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(54) Title: MULTI-BLADE RECOATER

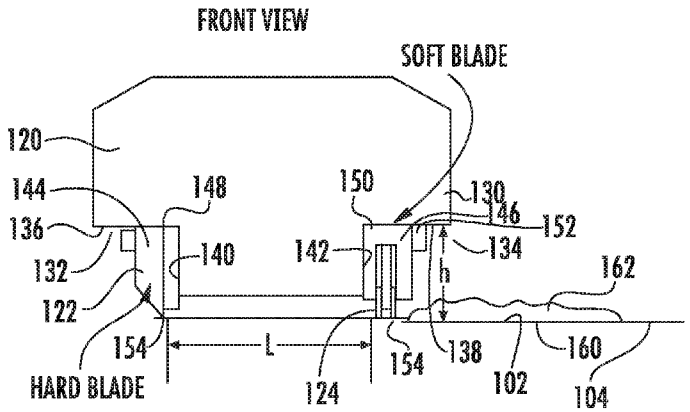

FIG. 3

(57) Abstract: An additive manufacturing device includes a recoater (108, 120, 130) arm having at least two recoating blades (122, 124) extendable therefrom. At least one of the blades (122) may have a different stiffness than another of the blades (124). Additionally, at least one of the blades (122) may include a plurality of segments. The blades (122, 124) or segments may be independently moveable toward, and away from, the housing (130) of the recoater (108, 120, 130), to selectively engage a layer of powder (162) dispensed by a dispenser and spread the powder (162) over the powder bed (104), or pass over the powder (162) without engaging therewith.

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MULTI-BLADE RECOATER

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present disclosure relates to the field of additive manufacturing. More particularly, the present disclosure relates to methods and equipment for the additive manufacturing of articles of manufacture.

BACKGROUND OF THE ART

[0002] Additive manufacturing techniques, commonly known as 3-D printing, include powder bed fusion and other directed energy techniques, wherein selected regions of a thin layer of a fusible powder are exposed to energy sufficient to fuse or react selective portions of the powder to form a layer or a slice of an article of manufacture. In this additive manufacturing process, the item to be manufactured is configured as a plurality of slices in a computer file, and the computer file is used to position and pulse a laser to fuse material in the shape of the slice. The slices are sequentially formed one over the other, and fused together, to form the part. To form each slice, a layer of powder of a material used to form the part is deployed adjacent to the powder bed, and then spread over the powder bed by a recoater having a wiper or "blade" which is pulled or pushed across the powder and thence over the powder bed to spread the powder over the powder bed at a desired thickness. The wiper is spaced a slight distance above the powder bed as it passes thereover. After the layer of powder is spread across the powder bed, a laser selectively melts portions thereof which are then allowed to cool and fuse together, and fuse to any previously formed portion of the part in the prior slice, if any, on the powder bed. This process is repeated, slice by slice, until formation of the article is completed.

[0003] Where additive manufacturing is used to manufacture an article having both rough and fine features, or simultaneously manufacture two or more articles on one powder bed wherein one article has fine features and the other does not, there is a trade-off between the hardness of the blade used to spread the next layer of powder over the previously formed slice(s) of the part, and the surface finish of the resulting part. If fine or fragile features are present, a soft blade, such as one manufactured of a compliant polymer and which is bendable as it passes over the powder bed, is used throughout the manufacture of the article,

and small or fine fragile features will not be damaged or moved (displaced by the blade) during the spreading of the powder over the powder bed, but the surface finish of the article being manufactured will be compromised. Additionally, soft blades wear quickly, resulting in non-uniform powder distribution over the bed and at times, the need to replace the blade. The blade cannot be replaced during the printing of an article, because a defect line will appear in the finished article, and thus the partially manufactured article must be scrapped if the blade becomes no longer useable during the printing of an article. If a hard blade is used, such as a stiff steel blade, both the useful blade lifetime, and the surface finish of the resulting article, is enhanced, but small and fragile features of the article being manufactured may be damaged by being distorted or "pushed", resulting in misalignment of the slices of the article from slice to slice, and any warpage or distortion of the blade distributing the powder can cause the article to be considered unusable. Thus, where the article has fine or fragile features, a soft blade must be used, and the surface finish and manufacturability of the article is diminished, and very large articles having the fine or fragile features cannot be made due to the wear of the soft blade over the period of manufacturing a large part resulting in the need to replace the blade before the article is completed.

SUMMARY

[0004] The present disclosure provides an additive manufacturing device, and a method of using the device, wherein multiple blades are simultaneously available to be swept across the bed and spread the powder used in the manufacturing of the next layer of the part.

[0005] An additive manufacturing device comprises a bed, and a recoater positionable to sweep over the bed. The recoater includes at least two blades therein.

[0006] In one aspect, the blades are moveable with respect to the body of the recoater, such that only one of the blades is contactable with a dispensed powder to spread the powder over the bed. In another aspect, the blades may be both positioned to simultaneously contact different portions of the dispensed powder to spread the powder over different regions of the bed. In another aspect, the blades may be moveable between an extended powder contacting position and a retracted position as the recoater crosses the powder bed. Additionally, the recoater may carry multiple soft and hard blades, such that upon wear of one of the blades of a type (soft or hard), it may be retracted inwardly of the recoater body, and a different blade of the same type may be extended from the carrier to contact the

powder and spread it over the powder bed. Additionally, blades of intermediate stiffness between soft and hard may be employed, such that soft, hard and intermediate stiffness blade(s) are available on a single recoater.

DESCRIPTION OF THE FIGURES

[0007] Figure 1 is a partial perspective view of a powder bed fusion device, showing the powder bed and recoater thereof;

[0008] Figure 2 is a partial perspective view of an additional powder bed fusion device, showing the powder bed and recoater thereof;

[0009] Figure 3 is an end view of a recoater having multiple blades;

[0010] Figure 4 is a side view of the recoater of Figure 3;

[0011] Figure 5 is a perspective view of the recoater of Figure 3;

[0012] Figure 6 is a bottom view of the recoater of Figure 3;

[0013] Figure 7 is an end view of an alternative construct of a recoater, wherein the blades are moveable with respect to the housing thereof;

[0014] Figure 8 is a partial sectional view of the recoater of Figure 7, showing the blade height adjustment mechanism thereof;

[0015] Figure 9 is a partial sectional view of the recoater of Figure 7;

[0016] Figure 10 is a perspective view of an additional construct of the recoater;

[0017] Figure 11 is a bottom view of the recoater of Figure 10;

[0018] Figure 12 is a perspective view of yet another alternative construct of the recoater;

[0019] Figure 13 is a bottom view of the recoater of Figure 12;

[0020] Figure 14 is a perspective view of a further construct of a recoater; and

[0021] Figure 15 is a perspective view of another further construct of a recoater.

BRIEF DESCRIPTION

[0022] Referring initially to Figures 1 and 2, a portion of two different types of commercially available additive manufacturing devices, in the embodiments described,

powder bed fusion devices 100, are shown. The powder bed diffusion device includes a base plate 102, a powder bed 104, sometimes known as a build plate, moveable upwardly and downwardly with respect to the baseplate 102, a powder dispense region 106 (not shown in Figure 2), and a recoater 108 having a recoating blade extending downwardly therefrom. In the embodiments described herein, to add a layer of powder to the powder bed 104, a powder dispenser is configured to dispense powder to the dispense region 106. This may be accomplished by spraying or releasing the powder from a moveable overhead nozzle or bar, or by providing the powder from below the base plate 102, with a moveable lower piston in an opening 110, (Figure 1), open to the base plate 102, and a quantity of powder disposed thereover. The piston of the dispenser moves upwardly, providing a quantity of powder above the adjacent surface of the base plate 102, and the recoater 108, with the blade extending therefrom, moves from the right side of the opening 110 of Fig. 1 past the dispensed powder, such that a blade thereon engages the powder extending above or on the base plate 102 and spreads it over the bed 104. After spreading the powder over the powder bed 104, the recoater 108 moves to the right of opening 110 in Figure 1 to a retracted position, to be positioned such that the powder dispense region is disposed between the recoater 108 and the powder bed 104. The bed 104 is likewise moveable, to retract inwardly into the base plate after each layer of powder is laser processed to selectively melt and re-solidify selected portions thereof.

[0023] After the powder is dispensed at a level above the surface of the powder bed 104, the recoater 108 moves to the retracted position, and a laser is used to selectively melt and thus fuse the powder in the powder bed 104 to itself, and to previously fused material, if any, of an earlier processed layer or slice of the article being manufactured. Once the laser has melted a portion of the powder, moving of the laser beam therefrom allows the melted powder to re-solidify. This sequence is repeated, in a thin layer or slice by thin layer or slice fashion, until a three-dimensional article is manufactured. During spreading of another powder layer, and retraction, the recoater 108 is driven across the print bed 104 by a lead screw, a hydraulic ram, or other mechanism, and in Figure 1 is cantilevered over the print bed 104, whereas in Figure 2 it is supported on either side of the print bed 104 and forms a moving bridge construct.

[0024] The article of manufacture may include both fine dimensioned and thus fragile portions as well as more roughly dimensioned, and thus sturdier, portions. These different portions may present themselves at the same slice level in different locations of the article,

or in different slice levels and thus at different times during the manufacture of the article, or both. Additionally, two different parts may be simultaneously undergoing manufacture on the powder bed 104. The recoater 108 hereof, by virtue of the multiple blades of different types hereof, can be used to provide a soft blade in regions of the article, or layers of the article, having fine, fragile features, while allowing the use of a harder, more rigid blade in other regions or layers of the part, thereby preventing the breakage or deformation of fine fragile features and simultaneously retain a good surface finish on the finished article and minimize wear of the soft blade over the course of manufacture of the article.

[0025] Referring to Figures 3 to 6, one embodiment of a multi-blade recoater 120 hereof is shown. The multi-blade recoater may be used in association with a powder bed fusion, or other three dimensional, printing devices. Recoater 120 generally includes a head portion housing 130, from which a first blade 122 and a second blade 124 extend on the underside 128 thereof, and a movement mechanism such as an hydraulic or pneumatic ram, a lead screw, or other linear motion device to move the recoater over the print nest while maintaining parallelism between the underside thereof and the baseplate 102. In the embodiment, the first blade 122 is a stiff "hard" wiper blade, comprising a metal such as stainless steel, and the second blade 124 is a soft wiper blade, comprising a compliant material such as a polymer. In a first aspect, the recoater 120 includes a housing 130 supportable on a moveable frame member (not shown), having a pair of notches 132, 134 extending inwardly of the underside 128 and sides thereof, which terminate in an upper wall 136, 138, and side walls 140, 142 respectively, and a wiper assembly 144, 146 received in each notch 132, 134. Each wiper assembly 144, 146 comprises a body 148 or 150 having a blade 122 or 124 connected therewith, and each body 148, 150 is, in the embodiment, secured to the housing 130 by fasteners 152, such as threaded fasteners 152. Upper walls 136, 138 are preferably co-planar, and the bodies 148, 150 and blades 122, 124 are constructed such that the tip or lower edge 154 of each blade 122, 124 in a "new", unused state extends the same distance 'h' from the upper wall 136 or 138 associated therewith and is parallel to the baseplate 102. Additionally, in a first aspect, the spacing "L" between the blades 122, 124 is greater than the width of the powder dispense region 160 and the powder bed 104 of the fusion bed reactor. Thus, in this aspect, the housing 130 is selectively positioned with respect to the dispense region 160 such that the powder dispense region 160 is located between one of the soft or hard blades 124, 122 and the powder bed 104, or between the two blades 122, 124. For example, the housing 130 may be located to the left

of a layer of powder 162 dispensed in a powder dispense region 160 as shown in Figure 3, and then the housing 130 moved to the right such that the soft blade 124 engages the powder 162 in the dispense region, and sweeps and distributes the powder over the powder bed 104. To dispense the powder, a mass of powder to extend above the surface of the base plate 102 is loaded in the dispense region 160, and then the housing 130 of the recoater 130 is moved to forward direction in Figure 2 to spread the powder over the powder bed 104, the thickness of the powder in the powder bed 104 being defined in part by the gap between the lower edge 154 of the blade 126 and the upper surface of the base plate 102 and any powder already in the bed 104. This is used to dispense powder using only the soft blade 124.

[0026] To dispense powder with the hard or stiff blade 122, the housing 130 is moved over the dispense region 160 before the plate thereof of Figure 2 is raised to present the powder 162 above the plane of the base plate 102, such that powder is present between the blades 122, 124, and the housing 130 of the recoater 108 is then moved to the right in Figure 3 to spread that powder 162 over the powder bed 104, again the thickness of the powder layer on the powder bed 104 being a function of the spacing between the tip 154 of blade 122 and the upper surface of the base plate 102 and any powder in the powder bed 104. Additionally, the recoater 108 may move to spread the powder with the soft blade 124, and then compact all or only a portion of powder spread on the powder bed 104 with the hard blade 122, whereby fragile or fine features of the most recently formed slice(s) of the article do not underlie a location where the hard blade is passed.

[0027] Referring now to Figures 7 to 9, another embodiment of the housing 130 is shown in section, wherein each of the wiper assemblies 144, 146, and the bodies 148 or 150 having a blade 122 or 124 thereon is moveable with respect to the lower wall 136, 138 of the body 130. In this embodiment, each of the wiper assemblies is independently moveably in a vertical, i.e., closer to or further from, the bed 104 position, with respect to housing 130, while maintaining parallelism between the baseplate 102 and the lower edge 154 of the blades 122, 124. To effectuate this relative positioning, the body 148, 150 of each wiper assembly 144, 146 is secured to the housing 130 via a lead screw assembly 170, comprising a threaded rod 172 extending from a motor, such as a stepper motor 174 secured in an opening in the housing 130, and a threaded nut 176 through which the threaded rod 172 extends, and which is secured to the body 148 (or 150) by a plurality if fasteners (not shown). The upper end of the body 148 (or 150) includes a clearance recess 178 therein

into which the threaded rod 172 extends. To help maintain alignment of the blade tip 154 parallel to the upper surface of the base plate 102, a pair of alignment pins 182 extend from the body 148 (or 150) and into alignment bores 180 in the housing 130. The mating threads of the rod 172 and the nut 176 are configured to enable finely tunable positioning of the lower edge 154 of the blade 122 (or 124) with respect to the upper wall 136 (or 138) and thus the upper surface of the powder in the powder bed 104, and pins 182 help maintain parallelism between the tip 154 surface and the base plater 102 and any powder previously located in bed 104.

[0028] In use, body 130 is scanned over the powder 162 in the powder distribution region 160, and the blades 122, 124 may be located closer together on the recoater body 130 as each blade 122, 124 may be independently extended to engage and spread the powder, or retracted to provide clearance between the blade lower edge 154 and the powder. Thus, as shown in Figure 3, powder 162 is dispensed in powder dispense region 160, and where hard blade 122 is to be used to spread the powder 162 over the bed 104, body 150 is held in a retracted position in recess 132 such that the lower edge 154 of the blade 124 thereof is above the uppermost extent of the powder 162, and body 148 is extended from its recess 132 by rotating the threaded rod 172 with motor 174. Because nut 176 is fixed against rotation, and the bodies 148, 150 cannot twist as the pins 182 extend therefrom into the alignment bores 180, the rotation of threaded rod 172 causes the body 148 (or 150) to move away from or toward the upper surface 136 (or 138). Then, the housing 130 is moved to the right of Figure 3 to spread the powder 162 over the bed 104. The housing 130 is then retracted back to the position thereof in Figure 3, the layer of powder is laser processed and then retracted, and the next portion of powder is dispensed.

[0029] In the aspect hereof shown and described with respect to Figures 5 to 7, either body 148, 150, and thus either blade 122, 124 may be used to spread the powder 162 over the powder bed 104. For example, as an article is being manufactured by a fusing process, the article design may change from one slice having rough or normal features, and a next slice having fine features. Once the first fine feature slice is completed by selective fusing of the powder in the bed 104, the next layer of powder 162 for the next slice is provided by maintaining the blade 122 in the retracted position, and extending body 150 and thus soft blade 124 downward from upper wall 138 to engage the powder 162 in the dispense region 160 and spread that powder over the bed 104 as the housing moves from the position of Figure 5 to the right and over the bed 104. Depending on the design and finish

requirements of the article being manufactured, the hard blade 122 or the soft blade 124 may be used to spread the powder 162 over the bed 104.

[0030] The construct of the housing 130 having blades 122, 124 moveable with respect thereto also increases the flexibility of the fusion bed printer 100. In particular, different materials which can be selectively fused with the laser of the printer 100 can be spread and processed at different maximum thicknesses. Currently, the maximum powder thickness of some material that can be processed is 20 μm, while other materials have maximum processable powder thicknesses of 30, 40, 50 μm and more. Typically, the powder layer thickness is set between 20 μm and 60 μm. In prior printers, the printer must be physically serviced to reset the spacing between the lower edge 154 of the single blade thereof and the surface of the base plate 102 and the bed 104 or surface of previously processed powder in the bed 104 to accommodate forming a different powder thickness to be processed on the powder bed 104. The embodiment hereof shown and described in Figures 7 to 9 hereof avoids this issue, as the blade tip 154 to bed 104 and base plate 102 spacing may be rapidly changed by simply rotating the threaded rod 172 to move the body 148, 150, and thus blade lower edge 154, with respect to the bed 104 and base plate 102. By properly providing a thread pitch of the threaded rod 172 and nut 176, each full rotation of the threaded rod 172 can provide one to five microns of travel of the blade 122, 124 with respect to the bed 104 surface. Additionally, because the soft blade 124, which is subject to wear and the need to replace it far more frequently than the hard blade 122, is used only when a fragile or fine feature is being printed or fused over in the next slice(s), the soft blade 124 need not be used in every slice as in the prior equipment, and thus the overall number of slices which may be processed with the printer 100 before soft blade 124 replacement is significantly increased, and the likelihood that a disruptive blade replacement will be required during the printing of an article is significantly reduced. Further, the variable spacing feature afforded by the embodiment hereof of Figures 7 to 9 may also be used with only one blade on the recoater, whereby utilization of the printing apparatus may be increased by eliminating the downtime needed to reset the blade height thereof. Likewise, the blade 122, 124 may be retracted after the powder has been spread during the return stroke of the recoater 108.

[0031] The embodiments of Figures 3 to 9 all require that a blade extending the width of the powder bed 104, either hard blade 122 or soft blade 124 or both, spread all of the powder for an individual slice. Referring now to Figures 10 to 13, additional embodiments are provided wherein the blades extend over only a portion of the bed 104, and thus where only

a portion of an article being manufactured has fragile or fine dimensioned portions, or multiple articles are being manufactured having different degrees of fine dimension and fragility, the blades may be selectively deployed in different regions of the bed. In each of these embodiments, a single soft blade 124, dimensioned to extend completely across the bed 104, is provided, whereas multiple hard blade segments 122 are collinearly aligned to, in combination, extend fully across the bed 104. In operation, only the soft blade 124, only the hard blades 122, or a combination thereof may be used to spread powder 162 over the bed 104. Each hard blade 122 segment is held and positioned by a separate body, for example bodies 200, 202 in Figure 10 and bodies 200, 202 and 204 in Figure 12, and each body 200, 202 and 204 is separately movable with respect to housing 130 by an independent lead screw assembly 170 dedicated thereto.

[0032] Where a slice to be fused is being formed over fragile layers on the article being manufactured, or on multiple articles across the bed 104, only the soft blade 124 is extended to spread the powder 162. Where soft or fragile features are not present on the article being manufactured, or in multiple articles located across the bed 104, only the hard blades 122 of bodies 200, 202 (and 204) are extended to spread the powder. Where fragile or fine features are only selectively present across the article, or in multiple articles across the bed 104, the soft blade 124 and selected ones of the hard blade 122 segments of bodies 200, 202 (and 204) are extended. The soft blade 124 is positioned, as in Figure 5, to first engage the powder 162 and spread the powder 162 across the bed 104. In those areas of the bed 104 where fine or fragile features are not present, the hard blades 122 are extended to sweep over the powder distributed by the soft blade, further compressing the powder to allow a better surface finish to be formed on that specific portion of the slice. At each slice, an evaluation of the presence or absence of fine or fragile features is made, and the hard blade 122 segments and the soft blade 124 may be appropriately extended to spread the powder over the powder bed 104.

[0033] Referring now to Figures 14 and 15, an additional embodiment of the recoater is shown, wherein multiple blades of the same type are arranged in parallel in the housing 130. In Figure 14, a single soft blade 124, a full length hard blade 122, i.e., one extending the full width of the powder bed, is provided, and a segmented hard blade 122 configured of three aligned bodies 200, 202 and 204 are provided. In this embodiment, where a part of the slice of the article being printed (fused) over contains fine or fragile portions, the soft blade 124 is deployed to spread the powder, and selected ones of the hard blade 122 segments in

bodies 200, 202 and 204 are deployed to further compress the powder in regions where the fine or fragile features are not present in the article or articles being printed. If the entire underlying slice is free of fine or fragile features, then only the full length hard blade 122 need be deployed to spread the powder.

[0034] Referring now to Figure 15, the housing of the recoater includes four blades, two soft blades 124a, 124b, a full length hard blade 122, and segmented hard blades 122 in bodies 200, 202. In contrast to the construct of the recoater in Figure 14, in this embodiment, as the soft blade 124a begins to wear, that blade 124a is retracted inwardly of the housing by its lead screw assembly 170, and soft blade 124b is deployed as needed to spread the powder for the next or later slices of the same article. Thus, larger articles, which were otherwise un-manufacturable because of the need for soft blade replacement during the manufacture thereof, can be manufactured. Likewise the hard blades 122 may be selectively deployed in segments, or as a full width blade 122, to spread the powder 162 when the article does not contain fragile or fine features in the slice(s) adjacent the next slice to be printed.

We claim:

1. An additive manufacturing device having a powder bed and a source of powder to be spread over the powder bed for selective energization thereof by an energy source, comprising:
a recoater moveable across the surface of the powder bed to distribute powder in a layer thereon, the recoater comprising a housing and at least two blades extending therefrom for selective contact with the powder.

2. The device of claim 1, wherein the recoater comprises a first blade of a first stiffness and a second blade of a second stiffness.

3. The device of claim 1, wherein the blades are selectively extendable, and retractable, with respect to the housing, such that only one blade is contactable with the powder upon scanning of the recoater across the surface of the powder bed.

4. The device of claim 1, wherein at least one of the at least two blades includes a plurality of segments, and each segment is independently selectively extendable from, and retractable toward, the housing.

5. The device of claim 1, wherein the at least two blades comprise two blades having the same stiffness, and each of the two blades having the same stiffness is independently selectively extendable from, and retractable toward, the housing.

6. The device of claim 5, further comprising a third blade of a different stiffness than the stiffness of the two blades having the same stiffness.

7. The device of claim 5, wherein the third blade comprises a plurality of segments, and each segment is independently selectively extendable from, and retractable toward, the housing.

8. The device of claim 1, further comprising a powder discharge region having a width over which powder for recoating the powder bed is provided, wherein the distance between

the at least two blades on the housing is greater than the width of the powder discharge region.

9. The device of claim 1, further comprising a powder discharge region having a width over which powder for recoating the powder bed is provided, wherein the distance between the at least two blades on the housing is less than the width of the powder discharge region.

10. A method of recoating a powder bed in an additive manufacturing device comprising a powder bed, a recoating discharge region, an energy source, and a recoater having a housing, comprising providing at least two recoating blades on the housing; and moving the recoater over the powder discharge region to spread a layer of powder over the powder bed.

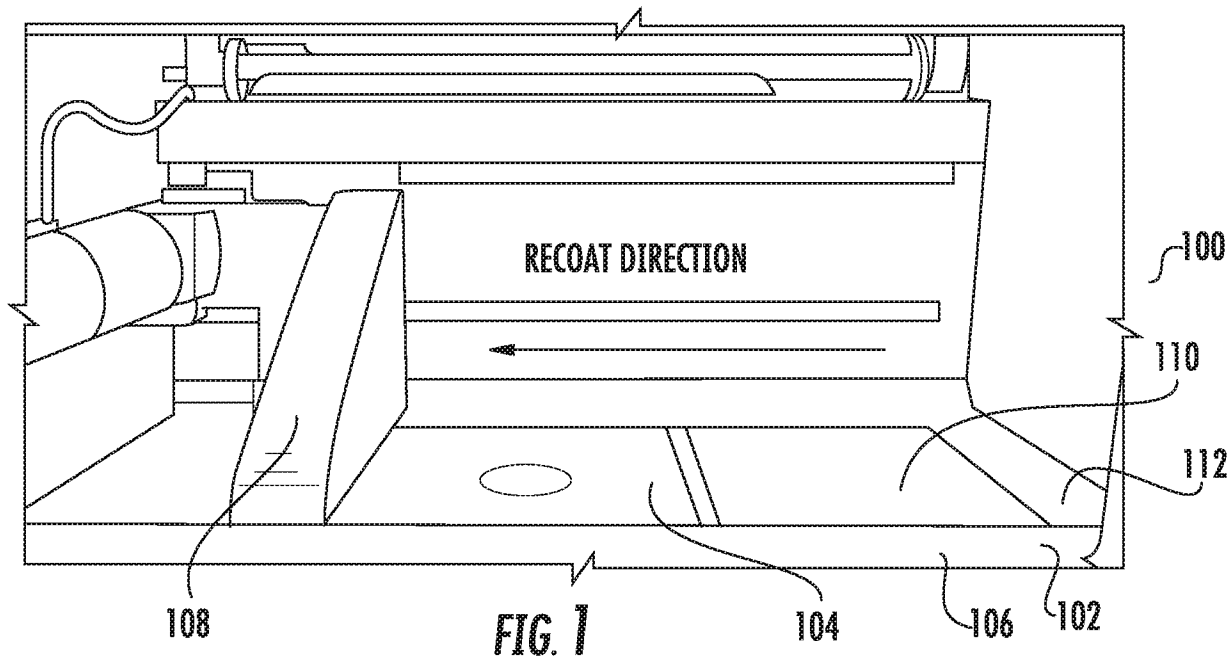
11. The method of claim 10, wherein the step of moving the recoater over the powder discharge region to spread a layer of powder over the powder bed comprises spreading the powder over powder previously spread over the powder bed.

12. The method of claim 10, further comprising selectively extending one of the at least two recoating blades from the housing.

13. The method of claim 12, wherein at least two of the at least two recoating blades have different hardnesses.

14. The method of claim 13, wherein one of the at least two recoating blades comprises a polymer.

15. The method of claim 10, wherein at least one of the recoater blades includes a plurality of segments, and the segments are independently movable with respect to the housing.


RECOAT DIRECTION
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106
102

FIG. 1

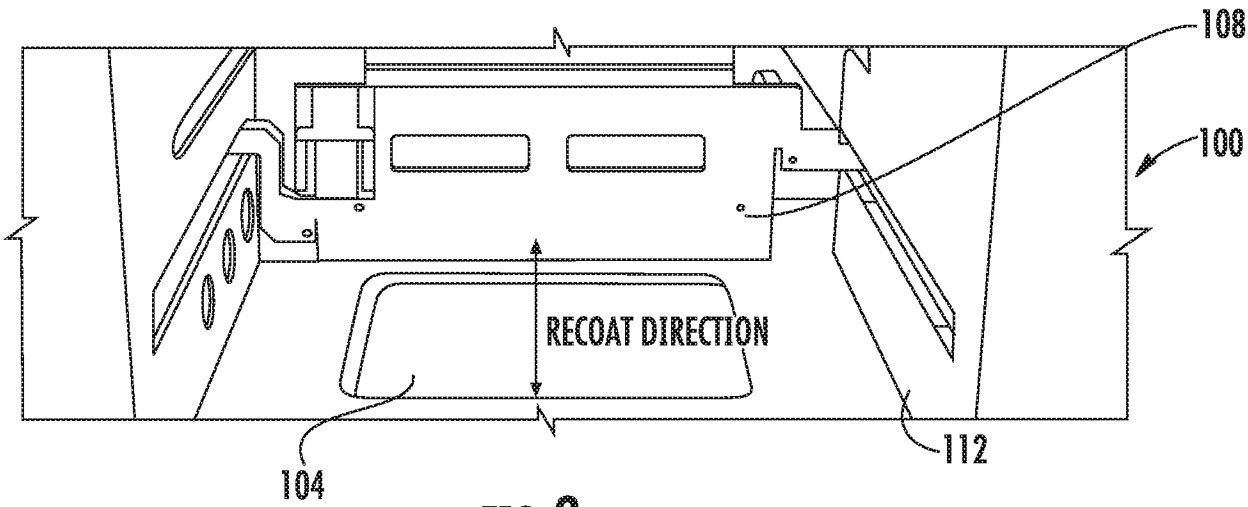
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FIG. 2

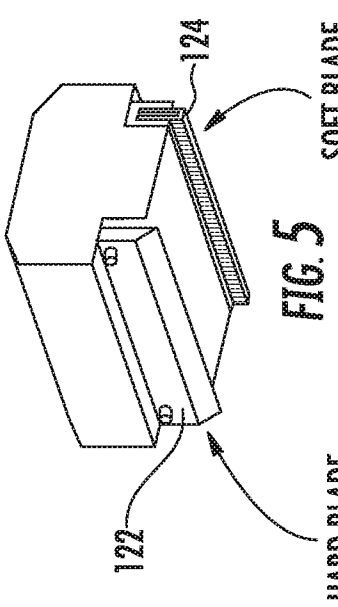


FIG. 5

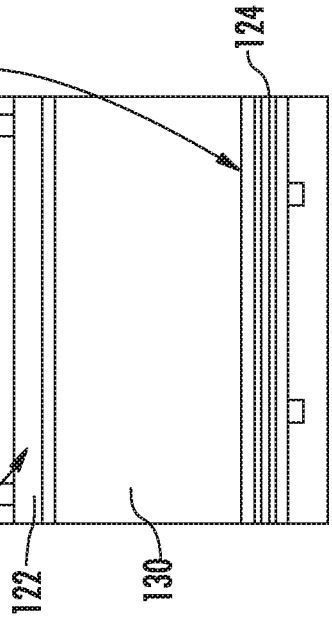


FIG. 6

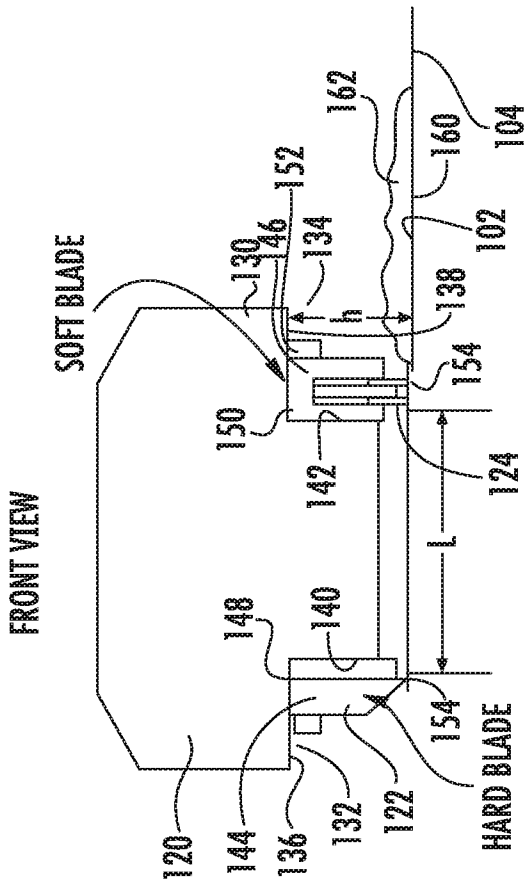


FIG. 3

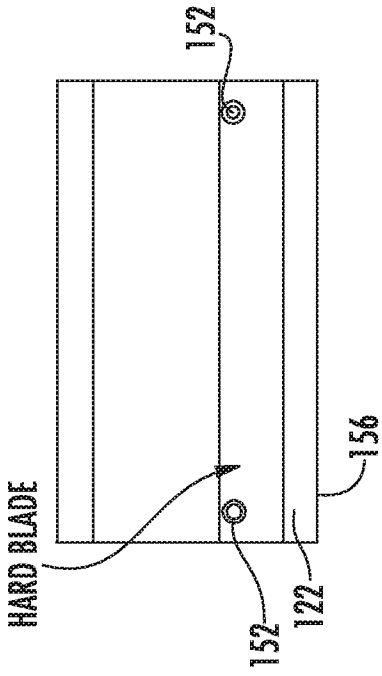


FIG. 4

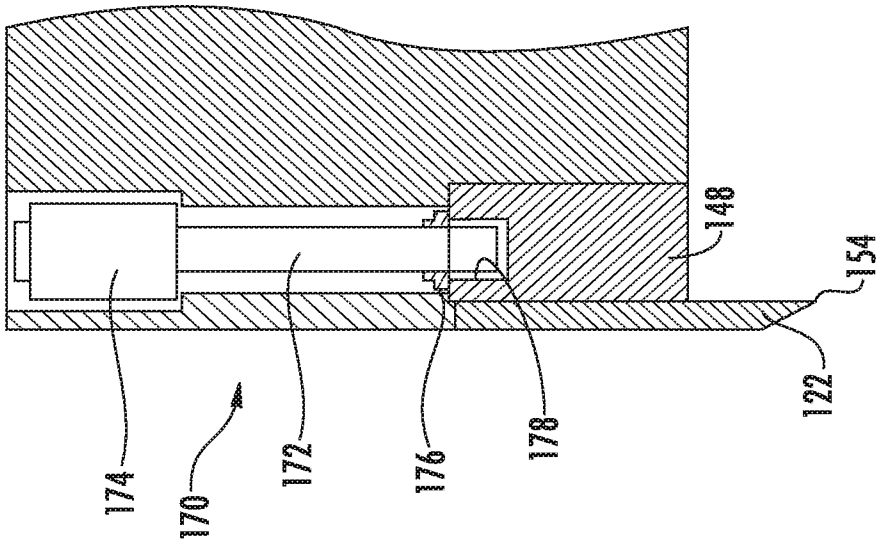


FIG. 9

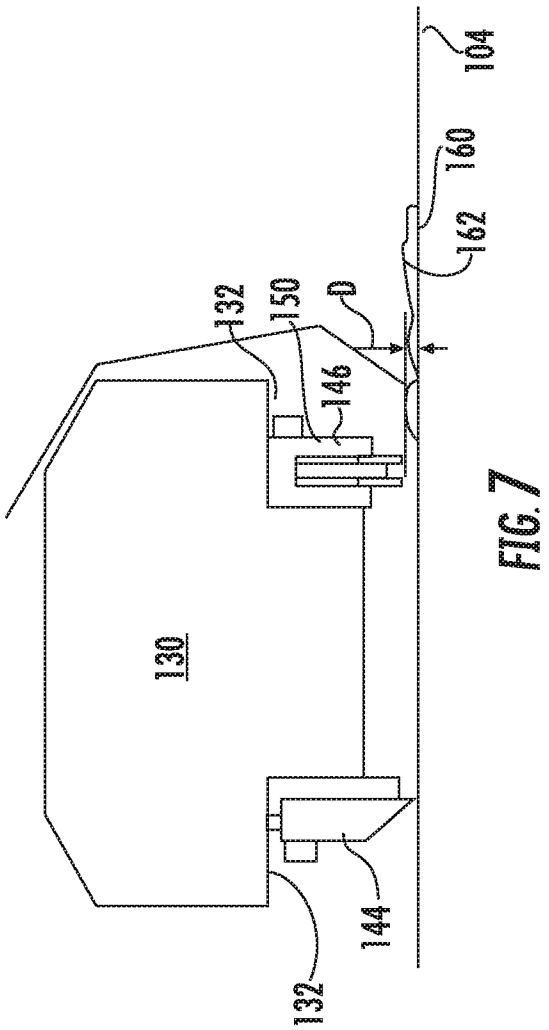


FIG. 7

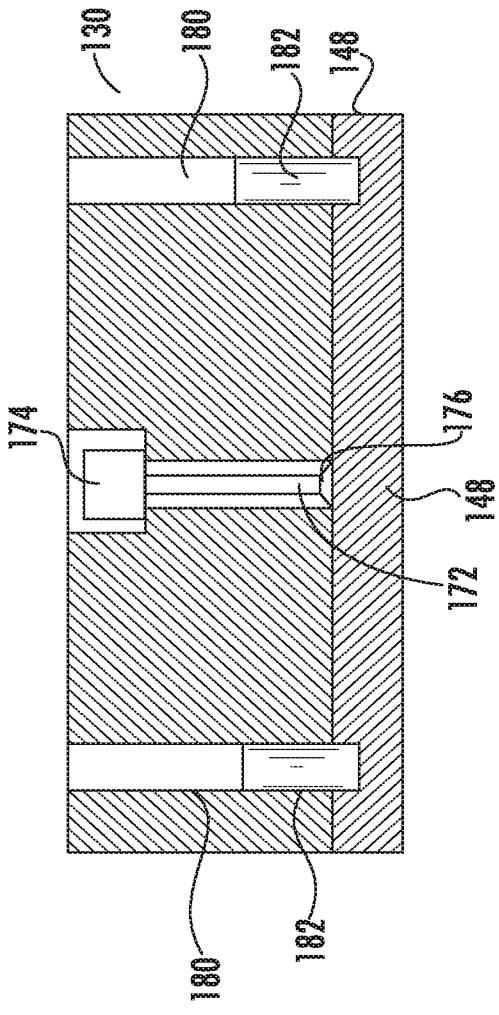
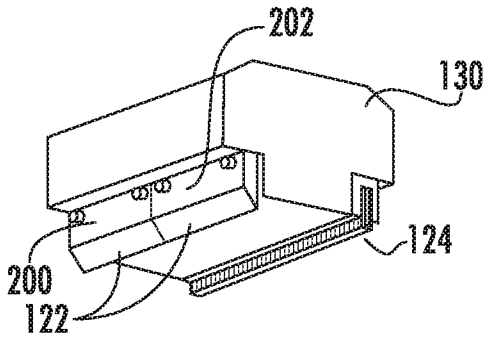


FIG. 8



DOUBLE BLADE (HARD OR SOFT)

FIG. 10

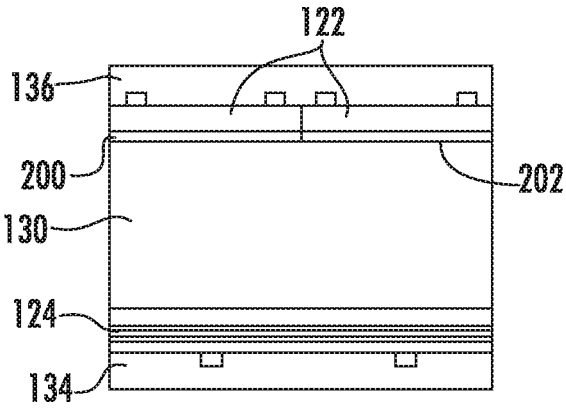
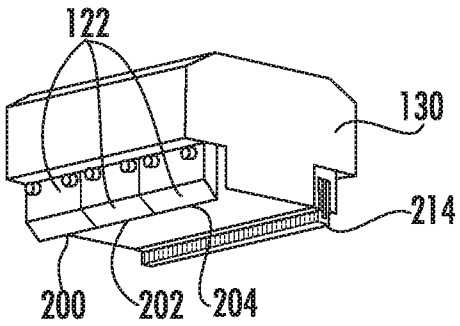


FIG. 11



TRIPLE BLADE (HARD OR SOFT)

FIG. 12

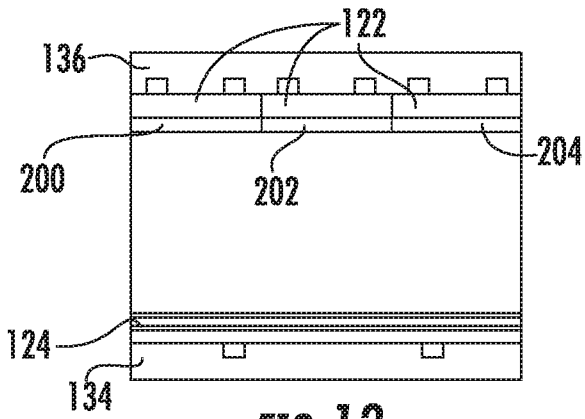


FIG. 13

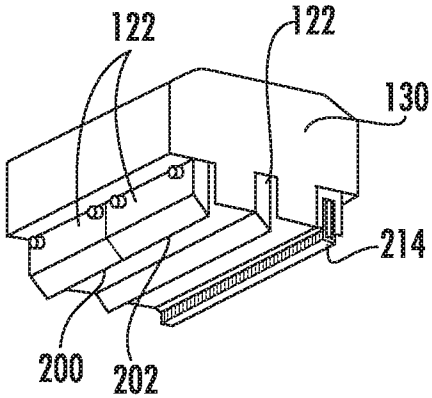


FIG. 14

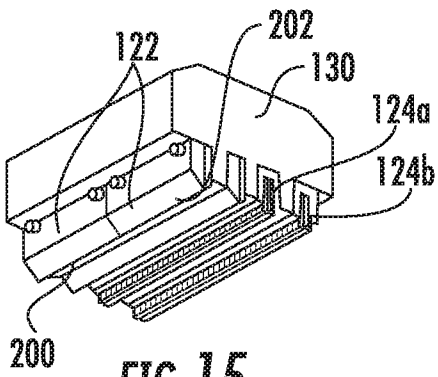


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/018309

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

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 B22F

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

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 2006 056422 B3 (CL SCHUTZRECHTSVERWALTUNGS GMBH [DE]) 17 April 2008 (2008-04-17) paragraphs [0013], [0028], [0029], [0031], [0034], [0037]; figures	1,2, 8-11,13, 14
X Y	EP 1 439 050 A1 (CONCEPT LASER GMBH [DE]) 21 July 2004 (2004-07-21) paragraphs [0008] - [0014], [0022], [0023]; figures	1-3, 8-13,15 5,6
X Y	US 2015/367415 A1 (BULLER BENYAMIN [US] ET AL) 24 December 2015 (2015-12-24) paragraphs [0292], [0299], [0328]	1,3,5, 8-12 5,6

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

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 May 2017	24/05/2017

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/018309

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