographic process, and a first conveying member to which the particle image having been formed by the particle image forming apparatus is transferred, the particle image forming apparatus forming the layer including the particle image on the first conveying member, and

the laminating unit includes a second conveying member arranged to receive the layer having been formed on the first conveying member, and to convey the layer to the lamination position, and a laminating apparatus configured to laminate the layer having been conveyed by the second conveying member.

[Claim 16] The three-dimensional modeling apparatus according to Claim 15,

wherein the plural rollers include a third roller arranged downstream of the second roller, and a fourth roller arranged downstream of the third roller, and

respective rotation axes of the second to fourth rollers are inclined relative to the rotation axis of the first roller.

[Claim 17] The three-dimensional modeling apparatus according to Claim 16,

wherein the rotation axes of the second to fourth rollers are parallel to each other.

[Claim 18] (Amended) A three-dimensional modeling apparatus used to model a three-dimensional object, the apparatus comprising:

a layer forming unit configured to form a layer on a conveying member; and

a laminating unit configured to laminate the layer having been conveyed by the conveying member to the lamination position via a sheet forming position,

wherein the layer forming unit includes a particle image forming apparatus configured to form a particle image through an electrophotographic process, and a first conveying member to which the particle image having been formed by the particle image forming apparatus is transferred, the particle image forming apparatus forming the layer including the particle image on the first conveying member,

the laminating unit includes a second conveying member arranged to receive the layer having been formed on the first conveying member, and to convey the layer to the sheet forming position and to the lamination position, a sheet forming apparatus configured to form the layer having been conveyed by the second conveying member into a sheet, and a laminating apparatus configured to laminate the layer having been formed into the sheet,

the laminating apparatus includes a changing device configured to change an inclination or a shape of a surface of the second conveying member at the sheet forming position.

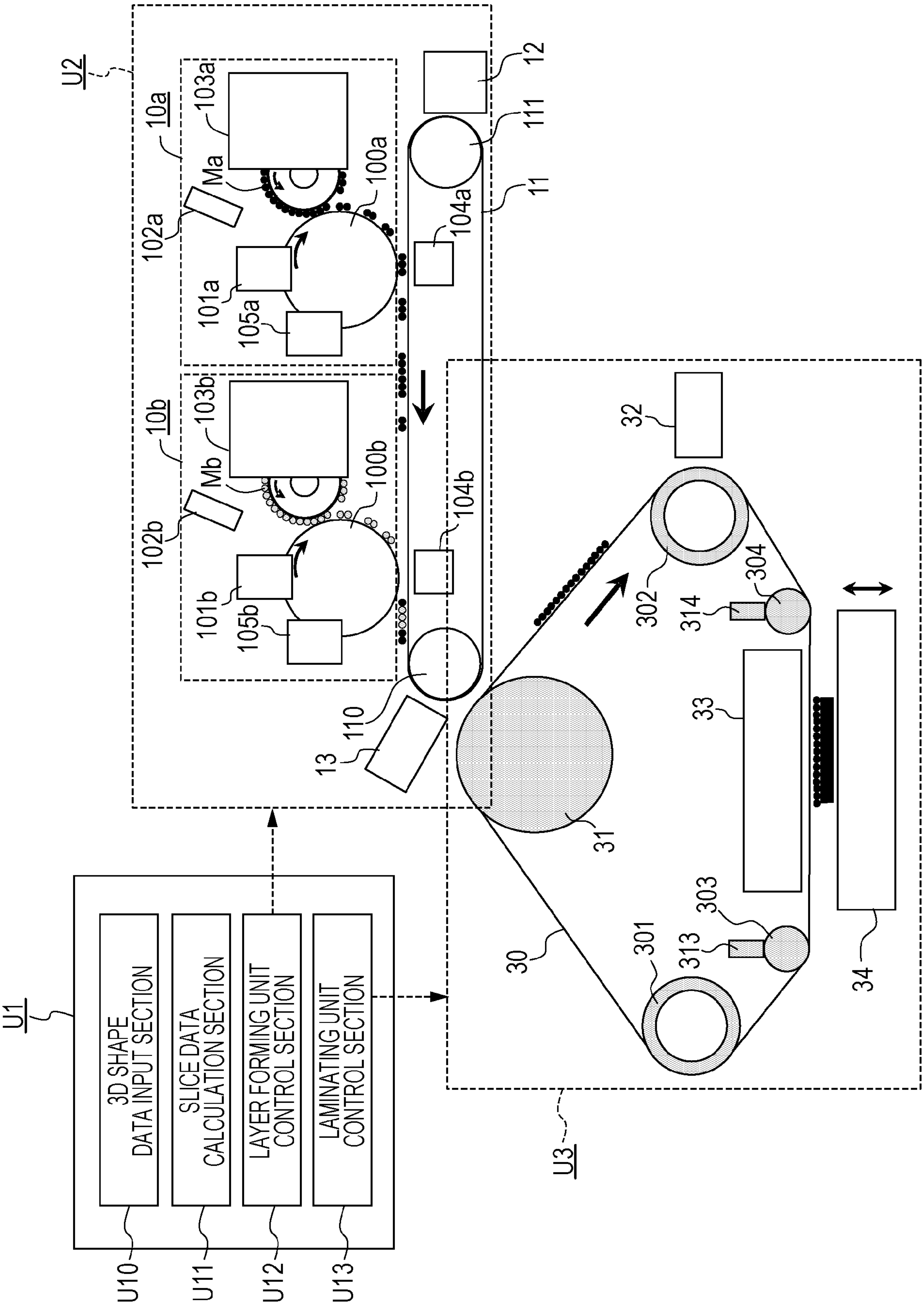
[Claim 19] (Deleted)

[Claim 20] (Amended) An article manufacturing method comprising the steps of:

manufacturing a three-dimensional object by employing the three-dimensional modeling apparatus according to any one of Claims 1, 2, 4 to 18, and

removing a support material from the three-dimensional object.

[Fig. 1]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SLICE DATA CALCULATION SECTION
LAYER FORMING UNIT CONTROL SECTION
LAMINATING UNIT CONTROL SECTION
U10
U11
U12
U13
U2
10a
10b
100a
100b
101a
101b
102a
102b
103a
103b
104a
104b
105a
105b
Ma
Mb
11
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111
U3
30
31
32
33
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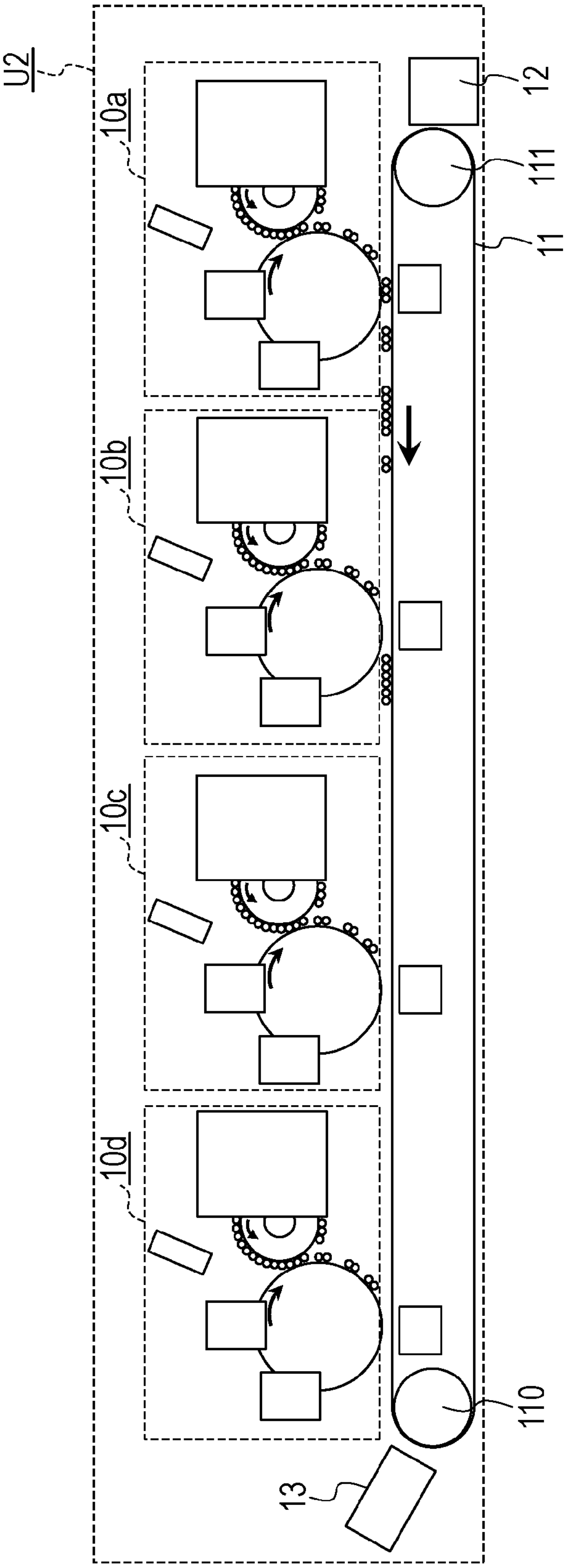
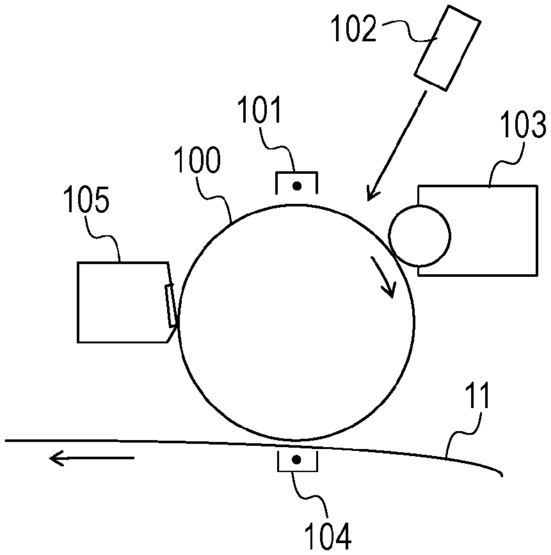
301
302
303
304
313
314

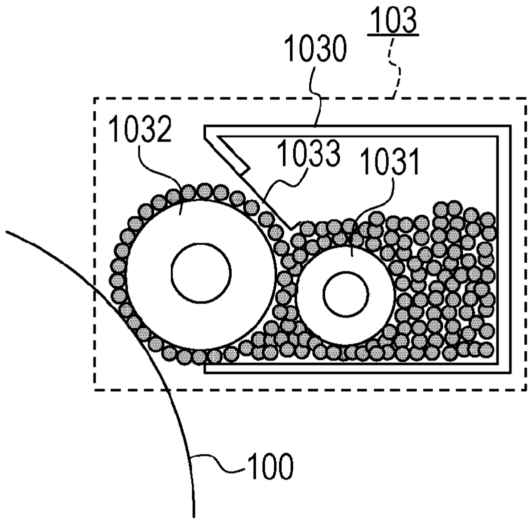
[Fig. 2]



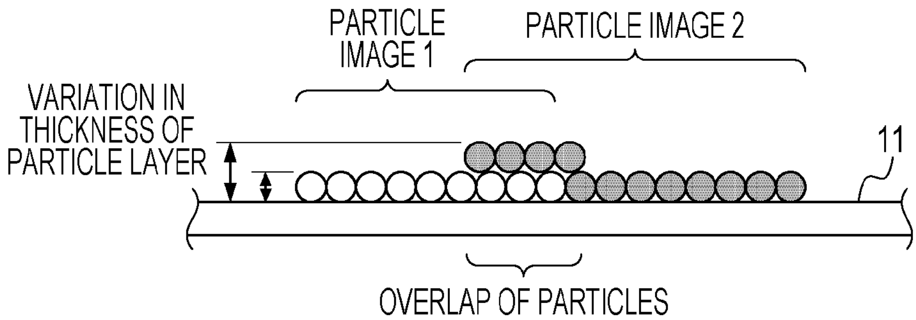
[Fig. 3A]



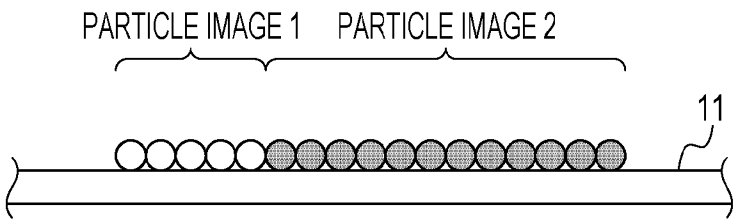
[Fig. 3B]



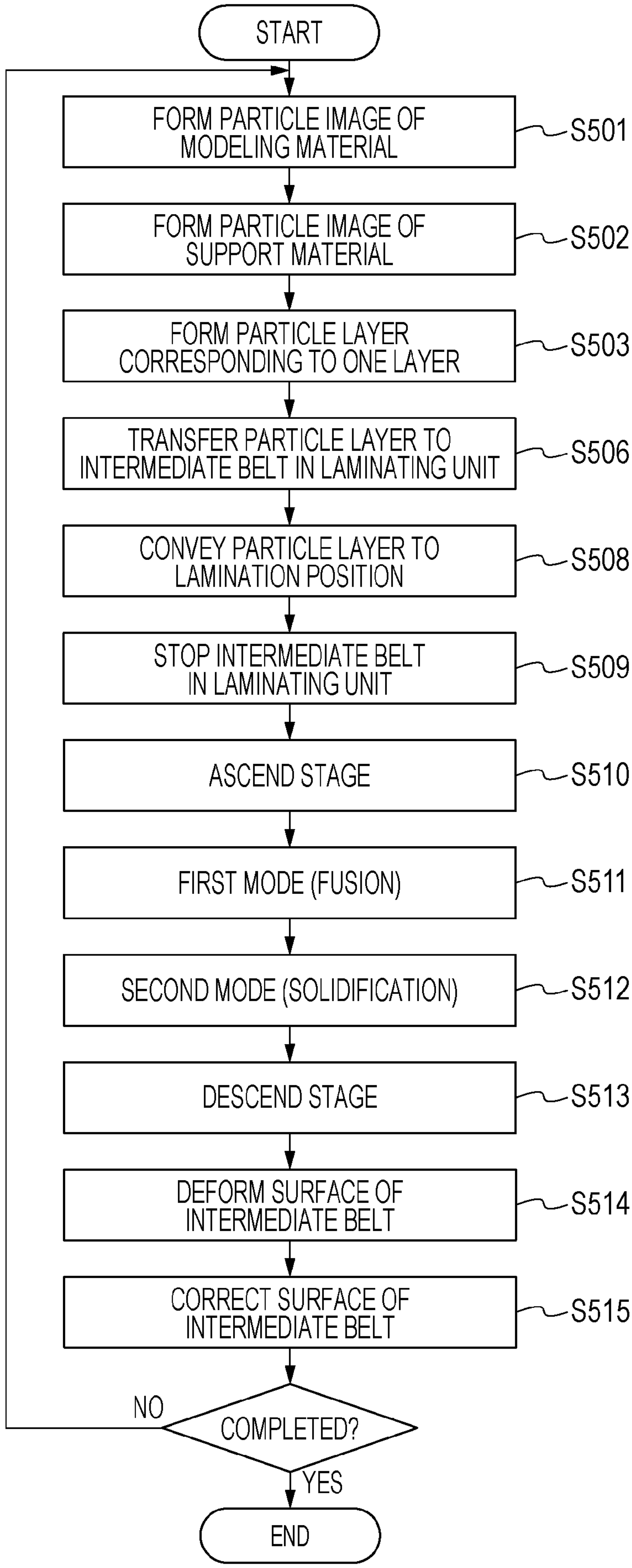
[Fig. 4A]



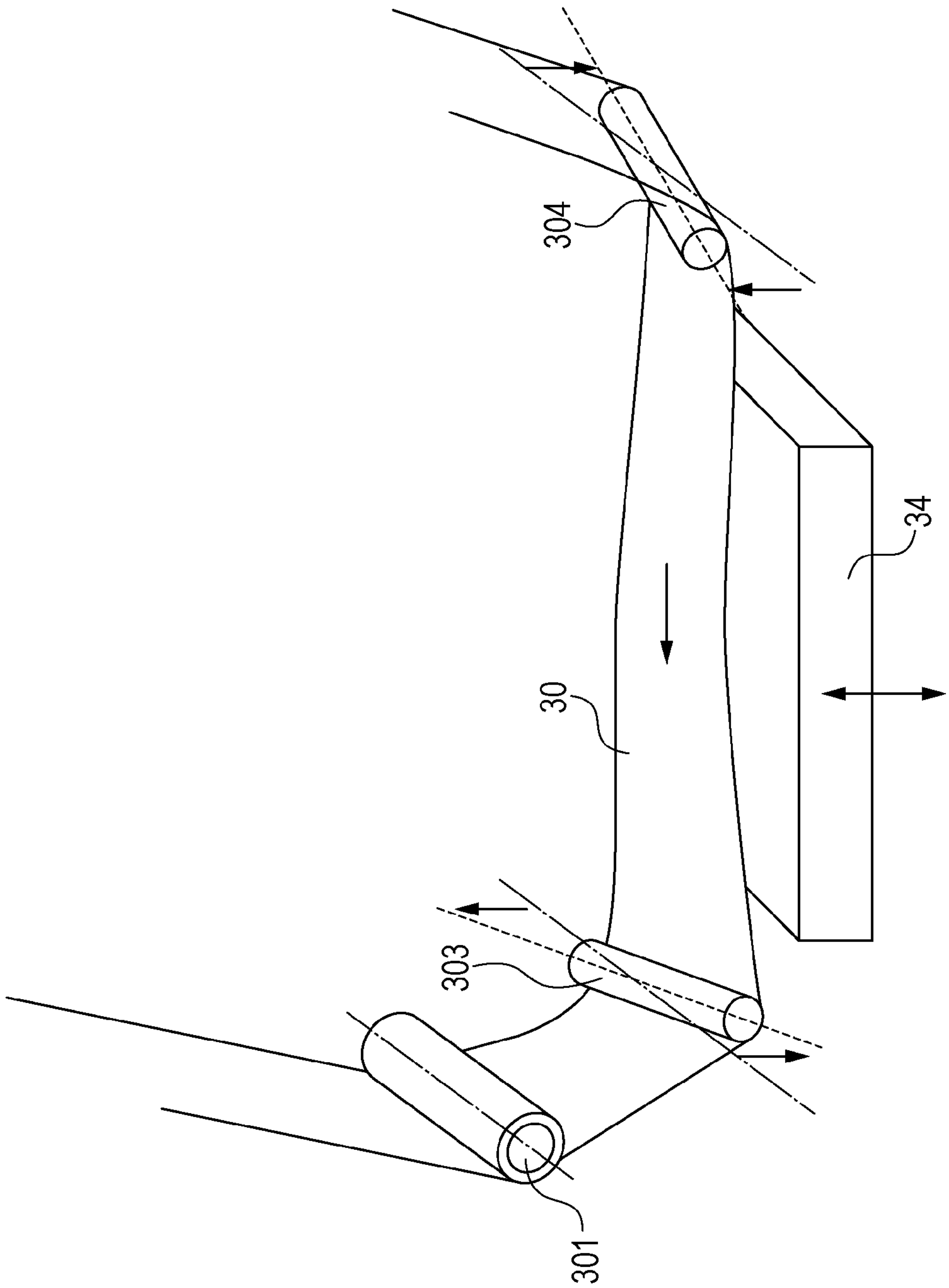
[Fig. 4B]



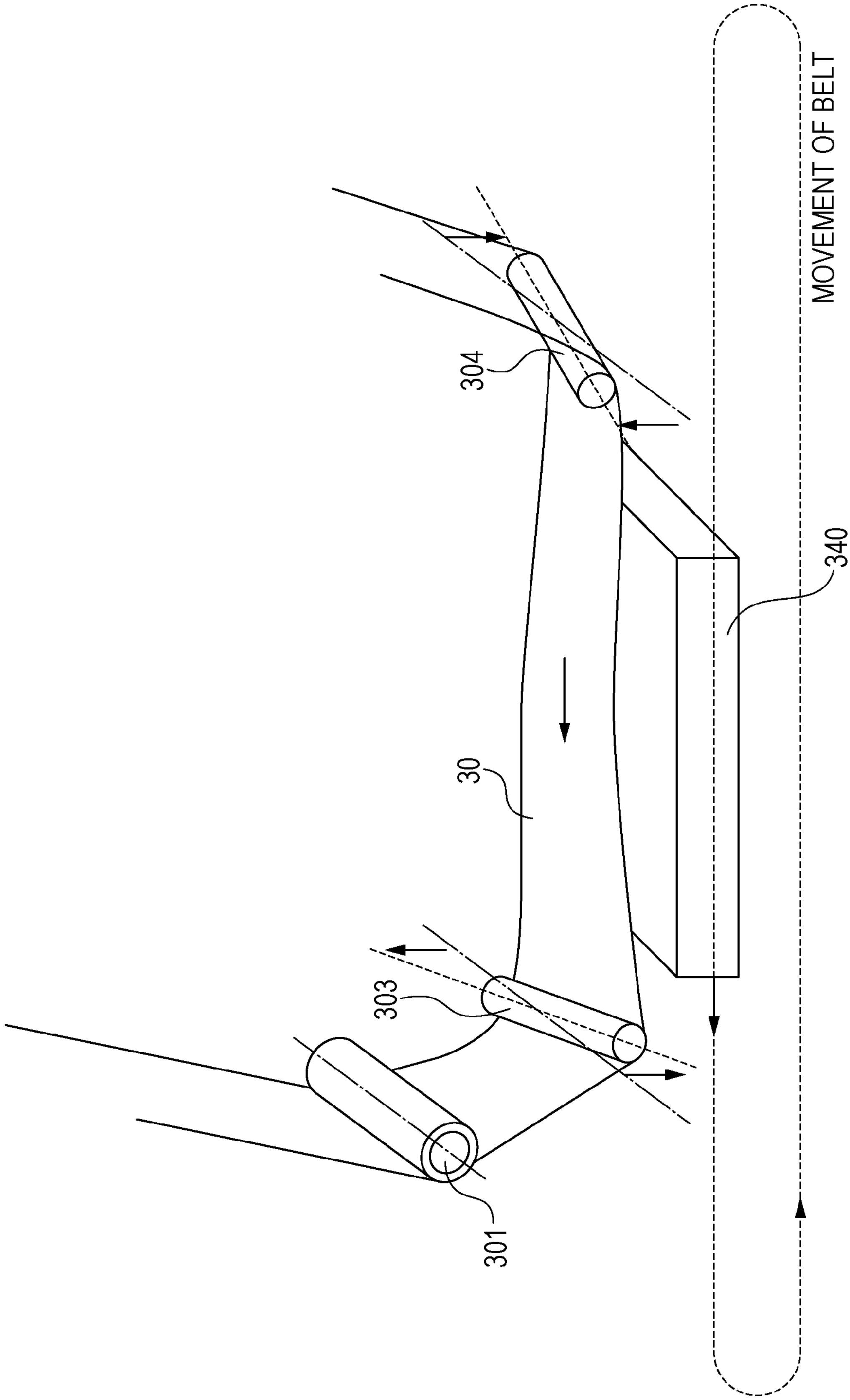
[Fig. 5]


START
FORM PARTICLE IMAGE OF MODELING MATERIAL
S501
FORM PARTICLE IMAGE OF SUPPORT MATERIAL
S502
FORM PARTICLE LAYER CORRESPONDING TO ONE LAYER
S503
TRANSFER PARTICLE LAYER TO INTERMEDIATE BELT IN LAMINATING UNIT
S506
CONVEY PARTICLE LAYER TO LAMINATION POSITION
S508
STOP INTERMEDIATE BELT IN LAMINATING UNIT
S509
ASCEND STAGE
S510
FIRST MODE (FUSION)
S511
SECOND MODE (SOLIDIFICATION)
S512
DESCEND STAGE
S513
DEFORM SURFACE OF INTERMEDIATE BELT
S514
CORRECT SURFACE OF INTERMEDIATE BELT
S515
NO
COMPLETED?
YES
END

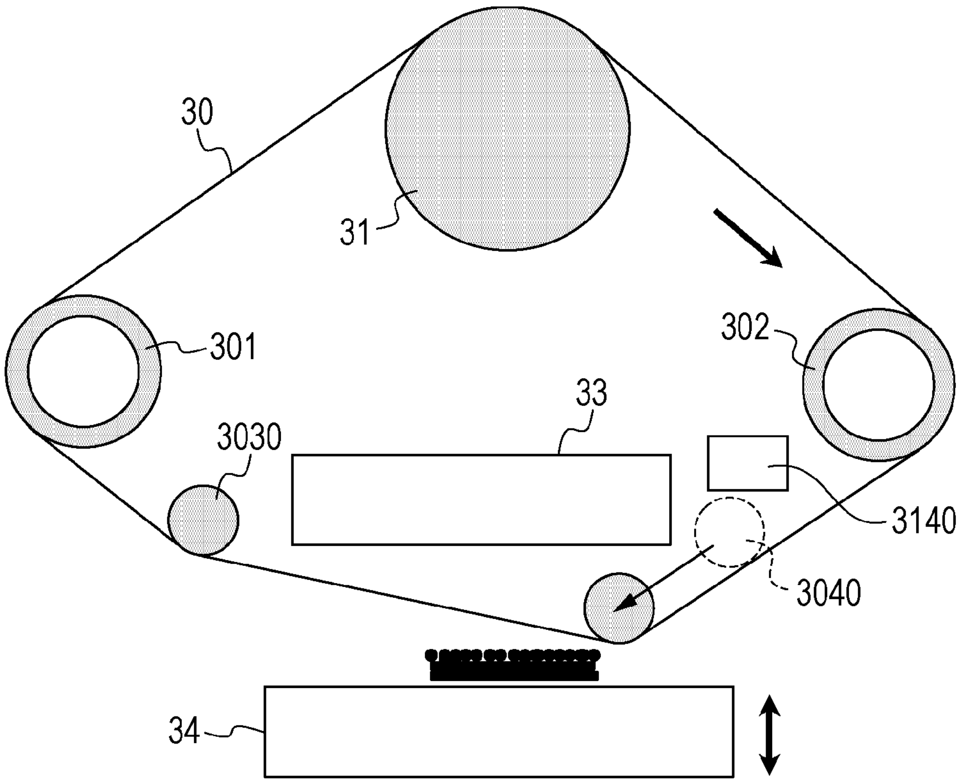
[Fig. 6]



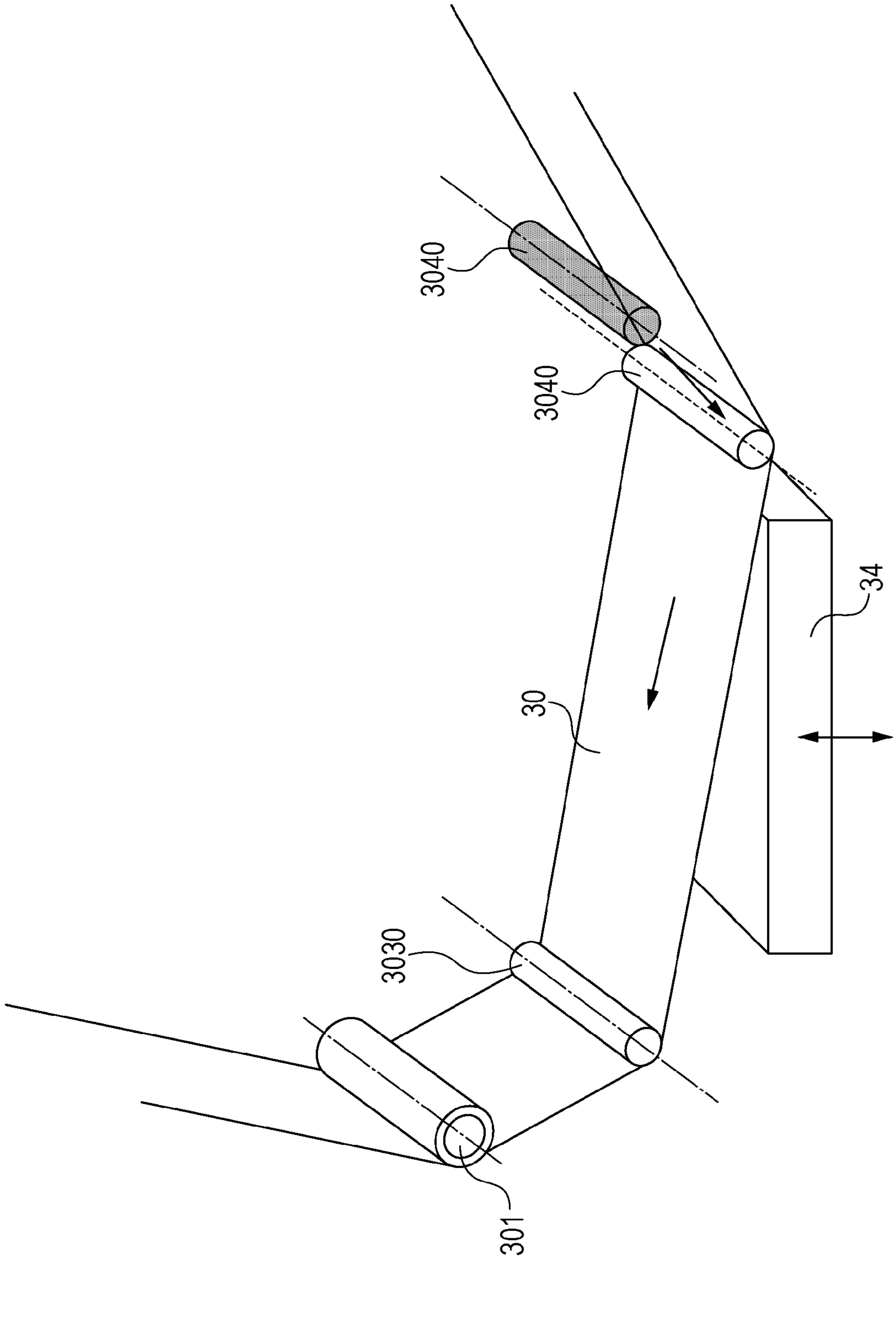
[Fig. 7]



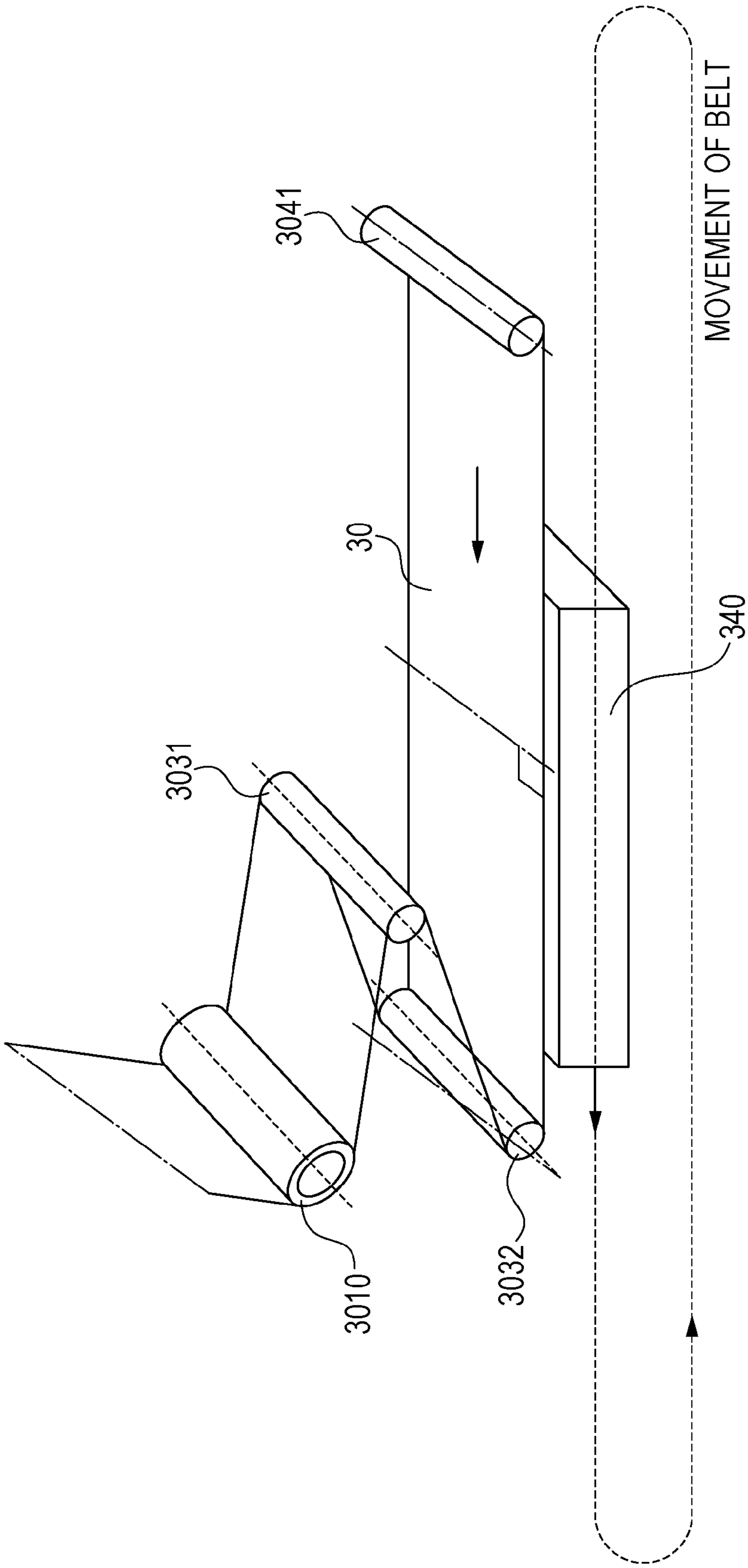
[Fig. 8]



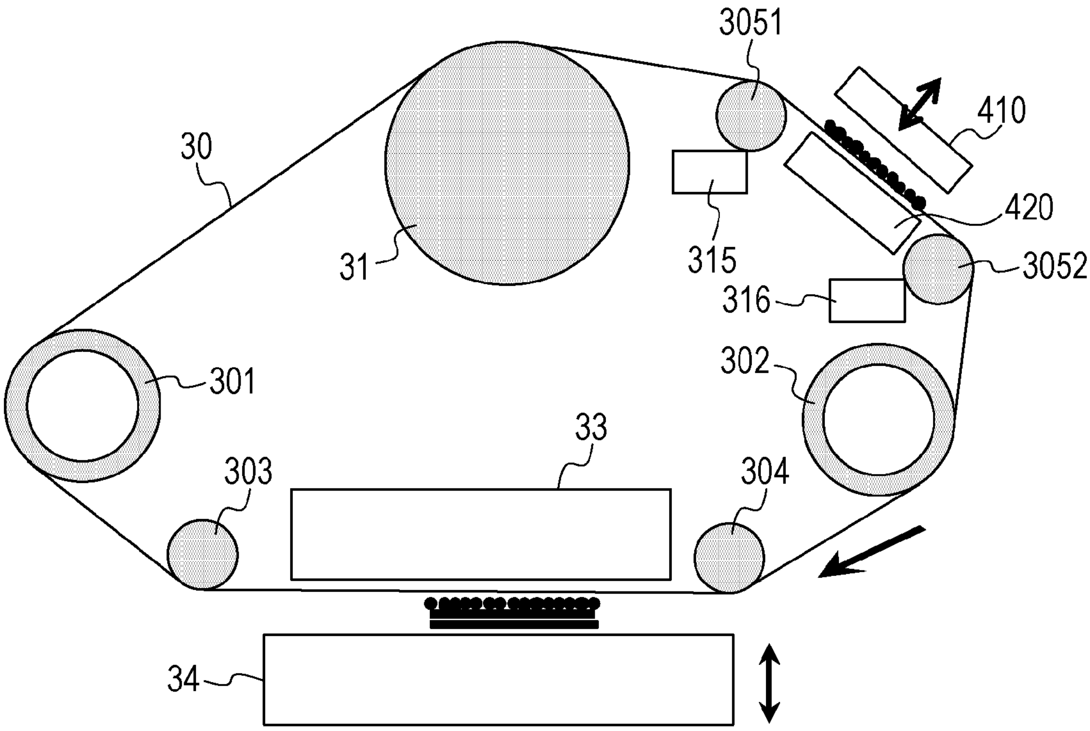
[Fig. 9]



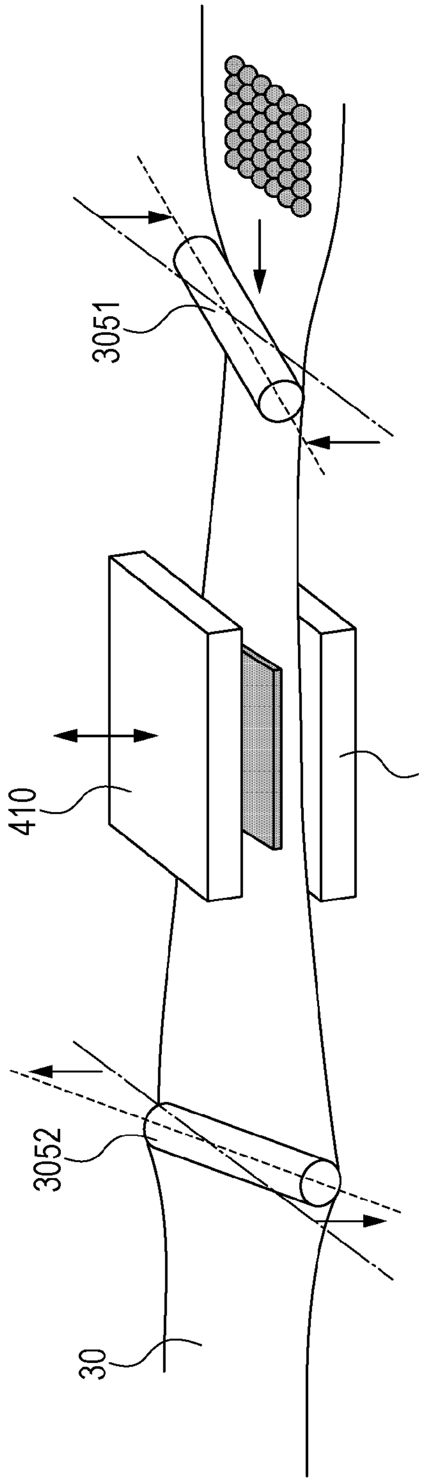
[Fig. 10]



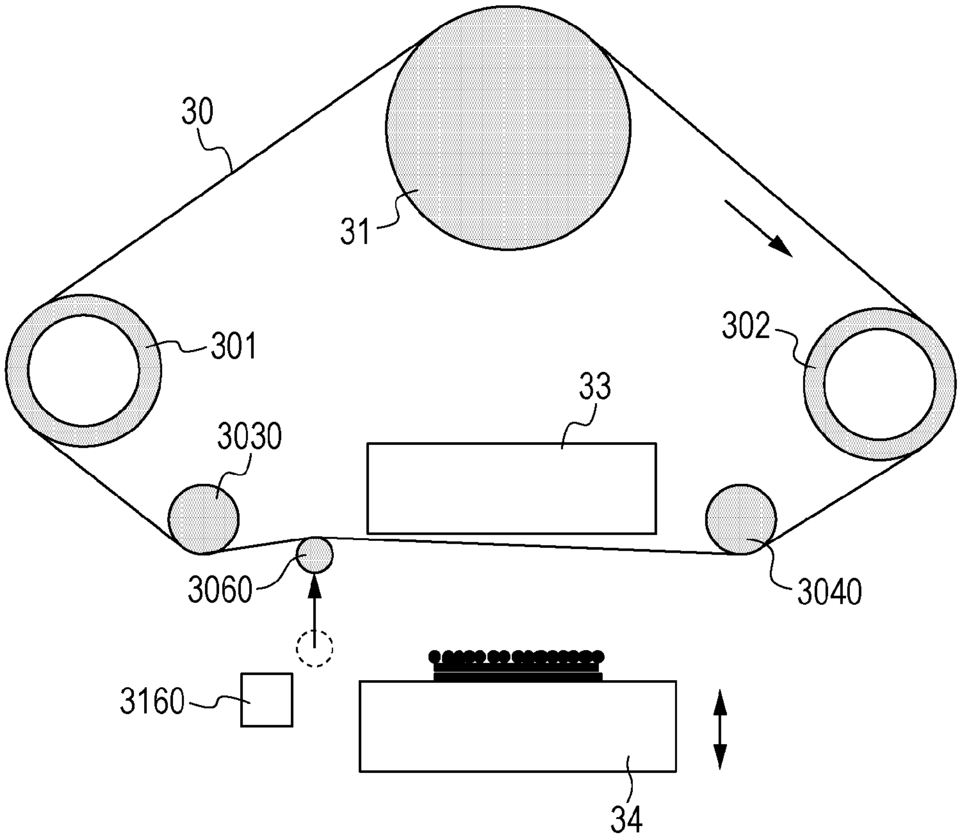
[Fig. 11]



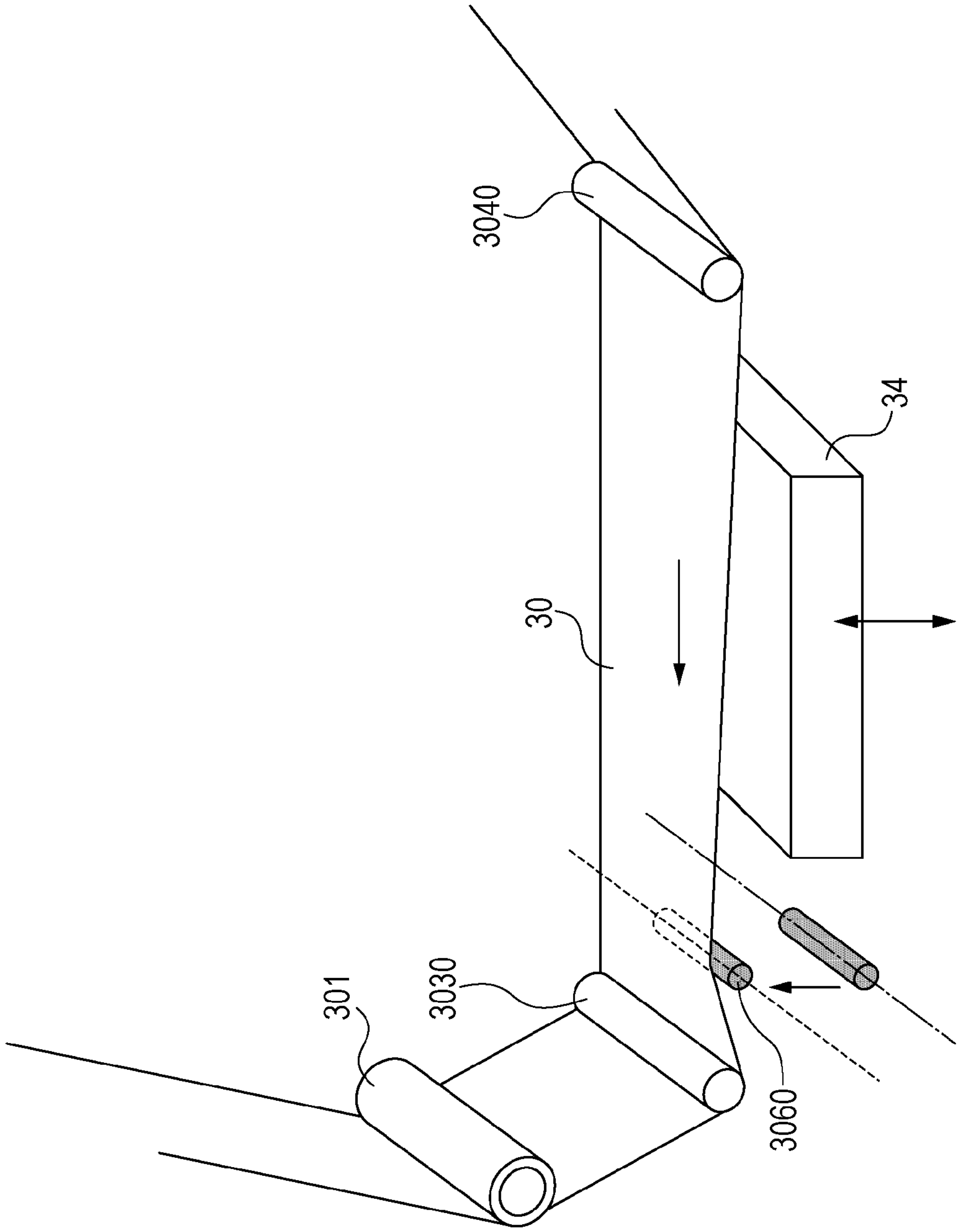
[Fig. 12]



[Fig. 13]



[Fig. 14]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2015/005765

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C67/00 G03G15/22 B33Y30/00
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)
B29C G03G 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	JP H07 227909 A (JAPAN SYNTHETIC RUBBER CO LTD) 29 August 1995 (1995-08-29) abstract; figures paragraph [0020] - paragraph [0024] -----	1,18,20
X	US 2013/075013 A1 (CHILLSCYZN STEVEN A [US] ET AL) 28 March 2013 (2013-03-28) figure 4c -----	1,2,18, 20

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

☒ See patent family annex.

* Special categories of cited documents :

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

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 January 2016	08/02/2016

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

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2015/005765

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		CN 203811991 U	03-09-2014
		CN 204222195 U	25-03-2015
		EP 2758837 A1	30-07-2014
		HK 1200220 A1	31-07-2015
		JP 2014533210 A	11-12-2014
		KR 20140065459 A	29-05-2014
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		US 2013078013 A1	28-03-2013
		WO 2013044047 A1	28-03-2013