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(54) Title: PRINTER HEAD AND EXTRUSION-BASED ADDITIVE MANUFACTURING METHOD

(57) Abstract: A printer head (100) for a 3D-printing apparatus, comprising a nozzle (110) arranged to deposit at least one filament (120) of a printing material in a direction (D) of movement of the printer head along an axis (A). The printer head further comprises at least one element (130) arranged adjacent said nozzle, wherein the at least one element further being arranged downstream of said nozzle with respect to the direction (D) and arranged at a distance (d) perpendicular to the axis (A). The at least one element is configured to be brought into abutting contact with at least one longitudinal side of the at least one filament during deposition of the at least one filament and configured to flatten at least a portion of the longitudinal side of the at least one filament.

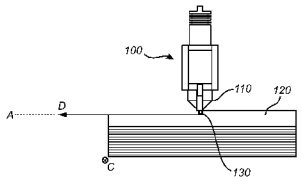

Fig. 1a

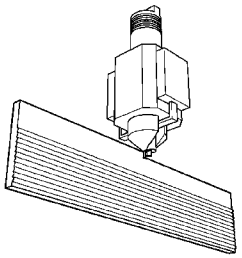
Fig. 1b

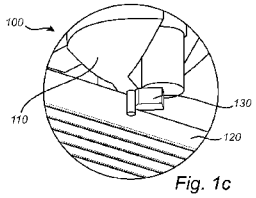

Fig. 1c

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Printer head and extrusion-based additive manufacturing method

FIELD OF THE INVENTION

The present invention generally relates to the field of additive manufacturing, which is sometimes referred to as 3D printing. More specifically, the present invention relates to a printer head for a 3D printing apparatus, a 3D printing apparatus comprising the printer head, and to an extrusion-based additive manufacturing method for manufacturing an object using the 3D printing apparatus.

BACKGROUND OF THE INVENTION

Additive manufacturing, sometimes also referred to as 3D printing, refers to processes used to synthesize a three-dimensional object. 3D printing is rapidly gaining popularity because of its ability to perform rapid prototyping without the need for assembly or molding techniques to form the desired article.

By using a 3D printing apparatus, the article or object may be built in three dimensions in a number of printing steps that are usually controlled by a computer model. For example, a sliced 3D model of the object may be provided in which each slice is recreated by the 3D printing apparatus in a discrete printing step. The 3D printing apparatus may deposit successive layers of an extrudable material from a dispenser, and the layers may be cured or otherwise hardened after deposition, e.g. using a laser to induce the curing process. An example of such a 3D printing apparatus is disclosed in US 2010/0327479 Al. This 3D-printing apparatus is an extrusion-based additive manufacturing system that can be used to build a 3D object from a digital representation of the 3D object in a layer-by-layer manner by extruding a flowable consumable modeling material filament through an extrusion tip carried by an extrusion head, and by depositing the modeling material on a substrate. This extrusion-based additive manufacturing method is also referred to as fused deposition modeling, fused layer modeling, or fused filament fabrication.

The majority of consumer 3D printers for performing the aforementioned extrusion-based additive manufacturing method comprise a moving head into which a plastic filament is fed. However, printers of this kind may suffer from the drawback of manufacturing objects which often show imperfections as a result of the method of

deposition. For example, these imperfections may include ridges and/or stepped structures, also referred to as "staircase" structures, as a result of successive deposition of individual filaments onto a previously deposited filament layer. Ridges may occur as the deposited material at its edges can flow due to a minimal surface tension, resulting in rounded edges.

Ridges and/or staircase structures are not only detrimental to the structural integrity (creating many initiators for cracks and delamination) and overall part tolerances of the printed object, they may also be aesthetically unpleasing. To avoid this, methods for smoothing the surfaces have been suggested, e.g. by means of solvent vapors, paintings and/or coatings. However, a significant drawback of these methods is that they require one or more extra processing steps.

Hence, alternative solutions are of interest, which are able to efficiently and conveniently eliminate or reduce the occurrence of ridges and/or staircase structures of 3D-printed objects, such that the objects produced may become more stable, more easily integrated and/or more aesthetically pleasing.

SUMMARY OF THE INVENTION

It is an object of the present invention to mitigate the above problems and to provide a method for creating objects by means of extrusion-based additive manufacturing (3D printing), wherein the objects so produced have improved stability, integration and/or visual properties compared to objects produced by extrusion-based additive manufacturing (3D printing) according to the prior art.

This and other objects are achieved by providing method, a printer head and a 3D printer having the features in the independent claims. Preferred embodiments are defined in the dependent claims.

Hence, according to a first aspect of the present invention, there is provided a printer head for a 3D-printing apparatus. The printer head comprises a nozzle arranged to deposit at least one filament of a printing material in a direction of movement of the printer head along an axis. The printer head further comprises at least one element arranged adjacent the nozzle, wherein the at least one element further being arranged downstream of the nozzle with respect to the direction along the axis and arranged at a distance perpendicular to the direction along the axis. The at least one element is configured to be brought into abutting contact with at least one longitudinal side of the at least one filament during deposition of the at least one filament and configured to flatten at least a portion of the longitudinal side of the at least one filament.

According to a second aspect of the present invention, there is provided a method, comprising the steps of providing a 3D-printing apparatus comprising a printer head according to the first aspect of the present invention. The method further comprises depositing at least one filament of printing material along a direction of movement of the printer head D along an axis A. Furthermore, the method comprises the step of bringing the at least one element into abutting contact with at least one longitudinal side of the at least one filament during deposition of the at least one filament, such that at least a portion of the longitudinal side of the at least one filament is flattened.

Thus, the present invention is based on the idea of providing a printer head for a 3D-printing apparatus which is configured to deposit at least one filament of a printing material. During this deposition, the element(s) of the printer head arranged downstream of the nozzle is (are) configured to flatten at least a portion of the longitudinal side of the at least one filament. In other words, the printer head of the present invention is capable of both depositing and flattening filament(s) during the same movement of the printer head.

The present invention is advantageous in that the printer head may both extrude filaments of a printing material while, during the same movement of the printer head, smoothen and/or flatten at least a portion of the longitudinal side of the filaments by the element(s). The present invention may hereby avoid any additional processing step related to a removal of ridges and/or staircase structures occurring on a printed object. It will be appreciated that additional processing steps may comprise mechanical after-treatments of the surfaces of the object and/or applications of solvent vapors, paintings and/or coatings to the object surfaces, which may lead to increases in manufacturing cost and/or time. In comparison, the printer head of the present invention, on the other hand, leads to a cost- and/or time-saving operation.

The present invention is further advantageous in that ridges and/or staircase structures of 3D-printed objects may be conveniently eliminated or reduced by the printer head after printing, such that the objects produced by the 3-D printing apparatus may become more stable, more easily integrated and/or more aesthetically pleasing.

It will be appreciated that the mentioned advantages of the printer head of the first aspect of the present invention also hold for the method according to the second aspect of the present invention.

The printer head of the present invention comprises a nozzle arranged to deposit at least one filament of a printing material in a direction of movement of the printer head along an axis. In other words, one or more filaments may be deposited in a downstream

direction in relation to a direction of movement of the printer head, wherein the direction of movement is along the axis. It will be appreciated that a plurality of filaments of printing material arranged adjacently may form a layer, wherein subsequently arranged layers may constitute an object produced by a 3D-printing apparatus comprising a printer head according to the present invention. By the term "printing material", it is here meant a material which can be extruded, e.g. a plastic material.

The printer head further comprises at least one element arranged adjacent the nozzle and downstream of the nozzle with respect to the direction of movement of the printer head and arranged at a distance perpendicular to this direction. By the term "adjacent the nozzle", it is here meant in a close vicinity of the nozzle.

The element(s) is (are) configured to be brought into abutting contact with at least one longitudinal side of the at least one filament during deposition of the at least one filament. By the term "brought into abutting contact", it is here meant that the at least one element is movable such that it may come into contact with the at least one filament. The at least one element is further configured to flatten at least a portion of the longitudinal side of the at least one filament. By the term "flatten", it is here meant to smooth, even out, or the like.

According to an embodiment of the present invention, the printer head comprises two elements configured to be arranged on either side of the axis A. As the nozzle of the printer head is arranged to deposit at least one filament of a printing material in a direction of movement of the printer head along the axis A, the two elements arranged on either side of the axis A are configured to be brought into abutting contact with at least one longitudinal side of the deposited filament(s). The present embodiment is advantageous in that the elements are configured to flatten the filament(s) deposited by the nozzle on both longitudinal sides, thereby saving time and/or cost during operation.

According to an embodiment of the present invention, the at least one element comprises at least one blade. The present embodiment is advantageous in that the blade(s) (e.g. in form of a spatula) is (are) able to efficiently and conveniently flatten the longitudinal sides of the deposited filament(s), eventually leading to a relatively smooth surface of the object produced by the 3-D printing apparatus.

According to an embodiment of the present invention, the printer head may comprise at least one scraper means configured to scrape at least a portion of the at least one blade. It will be appreciated that there may be a buildup of printing material on the blade(s) that may impede the blade(s) to function correctly during operation of the printer head. The

present embodiment is advantageous in that the scraper means may scrape the blades such that the blades may operate efficiently during flattening of the filament(s).

According to an embodiment of the present invention, the printer head may comprise at least one actuator coupled to the at least one element, wherein the at least one actuator is configured to move the at least one element. The present embodiment is advantageous in that the element(s) may be moved such that the printer head may adapt its operation to different deposition geometries, such as slopes, inclinations, or the like. The present embodiment is further advantageous in that the scraping of the element(s) may be performed even more efficiently.

According to an embodiment of the present invention, the at least one actuator is configured to tilt the at least one element around a tilt axis C perpendicular to the axis A. The present embodiment is advantageous in that the elements of the printer head hereby may be adapted to flatten at least one longitudinal side of the at least one filament deposited on a sloped (inclined) surface.

According to an embodiment of the present invention, the at least one actuator is configured to move the at least one scraper means relative the at least one element for scraping the at least one element. It will be appreciated that the actuator(s) may be configured to move the scraper means while keeping the element(s) still, or alternatively, to move the scraper means as well as the element(s). The present embodiment is advantageous in that the scraper means may efficiently scrape the element(s) from a buildup of printing material, such that the operation of the printer head of the present invention becomes even more efficient.

According to an embodiment of the present invention, the at least one element comprises at least one roller, and the at least one actuator is configured to rotate the at least one roller around a second axis F perpendicular to the axis A. Hence, the roller(s) may be brought into abutting contact with at least one longitudinal side of the at least one filament during deposition of the at least one filament and configured to flatten at least a portion of the longitudinal side of the at least one filament. The present embodiment is advantageous in that a buildup of printing material may be avoided due to lower friction forces and an improved flow of printing material provided by the roller(s).

According to an embodiment of the present invention, the at least one element is retractable in a direction parallel to a second axis F perpendicular to the axis A. For example, the element(s) may be retractable in a vertical direction. The present embodiment is especially advantageous in cases where the 3D-printing apparatus constructs an object with

one or more features having relatively small radii, i.e. with radii being smaller than the radius of the elements (e.g. in the form of roller(s)).

According to an embodiment of the present invention, the at least one scraper means is configured to scrape the at least one element during retraction of said at least one element.

According to an embodiment of the present invention, the printer head may comprise a cooling unit in thermal contact with the at least one element and be configured to cool the at least one element. By the term "cooling unit", it is here meant substantially any cooling unit, device, or the like, which furthermore is configured to cool the printer head. The present embodiment is advantageous in that the cooling of the printer head may reduce the adhesion between the element(s) and the printed material during the flattening of the longitudinal side of the filament(s). The smoothening of the peripheral edge of the layer(s) may hereby be performed more efficiently.

According to an embodiment of the present invention, the at least one element comprises a coating arranged to reduce the adhesion between the at least one element and the at least one filament. The present embodiment is advantageous in that the element(s) to an even higher extent may avoid a buildup of printing material on the element(s). The (low-friction) coating may comprise polytetrafluoroethylene, Teflon, or the like.

According to an embodiment of the present invention, there may be provided a 3D-printing apparatus comprising a printer head according to one or more of the previously described embodiments.

Further objectives of, features of, and advantages with, the present invention will become apparent when studying the following detailed disclosure, the drawings and the appended claims. Those skilled in the art will realize that different features of the present invention can be combined to create embodiments other than those described in the following.

BRIEF DESCRIPTION OF THE DRAWINGS

This and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing embodiment(s) of the invention.

Figs. 1a-c are schematic views of a printer head for a 3D-printing apparatus according to an exemplifying embodiment of the present invention,

Figs. 2a-b are schematic views of a printer head according to an exemplifying embodiment of the present invention, and

Fig. 3 is a schematic flow chart diagram of a method according to an exemplifying embodiment of the present invention.

DETAILED DESCRIPTION

Figs. 1a-c are schematic views of a printer head 100 for a 3D-printing apparatus according to an embodiment of the present invention. The printer head 100 comprises a nozzle 110 arranged to deposit at least one filament 120 of a printing material, e.g. molten plastics. In other words, the printing material is extruded from the bottom portion of the nozzle 110. The nozzle 110 of the printer head 100 is tapered in shape. The deposition of the filament(s) 120 is provided in a direction D of movement of the printer head 100 along an axis A, i.e. in a direction of movement from right to left in the figure. Individual filaments 120 may be deposited by the printer head 100 on top of each other, or alternatively, be arranged adjacently such that the filaments 120 constitute one or more layers.

In Fig. 1a, at least one element 130 is arranged adjacent the nozzle 110, wherein the element 130 is exemplified as a blade or spatula. The element 130 is arranged downstream of the nozzle 110 with respect to the direction D along the axis A, i.e. the element 130 is arranged slightly to the right of the nozzle 110 in the figure. The element 130 may comprise a non-sticky, low-frictional coating to reduce the adhesion between the element 130 and the filament 120. The coating may comprise polytetrafluoroethylene (PTFE, Teflon), or the like. Alternatively, or in conjunction herewith, the printer head 100 may comprise a cooling unit (not shown) in thermal contact with the element 130 and being configured to cool the element 130.

The element 130 is brought into abutting contact with the longitudinal side of the filament 120 during deposition of the filament 120 by the nozzle 110 of the printer head 100. The element 130 is hereby configured to flatten at least a portion of the longitudinal side of the filament 120 during the movement of the printer head 100 in the direction D. It will be appreciated that the printer head 100 may comprise two elements 130 arranged on either side of the axis A. By this arrangement, the printer head 100 is able to flatten at least a portion of the longitudinal side of the filament 120 on both sides of the filament 120 during the movement of the printer head 100.

The printer head 100 may further comprise at least one scraper means (not shown) configured to scrape at least a portion of the element (blade) 130 to impede the buildup of printing material. Furthermore, the printer head 100 may be provided with an actuator (not shown) configured move the scraper means relative the element 130 for

scraping the element 130. Alternatively, or in conjunction herewith, the actuator may be configured to move the element 130 for an efficient scraping of the element 130. The element 130 may furthermore be moved by the actuator such that the printer head 100 may adapt its deposition operation to different deposition geometries, such as slopes, inclinations, or the like.

The actuator may further be configured to tilt the element 130 around a tilt axis C perpendicular to the axis A. The element 130 of the printer head 100 may hereby be adapted to flatten at least one longitudinal side of the filament 120 deposited on a sloped (inclined) surface.

Fig. 1b is a schematic view of the same printer head 100 as shown in Fig. 1, and the references are omitted. However, the movement of the printer head 100 in Fig. 1b is from left to right.

Fig. 1c is a schematic, zoomed view of the same printer head 100 as shown in Fig. 1b. The element 130 of the printer head 110 has the form of a spatula configured to flatten at least a portion of the longitudinal side of the filament 120 during the movement of the printer head 100.

Figs. 2a-b are schematic views of a printer head 100 according to an exemplifying embodiment of the present invention. In Fig. 2a, the at least one element comprises two rollers 160 arranged on either side of the axis A, wherein the rollers 160 are in abutting contact with the longitudinal side of the filament 120 during deposition of the filament 120 by the nozzle 110 of the printer head 100. An actuator of the printer head 100 may be configured to rotate the rollers 160, such that the rollers 160 may flatten the filament 120 on both sides. It will be appreciated that the rollers 160 may comprise, or consist of, one or more materials which properties are beneficial for the rollers' 160 ability to flatten the filament 120 in a convenient and efficient manner. For example, the material(s) of the rollers 160 may provide a relatively low friction coefficient between the rollers 160 and the filament(s) 120, a low surface energy (i.e. a non-sticky surface) and/or a high heat resistance. Examples of materials of the rollers 160 may be polytetrafluoroethylene (PTFE), graphite, or the like. It will be appreciated that the at least one element 130, e.g. in the form of a blade or a spatula of Figs. 1a-c, may also comprise one or more of the mentioned materials to provide the same advantageous features.

Fig. 2b shows a schematic view of the printer head 100 in a direction F, perpendicular to axes A and C. Here, the rollers 160 are arranged at a distance d from the axis A, i.e. at a distance d along the axis C perpendicular to the axis A from the center of the roller

160 to the axis A. An actuator of the printer head 100 may be configured to rotate the rollers 160 around an axis F which is perpendicular to the axis A and to the axis C. The two rollers 160 may hereby flatten the filament 120 on both sides. It will be appreciated that the rollers 160 are arranged in a relatively close vicinity of the nozzle 110 in the direction along axis F. The rollers 160 may hereby be prevented to collide with previously deposited filaments 120.

Fig. 3 is a schematic flow chart diagram of a method 300 according to an exemplifying embodiment of the present invention. The method 300 comprises the steps of providing 310 a 3D-printing apparatus comprising a printer head 100 according to any one of the preceding embodiments. The method 300 further comprises the step of depositing 320 at least one filament of printing material in a direction of movement of the printer head along an axis. Furthermore, the method 300 comprises the step of bringing 330 an element into abutting contact with at least one longitudinal side of the filament during deposition of the filament such that at least a portion of the longitudinal side of the filament is flattened.

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims. For example, it will be appreciated that the figures are merely schematic views of printer heads according to embodiments of the present invention. Hence, any elements/components of the printer head 100 such as the nozzle 110 and/or the at least one element 130 may have different dimensions, shapes and/or sizes than those depicted and/or described. For example, element(s) 130 may be larger or smaller than what is exemplified in the figures.

CLAIMS:

1. A printer head (100) for an extrusion-based 3D-printing apparatus, comprising:

- a nozzle (110) arranged to deposit at least one filament (120) of a printing material in a direction (D) of movement of the printer head along an axis (A), and
- at least one element (130) arranged adjacent said nozzle, said at least one element further being arranged downstream of said nozzle with respect to the direction (D) along the axis (A) and arranged at a distance (d) perpendicular to the axis (A),

wherein said at least one element is configured to be brought into abutting contact with at least one longitudinal side of the at least one filament during deposition of the at least one filament and configured to flatten at least a portion of the longitudinal side of the at least one filament.

2. The printer head according to claim 1, comprising two elements configured to be arranged on either side of the axis (A).

3. The printer head according to claim 1 or 2, wherein said at least one element comprises at least one blade.

4. The printer head according to claim 3, further comprising at least one scraper means configured to scrape at least a portion of said at least one blade.

5. The printer head according to any one of the preceding claims, further comprising at least one actuator coupled to said at least one element, wherein said at least one actuator is configured to move said at least one element.

6. The printer head according to claim 5, wherein said at least one actuator is configured to tilt said at least one element around a tilt axis (C) perpendicular to the axis (A).

7. The printer head according to claim 4 and 5, wherein said at least one actuator is configured to move said at least one scraper means relative said at least one element for scraping said at least one element.

8. The printer head according to claims 5, wherein said at least one element comprises at least one roller (160), and wherein said at least one actuator is configured to rotate said at least one roller around a second axis (F) perpendicular to the axis (A).

9. The printer head according to any one of the preceding claims, wherein said at least one element is retractable in a direction parallel to a second axis (F) perpendicular to the axis (A).

10. The printer head according to claims 7 and 9, wherein said at least one scraper means is configured to scrape said at least one element during retraction of said at least one element.

11. The printer head according to any one of the preceding claims, further comprising a cooling unit in thermal contact with said at least one element and configured to cool said at least one element.

12. The printer head according to any one of the preceding claims, wherein said at least one element comprises a coating arranged to reduce the adhesion between said at least one element and the at least one filament.

13. The printer head according to claim 12, wherein said coating comprises polytetrafluoroethylene.

14. An extrusion-based 3D-printing apparatus, comprising a printer head according to any one of the preceding claims.

15. An extrusion-based additive manufacturing method for manufacturing an object using an extrusion-based 3D-printing apparatus according to claim 14, wherein the method comprises the steps of:

- depositing at least one filament of printing material in a direction of movement

of the printer head (D) along an axis (A), and

- bringing said at least one element into abutting contact with at least one longitudinal side of the at least one filament during deposition of the at least one filament such that at least a portion of the longitudinal side of the at least one filament is flattened.

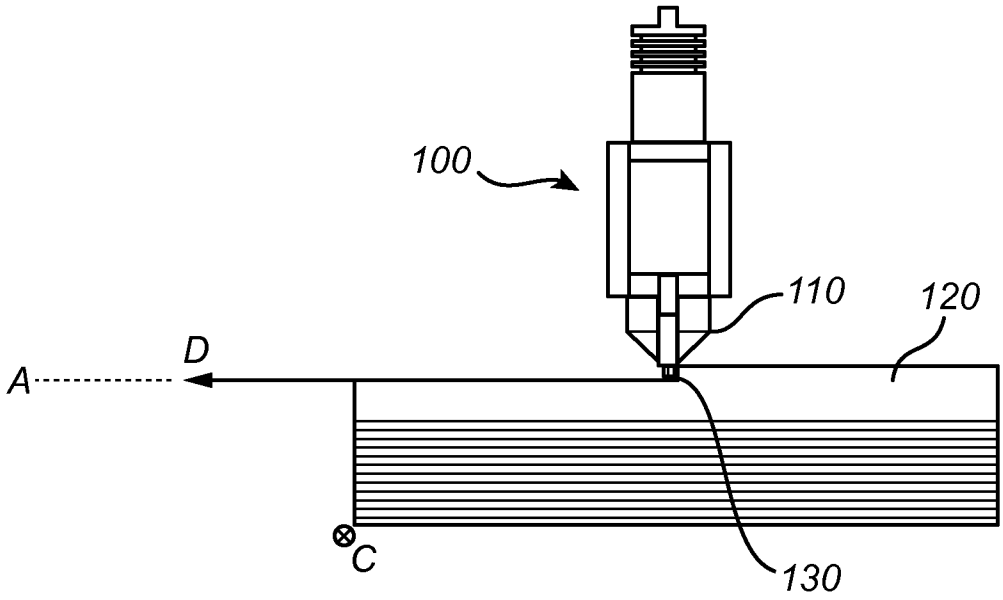

Fig. 1a

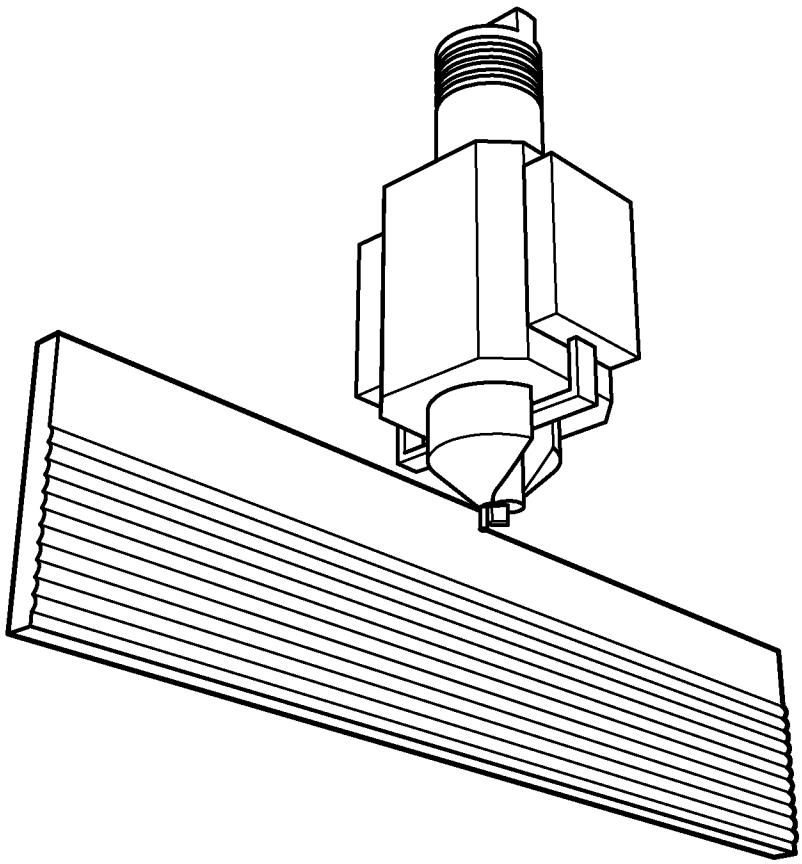

Fig. 1b

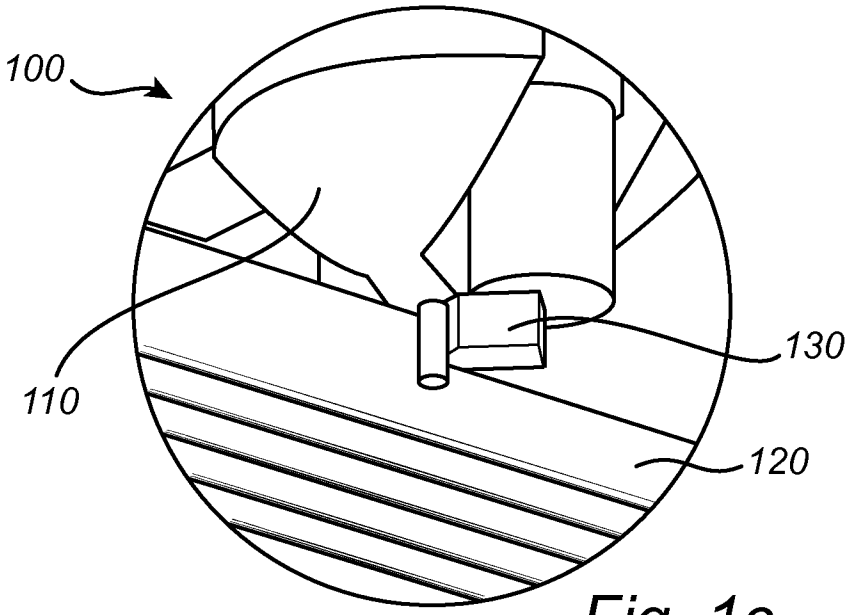

Fig. 1c

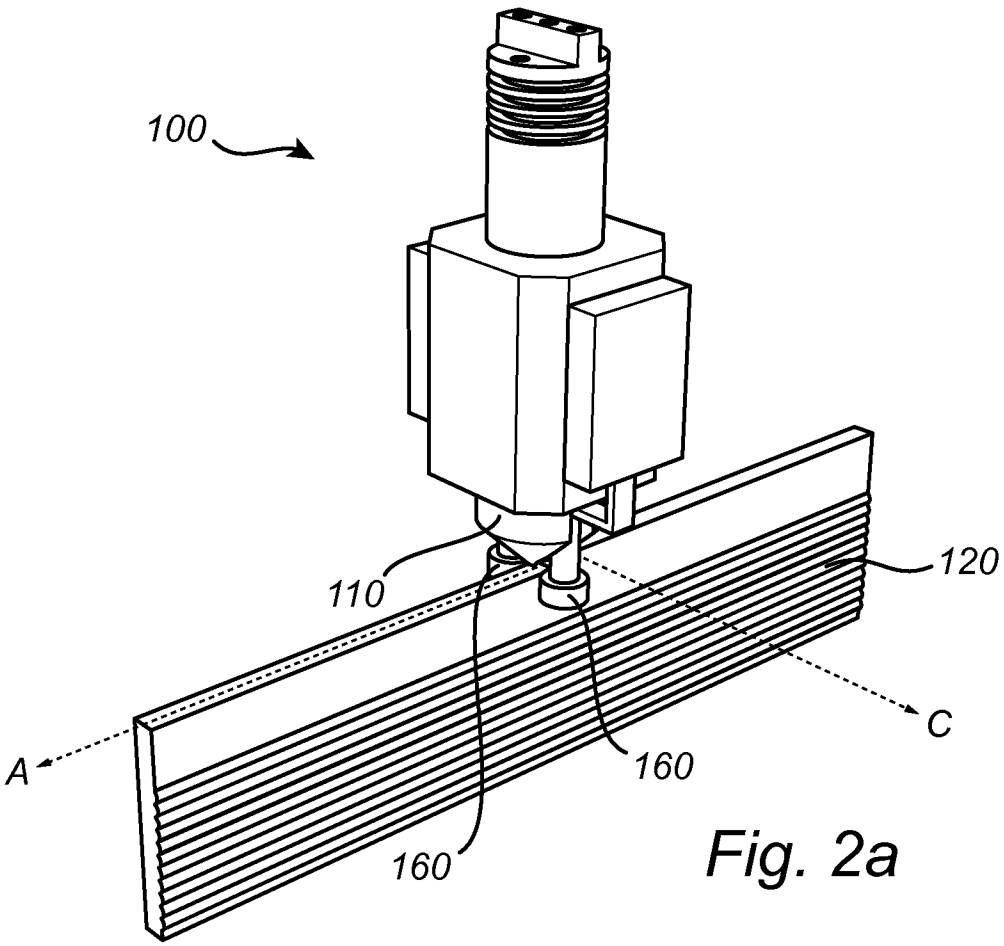

Fig. 2a

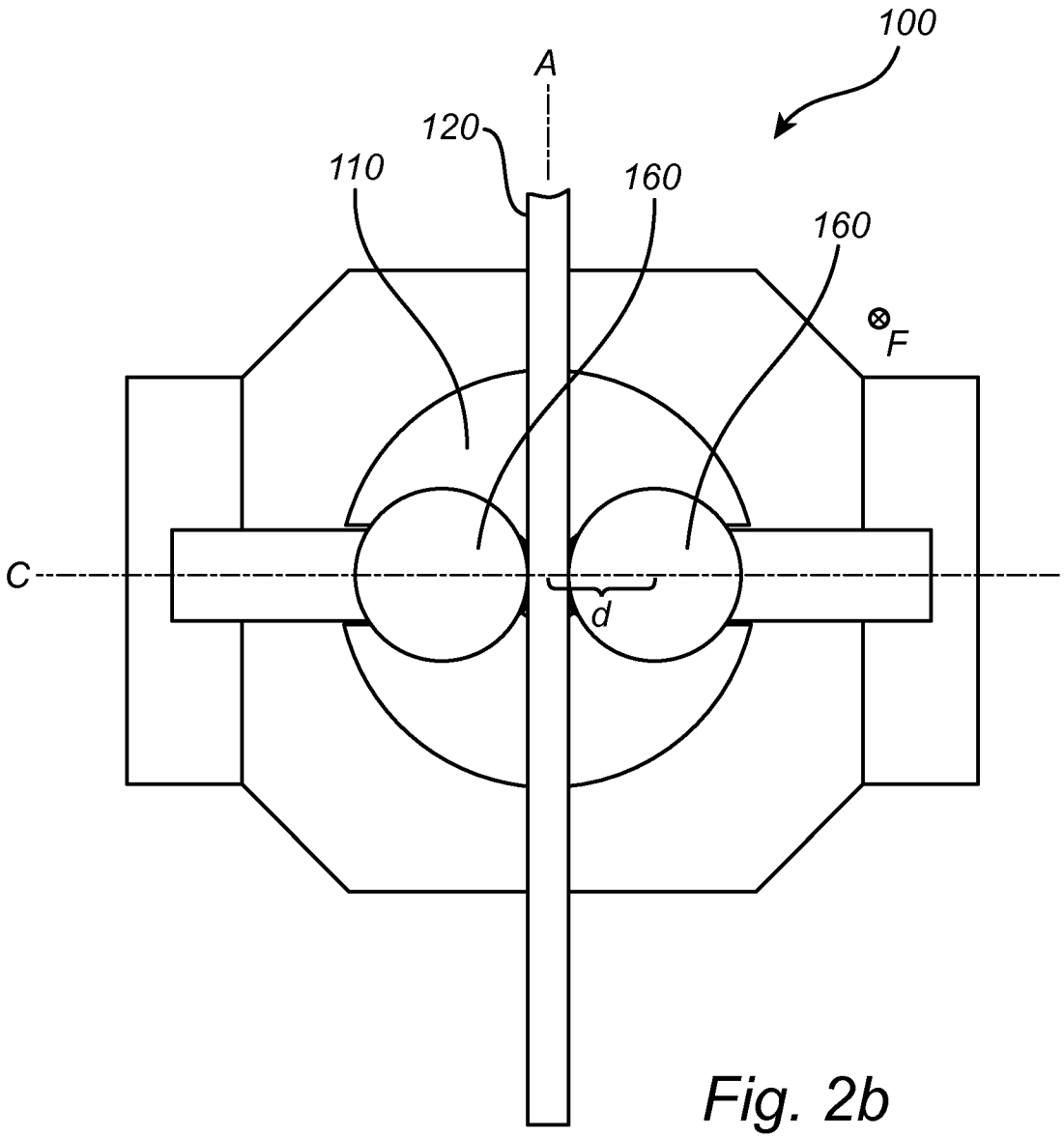

Fig. 2b

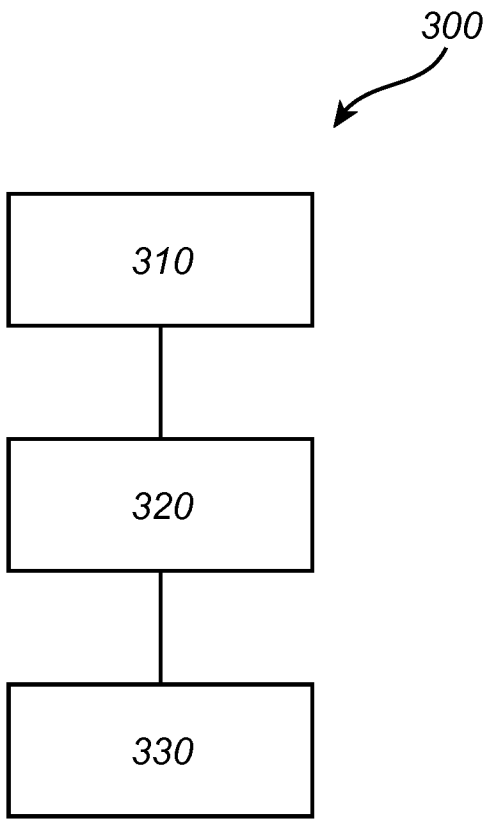

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/075667

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C67/00 B33Y30/00 B33Y10/00 B33Y40/00 B29C64/118
B29C64/209
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 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	DE 10 2014 220082 A1 (HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN COBURG [DE]) 21 April 2016 (2016-04-21)	1-3,5,6, 8,9, 11-15
Y	figure 1a figure 2 figure 6 paragraph [0015] paragraph [0023] paragraph [0082] paragraph [0088] paragraph [0099] paragraph [0166] - paragraph [0167]	4,7,10

Y	EP 1 674 243 A2 (OBJET GEOMETRIES LTD [IL]) 28 June 2006 (2006-06-28) paragraph [0011] paragraph [0067] paragraph [0071]	4,7,10

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
18 December 2017	05/01/2018

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 656 230 A (KHOSHEVIS BEHROKH [US]) 12 August 1997 (1997-08-12) figure 1 figure 12 column 5, line 61 - line 65 column 5, line 21 - line 36 column 7, line 36 - line 39	1-15
A	US 2013/197683 A1 (ZHANG HAIOU [CN] ET AL) 1 August 2013 (2013-08-01) figure 1 paragraph [0019]	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/075667

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