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

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
08 August 2019 (08.08.2019)

WIPO | PCT

(10) **International Publication Number**
WO 2019/151913 A1

(51) **International Patent Classification:**
B29C 64/209 (2017.01) *B23K 26/342* (2014.01) *B22F 3/10* (2006.01) *B33Y 30/00* (2015.01) *B23K 26/08* (2014.01) *C23C 24/10* (2006.01) *B23K 26/144* (2014.01) *B22F 3/105* (2006.01)

(21) **International Application Number:** PCT/SE2018/050080

(22) **International Filing Date:** 01 February 2018 (01.02.2018)

(25) **Filing Language:** English

(26) **Publication Language:** English

(71) **Applicant: STJERNBERG AUTOMATION AB** [SE/SE]; Magasinsgatan 29, 434 37 Kungsbacka (SE).

(72) **Inventor: STJERNBERG, Magnus**; Skördevägen 81, 434 40 Kungsbacka (SE).

(74) **Agent: VALEA AB**; Box 1098, 405 23 Göteborg (SE).

(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, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

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

(54) **Title:** METHOD AND ARRANGEMENT FOR DEPOSITION AND BONDING OF A POWDER MATERIAL

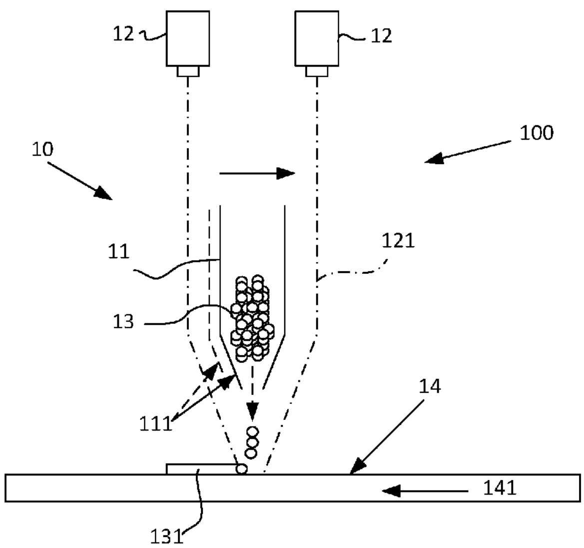

Fig. 1

(57) **Abstract:** The present invention relates to an arrangement (10) for depositing and melting a powder material (13). The arrangement comprises: a feed nozzle (11) configured to feed the powder material (13), and a laser source (12) configured to generate a laser beam (121). The feed nozzle (11) comprises a radially adjustable outlet (111) and the arrangement further comprises a device to generate a substantially circular laser projection concentric with said nozzle (11).

WO 2019/151913 A1

TITLE: METHOD AND ARRANGEMENT FOR DEPOSITION AND BONDING OF A POWDER MATERIAL

TECHNICAL FIELD

The present invention relates to methods and arrangements for distribution or deposition of a powder material in general and controlled deposition of powder material, e.g. for 3-dimensional printing, cladding, or similar in particular.

BACKGROUND

Cladding is bonding together of dissimilar metals or the like powder material. Laser cladding, for example, can be performed to improve the surface properties of metallic machine parts locally. A cladding material with the desired properties is fused onto a substrate by means of a laser beam. Laser cladding is considered as a strategic technique, since it can yield surface layers that, compared to other hard facing techniques, have superior properties in terms of pureness, homogeneity, hardness, bonding and microstructure.

Cladding may also be used for coating, in which powdered metal or similar is deposition material, in which the powder is injected into the path of a beam. The powder may be carried through a tubing (nozzle) using an inert gas that allows the coating material to be blown into the path of a laser beam. The blown powdered particles are partially melted by the beam. The laser creates a small melt pool on the surface of the substrate that fully melts the powdered metal (or other material). The melt pool that is created corresponds to a single level of clad.

In additive manufacturing, i.e. solid freeform fabrication or 3D printing, as another example, three-dimensional objects are built-up from raw material, such as powders in a series of two-dimensional layers or cross-sections.

According to some methods layers are produced by melting or softening material, for example, selective laser melting (SLM) or direct metal laser sintering (DMLS), selective laser sintering (SLS), fused deposition modeling (FDM), while others cure liquid materials using different technologies, e.g., stereolithography (SLA).

Additionally, there is sintering, a process of fusing small grains, for example, powders, to create objects. Sintering usually involves heating a powder, e.g. using laser beam. When a powdered material is heated to a sufficient temperature in a sintering process, the atoms in the powder particles diffuse across the boundaries of the particles, fusing the particles together to form a solid piece. In contrast to melting, the powder used in sintering need not reach a liquid phase as the sintering temperature does not have to reach the melting point of the material, sintering is often used for materials with high melting points such as tungsten and molybdenum.

Both sintering and melting can be used in additive manufacturing. Selective laser melting (SLM) is used for additive manufacturing of metals or metal alloys, which have a discrete melting temperature and undergo melting during the SLM process.

In above processes a material feeder travels above a receiving surface, i.e. a substrate, in a controlled manner and directions, and deposits material to bond together and/or with previous layer when exposed to a heating source such as a laser beam. The material feeder is normally a nozzle

Thus, it is of great importance that the powder depositions and melting process is controllable, especially when the nozzle can move in different directions. It is essential that the amount of powder passing through the nozzle is as precise as possible, together with power of laser depending on the deposited powder.

It is also essential that the distribution of both powder and laser power is as homogenous as possible or that the deposition and/or power distribution are controllable.

SUMMARY

The present invention provides a tool, an arrangement and method allowing precise, controllable deposition and melting of powder material on a substrate, such as the deposition rate can be controlled, preferably in any direction that the tool moves and apply a laser beam with controllable power distribution.

These and other advantages, described in the following description, are achieved by means of an arrangement for deposition and melting a powder material. The arrangement comprising: a feed nozzle configured to feed the powder material onto a substrate, and a laser source configured to generate a laser beam. The feed nozzle comprises a radially adjustable outlet and the laser source is configured to generate a rotating laser beam around the nozzle outlet with the nozzle outlet substantially being in centre of the rotation of said laser beam.

In one embodiment the nozzle is arranged to move in vertical and/or horizontal directions.

According to one embodiment, the nozzle comprises a first fixed tubular part and a first axially displaceable part inside said first fixed part, said second part. The nozzle comprises a second axially displaceable part surrounding said second first axially displaceable part.

In one embodiment, the arrangement comprises a temperature sensor measuring at a point where laser melts powder material.

According to one embodiment, a controller is configured for controlling one or several of laser power, power distribution in the melt by controlling the laser beam rotation and speed.

The invention also relates to a system for deposition and melting a powder material. The system comprises: a feed nozzle configured to feed the powder material onto a substrate, and a laser source configured to generate a laser beam; and a controller. The feed nozzle comprises a radially adjustable outlet and the laser source is configured to generate rotating the laser beam around the nozzle outlet with the nozzle outlet substantially being in centre of the rotation of said laser beam and the controller is arranged to control the rotation of laser and adjusting of the nozzle outlet.

The invention also relates to a method of deposition and melting a powder material on a substrate. The method comprises the steps of: distributing by means of a nozzle the powder material; illuminating the distributed powder material in a melting point; rotating a laser beam around the nozzle in the melting point; measuring the temperature at melting point; and with respect to the measured temperature, deciding to adjust one or several of laser parameters. The method may further comprise adjusting nozzle opening with respect to data from powder feeding, melting process and system speed.

The invention also relates to a computer-readable storage medium storing instructions that when executed by a computer cause the computer to perform a method for using a computer system for of deposition and melting a powder material on a substrate. The method comprises: distributing by means of a nozzle the powder material; illuminating the distributed powder material in a melting point; rotating a laser beam around the nozzle in the melting point; measuring the temperature at melting point; and with respect to the measured temperature, deciding to adjust one or several of laser parameters.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference is made to the attached drawings, wherein elements having the same reference number may represent like elements throughout.

Fig. 1 is a diagram of an exemplary tool in which methods and systems described herein may be implemented;

Fig. 2 illustrates a schematic sectional view of one embodiment of a nozzle outlet;

Fig. 3 illustrates schematically a sectional side view of the nozzle of the Fig. 2;

Fig. 4 illustrates a schematic view of one embodiment of a system according to the invention;

Fig. 5 is a flow diagram illustrating exemplary processing by the system of Fig. 4, and

Fig. 6 illustrates another schematic view of a second embodiment of the invention with rotating mirror for laser projection.

DETAILED DESCRIPTION

The following detailed description refers to the accompanying drawings. The same reference numbers in different drawings may identify the same or similar elements. The term “printing” as used herein, may refer to transfer and deposition of (powder) material onto a carrier and bonding the material together or a previous layer. The term “substrate” as used herein, may refer to any type of material on which a suitable powder material can be deposited and bonded. The term “nozzle” as used herein may refer to a substantially tubular dispenser device designed to deposit powder material and some embodiments control the direction or characteristics of a material flow as it exits a connected chamber or pipe.

Fig. 1 is a schematic view of the general construction of a plant showing a first embodiment of a method and arrangement of depositing and producing a composite material in accordance with the present invention. In Fig. 1, the reference numeral 100 refers to part of a plant comprising a tool 10, comprising a powder feeding arrangement in form of a nozzle 11 and a laser source 12. A backing material or a substrate is referred to as 14, which may be a strip of a suitable material arranged to travel under the tool 10 (e.g. in direction of the arrow 141).

The nozzle 11 is configured such that at least part of its outlet tip 111 is radially adjustable, i.e. the diameter of the opening can be adjusted. The nozzle may also be adjustable vertically with respect to the surface of the substrate piece 14. A gaseous medium, such as an inert gas, may be used to eject the powder 13 out from the nozzle and to shield the melt pool from polluting gases or other interferences.

The laser source 12 is configured to emit a continues or pulsating laser beam 121, which is rotated around the outlet of the nozzle, e.g. by the means of a motorized mirror system or optical elements. The laser beam melts the powder material on the surface of the substrate 141 building a melt/bonded layer 131. This may enable the system of the invention to displace the laser beam in any direction, creating the possibility to precisely apply laser beam anywhere around the nozzle opening, horizontally or vertically.

Fig.2 illustrates a bottom view of one exemplary embodiment of the adjustable opening section 111 of the nozzle 11, according to one example of the invention. According to this embodiment, the nozzle opening section 111 comprises a fixed portion 1111, which may for example be conical, and (at least) two parts 1112 and 1113, inside the fixed portion. Part 1113 may be arranged surrounding part 1112 and both may be moveable with respect to the nozzle's longitudinal axis. Each part 1112 and 1113 may have the same shape as the fixed nozzle head and comprise at least one slit 11121 and 11131 respectively, along their bodies. As illustrated in the schematic cross-sectional side view in Fig. 3, when parts 1112 and 1113 are displaced substantially simultaneously inside the nozzle's head along its longitudinal axis, each part extend out of the fixed portion 1111 and each part is squeezed together, permitted by its slit, and consequently change the nozzle outlet diameter. The movement of the parts can be controlled mechanically e.g. by means of step motors (not shown) at terminal end of each parts opposite to opening end. Of course, this is just one example of controllably adjusting the diameter of the nozzle outlet and other techniques may also be used.

According to one embodiment of the invention, the powder 13 (Fig. 1) of a suitable material may be injected via the adjustable opening of the nozzle 11, which is substantially centered in the tool 10, and deposited onto the surface of the substrate 14. By allowing the rotating laser beam 121 to circulate around the center (with respect to the nozzle opening center and substantially concentric with the opening), the deposition rate can be controlled by adjusting the opening of the nozzle, the pressure and flow rate of the powder carrier, such as using gas or a mechanical device, in any direction that the tool 10 (combined nozzle and laser) moves. The laser melts the deposited powder and builds the layer 131. Thus, the tool can be used for, e.g. 3-dimensional printing, ultra-solid laser cladding, welding, and other additive methods, without being dependent on rotational symmetrical details.

Fig. 4 is a schematic illustration of an exemplary system 100 according to the present invention. The system 100 comprises a controller 110, laser controller 120, nozzle controller 130, temperature unit 140 and the tool 10 as described earlier.

The controller 110 may comprise a processor 111, memory 112, interface portion 113 and communication interface 114.

Processor 111 may include any type of processor or microprocessor that interprets and executes instructions. Memory 112 may include a random access memory (RAM) or another dynamic storage device that stores information and instructions for execution by processor 111. Memory 112 may also be used to store temporary variables or other intermediate information during execution of instructions by processor 111.

The controller 100 or the memory may also comprise ROM (not shown) which may include a conventional ROM device and/or another static storage device that stores static information and instructions for processor 111. Additionally, a storage device (not shown) may be provided, including a magnetic disk, optical disk, solid state drive and its corresponding drive and/or some other type of magnetic or optical recording medium and its corresponding drive for storing information and instructions. Storage device may also include a flash memory (e.g., an electrically erasable programmable read only memory (EEPROM)) device for storing information and instructions.

The interface portion 113 may comprise an input device (not shown) including one or more conventional mechanisms that permit a user to input information to the system 100, such as a keyboard, a keypad, a directional pad, a mouse, a pen, voice recognition, a touch-screen and/or biometric mechanisms, etc. The interface portion 113 may also comprise an output device (not shown), which may include one or more conventional mechanisms that output information to the user, including a display, a printer, a speaker, etc.

The communication interface 114 may include any transceiver-like mechanism that enables system 100 to communicate with other devices and/or systems. For example, communication interface 114 may include a modem or an Ethernet interface to a LAN. Alternatively, or additionally, communication interface 114 may include other mechanisms for communicating via a network, such as a wireless network. For example, communication interface may include a radio frequency (RF) transmitter and receiver and one or more antennas for transmitting and receiving RF data.

The laser controller 120 communicates with the controller 110 and may obtain instructions from the controller 110 to control different parameters of the rotating laser, such as power, rotation rate, pulse intensity, etc. Additionally, the system may be programmable to control the laser power and power distribution in the melt by controlling the laser beam rotation by utilizing a rotating and tilting a mirror system, or fiber guidance, with position feedback. Another advantage of only one circulating laser beam is that, it can be easily implement pyrometer measurement directly in the beam path and measure feedback reflections directly in the melt, to be used for example in temperature control or process control. The laser controller or an additional controller may controller the rotation width of the laser beam with respect to the opening of the nozzle.

The nozzle controller 130 communicates with the controller 110 and may obtain instructions from the controller 110 to control the nozzle opening width and in some embodiments move the nozzle horizontality and/or vertically. The nozzle controller may thus control the feed of powder material into the nozzle (or a nozzle chamber) and provide the controller 110 with information about speed, direction, opening width, etc. and possible errors.

The temperature unit 140 is connected to a contactless temperature measuring apparatus 141. The measuring apparatus may be an infrared sensor, a camera, a pyrometer or the like. For example a pyrometer measurement directly in the beam path can measure feedback reflections directly in the melt, which can be used for example in temperature control or process control (laser control, material feed, etc.).

System 100, consistent with the invention, provides a platform through which laser cladding, SLM, DMLS, SLS, FDM, SLA for achieving 3d-printing, or any similar constructions may be achieved.

According to an exemplary implementation, system 100 may perform various processes in response to processor 111 executing sequences of instructions contained in memory 112. Such instructions may be read into memory 112 from another computer-readable medium, such as storage device, or from a separate device via communication interface. It should be understood that a computer-readable medium may include one or more memory devices or carrier waves. Execution of the sequences of instructions contained in memory 112 causes processor 111 to perform the acts that will be described hereafter. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement aspects consistent with the invention. Thus, the invention is not limited to any specific combination of hardware circuitry and software.

In one embodiment, the controller 110, laser controller 120, nozzle controller 130 and temperature unit 140 may be combined in one computer unit.

Flow diagram of Fig. 5 illustrates some exemplary method steps according to the invention.

The process starts at step 500 by receiving instructions for building a layer. The instructions may be stored in an internal memory or received from a computer, running a construction program, CAD or similar. The powder is distributed 501 by means of the nozzle. Laser illuminates 502 the melting point under the nozzle while it rotates around the nozzle. The temperature at melting point is measured 503. Depending on the temperature required 504, either laser parameters are adjusted 505 and the process continues, or the process continues until the process is finished 506, 507. The nozzle opening may be adjusted based on data from powder feeding, melting process (temperature) and plant speed (relative speed of plant/substrate).

The steps may be executed in one or several computers constituting the controller(s). A computer-readable storage medium may store instructions that when executed by a computer cause the computer to perform the method.

Fig. 6 illustrates a schematic exemplary system for rotating the laser beam. The system comprises laser beam source 12, one or several focusing arrangements 151 (additional optical elements may be arranged in the path of laser beam 121), a rotating mirror 152 (or another reflective element) and a reflecting and directing mirror system 153. The rotating mirror 152 is arranged to rotate around one of tits axes and direct the laser beam 121 onto the mirror system 153. The mirror system 153 may be a mirror following the rotation of the rotating mirror 152 or a circular mirror arrangement, in both cases inclined such that it directs the laser beam 121 from the rotating mirror 152 concentered with the nozzle 11.

In yet another embodiment, optical elements may be arranged to project a circular projection of the laser beam emerging from the laser source concentric with the nozzle.

A combination of above solutions is possible.

It should be noted that the word “comprising” does not exclude the presence of other elements or steps than those listed and the words “a” or “an” preceding an element do not exclude the presence of a plurality of such elements. It should further be noted that any reference signs do not limit the scope of the claims, that the invention may be implemented at least in part by means of both hardware and software, and that several “means”, “units” or “devices” may be represented by the same item of hardware.

The foregoing description of embodiments of the present invention, have been presented for purposes of illustration and description. The foregoing description is not intended to be exhaustive or to limit embodiments of the present invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of various embodiments of the present invention. The embodiments discussed herein were chosen and described in order to explain the principles and the nature of various embodiments of the present invention and its practical application to enable one skilled in the art to utilize the present invention in various embodiments and with various modifications as are suited to the particular use contemplated. The features of the embodiments described herein may be combined in all possible combinations of methods, apparatus, modules, systems, and computer program products.

CLAIMS

1. An arrangement (10) for depositing and melting a powder material (13), the arrangement comprising:
   - a feed nozzle (11) configured to feed the powder material (13), and
   - a laser source (12) configured to generate a laser beam (121);

   characterized in that the feed nozzle (11) comprises a radially adjustable outlet (111) and the arrangement further comprises a device to generate a substantially circular laser projection concentric with said nozzle (11).

2. The arrangement of claim 1, wherein the device for generating said circular projection by rotating the laser beam (121) around the nozzle outlet (111) with the nozzle outlet (111) substantially being in centre of the rotation of said laser beam.

3. The arrangement of claim 1 or 2, wherein said nozzle is arranged to move in vertical and/or horizontal directions.

4. The arrangement according to any of preceding claims, wherein said nozzle comprises a first fixed tubular part and a first axially displaceable part inside said first fixed part, said second part.

5. The arrangement of claim 4, wherein comprising a second axially displaceable part surrounding said second first axially displaceable part.

6. The arrangement according to any of previous claims, comprising a temperature sensor measuring at a point where laser melts powder material.

7. The arrangement according to any of previous claims, comprising a controller for controlling one or several of laser power, power distribution in the melt by controlling the laser beam rotation.

8. A system for deposition and melting a powder material (13), the system comprising:
   - a feed nozzle (11) configured to feed the powder material (13) onto a substrate (14), and
   - a laser source (12) configured to generate a laser beam (121); and

- a controller (110);

characterized in that the feed nozzle (11) comprises a radially adjustable outlet (111) and the system further comprises a device to generate a substantially circular laser projection concentric with said nozzle (11) and the controller (110) is arranged to control the concentric projection of the laser and adjusting of the nozzle outlet.

9. The system of claim 9, wherein the device for generating said circular projection comprises means for rotating the laser beam (121) around the nozzle outlet (111) with the nozzle outlet (111) substantially being in centre of the rotation of said laser beam and the controller is configured to control the laser beam rotation.

10. The system of claim 8 or 9, wherein adjusted based in data from powder feeding, melting process and tool speed.

11. The system according to any of claims 9-10, wherein the nozzle is displaceable in horizontal and/or vertical directions.

12. The system according to any of claims 9-11, configured for additive manufacturing.

13. A method of deposition and melting a powder material (13) on a substrate (14), the method comprising the steps of:
    - distributing (501) by means of a nozzle the powder material;
    - illuminating (502) the distributed powder material in a melting point;
    - rotating a laser beam (121) around the nozzle in the melting point;
    - measuring (503) the temperature at melting point; and
    - with respect to the measured temperature, deciding to adjust (505) one or several of laser parameters.

14. The method of claim 13, further comprising adjusting nozzle opening with respect to data from powder feeding, melting process and system speed.

15. A computer-readable storage medium storing instructions that when executed by a computer cause the computer to perform a method for using a computer system for of deposition and melting a powder material on a substrate, the method comprising:

- distributing by means of a nozzle the powder material;
- illuminating the distributed powder material in a melting point;
- rotating a laser beam around the nozzle in the melting point;
- measuring the temperature at melting point; and
- with respect to the measured temperature, deciding to adjust one or several of laser parameters.

16.

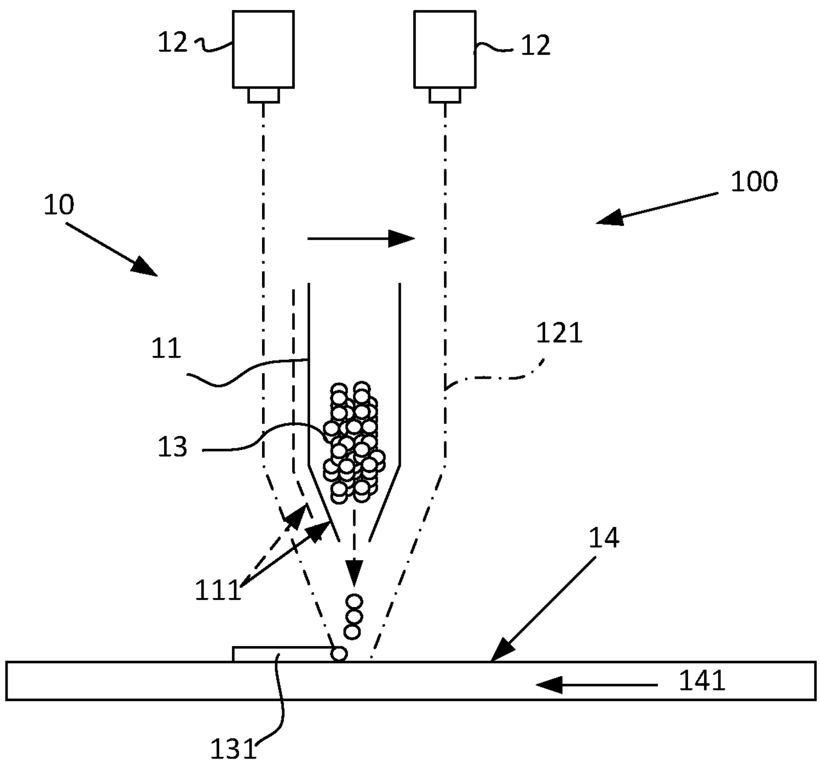

Fig. 1

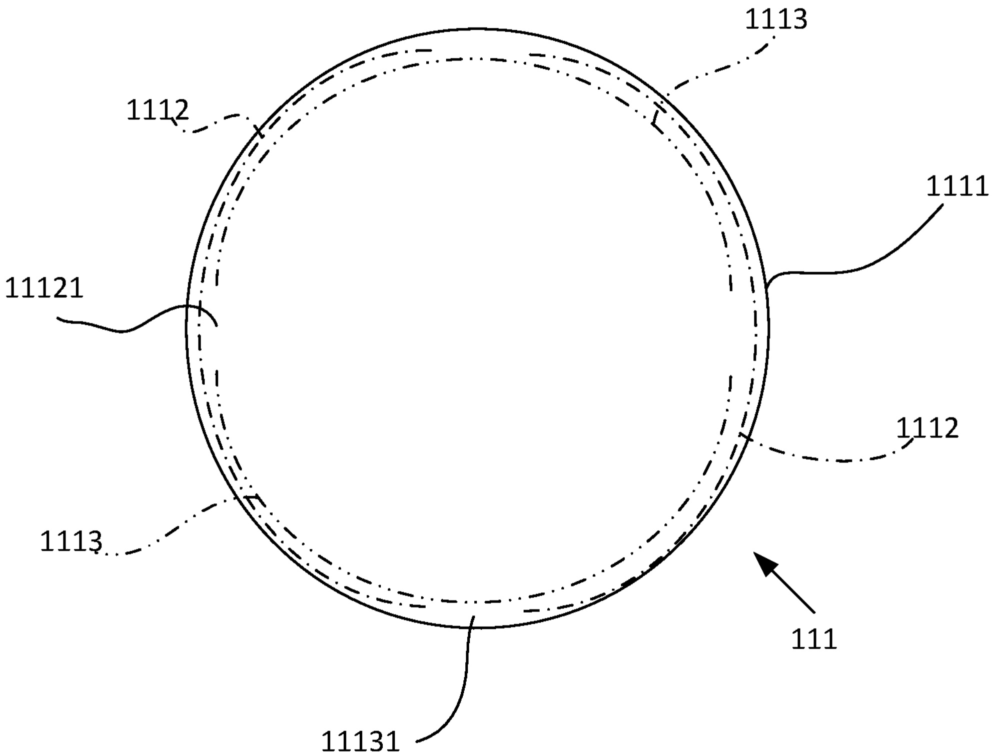
1113
1112
1111
11121
1112
1113
111
11131

Fig. 2

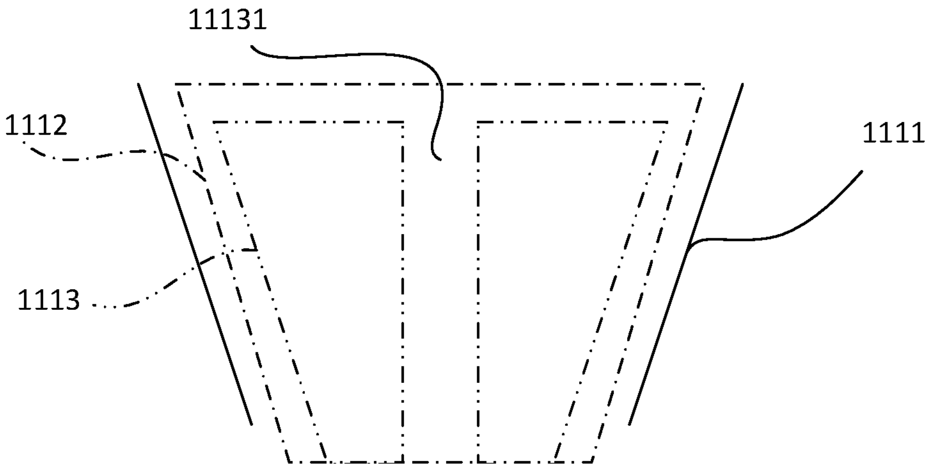
11131
1112
1111
1113

Fig. 3

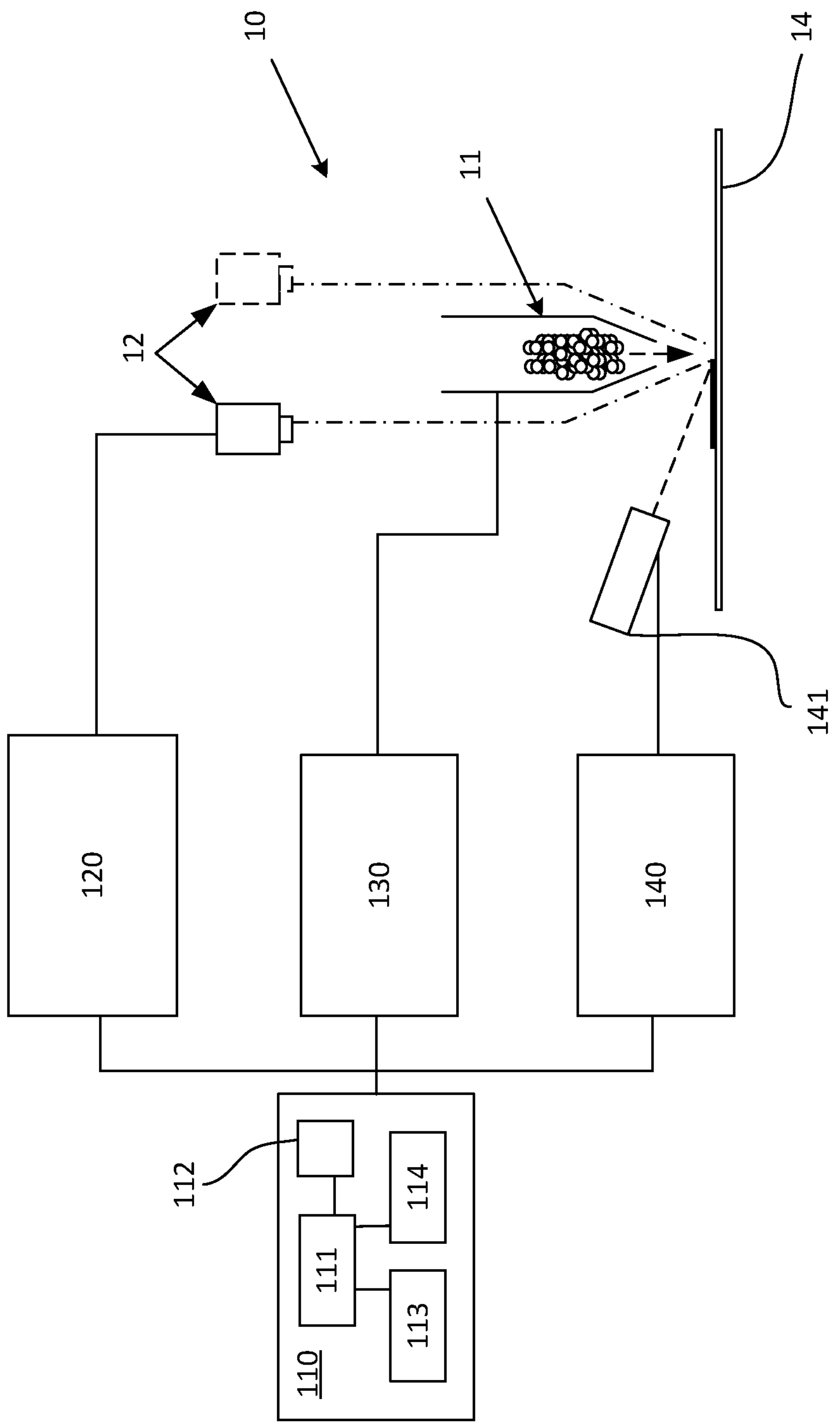

Fig. 4

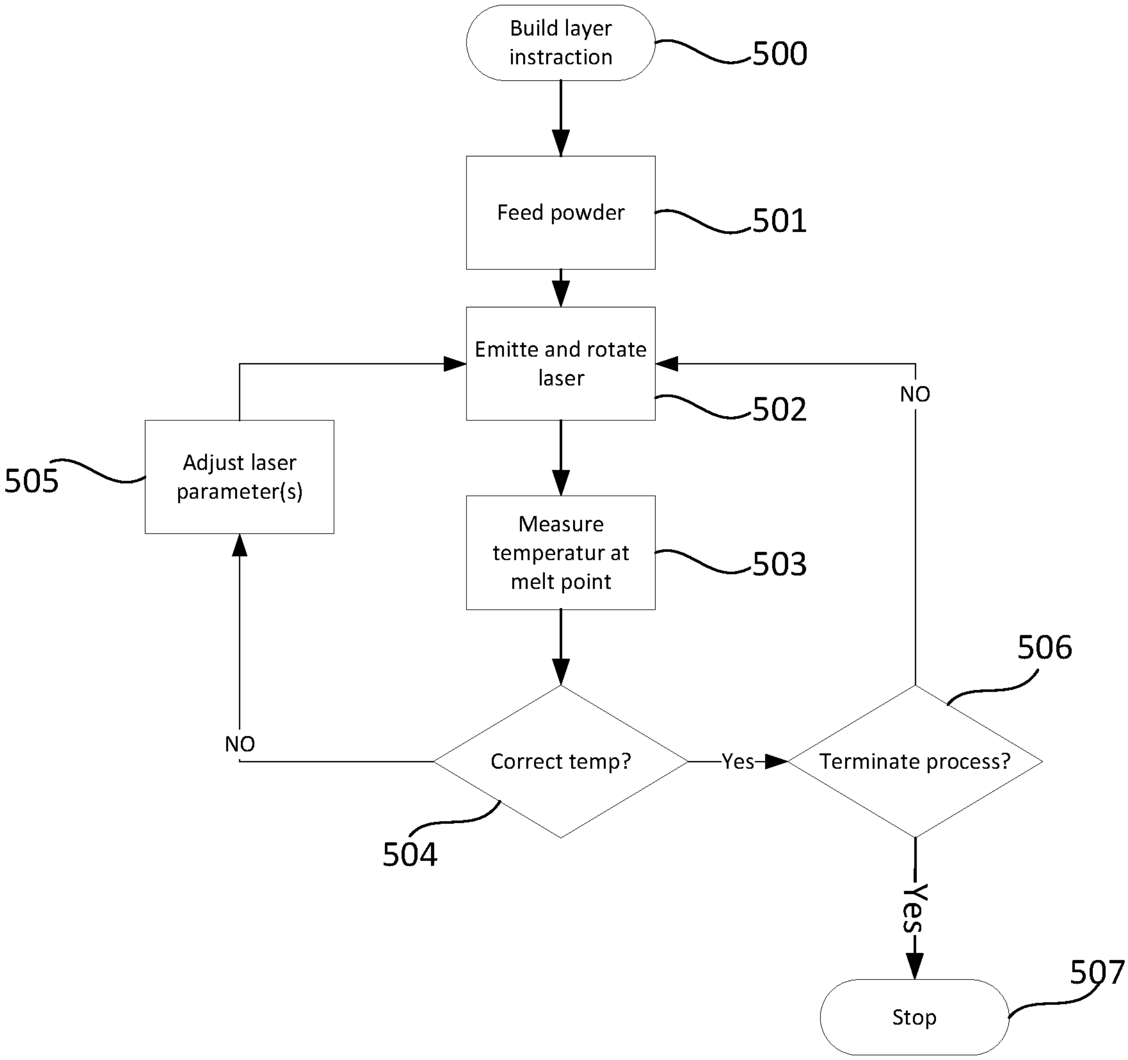
Build layer instraction
500
Feed powder
501
Emitte and rotate laser
502
NO
505
Adjust laser parameter(s)
Measure temperatur at melt point
503
506
NO
Correct temp?
Yes
Terminate process?
504
Yes
507
Stop

Fig. 5

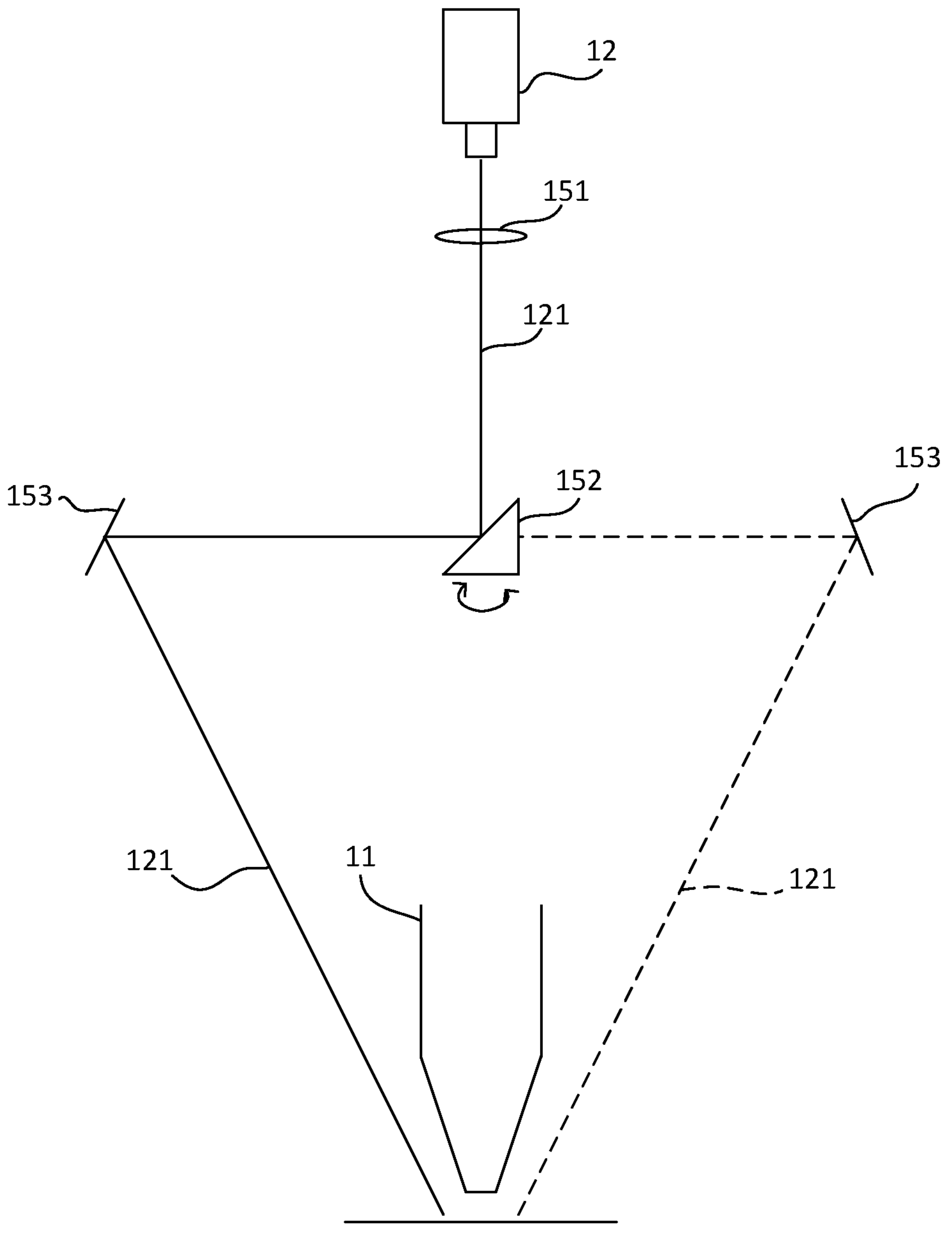

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2018/050080

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: B22F, B23K, B29C, B33Y, C23C

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20120199564 A1 (WASHKO JR JOHN F ET AL), 9 August 2012 (2012-08-09); paragraph [0025]; figures 3-4; claim 1 --	1-15
A	US 20110089151 A1 (MIYAGI MASANORI ET AL), 21 April 2011 (2011-04-21); paragraphs [0055]-[0062]; figures 1-3; claim 1 --	1-15
A	WO 2017100695 A1 (VELO3D INC), 15 June 2017 (2017-06-15); paragraphs [0246]-[0254]; claim 1 --	1-15
A	US 5477026 A (BUONGIORNO ANGELO), 19 December 1995 (1995-12-19); figures 1-7; claim 1 --	1-15

☒ Further documents are listed in the continuation of Box C. ☒ 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
03-10-2018	08-10-2018
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer Ingemar Wistrand Telephone No. + 46 8 782 28 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 3117982 A1 (BLUEFROG BVBA), 18 January 2017 (2017-01-18); paragraph [0058]; figures 3A-3C; claim 1 --	1-15
A	WO 2017152142 A1 (DESKTOP METAL INC), 8 September 2017 (2017-09-08); paragraph [0234]; claims 1-8 --	1-15
A	KR 20180000443 A (SOONCHUNHYANG UNIV INDUSTRY ACADEMY COOPERATION FOUNDATION), 3 January 2018 (2018-01-03); figures 4-5 --	1-15
A	JP 2017140647 A (TOYOTA MOTOR CORP), 17 August 2017 (2017-08-17); figure 1 -- --------	1-15

Continuation of: second sheet

International Patent Classification (IPC)

B29C 64/209 (2017.01)
B22F 3/10 (2006.01)
B23K 26/08 (2014.01)
B23K 26/144 (2014.01)
B23K 26/342 (2014.01)
B33Y 30/00 (2015.01)
C23C 24/10 (2006.01)
B22F 3/105 (2006.01)

US	20120199564	A1	09/08/2012	WO	2012109086	A1	16/08/2012
US	20110089151	A1	21/04/2011	EP	2314411	A2	27/04/2011
				JP	2011088154	A	06/05/2011
				JP	5292256	B2	18/09/2013
				US	8735769	B2	27/05/2014
WO	2017100695	A1	15/06/2017	US	10071422	B2	11/09/2018
				US	10058920	B2	28/08/2018
				US	20180161875	A1	14/06/2018
				US	9962767	B2	08/05/2018
				US	20170165752	A1	15/06/2017
				US	20170165751	A1	15/06/2017
				US	20170165792	A1	15/06/2017
				US	20170165754	A1	15/06/2017
				US	20170165753	A1	15/06/2017
US	5477026	A	19/12/1995	CA	2182083	C	20/11/2001
				CN	1142794	A	12/02/1997
				CN	1087992	C	24/07/2002
				DE	69431487	T2	03/07/2003
				EP	0741626	B1	02/10/2002
				JP	10501463	A	10/02/1998
				TW	275046	B	01/05/1996
				WO	9520458	A1	03/08/1995
				ZA	9500160	B	11/07/1996
EP	3117982	A1	18/01/2017	NONE			
WO	2017152142	A1	08/09/2017	AU	2017228507	A1	13/09/2018
KR	20180000443	A	03/01/2018	KR	101820920	B1	22/01/2018
JP	2017140647	A	17/08/2017	NONE			