(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 October 2021 (21.10.2021)

WIPO | PCT

(10) International Publication Number
WO 2021/209787 A1

(51) International Patent Classification:
B29C 64/118 (2017.01) *B33Y 40/00* (2020.01)
B29C 64/194 (2017.01) *B29C 48/05* (2019.01)
B29C 64/209 (2017.01) *B29C 48/30* (2019.01)
B33Y 30/00 (2015.01) *B29C 48/86* (2019.01)

(21) International Application Number:
PCT/IB2020/053528

(22) International Filing Date:
15 April 2020 (15.04.2020)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **RĪGAS TEHNISKĀ UNIVERSITĀTE** [LV/LV]; Kaļķu iela 1, LV-1658 Riga (LV).

(72) Inventor: **KĻAVA, Juris**; Riekstu iela 7, LV-2130 Ulbroka, Stopiņu nov. (LV).

(74) Agent: **FORTUNA, Jevgenijs**; FORAL Patent Law Offices, P.O.Box 98, LV-1050 Riga (LV).

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

(54) Title: A PRINTER HEAD ASSEMBLY FOR A PULTRUSION-TYPE 3D PRINTER

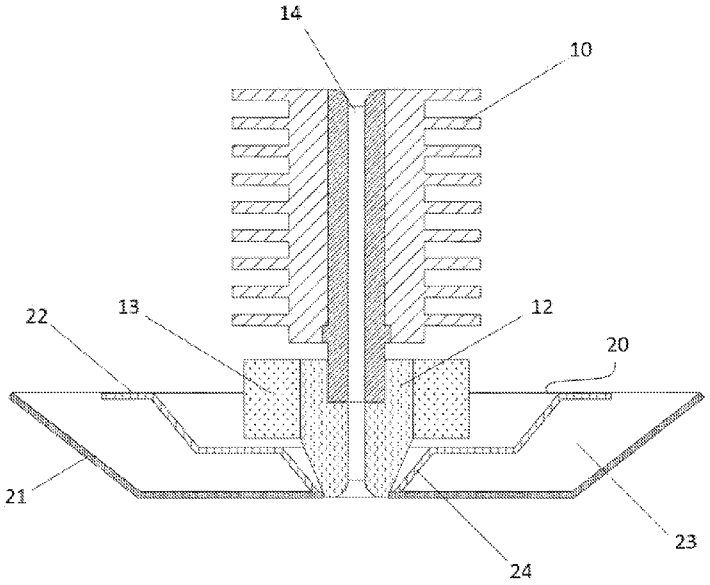

Fig. 5

(57) Abstract: Printing heads used in pultrusion-type 3D printers. The proposed printer head assembly comprises a cooling body (10), a cooling means, being in thermal communication with the cooling body (10); a heating body (12), a heating means (13), being in thermal communication with the heating body (12); the heating body (12) located under the cooling body (10) in a downstream direction; a through channel (14) arranged in the cooling body (10) and the heating body (12). The through channel (14) having an inlet (15) in the cooling body (10) and an outlet (16) in the heating body (12). The through channel (15) is adapted to allow pulling printing filament through it, wherein the outlet (16) is of progressively widening diameter in a downstream direction. According to the preferred embodiment, walls of the through channel in the heating body are provided with ridges (17) designed to transfer heat from the heating means (13) deep into a printing filament structure. According to yet another embodiment, the printer head assembly is further

WO 2021/209787 A1

[Continued on next page]

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

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

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

provided with a presser (20) mounted so to allow the presser to press a melted printing filament, which is pulled out from the outlet (16) increasing the level of compaction for deposited filament.

A printer head assembly for a pultrusion-type 3D printer

Technical Field

[001] The invention relates to systems for building three-dimensional objects in a layer-by-layer manner, known as 3D printers, more particularly, to printing heads used in pultrusion-type 3D printers.

Background Art

[002] Currently there are known more than ten types of 3D printing technologies, using different processes of application of material. One of such widely used technologies is material extrusion, where a filament of solid thermoplastic material is pushed through a heated nozzle, melting it in the process. The 3D printer deposits the material on a build platform (printer bed) along a predetermined path, where the filament cools and solidifies to form a solid object.

[003] GB2302836, US4575330, US7625200, US8827684 disclose 3D printers and processes applying extrusion-based layered deposition technology.

[004] A typical printer head used in extrusion-based layered deposition printing is characterized in printing nozzle having an outlet with smaller diameter than diameter of a thermoplastic material feeding channel. Also, the printing nozzle is adapted for pushing through it of a filament of solid thermoplastic material by an extrusion mechanism.

[005] Although not used directly for 3D printing, there are known pultrusion machines and methods (US2419328, US2786793, US 3556888). According to known solutions the reinforcement materials, such as fibres or strands, either woven or braided, are impregnated with thermoset resin, possibly followed by a separate preforming, and pulled through a heated stationary die where the resin undergoes polymerization. Resin provides the resistance to the environment, including the corrosion resistance, the UV resistance and the impact resistance, while the high-performance fibres provides mechanical strength.

Summary of the Invention

[006] The aim of the invention is to provide a printer head assembly for a pultrusion-type 3D printer, providing a cost- and performance-effective solution, interoperable with major existing devices, as well as ensuring bigger freedom of controlling properties of the printing filaments.

[007] The proposed printer head assembly for a pultrusion-type 3D printer, comprises a cooling body, a cooling means, being in thermal communication with the cooling body; a heating body, a heating means, being in thermal communication with the heating body; the heating body located under the cooling body in a downstream direction; a through channel arranged in the cooling body and the heating body. The through channel having an inlet in the cooling body and an outlet in the heating body. The through channel is adapted to allow pulling printing filament through it, wherein the outlet is of progressively widening diameter in a downstream direction.

[008] According to another embodiment, walls of the through channel in the heating body are further provided with one or more ridges, protruding towards the imaginary longitudinal central axis of the through channel, but not reaching it. The ridges are made of thermally conductive material and thus designed to transfer heat from the heating means deep into a printing filament structure. The ridges extend along the walls of the through channel in a downstream direction.

[009] According to yet another embodiment, the printer head assembly is further provided with a presser mounted so to allow the presser to adhere a melted printing filament, which is pulled out from the outlet, to a platform or an object being printed. The presser can be either rigidly, or floatingly mounted on the printer head assembly. The presser can be also operably connected with a vibration exciter to transmit vibration to the adhered/pressed printing filament in order to ensure printing filament compaction. The presser may have a double-wall structure, forming a cooling passage to allow air or liquid to pass through the cooling passage. The presser's surface, which is designed to be in contact with melted printing filament should preferably be covered by non-stick coating.

Brief Description of Drawings

[010] Fig. 1 shows cross-sectional view of the printer head assembly according to one embodiment of the invention;

Fig. 2 – enlarged cross-sectional view of a fusing and forming area of the printer head assembly according to one embodiment;

Fig. 3A – 3F shows five different embodiments of the one to seven ridges formed on the walls of the through channel;

Fig. 4 – cross-sectional view of a heating body with ridges formed in the through channel according to one embodiment of the invention

Fig. 5 – cross-sectional view of the printer head assembly provided with the presser;

Fig. 6 – cross-sectional view of the printer head assembly with the presser having elastic thermally isolating wall, according to another embodiment;

Fig. 7 – schematic cross-sectional view of the printer head assembly in operation.

Detailed Description of the Invention

[011] A printer head assembly for a pultrusion-type 3D printer (Fig. 1), comprising: a cooling body 10, a cooling means 11, adapted to be in thermal communication with the cooling body 10 and adapted to cool the cooling body 10; a heating body 12, a heating means 13 adapted to be in thermal communication with the heating body 12 and adapted to heat the heating body 12; the heating body 12 located under the cooling body 10 in a downstream direction; a through channel 14 arranged in the cooling body 10 and the heating body 12, the through channel 14 having an inlet 15 and an outlet 16, both in axial alignment, the inlet 15 is arranged in the cooling body 10 and the outlet 16 is arranged in the heating body 12, the through channel 14 is adapted to allow pulling printing filament through the cooling body 10 and the heating body 12, wherein the outlet 16 is of progressively widening diameter in a downstream direction. Thus, the diameter of the outlet 16 is bigger than the diameter of the through channel 14. In the through channel's 14 longitudinal cross-section the outlet 16 has rounded edges to prevent fracturing due to sharp bending of the filament, being pulled out from the outlet 16. The diameter of the orifice is selected depending on the bending properties of the fiber components.

[012] The heating body 12 is made of heat-conducting material and is adapted to transfer heat from the heating means 13 to the printing filament. The cooling body 10 is adapted to transfer thermal energy to the printing filament to prevent its melting until it has reached the heating body 12. Alternatively, part of the through channel 14, which is not located in the heating body 12 may be made of low heat conductivity material, to decrease heat transfer to the printing filament in order to prevent its melting until it has reached the through channel 14 in the heating body 12. The cooling means 11 can be designed to apply air flow or liquid flow for cooling.

[013] According to the preferred embodiment, the walls of the through channel 14 are made of thermally and/or chemically resistant material preventing or delaying their erosion due to thermochemical emissions.

[014] The walls of the through channel 14 in the heating body 12 can further be provided with one or more ridges 17, protruding towards the imaginary longitudinal central axis of the through channel 14, but not reaching it (Fig. 3A-3F). The ridges 17 are made of thermally conductive material and thus designed to transfer heat from the heating means 13 deep into a printing filament structure (Fig. 3F). The ridges 17 extend along the walls of the through channel 14 in a downstream direction. Longitudinal length of the ridges 17 is less than the length of the through channel 14 in the heating body 12. The ridges 17 are preferably located in the lower part of the through channel 14, ending in the outlet 16 and have longitudinal length from 1/3 to 1/1 of the through channel 14 in the heating body 12 (B in Fig. 2; Fig. 4).

[015] The printer head assembly can further be provided with a presser 20 mounted on the printer head assembly so to allow the presser 20 to press a printing filament, which is pulled out from the outlet 16, to a printer's build platform or previously deposited printing filament (Fig. 5, 7). The presser's 20 surface, which is designed to be in contact with melted printing filament, is preferably covered by non-stick coating, such as polytetrafluoroethylene.

[016] According to one embodiment the presser 20 is rigidly mounted on the printer head assembly. According to another embodiment the presser 20 is floatingly mounted on the printer head assembly, so to allow controllable change of the presser's 20 position in vertical direction, and/or in diagonal direction.

[017] According to yet another embodiment the printer head assembly is further provided with a vibration exciter. The presser 20 is operably connected with the vibration exciter and is adapted to transmit vibration to the pressed melted printing filament in order to ensure its compaction.

[018] According to yet another embodiment the presser 20 is designed to have a double-wall structure, comprising a first 21 and a second 22 spaced-apart walls, forming a cooling passage 23 between the first 21 and the second 22 walls so to allow fresh air or cooling fluid to pass through the cooling passage 23 (Fig. 5-7). An outer side of the first wall 21 is adapted to press a printing filament, which is pulled out from the outlet 16, to a printer's build platform or previously deposited printing filament, while the second wall 22 is adapted to provide thermal isolation between the cooling passage 23 and the heating body 12 and/or the heating means 13.

[019] According to yet another embodiment the presser 20 is further provided with an elastic or rigid thermally isolating wall 24 attached to the first wall 21 and the second wall 22, so to prevent heat exchange between an air passing through the cooling passage 23 and the heating body 12 and the outlet 16. The thermally isolating wall 24 can be also made of corrugated material, thus allowing it to spread and shrink along with the movement of the first wall 21.

[020] The presser 20 may be designed to have controllably changeable shape and configuration, so that it can be amended depending on the printable object's geometry, printing technology modifications used and cooling characteristics of the material.

[021] The proposed printer head assembly can be mounted on any type of positioning mechanism, using fused deposition modelling technology, such as 3D printers, robotic arm and other. The invention also proposes a printer, comprising the printer head assembly as disclosed above.

[0022] In contrast to extrusion methods, the proposed device is adapted for pulling out the printing filament. Using the pultrusion 3D deposition of filament by the proposed device allows to use printing filament comprising different type and range of reinforcement materials – high performance man made and natural continuous fibres and comingled with polymer filaments, acting as consolidation agent. The filaments may be arranged in the fibre in proportions and position depending on the desired properties of the deposited fibre.

[023] The device operates as follows. The printing filament, which preferably comprises one or more reinforcement filaments and one or more thermoplastic filaments, or reinforcement filaments fused in thermoplastic material, is put through the through channel 14 (entering into the inlet 15 and exiting through the outlet 16). The loose end of the printing filament is fixed to a printer bed or other adhesive surface. The cooling body 10 and the heating means 13 are brought into operation. A printer, a robotic arm or their equivalent starts moving the printer head along a predetermined path. The printing filament melted in the heating body 12 and pulled through the outlet 16 from the through channel 14 fuses to previously deposited printing filament, and solidifies upon a drop in temperature. According to the preferred embodiment, the presser 20 mounted on the printer head assembly presses a printing filament, which is pulled out from the outlet 16, to a printer's build platform or previously deposited printing filament (Fig. 7), thus, forming and additionally cooling the printed layer of the printing filament. Forming of a layer thus may comprise its alignment, compaction and lamination of the reinforcement filaments into the fused thermoplastic material. Also, use of the vibration exciter according to one embodiment, and the presser 20, floatingly mounted on the printer head assembly, may facilitate controllable compaction of the printing filament.

[024] The proposed device allows applying pultrusion-type 3D printing, which in turn, provides a cost- and performance-effective solution, if compared with extrusion-type 3D printing. The use of pultrusion-type 3D printing allows using continuous filaments in form of elastic comingled strand. Also, the proposed solution ensures operator freedom of variation of structure and properties of the printing filament, by choosing materials and proportions of reinforcement and thermoplastic filaments before printing.

Claims

1. A printer head assembly for a pultrusion-type 3D printer, comprising:
- a cooling body (10), a cooling means (11), adapted to be in thermal communication with the cooling body (10) and adapted to cool the cooling body (10);
- a heating body (12), a heating means (13) adapted to be in thermal communication with the heating body (12) and adapted to heat the heating body (12); the heating body (12) located under the cooling body (10) in a downstream direction;
- a through channel (14) arranged in the cooling body (10) and the heating body (12), the through channel (14) having an inlet (15) and an outlet (16), both in axial alignment, the inlet (15) is arranged in the cooling body (10) and the outlet (16) is arranged in the heating body (12), the through channel (14) is adapted to allow pulling printing filament through the cooling body (10) and the heating body (12), wherein the outlet (16) is of progressively widening diameter in a downstream direction.

2. The printer head assembly according to claim 1, wherein walls of the through channel (14) in the heating body (12) are further provided with one or more ridges (20), protruding towards the imaginary longitudinal central axis of the through channel (14), but not reaching it, wherein the ridges (17) are made of thermally conductive material and thus designed to transfer heat from the heating means (13) deep into a printing filament structure.

3. The printer head assembly according to claim 2, wherein the ridges (17) extend along the walls of the through channel (14) in a downstream direction, wherein longitudinal length of the ridges (17) is less than the length of the through channel (14) in the heating body (12).

4. The printer head assembly according to any preceding claims, wherein the printer head assembly is further provided with a presser (20) mounted on the printer head assembly so to allow the presser (20) to press a printing filament, which is pulled out from the outlet (16), to a printer's build platform or previously deposited printing filament.

5. The printer head assembly according to claim 4, wherein the presser (20) is floatingly mounted on the printer head assembly.

6. The printer head assembly according to claim 5, wherein the presser (20) is floatingly mounted on the printer head assembly, so to allow controllable change of the presser's (20) position in vertical direction, and/or in diagonal direction.

7. The printer head assembly according to any claims from 4 to 6, wherein the presser (20) is operably connected with a vibration exciter and is adapted to transmit vibration to the pressed melted printing filament in order to ensure its compaction.

8. The printer head assembly according to any claims from 4 to 7, wherein the presser (20) is designed to have a double-wall structure, comprising a first (21) and a second (22) spaced-apart walls, forming a cooling passage (23) between the first (21) and the second (22) walls so to allow fresh air to pass through the cooling passage (23); wherein an outer side of the first wall (21) is adapted to press a printing filament, which is pulled out from the outlet (16), to a printer's build platform or previously deposited printing filament, while the second wall (22) is adapted to provide thermal isolation between the cooling passage (23) and the heating body (12) and/or the heating means (13).

9. The printer head assembly according to claim 8, wherein the presser (20) is further provided with an elastic, corrugated, or rigid thremally isolating wall (24) attached to the first wall (21) and the second wall (22), so to prevent heat exchange between an air passing through the cooling passage (23) and the heating body (12) and the outlet (16).

10. The printer head assembly according to any claims from 4 to 9, wherein the presser's (20) surface, which is designed to be in contact with melted printing filament, is covered by non-stick coating, such as polytetrafluoroethylene.

11. A printer, comprising the printer head assembly according to any preceding claims.

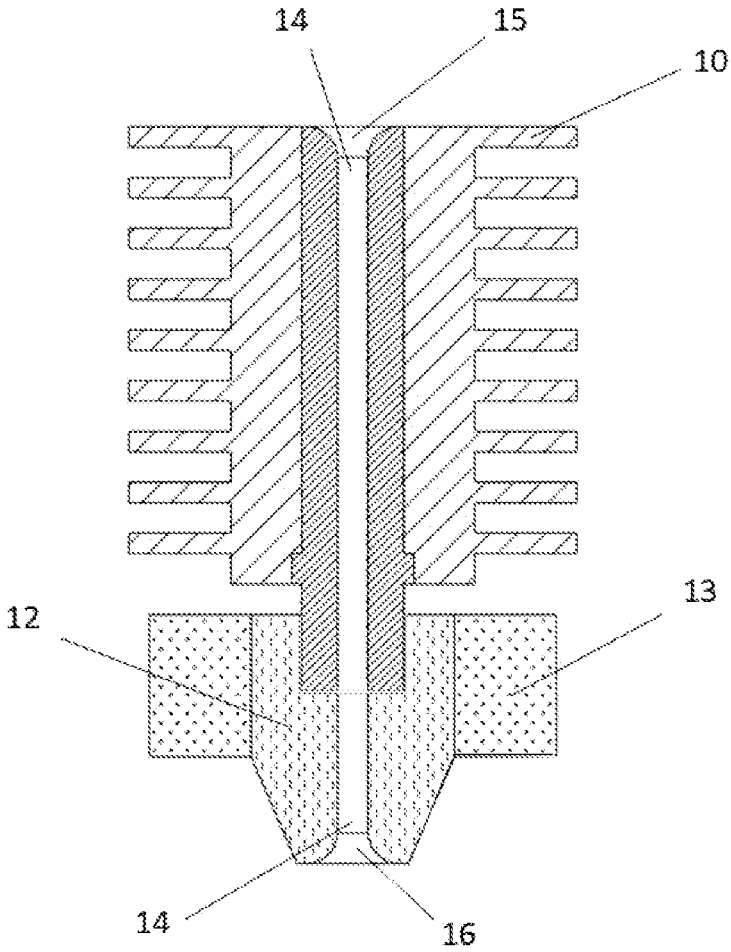

Fig. 1

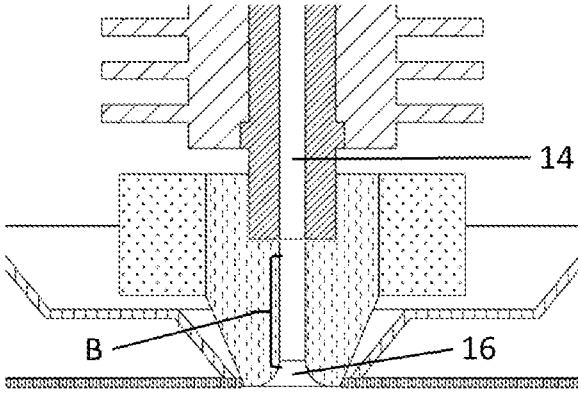

Fig. 2

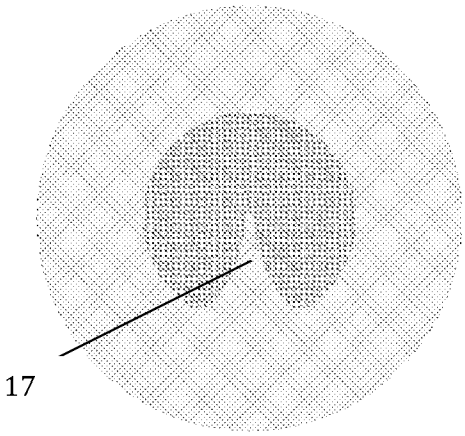

Fig. 3A

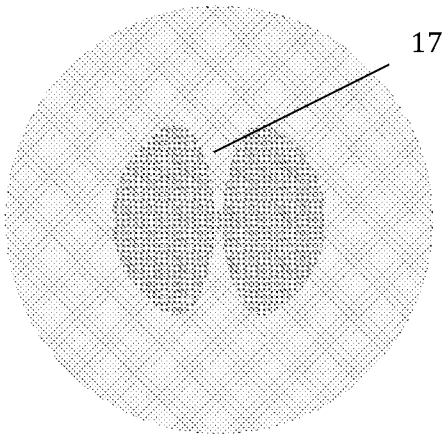

Fig. 3B

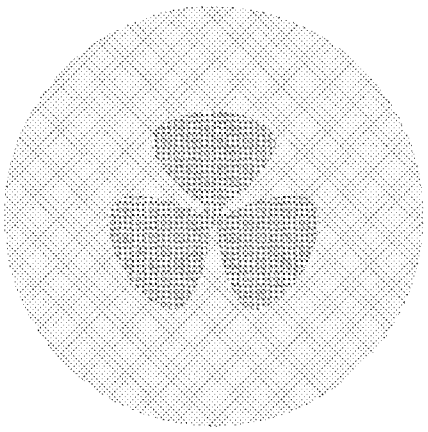

Fig. 3C

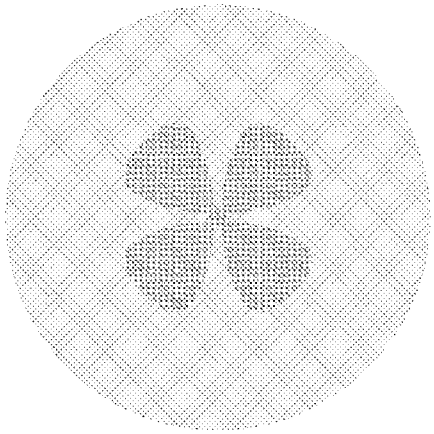

Fig. 3D

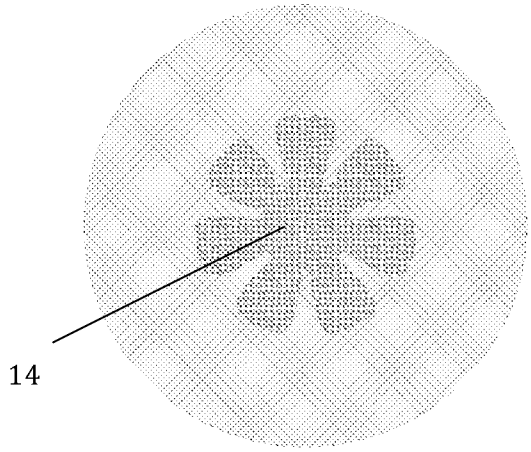

Fig. 3E

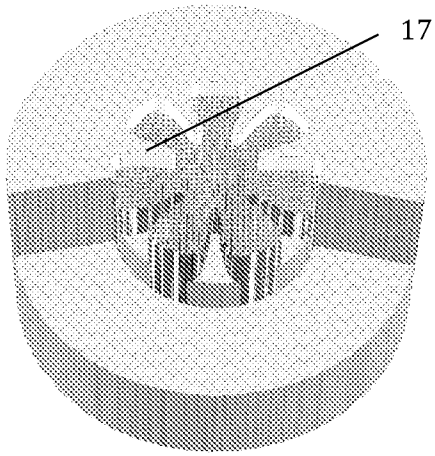

Fig. 3F

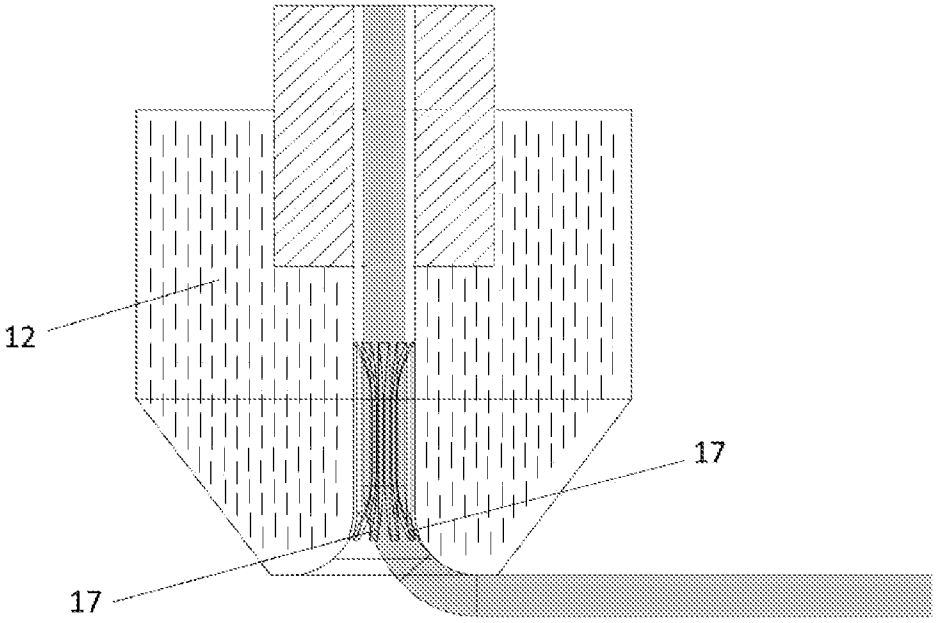

Fig. 4

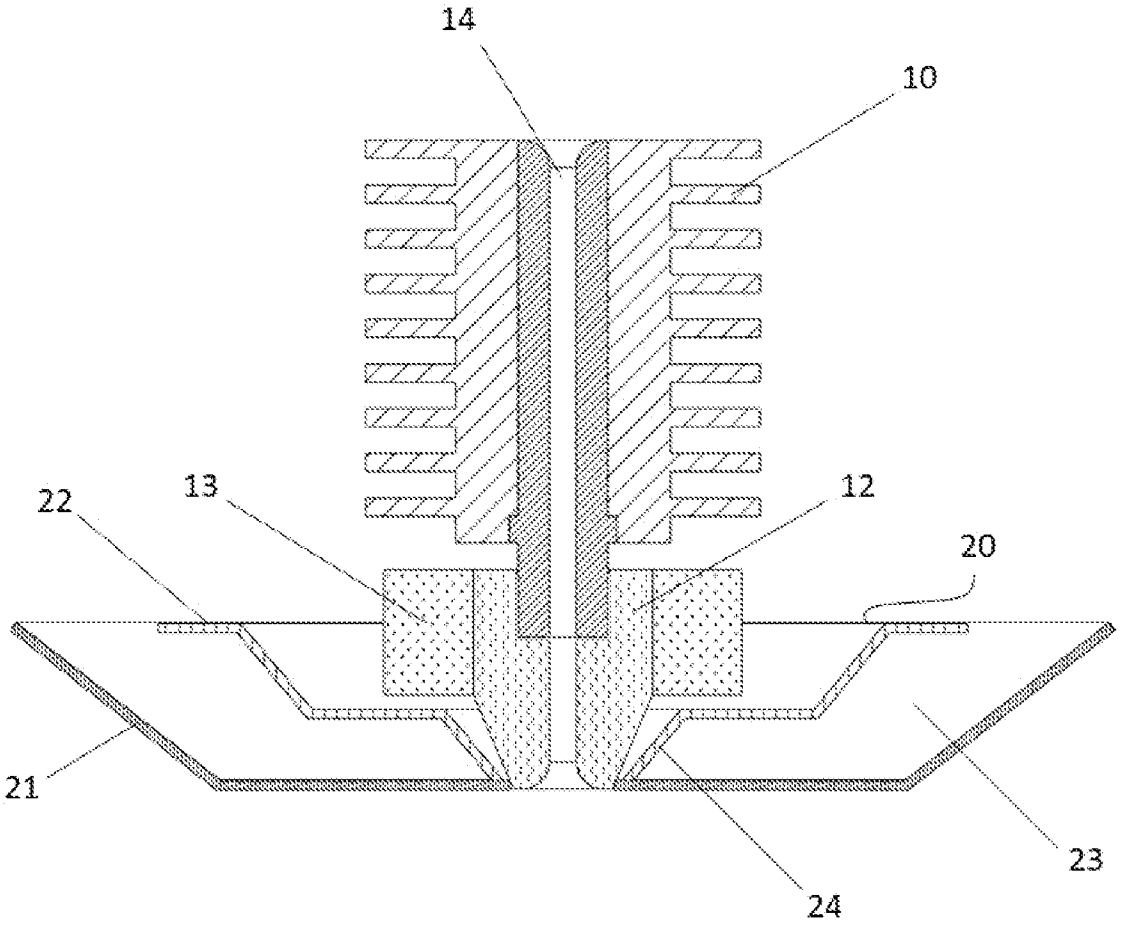

Fig. 5

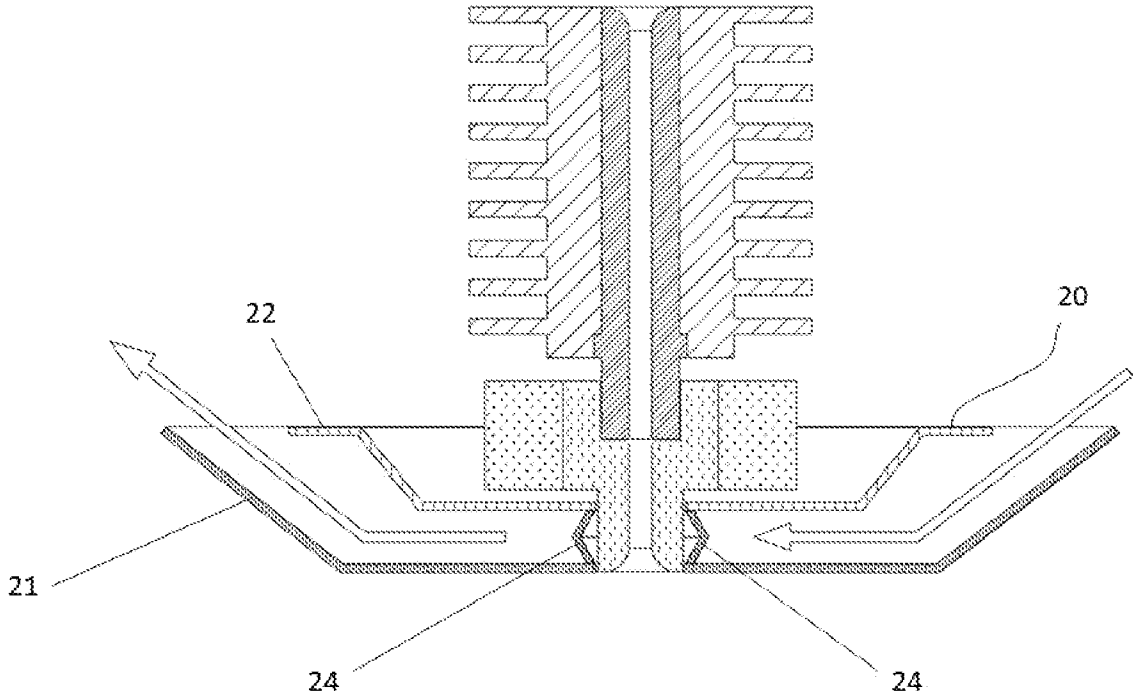

Fig. 6

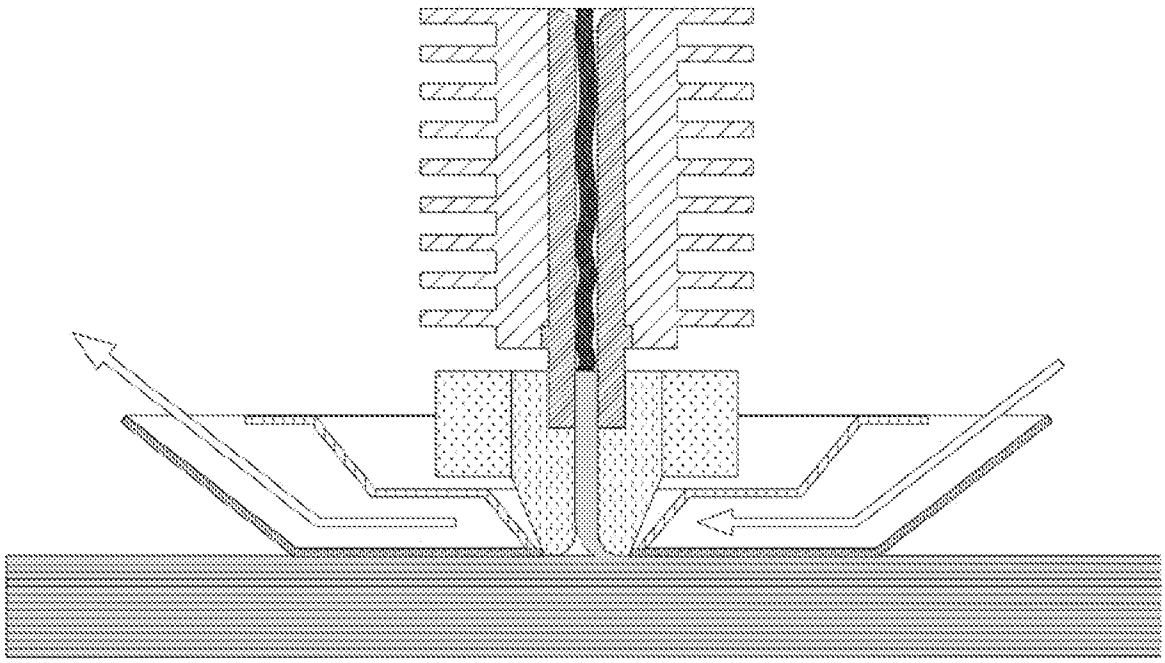

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/053528

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C64/118 B29C64/194 B29C64/209 B33Y30/00 B33Y40/00
B29C48/05 B29C48/30 B29C48/86
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	EP 3 613 581 A1 (MARKFORGED INC [US]) 26 February 2020 (2020-02-26)	1,4,11
Y	figures 1C, 1D, 14A-14C claim 1 paragraphs [0078], [0088], [0138]	2,3,5-7, 10
X	WO 2019/141892 A1 (ARCTIC BIOMATERIALS OY [FI]) 25 July 2019 (2019-07-25) figures 5, 8A claim 1	1,4,8,11
Y	EP 3 632 682 A1 (BOND HIGH PERFORMANCE 3D TECH B V [NL]) 8 April 2020 (2020-04-08) figures 1a, 1b paragraph [0043]	2,3

-/--

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

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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
8 December 2020	17/12/2020

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	Schmitt, Sebastian

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/053528

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2016/107389 A1 (LIND RANDALL F [US] ET AL) 21 April 2016 (2016-04-21)	5-7,10
A	figure 2 claims 1, 2 paragraphs [0022], [0024], [0025]	4,8,9

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2020/053528

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3613581 A1	26-02-2020	CN 105579220 A	11-05-2016
		CN 107443721 A	08-12-2017
		EP 3022046 A1	25-05-2016
		EP 3613581 A1	26-02-2020
		JP 6483113 B2	13-03-2019
		JP 2016531020 A	06-10-2016
		JP 2019123241 A	25-07-2019
		WO 2015009938 A1	22-01-2015
WO 2019141892 A1	25-07-2019	CA 3088589 A1	25-07-2019
		CN 111867808 A	30-10-2020
		EP 3740373 A1	25-11-2020
		KR 20200111716 A	29-09-2020
		US 2020346399 A1	05-11-2020
		WO 2019141892 A1	25-07-2019
EP 3632682 A1	08-04-2020	NONE	
US 2016107389 A1	21-04-2016	NONE	