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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

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(54) Title: METHODS FOR FIBER REINFORCED ADDITIVE MANUFACTURING

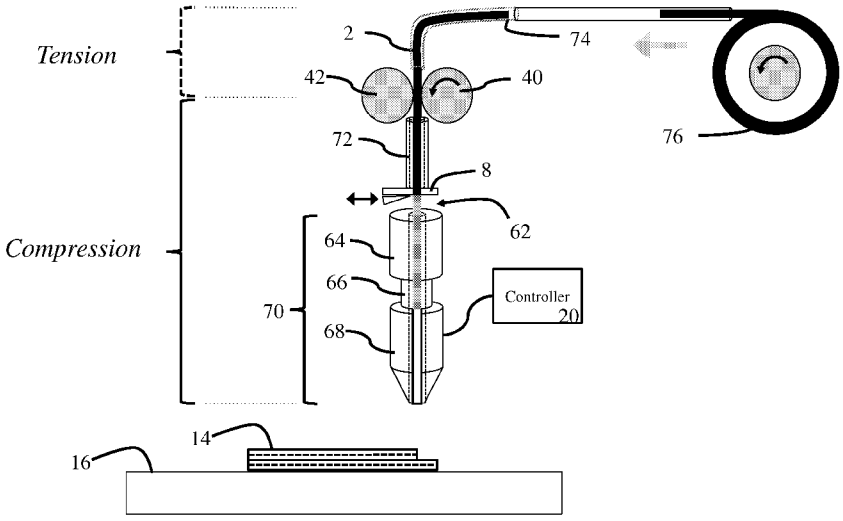

Fig. 10

(57) Abstract: Various embodiments related to three dimensional printers, and reinforced filaments, and their methods of use are described. In one embodiment, a void free reinforced filament is fed into an extrusion nozzle. The reinforced filament includes a core, which may be continuous or semi-continuous, and a matrix material surrounding the core. The reinforced filament is heated to a temperature greater than a melting temperature of the matrix material and less than a melting temperature of the core prior to extruding the filament from the extrusion nozzle.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 14/41161

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - D01D 5/08 (2014.01)
CPC - D01D 5/0985, D01D 5/08, D01D 5/12, D04H 3/16
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(8): D01D 5/08 (2014.01)
CPC: D01D 5/0985, D01D 5/08, D01D 5/12, D04H 3/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC: D01D 5/0985, D01D 5/08, D01D 5/12, D04H 3/16
USPC: 264/40.3,103,555,548,547; 425/72.2,131.1,132

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Patbase, Google Patents, Google Scholar Search terms used: Axial, fiber, fibre, strand, 3d, print, additive manufacturing, rapid prototyping, iron, flatten, tip, lip, filament, pressure, zone, segment, block, area, compress, plate, roll, resin, heat, melt, matrix, feed, sls, fff, fusion deposition, sintering, continuous, parallel, reinforce

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,002,712 A (GOLDMANN et al.) 26 March 1991 (26.03.1991), col 3, ln 54-col 4, ln 4; col 4, ln 26-36; col 5, ln 16-50; col 6, ln 36-51; col 7, ln 18-25; claim 8	1-9
Y	US 2012/0231225 A1 (MIKULAK et al.) 13 September 2012 (13.09.2012), para [0040], [0085], [0089]-[0091], [0093], [0097], [0129]	1-9
Y	US 5,037,691 A (MEDNEY et al.) 06 August 1991 (06.08.1991), col 2, ln 13-32; col 4, ln 11-22	2
Y	US 2002/0009935 A1 (HSIAO et al.) 24 January 2002 (24.01.2002), para [0006], [0034], [0037]	7
Y	US 2002/0113331 A1 (ZHANG et al.) 22 August 2002 (22.08.2002), para [0059]-[0060]	8
Y	US 2007/0228592 A1 (DUNN et al.) 04 October 2007 (04.10.2007), para [0030], [0040]	1-9

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

* 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
12 November 2014 (12.11.2014)	03 DEC 2014

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 14/41161

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

--please see information on extra sheet--

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-9

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Continuation of Box No. III -- Observations where unity of invention is lacking

Group I: claims 1-9: drawn to a method for additive manufacturing of a part comprising supplying an unmelted fiber reinforced composite filament including at least one axial fiber strand extending within a matrix material of the filament; feeding the fiber at a feed rate; heating the fiber in a transverse pressure zone to a temperature greater than a melting temperature of the matrix material to melt the matrix material interstitially within the filament; applying an ironing force to the melted matrix material and the at least one axial fiber strand of the fiber reinforced composite filament with an ironing lip as the fiber reinforced composite filament is deposited in bonded ranks to the part; and translating the ironing lip adjacent to the part at a printing rate that maintains a neutral to positive tension in the fiber reinforced composite filament between the ironing lip and the part, the neutral to positive tension being a tension less than that necessary to separate a bonded rank from the part.

Group II: claims 10-20: drawn to a method for additive manufacturing of a part comprising supplying an unmelted void free fiber reinforced composite filament including at least one axial fiber extending within a matrix material of the filament; feeding the unmelted fiber at a feed rate, along a clearance fit zone that prevents buckling of the fiber reinforced composite filament, threading the fiber reinforced composite filament to contact the part in a transverse pressure zone; translating the transverse pressure zone relative to and adjacent to the part at a printing rate to bring an end of the fiber reinforced composite filament to a melting position; and melting the matrix material interstitially within the filament at the melting position.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special technical features:
Group I requires applying an ironing force to the melted matrix material and the at least one axial fiber strand of the fiber reinforced composite filament with an ironing lip as the fiber reinforced composite filament is deposited in bonded ranks to the part; and translating the ironing lip adjacent to the part at a printing rate that maintains a neutral to positive tension in the fiber reinforced composite filament between the ironing lip and the part, the neutral to positive tension being a tension less than that necessary to separate a bonded rank from the part, not found in the other groups.

Group II requires feeding the unmelted fiber along a clearance fit zone that prevents buckling of the fiber reinforced composite filament, threading the fiber reinforced composite filament to contact the part in a transverse pressure zone; translating the transverse pressure zone relative to and adjacent to the part at a printing rate to bring an end of the fiber reinforced composite filament to a melting position, not found in the other groups.

Shared Features:
The only technical features shared by Groups I and II that would otherwise unify the groups are a method for additive manufacturing of a part comprising supplying an unmelted fiber reinforced composite filament including at least one axial fiber strand extending within a matrix material of the filament; feeding the fiber at a feed rate; heating the fiber in a transverse pressure zone to a temperature greater than a melting temperature of the matrix material to melt the matrix material interstitially within the filament.

However, these shared technical features do not represent a contribution over prior art, because the shared technical features are disclosed by US 5,002,712 A to Goldmann et al. (hereinafter 'Goldmann') 26 March 1991 (03.26.1991), which discloses a method for additive manufacturing of a part comprising supplying an unmelted fiber reinforced composite filament including at least one axial fiber strand extending within a matrix material of the filament feeding the fiber at a feed rate (col 5, ln 16-50); heating the fiber in a transverse pressure zone to a temperature greater than a melting temperature of the matrix material to melt the matrix material interstitially within the filament (col 6, ln 36-51).

As the shared technical features were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

Groups I and II therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.